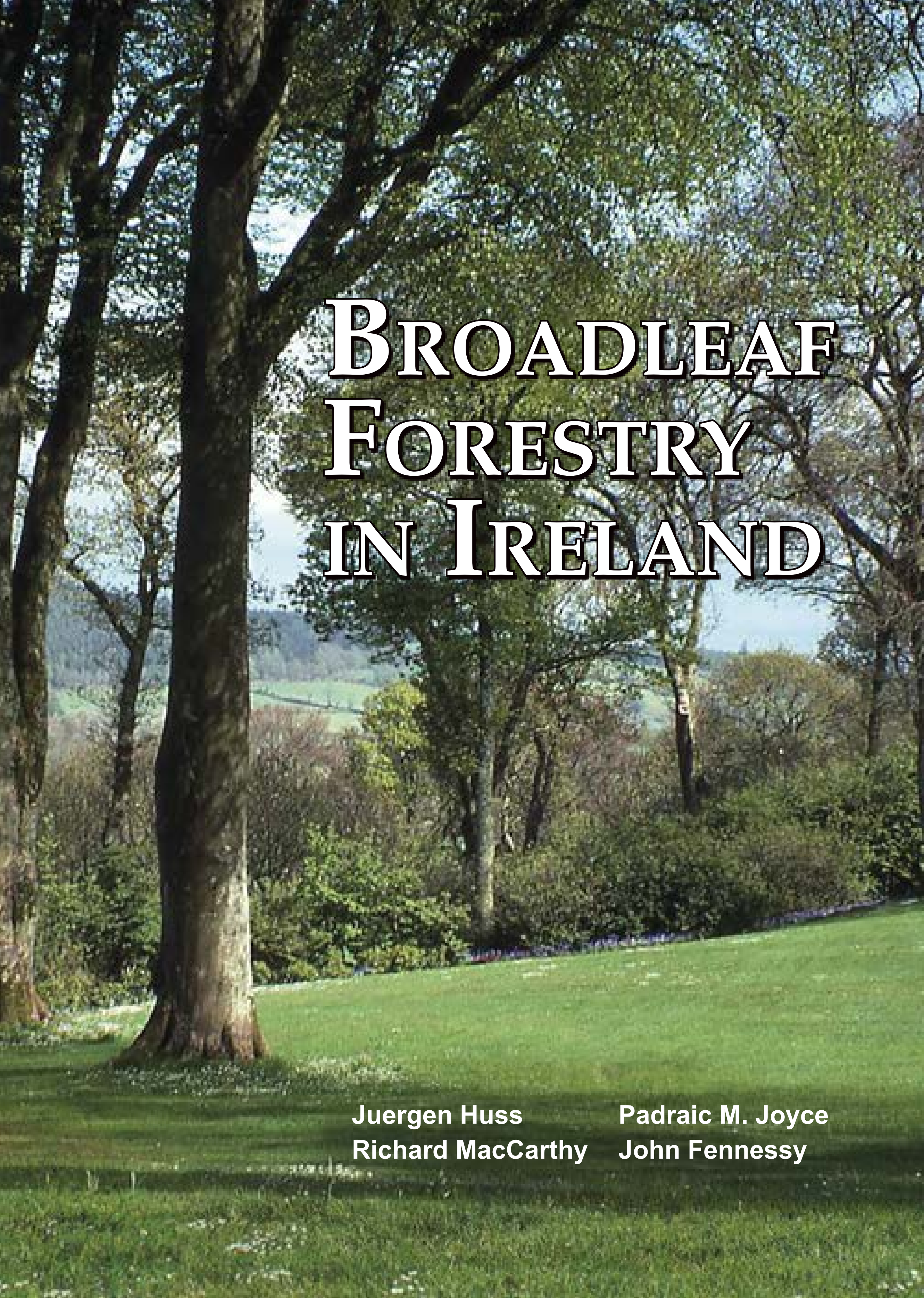

Broadleaf Forestry in Ireland

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Foreword

Planting of broadleaves has greatly increased over the past three decades as a result of state investment in afforestation schemes. The recently completed second national forest inventory shows that broadleaves account for over one-quarter of the forest estate. Broadleaves also comprise one-third of current afforestation. The importance of broadleaves in the afforestation programme has been confirmed in the recently published forest policy review, *Forests, products and people*, and in the new Forestry Programme 2014-2020.

These developments have put in place a broadleaf forest resource that contributes to climate change mitigation, biodiversity and forest recreation, and has the potential to support a new and developing hardwood processing enterprise, and add to an already thriving wood processing sector.

Silviculture is the key to growing quality broadleaves. Oak and other species may take upwards of 100 years to reach maturity, but realising high value hardwood crops starts at the very beginning of the forest cycle. Selecting good quality sites, suitable genetic reproductive material, and establishing adequate stocking are essential building blocks to realise high value hardwood timber at the end of the forest rotation. Tending and thinning begin when the trees are still in the juvenile stage; for some fast-growing species these early interventions can bring the crop cycle well within the owner's lifetime.

Well researched and up-to-date silvicultural information and guidance provide the basis for the range and timing of interventions essential for the production of high quality hardwood timber. The first publication to provide such information was *Growing Broadleaves*, written by Padraic Joyce and others, and issued by COFORD in 1998. It rapidly became, and remains, the most widely used publication on the silviculture and management of broadleaves in Ireland. It has also become an important reference in support of the Forest Service broadleaf thinning and tending grant scheme.

The years since the publication of *Growing Broadleaves* have seen a significant increase in silvicultural knowledge, as well as an expansion in the use of species such as alder and birch. *Broadleaf Forestry in Ireland* takes account of these developments in a comprehensive manner, and updates *Growing Broadleaves*.

In conclusion, the Department of Agriculture, Food and the Marine is delighted to be associated with this new publication and I am confident that it will contribute to the achievement of a sustainable high quality hardwood timber resource for future generations.

Andrew Doyle, TD

Minister of State for Forestry

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Since the publication of *Growing Broadleaves* by COFORD in 1998, substantial new information and experience have been acquired on the establishment and growing of broadleaves in Ireland. Those who have contributed to this advancement include researchers, foresters, land owners, and others with an interest in forestry practice. We are grateful to them for sharing their knowledge and experience with us during the compilation of this publication.

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Finally, if through an oversight we have omitted any person who has helped us along the way, please accept our sincere apology.

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Part I: Development, site demands, objectives and silviculture of broadleaves

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Self-sown sessile oak seedlings at Ballygannon Wood, Rathdrum, Co Wicklow.

1 Development of broadleaf forestry in Ireland

1.1 Introduction

A visitor to Ireland some 6,000 years ago would have found a landscape almost entirely covered in broadleaves. This was the climatic optimum during which a natural primeval forest existed over most of the country. From then onwards the forest went into a decline as it was subjected to increasing exploitation over the millennia. By the end of the 17th century it had shrunk to an estimated 1% of the land area. The opening stanza of the poem Cill Chais lamented its passing: *Cad a dhéanfaimid feasta gan adhmad, tá deireadh na gcoillte ar lár. (Now what will we do without timber? The last of the woods is laid low.)*

Concern about the parlous state of Irish forests at the beginning of the 20th century led to the establishment of a Committee of Inquiry in 1908. It recommended state involvement and an afforestation programme with *quicker-growing varieties of coniferous timber.* This set the scene for the establishment of the conifer forests which are a feature of our uplands and hills today. Broadleaves played only a very minor role in this programme.

Ireland's accession to the European Union in 1973 brought unprecedented opportunities for agricultural production and within a decade authorities had to contend with costly beef and butter mountains. In a belated attempt to curb production, the European Union turned to forestry as an alternative land use. To wean farmers away from agriculture, afforestation grants were made available and these were heavily weighted in favour of broadleaves. Landowners gradually responded and towards the end of the century broadleaf planting was averaging 2,000 ha/yr.

The emphasis on conifers for most of the 20th century had left a vacuum in the knowledge of broadleaf silviculture and particularly management. To address this issue the Council for Forest Research and Development, COFORD, published *Growing Broadleaves* in 1998. The publication, based on information on the actual growth and development of older stands, was viewed as an interim measure until the actual field performance of newly planted broadleaf species became apparent.

The past decade has shown a sustained broadleaf planting programme which has provided new valuable information on the growth performance of younger stands. This information has been analysed by the authors through discussion with forestry colleagues and forest owners during field studies. It has been supplemented by information gleaned from forestry literature on broadleaf species in European countries and bolstered by the lifetime experiences of the authors. All this information has been incorporated into the current publication, *Broadleaf Forestry in Ireland*. It represents the most comprehensive documentation of all aspects of broadleaf forestry in Ireland, from planting through establishment to silvicultural treatment and management.

To incorporate such a wide variety of topics the authors felt the book should be divided into two distinct parts.

In the five chapters of **Part I** this variety and range of topics is illustrated. **Chapter 1** traces the early colonisation of the country with broadleaf species, their exploitation and decline, as well as their virtual exclusion from the afforestation phase during most of the 20th century. It is concluded with a summary of the present broadleaf situation based on recent inventories.

The reader interested in planting the right tree in the right place will benefit from a study of **Chapter 2.** Here a detailed description is provided of the main factors of site, both soil and climate, with regard to species selection and a look into the future is ventured on how the effects climate change will impose on broadleaf tree species.

Although the production of high value broadleaf timber is emphasised throughout the book, forests are not confined to the provision of this raw material alone. They also provide a wide range of economic, ecological and socio-economic services and functions. All these are explored, from different points of view, in **Chapter 3**, with emphasis on the important role broadleaves play in the provision of these services.

Broadleaves require a much greater degree of skilled management and silvicultural expertise than conifers. These topics are addressed in **Chapter 4,** where the various silvicultural aspects of regeneration, thinning and harvesting are described in detail.

Planters of broadleaf trees have to be people with a vision for the future. How otherwise can one explain the undertaking of an enterprise from which the planter will rarely receive a dividend? In **Chapter 5** a look to the future is undertaken and the opportunities and potential of further broadleaf forest development in Ireland are explored. It is concluded that there are substantial areas available for broadleaf planting, not least the vast kilometres of hedgerows which could be enriched with benefit to their owners.

The four chapters of **Part II** are devoted exclusively to the characteristics of broadleaf tree species. After an **opening chapter** on ordering procedure, **the major, minor and rare species** are presented in separate chapters. For each of the major and minor species a description of the botanical, ecological and growth characteristics is provided, along with a brief outline of silvicultural management where appropriate. In the concluding chapter the potential of some rare exotic species in the Irish climate of the future is reviewed.

The book will be of special interest to professional foresters and forest owners, forestry academics and students of forestry, arboriculturists, ecologists and all those with an interest in conservation. For land owners with forest and those contemplating broadleaf forestry it provides a comprehensive insight into the requirements necessary for the production of a valuable high quality broadleaf resource.

1.2 Natural Development of Forests in Ireland

For more than 200 million years Ireland has been shaped and sculpted by geological and climatic change. Its surface has been lowered and then raised by earth movement. Its central plain of carboniferous limestone has been laid down under the sea and then uplifted. Entire landscapes have been eroded to leave parent rock exposed, as in the karst topography of the Burren. These developments, in the evolution of the country over the millennia, are reflected in the Ireland of today.

For a history of events that shaped the landscape of Ireland we are indebted to the publications of generations of scholars who have worked in this field. Drawing on these studies, the late Frank Mitchell, professor of quaternary studies at Trinity College, Dublin, has co-authored a book on the subject with Michael Ryan (Mitchell and Ryan, 1997). Much of what follows in this chapter is based on that book.

1.2.1 Effect of early ice ages on soils

A series of at least four ice ages, alternating with warm interglacial periods have occurred over a period of 600,000 years. The ice ages helped to shape the appearance of the Irish landscape and that of the whole of northern Europe. Ice sheets sculpted the parent primary rocks, and those of sedimentary origin and igneous intrusions, and reduced them by weathering. There is clear evidence that the movement of the ice sheets has transported this weathered material long distances from its place of origin. Many of Ireland's soils, therefore, bear no relationship to the underlying parent rock.

1.2.2 Interglacial period – forest cover

During the interglacial periods many tree species, which still exist in temperate zones of North America and the Far East, flourished in the Ireland of that time. This is also the case in Northern and Central Europe. Among them are redwood, hemlock, umbrella pine, swamp cypress and Douglas fir. The evidence for this can be found in the fossil remains of lake mud and brown coal deposits. Today in Ireland, these species are referred to as exotics and it is sometimes argued that, by their inclusion in a planting programme, they are only returning to an original natural habitat. This argument is, however, scarcely plausible as they have adapted to other climatic zones in the meantime.

1.2.3 Forest cover after the Ice Age

The intense cold of the last Ice Age ended in Ireland about 13,000 years ago. An ensuing warm period allowed vegetation to invade the bare land, but this in turn was interrupted by a cold spell about 10,600 years ago which had a considerable effect on plant life. The sustained rise in temperature, however, allowed the migration of tree species to Ireland and culminated in clothing the country with forest cover, mostly of broadleaf origin.

The migration route into Ireland for most species is thought to have been from east to west across land bridges from Britain. In the case of oak, however, there is strong evidence from DNA haplotypes that the route was south to north, from refuges on the Iberian Peninsula (Kelleher et al., 2004).

The periods before man began to influence the structure of the vegetation cover are sketched in Table 1.2-1. Pollen analysis provides ample evidence of the developmental progression of this vegetation and facilitates reconstruction of the main periods.

During the climatic optimum, some 7,000-6,000 years BP, a natural primeval forest in stable equilibrium existed over most of Ireland, determined largely by environmental conditions. Broadleaf forests with low species diversity dominated the landscape but a number of broadleaf species, which thrive in Ireland today, were not represented in this primeval forest. The most notable of these are hornbeam, lime, sycamore and beech, which failed to find a pathway to Ireland.

The ecogramme (Figure 1.2-1) gives an impression of the reinvasion phases of the main tree species in central Europe after the ice ages.

Table 1.2-1: Main periods of the development of forests in Ireland before present (BP).
(Adapted from Mitchell and Ryan, 1997)

Time BP	Period	Vegetation development
13,000	End of Ice Age	Retreat of ice; spread of grass/sorrel cover.
12,500	Favourable climate at first then returning to cold phase	Climate favourable to spread of **juniper** and **birch** until about 12,000 when short periods of colder climate intruded to break up plant cover.
11,750	Rising temperatures	Return of the flora to grassland and tundra-like conditions providing an excellent habitat for Irish giant deer and reindeer for ~750 years.
10,600	Return of ice conditions	Disappearance of grassland and with it the Irish giant deer.
10,000	Rising temperatures; end of cold stage	Development of grassland with dock and meadow-sweet. Rapid invasion by **juniper** which replaced the meadows over wide regions within 250 years.
9,500	Relatively stable temperature	Suppression of **juniper** scrub by **willows**; these in turn gave way to **birch** to give Ireland its first woodland. **Aspen** also present.
9,250		Appearance of **hazel**; spreading widely on suitable sites. Arrival of **pine**; spreading irregularly. Migration of **ash** and **elm** across Britain into Ireland. **Oak** arriving from the south-east.
9,000		Fen peat began to form on edges of midland lakes.
8,500		**Oak** and **elm** well established. **Elm** and **hazel** dominating on more fertile midland soils; **oak** flourishing on the more acid soils of the south and northeast. **Ash** confined to dry limestone sites.
8,000	Interruption of land barrier to Britain	**Beech, hornbeam, small-leaved lime, sycamore** failed to find a pathway to Ireland before the Irish Sea inundated the land bridges.
7,500		**Oak** and **elm** suppressing **hazel** on heavier soils.
7,000-6,000	Climatic optimum, July temperatures 1-2 °C higher than today	Optimum development of late-successional species: Tall dense woodlands dominated by **oak** and **elm** on the more fertile lowlands. **Wild cherry** and **yew** within or in the vicinity of woodlands. **Alder** began to establish on wetter soils in the vicinity of lakes. **Pine** occupying the more acid soils of the west.
5,000	Wetter and cooler climate	Spread of bogs (having started to develop 1,000 years earlier). Engulfing **oak** forests (remains as bog oak) in midland and western peatland.
< 5,000	Beginning of human influence	Primitive farming damages woodland. Decline of **elm** due to elm disease.

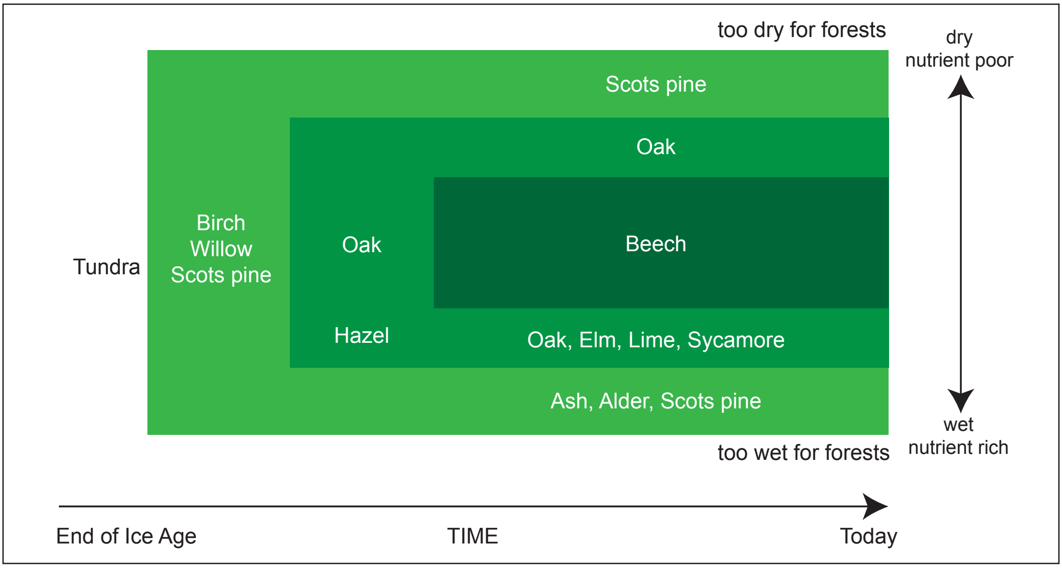


Figure 1.2-1: Reinvasion of tree species on continental Europe after the end of the Ice Age according to site conditions. (Source unknown)

The bottom line (X-axis) shows the time scale from the end of the ice ages (roughly 12,000 years before present) until today. On the vertical line (Y-axis) the quality of soils is given. On top are the sites too dry for forest growth, on the bottom those which are too wet. In between lie the transitions from dry to wet.

There are roughly four phases of this reinvasion:

(1) For some thousand years after the end of the Ice Age, tundra (grasses, herbs and some small bushes) covered the landscape.

(2) Pine (together with some birch and hazel), being extremely tolerant of a wide range of sites, occupied all land that could be colonised by trees.

(3) Oak, being more competitive, displaced pine on the best soils relegating it to the very dry or very wet sites.

(4) Beech was the last to reinvade, and being more competitive than oak, displaced it on moderate to good soils, eventually occupying 70-80% of central Europe. This was the primary beech region of Europe before man began woodland clearance and changed the distribution of species.

The late arrival of beech in Europe prevented it from reaching Ireland before the land bridges disappeared. Had beech migrated to Ireland there is little doubt that it would have dominated the majority of Irish sites and become the major tree within 1,000-2,000 years. Its growth since its introduction in the 18th century shows its suitability for many Irish sites. Furthermore, there is little doubt that other species like lime and sycamore would have reached Ireland had the land bridges existed for longer.

Conclusions

Tree colonisation after the last Ice Age followed a typical successional pattern. Early pioneers, such as birch and willow, paved the way for the long-living pioneers, oak and elm. During the climatic optimum, when temperatures were 1-2 °C higher than today, Ireland had primeval natural forests of relatively low species diversity. Had beech succeeded in reaching Ireland there is a likelihood that it would have become the dominant tree species of the forests.

1.3 History of man's influence on Irish forests to end of 19th century

1.3.1 Early human influences

Since the time plants and trees arrived in Ireland they have been greatly influenced by changes in climate, the development of bogs and above all by the actions of man (Plates 1.3-1 to 1.3-4). Although man's earliest presence in Ireland dates to ca. 8,650 BP the primeval forest remained largely undisturbed until the arrival of Neolithic farmers ca. 6,000 BP. From then onwards the forest suffered a gradual but sustained attack which eventually led to its almost complete destruction by the end of the 19th century.

Plate 1.3-1: Bare land in Connemara comparable to large areas in the world that have been cleared of forests by man.

Plate 1.3-2: Rehabilitation of forests around Kylemore Abbey, Connemara showing the potential to restore diverse forests even under adverse conditions.

Plate 1.3-3: Bare land in Turkey for comparison; very few trees remain. Destruction continues as one in the centre has been lopped recently.

Plate 1.3-4: Totally devastated rocky areas in E-Turkey with a small plantation forest illustrating the general potential that these poor sites have to carry woodlands.

The events which propelled this situation are outlined in Table 1.3-1.

Developments prior to the 7th century are based almost exclusively on pollen counts from lake mud deposits (Mitchell and Ryan, 1997). There is little information on how woodland was managed by the early Irish, although it is likely that the availability of iron cutting tools in Celtic times accelerated forest clearance. Furthermore, farming in ancient Ireland was predominantly pastoral, and grazing was probably the principal agent inhibiting regeneration.

1.3.2 Forest regulation in the Brehon Laws

The law-texts of the judgement of neighbourhood, *Bretha Comaithchesa*, of the early middle ages, deal with the various offences a farmer is liable to commit against his neighbour and includes a section on damage to trees and shrubs (Kelly, 1999). Four different degrees of damage are listed, and trees are ranked according to their economic worth for assessment of damage.

Table 1.3-1: Events leading to the **decline of the primeval forest** in Ireland. (References in text)

PERIOD	EVENT	EFFECT ON FOREST
6,600 BC	First appearance of man in Ireland	Hunter-gatherers who made no impression on the woodlands.
6,000 BC	Middle Stone Age (Mesolithic)	Very limited clearances.
4,000 BC	New Stone Age (Neolithic)	First people to till the land. **Elms** growing on the better soils were cleared for agriculture.
3,000 BC	Bronze Age	No evidence to suggest substantial increase in woodland clearance.
600 BC	Iron Age. Celtic Era	More robust cutting tools facilitated woodland clearance.
800 AD	Brehon Laws	Recognition of forest as essential for man's well-being and survival: community forest.
1600 AD	Tudor and Cromwellian conquest	Exploitation of **oak** forest for pipe staves, ships' timbers, charcoal and bark. **Coppice system** applied in many areas. Limited application of **coppice-with-standards**. Forest cover reduced to about 1%.
1740 AD	Afforestation incentives	Afforestation with conifer/broadleaf species: 140,000 ha of new plantations.
1870 AD	Land reform	Clearance of demesne woodlands.

The Brehon Laws indicate the existence of considerable tree cover in the 8th century, but also suggest the necessity to recognise the need for conservation and to afford legal protection to the woodland resource. Although many woods would have been privately owned, the law-texts emphasise that all law-abiding freemen in the community enjoyed limited rights in private woods.

The Brehon Laws era is the nearest Ireland has come to community forests such as those of continental Europe. It survived in Gaelic Ireland up to the end of the 16th century.

1.3.3 Tudor conquest

Woodland clearance during the 17th century became a part of colonization, both to provide agricultural land for the colonisers and to remove the cover which the trees afforded the natives. Furnaces were built wherever there was a supply of wood, and iron ore was imported for smelting with locally produced charcoal. During this time woodland was heavily exploited. Samuel Hayes of Avondale, writing in 1794, was led to comment that *such has been the waste of timber in Ireland during the last century from the unsettled state of the kingdom, and other causes, among which we may reckon the introduction of iron forges and furnaces, that there scarcely exists in some districts, a sufficiency to favour the supposition that we ever possessed a valuable growth* (Hayes, 1822).

By 1700 the ancient forest had been reduced to about 1% of the land area.

1.3.4 Tenant tree-planters

A series of Acts of Parliament from 1697 to 1791 attempted to halt or reverse the increasing destruction of woodlands. Directed at tenant tree-planters, the Acts of 1765 and 1789 gave certain classes of tenants who planted trees rights of ownership at the expiry of their lease (Smyth, 1997). The Dublin Society (Royal Dublin Society) initiated a grant scheme – the first of its kind – in 1741 to encourage the planting of trees. Premiums were granted for a total of 55 million trees planted between 1766 and 1806, but they were discontinued in 1808 because of fraudulent practices (OCarroll, 2004).

Commenting on the types of tree then planted by tenants, Smyth (1997) recorded that, in the last decade of the 18th century and first decades of the 19th century, broadleaf species were preferred to conifers by a ratio of 7:3. In the 1820s, however, the balance shifted in favour of conifers and by the 1850s they had outnumbered broadleaves by as much as 4:1. About 80% of tenant plantations were of mixed species. Sycamore, birch, elm and poplar were common among the broadleaves. Among conifers, larch, Scots pine and Norway spruce were the most favoured by mid-19th century.

1.3.5 Estate planting

Estate planting began in the 18th century when owners felt sufficiently secure to engage in estate improvement (Fitzpatrick, 1966). Adopting a practice then fashionable in England, estate owners in Ireland began to develop their demesnes through landscape planting and afforestation. The primary purpose of planting was not the production of timber, rather it was the enhancement of estate amenity and improvement of the owner's standing among his peers. Some large scale estate planting, however, had commercial objectives. Planting was seen as a mark of the progressive landlord (Plates 1.3-5 and 1.3-6).

Plate 1.3-5: Remnants of old oak woodlands at Devils Glen. (Ashford, Co Wicklow)

Plate 1.3-6: View inside a remnant of old oak woodland at Devils Glen. (Ashford, Co Wicklow)

Although broadleaf trees were well represented in the new plantations the main emphasis was on European and northwestern American conifers. European larch, Scots pine and Norway spruce were prominent among the European species, while Douglas fir and grand fir featured among the American exotics. Most of the new plantations were of mixed species, with broadleaves nursed by conifers, birch and alder. The list of broadleaf species resembles that of a forest nursery catalogue: ash, beech, oak, sycamore, alder, elm, birch, horse chestnut, Spanish chestnut, willow, poplar, hornbeam, lime, plane, and walnut in approximate order of importance (Feehan, 2005).

Some 53,000 ha of woodland was established in the 18th century. The most dramatic change to occur was in conifer plantings, which saw a sixteen-fold increase between 1791 and 1841, compared with a four-fold increase in overall tree planting (Smyth, 1997). By 1841 there were 140,000 ha of new plantations and the area under conifers had increased eight-fold. In the returns from the 1841 Census, the overall area of woodland including hedgerows, planted by landlord and tenant, was estimated at almost 200,000 ha (Smyth, 1997). Although established for a different purpose, these woodlands were to prove a valuable timber asset to their owners during the break-up of the estates towards the end of the 19th century.

1.3.6 Land Acts

The year 1880 marked the zenith of woodland area in private ownership. The following year saw the first of a series of Land Acts, which would eventually result in a major change in land ownership from landlord to tenant. Funding was made available by the British Exchequer to purchase estates which were then subdivided among tenants at an annual rent payable to the Exchequer. Under the Land Acts – over 40 in all – more than 50,000 tenants had purchased their holdings before the end of the 19th century (Durand, 1969). To avail of the particular Act, the landlord had to sell his entire estate. While this suited both landlord and tenant it was disastrous for the woodlands. The Land Commission, whose task it was to oversee the transfer of land, was not in a position to retain or manage these woodlands. They could only offer to purchase if they could recoup the cost by resale.

The Department of Agriculture and Technical Instruction was established in 1899. Although it was entitled to engage in forestry and acquire land for afforestation it did not have the funding. Under the terms of its establishment it could spend money, but it was not empowered to borrow it. The only outlets, therefore, in a position to purchase timber from landlord, the Land Commission or the new tenant owner were the sawmillers. The number of sawmills increased almost four-fold, from 245 in 1881 to 843 by 1907. Data compiled at the time show that forest cover in Ireland had fallen to about 120,000 ha, 103,000 ha of which was in the present Republic of Ireland (OCarroll, 2004).

Conclusions

Forest clearance began with the arrival of Neolithic farmers and continued at a gradual pace as the population increased. The Brehon Laws brought some order to woodland conservation and management with defined rights of usage for communities. Exploitation of remaining woodlands reached a peak in Tudor times and little remained at the end of the 17th century. The period of estate afforestation which followed created a largely coniferous resource, which was in turn largely liquidated as the estates were sub-divided among tenants. Woodland area reached a historic low at the beginning of the 20th century.

1.4 Development of modern forestry

1.4.1 Introduction: phases of development

The foundation of modern forestry was laid at the beginning of the 20th century when the first steps were taken to form a forest administration and re-establish forests by afforestation. In its development, which continues to the present, two distinct phases can be distinguished:

- 1904-1980: afforestation was driven by the state and dominated by coniferous species, partly because of site limitations;
- 1980-present: the balance shifted in favour of the private sector and with better sites available, broadleaves began to play a greater role.

This chapter explores the events which lead to the establishment of afforestation programmes that brought about the forest estate as it exists today.

Figure 1.4-1 provides a graphic overview of annual afforestation by the state and private sectors since records began.

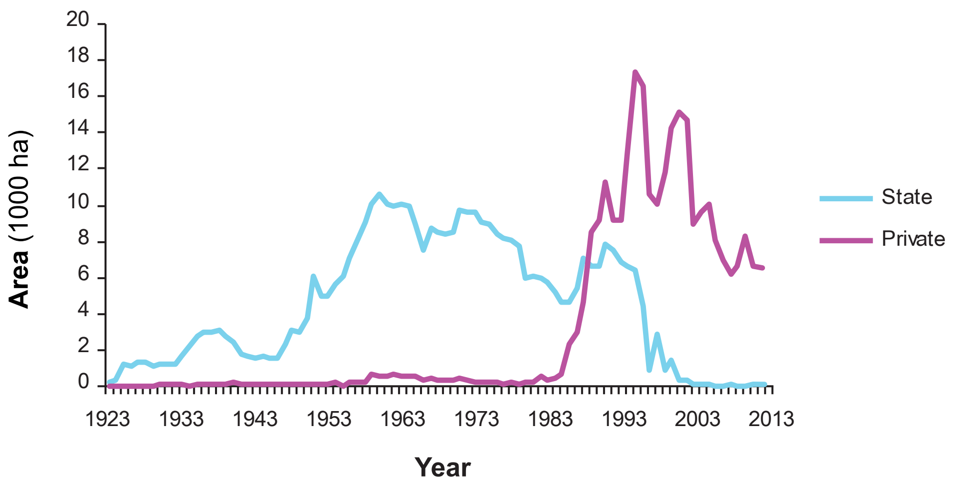


Figure 1.4-1: Annual Afforestation: State and Private: 1923-2013. (Forest Service, 2014)

Figure 1.4-2 data mirror that of Figure 1.4-1 from the 1920s to the 1980s showing the close connection between state and conifer afforestation. During this period broadleaf afforestation paralleled a somewhat static level of private sector planting. From the 1980s onwards, however, the private sector emerged as the major force in afforestation. It replaced the state sector as the main contributor and, although conifers still dominated, broadleaves began to play a greater role.

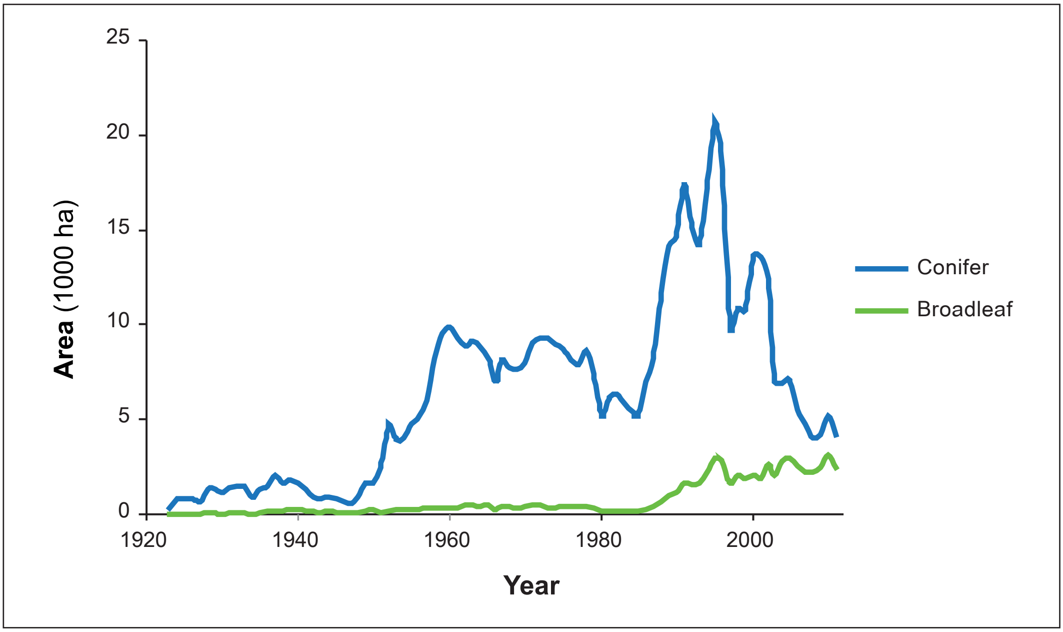


Figure 1.4-2: Annual Afforestation: Conifer and Broadleaf: 1923-2012. (Forest Service, 2013)

1.4.2 Conifer phase: 1904-1980

Events which helped to shape the course of forestry during this phase are outlined in Table 1.4-1.

1.4.2.1 First steps in forestry development: 1904-1922

Avondale Acquisition

In 1904, the Department of Agriculture and Technical Instruction (DATI) set about improving the depleted forest situation using monies from the Department's Endowment Fund to purchase Avondale House and Estate for the purpose of establishing a training school for foresters. A Forestry Section was created within the department and a forestry expert, A. C. Forbes, was retained. One of his first tasks was to establish experimental plots at Avondale in 1904.

1908 Committee of Inquiry

Following the acquisition of Avondale funding was made available by the Exchequer for the purchase of lands at Camolin and Dundrum. In the meantime the department appointed a Committee to inquire and report on matters relating to the improvement of forestry in Ireland. The Committee took oral evidence from 48 people and delivered its report in 1908. Among its recommendations were the necessity for State involvement because of the capital outlay required and the need for continuity of management. Pointing out that a forest authority already existed within the Department, it suggested that the objects of a national scheme of afforestation might be the maintenance of an area of woodland sufficient to produce the timber required for domestic and farming purposes, and the development of industries and commerce. For this purpose the Committee recommended an area of at least 400,000 ha of woodland (1 million acres).

Table 1.4-1: Events which shaped the **course of Irish Forestry:** 1904-1980.

YEAR	EVENT	OUTCOME
1904	Establishment of the Forestry Section in the Department of Agriculture and Technical Instruction.	Purchase of Avondale House and Estate as a centre for practical training in forestry. Establishment of species experimental plots.
1908	Committee of Inquiry	Objective: afforestation scheme to produce sufficient timber to meet country's needs, to be undertaken by or under the supervision of the State, an area of 400,000 ha required.
1916	Acland Sub-Committee	Strategic reserve needed in time of war: afforestation target for UK of 716,600 ha as an extension to the existing 800,000 ha: recommended establishment of Forestry Commission.
1919	Forestry Act,1919	Establishment of the Forestry Commission
1922	Establishment of Irish Free State	6,895 ha of woodland inherited by the Irish State. Afforestation policy to continue as before, influenced by recommendations of 1908 Committee and Acland Sub-Committee.
1925	Dept. of Agriculture decision	Announcement that land fit for agricultural purposes would be precluded from acquisition for forestry.
1928	Forestry Act, 1928	State control of tree felling and right to attach replanting conditions. Commencement of state grants for planting.
1946	Forestry Act, 1946	A more comprehensive version of Forestry Act,1928: statutory obligation to replant and maintain plantation for 10 years.
1948	White Paper	Proposal to plant 10,000 ha per year until 400,000 ha of new plantations had been established.
1951	Cameron Report	Endorsement of planting programme and recommendation for a forestry research organisation.
1957	Research Section	Silvicultural research; forest inventory.
1973	Ireland gained accession to the European Economic Community.	Agriculture prospered and land prices increased. State afforestation began to decline.

Quoting from the Departmental Committee Report, OCarroll (2004) commented that, although it made no recommendation on the choice of species, it suggested that the forestry section should adopt as its policy for the first rotation, the planting of *quicker-growing varieties of coniferous timber, though mixed, of course, with other species.* The report goes on to explain its reasons for this policy: *such timber will give the earliest returns; the returns are more certain; and that conifers grow more successfully on inferior classes of land. There is now, and there is bound to be for a very long time to come, a sure demand for well-grown coniferous timber at remunerative prices.*

The 1908 Committee Report envisaged the achievement of 400,000 ha by maintaining the existing 120,000 ha of private woodland, inducing private owners to plant a further 120,000 ha and the State to contribute the remainder. A contribution was also expected from the County Councils, but in the event neither they nor the private sector responded to any degree. If the target was to be realised the State would have to play a more active role.

Acland Sub-Committee

The situation in Britain as regards its timber reserves at the outbreak of World War I was far from reassuring. More than 90% of its timber had been coming in from overseas before the war and wood, as well as food, were the two bulkiest items of war supply (Ryle, 1969).

The war effort demanded wood, and Irish as well as British private woodlands were expected to supply it. Woodlands, that had survived the destruction during the break-up of estates in the late 19th century, were now exploited for the war effort. There was no obligation on the owners to replant (Durand, 1969). Many woods were left with only the unwanted culls, to be overgrown with weed species. Some found their way into State ownership.

In 1916, as World War I was assumed to be reaching a close, the Prime Minister *appointed the Forestry Sub-Committee of the Ministry of Reconstruction… To consider and report upon the best means of conserving and developing the woodland and forestry resources of the United Kingdom, having regard to the experience gained during the war* (Ryle, 1969).

In its report the sub-committee made the point that dependence on imported timber was a grave source of weakness in time of war: a point being hammered home by the U-boat campaign. This gave rise to the concept of a strategic reserve for emergencies which remained enshrined in British forest policy until the 1950s.

To implement afforestation programmes the sub-committee recommended the establishment of a Forestry Commission. This took place in 1919, and during its short period of responsibility for Irish forestry, the Commission acquired about 3,300 ha in Ireland, partly by purchase and partly by lease.

1.4.2.2 Early years of Afforestation: 1922-1950

In 1922, the newly established Irish Free State inherited a woodland area of almost 7,000 ha. Forestry reverted to the Department of Agriculture: planting continued as before amounting to a modest 400 ha in the following year.

Reflecting the findings of the 1908 Committee of Inquiry and those of the Acland Sub-committee, afforestation required *the ultimate creation of a home supply of raw timber sufficient to meet home requirements so far as it is possible to grow at home the types of wood required* (Gray, 1963). To this end, declarations of successive Governments were concerned with the promulgation of planting targets, accompanied by references to the advantages of self-sufficiency in timber and the social values acquired by the provision of employment, particularly in disadvantaged areas.

For the Forestry Division to enlarge on its nucleus, land for afforestation had to be acquired from a farming population for whom land ownership had become an emotive issue as a result of the land war in the previous century. Furthermore, agriculture was the main industry and the one on which the economy was heavily dependent. In the circumstances politics and pragmatism combined to effectively exclude from forestry land capable of reclamation for agriculture.

The Annual Report of the Minister for Agriculture for 1925-26 set out the position: *The Department do not desire to acquire for afforestation land fit for agricultural purposes which might be capable of being used to form new holdings or enlarge existing ones. With a view therefore to preventing such land being acquired for afforestation they have fixed a maximum price at such a figure as to render its sale to the Department for this purpose an uneconomic transaction* (Gray, 1963).

This policy remained in force for the next half-century. The maximum price allowed was €12-16/ha initially and although this was increased over the years it ensured that, apart from one short period in the 1930s, only the poorest sub-marginal agricultural land came to forestry. This effectively ruled out the more site-demanding broadleaves.

As a consequence of the maximum price allowed, land acquisition made slow progress over the next decade. The Land Commission continued its work in dividing estate land among the tenants and in the process offering any non-agricultural portions to forestry, but the supply was irregular and unreliable (OCarroll, 2004). Felling of timber continued on estates without any obligation to replant, but the Forestry Act 1928 changed this practice by imposing a replanting obligation. The Act also made provision for a planting grant to help defray the cost, but the amount was insufficient to motivate any considerable level of private planting. As a result, private planting until the mid-1950s, about 120 ha/yr, was mainly due to the replanting obligation. Afforestation during the first decade averaged 1,200 ha/yr (refer to Figure 1.4-1).

Economic War with Britain

The mid-1930s is significant for mixed conifer/broadleaf planting. The new government, elected in 1932, withheld from Britain the land annuities which were due in respect of the capital advanced by the British Exchequer in buying out the landlords in the previous century. Britain retaliated by imposing a tax on imports of Irish cattle and dairy produce and the Free State replied with duties on British goods. So began the so-called economic war which lasted for six years.

From 1932 to 1938, with no export market for their produce, many farmers suffered severe economic hardship. The Forestry Division was the only buyer for those forced to divest themselves of part of their holdings. Most of the land acquired during the period was of a quality superior to that previously available under the restrictive price regime. It is noteworthy that the best and largest areas of broadleaf woodland date from that period (Plate 1.4-1).

Afforestation during those years increased to some 3,000 ha/yr (refer to Figure 1.4-2). Conifers predominated even on land that would suit broadleaves:

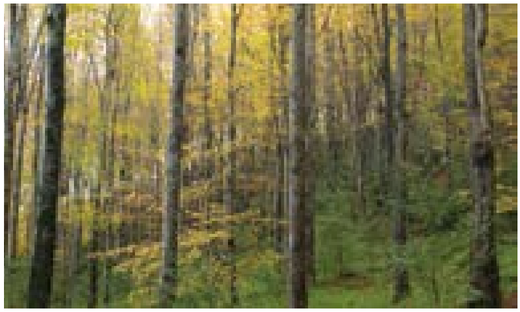


Plate 1.4-1: Beech planted originally in mixture with larch in the mid-1930s at Ballyarthur Estate. (Co Wicklow)

- **Norway spruce** was strongly favoured over much of the north midlands, often with groups of oak (Anderson groups) interspersed throughout the crop.
- **Scots pine** and **larch** were the species of choice on the drier sites of the south, with **Scots pine** in particular being chosen for the Old Red Sandstone podzols (a selection that was changed at a later date).
- Of the North American conifers **Douglas fir** found a place on valley slopes in the east and south, but **Sitka spruce** had yet to make a major impact. Its proneness to damage by late spring frost militated against its selection on lowland sites, where Norway spruce was preferred. When its potential was eventually recognised, however, it came to dominate the afforestation programme.

World War II

During World War II remnants of the old estate woodlands in particular were called upon for the production of timber and fuelwood for what was known as the emergency. Many were left in a devastated condition and, rather than face the cost of replanting, their owners sold them to the Forestry Division. Afforestation rates again declined, mainly because of unavailability of tree seed and the scarcity of netting wire needed for fencing against rabbits.

Post-war years

The war probably revived the idea of a strategic reserve of timber for times of emergency. In the event, post-war afforestation targets became a serious political issue. A change of government in 1947 brought a new dynamic to forestry in the person of Sean MacBride, Minister for Foreign Affairs. The annual afforestation target was increased to 10,000 ha per year for 40 years, a programme of 400,000 ha in total. At a time when the annual planting programme was 3,000 ha this was a truly ambitious target.

The new programme received much opposition particularly from administration who regarded it as inflationary. A flying survey was organised to assess its feasibility in the context of land availability: it reported favourably. In light of this information the government wished to have its conclusions checked by an independent source and requested the assistance of FAO in this matter. Roy Cameron, Chief of FAO’s Forestry and Forest Products Working Group for Europe, came to Ireland for a short period. In his report (FAO, 1951) he recommended the division of the programme into two parts of 200,000 ha each, one with a commercial and the other with a social objective. The report was accepted, but in its implementation the social element was ignored (Rea, 1985): all planting was classified as commercial.

1.4.2.3 Era of Expansion: 1950-1980

Land acquisition remained a critical problem. Caught between the quality of land it was allowed to purchase and the price it could pay, Forestry Division had little room to manoeuvre. The most likely source of supply to come within the imposed conditions was the peatlands of the West of Ireland, in Counties Kerry, Galway, Mayo and Donegal. Fortuitously, in the early 1950s the Forestry Commission (GB) had developed machinery which would make the drainage and planting of peat and peaty podzols possible and thus suitable for forestry. A number of these were purchased by the Forestry Division. Annual planting increased and the 10,000 ha target was eventually achieved in 1959 (refer to Figure 1.4-2).

Species selection
Species selection was simple:

- **Sitka spruce** was recognised for its outstanding qualities in terms of adaptability to site, growth potential and the versatility of its timber. It soon accounted for over half the species planted and would dominate in species selection for the coming decades.
- On the poorest of sites **lodgepole pine** was the only species with any potential.
- **Broadleaf species** played only a minor role because of the availability of land of only very poor quality.

Economic considerations
In the mid-1950s concern was expressed that the rate of afforestation was rising above the level needed to meet domestic timber requirements and that excess production would have to be sold on export markets. The resulting increased expenditure involved was exacerbated by a series of wage increases and the combination of both called into question the economics of the undertaking. This increase in emphasis on economic issues was part of the Government forest policy under the Government 1958 Five Year Programme for Economic Expansion which, while providing for the continuation of the 10,000 ha planting target, wished to ensure that it was based on sound economic lines.

A detailed economic analysis which followed showed the possibility of the forestry enterprise bearing a compound rate of 5.25%. This rather optimistic return involved treating non-capital expenditure in the Forestry Vote as a social service for a period of about 15 years, a procedure justified on the basis of the social advantages of afforestation (Gray, 1963).

Forest Amenities
The exercise in economics may have prompted the Forestry Division to emphasise other attributes of forests. By the mid-1960s more attention was being paid to the incidental values of forestry, particularly recreation and amenity. An open forest policy was adopted and people were encouraged to go into the woods. Forest walks were laid out and picnic sites were created. It is widely acknowledged that the Forestry Division has been very successful in providing forest recreation facilities, which continue to this day. In a country where the right to roam is circumscribed, forests remain the only place where recreation can be enjoyed without hindrance.

Wildlife Conservation
1970 was designated European Conservation Year by the Council of Europe and, as a contribution to this event, the Forest Service embraced the conservation function to the extent that it changed its name to the Forest and Wildlife Service. The name change became official in the spring of 1970 and remained so until the conservation function of the Forest Service was transferred to the Office of Public Works in 1988, in preparation for the implementation of the Forestry Act of 1988. This act provided the legal basis for the establishment of Coillte Teoranta.

During the 18 years of the Forest and Wildlife Service, the passing and implementation of the Wildlife Act of 1976, the EU Bird Directive of 1979 and Council of Europe Conventions on species and habitats (Bonn and Bern Conventions) gave a momentum to conservation issues that required additional resources to match a new legal environment. The ethos and resource needs of the two arms of the service caused difficulties for both and resulted in a gradual realisation that, on many issues, they were at opposite ends of the spectrum. The separation of functions in 1988 was, therefore, accepted with some relief by both practitioners and administrators (Mulloy, 2008).

Entry to the European Economic Community

The oil crisis of 1973 precipitated a recession accompanied by an economic crisis in Ireland. More positively, 1973 also saw Ireland gain accession to the European Economic Community (EEC) and, importantly for agriculture, accession to its markets and availability of Common Agricultural Policy (CAP) subventions. This promised a doubling of family farm income and, despite the considerable economic turbulence of the 1970s, it had largely delivered on that promise at the end of the transition period to full membership in 1978.

As agriculture prospered, the price of land increased rapidly and the State was gradually pushed out of the market. Drawing on its land reserves, it maintained its afforestation programme of 8,000 to 9,000 ha/yr but, by the end of the decade, State afforestation began a downward trend from which it only recovered briefly in the late 1980s. The target of 400,000 ha was eventually achieved in 1991 (OCarroll, 2004).

1.4.3 Conifer/broadleaf phase: 1980-present

Accession to the European Economic Community, and with it access to the CAP subventions, brought unprecedented prosperity to agriculture, but the policy had overlooked forestry as an alternative land use. Not until overproduction in agriculture became a costly embarrassment was forestry considered.

To induce landowners to remove land from agricultural use, a European Economic Community/National Exchequer co-funded afforestation programme with grants was attached to the Western Package in 1981. Response was slow in the beginning and over the next decade the Western Package was supplemented by other schemes.

A significant breakthrough occurred in 1986 when farmers in receipt of headage payments were compensated for moving out of traditional farming into forestry. (Headage payments were paid to farmers in disadvantaged areas on the basis of the number of animals stocked on the farm).

The introduction of annual premiums in 1989 gave a further impetus to farmer afforestation in that it provided them with direct income support. These were followed by the Common Agricultural Policy grant and premium scheme of 1993 and the Rural Development Programme of 2000, each of which contributed to an improvement in the amount of grant and premium. The private sector responses to these later incentives are shown clearly in peak afforestation following their introduction (refer to Figure 1.4-2).

Directed mainly at farmers, but in some cases both farmers and non-farmers, the above schemes were weighted in favour of broadleaves in both the initial grant and the value and duration of the premiums. Broadleaves were deemed by European Economic Community officialdom to be more in keeping with the environment.

Coillte Teoranta

As mentioned briefly above, Coillte Teoranta (The Irish Forestry Board Ltd.) was established under the Forestry Act 1988 as a separate entity to the Forest Service. The main functions transferred to Coillte Teoranta were ownership and responsibility for the management of all State commercial forest lands. The Act required that Coillte *carry on the business of forestry on a commercial basis and in accordance with efficient silvicultural practices and to have due regard to the environmental and amenity consequences of its operations.*

The Forest Service retained responsibility for national forest policy, promotion of private forestry, administration of planting and other forestry grant schemes, forest protection, control of felling and promotion of research in forestry and forest produce (OCarroll, 2004).

Strategic Plan

Towards the end of the 20th century the forest sector was recognised by Government as an important contributor to the economy of the country. To tap into its further potential a consultancy team was employed to bring forward a strategic plan for forestry related development to the year 2015 (Department of Agriculture, Food and Forestry, 1996).

Reviewing the then current forestry situation the team recognised the main characteristics of the sector:

- A total forest cover of 570,000 ha.
- 390,000 ha of the forest estate owned by Coillte Teoranta.
- Afforestation by the private sector, and particularly by farmers, had increased in recent years and had exceeded that of the public sector.
- About half of the forest estate was under 25 years of age.
- The predominant species was Sitka spruce – about 60% of the forest estate and 65% of the annual afforestation.
- Broadleaves accounted for an estimated 16% of the forest estate and 20% of the then current annual afforestation.

The conifer forest estate (84% of total) was the main contributor to the then 2.2 million m^3/yr timber production. Broadleaves contributed very little. Apart from the areas planted in the 1930s, the broadleaves were either recent plantings, and, therefore, immature, or mostly remnants of old estate woodland and largely of poor timber quality.

The Strategic Plan made the case for further investment in forestry on the basis of

(1) an afforestation target area of ideal size for the industry – a critical mass,
(2) the real rate of return on investment,
(3) future timber processing,
(4) employment.

(1) The term **critical mass** is used to define a scale of timber production of sufficient size to enable true competition and the operation of market forces, at a national and international level and to support a range of processing industries.

Achievement of a critical mass through additional afforestation would determine the timeframe of the Strategic Plan. This would be influenced by both the annual rate of afforestation and the productivity of the species planted. In the latter context, a species with high yield class would increase the volume of timber produced and help to shorten the timeframe. A low yield class species would lengthen the time within which a critical mass could be produced.

Conifers, with their greater volume production and shorter rotation, were an obvious choice to achieve critical mass in the shortest possible timeframe. Sitka spruce in particular was the most attractive commercial conifer because of its growth rate and adaptability to most sites.

The achievement of critical mass required a minimum timber production in the region of 10 million m^3/yr and preferably 12-15 million m^3/yr. Without any further afforestation from 1995 onwards the then current production of 2.2 million m^3/yr would rise to 5 million m^3/yr by 2035 as the then existing forests matured. To bridge this gap in production would obviously require an enlarged afforestation programme if the goal was to be achieved within a reasonable time scale.

(2) An **economic analysis** undertaken in formulating the Strategic Plan found *(inter alia)* that

- the estimated real rate of return on forestry (Sitka spruce) was 4.3%,
- without subsidies, forestry gave a better return than other agricultural activities except dairying.

The Strategic Plan took into account the external benefits of forests – landscape, amenity, wildlife habitat, tourism and recreation – but added the rider that they were difficult to quantify and that an estimate of about €26 million of annual indirect benefits might be appropriate.

(3) Achievement of a critical mass would benefit the **processing sector**. The value of total production and the value added would increase to about €1,600 million and €1,000 million respectively by 2035.

(4) An increase in **employment** in the forestry sector of 11,000 would be achieved by 2020.

Taking the achievement of critical mass by 2035, as well as the need for species diversification into account, the consultancy team recommended a strategic action for species selection of

- 60% Sitka spruce,
- 20% diverse conifers,
- 20% broadleaves of which oak would consist of 20%.

On this basis critical mass would be achieved by afforestation levels of

- 25,000 ha/yr to year 2000,
- 20,000 ha/yr from 2001 to 2030.

Bacon Report

Reviewing the Strategic Plan, Bacon (2004) commented that there had been considerable changes since 1996 and that further changes were to be expected with CAP reforms in 2005. The most notable feature was the failure to achieve the Strategic Plan afforestation target which had then fallen to just over 14,000 ha/yr for the period 1996-2003.

The situation had not improved in the following years. This was partly due to a decision of the European Commission that Coillte Teoranta was a public entity and as such could not avail of the afforestation premium. The decision became effective from August 1996 and, although it was appealed to the European Court of Justice, the ruling in October 2003 upheld the decision of the Commission (Bacon, 2004). The effect was to remove Coillte as a competitor for land and as a result public afforestation declined and had virtually ceased by 2006. It dwindled to 25 ha in that year and its planting activities became restricted to reforestation commitments.

Furthermore, the targeted species mix had not been achieved and, even though the broadleaf target of 20% had not been reached, it was increased to 30% in the CAP Rural Development Plan 2000-2006. This 30% target was eventually achieved in 2006 and 2007, but only as a proportion of a total afforestation of 8,000 ha and less than 7,000 ha in the respective years. Nonetheless, afforestation of broadleaves averaged consistently in excess of 2,000 ha/yr during the period 1998-2007 and, despite the shortfall in afforestation targets since 1996, private forests now account for 40% of the total forest estate. 90% of all new plantations have been established by the private sector and of those the vast majority are owned by farmers.

The Report was also critical of management practices. They were considered to be poor, particularly with regard to broadleaves, and private sector thinning was thought to be well short of its potential.

Looking towards the future, the reviewers concluded that 20,000 ha/yr was the most appropriate minimum target required to sustain a viable processing sector.

Conclusions

Afforestation in the 20th century significantly increased the forest area from 1.6% at the beginning of the century to over 10% in 2013. Most of the credit must go to the State sector which, although encumbered by price restrictions and poor quality land, persevered in its objective to afforest 400,000 ha. It achieved its target in 1991.

Against the odds it has created an important national asset with a timber resource which continues to supply a woodflow to the country's wood processing sectors. The predicted oversupply was easily absorbed by the demands of sawmills and the wood-based panel products sector.

In 2012 the national output of roundwood was 2.84 million m^3 of which 2.35 million m^3 was produced by the State sector, with the balance coming from the expanding private sector.

continued

Conclusions continued

In that year Irish sawmills utilised almost 1.7 million m^3 of roundwood, producing an estimated 0.78 million m^3 of sawn timber, most of which was sold on the home market. Sawn timber exports grew by 38% over the period 2008–2012.

The panel products sector, utilising 1.28 million m^3 of wood fibre, produced 704,000 m^3 of wood based panels, 89% of which was sold in overseas markets. Forest products exports from the Republic were worth €303 million in 2012 (Knaggs and O'Driscoll, 2012).

From a purely financial perspective, the State forest enterprise showed a return on investment, over inflation, of about 2% (Review Group on Forestry, 1985).

The 1996 Strategic Plan, which envisaged the afforestation of 20,000 ha/yr up to 2035, through the combined efforts of the State and private sectors, has fallen short of target. This is partly due to the cessation of land purchase by Coillte, the State sector, but also stems from failure on the part of the private sector and especially the farming sector. In the light of events, a re-appraisal of the Strategic Plan was undertaken and it reported in 2014 (Department of Agriculture, Food and the Marine, 2014).

1.5 Broadleaf species by area and growing stock

1.5.1 Role of forestry in the country

The Forest Service completed the first scientific National Forest Inventory (NFI, 2007) in December 2006. This involved a detailed field survey of Ireland's forests to assess the extent, status and composition of the entire national forest estate, both public and private. It provided a comprehensive source of information about many attributes of forestry in the Republic. Based on a scientific sampling procedure by permanent forest sample plots, the inventory provided information on land-use classification and generated estimates of growing stock and other attributes with related confidence limits. In 2013, a second inventory was completed. The main findings of this inventory are presented below.

For full details the original documents should be consulted (NFI, 2007 and NFI, 2013).

In this chapter an overview is given which shows the scale and composition of the most important forestry attributes and characteristics. The objective is to provide an outline of the country's main land-use types and the role of forestry. The main land-use types are presented in Table 1.5-1.

Table 1.5-1: Main land-use types in Ireland.
(Adapted from NFI, 2013)

Land-use type			Area 1,000 ha	Area %	
Agriculture	Grassland		3,725	*53.3*	*58.3*
	Cropland		352	*5.0*	
Forestry	Forest	stocked forest area	637	*9.1*	*10.5*
		unstocked area	17	*0.2*	
		forest open area	78	*1.2*	
Other land with trees	Hedgerow		272	*3.9*	*7.7*
	Scrub		83	*1.2*	
	Green space (rural + urban)		113	*1.6*	
	Other woodland		48	*0.7*	
Peatland	Bog + heath		916	*13.1*	*15.5*
	Cutover peat		169	*2.4*	
Settlement	Built land, roads, tracks		314	*4.5*	*4.5*
Other	Water body, coastal complex		166	*2.3*	*3.5*
	Bare rock + soil, stone wall, quarry		86	*1.2*	
		Total	**6,976**	***100.0***	

The data in Table 1.5-1 show:

- Almost 60% of the land surface is **agricultural land** of which nine-tenths is in pasture. This confirms the general impression that Ireland is predominantly pasture land. Travelling through the country it is apparent that the quality of the pasture varies widely: highly productive meadows in the lowlands and rough, stony or peaty moorland in the uplands. There are many intermediate types between both of these. The level of land becoming available for afforestation is likely to depend on the amount and level of State-financed incentives available for agriculture and forestry, and their relativities, and prices for both agricultural and forestry commodities, as well as a range of socio-economic factors. Work by Farrelly and Gallagher (2013) has quantified the amount of land available for afforestation, net of environmental constraints, and according to land use suitability classes. Although some marginal agricultural land of poor quality has been afforested in the last two decades this is unlikely to continue and this will be discussed in Chapter 3.6 and 4.7.

- The **stocked forest area** together with the **unstocked area** and the **forest open area** covers just over one-tenth of the whole country. The temporarily **unstocked areas** are mainly located in the public forests where older stands are regularly clearfelled and the felled areas reforested. Their area of 2% is normal and is in accordance with that in other countries.

  (Stocked forest area is defined as land with a minimum area of 0.1 of a hectare, has a minimum width of 20 m and trees reaching potentially 5 m in height and a canopy cover of more than 20%. Unstocked area is forest temporarily unstocked due to factors such as fire or following harvest, but is expected to be reforested. Forest open area is a non-stocked area which is greater than 400 m², and with a maximum size of 2 ha within the forest boundaries.)

- **Various types of tree-related land categories** such as hedgerows, scrub and green-space make up 8%. These may play a certain role for forestry in a wider sense in the future.
- **Bog, heath and cutover peat**, with over 1 million ha, is a major component of the Irish landscape. A certain proportion of it may be suitable for afforestation and thus play a limited role in the expansion of forests in the future. The area of cutover peat that may be suitable for afforestation has been estimated by Bord na Móna as between 12,000 and 16,000 ha. While most of this land is more suited to conifer forests, nevertheless, alder and birch may be accommodated on the less acid sites (BOGFOR Report, 2008).
- The remaining land-use types such as **settlements, roads, lakes and rivers** account for approximately 8% and are obviously not suitable for trees or forests. They do not need further comment.

The main findings with regard to land-use types are that Ireland has a very high proportion of land suitable for agriculture and forestry. The forest area could be increased substantially by utilising some of the current degraded woodland areas, such as other woodlands, scrub and open forest areas and by upgrading hedgerows through enrichment with ash, cherry, sycamore, oak. This, however, depends greatly on future developments in agriculture. More details are given in Chapter 4.7.

The forest areas will now be described according to ownership, main species, their distribution and growing stock as well as age classes.

1.5.2 Total forest area and growing stock by ownership

Today's forests have reached an area and development stage as shown in Table 1.5-2.

The data in Tables 1.5-1 and 1.5-2 provide the following information:

- The **total forest area** of 731,600 ha corresponds to 10.5% of the whole country. This is still very far from the goal of 17% envisaged for 2030 by the Strategic Plan (refer to Chapter 1.4-3).

  These forest areas contain approximately 97.4 million m³ of standing roundwood. On average, they carry a growing stock of approximately 148 m³/ha.

  This figure is relatively low compared with other European countries of the

Table 1.5-2: Forest area and growing stock according to ownership. (Adapted from NFI, 2013)

Feature	Unit	Ownership			
		public	private: grant aided	private: other	Total
Area	1,000 ha	395.8	246.1	89.7	**731.6**
	%	*53.2*	*34.0*	*12.8*	***100***
Growing stock	Mill. m³	61.2	21.6	14.6	**97.4**
	%	*62.8*	*22.2*	*15.0*	***100***

temperate zone (Austria 325, Germany 320, Switzerland 337 m³/ha in 2000). However, it does not reflect the true growth potential of Irish forests, but is due to a combination of factors including the early stage of development of many plantations and the low level of stocking in many of the older broadleaf forests.

- More than half of the forest area is **State-owned** (Coillte), and contains almost two-thirds of the growing stock.
- Approximately one-quarter of the forest area is **small scale forestry** on former farmland. It has been established – as shown in Chapter 1.4 – during the past three decades by the provision of planting grants and premiums. Nearly all of the stands established are, therefore, very young and contain a relatively low growing stock volume at present.
  The relationships between age class, area and growing stock will be discussed in more detail later (Tables 1.5-7 to 1.5-9).
- The **other private forests** comprise roughly one-eighth of the whole forest area and include a wide variety of smaller woods around the old estates, field woodlots, and ancient woodlands. As they are generally much older, their growing stock is somewhat higher and, therefore, accounts for almost one-sixth of the total. Some of this is over-mature, however, and of very poor timber quality.

1.5.3 Order of main species as distributed by ownership

As a background to this publication an overview of the order of tree species in relation to area, growing stock and their proportion may be of interest to the reader. The most recent data available are given in Table 1.5-3. (The **stocked forest area** of 637,000 ha is used as the 100%-basis for most of the following tables which are derived from NFI data.)

Conifer forests cover roughly two-thirds of the whole forest area; broadleaves 17% and mixed forests 14%. The proportion of **growing stock** for broadleaves is even less favourable, with conifer forests having nearly three-quarters of the total.

Table 1.5-3: Areas and **growing stock** of forest types. (Adapted from NFI, 2013)

Mixed: A forest composed of broadleaf and conifer species, the minor category making up at least 20% of the canopy.

Forest Type	Area 1,000 ha	Area %	Growing stock Mill. m³	Growing stock %
Conifers	437	*69*	72	*74*
Broadleaves	112	*17*	13	*13*
Mixed	88	*14*	12	*13*
Total	**637**	***100***	**97**	***100***

The above data contrast with the impression one gets while travelling through the country. The majority of hedgerows, small woodlots, single trees within the landscape and urban areas contain predominantly broadleaves and can give the impression that Ireland is a broadleaf country.

The distribution of the proportions of conifers and broadleaves with regard to area and growing stock by ownership is given in Table 1.5-4.

According to these data the proportion of conifer, broadleaf and mixed forests, varies considerably between public and private ownership:

- The **conifer** forests are growing almost entirely in the public and grant aided private forests, i.e. 97% of the area and 95% of the growing stock.

Table 1.5-4: Areas and **growing stock** of forest types and their distribution within the forests of different ownership. (Adapted from NFI, 2013)

Feature	Forest Type	Ownership: public (%)	Ownership: private, grant aided (%)	Ownership: private, other (%)	Total (%)
Area	Conifers	*60*	*37*	*3*	***100***
	Broadleaves	*25*	*20*	*55*	***100***
	Mixed	*58*	*30*	*12*	***100***
Growing stock	Conifers	*69*	*26*	*5*	***100***
	Broadleaves	*26*	*7*	*67*	***100***
	Mixed	*58*	*18*	*24*	***100***

- **Broadleaf** forest types cover only a little more than one-sixth of the forest area – as already shown in Table 1.5-3. The majority of broadleaves – 55% – are to be found in the other private forests, although their total area is very small. While public and grant aided private forests are comprised of stands that are almost entirely conifers, the opposite applies in other private forests. In this latter category broadleaves dominate both in terms of area and growing stock.
- The **mixed** forests are mainly in the public estate, i.e. 58% both by area and growing stock.

1.5.4 Role of broadleaf tree species according to areas

Following examination of this general classification some information on the role of the broadleaf species will be presented below.

Species have been classified by the National Forest Inventory into eight broadleaf species categories on the basis of similarity in growth rate and form. Five of these groups are more or less long-living tree species while three of them consist of short-living ones. The sequence of the species was adapted from the NFI.

Careful consideration is needed in the interpretation of stocked areas of individual species presented in the NFI, since many forests contain an intimate mixture of species. The total stocked area of a given species, therefore, does not represent distinct areas of land covered by pure stands of the species, but by and large may represent the sum of shares of areas of mixed forest apportioned to it.

The areas and the proportions are given in Table 1.5-5 and show:

- **Long-living broadleaves**
  They cover approximately 66,000 ha or just over 10% of the stocked forest area of 637,000 ha.
  The proportions of the long-living broadleaves are as follows:
  - **Ash** – comprising roughly 3% of the stocked forest area – is the dominant species.

Table 1.5-5: Area of broadleaf species groups and species within groups.

(Adapted from NFI, 2013. Many forests, particularly those in the early regeneration phase, contain a mixture of species, and as indicated, the area for a given species, as presented in the table, does not represent discrete areas covered by pure stands of the species. Neither is the species composition of mixed forests static; as individual forests age and develop, the proportion of short-living broadleaves such as willows will tend to decrease.)

Species Group		Species	Recorded On: Area (ha)	Recorded On: % Stocked Forest Area
Long-living broadleaves	**Ash**		**20,609**	***3.2***
	Oak		**16,837**	***2.6***
		Sessile oak	6,353	*1.0*
		Pedunculate oak	10,484	*1.6*
	Beech		**9,500**	***1.5***
	Sycamore		**9,249**	***1.5***
	Other long-living broad-leaves		**9,733**	***1.6***
		Holly	7,034	*1.1*
		Poplar	28	*0.004*
		Horse chestnut	241	*0.04*
		Large-leaved lime	132	*0.02*
		Small-leaved lime	559	*0.09*
		Spanish chestnut	455	*0.07*
		Strawberry tree	124	*0.02*
		Red oak	24	*0.004*
		Turkey oak	119	*0.02*
		Southern beech	141	*0.02*
		Whitebeam	43	*0.07*
		Field maple	124	*0.02*
		English elm	98	*0.02*
		Wych elm	611	*0.1*
		Total	**65,928**	***10.4***
Short-living broadleaves	**Birch**		**37,367**	***5.9***
		Downy birch	18,285	*2.9*
		Silver birch	19,082	*3.0*
	Alder		**15,084**	***2.3***
	Other short-living broad-leaves		**45,935**	***7.2***
		Other willows	191	*0.03*
		Goat willow	30,947	*4.9*
		Hazel	10,552	*1.7*
		Rowan	4,039	*0.6*
		Cherry	114	*0.02*
		Aspen	48	*0.007*
		Crab apple	44	*0.007*
		Total	**98,386**	***15.4***
Area and % of broadleaf species			**164,314**	***25.8***

- Of the two native **oak** species, pedunculate is recorded much more frequently than sessile. Together they are the second most important of the long-living species.
- **Beech** and **sycamore** occupy roughly the same forest areas with 1.5% respectively.
- The combined area of the **other long-living species** is only slightly larger than that of beech or sycamore. This group includes 14 species. It should be observed, however, that **holly** accounts for roughly three-quarters of the area of all tree species within this group at approximately 1%. All the others are of little importance.

• **Short-living broadleaves**
They are recorded on an area of roughly 98,000 ha or 15% of the broadleaf stocked forest area and contain the following species groups:

- The two **birch** species, downy and silver, are almost equal in terms of area. Together they are the most important species of this group and occupy almost 6% of the stocked forest area.
- Of the **other short-living broadleaves, willows**, with their ability to colonise un-grazed land, dominate the species group, followed by **hazel**. In the remainder, **rowan** features prominently.
- **Cherry, aspen** and **crab apple** have only a token presence.
- **Alder**, though only ranked third in this group, is more frequent than beech or sycamore and is only slightly less frequent than the combined oak species.

1.5.5 Area and growing stock in relation to forest ownership

Because of the extent of the data it is necessary to present the areas and the growing stock in two different subchapters and tables.

1.5.5.1 Broadleaf forest areas according to ownership

The proportion of broadleaf species as related to ownership is given in Table 1.5-6

Approximately 40% each of the total broadleaf species area belongs to the **State** and **other private forest owners** respectively, with only around 20% in the **grant aided private forests**.

Oak is obviously popular with growers, and is generally favoured by all forest owners, both public and private.

Ash, sycamore and **alder** are favourites especially with the private owners. They were planted to a larger extent within the grant aided forests.

Beech and other **long-living broadleaves,** as well as **birch** and **short-living broadleaves,** are under-represented in the grant aided private forests. This may be due to the fact that beech is considered a difficult species to establish and more site-demanding.

Birch is not listed as an approved species for grant aid.

Table 1.5-6: Tree species groups and **areas** in relation to forest ownership. (Adapted from NFI, 2013)
Area by species in all forests is given in Table 1.5-5 and do not need to be repeated here.

Species group	Ownership			
	public	private: grant aided	private: other	Total
	%			
Oak	24	42	34	100
Beech	50	8	42	100
Ash	27	33	40	100
Sycamore	24	45	31	100
Other long-living broadleaves	47	8	45	100
Birch	47	8	45	100
Alder	30	43	27	100
Other short-living broadleaves	40	14	46	100
Total 1,000 ha	**61**	**36**	**67**	**164**
Total %	***37***	***22***	***41***	***100***

1.5.5.2 Broadleaf growing stock according to ownership

Data on growing stock are given in Table 1.5-7. It provides the following information:

- The **long-living broadleaves** category, with almost two-thirds of the growing stock, is much more important having regard to their proportion of area. Oak alone contributes 20%. The growing stock per ha (147 m^3) for **other long-living broadleaves** is, however, surprisingly high. This is attributed to the extremely wide confidence limits (0.0 - 2,901,000 m^3) for the total growing stock (1,379,000 m^3) of this category, resulting from a small sample size. The value should, therefore, be treated with caution.
- The stands of **short-living broadleaves** contain less growing stock. This is especially obvious when looking at the values per hectare.
- With regard to **ownership category** it is worthwhile mentioning that slightly less than 60% of the broadleaf growing stock is concentrated in the other private forest. With only two exceptions – sycamore and alder – all broadleaf species groups have half or more of their growing stock volume in this ownership category. Even the **other short-living broadleaves** group have their maximum here.
- In the grant aided private forests the ratio between proportion of area (22%) and growing stock volume (9%) clearly indicates that most stands are very young.

Table 1.5-7: Growing stock of tree species groups as related to forest ownership. (Adapted from NFI, 2013)

Species Group	Growing stock			Ownership: public	private: grant aided	private: other	Total
	Mill. m^3	%	m^3/ha	%			
Oak	3.5	*20*	208	*33*	*5*	*62*	*100*
Beech	2.8	*16*	292	*47*	-	*53*	*100*
Ash	2.4	*14*	116	*28*	*17*	*55*	*100*
Sycamore	1.0	*6*	110	*34*	*21*	*45*	*100*
Other long-living broadleaves	1.4	*8*	147	*39*	*3*	*58*	*100*
Birch	3.0	*17*	82	*37*	*6*	*57*	*100*
Alder	1.3	*7*	88	*32*	*21*	*47*	*100*
Other short-living broadleaves	2.2	*12*	48	*29*	*9*	*62*	*100*
Total Mill. m^3	**17.6**			**6.2**	**1.5**	**9.9**	
Total %		***100***		***35***	***9***	***56***	

1.5.6 Age class distribution according to ownership

As most broadleaf stands have been established in recent years they are in a juvenile state. To provide a general overview, the data of the NFI (2013) have been summarised into three age classes of 50 year intervals (Table 1.5-8).

According to these data conifers are on average even younger than broadleaves, as only 2% by area of the conifer stands were older than 50 years, whereas 16% of the broadleaves were in this category. Nevertheless, only 7% of broadleaves and 2% of mixed forests are older than 100 years. These are almost exclusively broadleaves.

Table 1.5-8: Area distribution (%) of **conifers** and **broadleaves** by age classes of 50 years. (Adapted from NFI, 2013)

Species Group	Age class (yrs.) 1-50	51-100	≥101
Conifers	*98*	*2*	-
Broadleaves	*77*	*16*	*7*
Mixed	*90*	*8*	*2*

The data in Table 1.5-9 show the area of species groups by ownership categories and the percentage distribution of this area in two age classes for each species group. It is emphasised again that the species groups do not necessarily occur in pure stands and, especially in the case of the **other long-living** and

other short-living broadleaves, can be dispersed over the whole forest area, even among conifer crops.

Table 1.5-9: Distribution of area of tree species groups in relation to age classes and ownership categories. (Adapted from NFI 2013 and Redmond, 2014)

Species	Public			Grant aided private			Other private			Total		
	1-20 %	21+ %	Area 1,000 ha	1-20 %	21+ %	Area 1,000 ha	1-20 %	21+ %	Area 1,000 ha	1-20 %	21+ %	Area 1,000 ha
Oak	*1*	*14*	4.0	*21*	*7*	7.0	*2*	*11*	5.8	*9*	*12*	16.8
Beech	*1*	*16*	4.7	*2*	-	0.8	*2*	*8*	4.0	*2*	*10*	9.5
Ash	*7*	*12*	5.5	*20*	*14*	6.8	*12*	*12*	8.3	*13*	*12*	20.6
Sycamore	*3*	*5*	2.3	*12*	*13*	4.2	*5*	*4*	2.8	*6*	*5*	9.3
Other l-l. br.	*6*	*9*	4.5	*1*	*13*	0.7	*8*	*6*	4.2	*4*	*7*	9.4
Total	***18***	***56***	**21.0**	***56***	***47***	**19.5**	***29***	***41***	**25.1**	***34***	***46***	**65.6**
Birch	*35*	*19*	17.5	*7*	*17*	3.0	*30*	*23*	16.9	*24*	*21*	37.4
Alder	*9*	*6*	4.5	*19*	*14*	6.6	*3*	*7*	4.0	*11*	*7*	15.1
Other sh-l. br.	*38*	*19*	18.6	*18*	*22*	6.5	*38*	*29*	21.1	*31*	*21*	46.2
Total	***82***	***44***	**40.6**	***44***	***53***	**16.1**	***71***	***59***	**42.0**	***66***	***49***	**98.7**
Total area 1,000 ha	35.4	26.1	**61.5**	31.6	4.0	**35.6**	17.9	49.3	**67.1**	85.	79	**164.3**
Total area %	*57*	*43*	*100*	*89*	*11*	*100*	*27*	*73*	*100*	*52*	*48*	*100*

The following information can be derived from Table 1.5-9:

- Long-living species, such as oak, ash and beech, were recorded on 40% of the total area.
- Short-living species, mostly birch, alder, willow and other minor species, were recorded on 60% of the area.
- 52% of all broadleaf trees were 20 years old or less.
- Other short-living broadleaves (excluding birch and alder) were recorded on 28% of the area.
- There were great differences between ownership categories within the 1-20 age classes. Within the public category, the 1-20 age class occupied 57% of that area, whilst the grant aided and other categories occupied 89% and 27% respectively.
- Birch and other short-living broadleaves featured prominently in all three ownerships categories, but especially in those of the public and other private ownerships.

Conclusions

Broadleaves represent just over one-quarter of the stocked forest area of 637,000 ha. They comprise 17 million m^3 of the total growing stock of 97 million m^3 (end of 2012).

Analysis of the data clearly demonstrates that, as regards silviculture, broadleaf forests in public and grant aided ownerships are mainly young and a majority is in need of thinning.

There is a small proportion of broadleaf stands in the other private ownership category which allows more advanced treatments like natural regeneration and the sophisticated long-term management of mixed stands with longer production cycles. These areas are more amenable to the application of continuous cover forestry. Some of these forests are over-mature and of poor quality and they should be regenerated where possible.

2 Site suitability for broadleaf species

2.1 Introduction: Interaction of site factors

Correct decisions on the suitability of a site for growing particular broadleaf species (and conifers too) require an understanding of the role of site (climate and soil) factors affecting tree growth. Achieving that understanding is not a simple matter as there is a multitude of combinations of environmental factors which determine tree growth (Figure 2.1-1).

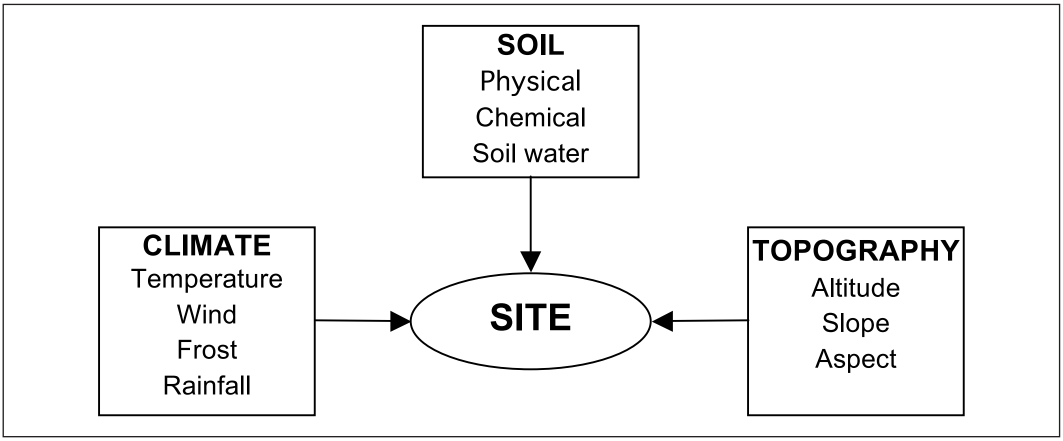


Figure 2.1-1: Environmental factors influencing site quality and tree growth.

The site (abiotic) component of the environment is dominated by climatic, topographic and soil factors. The relative impact of climate and soil on tree growth will depend on the nature of the terrain. In mountainous areas, climatic factors override the effect of soil differences, whereas in lowland regions soil differences are more important.

Examples in Ireland would be the dominance of climate in the mountains of Wicklow, Kerry and Donegal, in contrast to the dominance of soil as a factor in the lowlands of the Midlands and southeast. In North America the same applies between the Rocky Mountains in the west and the Great Plains in the mid-west and south.

In this chapter a description and evaluation is given of the site factors influencing the establishment, health, survival, growth and management systems of broadleaves. The ecological factors are dealt with in Chapter 3.

2.2 Climate

2.2.1 General characterisation of the Irish climate

Ireland has an oceanic climate, with mild winters, cool summers and a high frequency of winds and rainfall throughout the year. Such climatic features are due to the geographical position of Ireland on the western-most edge of Europe (Figure 2.2-1).

The warm ocean and air currents carried by the Gulf Stream and the North Atlantic Ocean have a dominant influence on the Irish climate. By contrast, Britain's climate is influenced to a greater degree by eastern continental air currents. Climates at similar latitudes in continental Europe are dominated by continental-polar and continental-tropical air currents.

The movement of low pressure systems from the North Atlantic Ocean brings to Ireland winds predominantly from the south-west. The low pressure systems are more intense and frequent in winter and because they pass over warm Atlantic waters, they are relatively warm and wet in winter. Thus, winters tend to be mild and wet, in contrast to summers which tend to be cool and cloudy. However, there is relatively

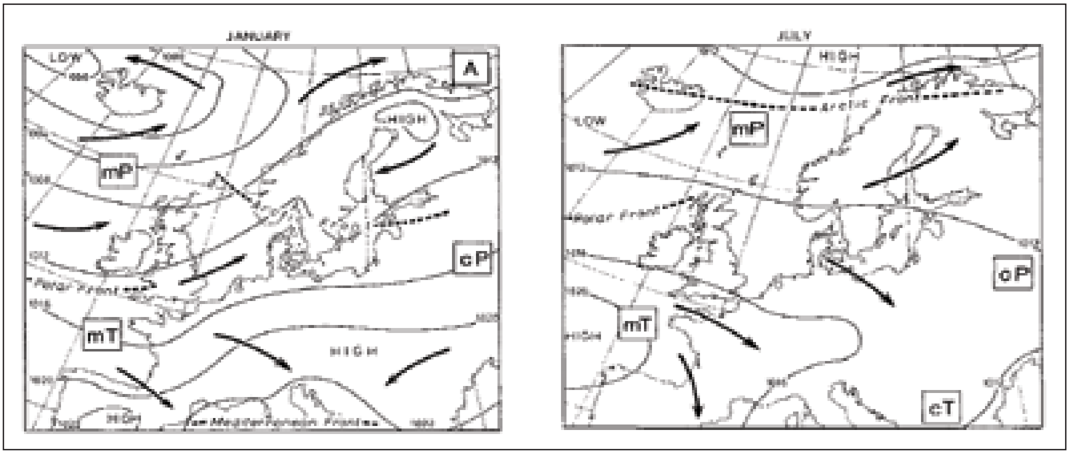


Figure 2.2-1: Mean positions of **air masses** and **air fronts** in January (left) and July (right) in **northwest Europe.** [generalised circulation indicated by arrows; air masses: A=arctic, mP= maritime polar, cP = continental polar, mT = maritime tropical, cT = continental tropical]
(Church et al., 1973; Collins and Cummins, 1996)

little difference between seasons, especially when compared to continental Europe.

Another feature of the Irish climate is its changeability within a short space of time. Indeed, one often hears the comment made about the day's weather that it contained elements of all four seasons.

Whether this represents a climatic disadvantage or not is open to question, but what is not open to question is the undoubted advantage of that other more important characteristic of the Irish climate, the long growing season. This is brought about by the mild winters, moderately warm summers, and a rainfall pattern distributed through the year.

2.2.2 Main climatic factors

2.2.2.1 Temperature

The annual average daily air temperature in Ireland, reduced to mean sea level, is about 10 °C, with a narrow national range, from 9.0 °C in the north to 10.5 °C in the south (Figure 2.2-2).

With regard to seasonal patterns, the mean daily air temperatures for 1961-1990 ranged from a low of about 4.5 °C in January (Figure 2.2-3a) to a maximum of about 15.5 °C in July (Figure 2.2-3b).

A feature of the winter temperature patterns is the higher temperatures in the coastal areas, particularly the Atlantic coastal areas, amounting to up to about 2.5 °C higher than in inland areas, notwithstanding that the sea is within 100 km of all places. The pattern is completely different for summer, being generally uniform over the whole country, although there is a clear though moderate latitudinal effect of a decrease in temperature from south to north of up to about 1.5 °C. In regard to extremes, air temperatures rarely go over 25 °C or below -5 °C.

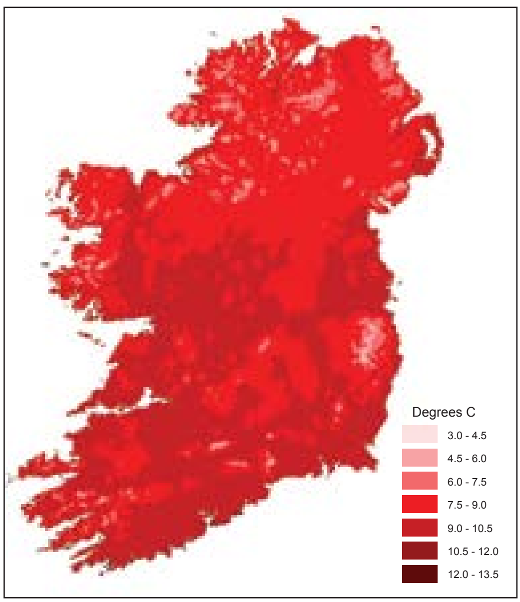


Figure 2.2-2: Annual mean daily air temperature (°C), **1961-1990.**
(Map by Fealy, NUIM, from data by Meteorological Service)

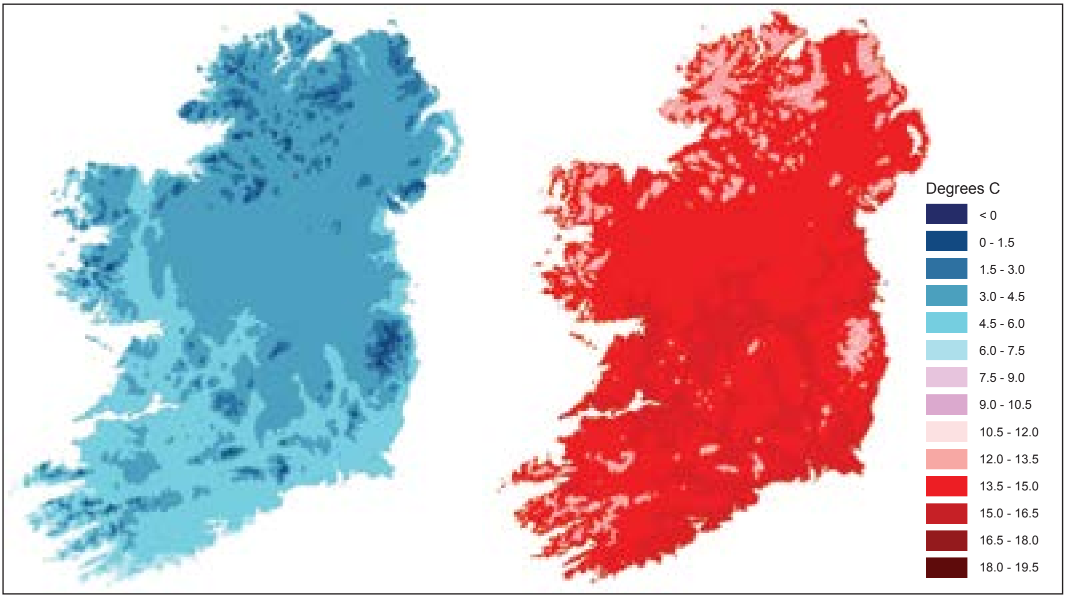


Figure 2.2-3a: Mean daily air temperature (°C) **for January, 1961-1990.**

(Map by Fealy, NUIM, from Meteorological Service data)

Figure 2.2-3b: Mean daily air temperature (°C) **for July, 1961-1990.**

(Map by Fealy, NUIM, from Meteorological Service data)

Two particular air temperature patterns at the lower end of the spectrum are of special interest to foresters in Ireland, that is, those relating to:
(1) the length of the growing season, and
(2) the occurrence of frost.

(1) Length of growing season

The length of the growing season is the number of days exceeding the minimum air temperature (estimated to be about 5 °C) required for growth. The moderate Irish climate, particularly in winter, enables growth to start early (Figure 2.2-4a) and end late (Figure 2.2-4b).

This results in long growing seasons, decreasing in a south-west to north-east direction, from 330 days (11 months) along the Kerry and Cork coastal fringe to 240 days (8 months) in the north-east (Figure 2.2-4c).

The significance of the information in Figure 2.2-4 is merely a demonstration of the relatively long growing seasons existing in Ireland. It is no more than this, since the only temperature-related influences on species selection in this country, at least within the main commercial broadleaf species used, are winter cold, exposure and frost. These influences are greatly affected by topographical features, often of a very local nature, such as terrain depressions.

(2) Occurrence of air frost

The importance of air frosts relates to their damage to plants, particularly at the time of bud-break in springtime and early summer; those occurring in early autumn are less damaging as shoots are reasonably developed at that stage. A prediction of the likelihood of their occurrence is facilitated by Connaughton's maps (Connaughton, 1969) (Figure 2.2-5) showing the mean dates of the last spring (Map 'a') and first autumn (Map 'b') air frost (accompanied by probability ratings), based on 1944-68 data.

The occurrence of frosts follows the familiar Atlantic coast to Midlands pattern, reflecting the general air temperature patterns mentioned above. With regard to spring frost, the last mean date of occurrence is estimated to be early March in the south-western

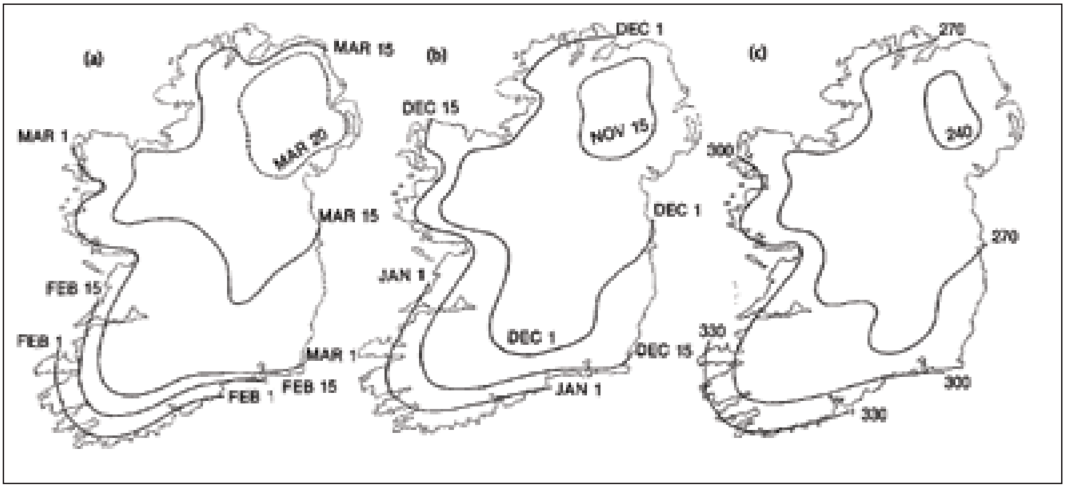
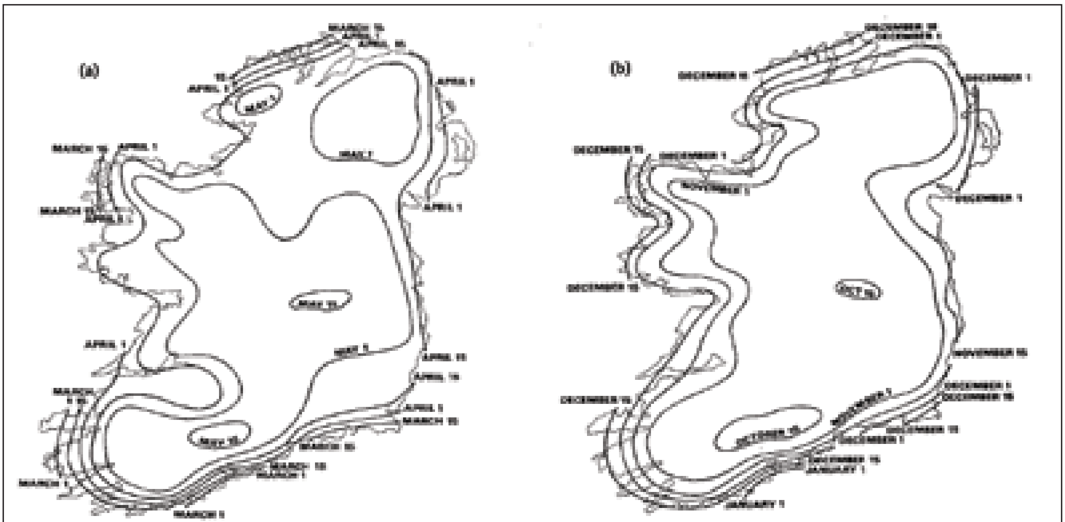


Figure 2.2-4: Growing season (days/year): (a) median dates of **beginning**, (b) median dates of **ending**, and (c) median **length.** (Connaughton, 1973; Barry, 1986)

coastal areas and mid-May in the Midlands. The number of air frosts is also not as frequent in coastal areas, Rohan (1975) reporting an average of about 10 per year in coastal areas compared to up to about 65 per year in inland areas.

The findings in Figure 2.2-5 convey an understanding of why frost is such an important restriction on species choice in Ireland. However, it is important to be aware that the results on which the maps are constructed are based on monitoring stations mostly located on flat terrain. They are, therefore, underestimating the occurrence of frosts in their classic



Probability (%) of air frost (a) after mean date		Probability (%) of air frost (b) before mean date			
Mean date	50	Mean date	50	Mean date	50
+ 5 days	40	+ 4 days	60	– 4 days	40
+ 11 days	30	+ 8 days	70	– 8 days	30
+ 18 days	20	+ 13 days	80	– 13 days	20
+ 27 days	10	+ 20 days	90	– 20 days	10

Figure 2.2-5: Mean date of (a) **last air frost in spring** and (b) **first air frost in autumn**, 1944-1968, reduced to mean sea level.

(Connaughton, 1969; Rohan, 1975; Keane, 1986; Collins and Cummins, 1996) environments, mostly of a local nature, such as (frost) hollows, depressions, narrow channels and valleys. Nonetheless, the use of the maps is invaluable if taken to complement knowledge of local topography.

2.2.2.2 Rainfall

Rainfall is characterised by the nature and extent of the following:
(1) precipitation,
(2) distribution,
(3) frequency,
(4) intensity and
(5) dry periods.

(1) Precipitation

Rainfall is the major component of precipitation in Ireland, the other forms, such as snow and hail, being only occasional.

(2) Distribution

Based on rainfall records for the 30-year period 1961-1990, the mean annual distribution of rainfall (Figure 2.2-6) can be roughly summarized as being over 1000 mm in the western half of the country, due to the prevailing south-westerly winds from the Atlantic, and less than 1000 mm in the eastern half. Rainfall exceeds 2000 mm at high elevations, even within the drier east, as in the Wicklow Mountains. Rainfall is highest along the western seaboard and lowest, less than 750 mm, in areas of the east in the lee of mountains. This occurs within the counties north of the Dublin-Wicklow Mountains, that is Dublin, Meath and Louth, and within Kildare and Laois to the northeast of The Slieve Bloom Mountains and The Castlecomer Plateau. However, most of the eastern half of the country has an annual rainfall of between 750 and 1000 mm.

Table 2.2-1 shows the monthly and annual rainfall at 26 stations averaged over the 30-year period, 1951-1980. The main features of the data are that: (1) December and January were the wettest months, and (2) the months September to January were very much wetter than February to August.

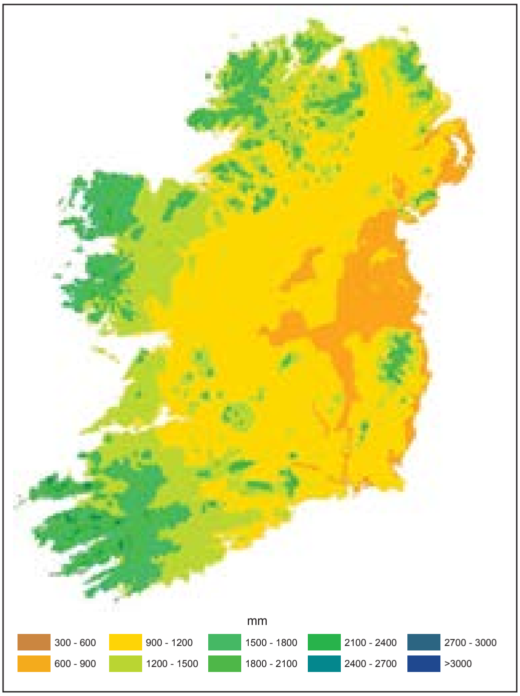


Figure 2.2-6: Mean annual rainfall (mm), 1961-1990.
(Map by Fealy, NUIM, from data by Meteorological Service)

Table 2.2-1: Mean **monthly and annual average rainfall** (mm), 1951-1980. (Rohan, 1986)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
122	85	84	67	74	71	81	93	107	113	119	128	**1144**

(3) Frequency

The average number of wet days (days with more than 1 mm of rain) ranges from about 150 days a year along the east and south-east coasts to about 225 days a year in parts of the west (Figure 2.2-7), so Ireland's reputation as a rainy country is valid only for the west and not the east.

(4) Intensity

The average hourly rainfall amounts are quite low – at least by comparison with many locations at similar latitudes in other countries – ranging from 1 to 2 mm. However, hourly totals of 10 mm are not unusual and higher totals of 15-20 mm in an hour can be expected at a lower frequency, about every five years.

(5) Dry periods

Several definitions to encompass the variations of dry periods are used. Two of these are the dry spell and the absolute drought:

- A dry spell is defined as a period of 15 or more consecutive days with less than 1.0 mm rainfall per day.
- An absolute drought is defined as a period of 15 or more consecutive days with less than 0.2 mm rainfall per day.

Figure 2.2-7: Mean **annual number of days with 1 mm or more rainfall,** 1941-1960. (Rohan, 1975)

The number of dry spells and absolute droughts at 13 meteorological stations are shown in Table 2.2-2 for the 25-year period, 1960-1984.

Table 2.2-2: Number of **dry spells** and **absolute droughts**, 1960-1984. (Rohan, 1986)

Location	Region	Dry spells (>15 days of <1 mm rain per day)	Absolute droughts (>15 days of <0.2 mm rain per day)
Belmullet	West	19	5
Malin Head	North-West	20	6
Claremorris	West-West Midlands	32	11
Clones	North Midlands	37	13
Mullingar	Midlands	37	13
Birr	Midlands	43	17
Casement Aerodrome	East	41	21
Dublin Airport	East	41	21
Kilkenny	South-East	44	20
Rosslare	South-East	52	24
Shannon Airport	South-West	41	14
Roche's Point	South	56	24
Valentia Observatory	South-West	23	14

Generally there are very low occurrences of dry periods in the west (Belmullet), north-west (Malin Head), and south-west (Valentia), with the highest occurrences featuring in the south (Roche's Point) and east (Rosslare). It is to be noted that it is not always safe to assume that locations with the most dry spells and droughts automatically have the lowest rainfalls. For example, Rosslare would normally have higher average rainfall than at Dublin and Kilkenny, yet compared to those places Rosslare had 8-11 more dry spells and 3-4 more absolute droughts during the 25-year period, 1960-1984 (Table 2.2-3).

Table 2.2-3: Number of **dry spells** and **absolute droughts** per month at **Rosslare** over a 25-year period, 1960-1984. (Rohan, 1986)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
Dry spells	1	3	2	8	6	9	7	5	3	6	0	2	**52**
Absolute droughts	1	1	2	3	4	1	5	3	1	2	0	1	**24**

As is clear from the data shown for the station at Rosslare in Table 2.2-3, the likelihood of dry spells and absolute droughts is greatest in the months April to August, with October and February also featuring strongly, especially for dry spell occurrences. The occurrences of most concern to broadleaf growers are likely to be those in the April-August period, especially in the latter months of that period when the cumulative effects of previous and recent occurrences would be greater than the effects from more isolated occurrences at other times.

2.2.2.3 Wind

Mean annual wind speed (1951-1970) varies from a low of about 4 m/s (15 km/h) in the east Midlands to 7 m/s (26 km/h) and over in the west and northwest (Figure 2.2-8). The highest wind speeds in the northwest are a consequence of the frequency of the low pressure systems from that direction.

The wind patterns over Ireland are evident by the 23-year (1962-1984) record of the frequency of wind direction and wind speeds at the main meteorological stations (Figure 2.2-9).

In Figure 2.2-9 it is shown that the winds are predominantly from the southwest, followed by those from the west and south. Exceptions to this are apparent at the stations at Dublin Airport, Shannon Airport and Valentia Observatory. These exceptions are due to local terrain factors:

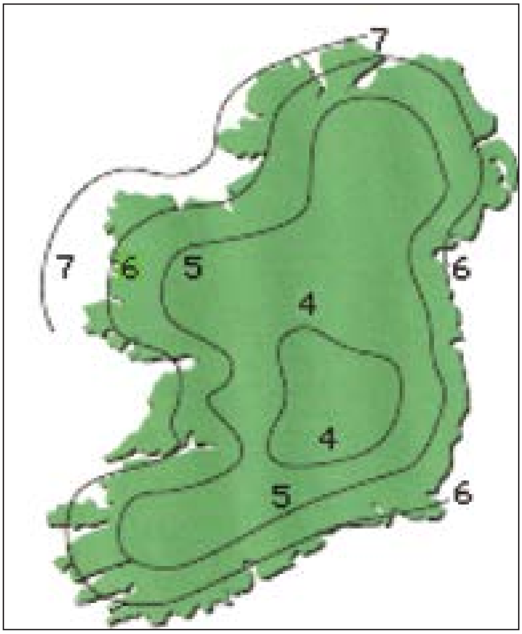


Figure 2.2-8: Mean **annual wind speed** (m/s), 1951-1970. (Rohan, 1975)

(1) The relative absence of winds from the south at Dublin Airport is due to shelter from the Dublin-Wicklow Mountains to the south,

(2) the predominance of westerly winds at Shannon Airport is due to the west-east alignment of the Shannon River in the vicinity of the station and

(3) the relative absence of winds from the southwest at Valentia Observatory is due to shelter from adjacent hills and mountains, which is confirmed by the relatively high frequency of calms recorded at that station, especially for one located at an exposed coastal area.

The last exception gives emphasis to the fact that the nature of the local terrain can sometimes be the primary factor in determining wind patterns rather than geographic location in the country. Examples would be sheltered mountain valleys in otherwise exposed terrains.

The findings in Figure 2.2-9, therefore, should be treated with caution by growers looking

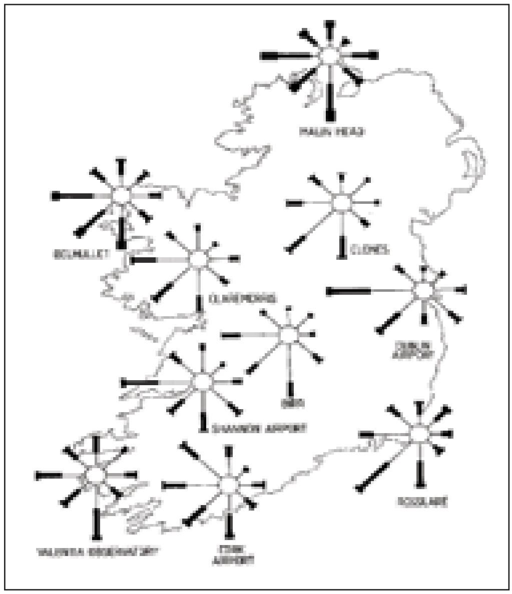


Figure 2.2-9: Frequency of wind directions for groups of wind speeds, 1962-1984. (Rohan, 1986)

Legend: The interpretation of the figure is conveyed according to the length and thickness of the radial lines displayed for each of the stations. The length of the line represents the scale of frequency of wind (% frequency increasing with length) and the thickness of the line represents the scale of wind speed (m/s, or Beaufort force, increasing with thickness).

to assess the role of wind in their selection of tree species, bearing in mind also that the data are from stations which are mostly situated on level and open ground. Thus, the trends exhibited in the figure must be supplemented with information on the potential impact of local factors on wind characteristics. This is not just from the amount of shelter provided, but from the effect of increasing wind speed with elevation and with locations of sites on wind-susceptible hillsides, not necessarily at high elevations.

Conclusions

Moisture and drought: Availability of soil moisture for broadleaves is usually not a concern in Ireland given the distribution of rainfall through all seasons of the year. Nonetheless, droughts do occur which limit growth performance. These tend to occur most frequently in the drier east and south-east, especially on the free-draining soils. Use of such sites for broadleaf planting, therefore, requires particular care with regard to site preparation. For example, practices that are more appropriate to wet sites should be avoided on dry sites, such as mound-planting, using instead flat planting and minimal or no drainage to minimise potential for drought impacts.

Wind: Wind is one of the most important factors affecting broadleaf growth, but the quantification of the windiness of a site is often the most difficult to assess. This is because the wind characteristics of a site are determined by several topographical factors, regional and local. The regional factors, which we have covered above, are generally well understood, but the local factors tend to present a greater difficulty due to the complexity of their influence. Minor obstructions to the passage of winds, such as small hills, hedgerows, and shelterbelts, affect wind speed and direction in local areas. The shape and extent of the hills will have an important bearing on their impact in reducing or increasing the local wind regime. Sites represented by the former will be most sought after for broadleaf planting. Their identification will be aided by keen observation of changes in local tree or shrub growth, both in form and vigour.

2.2.3 Main topographic factors affecting climate

Much of the discussion of Ireland's climate has focused on meteorological records expressed on a common base, mostly at sea level. This hides the topographical influences on climate, with special reference to (1) altitude, (2) aspect, and (3) terrain, which are responsible for localised climatic gradients.

(1) Altitude
Altitude has a major effect on local climate, with lower temperatures (decrease of 1 °C with every rise in 150 m), increased windiness and precipitation and an accompanying decline in soil quality, with increase in altitude. This effect is particularly severe in Ireland due to the frequency and severity of winds from the Atlantic ocean.

The known sensitivity of broadleaf species to the disadvantages resulting from increasing altitude in Ireland are shown by the fact that 88% of the total broadleaf area lies under 150 m, in comparison to 64% for conifers (National Forest Inventory, 2007). The discrepancy in distribution of broadleaves and conifers with altitude widens as one moves westwards, reflecting the decline in growing conditions from southeast to northwest.

The rate of lapse of growing conditions with altitude is much faster in Ireland – especially in the western parts – than in much of Europe. This fact is illustrated by the disparity in tree lines across Europe, ranging from less than 500 m in Ireland to over 2000 m in the Alps (tree line being the altitude limit of tree growth and beyond which only dwarf shrub growth of tree species is possible).

(2) Aspect
Exposure to sunlight, wind and degree of shelter, are the main elements of climate directly affected by site aspect. At the same altitude, southern aspects are warmer than northern ones and western aspects are more exposed and less sheltered than eastern ones. Also, an indirect alteration of climate with regard to aspect is the lower amounts of rainfall patterns found at eastern aspects, a fact mentioned in the previous section.

The importance of these aspect-induced effects lies in their relevance to tree growth potential in terms of site suitability for planting and species options. For instance, one can generally expect the warmer southern aspects to be optimal for broadleaves. However, the advantages bestowed by increased warmth can lead to greater potential for excessive evaporation, and thus to risk from droughts, especially on shallow soils.

(3) Terrain
Low-lying flat areas are most prone to the occurrence of the most damaging air frosts. Such areas are often bounded by higher ground or hills which act as conduits for the collection of cold air and then its entrapment.

Examples of the worst kind in Ireland are found in the Midlands, particularly in the flat, wet peatland areas, where frost hollows are common. Hollows are often caused by no more than a metre of surrounding higher ground or man-made structures.

2.2.4 Climate of Ireland in a wider European context

A sequence of five climate patterns exists across Europe, from oceanic on the north-western seaboards to continental in the inner continental regions (Figure 2.2-10). Ireland is dominated by oceanic and near-oceanic climates, the western half of Britain has a similar pattern, but the eastern half has some continental influence, and mainland Europe has a narrow western seaboard belt of oceanic and near oceanic before the emergence of the vast stretches of near continental and continental climates. Moving eastwards, therefore, and away from sea-

Figure 2.2-10: Climates of north-west Europe.
(Keane, 1992)

board influences contributing to oceanic climates, the climatic conditions feature warmer summers and colder winters, lower rainfall and greater sunshine.

The following examples highlight three important differences between the climate of Ireland and other parts of Europe, the first two (longer growing seasons and droughts) of which confer a growth advantage in Ireland, whilst the third (windiness) represents a growth disadvantage:

Temperature: The warmer winters prevailing in Ireland means that soil temperatures recover relatively quickly in spring leading to longer growing seasons than in continental and near continental Europe. In a comparison (Keane, 1992) of the length of growing seasons across a number of inland areas of western Europe, at a threshold air temperature of 5.6 °C (the temperature required for the initiation of grass growth), the duration of the growing season was shown (Table 2.2-4) to be longest in the south-Midlands of Ireland and northwest France (40 weeks) and shortest in northern Germany (33 weeks) and Denmark (30 weeks).

Table 2.2-4: Duration of the growing season (number of weeks) in inland areas of **western Europe.** (Keane, 1992)

Threshold air temperature	Ireland South Midlands	England East Midlands	France North-West	Holland	Germany North	Denmark
5.6 °C	40	38	40	35	33	30

Since this comparison was limited to western Europe and, therefore, excluded areas with continental climates and most of the areas with near-continental climates, it is clear that the differences in length of growing season between Ireland and such climate areas would be even greater still.

Rainfall: In a comparison of the annual rainfall distribution patterns across Europe (Figure 2.2-11) it is evident that there are many areas in mainland Europe with similar patterns to those found in Ireland, and especially for the lower rainfall category of 750-1000 mm typical of the lowlands in the eastern part of Ireland. Furthermore, much of the lowlands in mainland Europe (below 750 m) have lower rainfall amounts than in the driest parts of Ireland.

Areas in mainland Europe with less than 1000 mm rainfall are prone to drought periods since most of the rainfall occurs in winter and spring, whilst severe droughts in Ireland are much less frequent due to the relatively uniform distribution of rain throughout the year.

Wind: The windiness of the climate is one of the major limiting factors of tree growth in Ireland, particularly for broadleaves. The potential for harmful effects by wind are disproportionately greater here relative to other areas of Europe. This is very clear from an examination of the average annual windiness in Europe (Troen and Petersen, 1989) (Figure 2.2-12), where the strongest winds (indicated on map in purple) domi-

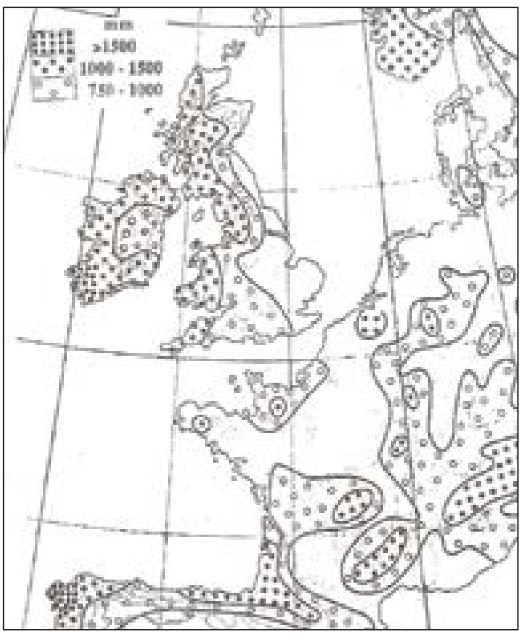


Figure 2.2-11: Average **annual rainfall** in Europe. (O'Reilly, 1992)

nate the western seaboard of Ireland, Scotland, north-west Denmark, Norway and Sweden. Wind intensities diminish in a southerly direction, with intermediate wind classes (red and yellow) dominant in south-east Ireland and England, and coastal areas of north-west mainland Europe, with the lightest wind classes (green and blue) dominant in the zone embracing the middle and southern parts towards the Mediterranean.

Colour signature	Topographic situation		
	sheltered	open plains	hills and ridges
Purple	>6.0	>7.5	>11.5
Red	5.0-6.0	6.5-7.5	10.0-11.5
Yellow	4.5-5.0	5.5-6.5	8.5-10.0
Green	3.5-4.5	4.5-5.5	7.0-8.5
Blue	<3.5	<4.5	<7.0

Figure 2.2-12: Wind speed (m/s) at 50 m above ground level for **different topographic situations** in Europe.
(Troen and Petersen, 1989)

The influence of terrain type on wind speed is dramatic, most spectacularly in the highest wind class (purple indicator), ranging from over 6 m/s in sheltered areas to over 7.5 and over 11.5 m/s respectively in open plains and hills/ridges. This contrasts sharply with the wind speeds typical of the lightest wind (blue indicator) ranging from less than 3.5 m/s in the sheltered areas to less than 4.5 and 7 respectively in the open plains and hills/ridges.

The magnitude of the differences in windiness between northwestern and continental regions of Europe goes a long way to explaining major differences in growth patterns between each region. The differences of most significance silviculturally with regard to Ireland are:

(1) The preponderance of conifers over broadleaves in the total forest resources of Ireland, the reverse of the trend prevailing in mainland Europe. The windiness of the climate is only one of many reasons for such a disposition. Other reasons include national policies in the period 1925 to the mid-1980s that dictated that forestry was not to be supported on agricultural lands thereby restricting forestry to the uplands and hence conifers.

(2) The restriction of broadleaves to lands below 200 m altitude. Poorer soil quality with increasing altitude would also have an influence on this restriction. High and damaging winds do occur below 200 m, such as in extensive open areas subject to severe exposure through lack of shelter from hills and mountains or local obstructions. Local shelter provided by the use of shelterbelts may be useful in overcoming the difficulties posed by such areas except perhaps on severely exposed sites. In any case, species selection options will at least be restricted in open exposed areas.

(3) The existence of a tree line at below 500 m, which is very low compared to the high tree lines elsewhere, increasing through Europe to 2,400 m in the centre of the Alps. The shelter afforded by major mountains – such as by the Black Forest in Germany, the Massif Central in France, and the Alps in Italy – is not available in Ireland where mountains are few and not extensive and all but two are below 900 m.

2.2.5 Broadleaf species favoured by the climate of Ireland

The broadleaf species most favoured by the climate of Ireland are listed in Table 2.2-5. This list is appropriate for the relatively benign climatic conditions prevailing in the lowlands at altitudes less than about 200 m. Nonetheless, some lowland sites – principally sites subject to frosts and/or exposure – have climatic limitations for most species. Clearly, where such limitations exist alternative species with some tolerance for the specific limitations prevailing should only be considered.

The impact of climate change on the suitability of the climate for broadleaf species could be profound if the projections come to pass, with adjustments in the susceptibility to frost ratings for the species in the above table. In addition, there would be greater scope for use of marginally suitable species, that is, those requiring more sunshine and warmth than is currently available. Examples of such species include southern beech, Spanish chestnut, walnut, and eucalyptus.

Issues related to species suitability impacted by climate change are discussed in Chapter 2.2.7.

Table 2.2-5: Broadleaf species favoured by the climate of Ireland subject to key climatic limitations.

Species	Climatic limitation	
	susceptibility to frost	sensitivity to exposure
Common alder Birch Hornbeam Rowan Sycamore	minimal	moderate
Grey alder Italian alder	moderate	moderate after canopy closure
Lime		sensitive
Red oak		sensitive
Norway maple		very sensitive
Beech (European)	very susceptible	sensitive at establishment
Wild cherry		very sensitive
Spanish chestnut		very sensitive
Oak (sessile and pedunculate)		very sensitive
Ash		sensitive

2.2.6 Climate of Ireland – a summary of key points with particular relevance to broadleaves

General climate

The location of Ireland in the track of the warm waters of the Gulf Stream/North Atlantic Drift means that the climate is overwhelmingly influenced by westerly winds, the predominant wind direction. This accounts for the moderate nature of the climate, featuring mild winters and cool summers, with relatively high rainfall and low sunshine.

There are two broad climatic regions: first that region along the western seaboard with a distinctly oceanic climate, and second the region in the Midlands and eastern parts featuring a climate with some continental characteristics. The increase in maritime influences towards the west has negative consequences for some of the most important climatic factors affecting broadleaf species, particularly in relation to increases in rainfall, cloudiness and wind-speed and decreases in temperature and solar radiation.

The growth of broadleaf species above an altitude of about 200 m is generally unsatisfactory, at least for timber-growing purposes, with deformed stems and coarse branching most often all that can be expected.

The moderate winter climate results in a relatively early onset of the growing season and consequently relatively long growing seasons. There is a wide discrepancy in the length of the growing season between the two broad climatic regions referred to above, due to the onset of the growing season seven weeks earlier in the south than in the north, and the ending of the growing season 4-6 weeks later in the south than in the north. This situation confers a significant advantage to the general southern region for broadleaf species in terms of growth potential and of consideration of the use of a wider range of broadleaf species.

Local climate
Local climate differences can be as important as the general climatic features in determining the suitability for broadleaf species. The nature of the local topography, with respect especially to its altitude and terrain, has a significant influence on the critical climatic factors (winter-cold, exposure and frost) affecting broadleaf species. Such influences need to be carefully evaluated to form a sound basis for species selection. The following are examples of the main critical climatic effects of topographic variations commonly encountered in Ireland.

Winter-cold and exposure: The prevalence of mountains and hills in the western seaboard regions reinforces the negative impacts of intense maritime influences with altitude resulting in lower temperatures and increased wetness and windiness.

Exposure: Parts of Ireland, most especially in the north and west, are among the windiest places anywhere, due to the nearness and prevalence of low pressure systems there. A very high frequency of gale force winds occurs in these areas, amounting to more than 50 days with gales each year compared to less than two days with gales each year in sheltered inland areas. Gales can cause windthrow, especially in broadleaf species if they occur when they are in leaf. Wind is one of the most important factors affecting broadleaf growth, but the assessment of the windiness of a site is often the most difficult to assess. This is because the wind characteristics of a site are determined by several topographical factors, regional and local. The regional factors covered above, are generally well understood, but the local factors tend to present a greater difficulty due to the complexity of their influence. Minor obstructions to the passage of winds, such as small hills, hedgerows and shelterbelts, affect wind speed and direction in local areas. The shape and extent of the hills will have an important bearing on their impact in reducing or increasing the local wind regime. Sites represented by the former will be most sought after for broadleaf planting and their identification will be aided by keen observation of changes in local tree or shrub growth, both in form and vigour.

Frost: Frosts in late spring and early summer tend to be more frequent and intense in inland and lowland areas, most especially in depressions or hollows in flat terrain, narrow channels and valley bottoms. Susceptibility to frost probably is the most frequent factor encountered limiting the selection of broadleaf species, other than those with at least some frost-tolerance. It is ironic that the conditions for their most frequent occurrence and highest intensity prevail in the altitude range (below 200 m) most suitable for broadleaf species.

Drought: Availability of soil moisture for broadleaves is usually not a concern in Ireland given the distribution of rainfall through all seasons of the year. Nonetheless, droughts do occur which limit growth performance. These tend to occur most frequently in the drier east and south-east, especially on the free-draining soils. Use of such sites for planting of broadleaf species, therefore, require particular care with regard to site preparation. For example as already stated, practices that are more appropriate to wet sites should be avoided on dry sites.

2.2.7 Climate change
Whilst there is a continuing debate on the causal factors of climate change, there is no doubt that changes in climate have occurred over a relatively short time, principally in the form of rising temperatures and lengthening of growing seasons. Proponents of the argument that such rapid changes are largely due to the increasing levels of greenhouse emissions have predicted further dramatic climate change, such as that the average global temperature will be about 2 °C above current levels by the end of this century, unless we curtail our increasing reliance on greenhouse fuels. Notwithstanding the uncertainty of such changes occurring, it is worth considering broadly their potential impact on the

growth of broadleaf species. However, it is useful to reflect on past and present climates in Ireland before considering its future potential climates (McWilliams, 2005).

2.2.7.1 Climate change in the past

The new and persistent attention being paid to concerns about climate change might give the impression that our climate has always been stable, with scant recognition for the immense and many changes throughout the ages, oscillating through different phases of deterioration and improvement.

A brief summary of the main climatic changes that have occurred in Ireland over the last 20,000 years is given in Table 2.2-6.

Table 2.2-6: Summary of **main climatic trends** over the **last 20,000 years**.
(Mitchell, 1986; Mitchell and Ryan, 1997)

Period	Climatic conditions
20,000 years ago	Ireland, and much of the northern hemisphere down to near the Mediterranean, was in the grip of an Ice Age (Midlandian Cold Stage in Ireland) – which originated about 75,000 years ago – with the country buried under deep glaciers.
10,000 years ago	Temperatures started to rise about 10,000 years ago (Littletonian Warm Stage in Ireland). There was a considerable warming of the climate at about 5000 BC, the average temperature being about 2 ºC above current levels.
3,000 years ago	At about 1000 BC there was a return to much colder conditions, with frequent storms and high rainfall, but the duration of this change was relatively brief.
1st – 10th century	The weather began to improve again in the early centuries AD, and by the 10th century temperatures were about 1 ºC above current levels.
10th – 18th century	There was another deterioration in climate to colder and wetter conditions after the 10th century – especially the period 1450-1850, known by meteorologists as the Little Ice Age – up to the middle of the 1800s when there was another change for the better.
1850 – early 1990s	From 1850 to about the mid-1940s the average temperature rose about 0.5 ºC, but since about 1950 to the late 1970s, there was a small decrease in temperature, which has been followed in the 1980s and early 1990s by variability in average temperatures.

From the early 1990s issues related to global warming started to emerge and gave concern to many because of their perceived potential for changing climate in an unnatural way.

2.2.7.2 Climate change in the present

The changes in climate (specifically temperature changes) in the past referred to above are explainable through natural and normal climate variations. In contrast, the present climate changes are considered by many only to be explicable as being due to humans, postulating that the human influence relates to the dramatic man-induced increase of greenhouse gases in the atmosphere. The concern is that the increases, especially of carbon dioxide, are the cause of the current rise in average temperatures and, if left unchecked, that they will lead to further increases with perhaps irrevocable consequences for the world.

The following is a brief summary of the main changes in climate that have occurred in recent times:

- The period 1995-2004 has been the warmest 10 years since detailed records began.
- The global temperature increased by almost 1 ºC in the 20th century, but the rate of increase has escalated in the past 25 years.
- The global average annual temperatures in 1998, 2003 and 2004 were particularly high, being 0.4-0.5 ºC above the 30-year average for 1961-1990. Similar trends are found in Ireland.

Evidence of recent and unusual weather extremes is plentiful, such as, (1) rainfall and misty rain is often being replaced by more intense downpours, which are often of longer duration, (2) the northwest is receiving one-third more rainfall than in the early 1900s, and (3) droughts have increased in frequency in the southeast.

2.2.7.3 Climate change in the future

It is predicted that without effective measures to reduce greenhouse gases that the global temperature will have risen by about 2 ºC in the second half of this century (McWilliams, 1991; Sweeney et al., 2003). The effects in Ireland are predicted to result in the following major changes:

- Winters will be warmer – the mean temperature up to 2 ºC higher than in the last quarter of the last century – and they will be much wetter, by as much as 20%. Summers will also be warmer, especially inland, and drier in the east and south by about 20%. This is a scenario that would approximate to the current climate in southern France.
- Trees will grow more vigorously because of increased availability of carbon dioxide, but that advantage will be offset to some extent by more frequent and intense droughts and by an increase in exposure to pests and diseases (and also to increased variety of pests and diseases).

The success or failure of new or existing tree species will be determined more by climate extremes than by climate averages. Unfortunately, climate change forecasts to date have little to offer in regard to the likelihood of extreme events of such critical factors as frost and gale force winds. The only guidance we have on these factors is the prediction that there will be decreases in the frequency of frosts and increased frequency of storms. However, even these predictions are made with great uncertainty and raised as possibilities since they would be presumed secondary outcomes of the increased carbon dioxide concentrations and the associated increases in temperature and precipitation. The limited information available on changes in frosts and gales does at least indicate opposing decrease/increase trends, and suggests that gales will be a bigger threat than frosts to the introduction of new broadleaf species.

The suggested projections for climate change (wetter winters, and drier, warmer summers, the expectation of less frosts and a greater frequency of weather extremes relating to droughts in summer and flooding in winter and summer), would have significant repercussions on the productivity of current species options and the opportunity for considering the introduction of new species.

If the projections above are solidly based then changes in species suitability are inevitable, as for example in the climate change scenarios considered below:

- **Wetter winters and drier, warmer summers:** Wetter winters will restrict rooting depths further and, therefore, expose trees to greater impact from summer droughts. This will be a more serious issue in soils subject to significant changes in water table depths between and within seasons. This would pose particular difficulty for drought-sensitive species such as beech and ash, so species with greater tolerance of fluctuating water tables (such as, alder, downy birch, sycamore, and pedunculate oak) would be leading options for consideration. With an increased frequency of high moisture deficits in summers, the use of drought-tolerant species will have higher representation than at present, such as Spanish chestnut on fertile soils and sessile oak on less fertile soils.
- **Warmer winters:** A decreased incidence of frosts as well as a later than usual bud break should pose less risk to exposure and to damaging frosts. This would result in a shift from more to less risk in the susceptibility to frost ratings in Table 2.2-5 above, and the potential for use of new species (such as false acacia), or greater use of what are now less utilized species (such as eucalypt, beech and cherry).

2.3 Soils

2.3.1 Main factors of soil formation

The type of soil produced at any location, in Ireland or anywhere else, is determined by the relative influence of five factors, that is, parent material, climate, topography, living organisms (plants and animals), and time. Parent material and climate have been especially important factors in the formation and development of soils in this country; hence, attention will be focussed mostly on the role of these factors. The role of topography is dealt with to a lesser extent, while the reader should refer to a textbook on soil science for information on the remaining factors, living organisms and time.

2.3.1.1 Parent material of soils

One of the main factors influencing soil development in Ireland is the type and nature of its geology (Figure 2.3-1) or, more accurately, its parent material. This parent material includes also the materials left behind in the melt-waters of the retreating glaciers, the underlying rocks having been crushed, transported and deposited as glacial drift.

- Parent material also takes cognisance of the fact that peat soils – which represent about 15% of Irish soils – are developed independently of geology.

The intense glacial activities over Ireland in its recent geological history have been responsible for the extreme variation of its soils, particularly the lowland soils, with soil characteristics in most places changing substantially across small distances, even within small fields. Such small-scale soil variability is understandable given that the type of drift material left behind can vary enormously, both chemically and physically. The chemical characteristics of the drift deposit will depend largely on the nature of the rocks (ranging from acid to calcareous) over which the glaciers travelled. The physical characteristics are influenced primarily by the source of the material (for example, marine or non-marine), how it was deposited (for example, sorted or unsorted), and by the extent to which pressure

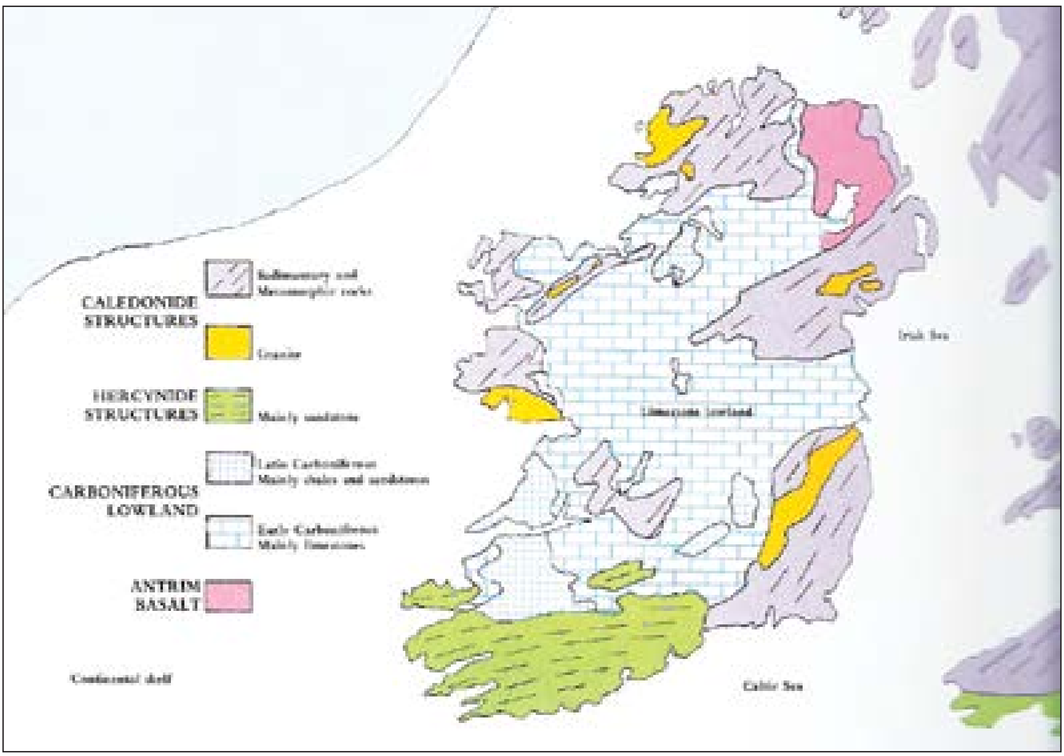


Figure 2.3-1: Bedrock geology of Ireland. (Mitchell, 1986)

was applied to it (leading to impeded drainage). Since Ireland was affected by at least two glaciations, each involving several advance and retreat phases, it can be appreciated that the scope for differences in deposits or parent materials which give rise to soils is great.

In spite of the complexities noted, two broad generalisations can be made:

(1) a close relationship exists between geological bedrock, parent material and soils produced and
(2) the beneficial effects that mixed parent materials have on soil quality.

(1) Relationship between bedrock, parent material and soils

In many areas the drift deposit is a reflection of the bedrock directly underlying it, as is evident when comparing the pattern of bedrock (Figure 2.3-1) with the distribution of soils (Figure 2.3-2).

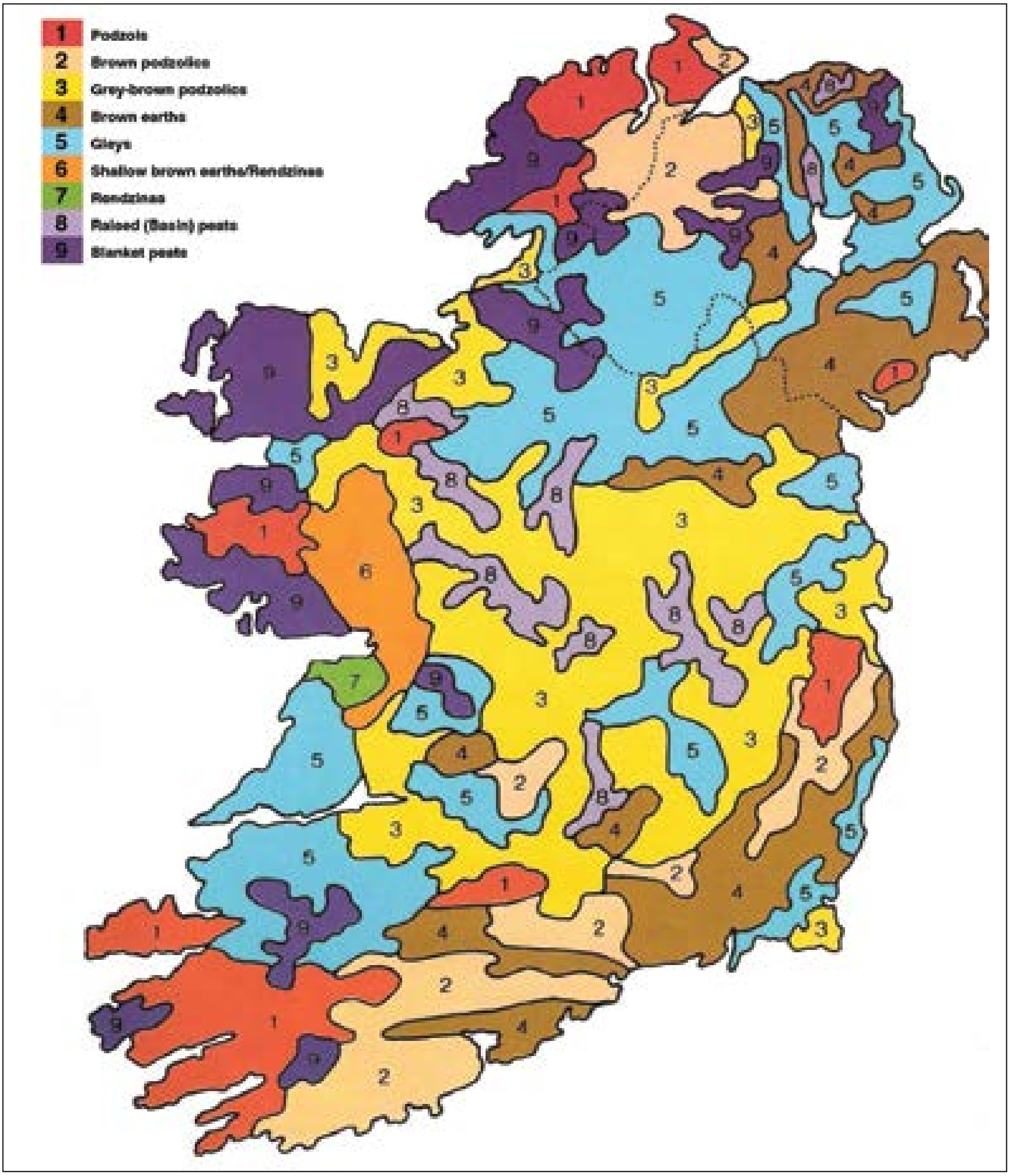


Figure 2.3-2: Principal soils of Ireland. (Adapted from Gardiner and Radford, 1980)

For example, the widespread limestone drift occurring in the general Midlands region of the country (represented in Figure 2.3-1 by the blue coloured area, which covers about half the country) coincides closely with the extent of the limestone bedrock.

Most soils suitable for broadleaf species are those derived from limestone drift, the most prominent soils being grey-brown podzolics and brown earths of high base status.

However, many of the soils within the limestone drift category can also have severe limitations for tree growth, the main ones being excessive levels of carbonate and impervious materials, both of which inhibit root growth.

(2) Beneficial effects of mixed parent materials

Intermixing of glacial tills from various origins is a common occurrence in Ireland. For example, the mixed limestone-sandstone-shale drifts in the valleys of the southern part of the country are generally derived from the underlying limestone rocks together with sandstone and/or shale transported and deposited from the surrounding hills.

These soils are generally very suitable for broadleaf growth, since the soils have favourable levels of fertility (conferred by the limestone) and ideal drainage (conferred by the mixture of drift materials of varying texture).

The soils occurring in this category will depend largely on the composition of the drift mix in the parent material. Thus, where limestone predominates then brown earth and grey-brown podzolic soils (alkaline soils) will occur, but where sandstone/shale predominates then acid brown earth and brown podzolic soils (acidic soils) will tend to prevail.

2.3.1.2 Climate as a factor in soil formation

The importance of climate as a soil forming factor in Ireland is due primarily to the rainfall component. The scope for varying influences as a result of this factor is great, since there is a wide variation in annual rainfall distribution. The influence of rainfall lies in its capacity to remove or leach, as it percolates down through the soil, nutrients and other elements from the upper to the lower soil layers. In extreme cases nutrients can be removed from the soil altogether. As the intensity of leaching increases so too does the degree of soil infertility.

Since rainfall is generally greater in elevated regions there is a tendency for upland soils to be more leached, and thus more infertile, than lowland soils. This is compounded by the generally thinner soils and poorer parent materials in most of the upland areas of Ireland.

The uplands, therefore, are covered mostly by soil types in which leaching is a dominant process. Such soils include the following: podzols, ironpan soils, and brown podzolics of low nutrient status. Where water movement is restricted – due for example to a flat or concave topography or to the presence of an ironpan layer in the soil profile – then peat will accumulate at the top of the soil, giving peaty variants of podzols and ironpan soils.

Lowland areas – where leaching is less intense – are comprised mainly of soil types where leaching is a relatively minor process in soil formation, because of the lower rainfall in such areas. Brown earths, grey-brown podzolics and brown podzolics of medium-high nutrient status are the principal soil types occurring in the lowlands.

2.3.1.3 Topography and soil formation

The main influence of topography on soil development is in its effect on the distribution of water or materials transported by water. The nature and extent of the topographic effects determines the type of soil produced.

For instance, flat areas commonly bear soils of poor drainage (peats and gleys), due to a tendency for receiving water as runoff from higher ground and from which there is little or no runoff or drainage. This is in contrast to steep-moderate slopes, where runoff is facilitated, a factor that promotes development of free-draining soils like podzols and brown podzolics.

Dramatic illustrations of the importance of topography as a soil-forming factor abound in Ireland. For example, drumlins, although small in area, often contain a logical pattern of very contrasting soil types. A typical case is the sequence of soil types – depending on parent material – from top to bottom of some drumlins:
(1) gleys on the poorly drained flat drumlin top,
(2) brown podzolics, brown earths or grey-brown podzolics on (the free-draining) drumlin mid-slopes, and
(3) gleys, peaty gleys, and peats on the poorly drained drumlin foot-slopes.

2.3.2 Distribution of soils in Ireland

2.3.2.1 General overview of the extent of soils

The general soil map of Ireland (Gardiner and Radford, 1980), published by An Foras Talúntais (now Teagasc), showed the extent of soils occurring, based on a division of the country into five broad geographical land units. These divisions are explained in Table 2.3-1, together with the resulting soils.

Table 2.3-1: Extent of **soils by geographic land unit** in Republic of Ireland.
(Adapted from Gardiner and Radford, 1980)

Land unit	Characteristics	Dominant soils	Area	
			million ha	% of land area
Mountain and hill	> 365 m, mostly wet soils	Peaty podzols, peaty gleys, blanket peats (high level), lithosols	1.1	*16*
Hill	150–365 m, mostly dry and acidic soils	Brown podzolics, rendzinas, grey brown podzolics, gleys	0.4	*6*
Rolling lowland	< 150 m, 3-9 ° slopes, mostly acid soils, wet and dry soils	Acid brown earths, podzols, brown podzolics, gleys, blanket peats (low level)	2.1	*31*
Flat to undulating lowland	< 100 m, 0-5 ° slopes, wet and dry soils, dry soils mostly limestone	Wet: gleys and basin peats Dry: grey brown podzolics, shallow brown earths of high base status and rendzinas	2.5	*36*
Drumlins	0-12 °+ slopes, wet and dry soils, mostly limestone and shale	Wet: gleys Dry: grey brown podzolics, brown earths and brown podzolics	0.8	*11*
		Total	**6.9**	***100***

Of most interest are the results for the most favourable categories for broadleaves, which are clearly the two lowland categories: the rolling lowland and the flat to undulating lowland and to a lesser extent the drumlins. These units – which in essence are all lowland units – account for 78% (5.4 million ha) of the total land cover (6.9 million ha), less major lakes and urban areas, but, unfortunately, one cannot assume that all of this 5.4 million ha is suitable for broadleaf production. The reason for this is that a significant proportion of the soils within these lowland units have unfavourable characteristics, the predominant one being soil wetness.

A breakdown of the lowland units into soils with poorly drained and well-drained status (Table 2.3-2) shows that about 66% of the lowland mineral soils, or 3.0 million ha, are well-drained, and can thus be generally assumed to have good potential for broadleaves.

2.3.2.2 Factors affecting patterns of soil distribution

The patterns of soil distribution in Ireland have been determined overwhelmingly by the impacts of (1) glacial events and (2) altitude and land form.

(1) Glaciation: Mention has already been made to the variability of soils in Ireland. Much of this variability can be attributed to differences in glacial history. The last glaciation (Midlandian) extended southwards to a line roughly from north Wicklow to the Shannon Estuary. Its soils tend to be more variable than those developed south of that

Table 2.3-2: Extent of **well-drained soils in lowland geographic land units** in the Republic of Ireland.
(Adapted from Gardiner and Radford, 1980)

Land unit	Total Area	Poorly drained	Well-drained	
	million ha	million ha	million ha	% of land area
Rolling and undulating (excluding basin peats)	3.7	1.0	2.7	*73.0*
Drumlins	0.8	0.5	0.3	*37.5*
Total	**4.5**	**1.5**	**3.0**	***66.7***

line on materials deposited by the previous glaciation (Munsterian).

The greater variability in the younger Midlandian areas is due principally to the shorter development time of its soils and the extensive occurrence of such glacial features as drumlins, eskers, kames and outwash fans, upon and around which several different soils are found. Here it is common to have different soils in very close proximity, a fact which makes for more difficult surveying of soils. The more weathered parent materials of the older Munsterian areas have produced more uniform and larger soil areas, and also smoother, more gently sloped landscapes.

(2) **Altitude and land form:** The enormous impact of altitude on soil development and distribution is due to the strong relationship between increasing altitude and worsening climate and soil quality. This relationship is so strong that it is especially useful to use the lowlands/uplands concept of land classification when considering broadleaves for particular soils and sites.

The landscape features illustrated in Figure 2.3-3 show the dominance of the Central Lowland and its surround of hills and mountains. The importance of the relationship between land form and soil formation can be appreciated by considering three of the most important land forms for broadleaves:

Figure 2.3-3: General **land forms** of Ireland.
(Collins and Cummins, 1996; from Herries, Davies and Stephens, 1978)

(1) The **Central Lowland** (map legend no. 1) is mostly on limestone, producing many alkaline or near alkaline soils (e.g., grey-brown podzolics) highly suitable for broadleaves.

(2) The **Leinster axis** (map legend no. 2) is dominated by the Wicklow and Dublin Mountains which are composed mostly of granite, that produces good free-draining forest soils (e.g., acid brown earths and brown podzolics) on the mid- and lower-slopes, and a large area of shales, widespread in Wexford, but also parts of Wicklow and Carlow.

(3) The **Ridge and valley sector** (map legend no. 3) in south Munster features east-west oriented mountains and hills composed of old red sandstone, generally bearing poorish soils for broadleaves (e.g. podzols, peaty podzols, peats, lithosols). The intervening valleys, however, can be very suitable for broadleaves, due to shelter, limestone in the valley bottoms and limestone-sandstone in the lower slopes, featuring better soils (e.g. acid brown earths and brown podzolics).

Looking at the other land forms in the Republic of Ireland, it is clear that since many of them feature **uplands** (4, 10, 12, 15 and 18, as well as some of 2 and 3) or **plateaus** (5, 6, 8 and 14) or less favoured **lowlands** (7, 9 and 13), that present extra challenges for broadleaf growth and that are not so prevalent in land forms 1-3 detailed above.

2.3.2.3 Patterns of soil distribution

Patterns of soils are evident across the country (refer to Figure 2.3-2). One of the soil distribution features of Figure 2.3-2 is the widespread extent of limestone soils in the lowlands of the Central Plain, extending southwards, and also westwards where shallower versions predominate in east Galway and parts of west Roscommon. Another prominent pattern is the occurrence of the peats along the western seaboard and at high altitudes and in the basin areas of the Midlands and the well-drained acid soils in the south and southeast.

The concept of looking at soils from the point of view of their lowland or upland location – together with categorising the nature of the parent material in terms of it being acid or alkaline – is used in the rest of this section to indicate the soil distribution patterns in this country:

(1) Lowland soils on alkaline parent materials (Table 2.3-3).
(2) Lowland soils on acidic parent materials (Table 2.3-4).
(3) Upland soils, predominantly on acidic parent materials (Table 2.3-5).

The terms lowlands and uplands are loosely interpreted, a rough separation between the two being the point where climatic conditions worsen to an extent conducive for advanced leaching (podzolisation) and peat accumulation on the soil surface.

The breakdown of lowland soils on the basis of the nature of its parent material is important given the range of preferences of broadleaf species, the majority of them doing best in alkaline conditions (including the most site-demanding, for instance: ash, beech, cherry, lime and pedunculate oak). The other broadleaves either grow best in acidic conditions (for instance: sessile oak and mountain ash) or are indifferent (for instance: sycamore, birch and common alder).

It should be noted that gleyed soils are found in all three soil categories, since the effects of drainage impedance is the dominant cause of their formation.

In the tables below the main areas where the principal soils occur are given, together with the specific soil map legend number, which indicates the location of the soil on the soil map (refer to Figure 2.3-2).

(1) Lowland soils on alkaline parent material

The lowlands on alkaline parent materials are primarily in the Central Plain of the country, encompassing the areas covered by limestone drift materials.

It is important to point out that some of the soils in Tables 2.3-3 to 2.3-5 below are composed of a range of soils which differ considerably in certain key characteristics (such as, depth of soil or permeability to water) which can affect the species options available.

Table 2.3-3: Distribution of **principal soils in lowlands on alkaline parent material.**

Principal soils	Main areas	Soil indicator number on map
Shallow brown earths and rendzinas	Central Galway, south Mayo, Clare, Limerick (limestone)	6 & 7
Grey-brown podzolics	Widespread in Central Plain, north Munster, east Galway, east Mayo and Sligo (limestone)	3
Gleys*	• Limestone parts of Cavan, and Monaghan, Leitrim, Roscommon • Louth, Meath, and east Wexford (Irish Sea muds)	5

* The predominant alkaline parent material in the lowlands on which gleys occur is composed mostly of limestone glacial till, which may have some shale and/or sandstone included.

This is particularly the case with the grey-brown podzolics, which range from an ideal deep, free-draining soil to one that is much less favoured, having impermeable subsoils. The species options will be wide with the former, but restricted with the latter.

(2) Lowland soils on acidic parent material

The lowlands on acidic parent materials generally extend from the fringes of the Central Plain to the coastal regions intermingled with uplands.

While the extent of the soils in Table 2.3-4 is considerably less than that on alkaline parent materials, the soils concerned are widespread and important forest soils, and indeed have borne many of the finest broadleaf forests in the country, particularly in Wicklow, Wexford and Waterford. This is because the soils have many of the characteristics required for attaining optimum growth of many forest tree species, most notably, the key characteristics of satisfactory soil depth, free drainage and moderate-high fertility.

Table 2.3-4: Distribution of **principal soils in lowlands on acidic parent material.**

Principal soils	Main areas	Soil indicator number on map
Acid Brown Earths	• East Leinster, Carlow and Waterford (granite) • Valley bottoms and ridges in Cork, Waterford, Kilkenny and Tipperary (sandstone and limestone) • Waterford, Carlow, Wexford, Wicklow, Louth, Meath, Kilkenny, Tipperary, east Clare, Monaghan, Cavan and Longford (shale)	4
Brown Podzolics	• Munster valley ridges (sandstone) • East Wicklow, Wexford and Tipperary (shale) • East Donegal (schist) • Lower slopes of Leinster Mountains (granite)	2
Gleys*	• West Clare, north Kerry, north Cork (shale) • Shale parts of Cavan, east Monaghan, Leitrim, Roscommon	5

* The predominant acidic parent material in the lowlands on which gleys occur is composed mostly of shale glacial till.

(3) Upland soils

The uplands constitute the mountains and hills where conditions are conducive to considerable leaching, and accumulation of peat at the soil surface, due to reduced decomposition of organic matter.

Also common in the uplands are

- gleys, and variants of the gleys such as the (peaty) podzolised gleys and peaty gleys of a kind differentiated from its counterpart in the lowlands by having a less decomposed peat at the surface and

- high level blanket peats, which occur above an altitude of about 150 m (Hammond, 1979).

While all the upland soils (Plates 2.3-1 to 2.3-5) have very limited potential for broadleaves, in terms of species options and growth quality, it must be reiterated that the uplands can also have soils comparable with those in the lowlands. Such soils will be found in sheltered upland valleys where climatic conditions are more benign.

Table 2.3-5: Distribution of **principal soils in the uplands.**

Principal soils	Main areas	Soil indicator number on map
Podzols and peaty podzols (weakly developed ironpan may be present)	Mountains and hills in Cork, Kerry, Waterford, Tipperary, Limerick, Wicklow and Donegal (sandstone or granite)	1
Compacted ironpan podzols	Upper slopes and flats of Old Red Sandstone hills in the south and southwest	1
Lithosols	Cork, Kerry, Galway, Mayo, Donegal and Wicklow (sandstone)	1
Gleys	Abbeyfeale Plateau, west Limerick (shale)	5

2.3.3 Identification of the main soil groups suitable for broadleaf species

The areal extent of the main soils as a percentage of total land area is presented in Table 2.3-6. The data have been extracted from the soils map of Ireland published in 1980 (Gardiner and Radford, 1980) and refer to all land in the Republic of Ireland, excluding major lakes and population centres. It shows that the best soils for broadleaves comprise about 48% of the land area, although that estimate is undoubtedly excessive given the significant developments of population centres since the date of the original data source. Nonetheless, it would be fair to say that more than 40% of the soils are suitable for broadleaves, particularly as some of the other soils would also be suitable in certain circumstances such as those in sheltered sites with at least moderate drainage.

The soils deemed most suitable for broadleaves are all to be found in the lowlands, which are defined for mapping purposes as representing elevations below 150 m. On practical

Table 2.3-6: Soils of the Republic of Ireland **as % of total land area.**

Soil group	Soil type	% of land area	Cumulative %
Soils most suitable for broadleaf species	Grey-Brown Podzolics	*18.4*	*48*
	Acid Brown Earths	*10.2*	
	Brown Podzolics	*8.3*	
	Basin Peats	*6.8*	
	Rendzinas	*2.6*	
	Brown Earths	*2.1*	
Soils more appropriate for conifer species	Gleys	*22.6*	*52*
	Peaty Gleys	*1.3*	
	Drumlin Peat and Peaty Gleys	*1.8*	
	Blanket Peats (lowland)	*5.8*	
	Blanket Peats (upland)	*7.1*	
	Podzols	*1.3*	
	Peaty Podzols	*5.6*	
	Lithosols (and outcropping Rock)	*3.9*	
	Miscellaneous	*2.2*	
	Total	***100***	

Plate 2.3-1: Podzol.

Plate 2.3-2: Deep gley.

Plate 2.3-3: Peaty gley.

Plate 2.3-4: Lithosol.

Plate 2.3-5: Blanket peat soil profile and landscape.

Table 2.3-7: The **major soils for broadleaf species**

Soils on alkaline parent materials	Soils on acidic parent materials	Other soils
(1) Brown earths **(2) Grey-brown podzolics** **(3) Rendzinas** **(4) Basin peats**	(1) Acid brown earths (2) Brown podzolics	(1) Alluvial soils (2) Man-made soils (reclaimed areas) (3) Shell marl and other lime-rich soils

grounds however, this is a conservatively low threshold in terms of the widespread evidence of successful broadleaf growth up to 200 m elevation. The reason for this is that many of the lower uplands or hills have enclaves with highly suitable conditions for broadleaves.

For the rest of this chapter the aim is to focus almost exclusively on the most suitable soils for broadleaf species, with briefer attention to some of the other soils, such as the reclaimed and alluvial soils. The intention is to give the grower guidelines as to how to identify the different kinds of soils, so that a well-based decision can be made on the species options available for each soil.

It is convenient to consider the best soils for broadleaf species in three groups (Table 2.3-7), two of them on the basis of their parent material source (alkaline or acidic) and a third group of diverse soils referred to here as other soils.

2.3.3.1 Soils on alkaline parent material

The first three soils in this group are mainly dry mineral soils whose high fertility is conferred by the nutrient-rich status of their parent materials, whether that be limestone or glacial drift dominated by limestone. The nutrient-rich status is generally stable since leaching of nutrients from the soils is low, due to the location of the parent materials in the lowlands where rainfall is relatively low. This results in relatively uniform soil profiles with little evidence of horizons. The fourth soil, the basin peats, is included with this group since they have been developed also over alkaline parent materials.

(1) Brown earth soils of medium to high base status (Plate 2.3-6).

Key points of brown earth soils of medium to high base status	
Characteristics	• Derived from alkaline (calcareous) parent materials, comprised mainly of limestone, and limestone drift materials (deposits of gravel, sand and mud left behind by the glaciers), otherwise known as glacial till. • Found only at low altitudes in areas of relatively lower rainfall. • Minimal leaching because of relatively lower rainfall and fine (non-sandy) texture. • High fertility. • Vegetation dominated by grasses and herbs.
Description	• Soil horizons not evident in profile. • Uniformly coloured profile. • Very rich humus.
Associated soils	Usually exists only as a minor soil associated with grey-brown podzolics or rendzinas.
Suitability for broadleaves	Optimal soils for most broadleaves, with exception of Spanish chestnut and sessile oak which have preference for less alkaline soils.

Plate 2.3-6: Brown earth of high base status.

(2) Grey-brown podzolic soils (Plate 2.3-7).

Key points of grey-brown podzolic soils	
Characteristics	• Derived from alkaline (calcareous) parent materials, comprised mainly of limestone, and limestone drift materials. • High soil reaction (pH) facilitates leaching of clay from topsoil. • Medium to high fertility.
Description	• Subsoil has higher clay than topsoil. • Rich mull-type humus.
Associated soils	Mainly gleys and brown earths.
Suitability for broadleaves	Same as for brown earths above.

Plate 2.3-7: Grey brown podzolic.

(3) Rendzina soils (Plate 2.3-8).

Key points of rendzina soils	
Characteristics	• Very shallow brown earth-like soils. • Developed mainly over limestone bedrock. • High fertility.
Description	• Topsoil usually less than 40 cm. • No subsoil, topsoil directly overlying bedrock. • Topsoil is darker than in brown earths. • Rich mull-type humus.
Associated soils	Shallow brown earths and shallow grey-brown podzolics.
Suitability for broadleaves	Suitable for a range of broadleaf species, but often sub-optimal because of shallow soil depths; unsuitable for oak and Spanish chestnut.

Plate 2.3-8: Rendzina.

(4) Basin peats (Plate 2.3-9).

Basin peats have developed most typically in low-lying lake areas in conditions that were extremely wet and anaerobic, conditions which impeded peat decomposition. The lake areas were heavily laden with mineral-rich material deposited by the melting glaciers. Given the alkaline waters prevailing, the growth of alkaline-loving swamp species was encouraged, principally *Phragmites* (reeds), which accumulated and eventually turned into *Phragmites* or fen peat.

A second type of fen peat, wood or woody fen peat, also exists.

Topographical position is the key to which type exists: *Phragmites* reedswamp peat usually developing in the lowermost levels over very alkaline (highly calcareous) marl material, while wood or woody fen peats were formed on more upland areas over less calcareous material.

As the depth of fen peat increases there comes a point when a vegetation-change has to occur, from one dominated by alkaline-loving species to one dominated by acid-loving species. This happens when the depth of peat is such as to render the nutrient-rich waters in the bog floor unavailable to the plants growing on the surface, the new and only water source now available being rainfall, which is naturally acidic. Mosses and heathers thrive in such conditions giving rise eventually to an acidic, nutrient-poor peat.

KEY POINTS OF BASIN PEAT SOILS	
Characteristics	• Represent the lower peat layers of basin peats, developed as fens or alkaline peats in valleys and basins with base-rich alkaline waters. • Vegetation dominated by rushes (*Juncus*) and reeds (*Phragmites*). • Old river and lake bottoms in Central Plain.
Description	• Surface peat is black, with depths up to 0.5 m, well-drained. • Underlain by peat,with mix of decomposed and undecomposed materials (wood and herbs) varying in colour from weak red, dark reddish brown and grey to black. • Depth of fen can be 1.5 m and over.
Associated soils	• Upper parts of basin peats. • Sub-peat marl mineral material, sometimes with shells.
Suitability for broadleaves	Suitable for birch, alder and oak. More demanding species possible provided adequate peat depth and relatively frost-free. If peat is too shallow underlying marl or till is likely to be severely limiting (see shell marl and other lime-rich soils).

Plate 2.3-9: Basin peat.

2.3.3.2 Soils on acidic parent material

It should be noted that the term acid usually prefaces brown earths developed on acidic parent materials to avoid confusion with brown earths developed on alkaline parent materials.

The defining feature of this group of soils, because of their free-draining nature and their acidic parent materials, is the role that the leaching process has had in their formation.

The links between the soils, and, therefore, the differences between them, are determined by the intensity of the leaching involved in their formation.

(1) Acid brown earth soils (Plate 2.3-10).

KEY POINTS OF ACID BROWN EARTH SOILS	
Characteristics	• Derived from acidic parent materials, comprised mainly of sandstones, granites, mica-schists, and non-calcareous shales. • Lowlands – but found at higher altitudes than (alkaline) brown earths – hence moderate rainfall. • Minimal leaching, hence mild expression of horizons in soil profile. • Low-medium fertility. • Free-draining. • Much more prevalent than (alkaline) brown earths.
Description	• Relatively uniform profile colour: topsoil darkish brown, subsoil a lighter brown, but darker than parent material. • Frequent stones and dominance of coarse loam textures allow free drainage. • Rich humus.
Associated soils	• Gleys, peaty gleys, and podzols. • Variants: Slightly gleyed brown earth (an inter-grade to ironpan soils and gleys) – slight/moderate occurrence of greying within the predominant brown.
Suitability for broadleaves	Optimal soils for most species, although can be marginally sub-optimal for ash and cherry.

Plate 2.3-10: Acid brown earth.

Plate 2.3-11: Brown podzolic.

(2) Brown podzolic soils (Plate 2.3-11).

Key points of brown podzolic soils	
Characteristics	• Derivation same as for acid brown earths, that is, from acidic parent materials, comprised mainly of sandstones, granites, mica-schists, and non-calcareous shales. • Moderate rainfall areas and medium elevations. • Leaching intensity more than in acid brown earths and less than in podzols. • Lower fertility than acid brown earths, but higher than podzols.
Description	• Brown topsoil has organic matter mixed with mineral material, overlies red-brown subsoil. • Less leached than podzols, so horizons not so obvious. • Leached layer faint if present. • Topsoil thicker than in podzol.
Associated soils	Acid brown earths, gleys, podzols, and blanket peats.
Suitability for broadleaves	Same as for acid brown earths.

2.3.3.3 Other soils

There are other soils which can be suitable for broadleaves under favourable circumstances, but they are of minor importance because of their limited extent and/or distribution in soil complexes.

(1) Alluvial soils (Plate 2.3-12).

The overflowing of streams and rivers results in material, known as alluvial deposits, being left behind in the flooded area. Coarser material is laid down near the watercourse and finer material further away. Alluvial soils are not as extensive as most of the other soils described, but they must be considered as they can be an important soil resource for broadleaf species provided the alluvial material is not from a highly calcareous source, such as, shell marl, and that the area is not subject to frequent damaging floods.

Key points of alluvial soils	
Characteristics	• Developed by material transported by water and deposited along rivers. • Soils may vary from coarse sandy to very fine texture.
Description	• Relatively undeveloped soil profiles due to recent deposition of materials. • Layers of alternating texture often evident reflecting separate depositions.
Associated soils	Acid brown earths, deep peats, peaty gleys, grey-brown podzolics.
Suitability for broadleaves	Suitability dependent on site conditions prevailing, especially source of deposit, drainage status, frequency and persistence of flooding, and climatic stresses.

Plate 2.3-12: Alluvial soil landscape.

(2) Man-made soils (reclaimed areas) (Plate 2.3-13).
This is a category of soils which cannot be ignored because of the extensive coverage of land reclamation carried out in Ireland in recent decades. The land reclamation has been of two types mainly: the first being that associated with drainage schemes, and the second, that associated with development of new roads and motorways.

If the works were done sensitively, the new soils will be roughly similar to the original soil.

Where best standards were not adhered to, then the works often resulted in negative consequences, such as (1) through increased soil compaction from frequent trafficking with heavy machinery over low-bearing capacity soils and (2) through importation of topsoil of uneven quality to replace that lost in the course of the initial works, with some of the new sections having less or inferior topsoil than the original displaced topsoil.

Plate 2.3-13: Ground after reclamation.

The suitability of the disturbed soils will, therefore, be dictated by the standard of reclamation performed. The importance of this issue is that many of these soils are in places where good soils are the norm and regarded as excellent soils for broadleaves prior to disturbance.

(3) Shell marl and other lime-rich soils (Plate 2.3-14).
The nature of the mineral material below fen peats ranges from extremely calcareous marls (a product left behind by lime-loving organisms which absorbed lime from the highly calcareous freshwater lakes following the glacial period) to glacial drift materials whose pH and lime content vary enormously, depending on its source and the degree to which the material has been weathered.

Shell marl soils are unsuitable for most tree species, including broadleaves, if drainage is poor, and especially if there is little or no overlying peat cover or mineral topsoil lacking shell marl. Reasonable growth of selected broadleaf species, such as alder, can be achieved if water-logging can be avoided. This situation is to be found – even on soils with a shallow peat cover – where lateral water flow is facilitated by the existence of an outfall and/or downward water movement is facilitated by a relatively porous sub-peat mineral material. For species more demanding than alder, an overlying fen peat depth of at least 30 cm is desirable, otherwise growth is likely to be sub-optimal.

Plate 2.3-14: Shell marl under peat.

Highly calcareous glacial tills in certain circumstances can be similarly problematic for tree growth as the marl soils, such as where the till material is extremely compact or coarse, which can lead to waterlogging and drought respectively, especially where the soil depth overlying the till is thin.

Conclusions

The major soils for broadleaves, mostly located in the lowlands, are the alkaline soils of brown earths of high base status, grey brown podzolics and rendzinas and, from the acid soils, the (acid) brown earths and brown podzolics. These would equate to soil types designated 'A', 'B' and 'C' in Table 5 of the Forestry Schemes Manual (Forest Service, 2011). There are only minor differences in suitability for broadleaves between soils within the 'A' and 'B' groups. However, soils within the 'C' group are less suitable for broadleaves than those within the 'A' and 'B' groups.

2.3.4 Soil aeration and wetness

2.3.4.1 Introduction

The growth of most trees, and indeed of most plant species, is dependent on the soil being adequately aerated, a condition which requires at least a moderately good soil drainage status.

Soil aeration is essential as it determines the levels of oxygen and carbon dioxide in the soil. This is crucial as these two gases are key components in the vital life-maintaining processes of respiration and photosynthesis.

Soil aeration is central to the smooth functioning of respiration and photosynthesis. Respiration will not be effective unless oxygen is supplied and carbon dioxide is removed. Soil aeration involves an interchange in the gases between the soil and the atmosphere.

Ideally a soil should be aerated such that the interchange of oxygen and carbon dioxide is rapid enough so that a deficiency of oxygen or an excess of carbon dioxide does not prevail.

2.3.4.2 Factors affecting soil aeration

Soil air can only be accommodated in the pores between the soil particles or particle clusters (for example, clods or crumbs), so those factors which affect the volume of soil pores also affect soil aeration. Chief amongst these factors are:

(1) **Soil texture**: a balanced proportion of sand, silt and clay is better than a high content of any one fraction.

(2) **Soil bulk density** (weight of dry soil per unit of volume): aeration better at lower bulk densities.
(3) **Soil structure**: aeration better where conditions favour a stable soil structure with resistance to breakdown of soil crumbs and compaction.
(4) **Organic content**: presence of organic matter is key to formation of soil crumbs and thus to creation of pore spaces.

It is self-evident of course that no matter how well these factors are favourably disposed for aeration, they will be over-ridden in situations where there is an excess of soil moisture (high water table) such that there is little or no space for air.

Pore space is normally lower in subsoils than in topsoils, resulting in subsoils having more deficiencies of oxygen. However, poor aeration in topsoils is also quite commonly found, and often through impacts of human activities. The main one of these is compaction resulting in reduced air permeability. This may arise from a number of situations, the most notable being

- the use of heavy machinery, or of frequently used light machinery as in soil cultivation practices and
- persistent cattle-grazing.

The effects from both situations will be greater in topsoils with a high clay or silt content, especially if they are wet.

Seasonal differences in soil aeration are largely the result of differences in soil wetness. This is not surprising given that the soil water table will be closer to the ground surface in winter than in summer. Rainfall is higher in the winter months (refer to Table 2.2-1) and evapotranspiration lower.

2.3.4.3 Effects of poor soil aeration

Poor aeration severely limits the decomposition by soil micro-organisms of soil organic matter. This is most amply illustrated in the poorly drained peatland areas of Ireland.

Poor soil aeration has three important effects on most plant species:
(1) Root growth is restricted,
(2) plant uptake of nutrients and water is reduced (this occurs even in soils with plentiful nutrients and water, due to insufficient oxygen and energy to drive the uptake process) and
(3) compounds formed in the soil which can be toxic to plants, for example, methane and hydrogen sulphide.

2.3.4.4 Variation in species tolerance to excess water and reduced aeration

The limiting effect of excess water and reduced soil aeration varies greatly between different species. Wetland species, such as willows and mangroves, have characteristics that facilitate tolerance of their roots to excess water (Savill and Evans, 1986). These species have the capacity to develop large air spaces in their roots, enabling them to furnish their oxygen needs internally.

Most of the other woody plant species – including the species capable of producing quality timber – rely more on small pores (lenticels) on the surface of its stems and roots in the aerated upper parts of the soil, for the uptake and passage of their oxygen requirements. The efficient functioning of that process will depend on adequate drainage and aeration. Nonetheless, there are variations between the species in their site requirements in terms of soil wetness/aeration. Thus, Kerr and Evans (1993) have suggested that on fertile mineral soils with no seasonal water-logging, a guideline for species options (in decreasing order) would be ash, cherry, beech, oak, and sycamore, whilst on soils which are subject to seasonal water-logging, the guideline for species options would be oak, cherry, ash, and sycamore. Of particular note are the respective positions of ash and oak, which reflect the divergent site requirements amongst species, particularly with respect to soil moisture and aeration characteristics.

2.3.4.5 Soil wetness in Ireland

The dominance of the wet and poorly drained soils (peats, peaty podzols, gleys and peaty gleys) has been noted in the west and north-west, and the dominance of the dry and well-drained mineral soils (brown earths, brown podzolics, grey-brown podzolics) in the south-east. This is reflected in Figure 2.3-4, which gives a rough division of the country into two broad land quality classes, based mainly on source of soil parent material and drainage status, and indeed, altitude:

(1) the physically poorer soils west of the line demarcating the limit of well-drained soils and
(2) the physically better soils east of the line.

The message that over half the total land area has poorly-draining soils is a stark one from the point of view of considering the growth of broadleaf species. However, that is not a surprising fact given the disproportionate amount of uplands there is in the regions west of the demarcation line.

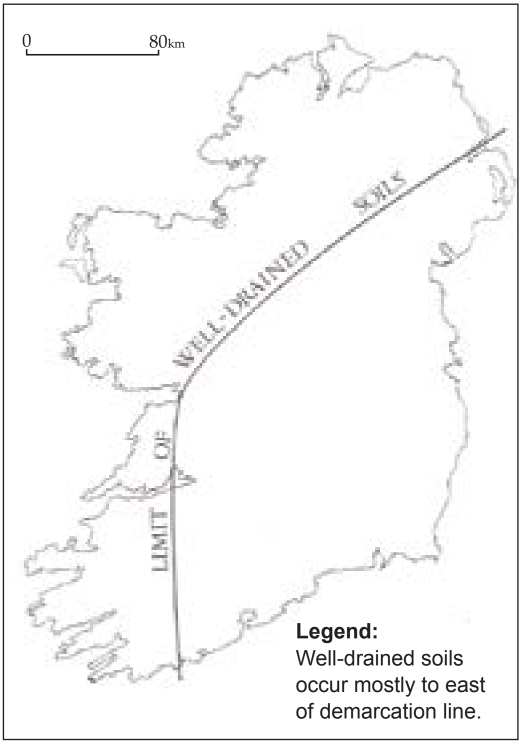


Figure 2.3-4: Distribution of **well-drained soils.** (Mitchell, 1986, based on Teagasc soils data)

A significant proportion of the lowlands, however, feature soils with poor drainage and aeration. Of the 3.7 million ha of lowland soils in Ireland, about one million ha (27%) is deemed to be poorly drained (Gardiner and Radford, 1980), due to various reasons, but mainly to high water tables arising from impervious layers. Such areas can be expected to pose problems for production of high quality broadleaf timber, restricting them to other uses of broadleaves (e.g. environmental) that have more modest site demands for their achievement.

The land planted with conifers often requires drainage and cultivation before planting if satisfactory establishment and growth is to be achieved. Drainage removes excess water from sites and increases soil aeration, benefits which are also provided by cultivation in addition to others such as increasing nutrient availability, ameliorating the effects of compaction, and limiting competition from ground vegetation. Land suitable for broadleaf species, at least for purposes of high quality timber, should be of a quality which does not require such intensive pre-planting site preparation. If it does, it would indicate, apart altogether from economic considerations, that the site is unlikely to be optimal for the main commercial species. However, less intensive site preparation methods – such as shallow ploughing, perhaps with mounding – may be appropriate and even necessary.

The enormous impact of altitude on soil development and distribution is due to the strong relationship between increasing altitude and worsening climate and soil quality. This relationship is so strong that it is especially useful to use the lowlands/uplands concept of land classification when considering broadleaves for particular soils and sites.

Conclusions

The maintenance of a good soil atmosphere (aeration and temperature), and its control by soil water, is crucial to providing high quality soils for optimal broadleaf production.

continued

Conclusions continued

Most higher plants can be limited in their growth by inadequate soil aeration. Likewise poor soil aeration, and low soil temperatures, reduce the effectiveness of the soil micro-organisms in their crucial roles, particularly in breaking down organic matter and increasing nutrient availability. Poorly drained soils have the additional problem of being a source of accumulated toxic gases, of which most of the commonly planted broadleaf species have a low tolerance.

2.3.5 Soil deterioration

Soil deterioration occurs where it is degraded by inappropriate land use practices.

There are two ways in which soil deterioration occurs:

- By removal of soil and plant materials. This causes a decline in the physical, chemical and biological well-being of the soil ecosystem, which in turn reduces its plant growth potential and
- by the accumulation of chemicals or contaminants to levels that become toxic, reducing plant growth or impacting on the environment (plants, animals, micro-fauna and water).

The following are examples of soil deterioration found in Ireland that would be problematic for successful growth of broadleaf species:

- **Arable (tillage) soils** are prone to deterioration over the long-term when subjected to intensive management practices of cultivation, such as ploughing. Cultivation leads to increased mineralization and reduction of organic matter and consequently nitrogen, increased permeability, increased droughtiness, increased nutrient removal, and increased risk of erosion on sloping ground. Cultivation also results in the development of plough pans, which can impede root development, and destruction of soil structure leading to loss of beneficial organisms such as earthworms (Curry, 2002). Earthworms confer enormous benefits to the soil, particularly by increasing its porosity, aeration and infiltration capacity (Curry, 2004). The absence of earthworms indicates limitations in several soil characteristics such as soil moisture content (too much or too little), fertility and soil reaction (strongly acid). Difficulties have been experienced in establishing broadleaf crops in some arable soils in north Co Dublin, due to the soils showing many or all of the characteristics of degradation detailed above.
- **Reclaimed areas** often present problems when the operation involves removal of the original topsoil and replacement with other material not always of equal quality to the original. Furthermore, before the replacement occurs, the area shorn of its topsoil has its subsoil subjected to varying intensities of traffic by heavy machinery causing compaction of that material, which in turn means reduced permeability to water.
- **Tile-drained areas** often present problems for tree species a few years after planting due to the roots blocking the drains, leading to the site becoming much wetter. Therefore, the precautionary approach should be taken of presuming that the existing tile drainage system will malfunction and instead, on the basis of that presumption, installing a drainage system appropriate to the site.
- **Residues removal** has become a subject of interest in recent times due to the potential of the previously non-commercial parts of trees (e.g. branches, roots and tree tops) as a fuel source. Such residues contain nutrients absorbed from the soil and precipitation (mainly mist and rainfall) and their removal will result in a serious deterioration in soil quality if the underlying soil is of poor fertility, particularly if the material is removed before leaves/needles are shed from the residues. Also, the removal of the residues on sloping

sites will increase the risk of soil loss through increased erosion. Soils on upland sites are most liable to such risks, especially given their generally shallower depths than lowland soils. Species options are likely to be reduced and fertilisation will be required to replace some or all of the lost nutrients.

- **Peat extraction** for fuel and horticulture continues to have a big impact on the quality of the medium left behind for planting. This is especially of concern in the good quality fen peats in the Midlands, which are the only peat type capable of sustaining a reasonable number of broadleaf species at a reasonable growth rate. However, this is subject to there being a reasonable depth of peat, as the underlying mineral material is often an unfavourable medium for tree roots, being either excessively calcareous or impermeable or both.

2.4 Inter-relationships between broadleaf species and site conditions

2.4.1 Introduction

The overwhelming influence of climate, altitude and soil factors on broadleaf tree growth potential has been dealt with in previous sections. In the context of assumptions regarding site needs of broadleaves it is worth repeating the close relationship between increasing altitude and diminishing quality of site conditions, particularly with regard to soils (such as shallow depth and reduced fertility) and climate (increased exposure, wetness and coldness).

This has relevance more for woodland species grown for timber than for those grown for other purposes, such as wildlife, conservation, and landscaping. Sufficient quantity and quality of production, the essential requirements for growing broadleaf crops for timber, cannot be assured in the uplands (above 200 m). Quality is not as important in other woodland uses, so whether it is uplands or lowlands is not a prime consideration. Hence, the lowlands should be the main domain for timber-growing woodlands, while the uplands and poorer lowlands should be the main focus for woodlands grown for other uses.

2.4.1.1 Broadleaf species in the uplands

While soil quality can be good, and climate can be benign in the uplands, specifically in sheltered upland valleys, there is no doubting the opposite tendency to be the norm. Nonetheless, some broadleaf species will grow in the uplands, even in extreme conditions of soil and climate, but the species options are limited and the quality potential is low. The low quality potential will not be a major consideration where the purpose of the woodland is non-commercial, such as in woodlands planted for the purposes of

- amenity and parkland,
- landscaping,
- wildlife conservation,
- soil erosion protection,
- soil enrichment,
- provision of shelter (for man, animals and plants),
- fuel supply.

The species options will depend on the purposes for which they are planted. Examples are tabulated in Table 2.4-1.

Table 2.4-1: Broadleaf **species options in the uplands and poor lowlands according to purpose.**

Purpose	Species options	Benefit
Soil enrichment/improvement	Alder, rowan, tree lupin, sea buckthorn	Provision of nitrogen (N) through N-fixation.
Soil erosion control	Poplar, willow, sea buckthorn, tree lupin	Vigorous rooting.
Planting of high (exposed) elevations	Birch, alder, rowan, willow (*Salix caprea*)	Moderate tolerance of exposure.
Planting of coastal areas	Sycamore, tree lupin	Tolerance of maritime exposure.

It should be noted that most of the species listed above are pioneer species, capable of occupying difficult sites quickly with the potential to make sites amenable for more site-demanding intermediate and late-successional species (see Chapter 4.1).

The successful pioneer species will have most of the following attributes:

- Abundant producer of very light seed,
- aggressive rooting systems,
- fast growth,
- short-living,
- capacity to enrich the soil and
- tolerance of adverse conditions.

Alder and birch are examples of all-rounder species in the sense that they have pioneer qualities. They may have to be controlled to facilitate introduction of intermediate and late-successional species. They also have the potential for fulfilling a timber-producing function.

2.4.1.2 Broadleaf species in the lowlands

In this section, the term lowlands is used in a general sense to refer only to those areas where favourable climate and site conditions prevail, as well as those equally favoured (generally sheltered) areas within the uplands. It is recognized that some lowland sites are inhospitable for broadleaves (for example, exposed coastal areas and bare or deteriorated land), and such places should be considered in the same way as the uplands. In this section also, the comments are made only in the context of broadleaf production for commercial purposes.

In Ireland, the most site-demanding species for commercial use are ash, oak and beech. With the exception of sycamore, these species are not endowed with the main attributes that define the pioneer, having adapted to the good or moderate conditions that normally exist in the lowlands, particularly those in the south-eastern part of Ireland.

The following conditions best exemplify the advantage for commercial broadleaf production of the lowlands over the uplands:

(1) lower or minimal climatic stress,
(2) greater soil depths available for rooting and
(3) higher soil fertility.

(1) Climatic stress: Winter cold and wind exposure are the main climatic stresses for broadleaves, which clearly are worst in elevated and coastal areas. For most broadleaves the lack of leaves and the unprotected buds renders them vulnerable to climatic influences, particularly wind and frost. Sycamore and, to a lesser extent, beech are exceptional amongst the potentially timber-producing broadleaves in having some tolerance for exposure.

(2) Rooting: Broadleaves tend to have a deeper and more extensive root system than most conifers, which generally have a shallow root system that is predominantly confined to the topsoil (exceptions would be grand fir and Scots pine). This confers an advantage to broadleaves in drier conditions by giving them greater access to moisture and nutrients in the deeper soil layers. On the other hand, shallow rooting conifers can tolerate wetter ground conditions than broadleaves.

(3) Nutrients: Broadleaf species absorb greater amounts of the major nutrient, calcium, than most conifers. This characteristic accounts for the reason that broadleaf species grow best where soil reactions (pH) are alkaline (pH 7 or higher than pH 7) or near-alkaline, since the availability of the major nutrients (nitrogen, phosphorus, potassium, calcium and magnesium) to plants is optimal at these levels. However, because of the deep-rooting habits of broadleaf species, reasonable growth can still be achieved on soils with acidic soil reactions in the topsoils provided the subsoils have alkaline or near-alkaline soil reaction status.

2.4.1.3 Overview of site conditions and species options

An overview of the impact of site conditions generally on broadleaf growth and/or species choice is shown in Table 2.4-2.

Table 2.4-2: Overview of general **assumptions regarding site conditions and broadleaf species**.

Condition	Comments on species options
Exposure, winter cold and frost	Species choice severely restricted.
High altitude (>200m) and poor soils	Species choice severely restricted.
Vulnerability to frost damage	• Very vulnerable: e.g. ash, beech, oak. • Moderately vulnerable: e.g. sycamore. • Frost-tolerant: e.g. birch and alder.
Aspect	Not a serious influence on species choice.
Soil reaction (pH)[1] and/or soil texture	• Limestone soils: optimal for ash and beech. • High clay soils: wide range of species possible, especially pedunculate oak. • Very acid (sandy) soils: unsuitable for good growth.
(Soil) nutrition	• High nutrient needs: e.g. ash, sycamore. • Moderate nutrient needs: e.g. oak, alder.
(Soil) excess lime[2]	Relatively tolerant [3]: alder, sycamore, maple, lime, poplar.

[1] Excess lime not necessarily present, and an insignificant influence if present.
[2] Excess lime a dominant influence over pH (high).
[3] Tolerance dependent on satisfactory drainage and topsoil characteristics.

2.4.2 Site classification guidelines for broadleaf species selection

Site classification guidelines for broadleaf species selection are provided below for a range of soils. The guidelines are based on a combination of climatic and soil factors, with a division by region into lowlands (Table 2.4-3) and uplands (Table 2.4-4) to indicate the major climatic and soil differences between both land areas. The guidelines for the lowland soils are also differentiated according to acidic and alkaline parent materials.

Table 2.4-3: Guidelines for broadleaf species selection in the **lowland soils.**

Species options and ranking	Soils (mostly alkaline parent material)					
	Acidic	Alkaline				
	Acid brown earths and brown podzolics	**Brown earths of high base status and grey-brown podzolics**	**Rendzinas**	**Deep fen peats** (> 40 cm peat)	**Shallow fen peats** (20-40 cm peat over marl or glacial till)	**Gleys** (moderate to well-aerated)
Good	Alder Beech Birch Spanish chestnut Hornbeam Norway maple Rowan Sycamore Sessile oak	Alder Ash Beech Birch Cherry Hornbeam Lime Norway maple Pedunculate oak	Italian alder Beech Hornbeam Norway maple Sycamore	Alder Ash[1] Birch Pedunculate oak Sycamore	Alder Birch Pedunculate oak Sycamore Poplar	Alder Downy birch Hornbeam Pedunculate oak
Moderate	Ash Cherry Lime	Sessile oak Red oak Rowan	Ash Birch Lime		Ash[1]	Grey alder Silver birch Pedunculate oak
Satisfactory		Spanish chestnut				Italian alder Cherry Norway maple Sycamore

[1] Suitability dependent on sites not being subject to significant waterlogging.

Table 2.4-4: **Guidelines** for broadleaf species selection in the **upland soils.**

(Species options are not given in any order of rank)

Soils (mostly acidic parent materials)		
Podzols, peaty podzols	**Ironpan soils**	**Gleys, podzolised gleys, peaty gleys**
Rowan Silver birch Red oak Alder Beech Downy birch Spanish chestnut Hornbeam Lime Norway maple Sessile oak	Alder Grey Alder Beech Downy birch Red oak Sessile oak Rowan	Alder Downy birch

Soils not included because they could not be accommodated within the structural basis of the above classifications are as follows:
(1) Alluvial soils,
(2) soils on reclaimed sites,
(3) lithosols,
(4) low-level blanket peats,
(5) upper sections of raised (basin) bogs,
(6) high-level blanket peats.

(1) Alluvial soils, (2) reclamation soils and (3) lithosols occur at all elevations and across all sources of parent material, and the remaining soils (4, 5, 6) are deep peats.

Whilst these soils represent minor sources of options for broadleaf species, they deserve consideration due to their considerable extent, more locally in the case of alluvial soils, reclamation soils and lithosols and more regionally in the case of the deep peats.

(1) Alluvial soils: Given the wide range of site conditions possible within this soil grouping, the task will be to identify which set of conditions most closely approximates that detailed in the general guidelines (Table 2.4-3 and Table 2.4-4) to obtain the appropriate species options.

(2) Soils on reclaimed sites: Species options will be dependent on (a) the reclamation standard practiced, in terms principally of the quality of the soil material used and its disposal such that a genuine and normal topsoil over subsoil profile is achieved and (b) the quality of the soil physical status achieved, with reference in particular to provision of a soil with a suitable and sustainable aeration and drainage status.

(3) Lithosols: Broadleaf species are not usually an option on lithosols due to their poor physical and chemical characteristics, and often due to extreme exposure.

(4) Low-level blanket peats: There are no broadleaf options as forest crops, but for other uses, birch, alder and willow could be considered.

(5) Upper sections of raised (basin) bogs: High acidity and poor fertility would be among the primary limiting factors against broadleaf species as forest crops.

(6) High-level blanket peats: The normally unfavourable conditions prevailing (for example, severe exposure, high acidity and poor fertility) dictate that there are no options for broadleaf species as commercial forest crops.

In using these guidelines the reader should be aware of potential limiting factors prevailing either on a local or broad scale that can have an over-riding importance of other factors, including the soil factor. The outstanding example of this is that, irrespective of how good the soil is, the quality of the crop will be largely dictated by exposure.

2.5 Discussion

The essence of this chapter has been to address the question of site quality and the assessment of its potential and limitations for broadleaves, with the view to deciding the best species to grow and for what purpose. The purpose must be achievable within the available site quality (Chapter 2.5.1 and Chapter 2.5.2).

The assessment of site quality has been complicated somewhat by the emergence in recent years of two factors whose influence is predicated on radical changes in their condition (Chapter 2.5.3): The first is the issue of soil deterioration (Chapter 2.5.3.1), not a new problem admittedly, but one whose scale has increased to such an extent that it has become a significant (negative) factor in assessing site quality for broadleaves. The second emerging factor is the inconsistencies in climate change projections (Chapter 2.5.3.2), an issue which may have positive (for example, lower frequency of frosts) as well as negative (for example, increased moisture stress) influences.

2.5.1 Site quality and the purpose of growing broadleaf species

The issues dealt with in the earlier stages of this Chapter indicate that we do not always have available a site of sufficiently good quality to allow a wide freedom of choice regarding the planting of broadleaf species. This means that sufficient attention must be given to the planting potential of each site in order to safeguard against serious disappointment in the future.

Mention has been made of the less than ideal conditions prevailing in many parts of the western half of the country for the purpose of growing quality broadleaf timber. However, such conditions also exist, though to a lesser extent, in the east. Broadly speaking though, the latitude for consideration of commercial broadleaf forestry will be less in the harsher conditions of the west than in the more benign conditions of the east; this means that the aesthetic or environmental purposes will feature strongly in the west, whilst the commercial and multi-purpose considerations will feature strongly in the east.

2.5.2 Focus on the better soils for broadleaf species

The physical characteristics of a soil (such as its proportions of sand, silt and clay and drainage capacity) are normally more significant than fertility status in determining its suitability for tree growth. It is possible to correct fertility problems by the application of fertilizers, but it is rarely feasible to change the physical characteristics of a soil. Therefore, free-draining soils of moderate fertility are much better than impermeable soils of high fertility.

Ireland has a rich resource of excellent soils because of their development in ice age drift deposits composed of mixed materials of different origin. The mixture of sandstone, shale or schist with limestone will often have a very beneficial effect on the physical development of the soils giving them a coarse loamy texture with good drainage. In addition, the limestone component will probably have contributed at least a moderate fertility status to the soil. Such soils have the widest use range, being the most suitable for tillage crops, hence the common reference to them as being tillage soils.

Given its widespread coverage of the country, limestone is often present in the drift mix and often exists as the main component. The proportion of the components varies, the influence of sandstone being strong in Munster, shale in the south-east and limestone in the Midlands.

The distribution of the main areas of these high quality soils are given below (Table 2.5-1), as well as the soil type and its parent material (refer to Figure 2.3-2).

Table 2.5-1: The source and **main areas of high quality soils** for broadleaf species.

Soil	Parent material	Main areas
Acid brown earths	Sandstone and limestone	Cork-Waterford
	Shale	South-east, Tipperary, Louth and Meath
Brown podzolics	Sandstone and shale	Cork
Grey-brown podzolics	Limestone, sandstone and shale	Limerick, Tipperary, Kilkenny
	Limestone, granite or sandstone	Laois, Carlow, south Kildare

Of course, not all soils derived from limestone are of similar stature to those referred to above. Many of the soils found in north Leinster and east Connacht have poor physical characteristics due in large part to the compacted nature of the parent materials and also to a relatively impure form of limestone, compared to that found underlying the good soils referred to above. A feature of these poorer soils is a heavy texture and poor drainage.

As noted elsewhere, good soils do occur outside of the more favoured south and south-east, but their number and extent is less. Prominent examples would be the brown podzolics developed on schist-dominated glacial drift materials in the lowlands of east Donegal, and the shallow brown earths and rendzinas on limestone parent material in mid Galway and south Mayo.

2.5.3 Changing conditions

The lack of stability in two of the three major factors affecting site quality for growth, soil and climate, has become an issue of increasing concern in recent times.

2.5.3.1 Soil deterioration

Soil quality and productivity are determined principally by its nutrient content, water-holding capacity, organic matter content, soil reaction (pH) and biological activity. Changes in these key characteristics can be for good or bad. They are bad when land practices result in damaging effects, direct or indirect, that produce a decline in water availability, nutrient availability and biological activity.

The damaging effects most frequently encountered in Ireland are:

(1) The destruction of soil structure and consequent development of soil compaction, which restricts root penetration and water permeability. This has become a common feature in the use of certain types of farm machinery and in disturbed lands on formerly good soils such as those affected by motorway construction around the country.

(2) The loss of topsoil through excessive soil cultivation and subsequent erosion on upland sloping sites, especially shallow soils in their natural state.

(3) The loss of biological activity in intensively managed soils, as manifested by reduced organic content and microbial activity, is a serious problem in many planted, former arable soils, leading to trees becoming deficient in nitrogen after about five years.

(4) The exposure of highly calcareous sub-peat mineral material through excessive removal of the overlying peat; such calcareous material can be a serious impediment to the growth of most species.

The consequences of soil deterioration are obvious enough. At worst, the land affected will be unsuitable for planting, at best it will be limited in its suitability, restricted only to minor species for aesthetic or environmental purposes.

Signs of soil deterioration will, therefore, have to be looked for when assessing land for broadleaves if serious mistakes are to be avoided.

2.5.3.2 Climate change

Despite the mounting evidence for relatively dramatic changes in climate since the mid-1990s, the reliability of predictions for future trends is open to question. The predictions are based on assumed data thresholds of temperature and rainfall that are submitted to analysis by different models. Given that the science of climate change is new, and with controversies between climatologists surrounding the appropriateness of the assumptions made and the modelling used, it is understandable and fair to say that predictions of future climate scenarios are still highly speculative.

Nevertheless, it would be foolhardy, at least for those involved in forest planning policies, especially for long-rotation broadleaf species, to ignore even tentative future climate predictions. It is fair to say that at some stage the science of predicting mid- to long-term climate scenarios will improve beyond the speculative.

Two of the most publicised predictions have been that by 2050 Ireland will have (1) warmer growing seasons, and (2) wetter winters. The elevated temperature levels envisaged for growing seasons would be such that conditions will have become considerably better for several broadleaf species, most notably sessile oak, Spanish chestnut, wild cherry, walnut, red oak and southern beech. However, the downside is that it can be expected that growth would be restricted by increased occurrence of droughts, especially in the drier mineral soils of the south-east, and possibly also by unwelcome changes in risk levels to pests and diseases.

Conclusions

Ireland's geographic location at the most western part of Europe means that its climate has an especially powerful influence on the growth potential of broadleaf species, directly from factors such as wind, exposure and frost, and indirectly through affecting other key factors (particularly soils and topography) that influence site quality and tree growth.

- Almost 90% of the total area under broadleaves in Ireland lies below 150 m altitude.
- Treelines in Ireland are generally much lower than in much of the rest of Europe, being less than 500 m, compared to over 2,000 m in the Alps.
- A considerable proportion of the lowlands – about 40% – are unsuitable for productive broadleaf growth for a variety of reasons. The main reason is the unsuitability of the soils themselves, due for instance to soils being too acid or too alkaline, too infertile or having a significant degree of impeded permeability.

The lowlands – and some well-favoured uplands – are a rich resource of very productive sites for a broad range of broadleaf species. They are sites which fulfil the basic requirements for successful growth of broadleaf species: low climatic stress, satisfactory rooting depth and fertility. The main areas of suitability are in the Central Plain, the Leinster hills, and in the Munster hills and valleys.

Detailed descriptions of the major soils are presented – from suitable to unsuitable – so that growers can be in a more knowledgeable position to make critical decisions as to site quality and species options.

To conclude, two site classification guidelines for broadleaf species selection are presented: one for the lowlands (mostly on alkaline soil parent materials) and the second for the uplands (mostly on acidic soil parent materials).

Consideration is given concerning various issues that can arise which should be taken into account given their sometimes negative impact on site quality; key examples are soil wetness and soil deterioration. Consideration is also given to changes in such conditions, specifically soil deterioration and climate change, and the potential for negative as well as positive influences of the latter, with the possibility for options to consider the planting of species outside of those normally planted in Ireland.

3 Economic, ecological and social values of broadleaf species

3.1 Introduction: Objectives and functions of broadleaf forest management

Before the goals and objectives of broadleaf management are discussed it may be helpful to outline some terms (Chapter 3.1.1.1 and 3.1.1.2), which reflect on the development of forest functions (Chapter 3.1.2) and to highlight the problems associated with the forecasting of long-term forestry development (Chapter 3.1.2.3).

3.1.1 Definitions

The terms goal and objective are often used interchangeably although they differ in some subtle, but critical respects. Because of the long-term horizon of forestry enterprises these differences become blurred and are, therefore, often ignored in forestry literature. Nonetheless, the definitions are presented here for the benefit of the reader:

- **Goals** are long-term aims that one wants to accomplish.
- **Objectives** are concrete attainments that can be achieved by following a certain number of steps.

The main difference is in their level of concreteness. Objectives are concrete, whereas goals are less structured.

More importantly, the terms “objectives” and “principles” of forest management, often tend to be confused in forestry terminology. To overcome any confusion it is, therefore, necessary to begin this chapter with some general explanations and examples.

3.1.1.1 Goals and objectives of forest management

The goals and objectives of forest management may be either tangible or intangible. They comprise economic, ecological, environmental, social and possibly other aspects:

- **Production goals**, such as the production of valuable timber, are unquestionably the most important. The economic targets should also include **employment goals**, for example, as well as securing a sufficient income for the forest owner. **Supply of material to the market**, specifically the timber industry, with the necessary raw materials is another production goal.
- The **protection of soils** against erosion may be deemed to be both a tangible and an intangible objective.
- **Nature protection** generally, and biodiversity conservation in particular, are the most important environmental objectives.
- **Social objectives** comprise mainly the creation of appropriate conditions within the forests for recreation.

The main objectives of the management of broadleaves will be discussed in greater detail in subchapters 3.2 to 3.6.

3.1.1.2 Principles of forest management

Three main principles have to be considered where long-term forestry is desired. These are
(1) principle of sustainability,
(2) principle of efficiency of all forest activities (economic law), and
(3) principle of contribution to the benefit of society.

(1) Principle of sustainability
Sustainability has been the leading principle of forest management since the development of documented forest management. The concept was first formulated by von Carlowitz in 1713 and from then, and more particularly from the beginning of the 19th century, the notion of sustainability was concerned primarily with the steady production of timber. Hartig (1792) expanded on this concept and emphasised a steady welfare for future generations.

Ideally, sustainability is achieved in the normal forest. The concept of the normal forest was developed in the 19th century. In the language usage of the time, normal was synonymous with ideal. In the normal forest model there are as many even-aged stands as there are years in the rotation, each characterised by an equal level of productivity. It entails a series of age gradations, with each stand a year further along in the rotation than the previous one, and each with an equal yield capacity. Every year the oldest stand is felled and regenerated. In this way, a sustained and equal yield is obtained indefinitely. However, a normal forest can never be truly achieved in practice, as site conditions are variable and storms or other catastrophes tend to disrupt forest productivity, where there is an even structure of age classes. Nevertheless, the outcome of the implementation of forest management planning since around the middle of the 19th century has led to more or less sustainable production from all forests in central Europe that are larger than 100 ha in size.

As early as the end of the 19th century it had become obvious to foresters in central Europe that sustainability could not be limited solely to timber production: the definition of sustainability had to be broadened. Furthermore, the true importance of the ecological challenges inherent in forestry, the restrictions placed on management by social constraints and the need to maintain an intact production basis, i.e. the soils, and the resultant emphasis on the protection of forest ecosystems and soils only obtained a foothold in the public consciousness in the second half of the 20th century. European Nature Conservation Year in 1970 provided a major impetus in this direction.

As a consequence, all forestry activities are now required to adhere to the principle of sustainability. This is the case regardless of whether a forest is managed through the clear-cut or the selection system. In each case the management must be carried out in a sustainable manner.

Since the Rio Conference in 1992, the terms sustainability and sustainable development have found use beyond the confines of the forestry sector and are now applied to all human activities, and possibly even the future of mankind in general. In the absence of sustainable management, future generations will not be able to derive from natural resources the same benefits that are enjoyed today.

The sentiments as expressed by Edmund Burke, the 18th century Irish philosopher and statesman, in relation to responsibility for future generations were eloquently echoed in the 1947 US Supreme Court case, State v. Dexter (Cubbage and Siegel, 1985): *A great unwritten compact exists between the dead, the living and the unborn. We leave to the unborn a colossal financial debt, perhaps inescapable, but incurred nonetheless in our time and for our immediate benefit. Such an unwritten compact requires that we leave to the unborn something more than debts and depleted natural resources. Surely, where natural resources can be utilised and at the same time perpetuated for future generations, what has been called constitutional morality requires that we do so.*

Thus, sustainability is not an objective in itself, but rather a principle guiding all economic activities, and is increasingly gaining an ethical dimension.

(2) Principle of efficiency of all forest activities
All human activities – including forestry activities – must adhere to an economic rationale. This is often misunderstood as merely the attainment of the highest possible profits. Rather, this means that all activities should be carried out efficiently, effectively and be economically oriented.

The principle of economic efficiency – also called the economic law – is formulated in two ways:

- A defined objective should be reached with the least possible input (minimal principle), or
- the highest possible output should be achieved with a given level of input (maximal principle).

Input and output refer to both tangibles and intangibles, and include financial resources, labour, machines, and the time required from concept formulation and planning and completion.

Human objectives can cover a wide material and non-material range. In most cases they have to be fulfilled using the least possible input – consequently following the minimal principle – as generally only limited resources are available.

(3) Principle of contribution to the benefit of society

Forests are increasingly regarded as areas with important values for the benefit and welfare of mankind, as well as for flora and fauna. Society is making ever greater demands on forests in regard to their functions and services. These include material and intangible goods such as timber and energy supply, landscape and nature protection, CO_2 storage, watershed management and recreation.

In most countries the management of State forests is oriented towards the principle of good governance which has come into discussion only recently. It means that the forests are administered on a multifunctional basis devoted to meet the various needs and requirements of society as a whole. It includes utilisation and participation of all groups which have an interest in the forests. Moreover, this implies transparency, coordination, collaboration and integration within the forest sector and with the other sectors. Finally, global responsibilities are getting increasing weight such as conserving ecological heritage and biodiversity. The EU Natura 2000 programme is such an example. Mitigating the human influence on global warming is another.

These obligations normally cannot be borne by private landowners and are, therefore, transferred mainly to the State. Nevertheless, private landowners are increasingly included in the process. This is exemplified by the fact that the EU and the Irish government have provided a number of different grants for the establishment and management of private forests.

3.1.2 Development of forest functions

3.1.2.1 Historical development of forest functions

The role of forests has changed radically over the past centuries. In Ireland, four phases can be distinguished – as partly illustrated in Figure 3.1-1.

(1) Forests with multiple-use functions in pre-industrial times

In the upper part of Figure 3.1-1 a great variety of overlapping objectives and uses are shown. Forests have been multifunctional for thousands of years. They have been used for the supply of timber and firewood, as pasture, for pannage and for the collection of various materials such as resin, litter, fruits and mushrooms.

Clearances for agriculture, however, reduced forest areas significantly and those that remained were located primarily on steep, stony and poor land, where agriculture was not possible. There were no clear boundaries between forests, agricultural fields and meadows. Even those forests that remained were relatively open and frequently trees were left standing on pasture land and within fields. This can still be seen today in many of the world's developing countries.

In pre-industrial times the forests consisted almost entirely of broadleaves, which provided high quality fuelwood and essentially served all of the populations' other needs. The ability of broadleaves to sprout shoots from stumps and thus establish new forests

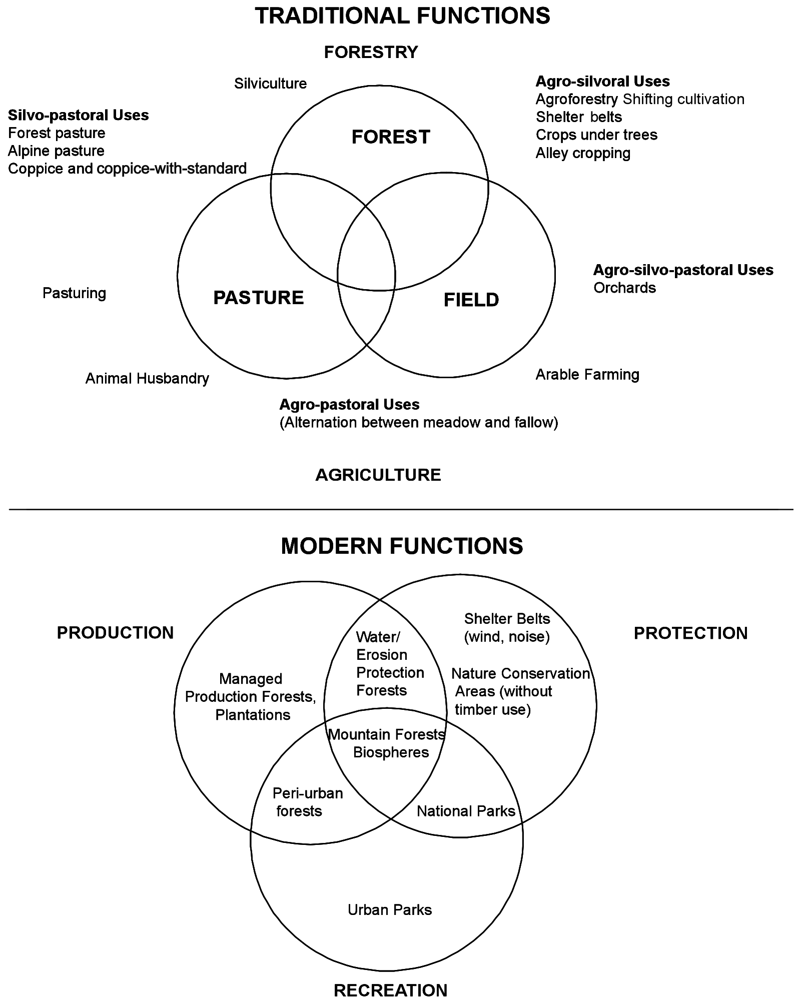


Figure 3.1-1: Development of the functions of forests depending on the economic conditions.

resulted in the conversion of many natural forests – where managed properly – to coppice forests. Most of the forests, however, deteriorated gradually and became degraded.

(2) Intermediate phase

As a result of the special history of Ireland, more or less all forests had been cut by the mid-17th century. At this time only about 1% forest cover remained. The population subsequently had to provide for its needs – especially the supply of fuel – from other sources such as peat. During the 18th and 19th centuries small woodlots, predominantly of broadleaves initially (refer to Chapter 1.3.3), were planted on many estates, mainly for the purposes of amenity and hunting.

(3) Monofunctional forests for timber supply

From the mid-19th century, following the industrial revolution, the needs of industry began to dictate forest use. This saw an increasing demand for conifer sawtimber. Encouraged by the growth of conifers introduced during the latter half of the 19th century, the planting of large areas, almost entirely of exotic conifers, began after World War I and continued for most of the 20th century (refer to Chapter 1.4). Predominantly of Sitka spruce, these forests still make up the core of Ireland's economically managed forests and thus the Irish forest sector.

(4) Multifunctional forests with overlapping uses and services
Forests started to become multifunctional once again towards the end of the 20th century, but from totally new aspects:

- Timber is still the main product. However, fuelwood has gained new importance against the background of rising energy costs, and continues to experience demand growth, despite the decline in oil prices experienced from mid-2014 to date. So far, these two functions remain the main possibilities for procuring an adequate income for the forest owners.
- Forests increasingly serve as refugia for endangered flora and fauna.
- Forests play an increasing role in protection against erosion, noise, pollution and are of major importance in the provision of a steady supply of clean water.
- Landscape protection concerns the preservation of a healthy environment, and is of growing importance from the perspective of both recreation and education.
- The focus on the role of forests as carbon sinks continues to grow.

This last phase in the historical development of the forests characterises the most recent developments and represents only a starting point, with each of these functions likely to continue to increase in importance. The planting of broadleaves, particularly on farmland, has added an enormous impetus to the multifunctional use of the forests. Of course, not all forests cover all of the functions listed – as is shown in the lower part of Figure 3.1-1. This is discussed in greater detail in following chapters.

A mix of forestry and pasture use (silvo-pasture) has been recently revived in several countries such as Ireland, New Zealand, and Chile. It is doubtful, however, if it will again achieve great importance (Plate 3.1-1).

3.1.2.2 Objectives of management, national economy and welfare

As previously mentioned, farmers, forestry enterprises and the State forest sector, Coillte, have mainly prioritised economic objectives and profit is the basis of their business. Large companies must satisfy their shareholders, whereas farmers and the owners of small forests seek to obtain an adequate livelihood from their forests. Timber and fuelwood are generally the only products that can be sold to generate a source of income. Therefore, timber production normally plays the major role in forestry.

Plate 3.1-1: A mix of forest and pasture (silvo-pasture) as practised in countries such as New Zealand and Chile.
(The Agri-Food and Biosciences Institute, Loughgall, Co Armagh)

In addition to providing the only source of income for forest owners, timber is an important raw material for the timber processing industry. The role of the latter in adding value to the raw material, which far exceeds the value of the raw material itself, cannot be understated. The timber processing industry has also become an important employer in recent times and there are clear indications that it will continue to grow and diversify in the future.

Society, having become ever more urbanised and detached from the rural environment, increasingly tends to regard forests as examples of the most natural form of ecosystems. As such, these require protection and there is often the view that any human interference should be prevented. At the same time, growing numbers of people wish to use forests for recreation and expect easy access and good infrastructure at no expense to themselves. Therefore, conflicts between the different aspects and objectives of forestry seem to be unavoidable.

3.1.2.3 Problems of long-term forestry forecasting

Forests develop slowly and this contrasts starkly with the ever accelerating speed of many of the processes occurring in today's society, industry and the markets. Predictions beyond ten years are generally viewed with increasing scepticism.

The production period for conifers usually extends to between 30 and 60 years while broadleaves may even require more than 100 years to reach their production targets. During these long periods objectives may change entirely.

For example, oaks initially grown to service the French Navy in the 18th century were ultimately used to provide timber for the lucrative veneer and wine cask trade in the 20th century. A related anecdotal example concerns oak grown for the Swedish Navy. In 1978, the head of the Swedish Forest Service wrote to his counterpart in the Swedish Navy advising him that 350 ha of oak, planted at the navy's request in 1829, were now ready for collection. The navy's reply was not recorded.

These are reasons why foresters and forest owners are largely left to their own devices by politicians, scientific experts and market specialists. As a consequence, they arrive at their own ideas and solutions concerning the possible role of forests and forestry in the future. In the process, however, they will find little room to avoid decision-making. When establishing a new plantation or even thinning an existing stand, they need to have at least some idea as to the possible utility of the final crop. Their management activities predetermine the products that will become available and also the services provided by the forests. This must be kept in mind when the probable role of forestry and the appropriate objectives with respect to future products and services are discussed. The chaotic economic and social development during recent years which was hardly foreseeable gives an illustrative example of how fast the entire background conditions may change and how difficult it is to make even short-term forecasts.

This problem is nicely reflected in an Arab proverb:

If you intend to amuse Allah, then tell him something about the future.

In the following subchapters the role of the different forestry functions will be reviewed.

3.2 Production of timber, fuelwood and non-wood products

3.2.1 General definition of timber assortments

Timber and fuelwood are usually the main products of economic value for the forest owner. Therefore, their production represents the primary factor influencing forestry activities. Generally, wood derived from broadleaves delivers a wider variety of products than conifers (Table 3.2-1).

Table 3.2-1 contains only the most important timber assortments and uses. Clearly broadleaf hardwoods are used for a much greater number of purposes, whereas conifers are mainly used as construction timber and for board manufacture.

Beech timber is particularly versatile. As veneer it can be peeled as well as sliced, giving different veneer faces. Although prone to decay, it can be rendered very resistant when treated with preservatives. When impregnated with various chemicals its properties are changed totally so that new products are created. Furthermore, beech can be steam-bent, which led to the development of compass-timber and a new style in furniture production at the end of the 19th century. Various compound boards and other materials have been produced and are currently in the test phase.

At this point it is not possible to delve too deeply into details, but it is sufficient merely to note that broadleaf hardwoods offer a wide range of uses and that further developments can be expected.

Whereas a strong market for conifer timber has developed in Ireland in recent decades, there is as yet little demand for home-grown hardwood timber, despite the fact that there are substantial imports from abroad. In the coming decades, however, as the broadleaf

Table 3.2-1: Comparison of **main assortments and uses of broadleaf and conifer timber species.**
(Terms printed in bold indicate greater importance, those in brackets minor use)

Main product type	Structural character	Main timber assortment	Special assortments: Broadleaves	Special assortments: Conifers
Industrial timber	natural	veneer	furniture, panels, plywood	(furniture, panels, plywood)
		sawtimber	**furniture, flooring,** (construction)	**construction** (beams, planks, roof lathes)
			finger jointed material (furniture, boards)	finger jointed material (laminated beams, boards)
			parquetry, inlaid floor	(parquetry, inlaid floor)
			pallets	pallets
			railway sleepers	(Douglas fir)
		pit props, fencing material	several species (oak, Spanish chestnut, robinia)	few species only (larch, Douglas fir)
	reconstituted	pulpwood	**soft and hardboards**	soft and hardboards
			card and paste board	**paper**
		chips	**particle boards**	**particle boards**
Fuelwood			pellets	(pellets)
	natural		split fuelwood (cleftwood)	(cleftwood)

hardwood stands established in the 1990s grow into timber of larger dimensions and as critical mass is achieved, new markets will develop.

3.2.2 Industrial timber

Industrial timber includes all timber in the form of sawtimber, poles, chips and pulp that is used for a wide variety of industrial purposes. Generally sawtimber is the main primary product. This latter aspect will be developed in greater detail in the following subchapters.

3.2.2.1 Economic superiority of sawtimber

Sawtimber usually commands better prices than other wood-based materials, such as industrial timber for chips (especially for particleboards) and pulp, as well as for fuelwood. Some prices are given in Table 3.2-2 to illustrate that higher prices can be achieved for sawtimber – although the prices for fuelwood have increased substantially in recent years.

Table 3.2-2: Roadside prices (€/m³) of roundwood timber for some selected species.
(Means of prices from 2003-2009; Forest Service Baden-Wuerttemberg. The diameter ranges of sawtimber correspond with the assortments actually preferred by the timber consumers)

Species	Sawtimber DBH cm	Sawtimber €/m³	Industrial timber €/m³	Fuel-wood €/m³	Relation Fuelwood: Sawtimber 2003/04 %	Relation Fuelwood: Sawtimber 2008/09 %
Norway spruce	20-35	62	28	15	*20*	*26*
Scots pine	40-50	63	22	21	*27*	*39*
Oak	50-60	156	27	31	*16*	*24*
Beech		78	29	32	*28*	*53*

The Forest Service of Baden-Wuerttemberg provided data based on large quantities of timber, covering the period 2003-2009.

These data show:

- There are distinct differences between the prices of sawtimber of the different species, oak being most highly valued.
- Industrial timber, which is mainly used for the production of particleboard, however, is generally cheaper, but shows only slight differences between species.

- Fuelwood prices are similar to those of industrial timber, but reflect the higher heating potential of the hardwoods.
- There have been some price fluctuations during the period 2003-2009 for sawtimber. The mean oak prices for instance varied between €142 and €173 per m^3, but there was no clear trend.
- Fuelwood prices on the other hand increased during these years depending on the fluctuations of oil and gas prices. Thus, prices rose sharply. At the beginning of this period (2003/04) the fuelwood price was 15-30% of the sawtimber prices while at the end (2008/09), it was 25-50%.

There are indications that the price of sawtimber will also increase. As energy prices will rise further energy calculations will become more important. For instance, the production of window frames is less energy-consuming if made from timber as compared with synthetic material or aluminium.

Conclusions

The production of broadleaf sawtimber is most profitable for growers. It does not make economic sense to have fuelwood production as the main objective. For this reason, the management of broadleaves should aim at producing the highest possible proportion of sawtimber.

Although fuelwood prices have risen in the past years, there are good reasons to assume that the sawtimber prices will maintain their superiority.

3.2.2.2 Importance of quality for broadleaf timber prices

The quality of broadleaf hardwoods, unlike that of conifers, is determined by a number of features listed in Table 3.2-3.

Table 3.2-3: Quality characteristics of broadleaf hardwoods.

No.	Characteristic	Detail
1	Dimension	≥40 cm middle diameter – the larger the better.
2	Freedom from branches	Essential.
3	Straightness	Very important.
4	Defects such as injuries, cracks, decay, wounds	Very often serious deterioration – especially decay – precludes any high quality use.
5	Even colour/discolouration	Partly dependent upon prevailing fashion.
6	Regular ring structure	Of some importance with ring-porous timber species, unimportant in the case of diffuse-porous.

High quality broadleaf hardwoods need to fulfil at least the first four features listed in Table 3.2-3:

- **Large stem dimension** is usually the most important consideration.
- **Freedom from branches (knots)** is another important factor. It is less important for the production of construction timber from conifers, provided the branches are not abnormally large. The prices for broadleaf hardwoods, however, are highly influenced by the size and number of branches (and associated knots), as hardwoods are often used for products like furniture where visual appearance plays a defining role.
- **Straightness** is also of relevance. Unlike most conifers, such as Sitka and Norway spruce whose stems tend to be naturally straight, most broadleaves tend to bend or to fork and form branchy crowns. A straight clear bole of 6-10 m in length, however, is

highly desirable and saleable.

- All the **other timber characteristics** in Table 3.2-3 should also be within an acceptable level in situations where broadleaf hardwoods are to be used for high quality products.

The standards for broadleaf softwoods such as poplar, aspen and willow are much less demanding.

The degree to which quality characteristics influence price will be illustrated in the following tables and graphs. To date, a market for broadleaf timber has not yet developed sufficiently in Ireland to provide realistic and reliable prices. Therefore, it was necessary to present data from other sources, mainly the continent, where there exists a long tradition of broadleaf timber markets and where relevant information is available. Data showing the general relationship between **quality grade and price** from the State forest of Baden-Wuerttemberg in Germany are given in Table 3.2-4.

Table 3.2-4: Prices of main broadleaf timber by quality grades in the State forest of Baden-Wuerttemberg, Germany (means of 1999-2006).

(Grade A represents timber of high quality, i.e. minimum diameter, free of branches, straight, no damage or discolourations; B is medium and C low quality. All prices are those at roadside, they include felling and extraction costs).

Species	Price according to quality grade (€/m³)				Total volume (m³/year)	Proportion of total (%)	
	A	B	C	Mean		Volume	Value
Beech	286	117	44	**82**	107,150	*78*	*68*
Oak	412	236	69	**142**	25,250	*18*	*28*
Ash	180	86	48	**62**	3,840	*3*	*2*
Sycamore and Norway maple	599	252	95	**194**	1,550	*1*	*2*
Wild cherry	501	289	121	**213**	175	*<1*	*<1*

The main findings are as follows:

- The data rely on a solid base of timber volume and prices.
- There was a distinct difference between the prices for timber of the five tree species and also between those of the three quality grades. This quality grade difference was greatest with beech (A:C = 6.5:1) and smallest with ash (A:C = 3.8:1). In all cases high quality timber achieved a much higher price than that of low quality.
- As in many areas of central Europe such as Baden-Wuerttemberg, beech is, with regard to volume production, by far the most important broadleaf species (almost 80%). The average price, however, was low. Therefore, its proportion of the value fell to only 68%.
- Oak on the other hand produced only 18% of the volume, but almost 30% of the value.
- The average price of cherry timber was highest, but only small volumes were available. Sycamore and oak also achieved reasonable prices, but the price of ash was the poorest.

The relationship between quality and price is even more complicated, as the **price differences within the quality grades** may also vary remarkably. This cannot, however, be illustrated by the mean sawtimber prices per quality grade compiled by the Baden-Wuerttemberg State Forest Service. Fortunately, data on the prices of oak and beech timber, which are differentiated according to quality and diameter classes, have been collected by the Bavarian State Forest Service for the period 1994-2004.

The main results are given in Table 3.2-5 and have provided the background to the data presented in Figure 3.2-1 below.

The most important findings are as follows:

Table 3.2-5: Volume and value production of oak and beech timber in the State Forests of Bavaria 1994-2004.

Species	Item	Quality high (%)	Quality good (%)	Quality low (%)	Quality poor (%)	Total Mill. m³	Total Mill. €
Oak	Volume	*7*	*35*	*54*	*4*	0.301	
	Value	*30*	*44*	*25*	*1*		36
Beech	Volume	*4*	*34*	*52*	*10*	1.9	
	Value	*16*	*47*	*33*	*4*		137

- During the 11-year period just over 300,000 m³ of **oak** timber was marketed and yielded a total of €36 million, i.e. about €120 per m³.
- The volume of **beech** timber marketed amounted to 1.9 million m³ and returned a financial yield of €137 million or about €70 per m³.
- These data are based on very substantial records of timber sales.
- Both timber species have been divided into several quality grades which are presented under four classes:
  - High = veneer and high quality sawtimber,
  - good = quality timber with minor defects such as small branches and knots,
  - low = slightly crooked stems with knots or discolouration (for example red heart),
  - poor = timber with major defects, but which can still be used as sawtimber.
- The proportion of high quality **oak** timber was only 7%, but yielded 30% of the revenue: 42% of high and good quality timber gave a return of 74%. The remaining 58% was of low and poor quality and yielded only 26% of the revenue.
- The outcome for **beech** timber was roughly the same: High quality timber was only 4%, but yielded 16% financially. High and good quality timber had a volume proportion of slightly more than 38%, but almost 63% of the value. The proportions of low and poor quality timber were almost the opposite; about 62% of the volume, but only slightly over 37% of the value.

Furthermore, the stems to be produced should not only be of high quality (i.e. straight, branchless, without any defects), they should also be of as large a dimension as possible. This is illustrated in Figure 3.2-1.

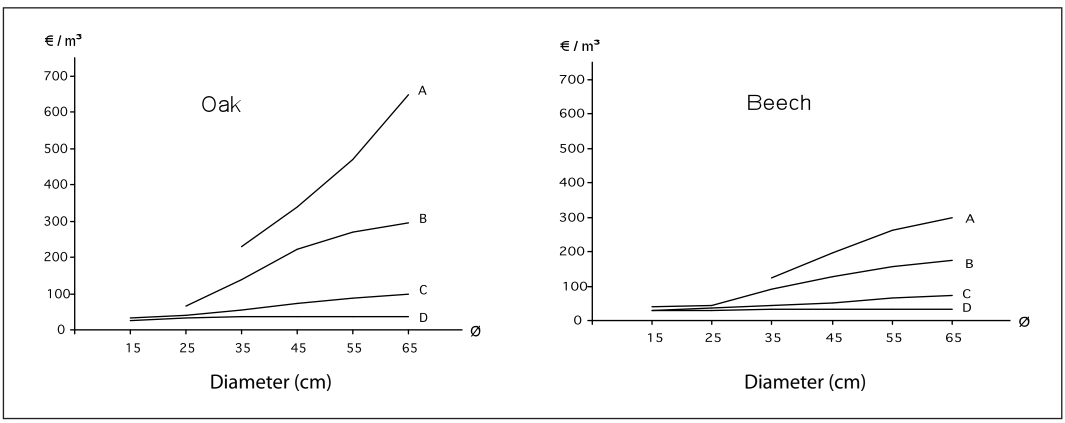


Figure 3.2-1: Price:diameter curves of oak and beech timber according to quality grade and diameter. (Bavarian Forest Service, 1994-2004).

The curves illustrate the following relationships:

- The price per m^3 of high quality stems increased substantially with diameter. This is especially the case with high quality **oak** where the increase in value was exponential. The price rose from € 230 per m^3 for a stem of 30-39 cm diameter to € 650 per m^3 for a tree of over 60 cm. The rise in price was even greater with true veneer stems (€ 400 per m^3 for a 40-49 cm diameter stem and € 1,100 per m^3 for a stem over 60 cm). Only 1% of the total oak volume, however, was in the true veneer oak category.

  The poorer the quality, the lower the rise in price with increasing diameter. Poor quality oak timber did not achieve any increase in price with increasing diameter. This shows that it does not make economic sense to produce large logs of low or even poor quality (grade C or D) as they will not achieve good prices. In recent times timber categorised as quality grade D has increasingly been converted to fuelwood – a consequence of the demand and the good prices paid for fuelwood.

- The conditions with **beech** timber were similar in principle – but to a much lesser degree. High quality timber had the greatest rise in price with growing diameter, and poor quality timber remained the same at a very low level.

- As a matter of record, the minimum diameter of high quality timber was 30 cm. Veneer timber began even with diameters of over 40 cm, while low and poor quality timber started with diameters of less than 15 cm.

These data underline the principle that quality timber production should be the major objective in managing broadleaves, when timber production is the goal.

3.2.2.3 Prospects for a developing broadleaf timber market

The following arguments can be made for an increase in the market importance of temperate broadleaf hardwood timber in the future:

- Markets tend to diversify, particularly in times when people have more money and the demand for better and more original style products increases. Therefore, high quality and fashionable furniture, in addition to standard products, will increasingly be sought after.

- In the long-term, energy input calculations will influence the price of all products to a much greater extent than is currently the case. Production incorporating aluminium, steel, synthetics and plastics expend much more energy, and ultimately cost more than timber. Energy balances have only recently come into consideration with increases in oil and gas prices.

- There is clear evidence that the import of high quality timber from the tropics and subtropics has begun to decline because of a reduction in the available resources and greater competition from other consumer countries. Further decline can be expected due to harvesting regulations and certification.

- Discussions within the EU have begun on how further deforestation and loss of biodiversity can be prevented. This could be achieved by promoting an ecologically based forest usage or by a ban on imports and trade in illegally harvested tropical timber. For this reason, it can be expected that tropical timber will become less available. Only a limited number of deciduous tree plantations exists whose products may become relevant. Teak is one. Therefore, it seems logical to assume that temperate broadleaf hardwoods will play an increasing role in the future. For Europe, there is an increasing need to rely on our own resources of native tree species in order to supply the market with a variety of timber products.

Selling high quality timber to maximise prices requires special preparations, for instance the stems may need to be transported to a central location, and sales catalogues need to be prepared, so that the potential consumers have the opportunity to view the range of timber on offer and prepare their bids (Plate 3.2-1).

Plate 3.2-1: High quality oak timber prepared and presented for auction.
(Forest Service of Lower Saxony, 2009)

3.2.2.4 Considerations of oversupply of high quality Irish grown hardwood timber

It is sometimes argued that future markets could be oversupplied with quality timber. Thus the prices may subsequently decline, provided all broadleaf forests were consistently managed for high quality timber production. This may be true for special timber assortments such as hurleys. The argument of flooding the market with high quality timber, however, can easily be refuted. Assuming that all existing Irish broadleaf forests are managed to produce quality timber – which of course is unlikely to happen – the following calculations may illustrate the possible maximum of quality timber production:

- Currently about 10% (66,000 ha) of the stocked forest area consists of long-living broadleaves, which are capable of producing quality timber (refer to Table 1.5-5).
- It may be assumed that the average increment of these quality producing stands is about 7 m³/ha/yr.
- Depending upon site conditions and other considerations only about 50% of all stands will finally reach this goal of quality timber production.
- Roughly 50% of the broadleaf timber production within the life cycle of a stand is harvested as thinnings, which deliver only small dimensioned low priced sawtimber and fuelwood.
- Only the bottom log with an average length of 5-8 m of the final harvest timber or 40% of the stem volume consists of quality timber. The upper stem parts and the crowns are low value material.

The amount of quality timber produced yearly in the whole country will then be about **46,000 m³** (66,000 x 7 x 0.5 x 0.5 x 0.4). Thus, the maximum amount of high quality timber that can be produced is around 10% (46,000:66,000 x 7) of the total volume production. According to Bavarian figures (refer to Table 3.2-5) less than 5% of the total production was of high quality, despite the fact that the stands there have been consistently thinned over long periods of time.

There is, moreover, little doubt that an over-production of high quality timber will be easily absorbed by a then more specialised and developed timber industry. Alternatively it can be exported to neighbouring countries.

Conclusions

The main points are:

- The objective should be always to grow as high a proportion of quality timber as possible.
- In general, an objective to produce fuelwood alone is not attractive economically. Fuelwood will always be a by-product and this may meet the demands of the rural regions in most cases.

continued

Conclusions continued

- High quality timber should be grown to diameters as large as possible. Prices obtained at veneer auctions in Bavaria were highest with some – admittedly rare – oak stems with diameters of over 80 cm.
- Large dimensioned stems are generally old, and old trees tend to deteriorate because of stem rot or injuries. Thus, diameter increases usually find their – naturally based – economic limits.
- Broadleaf hardwood timber of large dimensions should generally be of high or at least of medium quality. It does not make economic sense to produce large stems of low quality. These trees should be removed through thinning.
- Oak prices represent the upper price level, while those for beech the lower end. Ash and sycamore timber tend to follow the beech price structure, cherry and walnut the oak one. Although no similar detailed statistics exist for other broadleaf species, there is sufficient evidence that the same principles are also valid.
- Diameters quoted are always the mid diameters of the stem under bark. Therefore, depending on the length of the trunk and the thickness of the bark, some centimetres have to be added to obtain the diameter at breast height.
- The production of high quality broadleaf hardwood timber clearly has a promising future.

The main objective of growing broadleaves for timber is to generate a large proportion of high quality timber in order to create a viable timber processing industry. It is the main principle behind all the silvicultural procedures described in this book. Unfortunately, little evidence is currently available in Ireland on prices for hardwood timber of different quality grades to prove this assertion.

3.2.3 Fuelwood and biomass production

3.2.3.1 Fuelwood from the forests

The **production of fuelwood** was an important issue for centuries, for millennia even, as the main source of energy for heating (refer to Chapter 3.1.2.1). As long as there was sufficient wood in the forests, fuelwood was collected. It has been estimated that around 200 years ago, approximately 80% of the total wood production was used for energy purposes in European countries. This is still the situation in many African and Asian regions today.

As the forest resources gradually declined and wood shortages became a serious problem regionally, coppice forests were established and managed in a more or less planned manner. This was possible as most of the broadleaves – unlike almost all conifers – sprout easily from the stump. In past centuries, especially in France and Italy, many industries relied on the energy supply from coppice and coppice-with-standards forests. Roughly half of the forest area in France still consists of coppice forests which are now mostly unmanaged, while others are being transformed to high forest. Many of the once widespread coppice forests, however, were converted to high forest.

In the second half of the 19th century fuelwood and peat were gradually replaced first by coal and subsequently by oil and gas (Plates 3.2-2 to 3.2-4). Demand for fuelwood then declined as a forest product and its use was greatly reduced. However, it always has been and continues to be an unavoidable by-product of forest production. Part of the wood obtained from thinning is only suitable for use as fuelwood because of its small dimensions or low quality. Parts of the crowns of crop trees also fall into this category (Table 3.2-6).


Plates 3.2-2 and 3.2-3: Fuelwood is still the main source of energy in many developing countries and has gained increasing importance again in the industrialised countries.
(left: Freiburg, Germany; right: Montenegro).

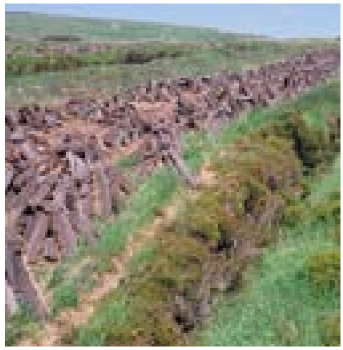


Plate 3.2-4: Peat is still used as an energy source on a small scale.
(Clifden, Connemara)

Table 3.2-6: Proportions of fuelwood obtained from a principal conifer and broadleaf species relative to the total stand production (including final crop and thinnings) and an average crop tree.

Species	% of fuelwood of	
	total stand production	final crop tree volume
Sitka spruce	*20*	*10*
Beech	*50*	*40*

These are rough calculations, but they show that hardwoods always produce relatively high proportions of fuelwood and material of a generally low quality. This is unavoidable.

On the Continent, the fuelwood market collapsed in the 1960s because of cheap oil and gas which is much easier to handle. At the same time a rising demand for raw material in the particleboard and paper industries compensated for the fall in demand. Now, after only a few decades of abundant cheap energy, rising oil and gas prices have brought about an unexpectedly early revival of fuelwood as a heating material, and it has gained a new reputation as a renewable energy source. Despite the steep drop in oil prices from mid-2014 the fuelwood market remains robust.

Fuelwood was almost entirely substituted in the urban areas, but to a far lesser extent in the countryside. Today it has recovered some of its earlier importance in rural areas, but less so in the cities although the use of densified wood fuels, such as briquettes and pellets, are making inroads in urban markets. Wood combustion for heating and other energy use can cause pollution, but more efficient systems and plants, and the application of air quality standards, have largely addressed this issue. There is currently much research underway into the use of fuelwood as a source of renewable energy.

In the long-term, the importance of fuelwood in small towns and villages is likely to increase given government targets and related policies.

Small dimensioned timber as well as chips, sawdust, bark and residues from sawmills are increasingly used in the production of pellets and briquettes. The opening up of the markets is providing an outlet for broadleaf thinnings that was previously almost non-existent. So, the new role of wood materials as an energy resource has created a new market outlet for wood resources, which should have a positive impact on stumpage prices in the long-term. While the energy outlet for wood will result in increased levels of competition for fibre, it will also drive efficiency, ensure better resource utilisation and recovery in the more traditional sectors.

In the 1940s wood chips were converted into biofuels in order to power trucks, but because of poor traction this was soon discontinued and finally stopped when gasoline and diesel became widely available. Most recent experiments with the gasification of wood, straw or other bio-waste led to the production of high quality gasoil. A small-scale industry has started to produce second generation cellulosic biofuels, which offer the prospect of being more economic and with higher greenhouse gas savings than those made from maize, oil seed rape or sugar beet (Wüst, 2008).

3.2.3.2 Ireland's energy supply and the growing role of renewable energy from biomass

Ireland´s forests were largely destroyed during past centuries mainly because of the land needs of the population – as described by OCarroll (2004). There are, however, some remnants as in Wicklow (Carey, 2009) which show that coppicing was practised at least to some extent (Plate 3.2-5).

Traditional coppicing has not been revived as a silvicultural system, however, coppice forests are regarded as special habitats which may be re-established because of their ecological values. Grant aid for coppice management restoration as an element of native woodland conservation is available under the Native Woodland Scheme.

Energy production from biomass is growing in importance in Ireland. Small-dimension wood from thinnings, and lower quality wood from harvesting, as well as sawmill residues, is being converted into firewood, chips and pellets. The use of wood for energy production was studied in a COFORD funded project. Its main findings are summarised in Table 3.2-7.

Plate 3.2-5: Native oak forest originating from coppice. (Glendalough, Co Wicklow)

Table 3.2-7: Estimate of **wood fibre potentially available for energy** in the Republic of Ireland, years 2012, 2020 and 2028. (Phillips, 2011)

Biomass source		Unit	Year 2012	2020	2028
Direct available from the forest	Tip-7 cm	1,000 m³	45	58	61
	Roundwood 7-13 cm		202	382	382
Indirect production (downgrade + wood residues)	Sawdust, residues, bark		626	915	1,191
Post-consumer recycled wood	Pallets, packaging materials, recovered wood		87	99	116
	Total		**959**	**1,453**	**1,750**
Energy content		millions GJ	6.61	10.02	12.07

The above table illustrates:

- The amount of available wood fibre will almost double over the next 16 years – provided the current price conditions prevail.
- The most important proportion of this wood fibre is coming from downgrade and wood residues with roughly two-thirds. This situation is likely to remain over the next two decades. Wood fibre coming directly from the forest constitutes slightly less than one-third. Post-consumer recycled wood constitutes less than 10% and is expected to remain at this level.
- The energy content, based on wood fibre production will also double within the period and is highly correlated with fibre volume production.
- One shortfall of the data is that broadleaf and conifer wood production is not differentiated.

However, from other data in the same study it can be deduced that the broadleaf volume production in 2012 will increase from 37,000 m³ (= 1%) to 1,200,000 m³ (= 16%). This increase in broadleaf wood production is due to the expansion of the grant aided private forest estate which is generally young and will require thinning over the next number of years.

3.2.3.3 Energy plantations

People with vision realised as early as the 1950s that cheap energy based on fossil fuel might come to an end within a matter of decades. The oil crisis of 1973 came as a first warning sign, but was rapidly forgotten in many countries when the prices of fossil fuels became cheap again. However, since mid-2014, oil prices have fallen by 70% mainly because of oversupply and the arrival of US shale oil. Currently prices are at an 11-year low but most analysts are expecting the price to stabilise in the second half of 2016 as supply and demand come into closer alignment.

Sweden and some other countries were an exception, and embarked on a long-term renewable energy strategy in the intervening decades. Implementation of the strategy continues to the present day. Sweden for example, has recently announced that the energy contribution from wood has – for the first time in recent history – exceeded that from oil. In 2006 it published plans to be an oil-free economy within 15 years.

Some experiments involving fast-growing broadleaves such as poplar, aspen and willow were initiated in Sweden in the late 1950s, to investigate the potential of **short rotation plantations** as a source of renewable energy. On the Continent and in Ireland similar trials began after the 1970s oil crisis (Plates 3.2-6 and 3.2-7).

Plate 3.2-6: Poplar energy plantation established in the late 1990s. (Central Germany, 2010)

Plate 3.2-7: Recently established willow energy plantation. (Boora Bog, Co Offaly)

These investigations are focused on biomass production, technical aspects of harvesting, transport and drying, as well as economic calculations of the energy output, costs and revenues. The continuing availability of relatively cheap fossil fuels has meant that these processes have as yet not achieved any large scale economic importance. Only recently has the search for alternative energy become a much more serious international issue, stimulated in part by polices to reduce emissions of carbon dioxide from the combustion of fossil fuels. . However, the energy balance between input (production in the field, transport and drying) and output (burning or combustion) is still disappointing. Since these experiments are still in the initial phase it is too early to draw final conclusions. Nevertheless, it is doubtful that short rotation plantations will gain any noticeable importance in the future. One additional aspect is that short rotation plantations need relatively good sites and, therefore, compete directly with agriculture which also has increased crop production in the last years.

Further information is available from TEAGASC (2015).

Conclusions

Ireland, as an island nation that imports more than 90% of its energy requirements, is in a difficult, if not critical position regarding over dependence on fossil fuels and security of supply. Moreover, the demand is likely to increase by approximately 5% over the long term (TEAGASC, 2007), but it is an open question as to whether it will continue in this way.

Like in all European countries an urgent search for alternative sources of energy is underway. The potential of wind, solar, hydro and thermal energy as well as biomass is being studied. Wood is considered by many as the main potential biomass energy contribution. There is evidence that this issue will cause major changes in wood production in the future; however, it is very much dependent on the speed and rate of oil and gas price increases as well as subsidies such as tax incentives.

The increased use of small-dimensioned wood material from thinnings has already improved the opportunity for early silvicultural treatments and promises to continue.

More information is provided in Chapter 3.6.

3.2.4 Forests for non-wood forest products

Non-wood forest products (NWFPs), sometimes called non-timber forest products (NTFPs), played an important role in the lives of rural people for thousands of years. They are still of vital interest for forest dwellers and some rural communities in developing countries. In highly industrialised countries, however, their importance has declined significantly during the past hundred years.

Non-wood forest products and services, including functions of the forests, are often confused in the literature. Recreation and protective functions are also sometimes subsumed into non-wood forest products. In this book, however, these different issues are treated separately in Chapters 3.3 (ecological values) and 3.4 (social values).

Since 1990 there have been several attempts to revive the production and use of non-wood forest products, even in industrialised countries. The reason for this is to create employment and income for the rural population and the owners of small forest properties.

Although not exhaustive, some non-wood forest products are listed in Table 3.2-8 in order to show their great variety.

Today, only a few items on this list are still of importance. Following the order of the list the options to make use of the non-wood forest products will be discussed. The arguments have been partly adapted from Collier et al., (2004):

- The use of **litter** for seedbeds and flowerbeds in horticulture is negligible as bark from sawmills is mainly used today.
- Ground vegetation plays a minor role in supplying the pharmaceutical industry, but its needs for plants are generally fulfilled by cultivation. **Medicinal plants** such as herbs and flowers (tea) are of minor importance today and only for private consumption. Only hawthorn seems to have some potential.
- **Mushroom** production at a local level is regarded as promising (Plate 3.2-8). Edible wild mushrooms grow under coni-

Plate 3.2-8: Forest fungi: First thinnings of ash which have been inoculated with mushroom spores. (Kilcornan, Co Limerick)

Table 3.2-8: A selection of **historically used and actual non-wood forest products**.

<table>
<tr><th>Item</th><th>Material</th><th colspan="2">Use</th><th colspan="2">Product</th></tr>
<tr><td rowspan="2">Soil</td><td rowspan="2">Litter</td><td colspan="2">Manuring of agricultural fields</td><td colspan="2">Mixture of litter and manure</td></tr>
<tr><td colspan="2">Soil improvement in orchards and nurseries</td><td colspan="2">Seedbed material</td></tr>
<tr><td rowspan="5">Ground vegetation</td><td>Lichens, mosses, grasses</td><td rowspan="2">Horticulture</td><td rowspan="3">Pasturing of domestic animals</td><td rowspan="2">Decorative material</td><td rowspan="3">Food for animals</td></tr>
<tr><td>Flowers, branches</td></tr>
<tr><td>Herbs</td><td>Food</td><td>Salads</td></tr>
<tr><td>Edible wild mushrooms</td><td colspan="2">Food</td><td colspan="2"></td></tr>
<tr><td>Medicinal plants</td><td colspan="2">Healing properties, raw material for plant ingredients (production and research)</td><td colspan="2">Powder, pill, extract, tonic, tea, confectionery</td></tr>
<tr><td rowspan="5">Shrubs</td><td>Flowers, foliage</td><td colspan="4">(See under ground vegetation above)</td></tr>
<tr><td>Berries, rose hips</td><td colspan="2">Food</td><td colspan="2">Jam; brandy</td></tr>
<tr><td>Thorny branches, sticks</td><td colspan="2">Fencing</td><td colspan="2">Wattle fence, pleached hedge</td></tr>
<tr><td>Medicinal plants</td><td colspan="2">(See under ground vegetation above)</td><td colspan="2"></td></tr>
<tr><td>Bamboo</td><td colspan="2">Small housing material</td><td colspan="2"></td></tr>
<tr><td rowspan="10">Trees</td><td>Foliage, Flowers</td><td colspan="2">(See under ground vegetation above)</td><td colspan="2"></td></tr>
<tr><td>Fruits</td><td colspan="2">Drinks,</td><td colspan="2">Brandy</td></tr>
<tr><td>Acorns</td><td colspan="2">Domestic animal and game feeding</td><td colspan="2">Meat</td></tr>
<tr><td>Nuts</td><td colspan="2">Food</td><td colspan="2">Hazelnut, walnut and nut of Spanish chestnut</td></tr>
<tr><td>Sap</td><td colspan="2">Drinks, sap concentrates</td><td colspan="2">Birch sap, maple syrup; cosmetics</td></tr>
<tr><td>Cork</td><td colspan="2">Distilleries, indoor housing</td><td colspan="2">Bottle corks, cork floor</td></tr>
<tr><td>Resin</td><td colspan="2">Sealing of ship seams; production of paints</td><td colspan="2">Paste; paint</td></tr>
<tr><td>Branches</td><td colspan="2">Brushwood revetment (willows), fencing; basket making</td><td colspan="2">Wickerwork, basket</td></tr>
<tr><td>Bark</td><td colspan="2">Tanning (oak)</td><td colspan="2">Fine leather; roof cover</td></tr>
<tr><td>Medicinal plants</td><td colspan="2">(See under ground vegetation above)</td><td colspan="2"></td></tr>
<tr><td rowspan="3">Animals</td><td>Honey, wax</td><td colspan="2">Food, lighting</td><td colspan="2">Honey, candle</td></tr>
<tr><td rowspan="2">Game (meat, skin, feather)</td><td colspan="2">Food, clothing</td><td colspan="2">Meat, leather</td></tr>
<tr><td colspan="2">Hunting</td><td colspan="2">Pleasure</td></tr>
</table>

fers, however, several broadleaf species such as beech and oak produce a large variety of sought after fungi. In Ireland the approach to eating wild mushrooms has been very reserved and conservative (Dowding and Smith, 2008). While mushroom picking has become an international pastime, it offers limited opportunities for the land owner for profit. High labour cost is one of the main obstacles.

- The same situation applies to most types of **fruits, berries and nuts**. Most are also cultivated in orchards (hazelnuts, walnuts, Spanish chestnuts, cherries, blackcurrants, raspberries) and in countries with a much more favourable climate. Blueberries are sometimes collected by local people, but because of Ireland's erratic climate the potential for profitable production is limited.
- The production of plants for **ornamental purposes** – mainly Christmas trees and decorative foliage – has developed internationally. It is mostly restricted to conifers. Of the broadleaves, holly, ivy with berries, willows with catkins, bog myrtle, corkscrew hazel and mistletoe have some potential. Much of this is produced in orchards or dedicated plantations and needs special husbandry. Thus, there is little opportunity, especially for farmers growing broadleaves, to make profit in this field.
- All other parts and products of plants like **resin, cork and bark** are used in special circumstances. However, they generally do not offer any opportunities to produce income for forest owners in NW Europe as the climate and soil conditions are not sufficiently favourable to grow the respective species on an adequate scale.
- Because of the predominance of conifers there is little opportunity to develop honey production at a commercial scale. This may gradually change in the long-term if the proportion of broadleaves increases.

Conclusions

The overall results, therefore, are not encouraging:

- Apart from a few exceptions, non-wood forest products generally contribute little to the income of forest owners.
- At present decorative materials are the most profitable product, but conifers as ornamentals are much more valued and in greater demand than broadleaves.
- Forest mushrooms may have some potential at a local level for forest owners in the future.
- There are two further obstacles for non-wood forest production: the problematic climate conditions and high labour costs both restrict competitiveness in this sector.

3.3 Ecological values of broadleaf species

Environmental protection is an increasingly important element of modern agricultural policy, which must now take on board a range of international commitments, EU Directives and national legislation concerning the environment.
Department of Agriculture and Food (2007)

3.3.1 Type and definition of functions and services

Environment is a far-reaching and comprehensive term and includes a variety of protective functions. Some are more ecologically orientated and others serve mainly social aspects. Broadleaves are generally regarded as being more valuable from the ecological perspective. This assertion, however, needs more detailed analysis if it is not to remain a mere statement without any quantitative background.

In this subchapter the ecological issues will remain in the foreground and the most important question to be considered will be the special contribution that broadleaf forests can make in this regard. The social functions and services – especially recreation – will be dealt with in Chapter 3.4. It has to be emphasized, however, that in several aspects both functions cannot always be separated clearly from each other.

A good example is national parks, as these serve the purpose of protecting and conserving special nature types as well as giving the people an opportunity to experience exceptional landscapes, different vegetation types and wildlife.

The protective functions of forests comprise two main components:
(1) landscape protection, which has a more abiotic focus and
(2) nature protection, which is more biotic.

They are inter-dependent.

(1) **Landscape protection** usually includes:
- Erosion control,
- water protection,
- protection of special geological features,
- protection of peatland,
- protection against pollution.

(2) **Nature conservation** comprises:
- Protection of wildlife in very many forms (nature reserves, national parks),
- protection of habitats, biotopes (SACs, SPAs, NHAs),
- protection of biodiversity,
- protection of genetic resources.

The protective role of forests, such as water protection should not be confused with the protection of forests against disturbance or destruction by man, or forest protection against stress and damage such as storm, deer or insects. These latter aspects will be dealt with in Chapter 4.4.7.

3.3.2 Actual role of protective functions

Where timber production is the primary objective, as in most forests in Ireland, the non-timber functions are usually regarded as constraints. This is the position adopted in the survey by the NFI (Table 3.3-1). Viewed from an ecological perspective, however, these constraints can be regarded as positive functions and services, and may even be more important to society than timber output in some instances. In the following paragraphs this hypothesis will be explored and evaluated.

Table 3.3-1: Constraints having a bearing on **forest management** (%).
(Adapted from NFI, 2007)
As some areas have more than one function the sum of the areas on which these percentages are based (782,000 ha) is 25% greater than the actual forest area (626,000 ha).

Constraints		Ownership: public	private: grant aided	private: other	Mean
None		39	54	29	**41**
Fisheries sensitive		34	27	13	**29**
Nature conservation		9	5	28	**10**
Soil constraints	Acid sensitive	12	9	6	**10**
	Boulder	1	2	2	**2**
	Limest. pavement	<1	0	3	**1**
Mainly social		4	2	12	**5**
Other		1	1	7	**2**
	Total	100	100	100	**100**

3.3.2.1 Main functions

The constraints on forest management, as detailed in the NFI (Table 3.3-1), will be evaluated below from the point of view of their contribution to society.

The main functions may be summarised under the following headings:

(1) General role of functions

- Just over 40% of all forests have no constraints. This means that they are mainly directed towards **economic forestry.**
- By far the most important with regard to constraints are **fishery sensitive forests**, almost one-third of all forests. These are mainly forests alongside lakes, streams and other riparian zones.
- All **nature conservation** issues together comprise approximately one-tenth of the forest area which is not very high compared with other countries. They will be divided into special fields of activity and discussed separately (see Table 3.3-2).
- **Soil constraints** with almost the same area (12%) are neither functions nor services, but may in fact restrict forestry activities. Acid sensitive soils are by far the most important group.
- **Social functions** appear unimportant. These will be dealt with in Chapter 3.4.
- **Other constraints** – utility lines and others are of less importance.

(2) Functions related to ownership

- More than half of grant aided private forests are not serving any function apart from production, whereas the other private forests are free of constraints to a much greater degree. Public forests lie somewhere in between.
- The important role of the other private forests is striking when the sums of the percentage figures for nature conservation, social issues and other constraints in the separate ownership categories are compared:

47% for other private enterprises,
8% for grant aided private forests, and
14% for public forests.

As shown in Table 1.5-2 and 1.5-4, the other private forests, although covering only 13% of all forests, contain 55% of the broadleaf forests within the country. Furthermore, these forests are older than the average and are more intensively mixed.

It can, therefore, be concluded that the other private forests contribute most to ecological, social and public requirements.

3.3.2.2 Landscape protective functions

None of the protective functions like **erosion and water control** has been mentioned in the NFI records. These play a major role in other countries and have led to significant constraints such as clear-cut bans in mountainous areas.

In Ireland serious flooding has occurred in some river catchment areas resulting in isolated landslides and flooding of houses. In these instances the level of rainfall was several times above normal and beyond the capability of drainage and river systems. The damage caused by the August 2008 floods was estimated at approximately €100 million, while the more recent 2014 and 2015/2016 events are expected to substantially exceed that figure.

Only these catastrophic events generally receive media attention. Erosion of fine soil – which gradually, but steadily deteriorates soil fertility and results in siltation of streams and rivers – goes largely unnoticed.

Rainfall can be apportioned into runoff, percolation and evapotranspiration.

Forests are capable of moderating the effects of heavy rainfall. Almost the full amount of rainfall will runoff from clean, smooth and impenetrable surfaces like asphalted roads and concrete surfaces. Under forests a substantial part of the precipitation can **percolate** into the soil and supply the ground water.

The intensity of **percolation** is dependent on a number of conditions:

- The main factor is permeability which can vary greatly.
- Sandy soils are very permeable; clays and gleys are not.
- The steepness of the terrain can also play an important role.
- Tree roots improve soil permeability.
- As some broadleaf species (e.g. oak) root much deeper than spruces they are preferable in regard to these benefits.
- Percolation and water retention is also higher if the soil is covered with humus and light ground vegetation. This is normally more often the case under broadleaves than under conifers (refer to Table 3.3-7).
- Percolation, moreover, leads to better water filtration.

Evapotranspiration is the sum of water evaporating from all surfaces and active transpiration from plants. The **evaporation** rate is normally greater from conifers especially in winter as most broadleaves have by then shed their leaves. The differences in **transpiration** rates, however, depends much less on the two species groups than on their specific characteristics and their rate of growth on various soil types.

In general broadleaves are more effective in this regard than conifers. However, the presence of forests is the most important factor of all.

Forests are capable of effectively reducing water runoff. They act as a buffer to balance the effect of heavy rainfall, moderating runoff and prolonging the supply to reservoirs. Moreover, by slowing down runoff, they indirectly diminish the erosive force of water. Although forests consume a proportion of rainwater through evapotranspiration, the decisive positive effect is the smoothing of water flow thereby reducing flash floods and water shortages.

Mankind has experienced over long periods that the destruction of forests can destroy the habitat and finally living conditions by deterioration of the agricultural fields, by causing severe floods and filling waterways and harbours with silt, sand and gravel.

Several cities in the Near East, such as Babylonia, Ur, and in the Mediterranean, such as Dion, Side and Aspendos, are good examples of this.

Erosion cannot be totally prevented. In mountainous regions the so-called relief energy is forming the landscape. This is a continuous process and depends on the relief of the landscape. Clearly no forestry measure can reduce runoff above the treeline. On steep hills the runoff of rainfall is leading to ongoing erosion. In flat areas erosion is caused by wind.

Nevertheless, flooding and erosion are largely man-made and can be substantially reduced by appropriate forestry measures. For this reason afforestation should be increasingly seen from the point of view of reducing erosion and improving water production and quality. A closed forest managed under an economic regime is not always the appropriate goal. Bush vegetation, which includes birch, rowan and willow, is often a cheap and effective alternative which may help to reach the desired outcome.

In some cases even a reduction in overgrazing would improve the situation, giving the vegetation a chance to recover, and form vegetation types with bushes and a variety of herbs and grasses that ensure higher rates of percolation and evapotranspiration than bare ground (Plate 3.3-1).

Plate 3.3-1: Heavily overgrazed hillside with traces of soil erosion (background) in contrast with developed vegetation (bracken and bushes) within a fenced area (foreground). (Connemara, Co Galway)

The Forest Service has published the *Forestry and Water Quality Guidelines* (2000a) which contain further comments and recommendations. Some guidelines relating to this issue are:

- It may be noted that subsoils are more prone to erosion than topsoils especially on peat and sandstone-derived soils on steep slopes.
- Buffer zones, 10-25 m in width, according to slope and erodibility of soil, should be provided and the vegetation structure improved in order to slow run-off velocity and increase infiltration, thus improving the water quality.
- Ground preparation causing soil disturbance has to be restricted in buffer zones.
- Sediment traps may be installed where erosion has become serious.

It may be added that the avoidance of larger clear-cuts and the use of group and shelterwood silvicultural systems on vulnerable sites will reduce erosion dramatically. On the Continent this is one of the main approaches to erosion and water control.

Ireland, although subjected to a plentiful supply of rain in most parts of the country, is already threatened with periodic water shortages in some areas. Not without good reason has the 21st century been declared the water century.

3.3.2.3 Nature protective functions

Native woodland once covered most of Ireland, but few remain. Recent years brought a growing recognition of the ecological and cultural value of these surviving fragments. Apart from minor proportions of conifers – Scots pine and yew being the exceptions – native woodlands consist almost entirely of broadleaves. Also excluded is a number of non-native broadleaves, such as beech, sycamore and Norway maple that have been introduced during the last 2-3 centuries. Nature conservation within the forests, therefore, is almost totally connected with indigenous broadleaves.

According to the NFI (2007) survey, forests with dominant nature protection functions add up to roughly 10% – not calculating the overlapping of several functions. This has been alluded to already in Table 3.3-1.

It may be noted, however, that other forests also serve to a certain degree in supporting natural conservation issues. The NFI (2007) records the functions are defined as constraints in the context of economic forest management. Here these constraints will be reinterpreted as nature conservation priority functions.

Further details concerning the type of conservation areas are listed in Table 3.3-2.

These data show that National Heritage Areas (NHAs) and Special Areas of Conservation (SACs) are the most important. Together with the Special Protection Areas (SPAs) they are designated as such under national, European Union and international legislation, conventions and protocols, which means that their importance reaches beyond Irish borders.

Table 3.3-2: Nature conservation priority function (%) having a bearing on forest management. (Refer to Table 3.3-1) (Adapted from NFI, 2007)

Nature Conservation Area Type	Ownership			
	public	private		Mean
		grant aided	other	
National Heritage Area	*4.7*	*3.0*	*11.3*	***5.2***
Special Area of Conservation	*2.4*	*1.7*	*12.7*	***3.8***
Special Protection Area	*1.1*	*0*	*1.7*	***0.9***
National Park	*0.6*	*0*	*0.7*	***0.5***
Nature reserve	*0.3*	*0*	*0*	***0.2***
Total	*10.5*	*5.4*	*33.0*	***10.6***

They are predominantly located in the other private forests reflecting the fact that it is here the old broadleaf forests with high ecological value are concentrated (Plates 3.3-2 and 3.3-3).

Plate 3.3-2: Remnants of old oak forest are regarded as especially valuable from the ecological point of view. (Rathdrum, Co Wicklow)

Plate 3.3-3: Semi-natural oak/holly woodland with extensive cover of mosses and lichens. (Rossacroonaloo Wood, Co Kerry)

In order to encourage a proactive protection of the existing native woodlands on the one hand and their expansion on the other, the Forest Service launched a *Native Woodland Scheme* in 2001, providing financial support for landowners, including grants for enhancing measures and premiums for long-term maintenance.

Some of the silvicultural measures being supported are:

- Overall: Conservation, biodiversity and a close-to-nature silviculture are prioritised. Nevertheless, wood production is encouraged where appropriate.
- Emphasis is placed on the use of natural regeneration. It may be facilitated by light scarification.
- Non-native species are excluded under the scheme. Invasive species like rhododendron may be eradicated.

- Planting stock must originate from suitable indigenous seed sources where planting is necessary.
- Fencing is the most important procedure of forest protection, in order to save young growth from browsing.
- Individual selection or small-scale coupe fellings will be stipulated.
- Maintenance of open spaces, rides and glades is encouraged.
- Restoration of coppice management is suggested in suitable locations.

The establishment element of the Native Woodlands Scheme was revised in 2011 and several items have been updated. Many aspects of the original scheme were considered too cumbersome in practice. For example, the input of a woodland ecologist as required in the original programme as well as the development of a native woodland plan are no longer a requirement. The grants and premium rates are now the same as the standard Afforestation Grant and Premium except that the scheme has its focus on native species. While the revised scheme still places a very strong emphasis on biodiversity, it also aims to produce quality commercial hardwoods.

3.3.2.4 Multiple functions

Forests produce a wide variety of public goods and services in addition to timber. These include protection of biodiversity, carbon sequestration and supplementing ground water reservoirs among others. Biodiversity, in particular, is increasingly emphasised in EU environmental policies. In a forest management context these functions are all regarded as constraints on wood production (Table 3.3-3).

These data again show (refer also to Table 3.3.1) that more than half of the forest area has no constraints. It is exclusively devoted to production. It is also apparent that the other private forests support a greater number of functions than the forests of either of the other two ownerships.

Table 3.3-3: Number of **constraints** (in %) having a bearing on forest management. (Adapted from NFI, 2007) (Basis: 626,000 ha; weighted means)

Number of Constraints	Ownership			
	public	private		Mean
		grant aided	other	
None	49	62	44	**52**
1-2	47	36	43	**43**
3-4	3	2	11	**4**
4+	1	<1	2	**1**
Total	100	100	100	**100**

3.3.2.5 Broadleaf species in riparian zones

Ireland is not only rich in peatland and coastal complexes (refer to Table 1.5-1), but also in lakes and wetlands. This is reflected in the findings of the NFI that almost one quarter of the forest area is fishery sensitive (refer to Table 3.3-1). Apart from their relevance for fisheries, wet habitats such as flushes, streams and swamps can substantially add to the plant, spider and hoverfly diversity of a site (Iremonger et al., 2007).

Concern has been expressed that plantation forests may impact negatively on surface water quality and fish populations by generating acidity (Farrell and Kelly-Quinn, 1992). Native riparian woodlands, therefore, play a major role in promoting water quality, cooling water temperatures and creating favourable conditions for fish and other components of aquatic and riparian biodiversity (Forest Service, 2001). Moreover they protect riverbanks from erosion and serve as corridors or stepping stones for plants and animals to move across the countryside, providing vital ecological connectivity between important habitats (Plate 3.3-4).

Riparian woodlands consist solely of broadleaves: a small strip, of bushy willows, alder and poplar, seldom with a closed canopy but interrupted by a rich flora of reeds, grasses and a great variety of herbal plants. They are often endangered by planted forest stands reaching too close to the water line which over-shade the very light-demanding species of the riparian flora (Plate 3.3-5). Therefore, a buffer zone of at least 20 m should be left un-afforested. By catering for a continuous band of buffer zones the fragmentation of the landscape can be effectively reduced. Riparian zones do not need any silvicultural treatment. Normally the site-adapted species will regenerate naturally.

Plate 3.3-4: Riparian forest edges which satisfy aesthetic purposes, but have a partly tunnelling effect. (Clifden, Co Galway)

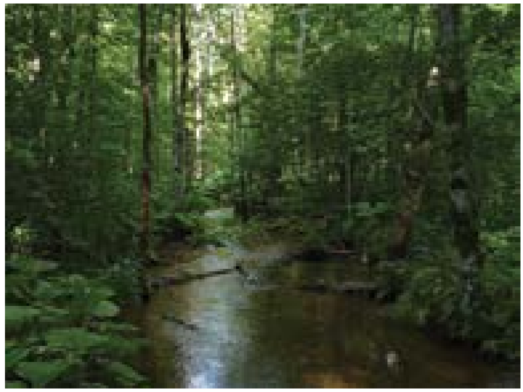


Plate 3.3-5: Dense shade in an ash/alder riparian forest.

3.3.3 Role of native and introduced species

From the ecological point of view, forests containing native tree species best adapted to the site conditions of the country are most highly valued. In Table 3.3-4 some information on this aspect is given about the tree species distribution within the forests in different ownership.

Due to its history after the ice ages (refer to Chapter 1.2), Ireland has a limited range of native tree species. Apart from juniper, yew and possibly Scots pine, no other conifer is native and broadleaves that are important on the Continent: beech, sycamore, hornbeam and Norway maple are also absent.

Table 3.3-4: Relationship of **native and non-native tree species** according to ownership (%).
(Adapted from NFI, 2007)
(Basis: 626,000 ha; weighted means)

SPECIES GROUP	OWNERSHIP			
	public	private: grant aided	private: other	Mean
Native	*15*	*14*	*74*	***22***
Non-native	*82*	*86*	*26*	***76***
Temp. unstocked	*3*	*<1*	*<1*	***2***
Total	*100*	*100*	*100*	***100***

It is, therefore, not surprising that public and grant aided forests are widely stocked with non-native tree species. They have been afforested with the main intention to produce large amounts of timber that can be sold profitably in the market, with Sitka spruce as the dominant species.

The situation is the opposite in the other private forests. They consist mainly of broadleaves as they have either developed naturally in small woodlots or have been planted for amenity or for hunting purposes. Their value is much higher from an ecological perspective, and it is easy to understand why they are so attractive to nature conservationists.

The species of all groups are described in Chapters 7-9.

3.3.4 Role of ground vegetation

The NFI 2007 results contain further data about the number of herbaceous plants found within the different types of forests (Table 3.3-5).

There is a clear increase in the frequency of plant numbers in the ground flora from conifer forest through to mixed forest, to broadleaf stands. This may account for the greater ecological value of broadleaf forests, but it may also be argued that site conditions for broadleaves are generally more appropriate for more species.

Table 3.3-5: Occurence of **herb plants** (%) depending on the forest types. (Adapted from NFI, 2007)

Forest Type		Number of plants			Area	
		none	1-10	11-20	1,000 ha	%
High forest	conifer	*<1*	*76*	*24*	402	*58*
	mixed	-	*62*	*38*	90	*13*
	broadleaf	-	*51*	*49*	72	*10*
Scrub		-	*46*	*54*	28	*4*
Other (temp. unstocked, burned, blown, undeveloped)					106	*15*
				Total	**698**	***100***

Scrub has even greater representation, possibly because of the mixture of open and partially closed microsites.

3.3.5 Role of fungi

Fungi comprise a varied class of organisms as numerous as the flowering plants. They range from tiny microscopic organisms to large solid bodies. Their role in organic life is extremely diverse. On the one hand they cause various diseases such as rusts, canker and rot in trees, while on the other hand they play a vital role in the disposal of organic waste, breaking down and recycling it (Plate 3.3-6).

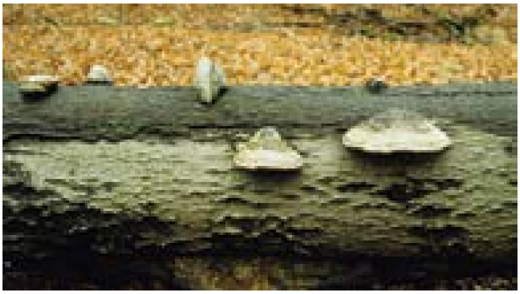


Plate 3.3-6: Fungi on decaying beech deadwood. Only larger stems are of greater ecological value for fungi and insects.
(Hainich National Park, Central Germany)

Most people take notice of fungi only when picking mushrooms, an activity that up to now is not as popular in Ireland as on the Continent. To increase our knowledge about edible and poisonous mushrooms and encourage people to make use of this natural food resource, COFORD has published a book on *Forest Fungi in Ireland* by Dowding and Smith (2008).

Most fungi living in the soil are associated with trees. In the form of mycorrhiza they cover tree roots and enlarge their surface thus improving water and mineral nutrient uptake for the trees while getting assimilates from them. There is no tree species that is not associated with one or more fungi, and some fungi live in association with several tree species. A greater number of fungus species can be found in broadleaves than in conifers (Table 3.3-6).

Table 3.3-6: Number of **mushroom species** associated with broadleaves and conifers out of a total of 75 species.
(Adapted from Dowding and Smith, 2008)
+ = association between fungus and tree species,
++ = strong association between fungus and tree species

Tree species	Fungi	
	+	++
Beech	12	-
Oak	7	4
Birch	2	5
Ash	3	-
Willow	2	-
Poplar	-	1
Total broadleaves	**26**	**10**
Pine	7	1
Spruce	6	-
Larch	5	-
Fir	4	-
Total conifers	**22**	**1**

There are many more less visible fungal species associated with trees. During past decades ecologists have come to realise the great number and diversity of species living not only in various symbiotic relationships, but also as parasites or pathogens in forest ecosystems.

Fungi play an important role as recycling agents, fragmenting, decaying and mineralising litter and deadwood. Only recently has it been discovered that some are specialists, relying totally on the existence of large dimensional and preferably broadleaf deadwood debris. As well as furnishing habitats for special insects, the retention of large dimensional woody debris, therefore, provides for the preservation and enhancement of some fungi. This is one of the reasons why the maintenance of coarse woody debris has become an important issue in recent times.

Conclusions

Fungi have only recently achieved serious recognition by ecologists and the public. One reason is the wider use of edible mushrooms as a natural resource. Another is the perception of fungi as sensitive organisms to monitor environmental influences such as climatic variation and pollution. They also react to silvicultural procedures and disturbances of the soil and are increasingly used as monitoring agents in the observation and study of the environmental effects brought about by these procedures.

Currently, many interactions are not fully understood and more monitoring and documentation is necessary to gain deeper knowledge about the interrelationships.

Moreover, fungi are indicators of biodiversity and will gain more attention in the future. Much research and field work, however, will be necessary to make further progress in this field.

As the greatest range of fungi is found in unmanaged ancient woodland with a large amount of woody debris and litter, it is recommended that some small inaccessible parts of commercial forests be retained beyond physical maturity, and that trunks be left to rot where they fall. Broadleaf forests or mixtures with broadleaves are especially advantageous in this regard.

3.3.6 Role of litter and humus

Litter and humus are likewise indicators of ecological conditions (Table 3.3-7).

Tree litter depth showed no clear difference under the various forest types and the scrub. However, the data illustrate that conifers seem to have relatively more stands without **humus** and by far the least with mull (richest form of humus), whereas broadleaves have much better values in this regard – again this may be partly due to richer soils.

Table 3.3-7: Litter depth (mm) and **humus form** by forest type (% of forest type area). (Adapted from NFI, 2007) (Basis: 626,000 ha)

Forest Type		Litter depth (mm)			Humus (%)			
		0	1-30	31->60	none	mor	moder	mull
High forest	conifer	16	57	27	*41*	*36*	*17*	*6*
	mixed	15	66	19	*34*	*28*	*26*	*12*
	broadleaf	8	70	22	*23*	*26*	*27*	*23*
Scrub		17	71	12	*39*	*13*	*22*	*26*

3.3.7 Role of deadwood

Deadwood or dead woody debris *forms a major component of the decomposer food chain. Its presence is vital for many wood decaying insects and fungi. They also serve as a habitat for many bryophyte and lichen species* (Iremonger et al., 2007). Some rare insects especially are the main indicators for ecologically sound conditions (Plates 3.3-7 and 3.3-8).

Although the NFI results do not supply information about the differences between conifers and broadleaf forests it is possible to draw some inferences from the data (Table 3.3-8).

Deadwood presence with approximately 60% has almost the same magnitude in the public and other private forests, whereas in the grant aided private forests there was hardly any deadwood. The presence of deadwood would, therefore, seem to be dependent mainly on the age of the forests as the tree species distribution differs tremendously between these two ownership types. As most of the grant-aided forests were established during the last two decades they had not sufficient time to produce any noticeable quantity of deadwood.

Plate 3.3-7: Very old decaying oak is an ideal habitat for birds, bats, insects and fungi.
(Central Germany)

Plate 3.3-8: Standing old oak deadwood is of highest ecological value for insects and fungi.
(Central Germany)

Deadwood type is of essential importance for insects, birds and fungi (Table 3.3-9).

Young stands – conifers as well as broadleaves – are normally of minor importance in this regard. They contain relatively high amounts of dead or dying suppressed individuals. Small-dimension trees that form the main proportion in conifer as well as broadleaf stands are of almost no ecological value. Standing deadwood especially is of higher ecological value, and can be found to a somewhat higher degree in the other private forests, presumably because of their older age structure.

Table 3.3-8: Presence of **deadwood** based **on area** by ownership (%). (Adapted from NFI, 2007)
Basis: 626,000 ha forest area; weighted means.

Deadwood	Ownership			
	public	private		Mean
		grant aided	other	
Absent	*38*	*94*	*40*	***55***
Present	*62*	*6*	*60*	***45***

Table 3.3-9: Type of **deadwood** based **on volume** by ownership (%). (Adapted from NFI, 2007)
Basis: 5.7 billion m³; weighted means.

Deadwood	Ownership			
	public	private		Mean
		grant aided	other	
Lying	*48*	*62*	*48*	***49***
Standing	*32*	*31*	*41*	***33***
Stump	*20*	*7*	*11*	***18***
Total	***100***	***100***	***100***	***100***

3.3.8 Role of carbon stock and sequestration

The threat of global warming, possibly caused by anthropogenic greenhouse gas emissions, has stimulated intensive discussion about the role forests may play as carbon pools and sinks.

3.3.8.1 Carbon pool according to ecosystem compartment

Excluding harvested wood products (now regarded by the Intergovernmental Panel on Climate Change as a pool in itself), carbon is stored in five pools within forests (Table 3.3-10).

By far the most carbon is stored in the soil, confining all other pools to almost negligible proportions. Together with the litter it represents roughly 90% of the carbon stock. This means that managing the soil carbon store is a priority goal.

Moreover, broadleaves may have an advantage compared with conifers. Data from the other private forests demonstrates that a higher proportion of old broadleaf stands offer an opportunity to increase the standing volume and thereby the size of the carbon store.

Table 3.3-10: Carbon stock of pools (%) based on **ecosystem compartment** and ownership. (Adapted from NFI, 2007)

Carbon pool		Ownership: public	Ownership: private, grant aided	Ownership: private, other	Total	Total
		%	%	%	%	Mill. t
Tree	above ground	*8*	*3*	*10*	***7***	**22.0**
	below ground	*3*	*2*	*3*	***2***	**8.2**
Deadwood		*1*	*<1*	*<1*	***<1***	**1.4**
Litter		*3*	*1*	*4*	***3***	**8.7**
Soil		*85*	*94*	*83*	***87***	**281.4**
Total		***100***	***100***	***100***	***100***	**321.7**

3.3.8.2 Carbon stock according to tree species group and ownership areas

Broadleaves can be viewed as better carbon stores than conifers because of their higher specific weight. Therefore, one could expect a higher relative carbon content in the broadleaves than their relative area. The results of the NFI do not help to support this assumption, however (Table 3.3-11).

Table 3.3-11: Amount of **carbon stored by species groups** per area and relationship between area and carbon stock according to ownership. (Adapted from NFI, 2007)
(Basis: 615,000 ha (total forest area minus temporarily unstocked area)

Category	Species group	Item	Unit	Ownership: public	Ownership: private, grant aided	Ownership: private, other	Mean
Carbon stock per species group	Conifers	Carbon stock	t/ha	64	22	93	**51**
	Broadleaves			40	26	56	**44**
Relation between area and carbon stock per species group	Conifers	Area	%	*83*	*85*	*19*	***75***
		Carbon stock		*89*	*82*	*28*	***78***
	Broadleaves	Area		*17*	*15*	*81*	***25***
		Carbon stock		*11*	*18*	*72*	***22***

In summary the following deductions may be made:

- In general the carbon stock (t/ha) of conifers was higher than that of the broadleaves.
- All conifer stands in the country contained approximately 78% of the carbon stock while covering approximately 75% of the area. All broadleaves together stored 22%, but covered 25% of the total forest area. This is probably a reflection of the young age of many broadleaf plantations.
- The relationship of carbon stock to area is best for the conifers in the other private forests, but the broadleaves have the highest carbon stocks in this ownership type.

3.3.8.3 Carbon stock according to tree species

Data on the carbon contents of the different tree species groups are presented in Table 3.3-12:

- Conifers obviously have lower carbon content per m^3 of growing stock than almost all broadleaves. The only exception is ash, but this is probably due to the very young age of the majority of the newly planted ash stands.
- Oak and beech forests show the highest amounts of carbon in relation to area (t/ha). This follows from the fact that they are the species with the highest proportion of old stands. The other short-living broadleaf stands comprise to a great extent willows with low stocking rates.

Table 3.3-12: Amount of **carbon by species**, total amount and per m³ as well as per ha. (Adapted from NFI, 2007)

Species group	Carbon content 1,000 t	%	t/m³	t/ha
Conifers	23,426	*78*	0.40	51
(Sitka spruce)	(18,140)	*(60)*	(0.43)	(55)
Oak	1,310		0.55	90
Beech	970		0.56	112
Ash	620		0.41	32
Sycamore	450		0.75	55
Other long-living broadleaves	510		0.65	53
Total long-living broadleaves	3,860	***13***		
Birch	1,320		0.72	45
Alder	580		0.68	50
Other short-living broadleaves	960		0.70	19
Total short-living broadleaves	**2,860**	***9***		
Total	**30,146**	***100***		

Nonetheless, the NFI findings do not support the hypothesis that a high proportion of broadleaves would substantially increase the carbon balance.

3.3.9 The role of broadleaf species in biodiversity

Apart from erosion, water and pollution control, all the above mentioned protection issues serve to promote biodiversity. According to the Final Report on *Biodiversity in Irish Plantation Forests* by Iremonger et al., (2007) there is currently across the globe unprecedented interest in biodiversity. The background is the obvious need to conserve biodiversity and the biological resources for reasons of ethics, economic benefit and finally human survival.

Biological diversity was defined by the United Nations Convention on Biological Diversity in 1992 as *the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and ecosystems*.

In general forests are among the most developed and highly structured ecosystems. Important components of the flora and fauna are dependent upon areas of closed-canopy tree cover and others are associated with open-space habitats within the forests. There are, however, great differences between natural forests and even-aged, pure plantations. The above mentioned report by Iremonger et al., (2007) contains a great number of recommendations for policy and practice.

Some of the mainly management and silviculture related recommendations are:

- Mapping of habitats with special ecological needs prior to afforestation.
- Omitting of afforesting semi-natural habitats unless mitigating circumstances are provided.
- Retaining of large diameter dead wood.
- Creation of a mosaic of stands of different age and structure at the landscape scale.
- Inclusion of a mixture of canopy species in a spatial arrangement.
- Leaving small unplanted areas to maintain gaps through the forest cycle.
- Leaving wet habitats and avoidance of drainage.
- Conservation of scrub and other marginal habitats.
- Promotion of broadleaf woody vegetation in young conifer plantations.
- Securing development of broadleaf tree and scrub vegetation by reduction of grazing and browsing pressure.

It is, therefore, obvious that apart from variation in forest type and the use of gaps, the favouring of broadleaves is an important way to increase biodiversity.

3.3.10 Genetic resources

Sustaining and developing Ireland's forest genetic resources has become an increasingly important issue during the past decades. Until the early 1990s mainly non-native conifer species were considered and the seed was often imported from foreign sources – sometimes of unclear origin. Broadleaves – as mentioned in Chapter 1.4 – came into prominence only during the last two decades. Much of the seed material and to some extent the planting stock material was collected from sources outside of Ireland.

The general philosophy for establishing broadleaves is to use site-adapted provenances as these have the greatest likelihood to withstand local abiotic and biotic stress conditions and threats. Besides showing the greatest ecological and physical stability they tend to have the highest production rates.

Fortunately, at least some stands from either indigenous or locally adapted home sources are still in existence. It has become obvious, however, that the need is paramount to conserve these genetic resources as soon and effectively as possible. Therefore, COFORD established a Working Group for the development of forest genetic resources in Ireland. An *Outline Strategy* was published in 2007 which indicated the necessary approaches and activities required (Cahalane et al., 2007).

The main findings of this strategy are as follows:

- The conservation of the gene pool of site-adapted species, native as well as non-native, is a general basis *per se* for valuable land-races. Their conservation is the main objective of the Native Woodland Scheme.
- These species may act as a natural buffer against environmental changes such as climate change, the occurrence of new pests, diseases and pollution.
- They may also form the basis for future selection and breeding as for example in seed orchards. So far, however, the production of genetically more advanced material is only aimed at Sitka spruce.
- They are essential in order to collect seeds in certified seed stands from the site-adapted native as well as non-native species for afforestation and reforestation.

Up to the end of 2011 the following seed stands have been selected as presented in Table 3.3-13.

The tree species and the area of seed stands reflect the existence of older broadleaf stands in the country that are suitable for seed collection.

These existing seed stands are obviously not sufficient to meet the amount of seeds required in the next years as shown in Table 3.3-14.

As the annual planting programme decreased remarkably in recent years these data are very speculative. Yet they show which tree species should be considered in future years and the approximate relationship between them. The dominance of alder, ash, oak and beech mirrors the patterns of plantings during the last two decades, but many other tree species, which have received little consideration so far, such as birch, wild cherry, whitethorn, holly and rowan, may gain increasing importance in the years ahead.

Table 3.3-13: Tree species represented in seed stand, their number and area.
(Fennessy et al., 2012)

Tree species	Number of stands	Area ha
Sessile oak	44	1,381
Pedunculate oak	44	780
Ash	8	156
Beech	18	80
Span. Chestnut	3	9
Sycamore	4	7
Alder	11	113
Birch	6	26
Total broadleaves	**138**	**2,552**
Conifers	203	1,586
Mixed species	3	53
Grand total	**344**	**4,291**

Cahalane et al., (2007) have also indicated which tree species should be allocated research funding in order of priority (Table 3.3-15). However, they did not give reasons for their preferences.

Table 3.3-14: Estimated annual **broadleaf plant requirement** for the period 2007-2016.

(Adapted from Cahalane et al., 2007)

Tree species	Annual requirement million plants
Ash	4.0
Oak	3.0
Beech	1.5
Whitethorn	1.3
Sycamore	0.45
Holly	0.1
Hazel	0.06
Rowan	0.05
Wild cherry	0.05
Alder	5.5
Common birch	1.0
Silver birch	0.5
Minor native species	0.08
Total broadleaves	**18.8**

Table 3.3-15: Priority species in forest **reproductive material programme** for the period 2007-2013.

(Adapted from Cahalane et al., 2007)

Species	Priority
Oak, ash, alder, birch	high
Beech, wild cherry, Spanish chestnut, sycamore	medium
Blackthorn, hazel, holly, whitebeam, whitethorn, wild apple	low

This information serves to illustrate the increasing need to make available home seed sources. Secondly, it is clear that the importation of seed from foreign sources, to meet future needs, is unavoidable, partly because species fecundity in the Irish climate is generally relatively low. Thirdly, undoubtedly increased efforts will be necessary to supply the forest owners with appropriate reproductive seed and plant material in the long run.

These are, however, only the direct benefits to be taken from such research programmes. There are presumably many more indirect effects that may derive from site-adapted tree species which cannot be imagined today in any detail.

Conclusions

The wide range of ecological functions and services of forests has been covered in this Chapter showing their important role in the landscape. Erosion and nature protection are the most relevant. These are generally better fulfilled by broadleaves than by conifers. The forest cover, however, is predominantly formed by non-native conifers. It will be a great challenge to further increase the proportion of broadleaves.

Recent activities are directed to improve the genetic basis for broadleaf seed and plant supply. It will, however, take some years until these become effective.

Ireland's land base is intensively used, mainly for agriculture. Many ecological functions and services are necessary at most localities. They are often overlapping, and their separation in a manner appropriate to the needs of the population is not possible. The authors assume that integration and interaction of all forest functions is the only possible consideration for this country.

Carbon sequestration is becoming an important issue and may strongly influence forestry in the future. Whether or not this will change the role of the species groups, is, however, an open question.

3.4 Social values of broadleaf species

3.4.1 Introduction

In the previous section the ecological values of broadleaf forests have been described. Here the social values will be discussed. It has to be kept in mind, however, that both the ecological and social functions and services overlap and have many interconnections.

Forests play an important role in rural areas as a source of income, employment and recreation. The economic aspects – especially income and employment – will be dealt with in the following Chapter 3.5. However, forests serve in many ways with intangible social functions as a source of recreation and as a background for amenity or aesthetics, which are closely linked. In the following paragraphs the increasing importance of the forests as recreational areas will be discussed as well as the expectations forest visitors have with regard to the recreational values of forests.

According to Cregan and Murphy (2006) developments in social forestry have been somewhat muted until recently. Urbanisation started relatively late in Ireland and is still lower than in many countries. This can be seen in Table 3.4-1.

All countries in Europe with comparable environmental and economic conditions have a higher percentage of urban population. Belgium has (with 3%) almost no rural population, and even France with over three quarters of urban population is well ahead of the Irish figure. Thus, there is a lack of experience and knowledge especially in the field of recreation and ecotourism. Research will be necessary in the near future in order to meet and understand the rapid changes in the country. This is going to become increasingly urgent as the rural, as well as the urban areas, will continue to undergo further substantial and irreversible changes as has been experienced in the recent past. These changes may even accelerate in future decades. This is primarily due to the ongoing decline in farming on less favourable sites and because of increasing urbanisation and urban culture which will attract the rural population and lead to further rural migration.

Table 3.4-1: Urban population (*%)* in some European countries and the US in 2006. (Adapted from FAO, 2009: *State of the World´s Forests*)

COUNTRY	URBAN POPULATION %
Belgium	*97*
Denmark	*86*
France	*77*
Germany	*75*
Ireland	*61*
Netherlands	*81*
Sweden	*84*
United Kingdom	*90*
United States	*81*

The more socially oriented values are:

- Landscape aesthetics,
- recreation,
- culture,
- education,
- other values.

These will be discussed later when considering the role of broadleaves.

It is questionable whether the main constraint for forestry in Ireland, fisheries sensitive category, amounting to 29% (refer to Table 3.3-1), should fall under social values. This may be more the sporting interest of the fisherman-clientele rather than the ecological aspects of conserving or improving the natural habitat for endangered fish species. Due to lack of information this question remains open.

Social aspects – documented by NFI as constraints – total almost 5%. The details are given separately in Table 3.4-2 and will be explained in the following paragraphs.

Table 3.4-2: Social constraints in Irish forests. (Adapted from NFI, 2007)

CONSTRAINTS	OWNERSHIP public	private grant aided	private other	Mean	
	%				1,000 ha
Landscape	*1.4*	*0.7*	*6.3*	***2.0***	**15.6**
Recreation	*1.9*	*0.2*	*5.7*	***2.0***	**15.6**
Archaeological sites	*0.3*	*0.2*	-	***0.2***	**1.6**
Utility lines	*0.3*	*1.1*	*0.7*	***0.6***	**4.4**
Total	***3.9***	***2.2***	***12.7***	***4.8***	**37.2**

3.4.2 Landscape aesthetics

In the 18th and 19th centuries in Britain and Ireland most forests and woodlands were planted for aesthetic purposes and hunting (Cregan and Murphy, 2006). For centuries these were the only existing forests in the country, but were reduced to less than 2% of the land surface around 1900 (refer to Chapter 1.3).

The publication of the *Forestry and the Landscape Guidelines* by the Forest Service (2000b) gave the **main objectives** with regard to the management of the landscape as

- achieving a balance of landcover,
- complementing landscape integrity,
- retaining and/or increasing existing character and diversity, and
- mitigating visual conflicts.

The main **criteria** of landscape elements, with **factors** (in brackets), are their

- extent (scale, size),
- disposition (arrangement, location),
- configuration (shape, pattern, proportion, edge), and
- composition (margin, texture, colour).

Most **recommendations** are very general, such as

- avoidance of block or other linear boundaries to outline of large forests especially on open mountainsides,
- achievement of successful integration of especially small woodland plots by creating a visual link with surrounding landscape elements such as field boundaries, streams, gullies or rock outcrops,
- avoidance of creating solid forest walls by providing panoramic views into the landscape or attractive views into the interior,
- pruning to encourage the development of attractive green undergrowth,
- establishment of open spaces within the canopy especially in large forests on mountainsides,
- choice of group and shelterwood silvicultural systems to avoid negative landscape impacts, thus obviating large clearfells and – if possible – screening brash from view.

Broadleaves, however, are mentioned only in a few cases. Their main role is to add visual variety to forests such as

- reduction of the monotony of large forest blocks in upland areas by introducing broadleaves or broadleaf/conifer mixtures,
- planting of broadleaves in order to achieve an appropriate contrast of colour especially of autumnal colour variation, shape of the crowns and diversity in structure,
- creation of diffuse edges and margins by establishing a zone of loosely scattered trees and outliers, using wide spacing and low growing species such as rowan and birch.

These recommendations seem to be mainly targeted at landowners who have established large plantations of exotic conifers, mainly Sitka spruce. These are sometimes criticised by environmentalists because of their overall monotony and lack of diversity.

3.4.3 Recreation

Forests have become more and more the source of sporting activities, jogging, horse riding, mountain biking, touring, forest trips, walking and family outings, mainly at weekends and on holidays (Plate 3.4-1). Improving the recreational value of forests, however, is a relatively modern issue and has come into focus in most European countries only in the second half of the 20th century.

In Ireland, forest recreation as an integral part of tourism is also a relatively new concept, and generally recreation was not valued by the general public in the countryside until recently. Increasing urbanisation brought this issue into the public domain because of the following aspects:

- Recreation for the urban population, and
- possible increased income earning potential for the rural population from tourism.

As mentioned, recreation was considered as a constraint category in only 2% of the Irish public forests (refer to Table 3.4-1). Here recreation has the highest priority. However, forests in the other private forests category with recreation constraints reach almost 6%. The question can, therefore, be asked as to why forests in one category are seemingly more attractive than those of the other categories?

The following reasons are suggested:

- First, they are frequently found **at more scenic locations,** possibly connected with appealing landscape elements like coasts, lakes, streams, rivers, swamps or rocky areas (Plates 3.4-2 to 3.4-4).
- Second, they often contain **characteristic specimens of old woodlands** which are generally broadleaves or mixed woodland.

Plate 3.4-1: Forests, such as these old oak remnants with a holly understorey, are increasingly popular for recreation.
(Mount Callan, Co Clare)

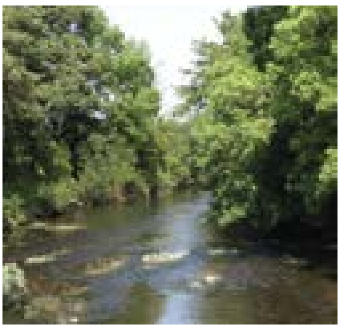


Plate 3.4-2: Broadleaves along a stream have greater recreational value.
(Glen of Aherlow, Co Tipperary)

Plate 3.4-3: Broadleaves bordering a lake provide additional visual impact.
(Lough Ennell, Mullingar, Co Westmeath)

Plate 3.4-4: Broadleaves add an extra visual dimension to lakeside habitats which are important for aquatic plants and animals. (Potsdam, Germany)

Studies in Central Europe have provided evidence that tourists and walkers greatly appreciate old picturesque trees with a natural appeal which are often located in park-like situations, with single trees or groups which served in earlier times as woodland pastures (Plates 3.4-5 to 3.4-7).

Recreation seems to be by far the most important woodland feature in and around urban centres. Therefore, old trees have to be retained and conserved especially in city parks, woodlands and in urban forests. Fortunately, these endeavours coincide positively with the needs to preserve old trees for ecological purposes.

- Finally, the attention of most visitors to forests is mainly focused on the **forest edges** (Plate 3.4-8). Therefore, shape, diversity and composition of the forest edges are essential features needing attention when managing recreation forests. Broadleaves and minor species play an important role in this context.

Plate 3.4-5: Old oak remnants in a former pasture.
(Shinrone, Co Offaly)

Plate 3.4-6: Prominent parkland beech.
(Kilkenny Castle, Co Kilkenny)

Plate 3.4-7: Sturdy old beech with character.
(Avondale, Co Wicklow)

Current research needs concerning recreation are mainly required in the following fields (Cregan and Murphy, 2006):

- Data collection in order to estimate visitor usage under Irish conditions.
- The direct use and the economic activity generated through tourism based on forests and trails.
- The need to quantify the benefits which forests contribute to health and well-being.
- Evaluation of the public perception of forested landscapes.
- Development of landscape evaluation techniques for use in outdoor recreation.
- Evaluation of the impact of recreation on forests (usage of trails, picnic places; opening access to all forests; vandalism and bad behaviour by a minority of forest visitors).
- Examination of the reasons for public preferences for natural areas as against managed forests.
- Economic analysis of the contribution that forestry can make to ecotourism.

Plate 3.4-8: Aesthetic effect of an individual broadleaf tree in a conifer wall.
(Southern Black Forest, Germany)

Some of these items include aspects concerning perspectives of best practice for designing and managing recreation forests, but obviously research is necessary in this regard.

The publication *Forest Recreation in Ireland: A Guide for Forest Owners and Managers* by the Forest Service, (2006) may be consulted for further information. It contains, however, only some very general recommendations regarding the management of forests to meet the expectations of visitors such as

- identification of attractive features and attributes,
- easy access by well-constructed and maintained footpaths,
- increase of optical diversity – for instance by introducing broadleaves alongside conifer stands,
- introduction of open spaces and viewpoints,
- treatment of woodland edges and gradual transition – for instance from grass to native shrubs and small trees, up to woodland canopy.

Surprisingly, the role of single old or groups of picturesque trees – mainly remnants of pasture woodlands – has not been pointed out.

It may be also mentioned that on the Continent there is an increasing conflict between the forest owners and society as well as a growing pressure of population on the forests. In Central Europe urban people often have no idea and appreciation of who owns the forests. They regard all forests as public property – i.e. their property.

3.4.4 Culture

The Irish countryside is rich in physical remains of human activities. **Archaeological sites and monuments** are an important part of the national heritage. In earlier times forests often protected them because of minimal disturbance as compared with agricultural activities. Nowadays, however, site preparation and harvesting can cause structural damage or even total destruction of ancient sites (ringforts, tombs, old roads, territorial boundaries) or of more recent periods (church sites with graveyards, farmhouses, limekilns, mills). Therefore, it is not surprising that archaeologists view ongoing afforestation activities with concern (Cooney, 1993). These remains should be left unplanted with an exclusion zone around them of at least 20 m, and the boundaries of the exclusion zone must always be clearly defined on the ground.

Further details are given in *Forestry and Archaeology Guidelines* by the Forest Service, (2000c).

Several **place names** indicate the earlier presence of tree species, mainly broadleaves (Joyce, 1905). According to Nelson and Walsh (1993), many place names contain root-words that have derived from trees or woodlands. One of the most frequent terms is doire, anglicised as derry, meaning an oakwood which can be found in over 1,600 townland names in Ireland.

Remains of **historical land-use types** like pasture woodlands or coppice forests may be also worth conserving and may need to be managed as in the past. These may – along with ecological values – be of increasing importance for education and demonstration.

3.4.5 Education

As mentioned, urbanisation has increased remarkably over the last decades, and there are good reasons for assuming that this development will continue (Table 3.4-3).

It shows, that within a period of about 10 years, the percentage of the rural population has decreased by almost 3%, while the total population increased at the same time. Thus the number of rural inhabitants remained more or less stable, but the urban population grew.

Table 3.4-3: Development of the total population and the percentage of rural population in Ireland. (Adapted from FAO, 1997, 2003, 2009: *State of the World´s Forests*)

Item	Unit	Year		
		1995	1999	2006
Total population	Mill. inhabitants	3.6	3.7	4.0
Rural population	%	*42.5*	*41.7*	*40.0*

As in other highly developed countries, an increasing part of the population is losing contact with rural life. Urban living by its very nature reduces the opportunities for understanding complex ecological connections and processes as well as using the natural resources for production of food and forest products.

Urban woodlands and parks are nowadays gaining increasing importance. These woodlands are relatively uncommon in Ireland and those that exist are fairly recent in origin (Cregan and Murphy, 2006). They will, however, become an essential resource for education with the understanding that *all education is environmental education* (Orr, 1994).

It has to be acknowledged, however, that this issue is in general a broader challenge for all institutions and personnel in the forest sector, and not a special issue of concern only to broadleaf management.

3.4.6 Other values

In a wider sense utility lines, which cause constraints on 0.6% of all forests, also belong to social factors within the forests. Utility lines are mainly power transmission lines. Trees have to be removed from under the wires when they reach a certain height. Therefore, the line areas are cleared regularly providing open space for various plants and animals as well as providing views into the landscape. Meanwhile minor and pioneer species such as birch and willows tend to colonise these areas, thus adding to the diversity of the landscape. As the utility lines are mainly stocked with broadleaves they often represent alternative habitats in large conifer plantation areas.

Conclusions

Social functions of forests, although obviously important at present, only account for a small proportion of Irish forests, but will gain greater relevance in the near future. Recreation needs, driven by increasing urbanisation, will require greater public attention especially in the surroundings of the cities and in some tourist centres. Woodlands and parks need special management, and here broadleaves will play an important role.

3.5 Economic values of broadleaf species

Virtually every forestry undertaking involves the interaction of invested capital and land for a particular purpose. This chapter deals with the economic aspects of specific activities and the issues and procedures contained in their appraisal. It does not purport to be a treatise on forest economics. There are various approaches to this task but all are circumscribed by the fact that no one can foretell what the situation will be in 50 or 100 years from now when the crop is mature.

Taking the establishment and growing of oak as an example, the standard methodology involved in assessing its profitability will be illustrated. The activities listed in the example may or may not be relevant in all circumstances. Neither is the list exhaustive and it may be necessary to add others in certain situations. The grants and premium rates date to those applicable from 2007. However, subsequent changes to the rates do not invalidate the conclusions in paragraph 3.5.2.6.

This will be followed by exploring the contribution that forests and forestry makes to the economy in general.

3.5.1 Growers and the national objectives

The objective of establishing, growing and managing plantations will be influenced by the financial circumstances and perspectives of the forest owner, but for most individuals it will involve the expectation of a monetary dividend at some time in the future. Kearney (2001) referred to a study in 1997 by Frawley of farmers' attitudes towards forestry as a farm enterprise, and observed that two-thirds of those who planted regarded the economic aspect as the main justification. Since quality timber commands a premium price this economic aspect is best satisfied by the production of material goods in that form (refer to Chapter 3.2).

The consequences of large scale afforestation extend far beyond the objectives of the individual owner. The timber production aspect is enhanced by the concomitant non-market products which benefit the public at large. As mentioned in previous chapters, forests transform the landscape, provide facilities for recreation and absorb carbon dioxide from the atmosphere, in addition to providing a timber resource for industry. Therefore, as forests develop they have the potential to make a significant economic contribution to local and national economies.

This economic contribution both to the individual grower and to the national economy will be explored below.

3.5.2 Factors influencing the economics of forestry for the individual owner

Forestry is in many ways similar to an agricultural land use such as tillage in that it involves land and its cultivation, the planting of a crop, its maintenance and eventually its harvesting. There is, however, one very important difference – the time scale involved. Whereas an agricultural crop is harvested at the end of one growing season, a forest crop may take anything from 40-100 years to reach maturity depending on the species. This time frame has important implications for the economic viability of the undertaking.

The principal factors influencing the economics of a timber growing enterprise are listed as

- time scale,
- rate of interest,
- price of land,
- cost of establishment and early management,
- cost of roading,
- cost of maintenance,
- revenues from grants and premiums,
- revenues from intermediate thinnings and final harvest.

These will now be dealt with in sequence.

3.5.2.1 Time scale

Forest economics, and particularly that relating to broadleaf timber production, is dominated by the time scale involved in growing the produce to merchantable dimensions. Even the fastest growing broadleaves such as poplars will require 15-20 years before they reach maturity and some species such as oak and beech will need a century or more.

3.5.2.2 Rate of interest – the discount rate

Closely associated with the time factor is the rate of interest used in discounting. The discount rate is a measure of the investor's time preference – the rate at which the individual discounts the value of future income to make it comparable to present income – and will vary with the individual's circumstances. Over the years discount rates have been the subject of considerable debate by foresters and economists alike, who are acutely aware of the sensitivity of forest economic analysis to the discount rate over long time-horizons.

The reason for this concern is illustrated in Figure 3.5-1, which shows the interaction between the time scale and varying discount rates. For example, when €1000 is discounted at 2% over 10 years it is worth more than €800, but this decreases to less than €400 when discounted at 10% over the same time period. When the time period is extended to 100 years the difference between the rates is even more striking with the values falling to less than €140 and €0.07 respectively.

This long time period obviously militates against returns, such as the final harvest value of a broadleaf crop, coming at the end of a long rotation and discounted at a high rate.

The sensitivity of interest rates to long-term discounting prompts the question as to what is an equitable discount rate for forestry.

Forestry is regarded as a low-risk investment and one that has kept pace with inflation during the 20th century (Convery, 1979).

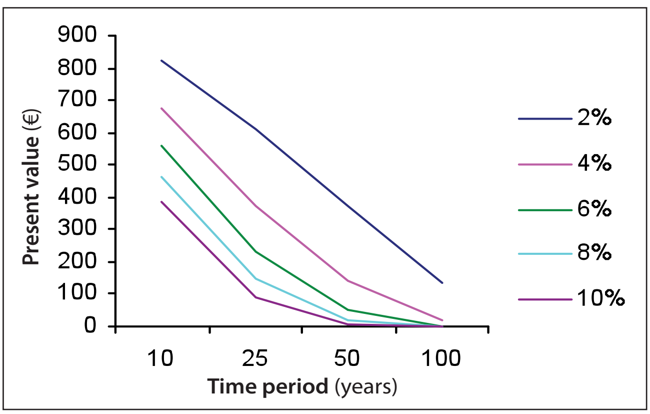


Figure 3.5-1: **Present value** of €1000 **discounted** at varying interest rates over time periods ranging from 10 to 100 years.

Low-risk investments will usually command lower than normal discount rates, but forestry is not entirely risk-free.

Discount rates for forestry are a reflection of interest rates on capital which are now determined by the European Central Bank (ECB) rate. Traditionally, discount rates of 3-5% have been applied in forest valuation and investment analysis of conifers in Ireland and the UK (Phillips, 2005). These are in keeping with recent ECB rates and have been justified on the basis of unquantified non-wood benefits, social aspects associated with investment in rural areas and the belief that timber prices will increase relative to other commodities in the long-term.

Rates for broadleaves have been much lower than those for conifers reflecting the realism associated with discount rates over long time periods. For this reason broadleaves on the European Continent are more often associated with State forestry or the larger estates rather than farm forestry. There they form part of the historical mix of species dating back to the period when broadleaf forests were the main source of fuelwood for industry and heating and provided the hunting facilities enjoyed by the nobility.

3.5.2.3 Price of land

In general there is a distinct difference between conifer and broadleaf afforestation:

- Afforestation with conifers generally occurs on poorer farmland. Kearney (2001) remarked that much of the land afforested may not have been producing much in the line of agricultural output, while the balance of planting may have occurred on land where agricultural activity was low.
- Afforestation with broadleaves on the other hand impinges directly on agricultural output. Planting with the more demanding broadleaf species can only be done profitably by transferring land from agriculture to forestry.

The price of land began an upward trend when Ireland joined the EU in 1973 and this trend continued until the autumn of 2008.

Malone (2008) cited Central Statistics Office (CSO) data which showed the average price for agricultural land almost tripling during the decade 1996-2005, from almost €6,500 to over €17,000/ha.

Mac Connell (2008), quoting from a survey by specialists in agricultural property, stated that the national average price for farmland was over €50,000/ha, remarking that this represented a drop of 1.9% on the previous year. In a previous article he elaborated on these prices, which he stated were then the highest in Europe, approaching €60,000/ha. He quoted Ashmore, Associate Director at Savills HOK Country, to the effect that only a tiny percentage of Irish farmland is sold each year, about 8,000 ha out of a total of almost four million ha, and that lifestyle farmers and hobby farmers were mainly to blame for pushing up the price of land. He went on to comment that it is no longer possible to buy an Irish farm on a commercial basis, by paying prices in the range €62,000-86,000/ha, and then being able to make a living from it.

Forestry is no different to agriculture in this respect and, even with generous supports it will not prove financially viable when land values approach this extraordinary level.

The economic downturn in 2008 brought a measure of reality to land market prices. The average price of farmland sold at auction in 2008 fell to €26,000/ha from an average of almost €60,000/ha in 2007 (O'Sullivan, 2009). By 2015 the situation had not changed materially. The average price for farmland nationwide in that year remained relatively constant at €10,336/ac [€25,530/ha] (Ganly 2016). This represents a 1.8% decrease on the average price in 2014.

Land prices in Ireland have been greatly distorted by EU subsidies, a fact that has led Clinch (1999) to argue that the price of land for forestry should be based on shadow prices by calculating the opportunity cost of afforestation. He cited a study by FitzGerald and

Johnson (1996) who estimated the social value of agricultural output to be approximately €100/ha. This amount, when capitalised at the test discount rate of 5%, gives a land value of €2,000/ha, which is the shadow price of land. Even allowing for inflation in shadow price since 1996, the current market price of farmland bears no relationship to the shadow price.

Short of a complete dismantling of subsidies on agricultural products there is little likelihood of land ever being traded on the basis of shadow prices.

Taking all factors into account it is suggested that the maximum land price that broadleaf forestry will bear is in the region of €10,000-15,000/ha, with site accommodating species such as oak at the lower end and more site demanding species such as ash at the upper end.

In the following Chapters 3.5.2.4 -3.5.2.6, the growing of oak will be used as an example to illustrate the procedures involved and the factors to be included in assessing its profitability. The choice of oak is made because of its popularity, longevity and the mystique attached to the species. It commands excellent prices at maturity when its timber is of high quality (refer to Figure 3.2-1). Its obverse trait is that it requires a long rotation and, therefore, the income from its final harvest has a long discounting period. In essence the growing of oak is for the benefit of future generations.

In the procedure adopted many of the assumptions made in regard to costs and revenues are necessarily subjective, but are based on the best information available.

3.5.2.4 Costs

Costs involve those related to (1) establishment and early management, (2) ongoing costs incurred in maintenance of the plantation and (3) cost of roading.

(1) Costs of establishment and early management

Establishment costs vary between conifers and broadleaves, and even among broadleaves, with the higher costs for oak and beech representing those associated with plants and planting at higher densities.

Diverse growth patterns between individuals are also much more common in broadleaves and require early attention. Oak will require attention for shaping a proportion of trees that are forked or heavy-branched, but would otherwise qualify as potential crop tree candidates. If pruning is required there is no immediate or medium-term return to the grower, other than better quality stems at some future date. Tending and first thinning can also be expected to incur a financial loss, its magnitude conditioned by the price and saleability of small size material, and the availability of grant aid for first thinning of broadleaves. These operations are assumed to result in a cost to the grower which may be partially recouped, in the case of thinning, by sales of firewood and drawing-down of grant aid.

Typical data associated with the establishment and early management of an oak plantation are shown in Table 3.5-1.

(2) Ongoing costs of maintenance

The impression that forestry plantations are maintenance-free is misleading. All plantations require routine maintenance to ensure against damage to fencing and trespass by both wild and domestic animals, as well as to check that drains are not blocked and result in destabilisation within the plantation.

The costs of maintenance are estimated at €20/ha/yr.

(3) Costs of roading

Costs of roading vary, among other factors, with road density – the number of linear metres of road/ha. Road density in turn varies

Table 3.5-1: Schedule of **costs** (€/ha, exclusive of VAT) **for an oak plantation**.

(Partly adapted from Forest Service, 2007)

Activity	Item	Cost
Establishment	Fencing	700
	Scrub clearance	200
	Ploughing and ripping	250
	Plants	1,500
	Planting	700
	Filling-in	350
Early management	Vegetation control	700
	Shaping	400
	Pruning	300
	Tending	500
	Roading	500
	First thinning	850
	Total	**6,950**

with configuration (shape) of the forest area. It can be higher for long narrow strips and lower for areas approaching a square configuration. For purposes of the example chosen, a roading density of 14 linear m/ha is assumed at a cost of €37/linear m. This equates to a road development cost of approximately €500/ha.

This schedule will be used in Chapter 3.5.2.6 in calculating the profitability of the undertaking.

3.5.2.5 Revenues

Revenues are derived from two sources:

(1) In the early years establishment grants and annual premiums provide a supplementary income.

(2) Later in the rotation, a tending and thinning grant, returns from intermediate thinnings and from the final harvest provide the main revenue.

Together they provide the total revenue.

(1) Revenues from grants and premiums

In the late 1980s and early 1990s the Common Agricultural Policy of support for agricultural production generated large export surpluses. These disrupted international trade and led to strong opposition from other agricultural producers, notably the USA. In an attempt to curb agricultural production the EU introduced measures for changes in land use which included afforestation. These were directed at landowners with the specific intention of inducing them to convert the better quality land to broadleaf plantations. Subventions, similar to those associated with agricultural use, had to be put in place in the form of planting grants and premiums to make the change financially attractive. These were periodically reviewed to ensure adequate uptake.

Forestry became an attractive alternative land use for many farmers. Grants and premiums were weighted in favour of broadleaves in recognition of their generally higher establishment costs, slower growth and delayed monetary returns.

The grants and premiums applicable for afforestation with broadleaves and conifers that formerly applied are shown in Tables 3.5-2 and 3.5-3. Grants are paid in two instalments, 75% in year one and 25% in year four. Premiums are paid annually for the stated duration and the amount is dependent on plantation size and species.

Data in Table 3.5-2 show the clear weighting of grants in favour of broadleaf species.

Table 3.5-2: Grants for Afforestation Scheme (applicable from 01.09.2006). (Adapted from Forest Service, 2007)

Category	Species	Total Grant €/ha
Broadleaf woodland	Approved species other than oak and beech	5,200
	Oak 75 -100% stocking	6,920
	Beech 80-100% stocking	7,600
Enclosed and improved land	Diverse conifers	3,900
	20% diverse conifers	3,600
	Non-diverse conifers	3,400
Unenclosed land	All	3,400

* Grants and Premiums are subject to change. For current (2015) levels see the Forest Service website www.agriculture.gov.ie/forestservice.

In addition to the grants and premiums for afforestation, a grant for road construction is available. It is assumed that this grant will continue to be available in future and, since this grant effectively covers the cost of road construction, it makes the operation cost neutral.

In 2009,two changes to the grants and premium schemes were introduced. Under the Woodland Improvement Scheme a tending and thinning grant, up to a maximum of €750/ha, became available to encourage owners to undertake early management measures in broadleaves which are invariably uneconomic.

For oak and beech in particular the grants are almost twice that of conifers. The difference in premium rates between broadleaves and diverse conifers is of lesser degree (Table 3.5-3).

For the oak example chosen, the relevant grants and premiums for oak are summarised in Table 3.5-4.

(2) Revenues from thinnings and final harvest
The main source of revenues from a forest plantation is that obtained from the sale of intermediate thinnings and timber from the final harvest. In order to derive such revenues for oak certain assumptions must be made in regard to the plantation characteristics.

These assumptions are

- productivity of yield class 6 (6 m^3/ha/yr),
- rotation length of 120 years,
- timber of reasonable quality.

Table 3.5-3: Premium Rates* for Afforestation Scheme.
(Applicable from 01.01.2007)
(Premiums were modified in 2009 by a reduction of 8%)
(Adapted from Forest Service, 2007)

Species	Ownership: farmer <6 ha (€/ha/year)	farmer >6 ha	farmer >12 ha	non-farmer
Broadleaves (except oak and beech)	510	520	540	210
Oak	540	560	570	210
Beech	540	560	570	210
Diverse	480	490	510	200
20% diverse	450	460	480	200
Sitka spruce/Lodgepole pine	380	400	420	200
Unenclosed	240	240	240	200

* Grants and Premiums are subject to change. For current (2015) levels see the Forest Service website www.agriculture.gov.ie/forestservice.

Table 3.5-4: **Grants** and **premiums** for **oak.**

Activity	Grant €/ha	Premium €/ha/year
Afforestation	6,920	515 (= 560 less 8%) for 20 years
Roading	500	
Woodland Improvement Scheme (tending and thinning)	750	

* Grants and Premiums are subject to change. For current (2015) levels see the Forest Service website www.agriculture.gov.ie/forestservice.

Forestry Commission yield models provide the data for periodic thinning and final harvest volumes/ha for an oak plantation of yield class 6 grown on a 120 year rotation (Edwards and Christie, 1981). These volumes apply to fully stocked stands. Since a small portion of the area is occupied by roads and other unstocked areas it is customary to make an allowance for these by deducting 10-15% of yield table volumes. In the example chosen this is taken to be 10%.

These volumes are summarised in Table 3.5-5 and converted to monetary values by combining them with a price per m^3 based on size category (average diameter) obtained from Figure 3.5-2. The price/size curve is based on a synthesis of the best information available from a number of sources (Barry, 2009; Heaney, 2008; Phillips, 2005; Pryor and Jackson, 2001).

Table 3.5-5: Revenues from oak thinnings and final **harvest**.

Activity	Volume m^3	Price €/m^3	Value €
Periodic thinnings	288*	22-72	8,163
Final harvest	257	108	27,756

*Sum of all profitable thinnings. Note that the 1st thinning is assumed to incur a cost (refer to Table 3.5.1).

(3) Total revenue
To complete the schedule of total revenue, income from appropriate grants and premiums (refer to Table 3.5-4) are added to the returns from thinnings and the final harvest (Table 3.5-5). This schedule of revenues will be used in calculating profitability.

3.5.2.6 Calculation of profitability

Analysis of profitability for most enterprises involves an annual comparison of costs and revenues. Forestry, however, differs from all other enterprises because of its long rotations. Furthermore, most of the costs come in the early years while revenues come in the latter half of the rotation. To compare these costs and revenues they must all be brought to a common base which is usually year zero – the present.

The procedure is summarised by Davis and Johnson (1987) and involves four steps:

(1) A decision regarding the length of the period over which the costs and revenues will be evaluated.
(2) Identification of the schedule of operations associated with the project.
(3) Conversion of the operations to their equivalent schedule of costs and revenues.
(4) Adjustment of the costs and revenues by bringing both to a common point in time using compound interest formulae.

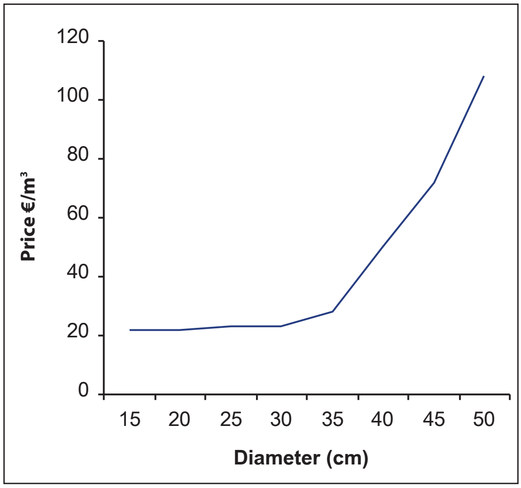


Figure 3.5-2: Stumpage price-size curve for Irish oak.

The information required to complete steps (1)-(3) for the oak example has already been provided in Chapter 3.5.2.5 and Tables 3.5-1 to 3.5-5. To complete step (4), the costs and revenues are discounted to year zero using test discount rates of 2, 3, 4 and 5%.

The value for each discount rate at year zero is referred to as the net present value and represents the difference between discounted revenues and discounted costs. The net present value can also be expressed in terms of an annual payment over the lifetime of the project – annual equivalent. Both of those financial indicators – **with** and **without** grants and premiums – for the above four test discount rates, are shown in Table 3.5-6.

Table 3.5-6: Net present values and **annual equivalents** - with and without grants and premiums. (Land value = €10,000/ha)

Discount Rate	Net Present Value		Annual Equivalent	
	with grants and premiums	without grants and premiums	with grants and premiums	without grants and premiums
%	€/ha			
2	3,398	-12,056	75	-265
3	227	-14,249	7	-440
4	-1,281	-14,916	-52	-602
5	-2,177	-15,079	-109	-756

The data in Table 3.5-6 show that (**with** grants and premiums included) a discount rate of 2% will return a net present value of almost €3,400/ha for the project. At 3% the return is much lower at almost €230/ha and at 4% the return is negative, i.e. even with grants and premiums it needs a substantial subsidy to satisfy a 4% discount rate.

From inspection it will be observed that the discount rate, at which discounted costs equal discounted revenues, is slightly greater than 3%. When determined by formula it is found to equal 3.1%. This is known as the internal rate of return. It is the earning power of the project and in forestry terminology it is often referred to as the financial yield**.**

The contribution to profitability made by grants and premiums can be evaluated by recalculating the same data, but **without** the inclusion of grants and premiums (Table 3.5-6). At the test discount rates selected all data for net present value and annual equivalent show negative values. The internal rate of return (0.06%) – the financial yield from the project – is less than 0.1%, a rate of return unlikely to attract many investors. This highlights the necessity for subventions, especially for long rotation broadleaves, when grown by the farming sector. For large organisations the need is less acute as broadleaves form part of a much larger portfolio of species.

It should be emphasised that the evaluation procedure outlined above is based on estimates of current costs and revenues and the assumption that these relativities will be maintained. The method makes an assumption of stability over the next century which is unlikely to be achieved judging by events of the past. Economists will argue that financial forecasting for a period longer than 10 years is all but meaningless. For that reason, the growing of oak requires an act of faith in the future. Markets will undoubtedly change as they have done in the past. It is worth recalling that the growing of oak for the navy in previous centuries produced the veneer and furniture quality oak of today. There is no way of foretelling what the value of oak will be when the stand matures over 100 years from now. Yet, the indications are that quality oak timber will become a premium product as the supply of tropical hardwoods continues to decline. However, in the absence of concrete data this was not factored into the calculations.

It will be noted that the greater majority of the revenue comes from the final harvest (refer to Table 3.5-5). This can be increased by improving the quality (and price) of harvested product, a process which commences at the qualification phase and is reinforced at the dimensioning phase of stand development (see Chapter 4.5.3.1).

It is sometimes argued (since private owners do not have to purchase the land and it remains their property at the end of the rotation) that it should not be regarded as a cost. This is a specious argument that ignores the opportunity cost of afforesting the land. It can be estimated as the agricultural output foregone or the rental income from leasing the land. Advances in agricultural technology may increase this opportunity cost. Nonetheless, a financial analysis should include the price of land although it should be recognised that not all land owners are motivated to plant broadleaves for purely financial reasons.

Conclusions

The above calculations show that grants and premiums undoubtedly play an important role in forestry and for very good reasons. As illustrated in the example, the growing of oak, and by extension most broadleaves, would not be profitable for small landowners without subventions. For many landowners, and particularly for older dairy farmers anxious for a less arduous way of life, but unwilling to sell their land, broadleaf premiums provide a secure income for 20 years without having to incur the daily hardship of animal and crop husbandry. However, it is worth noting that while trees are less demanding on the owner's time than livestock or tillage they will handsomely repay inputs in timely shaping, pruning and thinning.

3.5.3 Economic impact of forestry on society

The contribution made by forests extends far beyond economic benefit to the individual. The previous Chapter 3.5.2 took into account only the benefit to the individual. Any benefits that might accrue to a community or to the nation were not taken into consideration. This aspect of forestry will now be addressed.

In recent years a number of studies have explored the economic contribution of forestry to Irish society in general, among which the following are considered to be relevant:

- Clinch (1999) employed a cost benefit analysis framework to assess the social efficiency of afforestation in Ireland using the 1996 Strategic Plan as a case study (refer to Chapter 1.4). In his approach he estimated the value of non-market outputs (recreation, carbon storage, biodiversity, water quality) associated with forestry by using non-market valuation techniques to assign monetary values to these externalities. The approach allowed evaluation of the costs and benefits of forestry to members of society other than the forest owners.

  Tangible inputs of land and labour and the marketed output of timber were also taken into account in the analysis. Benefits and costs were adjusted for time of occurrence using test discount rates. It was concluded that implementation of the Strategic Plan, and the resulting expansion of the forest estate, would yield a rate of return of approximately 4% to the national economy.

- In reviewing the Strategic Plan, Bacon (2004) estimated that almost 4,000 people were employed in crop establishment and harvesting and in excess of 6,000 in timber processing. Commenting on the linkages with other sectors of the economy it was estimated that for every five jobs created directly in forestry, three additional jobs were supported elsewhere in the economy. The reviewers accepted that it was difficult to put precise estimates on the value of public goods for which prices and markets did not exist. Nonetheless, employing analytical techniques similar to those used by Clinch (1999), it was deduced that the then current total non-timber benefits of Irish forests were worth €88.4 million/year.

- The linkages that connect the forestry sector with other sectors of the economy were addressed by Ní Dhubháin et al., (2006) using an input-output approach. This enlarged on previous studies by evaluating the impact of the forestry sector on the national economy.

  The ways by which forestry contributes to the economy were assessed through direct, indirect and induced contributions.

  Direct contribution is the impact of the spending by the forestry sector on goods and services.

  Indirect contribution is that which occurs when suppliers to forestry firms purchase goods and services to meet demand.

  Induced contribution refers to the additional consumer expenditure that takes place when the wages and salaries generated from the direct and indirect contributions of forestry are in turn spent.

  The sum of these three contributions represents the total contribution of forestry to the economy which can be expressed in monetary terms or in employment.

  Output and employment multipliers were derived for forestry and the wood product (panelboards, sawmills and other wood products excluding furniture) sectors. These were applied to data to determine the direct, indirect and induced contributions of forestry to the Irish economy.

  Key results from the study showed that the activities of the forestry and wood product sectors made the following contributions to the national economy in 2003 (Table 3.5-7).

Table 3.5-7: Contributions of the forestry and wood products sectors to the national economy. (Ní Dhubháin et al., 2006)

Sector	Output		Gross value added		Employment	
	direct	total			direct	total
	€ million			% of GNP	no. of people	
Forestry	255	472	135	*0.12*	3,789	7,182
Wood products	975	1,650	312	*0.27*	6,870	12,246

The data for these sectors indicate:

- **Forestry**
  The **total gross output** was €255 million, but for every euro of output from forestry a further 85 cent was generated to give a total output (including indirect and induced outputs) of almost €475 million. €135 million of the above €255 million was gross value-added, representing 0.12% of GNP.

  Direct employment in forestry was almost 3,800, but taking into account indirect and induced effects, the total employment was estimated to be almost 7,200.

- **Wood products**
  In this sector **direct output** was €975 million. €312 million of this was gross value-added, representing 0.27% of GNP.
  The three wood products sectors – panelboard mills, sawmills and other wood products (excluding furniture) – generated a total value to the economy of €1.65 billion, nearly 3.5 times the forestry sector contribution of €472 million.
  Direct employment in the wood products sector was 6,870 persons. When indirect and induced impacts are taken into account the wood products sector supported almost 12,250.

Conclusions

Growing broadleaves involves a large financial investment over a long time period with relatively low economic returns until final harvest. It is a low-risk investment, but the interest accumulation over a long rotation can be considerable. Subventions in the form of grants and premiums are essential for the private owner undertaking such a project.

Timber quality, particularly that coming from the final harvest, is paramount.

Wood provides the raw material for many industries such as sawmills, panelboard mills and other wood products thereby generating employment and gross value-added.

In addition to material products the forest generates externalities which are enjoyed by society. Non-market valuation techniques have helped to quantify these benefits.

3.6 Forest policy

Policy generally refers to the principles that govern action directed towards a defined goal or objective.

Forest policy is defined as a course of action, selected and adopted by a government, organisation or individual, which is followed in order to guide and determine future conditions relating to the forestry sector.

Forest policy in Ireland is formulated by government along with other stakeholders. Organisations involved include landowners, including the farming community, the processing sector and NGOs.

The events that led to the creation of forests during the 20th century have been described in Chapter 1.4. In this chapter, EU developments relating to forests will be addressed. This will be followed by a discussion on the forest policy being pursued by the Irish Government. The role played by the other organisations will be referred to as appropriate.

3.6.1 EU developments relating to forest policy

The EU does not have a forest policy as such; it is a Member State competency. However, there is a long history of EU measures supporting certain forest-related activities, coordinated mainly through the Standing Forestry Committee.

A significant policy-related process is the EU Forest Strategy. In September 2013 the EU Commission adopted a new strategy to address new challenges facing forests and the forest sector. It replaced the earlier strategy which dated back to 1998.

The strategy addresses aspects of the value chain (the way forest resources are used to generate goods and services), which influence forest management. It states that the role that forests play is important not only for rural development, but also for the environment and biodiversity, for forest-based industry, bioenergy, and in the fight against climate change. It also emphasizes that the impacts of other policies need to be taken into account. It advocates that linked EU policies should be considered in national forest policies.

A cornerstone of the strategy is sustainable forest management defined as:

Sustainable forest management means using forests and forest land in a way, and at a rate, that maintains their biodiversity, productivity, regeneration capacity, vitality and their potential to fulfil, now and in the future, relevant ecological, economic and social functions, at local, national, and global levels, and that does not cause damage to other ecosystems.

To achieve common objectives and improve coherence and synergies, the strategy states that coordination with and between Member States is important. Member States were asked to consider the **guiding principles** and goals of the strategy when setting up and implementing their action plans and national forest programmes.

The guiding principles comprise:

- Sustainable forest management and the multifunctional role of forests, delivering multiple goods and services in a balanced way and ensuring forest protection;
- resource efficiency, optimising the contribution of forests and the forest sector to rural development, growth and job creation;
- global forest responsibility, promoting sustainable production and consumption of forest products.

The strategy enunciates a number of forest objectives, developed together with Member State authorities and stakeholders, which address the three dimensions of sustainable development in an integrated way, providing a holistic approach to forest management and policy. Its purpose is:

To ensure and demonstrate that all forests in the EU are managed according to sustainable forest management principles and that the EU's contribution to promoting sustainable forest management and reducing deforestation at global level is strengthened, thus:

- contributing to balancing various forest functions, meeting demands, and delivering vital ecosystem services;
- providing a basis for forestry and the whole forest-based value chain to be competitive and viable contributors to the bio-based economy.

Conclusions on the new strategy were adopted by the Agriculture and Fisheries Council in May 2014. The ministers acknowledged that the new EU Forest Strategy should enhance coordination and facilitate the coherence of forest-related policies and should allow for synergies with other sectors that influence forest management and offer the key reference in EU forest-related policy development.

The European Parliament adopted a Resolution in April 2015 welcoming the strategy. The Resolution stressed that the EU forest strategy must focus on the sustainable management of forests and their multifunctional role from the economic, social and environmental viewpoints and must ensure better coordination and communication of Community policies directly or indirectly linked to forestry.

EU influences on Irish forestry

Since accession to the EU in 1973 Irish agriculture has benefited enormously. The benefits to forestry, however, came later by an indirect route. Not until large agricultural surpluses became a costly embarrassment did forestry emerge as an alternative land use (refer to Chapter 1.4).

In the 1990s EU Forest Policy merged with Irish government policy to produce afforestation grants and premiums as a form of support to landowners, mainly farmers, exiting agricultural production. Nonetheless, forestry benefited indirectly and afforestation by farmers became the main driving force of the Government Strategic Plan for the development of the forest sector (refer to Chapter 1.4.3). The grants and premiums were weighted in favour of broadleaves. It was also stipulated that broadleaves should constitute 20% of all afforestation. This target was subsequently raised to 30%. Combined EU and Irish Government grant aid ceased in 2008 when the Irish Government assumed sole financial responsibility. At that time, the EU Forest Action Plan contained a number of principles relating to the enhancement of biodiversity, the health of forest ecosystems and the general protection of the environment. EU membership brought with it an acceptance of these principles and accompanying measures which have an impact on landuse. The directives which affect forestry are summarised in Table 3.6-1. Their impact on afforestation will be considered in Chapter 3.6.2.

Table 3.6-1: Main **directives with an impact** on forestry.

Directive	No.	Designation	Impact
Birds	79/409/EEC	Special Protection Area (SPA)	Afforestation may conflict with species whose habitat is marginal agricultural land.
Habitats	92/43/EEC	Special Area of Conservation (SAC)	Prohibition on forestry operations (e.g. drainage, cultivation, thinning) without consent of Minister of the Environment, Heritage and Local Government.
Environmental Impact Assessment	85/337/EEC	Mandatory EIA	This assessment required for proposed plantation exceeding 50 ha.

3.6.2 Forest policy in Ireland

Review of policies and objectives

A renewed forest policy was issued in 2014 as *Forests, products and people – Ireland's forest policy – a renewed vision*. The policy sets out an updated national forest strategy, and reflects the substantial changes that have occurred in Irish forestry since the previous strategy *Growing for the Future* was published in 1996. The new policy is designed to steer the expansion of the forestry sector to 2046 in a sustainable and cost efficient manner. The strategic goal is stated as:

To develop an internationally competitive and sustainable forest sector that provides a full range of economic, environmental and social benefits to society which accords with the Forest Europe definition of sustainable forest management.

The renewed policy continues the target for broadleaves at an area equivalent to 30% of the annual afforestation programme. It goes on to state that in order to broaden the scope and responsibility for increasing the area of broadleaves, the Department of Agriculture, Food and the Marine will introduce an overall indicative national target level of 10% broadleaf species in reforestation, taking into account economic and site suitability considerations. This figure will be monitored and reviewed periodically (Department of Agriculture, Food and the Marine, 2014).

A summary of the recommended policy and actions is outlined below:

- Expansion of the forest resource – To increase the forest area, in accordance with sustainable forest management principles, in order to support a long-term sustainable roundwood supply of 7/8 million cubic metres per annum.
- Management of the resource – To ensure the sustainable management of the forest resource in accordance with best practice thereby ensuring its capacity to provide the full range of timber and other benefits.
- Environment and public goods – To ensure that afforestation, management of existing forests and development of the forestry sector are undertaken in a manner that ensures compliance with environmental requirements and objectives and enhances their contribution to the environment and their capacity for the provision of public goods and services.
- Supply chain – To further develop an efficient, sustainable and environmentally responsible supply chain that is compatible with forest volumes, which will enhance the

competitiveness of the processing sector and its wood paying capacity to forest owners.

- Wood processing – To support the development of a competitive, innovative, value-added and market focused wood processing sector which provides sustainable solutions to a diverse portfolio of users in the construction, lifestyle, renewable energy, furniture and related markets.
- Forest protection and health – To maintain a healthy forest environment through sustainable forest management and early detection and control measures to prevent the introduction and spread of harmful invasive alien species, pests and diseases.
- Education training and research – To ensure the availability of suitable programmes of education and training across the sector and research programmes targeted at identified needs.
- Quality standards and certification – Forest products, forest services and the management of the forest resources will have a strong, market-led, quality focus.
- Policy implementation and review – Policy will be implemented through ongoing monitoring and reporting of progress in consultation with stakeholders, and the policy will be updated to meet changing needs and circumstances.
- Funding – To support the development of the forest sector through a combination of funding and fiscal arrangements including joint EU funding, direct state funding and facilitating private investment.
- Legislation – To ensure that forest related legislation is relevant to the needs of the sector and underpins the principle of sustainable forest management while recognising the multifunctional nature of forestry.
- Institutional arrangements – To support the development of the Forest Service as an efficient delivery service organisation meeting the needs of Government, national forest policy and the forest sector.
- Sectoral Development – To set up a Task Force to consider the establishment of a stand-alone government body or agency which could have the responsibility of addressing the development and promotional issues of the forest sector.

In its review of the 1996 Strategic Plan, the Bacon Report (refer to Chapter 1.4.3) reaffirmed the Plan's objectives and concluded that 20,000 ha per annum up to 2035 was the most appropriate minimum target to secure a sustainable commercial processing sector (refer to Chapter 1.4). Although afforestation, at the then average rate of 14,000 ha/yr, would see a major increase in output during the period 2030-2040, it would lead to a fall of 25% after 2040.

The shortfall in afforestation targets in the 1996-2003 period was noted with some concern. This was, however, tempered by a general expectation that the then impending reform of the Common Agricultural Policy in 2005 would bring about a change in farmers' attitudes with regard to forestry. The extent of this change was expected to provide sufficient land for an afforestation programme of 20,000 ha/yr. This expectation was not realised. On the contrary the rate of afforestation continued to decline and in 2007 had reached its lowest level in the previous 20 years at less than 7,000 ha, and has continued at that level in more recent years.

This low level was influenced by a number of factors which are discussed below.

Factors affecting afforestation targets

The factors influencing afforestation targets can be grouped into three categories:

(1) economic,

(2) socio-economic and
(3) environmental.

(1) Economic factors
The main economic-related factors affecting afforestation in the State and private sectors are:

- **Withdrawal of Coillte** from afforestation activities.
- The relativity between payments under **competing land use** schemes.
- The **price of land and land availability**.

These factors will be considered in detail below.

Withdrawal of Coillte from afforestation programme
Implicit in the 1996 Strategic Plan was the expectation that the afforestation programme would be undertaken on a shared 70:30 basis between the private and public sectors (Coillte). Any likelihood of this occurring was, however, quashed by the decision of the European Court that Coillte as a public entity could not claim premium payments (refer to Chapter 1.4). As a consequence of this decision, Coillte considered that it did not make economic sense to purchase land for forestry purposes. Its land leasing and partnership arrangements with landowners had contributed little to the overall target.

Competing land uses
Of the competing land uses the Rural Environmental Protection Scheme (REPS) was identified in the Strategic Plan and the Bacon Review as a major competing attraction to afforestation for many farmers.

(REPS was a contract scheme designed to reward farmers for carrying out their farming activities in an environmentally-friendly manner and to bring about environmental improvement on existing farms. The contract period was five years).

In 2009 REPS was discontinued for all new entrants. Those already contracted would have their contracts terminated at the end of the contract period.

Compared with the long-term change of land use associated with forestry, REPS provided financial support over a relatively short time-frame without significant change in land use. It was a very popular scheme with landowners and had an estimated 60,000 participants in contrast to less than 17,000 engaged in forestry (Farrelly, 2007).

A number of initiatives were designed to restore the balance between the competing schemes. Of these the most significant was the Forest Environmental Protection Scheme (FEPS) which was designed *to encourage the establishment of high nature forestry on farms which participate in REPS*.

Grants and premiums were payable at full afforestation rates with an additional annual premium of up to €200/ha/yr for the first five years. Malone (2008) reported that those involved in the sector recognised the initiative as a reasonable attempt to put forestry on a level footing and to create a synergy with the Rural Environmental Protection Scheme.

GLAS is the new agri-environment scheme of the Department of Agriculture, Food and the Marine, and is part of Ireland's Rural Development Programme 2014-2020. The scheme aims to preserve traditional hay meadows and low-input pastures, and to retain soil carbon stocks in soil through habitat preservation, and practices such as minimum tillage. It includes a measure called *Planting a Grove of Native Trees*, with a minimum area of 0.05 ha containing 250 trees and/or maximum area of 0.09 ha containing 450 trees. Native trees only are permitted to be planted.

Price of land and availability
Although the high price of land may not be an issue for landowners considering afforestation it has a major influence on forestry investment companies' decision-making and was the

main factor causing Coillte to withdraw from afforestation. The prevailing price of land can be expected to have an impact on afforestation in areas other than the farming category (refer to Chapter 3.5.2.3).

While price has an impact on land availability to Coillte and the private investment sector, land availability is not an inhibiting factor to afforestation within the farming community. In a study of factors influencing farmer participation in forestry, Collier et al., (2002) estimated that 37,000 farmers owned 490,000 ha of land that was difficult to farm which could be planted without having an impact on other scheme entitlements. Possible reasons as to why this land is not being afforested will be explored below.

(2) Socio-economic factors

Although the factors listed above, which are largely economic, are considered to be the main impediments to afforestation in general there are others of a socio-economic nature which provide constraints on farm afforestation.

Kearney (2001) cited a study by Hannan and Commins (1993) on the influence of such issues on decision-making relating to land use. They concluded that the availability of land for afforestation is dependent on the interplay of a number of factors giving rise to the following trends:

- A reduction in the number of people entering farming and an increase in part-time and retirement farming.
- With the rural economy becoming more dependent on non-farm jobs, land-use is likely to change with part-time farming, but this can also have a negative influence on land mobility.
- Public policies of an economic, social or structural nature have a profound influence on the character of land-use and land mobility.
- Individual decisions with regard to land use will be influenced by the subjective disposition of the landowner, the characteristics of the farm household and of the holding.
- The availability of land for afforestation depends not only on the incentives available, but also on awareness levels, promotion activities and technical support systems.

Exploration of these trends is beyond the scope of this chapter, but the following points are relevant:

- Availability of off-farm employment makes afforestation more attractive to many landowners.
- The most often cited reason for planting was that the land was of limited utility for other enterprises – in short, it was considered to be of little use for anything else.
- Concern that the decision to afforest once enacted becomes irrevocable.
- Forestry is generally considered by farmers to be too long-term in nature.

Although many farmers are not interested in forestry, there is a growing number of young farmers who have taken to forestry with enthusiasm, as well as a larger group of older farmers who see forestry as a less arduous way of life.

(3) Environmental considerations

As stated in Chapter 3.6.1 the 1998 EU Forestry Strategy framework adopted as its overall principle the enhancement of sustainable forest management and the multifunctional role of forests. Within this framework the EU Forest Action Plan contains a number of objectives which include the enhancement of biodiversity, the health of forest ecosystems and the general protection of the environment.

In addition, there are number of EU Directives, that impact on afforestation. These are summarised in Table 3.6-1.

The EU directives have influenced afforestation and forestry operations in certain areas. These include areas which are designated as Special Protection Areas (SPAs) or Special

Areas of Conservation (SACs), which are in certain circumstances excluded from grant aid for afforestation. Also, arising from the EU directives, there are a number of Forest Service regulations and guidelines aimed at the protection of the environment which impinge on afforestation.

The Forest Service Biodiversity Guidelines require that plantations in excess of 10 ha must have a minimum of 15% of the total area set aside as Areas for Biodiversity Enhancement (ABEs). Although the annual premium is paid on this area for 20 years, after that time it is no longer generating income. With forest land costing about €10,000/ha this can represent a significant cost to the owner.

The greatest impacts of these guidelines on forestry, however, will probably be in relation to water quality and biodiversity. They are briefly described below.

The framework of sustainable forest management in Ireland encompasses the *Code of Best Forest Practice (Forest Service, 2000a)* and the environmental guidelines relating to afforestation near rivers and streams and the effect on water quality.

Of particular relevance to afforestation with broadleaves such as oak is the restriction on planting in highly sensitive acid areas, which cover some 9% of the country and in which most of the sessile oak native woodlands are located. On such sites water testing is mandatory prior to an application for afforestation. No planting is allowed where the level of calcium carbonate is below 8 milligrams/litre. Consultation with the Environmental Protection Agency is required where the level is 8-15 milligrams/litre (Forest Service, 2002b).

Appraisal of recent Irish forest policy

Annual levels of afforestation have fallen short of the targets in *Growing for the Future*, which in hindsight were overly optimistic. Reasons for this are put forward in general terms in Chapter 3.6.2 above. More specifically, the relative attractions of competing land use schemes, e.g. REPS and the single farm premium, when weighed against the irreversibility of the decision to afforest, has likely caused landowners to adopt a wait-and-see attitude.

Surveys have revealed that many farmers view forestry as suitable only for land perceived to have limited utility for other land-use enterprises. The surge in farm forestry in the years preceding the 1996 Strategic Plan reduced the level of marginal agricultural land resource and as further planting began to encroach on better land it led to a gradual fall in afforestation.

In the Common Agricultural Policy Rural Development Plan 2000-2006, which supported the forestry programme during that period, it was pointedly stated that the objective of forestry was to provide additional income to farmers and rural dwellers (Collier et al., 2002). This puts forestry in the position of being a mere adjunct to agriculture in the context of policy implementation, and it becomes primarily another avenue to disburse supplements to farm income supports.

Remarking that this view dominated the approach by both policy-makers and growers, Bacon (2004) recommended greater emphasis on enterprise development. The recent assumption of full responsibility for forestry supports by the Irish Exchequer might, however, provide the opportunity to break this link between forest and farm. *Forests, products and people. Ireland's forest policy - a renewed vision* (2014) made a number of recommendations regarding the duration and level of premium support for afforestation as well as removing the difference in support between farmers and non-farmers. Most of these recommendations have been taken up in the Forestry Programme 2014-2020. More recently COFORD has published a comprehensive report on *Land Availability for Afforestation - Exploring opportunities for expanding Ireland's forest resource* (2016).

3.6.3 Future prospects

Future policy developments should take into account the possible contribution to afforestation targets by both private and public sectors and how this should be apportioned between conifers and broadleaves. In this context it should be noted that, whereas conifers can be accommodated on marginal land, in general the growing of high quality timber producing broadleaves comes into direct competition with agriculture usage. Using current land usage as a benchmark it should examine future events which have the potential to increase or decrease the availability of land for afforestation in both (1) private and (2) public sectors.

These events are explored below for both sectors.

(1) Private sector

The potential contribution of the private sector to afforestation rests with landowners, who are mainly farmers, since the price of land has effectively ruled out private forest investment companies.

At the global scale biofuel production and liberalisation of world trade were previously regarded as having a potential to influence land usage by farmers and possibly the potential availability of land for afforestation. While these issues have to some extent been overtaken, on the one hand, by the fall in oil prices and on the other by the overall failure of world trade talks, they may re-emerge at a future date. These points are separate to the ongoing trade negotiations between the EU and the US under the Transatlantic Trade and Investment Partnership (TTIP) process.

Biofuel

Volatility in the price of oil has been a major factor of concern in the western world for some time. As the price of crude continued to rise in the spring of 2008, to reach a peak at over $147 a barrel in July, the debate on choice of alternative energy sources was again resumed. This debate has become more muted since the fall in oil prices from mid 2014. Nevertheless arising from the EU Council Decision in October 2014 to reduce greenhouse emissions compared to 2005 levels by at least 40%, and following the recent Paris Agreement on climate change, there is strong policy imperative to reduce the use of fossil fuels.

Europe has to some extent embraced biofuel production in the form of biodiesel which accounted for half of EU vegetable oil crops such as oil seed rape. Its production targets were 5.75% by 2010 and 10% by 2020. Irish farmers were also being encouraged by Government to become stakeholders in biofuel production. In early 2008 an immediate target of 2.2% of transport fuel was announced, but this was soon modified to a more gradual sustainable increase backed up by research.

When it comes to land use the current generation of biofuels are extravagant and inefficient. According to Caslin (2009), tillage land in Ireland amounts to approximately 300,000 ha. To have achieved the EU liquid biofuel target of 5.75% by 2010 would have required 180,000 ha of oilseed rape (OSR) to produce biodiesel (replacing diesel) and 75,000 ha of wheat to meet the ethanol (replacing petrol) target.

Although second generation cellulose to ethanol and biomass to liquid (BTL) technologies are likely to become commercially realisable in the near future, there is still a need to adopt some level of development of first generation biofuels if second generation biofuels, which require less land, are ever to make a contribution.

In the autumn of 2008 the urgency of biofuel production receded as global events became more pressing. Malpractice in the banking sector led to a credit crisis and a global economic downturn. The credit crisis evolved into a credit crunch causing serious disruption to national economies and bringing about a recession in the western world. Concern about energy sources was shelved as countries sought to save their banking systems from collapse. The demand for oil plummeted due to constriction in industrial output and crude prices tumbled to $53 a barrel in November 2008 and below $36 a barrel at the end of that year. The return of cheap energy from fossil fuel took the pressure off biofuel production, at least temporarily. Despite the subsequent recovery in oil prices they have fallen again in the period since 2014 to levels below those obtaining at the end of 2008.

In the absence of an energy revolution it is likely that solid biomass and to a lesser extent liquid biofuel, along with wind, solar and wave energy, will continue to have a strong role in energy policy, but not to the extent that It will result in the levels of land-use change for biofuel production foreseen by some commentators.

Liberalisation of trade

The World Trade Organisation (WTO) negotiations aimed to liberalise world trade in agriculture, industrial products and services by cutting tariffs and trade-distorting subsidies. The EU estimated that agreement could have boosted global income by as much as €100 billion each year. After seven years of failure to reach agreement the negotiations collapsed in July 2008.

The collapse was greeted with enthusiasm by the Irish Farmers Association who had predicted that an agreement would put 50,000 farmers out of business as Irish beef prices came into competition from South American imports. Although the magnitude of the impact on agriculture was strongly disputed by Matthews (2008) it is likely that some livestock farmers might have resorted to alternative land-use in the event of an agreement. The collapse of negotiations has maintained the status quo. As of 2015 the WTO reported that 'Divergence remains as WTO members look at new agriculture proposals'. The outlook for availability of farm land for broadleaves is not promising.

From a forestry point of view, afforestation targets since 1996 have fallen short of expectations. If the new target in *Forests, products and people. Ireland's forest policy - a renewed vision* is to be realised the commercial state sector needs to be more actively involved in afforestation. It is significant, however, that while conifer planting sustained an almost continuous decline in recent years, broadleaf afforestation maintained a steady 2,000 ha/yr. This should be accepted as the new broadleaf target for the private sector over the next decade.

(2) Public sector

As stated in to Chapter 3.6.2, the policy statement set the annual broadleaf afforestation target at 30%. To date the private sector has been almost the sole contributor to the broadleaf target.

The EU finding that Coillte was a public entity, and could not avail of grants designated for farmers, effectively ruled it out of acquisition of land for afforestation because of the high costs involved. As a result, its planting activities were confined to reforestation for which no grant is available and, for commercial reasons almost all its reforestation was of conifer species. However, with the decrease in land price (refer to Chapter 3.5) Coillte is now in a better position to enter the market for land. Furthermore, it possesses considerable areas of old estate land suitable for the growing of high quality broadleaves, as well as broadleaf forests that would benefit from species enrichment.

To attain sustainability in the broadleaf programme, and eventually achieve a critical mass, broadleaf afforestation cannot depend solely on the private sector, however laudable its contribution may have been in the past. The State sector must assume a leading role. In that regard, the position today is not very different to a century ago, except that now the target is directed specifically towards broadleaves (refer to Chapter 1.4). It is recommended that the State forest sector should order its land acquisition programme towards land suitable for broadleaves. It should be supplemented by reforestation with broadleaves on suitable sites, already in State ownership, as mature conifer crops are harvested. Under-stocked and over-mature broadleaf forest can be enriched. An overall quota of 2,000 ha/yr over the next decade does not seem unrealistic. This, together with a contribution of 2,000 ha/yr from the private sector, would provide a target of 4,000 ha/yr.

Conclusions

The price of land, in conjunction with competitive land uses such as the Rural Environmental Protection Scheme and the long-term nature of forestry, has been the dominant factor in declining annual afforestation.

EU and public policies have a major influence on land use. For landowners, the future uncertainty associated with such policies reinforces the argument for non-committal to a long-term project which is irrevocable. It is to be hoped that the new afforestation and native woodland establishment schemes under the Forestry Programme 2014-2020 will counterbalance such concerns.

In addition to economic and socio-economic factors, private afforestation is also circumscribed by a number of EU environmental directives which impact on the level of afforestation. Taken together they can retard the progress of afforestation, particularly when the owner has alternative land use options.

The maintenance of the status quo in supports for agriculture is likely to reduce the movement of agricultural land into forestry. Short of a significant long-term financial incentive it is likely that the rate of afforestation in the private sector will continue to decline as marginal land becomes less available.

The decline in the private sector has been most pronounced in conifer afforestation, but broadleaves have remained at a consistent level of more than 2,000 ha/yr. This should be the private sector target for broadleaves over the next decade.

The high cost of acquiring land has ruled out afforestation by the public sector in the past decade. Having regard to the cost of land, it is worthwhile examining the silvicultural condition of broadleaf woodlands (excluding native woodland) in both the private and public sectors with a view to regeneration and improvement of their productivity.

The downturn in the economy in 2008 brought more realism to the market but land prices have stabilised over the past 2-3 years and are now more affordable. For its part Coillte should also aim at reforestation of a portion of existing conifer woodland with broadleaves where the land is suitable. With the enrichment of under-stocked and over-mature broadleaf forest an annual programme of 2,000 ha/yr should be feasible. This will provide a more balanced structure to the national forest estate which is currently dominated by conifers.

There are some 30,000 ha of degraded broadleaf woodland in the private sector with potential for improvement through enrichment or reforestation. In their present condition they may be regarded as areas of biodiversity, but one would question whether that role cannot be adequately fulfilled by productive broadleaf woodland and whether the country can afford the luxury of unproductive woodland at current land prices (see Chapter 4.7).

The issue to be decided by government is the role that broadleaf forests fulfil in the development of national, social and economic policy and what measures are needed to fulfil that role.

4 Silvicultural strategies and procedures

4.1 Characteristics of broadleaf species and forest dynamics in silviculture

4.1.1 Choice of species and their management

Silvicultural planning and management is a complex process that requires extensive background information combined with clearly defined objectives. Many factors have to be considered in choosing particular tree species or mixtures and in their subsequent silvicultural management. These include ecological and socio-economic issues.

Factors that influence the selection of appropriate tree species and the forms of silvicultural management required are illustrated in Figure 4.1-1.

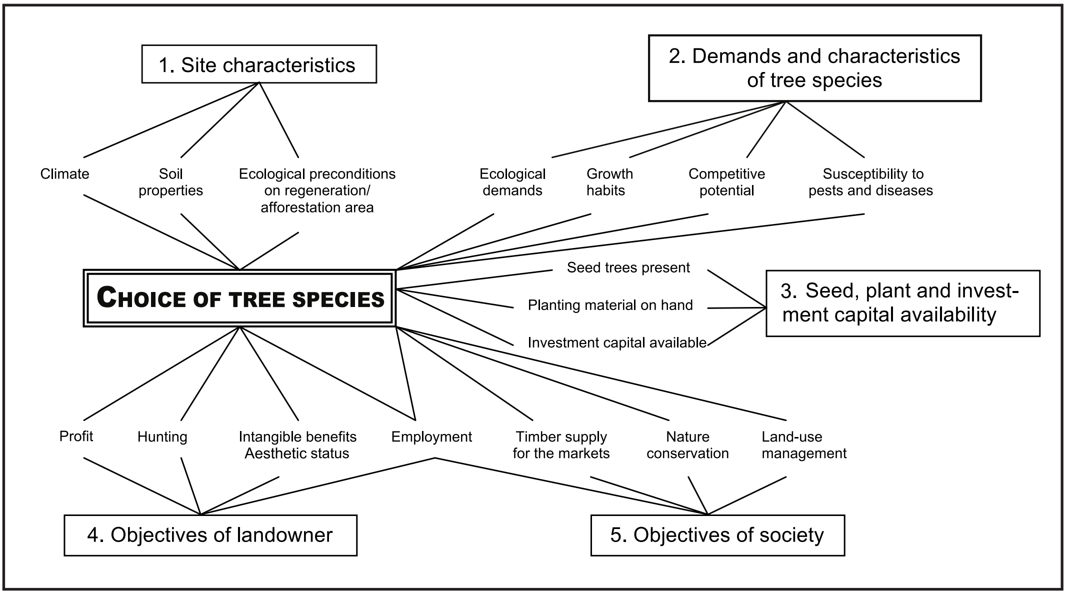


Figure 4.1-1: Main factors concerning **choice of tree species**

There are five main components:

1. Site characteristics,
2. demands and characteristics of the tree species,
3. seed and plant availability,
4. objectives of landowners and
5. objectives of society.

Economic, social and socio-economic factors have been covered in Chapter 3. The main site characteristics – climate and soil – are referred to in Chapter 2, and more information is provided in Chapter 4.4.

Fundamental to silviculture, however, are the demands and characteristics of each tree species. This aspect is dealt with here in detail.

4.1.2 Demands and characteristics of broadleaf species

Apart from site conditions there are other features which influence geographic distribution, growth, regeneration, genetic differences of the species, and ultimately silvicultural management.

These are as follows:

1. Ecological behaviour of broadleaf tree species,
2. regenerative capacity,

3. growth habits,
4 . competitive potential,
5 . provenance,
6 . forest dynamics,
7. potential natural vegetation.

These will be dealt with in the following paragraphs.

4.1.2.1 Ecological behaviour of broadleaf species

From the ecological point of view tree species are divided into pioneer, intermediate and late-successional. This is a comprehensive grouping, which explains ecological differences between the species and is the basis of forest succession. The theory behind it is outlined in Chapter 4.1.2.7, forest dynamics.

Expressed in a generalised way the species within the groups behave as shown in Table 4.1-1.

Table 4.1-1: Main **characteristics of ecological tree species** groups.

Factor	Species group			
	Pioneer		Intermediate	Late-successional
	short-living	long-living		
Ecological behaviour	Highly light-demanding. Frost- and drought-tolerant, not soil-demanding.	Light-demanding, (moderately) tolerant of climatic stress.	(Moderately) shade-tolerant. Slightly tolerant to climatic stress.	Highly shade-tolerant. Intolerant of early and late frost, as well as drought.
Fruiting	Many light seeds, prolific seed production, which starts early (5-10 yrs).	Light seeds, regular fruiting at 2-3 yr intervals.		Heavy seeds, rare mast years, seed production late (30-50 yr).
Timber	Low density, low durability.	Medium density, intermediate durability.		Dense.
Species	Willows, poplars, alder, (birch).	Ash, rowan, Norway maple, walnut, cherry, (oak), (birch).	Lime, sycamore, hornbeam, (oak).	Beech
Life span (yr)	40-60 willows, 60-80 poplars.	60-80 cherry, -500 oak.	-150 sycamore, -500 lime.	200

The information in Table 4.1-1 is a very general overview and is explained in greater detail below:

- **Pioneer species**

  Pioneer species have the capacity to quickly invade newly exposed soil, for instance on landslides, dunes as well as on bare ground such as clearfells. This is because of their resistance to frost and drought stress and their light demands on soil.

  With some notable exceptions pioneers produce large quantities of very light seed which is distributed by wind over long distances from the parent tree. The seeds need immediate and ready access to moisture and nutrients as they lack reserves in the seed. The notable exceptions are long-living pioneers like oak, walnut and cherry. Pioneers develop best on mineral soil, but many succeed on poor soils such as sand, clay, or even in rock crevices because of their low nutrient requirements.

  Seedlings and saplings grow fast over the first two years which enables them to compete with the herbaceous vegetation and to escape the shading effect of the other tree competitors. As they are very light-demanding, they are not very competitive in this regard, therefore, they have to struggle to keep their crowns free.

  Apart from the exceptions mentioned above their timber tends to have a low density and is not very durable. Their life span is relatively short. Typical members of this group are willows and poplars. Their ecological strategy and growth characteristics conform broadly to the factors given in Table 4.1-1.

  As is often the case in biology and ecology, some species do not always comply with systematic classifications. Short-living pioneers tend to grow on poor soils. Black poplar, however, is one of these short-living pioneer species which grows well on undeveloped soils, but only if they have a steady water flow and a high nutrient content. Birch is another exception: though very light-demanding and producing a profusion of light, wind-distributed seed, it produces a more dense timber which resembles that of intermediate species.

There are many more species which do not follow some of the main characteristics of the pioneers. They are those that are light-demanding, but reach a relatively advanced age and have a quite heavy and durable timber. Oak is a very good example of a tree that is light-demanding and intolerant of late frost, but produces heavy seeds in small numbers and has rare mast years – and has a heavy durable timber. The pioneer group can, therefore, be divided into short- and long-living pioneers.

- **Intermediate species**
  Some species such as lime and sycamore are less light-demanding. In their youth they even tolerate relatively heavy shade. Again, there have been attempts to divide this group in two, as some of the species could be regarded as at least moderately shade-tolerant. Hornbeam is an example. Its timber is the hardest of all species native to Europe. However, it does not tolerate too dense a shade, such as that created by a closed canopy of beech.
- **Late-successional species**
  These follow a strategy opposite to that of the pioneers: they are very shade-tolerant. Their seedlings and saplings are able to survive for decades under closed canopy and strong shade, and they need shelter for protection against frost and drought, at least when young. They seed relatively rarely and their timber is dense. Beech is a good example of such a species.

In general, pioneers such as poplars and willows are short-living, whereas most of the others live longer. This grouping system has also been used in the National Forest Inventory.

4.1.2.2 Wood properties of ecological tree species groups

The main timber characteristics of broadleaves relate to their ecological behaviour. Pioneers have soft timber with a low density, while late-successional species have hard timber with a high density (Table 4.1-2).

From this table it is apparent that:

- **Oven-dry weights** which are comparable with density values show a wide range roughly between 0.4 and 0.8 g/cm³.
- Timber **hardness** and **bending strength** generally follow the same trend from very soft (poplar) to very hard timber (hornbeam).
- **Shrinkage rate**, however, only shows a weak correlation with density.

Table 4.1-2: Wood properties of the main broadleaf tree species. (Adapted from: Knaggs and Xenopoulou, 2004)

Species	Oven-dry Density g/cm³	Hardness N/mm²	Bending strength N/mm²	Shrink-rate % of vol.
Poplar	0.42	31	64	*13.8*
Alder	0.49	43	95	*14.2*
Syc./maple	0.57	66	95	*11.5*
Birch	0.61	58	120	*13.7*
Ash	0.65	75	105	*13.2*
Oak	0.65	66	95	*13.6*
Beech	0.68	81	120	*17.9*
Robinia	0.74	78	136	*11.8*
Hornbeam	0.79	87	160	*18.8*

4.1.2.3 Regenerative capacity

Generally the number of seeds/kg or the weight of a single seed reflects the successional status of the main tree species. Short-living pioneers produce very light seeds which can be easily transported by wind across long distances, whereas late-successional species produce only small numbers of relatively heavy seeds which need distribution agents like birds or mammals.

Yet some species do not fit perfectly into the group characteristics shown in Table 4.1-1. Oak is an example: it is relatively light-demanding, but its acorns are very heavy and dispersed by birds, squirrels or mice.

The number of seedlings that can be gained from the seeds or the seedling percent also differ remarkably (Table. 4.1-3).

There is also another ecological strategy behind seed size and numbers:

Table 4.1-3: Mean number of seeds/kg and **number of seedlings** produced from 1 kg of seed. (Partly according to Zentsch, 1982)

Species	Seeds number/kg	Seedlings number/kg	Seedling %
Birch	7 Mill.	16,000	*<1*
Alder	1.2 Mill.	16,000	*1*
Elm	120,000	7,000	*6*
Hornbeam	27,000	1,500	*6*
Lime (small-leaved)	25,000	2,000	*8*
Ash	14,000	1,500	*11*
Lime (large-leaved)	11,000	700	*6*
Sycamore/maple	10,000	1,000	*10*
Beech	4,500	800	*18*
Oak	300	200	*67*

- **Light seeds**, being wind-dispersed are able to reach areas far from the mother tree. Their high numbers assure a wide cover of seeds per unit area. Their disadvantage, however, is that they do not contain any store of nutrients and have almost no water retention capacity. Therefore, they need favourable topsoil conditions with a ready supply of moisture and nutrients. Their germinants and subsequent seedlings have little tolerance against weed competition. So it is not surprising that a high percentage will never germinate and survive. Species like poplar and birch are typical of this group.

- **Heavy seeds** on the other hand are well supplied with nutrients. Therefore, they are less dependent on favourable topsoil conditions and generally have a higher probability of survival and development. They need, however, a dispersal mechanism such as birds, squirrels or mice, who may cause predation but nevertheless help to distribute seeds to places where they can germinate.

  (According to observations of Belgian ornithologists the jay distributes and buries single acorns in locations with appropriate light conditions. In the following spring they break off the cotyledons of the oak germinants in order to feed their young. The seedlings are often not affected by the loss of these seed leaves as they usually have formed a tap-root and are sufficiently well-established and supplied with water and nutrients (Bossema, 1979).

  This strategy is typical for some late-successional species which tend to operate with low numbers of seeds, although there are some exceptions like oak and walnut.

- **Fleshy seeds** are normally small. The pulp attracts birds and their droppings contain the stony seeds. Cherry, rowan and whitebeam are typical examples.

Conclusions

Species with light seeds may easily cover bare areas and clearfells, even if there are only a few seed trees in the vicinity. Birch and willow are good examples. However, one can never fully rely on this type of regeneration as the soil conditions may not be suitable. Poplar and aspen, for instance, need very specific topsoil conditions.

Tree species with heavy seeds can normally be regenerated only if there are seed trees in the vicinity of the area to be regenerated. Most seed carriers such as birds and mice tend to avoid large open areas.

Fleshy seeds are usually dropped around woodland edges.

This is the reason why natural regeneration on large bare areas either does not work well, or the species distribution does not meet the expectations of the owner. Therefore, planting is often inevitable.

4.1.2.4 Growth habits

Tree species follow different height and volume growth strategies according to their successional characteristics. These are illustrated below.

(1) Height growth

Pioneers tend to colonise bare land as quickly as possible and grow fast in youth, but slow down at a later stage. Late-successional species, however, start slowly, mainly under the shelter of old trees, but later on exhibit sustained growth. This is illustrated in Figure 4.1-2 which shows the height growth pattern of selected tree species based on good sites. Species generally show optimal growth rates in the lowlands or the foothills of mountainous regions on sandy-loamy soils well supplied with nutrients and water. The data have been collected on the basis of extensive permanent sample plots monitored over many years in Central Europe. Climate conditions differ, but relative performance should be similar in Ireland.

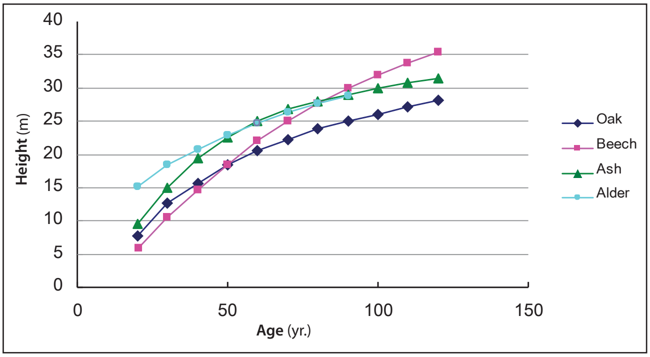


Figure 4.1-2: Height:age-relationship of selected tree species (all optimal yield class).
(Yield table data by Schober, 1957: alder by Mitscherlich, 1945; ash by Wimmenauer, 1919; oak by Juettner, 1955; beech by Wiedemann, 1931)

In detail it is shown:

- Alder, as a typical pioneer, can reach 15 m at an age of 20 years, whereas beech as a late-successional species has a height of only 5.5 m at the same age. Ash falls between the two at this age, at about 11 m, while oak is only slightly taller than beech at 8 m. At this age these species show the greatest absolute difference of approximately 10 m.
- At age 80 years the height of all four species varies between 25 and 28 m. For alder, ash and oak their height growth has declined substantially, whereas beech maintains its growth performance. Finally, at 140 years beech has outgrown oak by approximately 8 m.

All species grow more slowly on less favourable sites.

(2) Height increment

The large differences in height growth become even more obvious when the height increments are illustrated (Figure 4.1-3):

- The current annual height growth of alder has already culminated at about 5 years with an increment of 90 cm.
- Beech by contrast reaches its peak at about 25 years of age and continues at rates of 40 cm/year, decreasing to 20 cm/year over the next 100 years.
- Ash and oak are intermediate between the two.

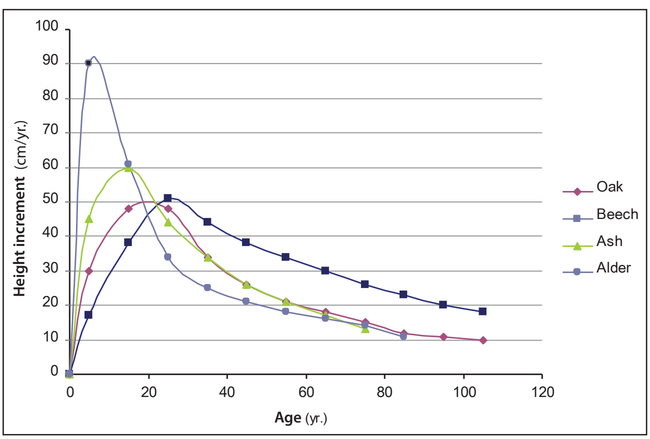


Figure 4.1-3: Height increment (cm/year) for alder, ash, oak and beech.
(Source: yield tables as cited above Figure 4.1-2)

Many foresters do not realise how early in a rotation height growth culminates. Height growth and crown extension are highly correlated. This means that trees with early height growth culmination are able to expand their crowns only in the early years. If released at later stages they react only slowly. The recommendations for management practice will be explained later (see Chapters 4.4.5 and 4.4.6.7).

(3) Culmination of volume increment
Volume increment lags behind height increment. Nevertheless, as shown in Table 4.1-4, it follows the same pattern.

From this table the following inferences may be drawn:

- Culmination of current annual volume increment is much earlier than that of mean annual volume increment.
- Both increment features show similar relations with regard to tree species characteristics: alder as a pioneer species culminates much earlier than beech as a late-successional species. Ash and oak are somewhat in between.
- Volume culmination – irrespective of c.a.i. or m.a.i. as well as tree species – culminates later in stands with lower productive capacity (yield class).

Table 4.1-4: Age (year) **of culmination of current annual volume increment** (c.a.i.) **and mean annual volume increment** (m.a.i.) according to tree species and yield class (m³/ha at age of 100 years). (Adapted from yield tables cited in Figure 4.1-2, slightly altered)

Species	Yield Class						
	8	7	6	5	4	3	2
Current annual increment							
Alder	25	30	30	30	35		
Ash			40	40	50		
Oak		30	40	45	50	60	70
Beech	60	60	65	70	75	75	80
Mean annual increment							
Alder	55	60	65	70	75		
Ash			60	70	75		
Oak	125	130	135	145	150	155	160
Beech	>140						

If maximisation of volume production is the objective, a stand of the respective species should not be harvested before time of culmination of mean annual increment. If value maximisation is the target, the rotation period is normally even longer. This depends on the price:size relationship (refer to Figure 3.2-1). If maximisation of interest rate is the goal, the length of the rotation tends to be much shorter, but this is highly dependent on the rate of interest (refer to Chapter 3.5).

It needs to be borne in mind that the yield table data are based on pure, even-aged research stands. Growth habit will change if the trees are growing under shade or in mixtures, but reliable data are not available on these effects. Nevertheless, the statements made are generally applicable, and there is clearly a need to intervene early with pioneer species in order to take advantage of their growth potential in the early years. With late-successional species there is a tendency to underestimate the high growth potential that older stands may still possess.

4.1.2.5 Competitive potential

The potential to compete with other tree species is very much dependent on the height growth and crown expansion capacity of the species.

This raises two important issues for practical silviculture:

- In **pure stands** of pioneer species, individuals will differentiate in the early years, and only then will react strongly to enlargement of the growing space. At a later stage they respond less to an enlargement, although beech, in particular, is able to utilise greater growing space even at an older age.
- In **mixtures,** the pioneer species may, therefore, gain a lead in the first 2-3 decades, but later on more shade-tolerant species will catch up and overtake the pioneers and suppress them.

This is illustrated in Figure 4.1-2. On favourable sites, both oak and beech will show optimal growth. In this case oak takes a lead of about 2 m between the ages of 15-30 years. At around 50 years of age they are equal in height (18 m), but then beech outgrows the oak and gains a lead of 8 m at an age of 140 years.

These interactions between different species are frequently ignored and cause unsatisfactory structures in mixed stands.

4.1.2.6 Provenances

As a result of variation in site conditions throughout a species' natural range there is a tendency for populations to develop provenances that are adapted directly to local climate and soils and indirectly to pests and diseases. These populations develop their own distinctive genetic characteristics.

(1) Role of provenances in forestry

Trees are prone to many abiotic and biotic influences during their long lives. Some of these influences, such as extremely cold weather events, occur at unpredictable frequencies. These may kill a whole population if adequate resistance has not been developed. This is the main difference to the short rotation production cycle in agriculture. If field crops are damaged by catastrophic events, such as heavy rainfall or long droughts, only the production of one year is lost or reduced. Therefore, unlike foresters, agriculturists do not need to be overly concerned with such rare events. Minimising or even avoiding risks by choosing site-adapted species and provenances, therefore, is essential in forestry and has become a widely accepted strategy.

Apart from the general aim of reducing risks, there are some other goals which relate to site-adapted provenances:

- **Selection** of those provenances with a high production potential, including increment and form. This is mainly in the interest of economic forestry.
- **Maintenance** of the genetic pool *per se* and for further research purposes. This is the issue of nature conservation, for instance in the Native Woodland Scheme, but also for purposes of gene conservation of unique and threatened populations, clone banks and conservation orchards.
- The **source** of plant and seed material as a foundation for further breeding programmes.

(2) Trends of provenance formation

To understand better the interactions between site conditions and formation of adapted provenances some general trends are given in Table 4.1-5.

In many cases large differences have developed in growth characteristics, production, resistance to stress and disease, as well as competitive potential and, lastly, shape, form and structure of crown, stem, leaves and root system.

(3) Research on provenances

The existence of provenances has been observed over a long time. Vilmorin started a first experiment with pines in France in the first half of the 19th century in order to study the differences in growth performance and reactions towards stress and disease. However, provenance trials on a greater scale were established only at the end of the 19th century.

Up to the second half of the 20th century provenance research concentrated mainly on conifers because of their dominant economic importance. Despite this research, however, serious mistakes were made in the selection of reproductive material mainly because of short-sighted economic reasons: as in buying cheap seed from areas where seed collection was easy and the wages low. This very often resulted in poor performance of many forest stands with regard to

Table 4.1-5: Main climatic gradients as causal agents in the formation of provenances

Gradient	Characteristic	Provenance reaction
Continental versus maritime climate	Continental climate: warmer, drier summers and colder, mostly dry winters. Maritime climate: high humidity, moderate climate with a much smaller amplitude.	Continental tree populations are more tolerant of colder winter temperatures and of drought. Maritime provenances suffer from stress conditions under continental conditions. Continental provenances brought to maritime regions suffer from fungal attacks.
Long day versus short day climate	Boreal regions (e.g. Scandinavia) provide favourable growth through long days in summer, but at relatively low temperatures.	Boreal provenances show a reduced growth and productivity when moved south, but are better adapted to low temperatures. They are more susceptible to late frost as they start to flush at lower spring temperatures. Southern provenances react in a reverse manner.
Lowland versus mountain climate	Lowlands have a much longer vegetation period, snow and ice are less common.	Provenances from the lowlands tend to grow faster and have a longer vegetation period. Therefore, they are more productive. Because of their broader crowns they can be damaged by snow and ice. Provenances from the mountains are especially sensitive to late spring frost.
Dry versus wet climate (soils)	Lower mean precipitation and long dry periods. Partly similar to continental versus maritime climate.	Provenances from dry climates show reduced growth, deeper rooting, harder foliage. Provenances from wetter sites tend to suffer especially from longer drought periods.

growth and physical stability as well as resistance to stress and poor resilience – the ability to recover easily from stress or disease. These mistakes eventually led to national and finally EU laws regulating the exchange of seed and plant material in the (international) market.

Research on broadleaf provenances – with the exception of oak and poplar – was undertaken rather late. Oak was widely sown and planted on the Continent, and it was obvious that material from some areas, such as the Spessart mountains in Bavaria, was superior to others. Poplars cross easily and produce seed very early. They were, therefore, attractive to geneticists and much breeding work was undertaken. Poplar hybrids – particularly the Euramerican hybrids – became important in warm areas with adequate water and nutrient supply, such as the lowlands of the river Po in Italy and along the rivers Ganges and Indus in India. Most other broadleaves were regenerated naturally – especially beech – or were considered to be of minor importance.

Research has mainly concentrated on the identification and selection of suitable provenances or even individuals within provenances. The long life cycle of forest trees, especially broadleaves, however, militates against the development of new breeds. Because of this, improving the plant material by selecting the best stands as seed stands is increasingly used as an interim measure until best individuals are selected and tested and the very best individuals used to create seed orchards. It has, however, a major drawback as it takes such a long time to complete.

Selection of suitable provenances of non-native species has become especially important as they react quite differently to the climatic conditions of their new environment. Again in the past, work was concentrated predominantly on conifers.

(4) Provenance trials in Ireland

In Ireland provenance trials started with conifers in the mid-1950s. Little work was undertaken in broadleaves at this time. In the Forestry Research Review Report of 1964-70 (1972), some work on beech, silver and common birch as well as ash and sycamore during that period is highlighted. In the early 1990s Coillte recorded its Broadleaf experimental programme (1991) and listed a series of provenance and clonal trials in several species including oak, ash, eucalyptus, willow, poplar, alder and sycamore. However, the site chosen for the trials proved to be largely unsuitable for broadleaves, with the result that growth was very poor. By the mid 1990s, however, the policy of encouraging broadleaf planting provided a boost to broadleaf provenance and tree improvement work and from the late 1980s an extensive range of trials was established which continues to the present (Table 4.1-6).

From this list it can be seen that many broadleaf provenance trials have been established

Table 4.1-6: Overview of **broadleaf provenance trials** in Ireland

Species	Year of establishment	Trial detail	Result	Author/ Source
Southern beech - Rauli	1980	A field trial of six different provenances of Southern beech – Rauli (*Nothofagus obliqua*) at one field site at Bree, Co Wexford, covering a range of provenances from V. Blancas, Malleco (Chile) to Frutillar, Llanquihue (Chile)	Of the provenances tested under Irish conditions, the Frutillar provenance performed best.	Lally and Thompson, 1998
Oak	1988	Field trials at four different locations comprising 29 native provenances each from mast year of 1984. Progeny test from ten individuals at sites at Belturbet/Cavan and Camolin Park. Collection of provenances at Ballinasloe/Galway.	Consistent differences in height and diameter performance between location groups, but varying growth at different locations. Camolin trial has been damaged by grey squirrels.	Felton et al., 2007
Ash	1989	Two field trials established in Drumsna, Co Leitrim, one consisting of 16 native ash provenances and an adjoining experiment - an ash progeny trial.	Due to the poor nature of the site type and some trespass these trials have now become moribund.	–
Birch	1998/99	Seed collection from plus trees: 27 Irish downy birch, 16 Irish silver birch, seven Scottish, two German, one French provenances. Field trials at three different locations established in 2001.	Identical growth on poorer site (Castletown), slight dominance of silver birch in a more favourable site. Provenance and family differences in growth and quality apparent after eight years.	O' Dowd, 2004; O'Connor, 2006; E. O' Connor, 2010 (pers. comm.)
Oak	1990	IUFRO provenance trial – 23 provenances consisting of five Irish, five from the UK, four French, three Dutch and six German sources were planted in a field trial in Clonegal, Co Carlow.	The results of this trial show that when Irish sources are not available, Dutch and British sources are good options.	Felton, 2008
Beech	1994	A field trial of seven provenances of beech – three home sources and one from Germany, one from Britain with one from Holland and a French source.	No report available on this trial.	–
Beech	1998	One in a series of beech provenance trials located in 21 European countries and the Irish trial established at Glenmalure, Co Wicklow.	Early results suggest that the use of home collected seed or material from British sources are best suited to current Irish climatic conditions.	Thompson and Fennessy, 2010
Birch	2000	Polymix trials with both birch species + field testing	No results to-date.	–
Ash	2005	EU funded project Realising Ash's Potential – one trial of 47 provenances on several sites across Europe and a second smaller trial of a selected subset of provenances.	Very early growth results – only ten years in field. Flushing data has been collected.	–
Oak	2006	Field trials at three different locations testing the performance of a number of Irish selected and source identified seed stands and open pollinated progeny of phenotypically selected grafted plus trees from the EU ECLAIR Programme as well as British and European sources.	Since these trials are still very young no meaningful results are available, however, all trials are growing well, although growth increment was considerably less in 2008 when compared with 2007.	Felton et al., 2006
Oak	2008/2009	Trials at two sites of further 23 provenances from Irish selected and source identified seed stands.	Very young trials – no results.	Felton, 2006
Ash	2008/2009	Trials on two sites at Camolin, Co Wexford, and the Manch Estate, Co Cork, comparing Danish, Dutch, German, UK and Irish sources.	Very young trials – no results.	Felton et al., 2008
Beech	2008/2009	Trial on two sites at Camolin, Co Wexford, and the Manch Estate, Co Cork, comparing Danish, Belgian, German, Dutch, UK and Irish sources.	Very young trials – no results.	Felton, 2008
Alder	2008/2009	Seed collection from plus trees at 18 sites. Trials established on three sites: Corcovety, Co Cavan and Kilclaren, Co Clare (2008) and Lavagh, Co Sligo in 2009.	Very young trials – no results.	E. O' Connor, 2010 (pers. comm.)

only relatively recently and since most of these trials are quite young, few detailed results are available:

- Experimentation in **oak** is especially important as it has been the dominant tree species on a wide variety of sites since earlier times. Furthermore, it has been common practice over many decades to remove better quality trees thereby resulting in genetic impoverishment. On this account selection of stands with specimens of good growth and form is an essential consideration in establishing seed stands.

- **Birch** has come to be accepted as a valuable species for its timber properties and for amenity. It is a relatively easy species to work with as it reaches sexual maturity early and can produce seed in abundance within a short period. Imports from Scandinavia met with limited success due to low survival rates and poor growth. However, imports from the Continent seem to be more promising.
  In 1998 a COFORD funded programme was established for birch in Ireland using conventional tree improvement methods. Limited quantities of improved seed are now becoming available from these trials.
- **Alder** planting has increased dramatically in the past number of years and initially relied on unimproved material. However, all alder seed is now supplied from indigenous material. In 2006 an improvement programme for alder was started and proceeds along similar lines to that of the birch programme. 18 phenotypically superior alder stands were identified and 89 superior trees were selected. Seed and scion wood were collected from these selected individuals and the seed was grown and eventually outplanted on three sites at (1) Corcovety, Co Cavan (2008): (2) Kilclaren, Co Clare and (3) Lavagh, Co Sligo (2009). The trials are too young to provide results, but scion wood from the 89 individuals has been used to establish an untested indoor seed orchard.
- **Sycamore** as one of the most important non-native species is also included, but no results are available so far.

In the period 1990 - 1995 an EU programme (ÉCLAIR) resulted in plus tree selections in four species: ash, oak, sycamore and cherry. As a result of this programme up to 100 plus trees were selected in each of the species and a number of untested clonal orchards were established with this selected material.

(5) Selection of seed stands

On joining the EU in 1973 Ireland – in common with other European countries – had to conform to directives on forest reproductive material. This included a programme of seed stand selection for all species including broadleaf species over the years. The criteria for selection has been phenotypical: stem form, production potential and vigour. Up to the end of 2011 a number of seed stands have been selected in broadleaf species as shown in Table 4.1-7.

As can be seen oak comprises 85% of all seed stands. Ash and common alder cover another 11%, so all the others account for less than 5%.

Table 4.1-7: Area of broadleaf seed stands - December 2011

(Adapted from Fennessy et al., 2012)

Species	Area ha
Sessile oak	1,381
Pedunculate oak	780
Ash	156
Common alder	113
Beech	80
Downy birch	26
Sycamore	7
Span. chestnut	7

Conclusions

Maintenance and selection of site-adapted provenances of the main broadleaf species have only recently been considered. Broadleaf provenance trials are still at an early stage of their life cycle.

Seed production has started to rely increasingly on the supply from selected seed stands. Nevertheless, seeds and plants were still imported from partly uncertain sources of origin. Modern methods to identify provenances, such as DNA-analysis, are likely to become standard and will help to better identify and control the seed and plant trade as well as the selection of seed stands.

Although the level of afforestation has reduced slightly in recent years, the supply of site-adapted plant material remains important. The best performing of the newly established broadleaf plantations will become the seed stands of the future.

4.1.2.7 Forest dynamics

Land on which forests existed in former times and cleared for agriculture may undergo a natural succession if left undisturbed. Terms like pioneers and late-successional species, which are derived from succession theory have been used several times in this book without being fully explained in detail.

Forest succession is a very important aspect in Ireland as almost no fully developed, mature forests exist within the country. All areas naturally colonised by shrub and tree species show features of succession. Even in plantations there are indications of the direction the vegetation would take if left undisturbed. It is, therefore, obvious that forests are not static formations, but undergo continuing dynamic processes.

An important milestone in forest ecology was the succession theory derived by the American ecologist Clements in 1916. He found that forests are always the final link of vegetation, provided the site conditions are sufficiently favourable so as not to exclude the growth of trees – i.e. low temperatures in the high mountains and arctic regions, or insufficient water in the hot and cold dry areas of the world.

Sites generally suitable for forests tend to be settled in a typical chronology (succession) as shown in Figure 4.1-4.

The primary colonisation of newly developed immature soil (such as sand dunes, alluvial soils, landslides) is called **primary succession**.

The colonisation of areas on which vegetation has been destroyed by fire or storm is a **secondary succession**. In this case young plants develop from the seed bank, from sprouts or root suckers. Thus some development stadia may be skipped.

Clements and his fellow researchers assumed that these succession steps or **stadia** would follow a natural law. Accordingly, the final links of this development should generally be stable climax forest with shade-tolerant tree species dominating. Climax is a greek term for ladder. In this context the final stadium means the highest rung of a ladder.

In cases where catastrophic events have not interrupted this development and the vegetation has reached the climax, forests will go through different **phases**: maturity, senility, decay and regeneration (Figure 4.1-5).

According to the succession model, as shown in Figure 4.1-5, the large cycle follows the line from colonising bare land to the climax forest (Plates 4.1-1 to 4.1-4). This sequence of stadia may, however, be interrupted as mentioned, which brings forest development back to an earlier stadium. After reaching the climax stadium forests may remain in the small cycle in eternity – provided no major disturbances occur.

It has been assumed that boreal forests follow the large cycle with a total destruction by fires or insects of the climax forest. Tropical forests, as well as beech forest, tend to remain in the small cycle after

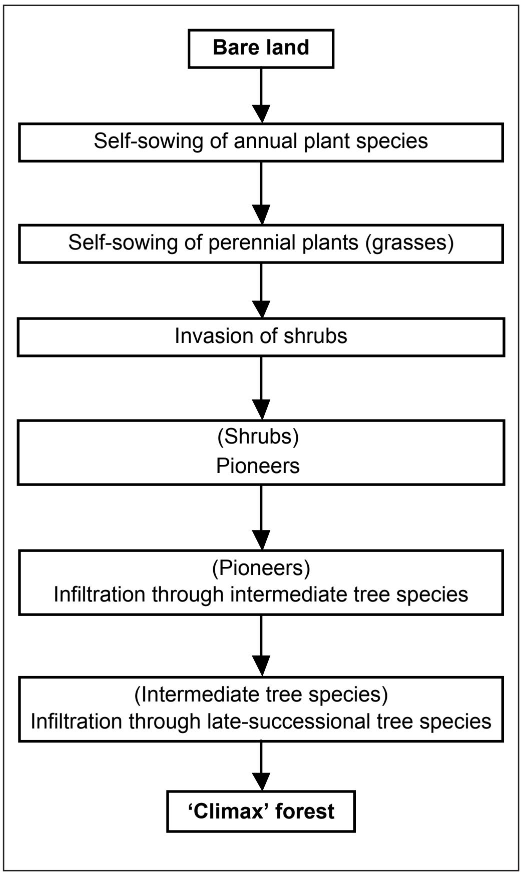


Figure 4.1-4: Main stadia of the vegetation succession from bare land to a climax forest.

reaching the climax stadium. Most other forest types may lie somewhere in between, being disturbed now and then by fire, storm or insects.

Unfortunately, this theory in its very general form did not prove valid. Consolidated findings and local variations have led to its differentiation and revision.

Some of the fundamental arguments are as follows:

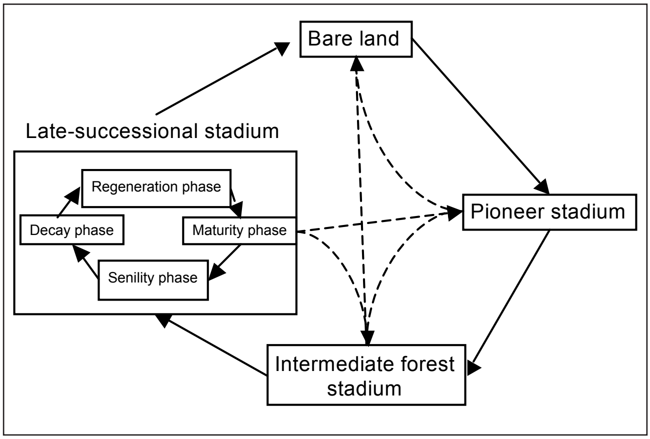


Figure 4.1-5: Large and small cycles of forest succession. (Adapted from Schmidt-Vogt, 1991)

- Numerous extreme sites with temporary or permanent climatic or edaphic stress conditions can be colonised only by stress-tolerant pioneer or specialist species. In this case the pioneer stadium of the vegetation is also the mature plant community, i.e. the pioneer and climax stadia are one and the same. A succession in the original meaning of the term does not happen. Shrub vegetation on peaty soils may be an example.
- Successions may be interrupted now and then by catastrophes and thrown back to earlier stadia. Such catastrophes may be caused by abiotic forest-destroying events such as storms, fires, snow or ice, volcanic eruptions or landslides. Also, biotic phenomena such as insect attacks can lead to a breakdown of whole forest ecosystems. These external disturbances

Plate 4.1-1: Forest dynamics in the large cycle: Extensive areas of mature and predominantly even-aged fir.

Plate 4.1-2: Destruction of old growth by fire.
(All photographs are from Alaska; courtesy Schmidt-Vogt)

Plate 4.1-3: Pioneers (birch, aspen, willow) colonising the area after fire.

Plate 4.1-4: Late-successional fir and spruce recolonising and gradually replacing the pioneers.

are mainly viewed as natural events that are associated with special areas and vegetation types. The catastrophes are thus regarded as the motor of the dynamics of development momentum. Now it is questionable, however, how often such profound and momentous events occur or in other words how long the intervals are between disturbances.

There is, moreover, increasing uncertainty in scientific opinion as to what degree the dynamics are really natural or anthropogenic. The many hypotheses that climate change may more often cause droughts or storms are the basis for these doubts.

- Succession may need long periods – even centuries. During this time the climate will change and alter the direction of the vegetation development. According to historical reports and documentation, climate has never been stable over the centuries and millenia. Therefore, it has to be concluded that climatic constancy does not exist and hence no site specific succession can be determined.
- The recolonisation by vegetation after the ice ages – as it has been described in Chapter 1.2 – was often also called a succession, but it is now understood that this recolonisation took many thousands of years, while the climate was undergoing profound change. Moreover, it is argued, that at least on the Continent, this process was not finished before man started to influence forest dynamics.

Recent opinion is, therefore, that the final stadium of succession cannot be clearly defined by a precise structure and composition of trees and other species. In reality the final stadium may differ in many respects, since the tree species distribution especially may vary over time. The term climax species, therefore, has been changed to late-successional stadia and species, as it is more in keeping with recent findings. Nevertheless, there is general consensus that vegetation types tend to develop to more diversified, complex ecosystems, which exploit the resources available to them on the respective sites in the most efficient way (Plate 4.1-5 to 4.1-8).

Plate 4.1-5: Pristine forest with varying proportions of fir, spruce and beech; here the conifers are dominant. (Czech Republic)

Plate 4.1-6: Pristine forest with varying proportions of fir, spruce and beech; here the beech is dominant. (Czech Republic)

On the Continent, the traditional term used to classify stands, forest stand type, infers a condition that is too static. Therefore, it has recently been changed into forest development type (see Chapter 4.1.2.9). This takes into account the possible progression towards a late-successional type.

Plate 4.1-7: Pristine beech and oak forest at lower altitude. A typical feature of pristine forests is the large amount of deadwood. (Czech Republic)

Plate 4.1-8: One of the rare beech/conifer stands in Central Europe that has been little affected by man because of its location in a remote valley with steep terrain. (Upper Danube valley, Germany)

Conclusions

There are several silvicultural options based on the knowledge gained from forest succession:

- As a precaution and in order to reduce the risk of exposure to loss by climate change, forests should be established in mixtures, including stress tolerant tree species.
- Silvicultural procedures, moreover, can help to accelerate the succession processes, for instance, by favouring the growth of late-successional species within a stand of pioneers.
- The succession may on the other hand be impeded by favouring pioneers rather than late-successional species, provided this is the objective of the forest owner. This means that the forest owner has to work against a natural development. For example Continental foresters often have to release ash, sycamore, wild cherry, oak from the competition of beech in order to increase the production of valuable timber in the stand.

The study of natural dynamics, especially in near-natural forests, had a very stimulating effect on the development of close-to-nature forestry during the past decades.

4.1.2.8 Potential natural vegetation

Although the vegetation, and especially the forest cover of Ireland, has been significantly altered by human activities through the last millennia, it would be of general interest and could serve as a background for forest planning to derive some ideas as to how the vegetation would look without human interference. As mentioned it is almost impossible to predict with certainty the terminal stage of the vegetation in the absence of human interference. To overcome the problems of forecasting the trends of the long-lasting development, Tuexen developed the concept of the potential natural vegetation in 1956.

Incorporating later modifications it is now defined as .. *the vegetation that would finally develop in a given habitat if all human influences on the site and its immediate surroundings would stop at once and if the terminal stage would be reached at once* (Westhoff and van der Maarel, 1973).

The potential natural vegetation should not be misinterpreted as more or less equal to the historical vegetation cover. Apart from climatic shifts, the soils may have been radically altered by drainage and site cultivation, peat exploitation or fertiliser application.

Most European countries have already detailed maps of the potential natural vegetation. Their species composition and structure is the result of an optimal adaptation to the site conditions or in other words to nature´s potential.

Maps of this kind were recently also published for Ireland by Cross (2006) in which he has segregated vegetation formations based on physiognomic and ecological systems of natural plant cover. Each formation is subdivided according to dominant species and groups of species. The formations are further subdivided into units according to edaphic, climatic and phytogeographical conditions. Only three formations and nine units are dominated by trees:

- The **sub-arctic, boreal and nemoral-montane forests** formation is the smallest and the most speculative. It contains only one unit.
- The majority of Ireland´s forests fall into the formation **mesophytic deciduous broadleaf forests** with six units. Late-successional communities would be mainly dominated by oak and/or ash. Birch species would be common. Wild cherry, alder and others are occasional components.
- Finally, the formation **alluvial and other wetland forests on wet soils**, is subdivided into two units. Its forests occur mainly on alluvial soils or on heavy impermeable clays which remain wet for much of the year.

Figure 4.1-6 contains maps of the nine units. They are listed and described in Table 4.1-8.

Cross (2006) pointed out that it is difficult to make certain predictions of the potential natural vegetation as the effects of human influence may persist for a long time. Edaphic and climatic changes, grazing and especially the legacy of introduced species pose particular difficulties. Nevertheless, the remaining semi-natural vegetation and the extended network of hedges and shelter-belts acted as refugia for native woodland species.

The role of introduced species, such as beech and sycamore, in the potential natural vegetation is not clear. Cross argued on the one hand that they may only form an element of the flora, and on the other, that they play a major role. We tend to support his latter assessment as we assume that beech especially would become dominant on many sites (refer to Chapter 1.2 and see Chapter 6.3).

Conclusions

In this study of potential natural vegetation in Ireland it is again highlighted that broadleaves would play a dominant role under today's ecological conditions, provided human interference ceased.

The natural potential vegetation, however, is partly a theoretical construct. Under Irish conditions most forests are far from natural structures. Their development towards the natural potential vegetation would normally need long periods in which the site conditions might alter according to climate change predictions. Moreover, there are some tenuous assumptions made when deducing the units. Nevertheless, they can provide an indicative guideline for landscape classification, for nature conservation purposes, for determining the degree of naturalness of the actual vegetation, for monitoring changes in ecosystems and for planning and restoration programmes, e.g. selection of appropriate species for afforestation.

4.1.2.9 Forest development types

One of the major revelations of recent decades has been the understanding that forests are neither stable nor permanent with regard to species composition and structure. They undergo gradual and abrupt changes as they become subject to various influences:

(1) Site conditions cannot be regarded as stable or long-lasting any more, because of climate change and soil alterations through drainage and input of nutrients.

(2) The impact of human activities change according to changing requirements. The decreasing grazing pressure by domestic animals illustrates this. It has led to local recovery of vegetation cover and reinvasion by some tree species.

(3) Newly established forests on former pasture land affect characteristics such as soil structure, root penetrability and water regime and, therefore, gradually change their own environment.

Forest planning, which tended to assume stable environmental conditions, was more or less static. This way of thinking is convenient for rotations of 30 to 40 years with clearfelling and subsequent replanting. These procedures always create artificial conditions with regard to the soil cycle of deterioration and restoration followed by soil preparation and fertilising. The more forests are managed according to close-to-nature concepts, the more it becomes clear that forests develop according to natural dynamics. Static planning models do not satisfy the development trends.

Therefore, on the Continent during the last two decades, the concept of forest development types has been established and continues to gain importance.

As mentioned in the concept of the potential natural (tree) vegetation the time factor and many changes that might happen during long production periods are not included. Moreover, the species composition and structure may totally differ from that of the existing forests.

Forest development types are much more realistic. They are partly based on the present tree species composition. The possible development towards the potential natural (tree) vegetation is calculated within a period of about 50 years. Thus, they are more realistic and can be adapted following the changing influences or objectives during the time of operation.

The use of forest development types offers some advantages:

- The direction of the development a forest may take is indicated by these advantages.
  For instance a pioneer forest may be gradually infiltrated by shade-tolerant species, provided there are seed trees in the vicinity. By encouraging young growth the conversion into late-successional forest types may be accelerated.

- Economic efficiency is taken into account.
  Identifying the development trend, especially with regard to growth characteristics, may help to apply certain treatments effectively at the optimum phases. In particular the effect of measures in mixed forests is highly dependent on the right development stage. Therefore, by classifying forest development types the economic efficiency is taken into account.

- An undesirable development can be seen in time.
  The forest owner may even take the converse decision. Realising the natural development the owner may come to the conclusion to counteract this development. The owner may for example eliminate young broadleaves from conifer stands to avoid competition and reduced growth.

Two examples may help to explain these interactions:

(1) A Sitka spruce stand on a rich former broadleaf site shows a great number of naturally regenerated broadleaf seedlings and saplings. The forest owner thus may plan to convert it via successive fellings into a broadleaf stand. The forest's development type will then be: broadleaf (oak, beech, hornbeam, ash) forest.

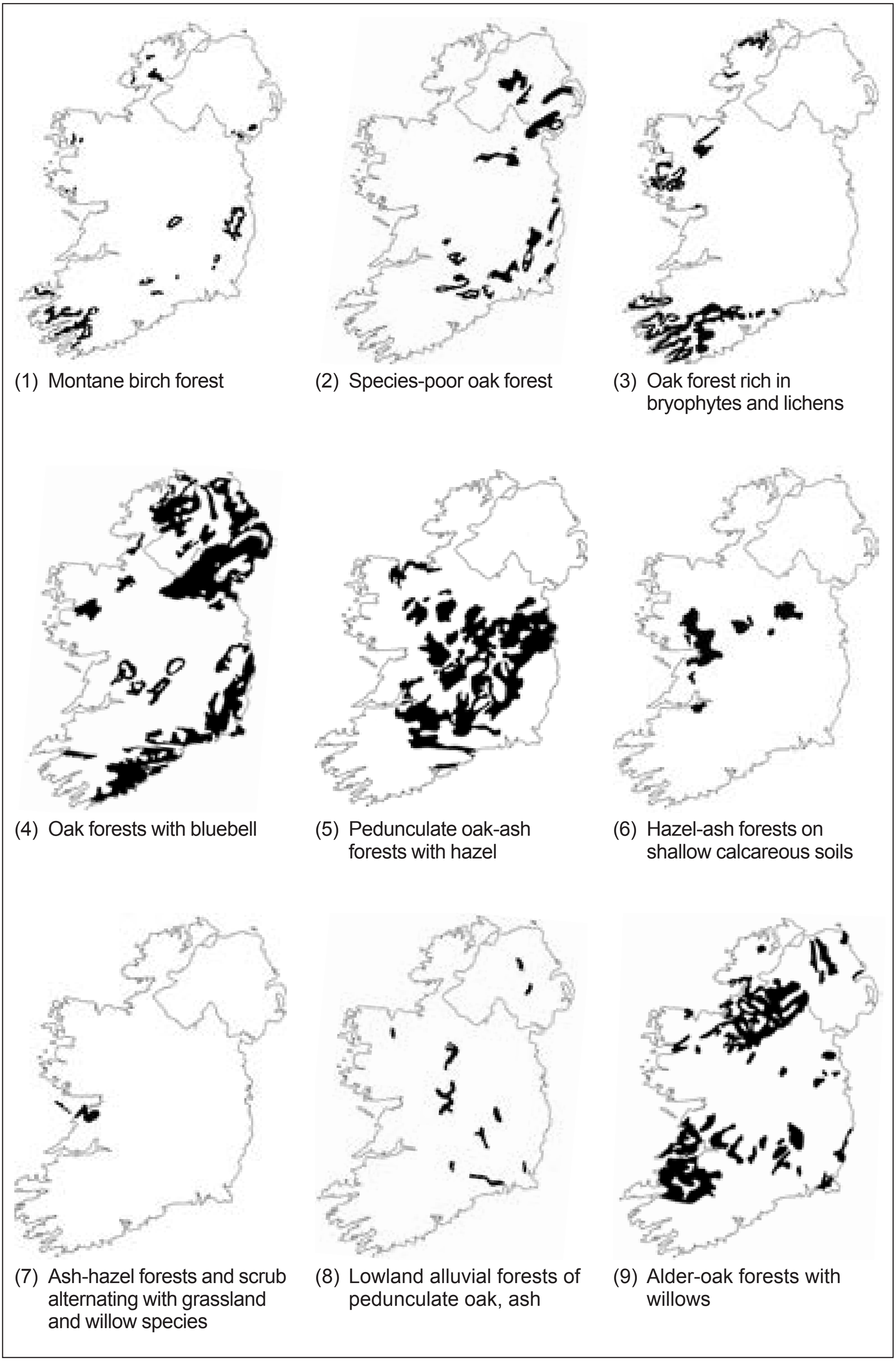


Figure 4.1-6: Potential natural forest units. (From Cross, 2006)

Table 4.1-8: Description of the **main potential natural forest units** in Ireland. (Adapted from Cross, 2006)

No.	Unit	Habitat / distribution	Site / soil	Main tree species	Importance
Sub-arctic, boreal + nemoral-montane forests					
(1)	**Montane birch forests**	Montane to submontane communities (400-700 m), too steep for blanket bog formation. Throughout Ireland at suitable altitudes. Mainly in the southwest	High precipitation (1,200-2,400 mm/yr.). Frequent strong winds. Underlying rock: Old red sandstone, slates, schists, granites. Oligotrophic, sandy stony podzols.	Dominance of montane birch, some rowan. On rocks yew and aspen. General absence of oak, sessile oak at lower altitude. Scattered willows.	Plantations of spruce and pine. Extensive rough grazing, often overgrazed. Cessation of grazing would encourage the formation of the community.
Mesophytic deciduous broadleaf forests					
(2)	**Species poor oak forests**	On lower slopes and in valleys of siliceous uplands throughout the eastern half of the country.	Sandy to loamy , well drained, sometimes shallow, acidic to strongly acidic podzols and brown earths with low nutrient status.	Dominated by sessile oak, montane birch, rowan. Locally introduced beech. Other tree species are rare.	One of the most extensive woodland types in eastern Ireland on poor soils and steep slopes. Differences in grazing pressure. Extensive areas underplanted with conifers now being restored.
(3)	**Oak forests rich in bryophytes and lichens**	The main area for this woodland in the extreme south-west, small stands in the north-west.	In regions with rainfall exceeding 1,200 mm/yr., constant high humidity. Confined to acidic, often shallow, rocky, sandy to loamy podzols.	Relatively species rich, dominated by sessile oak, montane birch, rowan. Alder on locally moister sites. Beech co-dominant, potentially an important constituent. Rhododendron can be dominant in shrub layer.	Grazing by sheep and deer characteristic. Most stands formerly used for timber production, partly coppiced. Widely planted with conifers in the past. One of the best-represented forest types in Ireland. Many stands under threat of overgrazing.
(4)	**Oak forests with bluebell**	In lowlands, in the low hills or lower slopes of the uplands, mostly beyond 200 m in the south, south-east and north; locally elsewhere.	On more fertile, acidic soils transitional between acidophilic oak forests and mixed ash-oak woodlands on more fertile soil. Possible variations between north- and south-facing slopes.	Sessile oak (locally pedunculate oak) with small amounts of montane birch, ash, locally wild cherry, beech naturally regenerating locally. Hazel, holly in shrub layer.	Nearly all cleared for agriculture. Small areas afforested with conifers and more recently beech, ash, oak. Continues to be under threat from land reclamation.
(5)	**Pedunculate oak-ash forests with hazel**	Potentially one of the most extensive forest types, on the central lowlands and the broad valleys between the mountain ranges in the south, locally elsewhere.	On flat to undulating glacial deposits over limestone. Mostly deep, base-rich; well drained to moist; brown earths and grey-brown podzols.	Rather variable woodland type. Ash, pedunculate oak principally form canopy. Birch species sometimes present. Wild apple tree, wild cherry, whitebeam, rowan occasional. Beech, sycamore often naturalised.	Most of the area devoted to agriculture and improved pasture.Only small fragments remain. Important for conservation: some of the oldest known oak trees. Removal constant threat.
(6)	**Hazel-ash forests**	Principally in west-Central Plain and other localities in the west.	Undulating to flat, often rocky lowlands over carboniferous limestone with shallow brown earths, locally rendzinas.	Forest scrub communities with ash as the dominant species. Pedunculate oak rare. Beech widely planted and regenerating easily. Yew locally important.	High forest stands rare. Substitute vegetation species-rich calcareous grassland of high conservation value. Stands of yew of international significance.
(7)	**Ash-hazel forests**	Small area in the Burren and locally on the Aran islands.	Karst with pavements, cliffs, rock debris, dry valleys over carboniferous limestone.	Forest (ash) and scrub margins.	Extensive grazing declining, abandoned land being invaded by hazel scrub. Remarkable for the variety and richness of vegetation.
Alluvial and wetland forests on wet soils					
(8)	**Lowland alluvial forests**	Potentially along all the major lowland rivers. Most extensive stands along the Shannon and its tributaries.	Alluvial soils, mainly with calcareous or base-rich deposits. Flooding variable. Swampy conditions in depressions.	Zoned vegetation. On infrequently flooded, but poorly drained soils: alder, ash, oak. On drier ridges: mixed oak-ash forests. On aquatic habitats: willow, alder.	Only very small and modified forest remain.
(9)	**Alder-oak forests**	Principally on drumlins in north-central Ireland, on plateaux in Clare, Limerick, N-Kerry and Castlecomer.	In the lowlands, on drumlins, low plateaux over shales, glacial tills, boulder clay. Often poorly drained, mesotrophic gleyed soils.	Mixed oak-ash forest on drier calcareous as well as acid soils.	Only small stands remain under the threat of being felled and reafforestation or attempts of land improvement.

If the forest owner decides to continue growing the former species the forest development type will be: Sitka spruce forest, but then the owner knows that one has to eliminate the broadleaves especially in the tending phase while accepting a higher risk as to abiotic and biotic disturbances.

(2) A Sitka spruce stand on a poor, sandy soil regenerates freely and its regrowth does not need to compete with that of other tree species. Therefore, there is no reason why Sitka spruce should not be accepted for the next forest generation. The forest development type will then be: Sitka spruce forest.

There is always discussion as to how many forest development types should be defined: A small number may not account for variations within the sites and too many are not practical.

Conclusions

At present the classification of forest development types may not be relevant in Ireland. However, in the long run they may largely replace the classical, but static forest stand types or equivalent classifications.

4.2 Silvicultural systems

Silvicultural systems take into account the characteristics of the tree species and translate their demands into practice. They are, however, also directed towards ensuring an easier management of stands. Minimising damage and achieving economic as well as ecological objectives are inherent characteristics.

4.2.1 Definition

Silvicultural systems constitute the combination and integration of all silvicultural and operational procedures for the management of forests.

They contain the following elements:

- Methods for regenerating, thinning and harvesting forests,
- the working technique and locally orientated felling and extraction procedures within the stands taking care of the regrowth,
- the infrastructure and accessibility of forest units, and
- the spatial order relating to a reduction of abiotic damage, mainly from storms.

Silvicultural systems, therefore, go far beyond silvicultural treatments in the narrow sense and have consequences for the whole forest enterprise and even outside activities.

Silvicultural systems are firstly divided according to their regeneration pattern into

- **high forests** that are reproduced by natural regeneration or planting,
- **coppice forests** being renewed vegetatively by using the capacity of broadleaves to sprout from cut stumps,
- **coppice-with-standards forests** which are renewed either vegetatively or by a combination of coppice regrowth and natural regeneration.

High forests are by far the most important category in Ireland and, therefore, only this system is considered in more detail in the following sections. Coppice forests today, either with or without standards, are mainly of historical importance.

High forests comprise a range of different silvicultural systems with two extremes:

- **Clear-cut system**
  All trees of a harvestable size are clear-cut on a large area, and the site regenerated afterwards. This leads to homogeneous, often single-storied single age class forests with a distinct separation of all the following development phases: regrowth, thicket, pole and tree stage.

- **Single tree selection system**
  In this system individuals of all development phases are tended, thinned and harvested as single trees. This results in stands with trees of all ages and development stages in an intensive vertical and horizontal mixture. In addition to maximum age differences they show a great structural diversity.

Between these two extremes there are several other high forest systems and combinations of these which are illustrated in Figure 4.2-1.

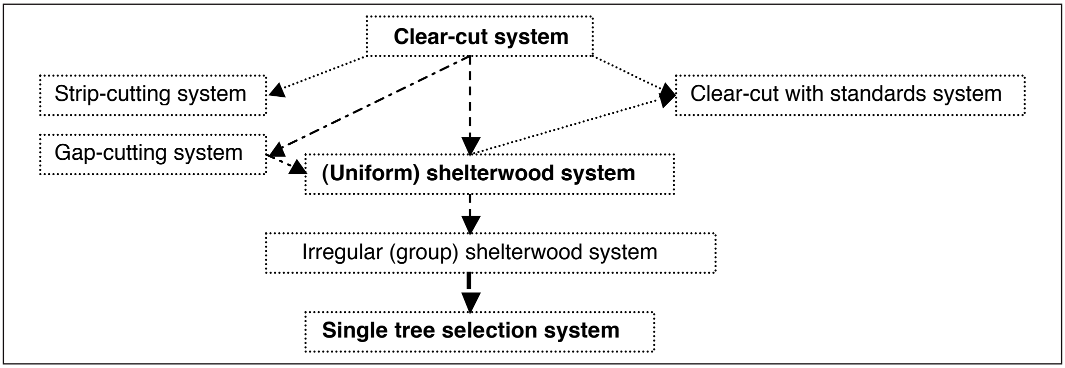


Figure 4.2-1: Main **types of silvicultural systems** for high forests. (The systems with **bold** letters are the most important ones.)

The choice of a specific silvicultural system has far-reaching consequences for a number of silvicultural and operational activities:

- **Climatic conditions on clear-cut areas or within forest stands.**
  Pioneer species, like birch, aspen and poplars, because of their light requirements and good stress tolerance, find bare land conditions suitable. Shade-tolerant but stress-intolerant late-successional species like beech, however, need shelter from older trees against late frost and drought. Long-living pioneers such as oak and ash tolerate shade for a few years, but need to be released from shelter at an early stage.
  The amount of light can also influence tree form: individuals tend to grow straighter and with fine branches under shelter, but are less stable against wind. When kept too long under a dense canopy, however, their leaders tend to grow towards the light, turning towards the horizontal, and forming long side branches.
  These interactions between ecological conditions and the specific demands of the tree species are normally the most important issue in the choice of a silvicultural system.

- **Biological-technical aspects**
  These comprise the organisation of the regeneration, thinning or harvesting operations, the concentration of timber volume, the value of the stocking volume, protection against storms or erosion, and finally the infrastructure of a forest.

- **Economic aspects**
  They include the time taken to reach production goals, the amount of income generated and its distribution over time.

- **Infrastructure of an enterprise**
  It contains details of the road and rack system in the forests, equipment, machines and tools, the type of workers needed, as well as their training and experience.

- **Other aspects**
  These deal with forest aesthetics, the sense of proprietorship of the owner, or the use of the property for hunting and other activities.

These are only the main characteristics, interactions and combinations of the silvicultural treatment of forests. Details are provided in the following sections.

The above list of activities comprises silvicultural activities that include a wide range of aspects and can have far-reaching consequences. Therefore, the term silvicultural systems is appropriate.

Most of the silvicultural systems have been developed in France and Germany, some of them like the shelterwood system, hundreds of years ago. Their formal systematisation and further development started around 1800. Some combined systems like the strip and group system were developed around 1900. The continuous cover system is relatively new and embraces several elements of the systems described later.

Some of the systems are still of relevance today, but many are practised in a flexible way by not following the original rules in a rigid manner. Nevertheless, it is still worthwhile to have a knowledge of their main features in order to understand the interactions between ecological conditions in different stand types, tree species characteristics and economic necessities.

In the following sections (Chapters 4.2.2 to 4.2.4) the main systems are described with particular reference to their silvicultural and ecological aspects. Later, their influence on technical, economic, protective and other aspects is discussed (Chapter 4.2.5).

4.2.2 Main high forest systems

An overview of the systems to be described in the following sections is presented schematically in Figure 4.2-2.

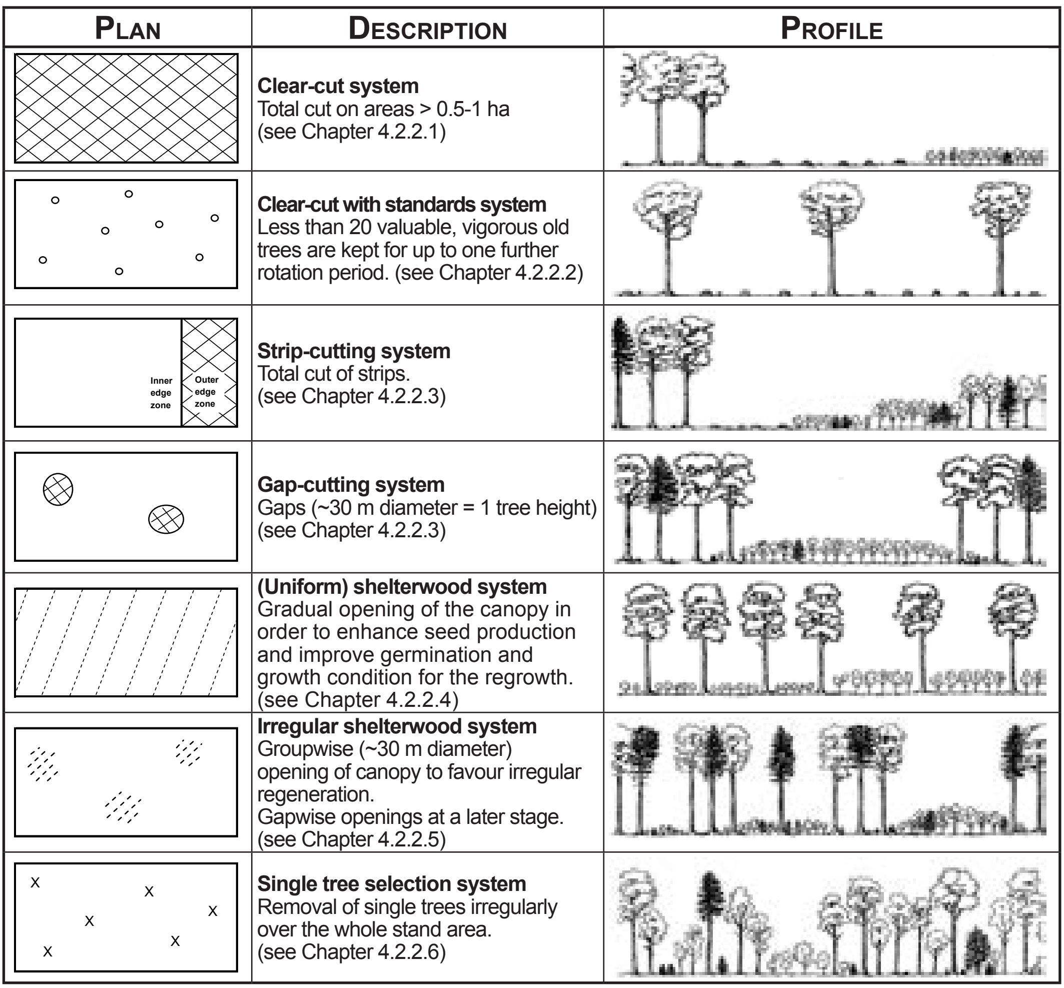


Figure 4.2-2: Diagrammatic overview of the **main silvicultural systems** for high forests.
(Drawings by A. Kuehnen)

4.2.2.1 Clear-cut system

Clear-cutting is the easiest silvicultural system to implement as it facilitates harvesting as well as the subsequent operations of planting, tending and thinning. These operations can also be more readily mechanised and systematically handled. Clear-cutting generally requires less skilled and experienced management and labour. Because of these advantages it is, therefore, the most widely practised silvicultural system worldwide and is likely to remain so in the future.

From the **ecological point of view** a clear-cut area can be defined as such only if it is large enough to create a bareland micro-climate. Large clear-cuts are those greater than 5 ha in extent (Plates 4.2-1 and 4.2-2). Its minimum area, therefore, is 0.5-1 ha depending on the height of the surrounding sheltering trees and the exposure of the site.

Shelter can take many forms (Plate 4.2-3). Its main ecological features are summarised in Table 4.2-1.

Table 4.2-1: Ecological conditions on **clear-cut areas.**
(After Burschel and Huss, 2003)

Ecological factor	Description
Radiation	Shading by surrounding stands from east in mornings and west in evenings. Edge at south never exposed to full sun light. Maximum of light slightly moved towards north. Water supply best at south side. Regeneration conditions here best for seedlings, but susceptible to heat and drought.
Temperature	Shift of main meteorological and assimilation activities from the crown canopy to the ground surface: Higher temperatures during the day, particularly in summer, and lower ones during the night, particularly in winter compared with the conditions in, and especially under the neighbouring stands.
Water balance	No interception by sheltering trees. Most precipitation reaches the ground surface. Water supply improved on sandy soils for the regrowth, but reduced on compacted soils because of lack of water uptake by older trees. Similarly with snow masses. Increase of erosion depending on slope and soil conditions.
Soil activities	Improvement of living conditions for soil organisms through increase of temperature and available water. Accelerated mineralisation of litter and humus. Advantageous in case of thick litter layer, disadvantageous in case of leaching and, therefore, loss of nutrients in hilly terrain.
Development of ground vegetation	Often ideal conditions for the development of field layers of herbaceous plants because of increased availability of radiation, water, temperature and nutrients – mainly for a short period. Normally prolific spreading of already existing or newly self-sown seedlings. Sometimes fast distribution of bushes. Positive: Field layers slow down water flow and can act as nutrient stores (small nutrient cycle). Negative: Thick grass impedes succession. Field layers cause severe competition for tree regrowth. Weed control can be labour intensive and costly. Often favourable habitats for damaging animals (e.g. bank vole – *Clethrionomys glareolus*).
Wind and storm	Reduction of wind speed and intensity only in the lee side of surrounding stands. At the windward facing forest edges impoverishment of the soil and desiccation. Increased risk from storms.

Plate 4.2-1: Clearfelled spruce area with large volumes of slash providing little shelter for reforestation.
(Connemara, Co Galway)

Plate 4.2-2: Clearfelled spruce stands create large open and very exposed areas.
(Glendalough, Co Wicklow)
In these conditions young plants, whether they are naturally regenerated or planted, suffer from stress conditions (drought, desiccation and frost). It may be difficult to establish broadleaf species in such a situation.

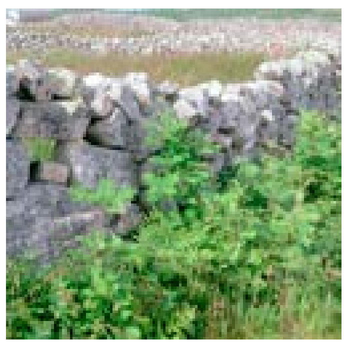


Plate 4.2-3: Here, even stress-tolerant rowan (and bracken) in a very exposed situation, is benefiting from a stone wall shelter.
(Athenry, Co Galway)

Suitable tree species
Pioneer species are suitable for restocking of clear-cut areas generally. They are adapted to stress conditions and tend to grow well because of the ready availability of light, water, nutrients. Many late-successional species (beech, yew), intermediate ones (Sitka spruce, maples) and long-living pioneers (oak, ash) suffer from late spring frost on clear-cut areas.

There are fewer problems:

- On sloping terrain, as the cold air can flow downwards,
- at higher altitudes, as late frosts and long dry periods are less frequent, and
- on north-facing slopes, because of shading during the whole day.

Under these conditions it may even be possible to establish rich mixed forests of planted late-successional species and naturally regenerated pioneer species.

Critical assessment

Naturalness
Clear-cuts change the natural cycles in the following ways:

- Clearing of a forest stand alters the ecosystem, but in many ways provides conditions resembling natural catastrophes, although these occur less frequently.
- Forest stands tend to be harvested before they have reached the end of the physical age. They are always kept in their main productive phase.
- Nutrient loss can become serious when the trees are totally removed on poor soils. The nutrient losses are marginal in cases where only logs are removed and needles, leaves, small branches and the bark remains on the site. Nevertheless, nutrient drain is greater than with storm catastrophes when the bulk of biomass remains on site. These losses are small, however, compared with the outcome from extended fires where leaves, small branches and litter are destroyed.
- The soil may be damaged or compacted by careless felling and inappropriate timber extraction operations. This is more serious in larger clear-cuts, on steeper terrain and on fragile soils.
- Clear-cutting is sometimes used to replace a semi-natural forest type by more productive, but sometimes less well adapted tree species.

Clear-cuts are normally considered by ecologists and many foresters as unnatural. The examples mentioned show, however, that this view is not always justified. It depends very much on the size of a clear-cut, the site conditions and the existing forest.

Growth and economic characteristics
Most of our knowledge about growth and yield of forest trees has been derived from even-aged stands that have been established on clear-cut areas. There, the growth processes are reasonably well-studied. However, the development sequences of trees growing for long periods under the shelter of old trees are less well-known and there is a need for further research in this area.

Early attempts to compare the growth and yield of stands in the clear-cut system with those that have been managed in shelterwood or even single tree selection systems have not given clear evidence of better growth. Because of a higher proportion of large dimensioned timber, however, single tree selection forests seem to produce higher economic yields – as long as large dimensioned timber is sought by the market.

It has to be realised, however, that for reliable findings long-term studies in comparable enterprises are necessary. Unfortunately, site conditions are seldom uniform and the objectives tend to alter with time. Therefore, the management procedures tend to change.

Conclusions

At present no clear statements can be made about the natural or economic superiority of one or other silvicultural system.

The clear-cut system will remain the most practised worldwide as it is technically the easiest and can be implemented with less well-trained or experienced staff. Also, because large quantities of wood are obtained per unit of area, the costs of timber harvesting, transport and those associated with accessibility and road-building are relatively low.

During recent years a somewhat different attitude towards clear-cuts has developed:

- Large clear-cuts give cause for concern if they lead to areas being damaged by erosion, soil compaction and loss of nutrients. In Ireland, because of the relatively high exposure, all possible protection against wind should be maintained.
- Small clear-cuts – 1-2 ha in area, provided they do not lead to erosion or damage to the soil – present the opportunity to increase the variety of tree species, as well as the fauna, and lead to enhancement of the landscape. Felling over existing regrowth is generally not a problem. This is especially the case for light-demanding species such as oak, ash, cherry and sycamore.

4.2.2.2 Clear-cut with standards system

Some trees may be left on clear-cut areas for the following reasons:

- To serve as the seed bearers and may also be used for seed collection. (Therefore, it is sometimes referred to as seed tree system.)
- They are healthy and vigorous, of good form and will lead to the production of high quality timber.
- They are kept for aesthetic or landscaping reasons in order to moderate the impression created by clear-cutting.
- They serve as a standing reserve for the enterprise and can be harvested in times of favourable market conditions or shortage of liquidity.

Scots and Corsican pine and larch have mainly been used as seed trees over young broadleaves as they tend to be windfirm, long-living and have the potential to produce high quality timber. Oak is suitable only if kept in groups because of its tendency to produce epicormic branches. If they have formed large crowns by being conditioned over time to grow more in the open they are less prone to epicormics. Ash is much less likely to produce epicormics and can, therefore, be kept as single standards.

The standards should not restrict the regrowth. Therefore, only a small number, 10-20 trees/ha, should be retained. Their influence on the microclimate is slight and is the reason why this system is closely related to the clear-cut system. If a larger number is retained it resembles the shelterwood system (see Chapter 4.2.2.4).

Conclusions

The opportunity to retain standards after clear-cutting broadleaf stands is limited in Ireland. Nevertheless, in some cases it may be possible to keep some older trees for the reasons mentioned. It can be anticipated that these advantages will be of more value in the future.

4.2.2.3 Strip and gap-cutting systems

As sketched in Figure 4.2-2 both strip and gap high forest systems are closely related to the clear-cut system. In both, all trees are removed, but only on small areas. The clear-cut areas created are small enough to be influenced by the adjoining stands and the typical open ground microclimate will not be created. Therefore, with both systems, it is possible to meet ecological demands, especially of long-living pioneers like oak which need shelter against climatic stress and also light for their development.

The main differences between the two systems are described below.

(1) Strip-cutting system

This system is defined by a clear-cut strip of one tree height (25-30 m) in width. At the inner and the outer edge different regeneration possibilities are provided:

- At the **inner edge** zone the climate of the sheltering stand dominates. Towards the centre of the stand the light availability gradually decreases.
- At the **outer edge** zone the moderating effect of the sheltering stand decreases in the form of a gradient. At the same time light availability and the temperature amplitude increase.

Edge cuttings are favourable for releasing regrowth that has already been established and needs more light. Afterwards, new regrowth that develops at the inner edge zone is released from shelter. The trees are generally felled into the stand so as not to damage already fully established regrowth. Edges are, therefore, very favourable with regard to removal of the old trees.

As soon as the outer edge zone is fully regenerated a new edge can be cut parallel to the preceding one. In practice an edge progress of one tree height is usual. The clearance of a stand area is thus relatively slow.

The management of edges is normally directed towards:

- **Favouring natural regeneration**
  They are often directed from north to south in order to supply humidity and shade to ease the germination and establishment process of the seedlings.

- **Reducing storm damage**
  Strip cuttings should always proceed against the prevailing wind direction. In this way the older parts of the stand protect the younger parts against storms. This procedure is far more important in conifer stands, but it is advisable to follow the same approach with broadleaves on compacted (unstable) soils in areas prone to storm damage.
  Stands established in this way are uneven-aged in the direction of the strips, but even-aged parallel to strip edges.

Conclusions

The strip-cutting system is of limited importance for broadleaves. It is not favoured for late-successional species like beech. However, it is sometimes used in association with other high forest silvicultural systems. After the regrowth has been encouraged by opening the canopy, the remaining shelter trees are removed in a type of strip-cutting.

(2) Gap-cutting system

Gaps are often caused by storms. Obviously gap dynamic is the most important driving force in natural forests (Plates 4.2-4 and 4.2-5). However, these gaps are often small and therefore, do not always suit the ecological needs of light-demanding species (Plate 4.2-6).

Gaps as a common phenomenon are increasingly adapted in semi-natural silviculture (Plates 4.2-7, and 4.2-8).

When artificially created, gaps of roughly one tree height (25-30 m) in diameter are cut in forest stands (Plate 4.2-9). Without shelter the microclimate of the forest floor in these gaps resembles the climate in the adjoining stand. In this situation the amount of light is higher

Plate 4.2-4: Even in a late-successional beech dominated forest, gaps caused by storms are a usual event. (Czech Republic)

Plate 4.2-5: Gaps in conifer stands are often colonised by pioneer species such as birch. (Bavaria, Germany)

Plate 4.2-6: A group of young sycamore planted in a storm-created gap in a beech/Norway spruce stand. (Kelheim, Germany)

As the surrounding trees developed, their crowns partially closed the gap and the sycamore suffered from lack of light.

Plate 4.2-7: Gaps either created naturally or artificially can be used to plant site-adapted species and gradually transform the species proportion. (Black Forest, Germany)

Here ash has been planted into a former Norway spruce stand.

and reaches values of about 80% of the above canopy light in the centre. Greater amounts of rain also reach the floor.

Creation of gaps is advisable if regrowth of light-demanding tree species already exist and should be allowed to develop. This is the case for instance with oak, ash, sycamore, cherry.

Gap-cuttings are problematic, however, if regrowth has not already been established. In this case grasses or other herbs might colonise the site and impede the regeneration of tree seedlings. Then planting is unavoidable. This may be necessary, anyway, if conversion of the forest to one or more mixed tree species is desired.

Gap-cutting is often combined with other silvicultural systems so it is possible, for

Plate 4.2-8: Natural regeneration of sycamore in an artificially created gap.

(Southern Black Forest, Germany)

Plate 4.2-9: 100 year-old sessile oak that were planted in gaps of 30 m diameter into a Scots pine stand. (Brandenburg, Germany)

This was the first approach to break up the monotony of pine stands. Around ten years after the establishment of the oak the pine stand was harvested and replanted with pine. Almost 3,500 of these 'Mortzfeldt groups' have been detected by aerial photographs.

instance, to regenerate light-demanding species like oak in gaps and shade-tolerant species like beech under denser canopy sections.

Storms may throw some trees along the borders of the gaps, nevertheless, stands with gaps are more stable than those treated in uniform shelterwood systems as some parts of them are still fully closed.

Conclusions

The gap-cutting system will probably play a more pronounced role in the future, especially if it is aimed at introducing light-demanding tree species into stands of shade-tolerant species. But it will also gain importance if oak and other light-demanding species continue to regenerate arbitrarily in groups, as they have done increasingly in recent decades on the Continent.

4.2.2.4 (Uniform) shelterwood system

(1) Definition and importance

In the shelterwood system a stand is regenerated naturally under recently opened canopy. This system is especially useful for species that produce heavy seeds like oak and beech as these are not distributed by wind. The canopy supplies shelter against climatic stress, but at the same time it causes competition for light, water and nutrients for the young plants.

Two forms of the shelterwood system can be distinguished:

- In the **(uniform) shelterwood system** the canopy is opened more or less homogenously over large areas (more than 5 ha), and
- in the **irregular shelterwood system** the canopy is opened irregularly over the whole stand, lightly at first and gradually increasing in intensity.

The shelterwood system was created in the mountainous regions of Central Europe, mainly in beech forests, but also oak stands. Its main elements, however, have been transferred to other species. The more even-aged monocultures are transformed into uneven-aged mixed species stands, the more the shelterwood system will gain in importance.

(2) Description of the shelterwood system and its effects

Originally the shelterwood system was developed mainly for beech stands. As beech produces seed at intervals of 8-10 years it was necessary to take advantage of the rare mast years and to regenerate those stands that had reached the production target. This operation was carried out on large areas, with 20 ha in one block being no exception. This uniform large scale procedure brought the system into disrepute. Moreover, the long regeneration phases of more than 20 years between the first openings and the final fellings favoured only shade-tolerant species like beech and led to a decline and eventual elimination of the light-demanding species, resulting in large pure stands of beech.

Also problematic was the felling of old beech with large crowns as they often cause serious damage to regrowth.

The system was subsequently modified as shown in Figure 4.2-3.

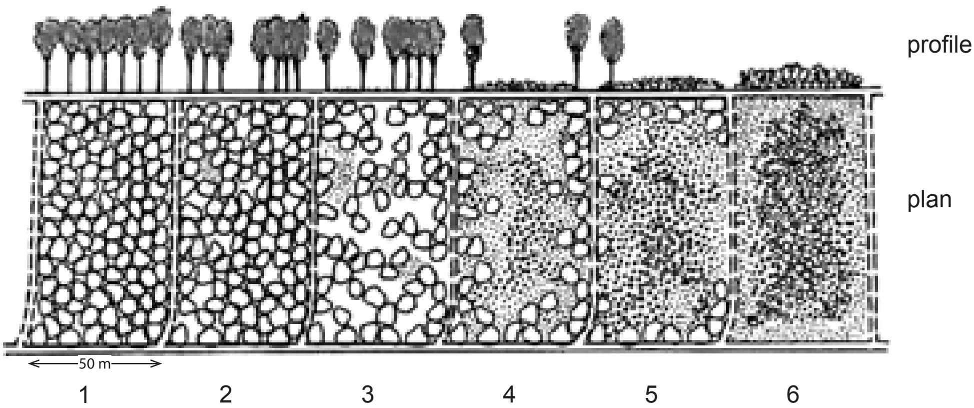


Figure 4.2-3: Schematic representation of the **modified shelterwood system**. (Burschel and Huss, 2003)

The modified uniform shelterwood system entails:

1. Presence of a mature fully stocked closed stand at the regeneration stage. Installation of extraction racks if not already existing from the thinning phase.
2. Preparatory felling to start regeneration: A cautious, relatively even opening of the canopy through removal of 15-20% of the standing volume. This is mainly to encourage seed production on the more vigorous individuals.
   At the same time by improving water and temperature conditions, soil activitiy should be stimulated encouraging litter breakdown thus creating appropriate seed bed conditions. It may become necessary to remove shrubby or herbaceous vegetation.
3. Seeding felling in mast year: removal of 30-40% of the standing volume. This operation takes place generally after seed fall. The seedlings should get sufficient light to grow, but also sufficient shelter from late frost and drought.
4. Removal fellings: beginning in the centre area between two racks, the shelter is gradually removed. The number of interventions depends on the development of the seedlings and can last 8-20 years.
5. Final felling: Removal of the remainder of the old crop. Trees on the margins at the gaps, which do not present a danger to the regrowth may be retained longer.
6. A young stand, slightly uneven-aged, replaces the old crop.

Although the canopy of the mature stand is evenly opened in the modified shelterwood system at the beginning, the remaining trees will later be removed from the centre of each area between the racks. The old trees should always be felled and extracted in the direction of the racks, thus avoiding damage to the regrowth. Damage to trees on the margins is compensated by later regeneration. If the centre zone is opened quickly light-demanding trees get a chance to become established. If they do not regenerate naturally they can be introduced by enrichment planting.

Plates 4.2-10 to 4.2-13 illustrate the system and some of the problems also.

In principle the shelterwood system works the same with oak stands. Because of the greater need for light and reduced demand for shelter of the seedlings the steps shown in Figure 4.2-3 will follow each other much more rapidly. Whereas beech stands may need more than 20 years to become fully regenerated, it will take 5-8 years with oak. Moreover, the preparatory felling will be much heavier.

Plate 4.2-10: A shelterwood beech stand after the first seeding felling. (Northern Germany)

Plate 4.2-11: Shelterwood system: Beech stand with intermediate fellings. (Black Forest, Germany)

The regrowth has reached a height that it needs less shelter and more light. The canopy has been partly opened above these sapling groups.

Plate 4.2-12: Shelterwood system: Last phase of removal of the canopy trees in a beech forest. (Netherlands)

Since the first regeneration openings were undertaken, 20-25 years have elapsed. Felling of the last valuable old trees needs highly skilled workers.

Plate 4.2-13: Highly overthinned old beech stand with a thick layer of ground vegetation and poor regeneration as a result. (Zonguldak, Turkey)

If beech regeneration fails after a mast year and the canopy has been opened, the ground vegetation often develops and this impedes germination of beech seedlings. This has proved to be one of the great problems with the uniform shelterwood system.

(3) Climatic characteristics and effects on the regrowth

The main factors are described in Table 4.2-2.

Table 4.2-2: Ecological conditions under (uniform) **shelterwood** stands.

Ecological Factor	Description
Radiation and Temperature	Opening the canopy increases radiation on the soil and thereby increases air and soil temperatures. Improvement of radiation, however, is less than proportional to the increased opening of the canopy. Therefore, there is a restriction of regrowth even under widely opened canopies. At the same time sheltering has an effect against late frost. Danger of competition from spreading ground vegetation.
Water balance	Reduction of water flow depends on extent of canopy opening. Increase of precipitation noteworthy only after large openings. At the same time reduction of water use by the old trees, resulting in gradual improvement of water supply for the young trees – but also for the ground vegetation. By careful felling and timber extraction no intensified water run-off, however, higher water percolation into the soil.
Soil activities	Improvement of ground organisms because of higher temperature and increased water supply. Acceleration of mineralisation of litter and release of nutrients, but processes reduced compared with clear-cut areas. Nutrients kept within the soil-plant cycle: first absorbed by the old trees (increase of increment), later available for the regrowth.
Development of ground vegetation	Reduced development at the beginning, but often followed by quick spread of existing grasses after creation of openings.
Wind and storm	Air movement above ground considerably reduced even after major canopy openings. Therefore, less stress through transpiration and soil desiccation. Increased danger of wind throw, especially if old trees have not been prepared in time by long-term preparatory thinnings. Broadleaves less at risk because of deeper root systems and defoliation in winter. Therefore, uniform shelterwood system mainly suitable for them.

(4) Critical assessment

Naturalness

The shelterwood system ensures permanent stocking. While the old trees are removed gradually the regrowth develops. Thus the soil is constantly covered and protected against erosion. Temperature and precipitation are gradually increased. The mineralisation of the litter is slow and nutrients are not lost. Compared with many natural forests the fluctuations of biomass above and below ground are reduced. Light-demanding tree species may be handicapped, but as mentioned, the system is also suited to species like oak by accelerating removals.

Growth and economic characteristics according to tree species

Individuals of light-demanding tree species are not able to tolerate long-term shading when young and old trees respond little when released. The system, therefore, is more suited to shade-tolerant species, but even then it does not make sense to retain older trees. Their longer maintenance may be justified only if they have been prepared in advance to form large crowns, and if their stem quality is sufficiently good to act as shelter trees.

Conclusions

After the clear-cut system the shelterwood system is next in importance. Although originally developed for the regeneration of beech stands, it can be adapted to stands of other species, especially oak, when the progress of all steps is accelerated, and when it is managed less schematically and especially in smaller management units. It can then be used to establish mixed stands, including those of light-demanding species, and provides the transition phase towards the irregular shelterwood system.

4.2.2.5 Irregular (group) shelterwood system

The irregular shelterwood system is also called group shelterwood system or femel system. Small shelterwood fellings distributed groupwise throughout a stand create varying conditions on small areas and thereby meet the ecological demands of many tree species.

The most important steps of the procedure are shown in Figure 4.2-4.

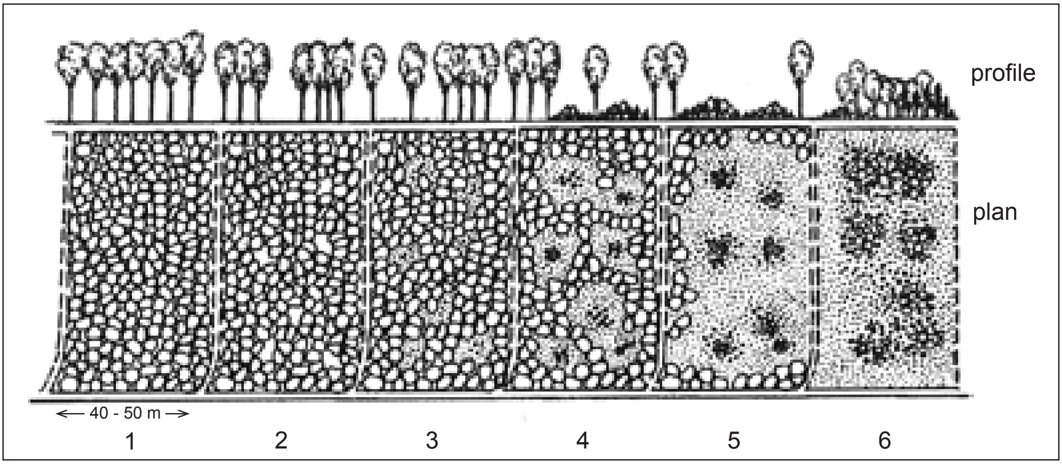


Figure 4.2-4: The **irregular** (group) **shelterwood system**. (Burschel and Huss, 2003)

The figure can be seen as a follow-up of procedures in time or as neighbouring areas of different phases beside each other in the locality.

The system includes the following steps:

1. Closed mixed broadleaf/conifer stand with an existing or newly installed rack system.
2. Irregular light openings of the canopy, either to improve the growing conditions over already existing groups of seedlings or of planted individuals. Larger parts of the stand remain untouched. Removal of 5-10% of the standing volume.
3. Peripheral felling around the groups thereby widening them. All other parts of the stand are still kept closed. Removal of 10-15% of the standing volume.
4. Further peripheral fellings forming irregular group sizes. Moderately shade-tolerant species now have a chance to regenerate. In the centre of the groups even light-demanding species may be established. In cases where the natural regeneration does not succeed planting should be carried out. Removal of 20-25% of the stocking volume.
5. Final removal of the last standing trees after the whole area is fully stocked with regrowth. These last trees are located along the racks so that no damage occurs when they are harvested. The total likely time scale depends largely on the tree species involved. It may last more than 30 years with beech and admixed conifers.
6. The young trees differ in height for some decades, but this variation gradually becomes less.

The system is especially adaptable to the regeneration of species with differing light demands (Plate 4.2-14). The canopy should be further opened only if sufficient regrowth has developed. It allows for a very flexible application. If a desired species has not regenerated due to an absence of seed or the soil was covered by competing ground vegetation then planting is necessary.

The procedure of canopy opening and removal of the old trees provides an opportunity to exercise some control over the proportion of tree species: Slow progress favours the shade-tolerant ones, rapid removal the light-demanding ones.

In practice, some general difficulties have to be acknowledged:

- Considerable skill is necessary in felling and timber extraction to avoid causing too much damage to the regrowth.
- The whole regeneration-cycle from the first openings of the canopy to the removal of the last trees involves a long time period, depending of course on the species involved.

It is doubtful whether many owners or their staff are in a position to guarantee the necessary continuity over decades.

- The required tending and thinning needs highly individual treatments on very small areas.
- Stands with irregularly opened canopies can be prone to storm damage especially on gleys. This is particularly the case with trees that have been kept dense in their youth and are not adapted to wind stress. However, by directing the fellings towards the main wind direction – mainly heading from east to west, as shown in Figure 4.2-4 – this danger can be reduced.

Plate 4.2-14: Irregular shelterwood system in its last phase: Background: fully regenerated; foreground: regeneration to come.
(Kelheim, Germany)

Practitioners tend to confuse the gap-cutting and the irregular shelterwood systems. With the gap-cutting system openings are created at the very beginning of all treatments, whereas with the irregular shelterwood system they develop only after several interventions – as shown in Figure 4.2-4.

Conclusions

The irregular (group) shelterwood system permits very flexible and unsystematic procedures. Over long periods the regenerated stands show a great variety of ecological and visual differences. This makes it very attractive for many foresters and environmentalists. For this reason it is being increasingly recommended to forestry practitioners.

Furthermore, some of its elements have become important as features for the continuous cover system (see Chapter 4.2.2.8).

4.2.2.6 Single tree selection system

(1) Definition and description

In the single tree selection system trees of all ages and size categories are mixed more or less at random, in both the horizontal and vertical planes, throughout the stand. Some individuals have already reached target dimensions whereas others are just germinating. Silvicultural treatments always include combined aims. The removal of old trees is the harvest. It provides space for the intermediate and suppressed individuals and this has the characteristics of a thinning. At the same time it improves the soil conditions for natural regeneration.

The system is characterised by single tree interventions and, therefore, represents the other extreme from the clear-cut system with its whole stand treatments.

Selection forests can be managed sustainably even if they are very small in size. This, however, is possible only if the amount of timber harvested every year or few years is equal to the increment for that period. Continuous inventory is, therefore, essential as a guiding factor.

(2) Importance

The selection system has been practised for centuries on farm forests in Austria, Germany, Switzerland and France. Farmers collect a variety of timber assortments each year as necessary for the farm including fuelwood, while large dimensional timbers are produced for building construction.

Selection forests can only be established with very shade-tolerant tree species as the regrowth of other tree species is not able to withstand the continuous dense shade of the old trees. Silver fir is usually the main component. This is the case in some mountainous regions with high and permanent humidity as well as moderate to good soils. There selection forests help to minimise soil erosion and the risk of avalanches. As an exception, beech has been used to produce fuelwood on a sustained yield basis on limited areas (Plate 4.2-15).

The opportunity to establish selection forests is, therefore, extremely limited. In Europe the existing areas are relatively small in scale in comparison with the attention given to the selection forest system in the literature and by the public.

For almost a hundred years selection forests have been regarded as the most natural form of forest, close to the concept of nature-based forestry. Even foresters believed that it might be possible to convert all forests into multi-structured, mixed uneven-aged forests. The results were generally very disappointing and the inclination to follow this approach is nowadays assessed much more realistically.

Evidence suggests that it will not be possible to establish any selection forest in Ireland – at least not within the foreseeable future. Nevertheless, selection forests are still the dream of many ecologists and foresters as to how forests should look everywhere. In a certain way this view forms the background to the continuous cover movement. For this reason, an overview of some ecological issues might be helpful for a general understanding of the following aspects, (3) and (4).

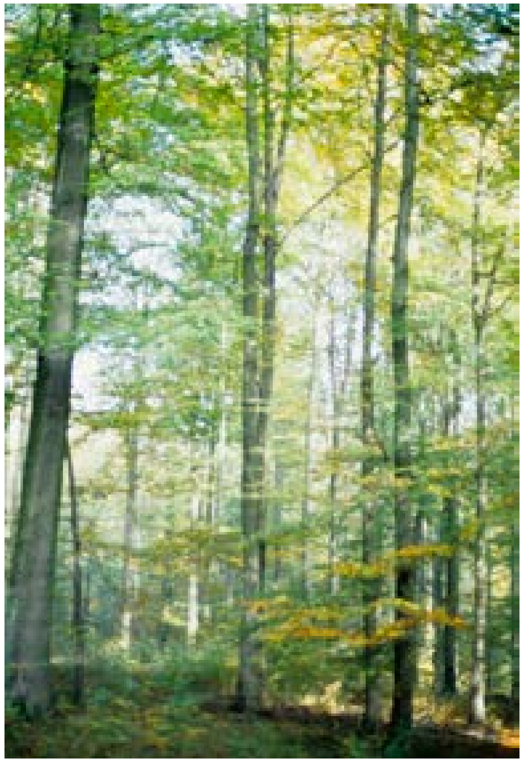


Plate 4.2-15: One of the rare selection beech forests. (Hainich, Central Germany)

Beech has been managed selectively here for centuries in order to produce fuelwood on relatively small areas on a sustained yield basis. The quality of the stems, however, is mostly unsatisfactory, showing that beech should be grown in groups to provide better natural pruning.

(3) Climatic characteristics and effects on plant growth

Selection forests show a much smaller variation in climatic factors on the ground over long periods as the stands are never fully harvested or fully opened up. Therefore, they ensure a type of steady state. Only very shade-tolerant trees and ground vegetation are able to regenerate and grow under the shelter of the multi-storied canopy of the more advanced individuals. These tend to intercept a great part of the precipitation and also cause root competition. Therefore, the regrowth is able to survive only where sufficient water is regularly available.

The soil activity is also relatively limited as the ground will never be opened up.

(4) Critical assessment

Selection forests are always kept in a steady state by regular interventions in the different layers of the canopy. Such a structure, however, is rare in natural forests. Regular interventions are, therefore, necessary to maintain the structure of a multi-layered canopy. If such activities are omitted, the canopy layer tends to become uniform. Thus selection forests are a very artificial and fragile creation.

Catastrophic events like those in natural forests, which cause greater differences in stocking density, are generally avoided as even the old trees are cut before they become moribund.

Dominant, intermediate and suppressed individuals are harvested regularly. This leads to a typical distribution of smaller (younger) and larger (older) trees – an inverse j-shaped curve, which is sometimes referred to as the selection forest diameter curve.

The growth habits of the trees of the different canopy layers differ very much from those in even-aged forests. For this reason the increment of a whole stand has to be estimated as the main basis of the annual cut. This approach has become the leading principle of forest inventory and regulation for cutting allowances in many European countries during recent decades.

Conclusions

It is doubtful that selection forestry will be widely used in Irish forestry. Nevertheless, it is important as a model for many aspects of forest ecology, structure and growth. Many of its components have influenced forest thinking and presumably will continue to do so in the future.

4.2.2.7 Combined systems

In Central Europe, several silvicultural systems have been developed for high forests, combining various elements of the systems mentioned so far in order to meet the autecological demands of the tree species, especially as mixtures (Plate 4.2-16).

A good example is the combination of the shelterwood system with the strip-cutting system in order to regenerate shade-tolerant species and also to provide conditions for light-demanding species to develop.

Conclusions

In the long-term various elements of several silvicultural systems will be used in Ireland. Experience from Central Europe has shown that they cannot be applied in a rigid manner to many forest types, but have to be adapted to local conditions. There are no schemes that can be used everywhere.

Most of the systems include long regeneration phases and need great skill and patience from the forest owners and foresters. For this reason they are expensive to manage. In many cases they cannot be successfully implemented often, since neither the personal, organisational nor economic conditions are favourable. Nevertheless, some elements are incorporated in the continuous cover system.

4.2.2.8 Continuous cover forest system

Foresters in many countries are aiming to structure their forests so that all functions remain constant and sustainable on small areas.

The selection forest was regarded as the ideal for a long time, and attempts were made to create it in all types of forests. As discussed in Chapter 4.2.2.6, it was found, however, that only young plants of very shade-tolerant species – like silver fir and beech – are able to survive under the dense cover of the canopy.

On most forestry sites the conditions are less favourable. The drier or poorer the soils and the more light-demanding the species present, the more the stands tend to be structured in groups.

Plate 4.2-16: A combination of irregular shelterwood and strip-cut systems provides the opportunity to naturally regenerate broadleaves and conifers, of different ecological requirements, together. (Kelheim, Germany)

Therefore, the irregular (group) shelterwood or the gap-cutting systems are more advisable. In the long-term it will be possible to establish stands with groups of one species, but with each differing in age and size. On a given stand area all forest activities like harvesting, regeneration and thinning will happen simultaneously, as in the selection forest.

Continuous cover forest systems (CCF) include all variations of sheltering canopy and uneven-age structure on a forest area excluding clear-cuts. However, even cutting of large gaps is acceptable as long as they do not create bare land conditions – depending on the height of the surrounding stands, and the gap size not exceeding 0.5 ha. Moreover, as long as the soil is not exposed and erosion is not a problem larger gaps can be tolerated. Gap regeneration will lead to groups of even-aged trees within the stands, but normally they tend to be small.

Long-term canopy cover on large areas – as is possible with beech – seems to be impractical under Irish conditions. Most of the relevant Irish tree species are light-demanding. Therefore, either gap-cutting or a rapid removal of light canopies over young regrowth is generally necessary when these species are regenerated. This will lead to brief overlapping periods of the tree generations with only short-term uneven-age categories.

Experiences from Germany have shown that tourists and walkers do not very much appreciate large continuous cover forest areas. In contrast, they prefer sufficient open spaces and wide scenic views in mountain regions rather than a long sequence of continuous cover forests.

Recently in Ireland a synonym for CCF has been introduced: a less intensive, alternative silvicultural system called low-impact system (LISS = **L**ow **I**mpact **S**ilvicultural **S**ystem). This term, however, seems to be somewhat ambiguous, as it is not clearly defined. Does low impact mean: low impact of plants, of man-power, of costs of the different procedures, low intensity of each intervention, energy for machines, small amounts of fertilisers, avoidance of compaction of soils, ecological impact?

The following examples may illustrate the definition problems:

- Clear-cuts for instance require less well trained workers and harvesting tends to be cheaper per unit of harvested timber. Thus the impact is lower in this regard, but planting is costly and regeneration requires high inputs of money and labour.
- Selection forests on the other hand need intensive and very skilled management at frequent intervals, but are low impact with regard to regeneration.
- Low or high impact is also vague with regard to flora and fauna: small clear-cuts or large gaps can provide many more niches for plants and animals than selection forests or very large clear-cuts.

So without a clearer definition, LISS may add more to confusion than to a clear understanding of the complicated interactions of economy and ecology within silviculture.

A special variant of the continuous forest cover approach is the **target diameter harvest system**. Its main aim is to harvest healthy trees that have reached dimensions which permit optimal marketing. This leads to the felling of single trees or small groups of individuals. By this means the economic gains are improved. Because of rapid changes in timber markets it is difficult, however, to assess the target diameters over long periods.

In order to favour special tree species the regeneration of the stands and possible tending measures are not considered. It is assumed that regrowth will develop sufficiently under the unevenly opened canopy and form acceptable new stands. There is, however, some evidence that this system will cause long-term shelter situations and that light-demanding species will generally be outshaded.

Conclusions

The continuous cover forest system cannot be clearly defined as it contains elements of all the silvicultural systems for high forests, except the clear-cut system.

The continuous cover forest system has great attractions for many foresters and people who are interested in forests. For its practical implementation, however, the following points are valid:

- It needs great silvicultural skill, and activities must be directed to small areas.
- Large enterprise units with low staff availability and increasing mechanisation with big machines, however, are less conducive to the practice of such a system.

From the ecological point of view a reduction of large clear-cuts is desirable as these are often connected with soil erosion and disturbances to landscapes. Restricting the use of small clear-cuts, however, does not seem appropriate for a number of reasons: in particular it is not appropriate for light-demanding species, and most of the species common to Irish forests are light-demanders.

Therefore, the continuous cover system is not suited to address all forestry problems, as highlighted by many foresters, and as a vast number of publications would have us believe.

4.2.3 Coppice systems

Coppice forests originate from stool shoots or sprouts. Most broadleaves have sprouting ability, but there are great differences in vigour (Table 4.2-3).

Oak, hornbeam and ash sprout easily, beech less reliably. Aspen produces only root suckers. Very few conifers apart from yew and redwood are able to sprout from the stump.

Table 4.2-3: Coppicing capacity of the main broadleaf species.

Capacity	Species	Comment
Good	Alder, ash, field maple, hazel, hornbeam, lime, oak, Spanish chestnut, willows, wych elm.	Classical tree species of coppice and coppice-with-standards forests.
Medium	Birch, crab apple, hawthorn, holly, poplar, rowan, sycamore, wild cherry.	Mainly good sprouting also, but seldom stand-wise. Cherry produces suckers better than coppice shoots.
Poor	Beech, small-leaved elm.	Reasonable sprouting in higher altitudes without competition of other broadleaves.
None	Aspen	Root suckers instead.

The main production goal of coppice forests was primarily to produce fuelwood. Although once widespread, traditional coppice forests no longer exist in Ireland. Today, however, there may be an opportunity to establish some areas of short rotation forest as a modern approach to this type of silvicultural system. Both are treated briefly in the following sections.

4.2.3.1 Traditional coppice system

Traditional coppice forests were widespread in pre-industrial times all over Europe – except for the Boreal zone (Plates 4.2-17 to 4.2-20). Their main objective was to produce fuelwood for energy and charcoal for household use as well as for industry and mines. Other important, but partly local uses were bark for tannin, poles for fences and vineyards and material for wattles and weaving (Plates 4.2-21 and 4.2-22).

Coppice forests produce small-dimensioned stems which can be easily felled, extracted and transported. They can be managed with simple equipment and do not need intensive forest infrastructure and transport means. Cut stumps remain alive and there is no need to expend effort in regeneration. These sprout vigorously – often more than 1 m height growth in the first year. Therefore, the soil is quickly protected

Plate 4.2-17: Coppice managed forests are still found in many countries: Oak coppice still managed on a minor scale. (Luxemburg)

Plate 4.2-18: Very poor oak coppice woodland. (Northern Turkey)

Plate 4.2-19: Oak coppice forest of reasonable quality. (Montenegro)

Plate 4.2-20: Remnants of beech coppice. (Black Forest, Germany)

Plate 4.2-21: Products of coppice forest: fuelwood and bark. (Black Forest, Germany)

Plate 4.2-22: Products of coppice forests: bark still used for fine leather. (Luxemburg)

against erosion and, moreover, no tending procedures are needed.

Coppice forests do not reach great heights as they are harvested in relatively short rotation periods – after 20-40 years – according to site conditions and species.

The first simple management systems were developed in coppice forests. In order to reach sustainable production the total coppice forest area was divided by the number of years of the rotation. This area then formed the basis for the annual cut. Most coppice forests, however, have not been subject to regular planning.

Coppicing was carried out in two forms (Figure 4.2-5).

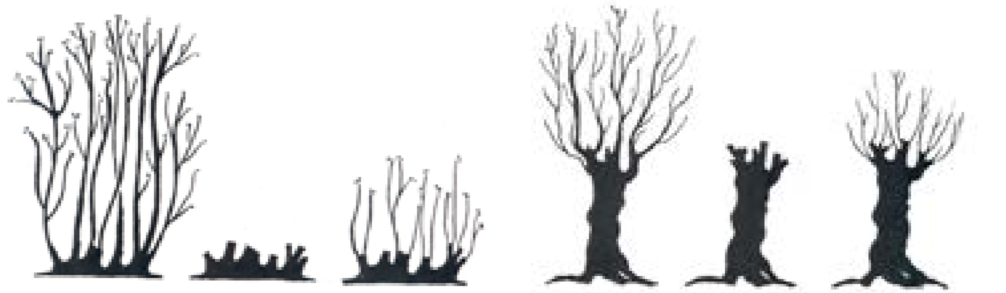


Figure 4.2-5: Types of **coppicing.**

Traditional coppicing has been practised most. Pollarding was common with willow groves/osiers. By cutting higher than cattle could reach the young and tasty shoots could not be browsed.

In Western, Central and Southern Europe, as well as in Turkey, oak was the main tree species in coppice forests, often with mixtures of ash, hornbeam, elm, hazel, lime, cherry, service tree and maple species. Beech, because of its lower sprouting capacity and slower early height growth was gradually suppressed in the lowlands and could only develop in the mountainous regions without competition from other broadleaf species.

The sprouting potential of many coppice forests deteriorates after several cuttings. Furthermore, they tend to grow less straight. There is evidence that the stumps undergo a process of ageing and, therefore, need to be regenerated generatively, or from seed, by planting or by layering.

With poor demand for coppice material many coppice forests have been abandoned and have grown into types of high forests which are mostly of low height and of poor growth and form. Some oak forests in the vicinity of Glendalough are typical examples (refer to Plate 3.2-5). Remnants of this type of forest are still evident in Ireland.

Conclusions

Traditional coppice forests are unlikely to gain the importance of earlier times. The main reason is the low level of production compared with high forests. Fuelwood needs can also be readily supplied from high forests, as approximately 50% of the timber production of broadleaf high forest is fuelwood or industrial wood of low quality and value.

4.2.3.2 Short rotation coppice system

Coppicing as a potential source of renewable energy was given a new impetus by Swedish scientists in the 1960s – as mentioned in Chapter 3.2.3.3. The process involved planting poplar and willow cuttings at very high densities and harvesting after a few years.

The oil crises of 1973 and 1979 caused politicians and scientists in central Europe to think of biomass as an alternative source of energy. Trials were carried out on agricultural tillage land, densely planted with cuttings of willows or poplars and harvested after 3-5 years. However, they never really developed from the experimental stage.

As energy became relatively cheap during the following years interest (as in late 2008) in such experiments began to wane. This changed, however, (post 2008) during recent years when the oil prices increased dramatically again. People have now begun to realise that energy will never become as cheap again as it was in the last quarter of the 20th century. For this reason short rotation coppice has gained greater attention (refer to Plates 3.2-6, 3.2-7, Chapter 3.2.3.3 and 3.6). Information on Irish experiences has been compiled by Teagasc (2007) and is given in Table 4.2-4.

Table 4.2-4: Establishment and management requirements of short rotation coppice with willows. (Adapted from Teagasc, 2007)

Item	Detail	Requirements
Site selection	Soil	Good quality land; ensuring optimum soil fertility levels.
	Access, traversable	Large, regular shaped areas with easy access.
Establishment	Soil preparation	Good soil cultivation to promote successful establishment.
	Vegetation control	Killing off all grass and weeds prior to planting.
	Plant material	20-25 cm long cuttings with a minimum diameter of 9 mm 1 yr. old shoots from cuttings; planting immediately or cold storage before planting; mixture of different clones to avoid fungal (rust) damage.
	Planting	Machine planting in February-May; inserting cuttings ¾ into the soil.
	Stocking density	20,000 cuttings/ha
	Fencing	Good fencing essential against livestock, deer, rabbits, hares during the growing season.
Maintenance	Vegetation control	Complete control of competing vegetation essential, especially in the first 2 years with overall residual herbicide post planting.
	Cut back of shoots	After 1 year in order to encourage the development of multiple shoots.
	Fertilising	Repeated applications to maintain productivity (possibly sludge or slurry).
Harvesting	Time	In winter when shoots ~6 m long; first time after 4 years, later in 2-3 yr cycle.
	Equipment	Heavy, expensive machinery.
Production of chips		Drying of chips before storage necessary. Expensive drying facilities required.
Production rate		6-12 t/ha/yr.
Life span of shoots		15-25 years.

At present it is difficult to assess the likely future importance of this system. Some of the main issues are highlighted in the conclusions.

Conclusions

Short rotation coppice is similar to tillage systems in agriculture. Large areas will not be available as it requires good land of adequate size and access. Its use competes directly with other more lucrative types of agricultural production.

The revenue:cost balance is not very encouraging as the profit margins are low, because of a low-value product on the one hand, while establishment and early management costs are high on the other. Danger from rusts and other diseases.

In combination with other processes, like the disposal of sludge and slurry, the relatively low maintenance costs of short rotation coppice may become more attractive for farmers or other enterprises. Moreover, cooperation with neighbours would enable the costs to be reduced, especially for machinery and drying installations.

Grants should be available to establish short rotation willow plantations (Teagasc, 2007).

There are some indications that diesel oil produced from willow or poplar chips is of better quality and that a greater quantity can be produced per unit of area than that derived from oil seed rape or sugar beet (Wüst, 2008).

Therefore, it is possible that short rotation coppice may gain more importance in the long-term.

4.2.4 Coppice-with-standards

Coppice-with-standards represents a transitional form between coppice and high forests. Fuelwood is produced from material harvested after one coppice rotation and sawn timber from trees that have been retained for more than one rotation period (Plates 4.2-23 and 4.2-24).

Plate 4.2-23: Typical coppice-with-standards forest with oak standards and oak/hornbeam coppice. (Neuf-Brisach, France)

Foreground: The coppice has recently been cut and is resprouting. Background: older coppice, ready for harvesting.

Plate 4.2-24: Managed coppice-with-standards forest. (Sicily)

The downy oak *(Quercus pubescens)* which resembles sessile oak is vigorously re-sprouting after harvest.

The standards left after the first rotation of generally 30 years are 60 years old at the end of the second coppice rotation. They can then be used for poles and small beams. Some of them will be left for another one or two rotation periods and after 120 years specimens of 60, 90 and 120 years of age with a wide range of diameters are then available.

Most standards are of oak. Grown at relatively low densities they form large crowns and are regular seed producers. In times past their seed mast production was important for feeding pigs which were the only meat stocks for winter and also for ship voyages (Plate 4.2-25). This practice still plays an important economic role in SW Spain (Serrano ham) in large holm oak forest areas and in Tuscany (Parma ham) with sessile oak. Efforts are being undertaken to revive this silvipastoral method in Germany (Plate 4.2-26).

Trees intended as standards were often planted and of seedling origin, as coppice shoots do not always grow sufficiently vigorously. This is another reason why coppice-with-standards forests forms a link between high forest and coppice.

Coppice-with-standards forests covered large areas in Europe for centuries and met the needs of households as well as industries in an ideal and sustainable way. Their remnants cover almost half of the forest area in France and Italy. There they are still partly managed in the traditional way in some countries, but many have been converted into high forests (Plates 4.2-27 and 4.2-28).

Plate 4.2-25: Acorns being harvested from oak standards for pannage.

(From 'Les Très Riches Heures du duc de Berry' (1412-1416). This 'the November' painting by Jean Colombe, however, was inserted in the book only at the end of the 15th century).

Plate 4.2-26: Modern revival of mast for pig food in a coppice-with-standards forest.

(Iphofen, Germany; courtesy: H.-H. Huss)

Samuel Hayes of Avondale made a strong case for the retention of standards (which he referred to as reserves), arguing that retaining standards dramatically increased the value of a stand of oak coppice (Hayes, 1822).

Carey (2009) suggested that there is no information on when the coppice system was first introduced to Ireland. He stated that the interest in tree planting in the 18th and 19th centuries was a new fashion. However, the demand for timber for ships, charcoal for smelters and tree bark for tanning collapsed in the second half of the 19th century. This event had far reaching implications for the oak woods, most of which had been managed on a coppice-with-standards system.

Plate 4.2-27: Former coppice-with-standard forest which is now partly converted into high forest by planting.

(Darmstadt, Germany)

Plate 4.2-28: Another example of the formerly widespread coppice-with-standards forest in transformation to high forest.

(Freiburg, Germany)

The lower crown branches show the height to which the coppice once reached.

In recent decades the lower trunks of oak from French coppice-with-standards forests have been sold as veneer timber and high quality wine barrel staves. For this reason, the discussion nowadays in Central Europe is about the management of crop trees as standards to produce short, but large diameter boles of high quality. This approach is called free growth of oak (see Chapter 4.5.5.6 (2)). As oak tends to freely produce epicormic shoots, pruning is necessary almost annually. Therefore, it is doubtful that this system will gain wider acceptance.

Conclusions

Coppice-with-standards forests were very important in several European countries – sometimes even more than high forests. There is little evidence, however, that this situation will arise again. Nevertheless, it could be worthwhile to adopt some features of this system by planting standards at wide spacing into scrub or other forms of degraded forests, using the ground cover as fillers in the manner of coppice, to improve the quality of the lower trunk.

4.2.5 Characterisation of the silvicultural systems

Silvicultural systems have more wide-reaching influences on forestry than just directing the composition of species and structure of stands as a result of changes in the ecological conditions. In fact, they have an impact on almost all aspects of forestry.

This is illustrated by means of selected systems in the following three tables:

- In Table 4.2-5, the influences of the systems on ecological conditions,
- in Table 4.2-6, on biodiversity and recreation as well as landscape scenery, and
- in Table 4.2-7, timber production and structure of forest enterprises.

These tables are partly intended as summaries and do not need explanation as most aspects have been mentioned already.

Table 4.2-5: Influence of selected silvicultural systems **on ecological features**.

Silvicultural system	Influence on micro-climate	soil	ground vegetation	tree species type	species diversity	naturalness	safety of stands
Coppice	Strongly changing, bare land climate for a short while.	Regular frequent harvest of total above ground biomass can cause high nutrient losses. On slopes low erosion danger because of fast sprouting.	Poor development because of fast growth of sprouts.	Exclusively tree species with sprouting ability.	On rich sites many broadleaves. On dry soils mostly only oaks.	Far from nature, no equivalent in natural forest.	Very high: no danger from storms or from fires.
Clear-cut	Bare land climate on the whole clear-cut area for some years.	On slopes erosion danger. Nutrient losses because of mineralisation possible.	Often strong vigorous dense vegetation until thicket stage is reached.	Pioneers.	Mainly stress-tolerant species, late-successional species only in protected sites.	Relatively far from nature; distantly comparable with catastrophic events like storms and fires.	Danger of fires in young phases (ground vegetation); even-ageness and monoculture cause danger from storm.
Shelter-wood	Because of changing canopy density, moderation of all climatic effects.	Favouring of mineralisation and soil activities. Nutrients stay in plant cycle. Little erosion danger because of permanent stocking.	According to speed of removal possible distribution and competition for tree regrowth.	According to speed of tree removal: Pioneers and/or shade-tolerant species.	In cases of long time sheltering limitation to shade-tolerant species.	Comparable with overmature phase in natural forests, but less dead wood debris.	Mainly suitable for broadleaves. Danger from storms in cases of insufficient stability of trees by timely thinnings.
Single tree selection	Concise, balanced and continuous inner stand climate.	Low, but continuous soil activities. Optimal erosion control.	Slight development., Only shade-tolerant species with little generative reproduction rate.	Exclusively shade-tolerant tree species (beech, silver fir).	Relatively low, only shade-tolerant species.	Rare in natural forests (selection phase). Maintained only by regular interventions.	No fire danger because only possible in humid regions. Low storm danger because of high stability.

Table 4.2-6: Influence of selected silvicultural systems **on biodiversity, nature protection, suitability for recreation** and **landscape scenery**.

Silvicultural system	Influence on biodiversity	suitability for nature protection	suitability for recreation	landscape scenery
Coppice	Only limited number of broadleaves, normally a mixture of several species. Variable quality habitat for fauna and flora.	Important habitat for some specialised species, however, limited suitability in total. Lack of dead wood disadvantageous.	Relatively monotonous, therefore,less attractive from the aesthetic point of view. Some phases provide little shade and shelter. Characteristic (old) specimens lacking.	If applied on large areas little differentiated and, therefore,lacking visual diversity. But because of short rotation periods some interruptions provided.
Clear-cut	High density of species possible on clear-cut areas for some years. Ecological poverty for long time after crown closure in the thicket stage.	Very limited if applied on large areas. Lack of dead wood disadvantageous.	If applied on large areas monotonous because dominance of young and middle age classes. If applied in form of small areas attractive views and visual changes. Irregular boundaries advantageous.	Extremely dependent on size of areas. Not generally monotonous if stands of different age follow each other. Less problematic if clear-cuts are carried out over established regrowth.
Shelterwood	Tendency to pure stands with richness in structure for some periods. Advantageous for specialised species.	Differences in stand structure on small areas provides variety of habitats. Crown wood often remains in stands as dead wood.	Aesthetic structural richness according to development phase. Never produces impressions far from nature like clear-cuts.	Even if applied on large areas at least with visual diversity of structure for some time during the (long) phases of regeneration.
Single tree selection	Very limited number of dominating tree species. Permanently restricted living opportunities for other animal and plant species. Sometimes some more dead wood present.	Because of its diversified structure advantageous for enrichment of forest areas.	Very suitable for the environment of cities and tourist centres because of their small sized structures. Existence of large dimensioned specimens attractive. Lack of visual variety and too much shade disadvantageous.	Over large areas very monotonous, eventually slightly reduced through its uneven canopy.

Table 4.2-7: Influence of selected silvicultural systems **on forest appearance, infrastructure** and **type of enterprise**.

SILVI-CUL-TURAL SYSTEM	INFLUENCE ON: forest appea-rance	accessibility	concentration of timber volume	sustainability of timber production	quality of personnel	structure of enterprise	suitability for type of enterprise
Coppice	Area-wise homo-genous, only sapling, thicket and pole stages.	Simple racks suf-ficient, no sophi-sticated opening-up/ accessibility necessary.	Exclusively very small dimensio-ned assortments for fuelwood and industrial wood.		Felling by less experienced workers pos-sible.	Minimum area neces-sary (e.g. 20-30 ha at 30 yrs. rota-tion).	(Farm) vil-lage forests. In cases of indus-trial wood pro-duction much larger areas advantageous.
Clear-cut	Area-wise clearly sepa-rated into different age classes.	Forest roads necessary for transport of heavy timber, but concentration of road building in working blocks possible.	Standwise pro-duction/onset of different timber assortments of small sized to big-ger dimensioned timber in homo-genous distribu-tion.	Only possible if stands exist of more or less equal size and of all age classes are represented.	Relatively simple felling procedures.	Large mini-mum areas necessary (e.g. 50-100 ha at rota-tion period of ~100 yrs).	Medium to large sized enter-prises.
Shelter-wood	Area-wise age classes less visible because of (long-term) sheltering phases.	Well maintained, permanently usable forest roads necessary for transport of big dimensioned timber from removals.	As above, but greater amounts of big dimen-sioned from shel-terwood fellings.		Well trained and experi-enced workers for fellings over regrowth nec-essary.		
Single tree selec-tion	Pronounced uneven-age character. Vertical and horizontal mixture of trees of all development phases.	Well developed road and rack system over the whole area for extraction of even small amounts of big dimensioned tim-ber necessary.	Very variable (het-erogenous) vol-umes of all assort-ments on very small areas (~1 ha) possible.	In extreme possi-ble on 1 ha.	Very well trained and experienced workers as well as trac-tor operators for felling and extraction pro-cedures over regrowth nec-essary.	Suitable for small farm forests with little forest area.	All sizes of enterprises, but farm forests only if access organised in cooperation with other farm-ers.

4.2.6 Future role of the silvicultural systems

The ecological aspects – site and tree species demands – have been described as well as an explanation of the role played by economic, technical and protection arguments, when making a choice about which silvicultural system to adopt.

The relationship between silvicultural systems and all of these factors is illustrated in Figure 4.2-6.

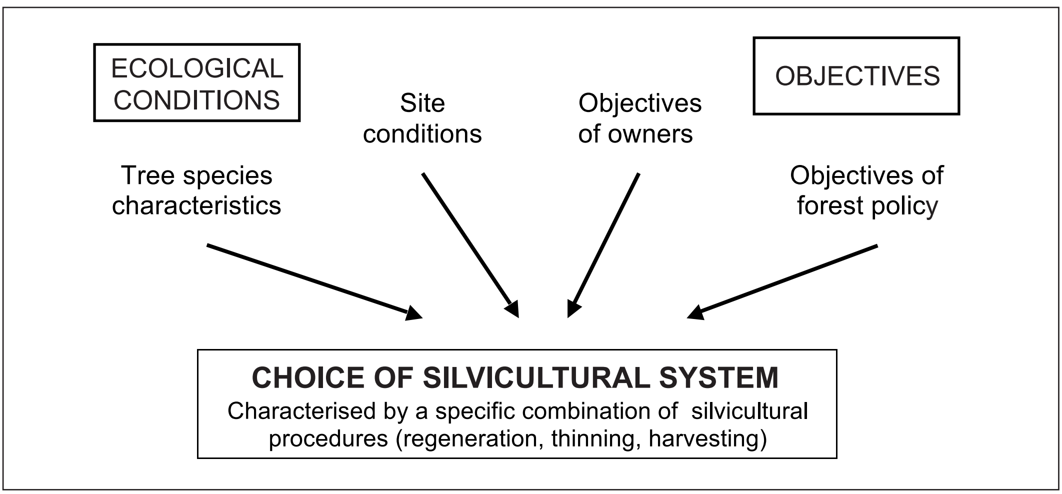


Figure 4.2-6: Dependence on ecological conditions and objectives in the **choice of silvicultural system**.

From the figure it is evident that forest owners do not have complete freedom on the choice of a silvicultural system.

The local conditions often provide limited choice as explained below.

Ecological conditions

Because of its historical background, broadleaf forestry in Ireland is mainly based on recent afforestation on bare land with a single species dominating. Therefore, even-aged pure stands with stress-tolerant pioneer species will remain the norm for the immediate future. Later generations will have the opportunity to gradually convert some of these into mixed and uneven-aged stands if they wish to do so.

Some of the broadleaf stands of the other private forests offer an opportunity to adopt a more sophisticated silvicultural approach along the lines of the continuous cover system. Many of them, however, serve as native woodlands and are not available for conventional forest management.

Broadleaf species are relatively site-demanding and, apart from birch and willow, most of the soils available are not favourable for them. Therefore, the distribution of many broadleaf species and demanding mixtures will remain limited.

Objectives

The public forests (Coillte) and the grant aided private forests are mainly economically driven. One of the reasons for allocating grants to farmers was the government's objective to establish a roundwood resource for the wood processing industry. Therefore, the production of high quality timber will play an increasing role, leading to longer rotations and in the long-term to natural regeneration under the shelter of seed trees.

There is also some evidence that wood will play an increasing role in the future leading to the production of more firewood and reviving ancient land-use systems like coppice and hedgerows.

As has been mentioned in Chapter 2 and again it will be shown in Table 4.4-8, the proportion of soils where trees are stable is not very high, due to the dominance of conifers and their restriction to difficult sites. Therefore, only in a few areas will a permanent forest cover be necessary in order to protect the soils. Nevertheless, on steep slopes large clear-cuts should, where possible, be avoided.

For nature protection, large forest areas should preferably be kept free from regular forest management. This will, however, conflict with the economic goals of most forest owners.

It is national forest policy to substantially increase the forest area in Ireland. This again would be possible only by planting and thus establishing further even-aged stands with a single pioneer species dominating. It is doubtful, however, whether sufficient land will be available to continue the remarkable afforestation programme of recent decades.

Conclusions

As most of the Irish broadleaf forests have been established only recently on green field sites, even-aged forests and the clear-cut system will probably continue to dominate their management. In the long-term, however, a gradual change towards more sophisticated systems is likely to take place.

With regard to the many aspects and arguments which have been dealt with, it can be stated that in general all procedures, if undertaken on small areas, meet the functions and services of forests best and find the highest acceptance by the public. Operations on small areas are, however, more costly and are, therefore, less often practised. This is unlikely to change much because of financial constraints.

continued

Conclusions continued

Large scale clear-cuts are regarded by the public as destructive of the landscape. In fact they are the cause of most discussions as to whether forests should be managed at all. The ecologically-concerned urban population, without much knowledge of agriculture or forestry, is especially critical of such management practice.

In this section the aim was to clarify:

- the many tangible and intangible issues and considerations that have to be taken into consideration when choosing a silvicultural system,
- the complicated process of reconciling different ecological or socio-economic issues often leaves little or no scope for the manager,
- that silvicultural systems can seldom be applied in a rigid fashion following text-book prescriptions, but rather appropriate elements should be used and adapted to suit local conditions.

It was also the aim of the authors to demonstrate the management of forests is influenced by many more factors and considerations other than silviculture alone. In practice, silvicultural aspirations are often the last link in a chain of various objectives of the forest owner and society.

4.3 Main silvicultural activities: Stand establishment and management

Silviculture, as an applied and practically oriented forestry subject, has two main fields of activity:

- The establishment or regeneration of stands and
- their subsequent tending, thinning and harvesting.

Both activities comprise the main components of all silvicultural systems, but with varying degrees of importance. Their respective weightings depend on the economic and sociological circumstances which are current at the time, the site conditions and on historical causes. Furthermore, their importance changes over time.

4.3.1 Changing emphasis of regeneration and thinning

In many countries across the globe forests have either been completely destroyed or heavily degraded by man, and therefore, have to be restocked. The establishment phase is normally characterised by afforestation through planting, mainly with pioneer trees. Thus forestry is **afforestation oriented**.

After plantations have been established for a number of years foresters begin to focus on thinning. Gradually the emphasis changes and forestry becomes **thinning oriented**.

This was typically the case in Central Europe and can be recognised from the structure of the many silviculture text books published during the 19th century. Initially the authors dealt exclusively with afforestation and regeneration problems, whereas towards the end of the century they concentrated much more heavily on tending and thinning.

Stands that have been managed by thinning over an extended period of time frequently exhibit good natural regeneration. Where possible, this option is availed of much more often. In reality there are, however, only few areas – mainly in Central Europe – where natural regeneration is standard and thinning the major issue. Nevertheless, there is a current tendency for forestry to become **natural regeneration oriented**.

In the later regeneration phase it is possible to transform the typical even-aged structure of the artificially established forests into an uneven-aged distribution with diverse mixtures and structures. The continuous cover concept is a step in this direction that has attracted great interest Europe-wide. Thus forestry becomes **nature oriented**.

4.3.2 Silvicultural activities after succession

Apart from the dominating activity of re-establishing forests by planting they may also come into existence through succession. Abandoned land no longer used for grazing or extensive agriculture will be invaded by shrubs and trees normally within a short period. Pioneers like birch and willow tend to be the first species. These will later be infiltrated by late-successional species, provided the site conditions are favourable for the establishment of trees and where there is a suitable source of seed locally. This is usually the case all over Europe with minor exceptions.

During recent years forest pastures have been gradually abandoned in large parts of European mountainous regions. This occurs especially in regions of the Swiss, Italian, French and Austrian Alps where forests are now invading whole valleys. These regions tend to lose their attraction for tourists through a change in the special character of the landscape. In Ireland, large areas of birch and willow on peat and extensive pastureland, as well as hazel on limestone, show similar developments. The management of these successional forests has become a new silvicultural problem, especially in relation to their protective function.

While the stands have come into existence without any silvicultural interference their further development can be influenced by thinning. Sometimes, however, the pioneer stands are underplanted with more productive trees using the overstorey shelter for a nursing effect. The silvicultural activities are, therefore, oriented to transforming a pioneer forest into a late-successional one. These relationships have been explained in Chapter 4.1.2.7.

Conclusions

At the beginning of regular forest management silvicultural activities always start with regeneration. After the young stands have reached the thicket stage tending will become important. At more advanced stages of stand development thinning will become the main focus.

Due to special historical circumstances Ireland's broadleaf forests are mainly even-aged at present. This common practice of planting on bare land is likely to continue into the foreseeable future.

Natural regeneration will only be possible in the few remaining ancient woodlands and in old woodland sites situated in estates.

The invasion of semi-abandoned land by pioneer species through succession may play a progressively important role if agriculture withdraws from marginal sites, and as seed sources from the surrounding areas become available. Nevertheless, afforestation will remain the main area of silvicultural activities in the immediate future, especially with regard to the production of high quality broadleaf timber. Thinning will become increasingly important for the forest owners and foresters as the planted stands develop.

Stand establishment and all later operations involved in forming a stand are combined in silvicultural systems. There are mutual dependencies and interactions in later development phases.

Broadleaf forestry in Ireland is still in its infancy and, therefore, the current predominant silvicultural activities – stand establishment and thinning – are carried out consecutively. This is the reason why they will be described separately (see Chapters 4.4 and 4.5).

4.4 Establishment of broadleaves

4.4.1 Role of stand establishment procedures

4.4.1.1 General practices of stand establishment

Forests can be established using the procedures described in Table 4.4-1. These will be expanded and discussed in the following sections.

Table 4.4-1: Types of **stand establishment**

Establishment type		Description
Artificial regeneration	Planting	Main procedure for establishing forests on bare ground (afforestation), after destruction by natural causes (reconstitution) or after harvest of former stands (reforestation).
	Direct seeding	Less expensive; needs favourable soil conditions; less reliable. Scarcity of seeds causes major problems. Thus, usually plays only a minor role.
Natural regeneration	With target species	Target species in vicinity (wind dispersed seeds – ash, sycamore) or on regeneration area (heavy seeds – oak, beech). Increasingly important when old stands present.
	Succession	Invasion of abandoned land by pioneer species; mainly after withdrawal of agriculture from marginal sites.
Vegetative regeneration	Stool shoots (Coppice)	Broadleaves only. Often in combination with reforestation of former stands with broadleaves. Not regeneration in a narrow sense (only shoots are renewed).
	Root suckers	A few species such as aspen and grey alder produce sufficient regeneration, which often has to be eliminated because of competition to target species.

4.4.1.2 Regeneration practice in Ireland

The results of the National Forest Inventory (NFI, 2007) present some information as to how Irish forests have been regenerated in the last century (Table 4.4-2). Although the data are not divided according to conifer and broadleaf categories, nevertheless, they allow some conclusions to be drawn in relation to the establishment of broadleaves.

The data in the table illustrate that two-thirds of Irish forests have been established artificially by **planting**. Most of the reforested areas will also have been planted. Therefore, roughly 90% of all Irish forests have been established artificially and this will presumably continue for the foreseeable future, either on bare ground or on former agricultural land. Although these data relate mainly to conifer planting most of the younger broadleaf stands have also been planted as was shown in Figure 1.4-1.

Table 4.4-2: Forest area in relation to rotation type by ownership (%). (Adapted from NFI, 2007)

(Basis: 626,000 ha, weighted means)

Rotation Type	Ownership			
	public	private		Mean
		grant aided	other	
Afforestation	*61*	*95*	*22*	***66***
Reforestation	*32*	*1*	*13*	***21***
Semi-natural	*7*	*4*	*65*	***13***
Total	***100***	***100***	***100***	***100***

Semi-natural forests exist mainly in the other private forests category. As they consist largely of broadleaves it can be assumed that at least some of them have developed through **natural regeneration**.

Level of planting and natural regeneration

Further information about the role of regeneration methods has been compiled by the NFI and is presented in Table 4.4-3.

These results show that two-thirds of all forests contain trees that are mainly – more than 50% – planted, whereas one-third has been predominantly regenerated naturally. However, the percentage of naturally regenerated broadleaf stands can be estimated only indirectly. They are concentrated in the other private forests. These consist mainly of the few old growth broadleaf stands that have remained in the old estates at the beginning of the 20th century, when natural regeneration was possible to a limited extent. When the newly established young stands have reached maturity it can be expected that natural regeneration will gradually gain greater importance.

The forests which are regenerated, partly artificially and naturally – 12% of the total area with regrowth – may have come into existence mainly by planting and natural seeding of pioneers from neighbouring trees.

Table 4.4-3: Origin of regeneration by ownership (%). (Adapted from NFI, 2007)
(Basis: 450,000 ha stocked forest area with regrowth present; weighted means)

Origin of regeneration		Ownership			
		public	private		Total
planting	natural		grant aided	other	
>80	*<20*	*58*	*83*	*8*	***60***
50-80	*20-50*	*8*	*5*	*4*	***6***
20-50	*50-80*	*6*	*4*	*8*	***6***
<20	*>80*	*28*	*8*	*80*	***28***
		100	*100*	*100*	***100***

Forests that have originated from **succession** are not specifically mentioned. Presumably many of the birch, alder and willow forests and scrub have developed after seeds were distributed by wind over long distances. Succession, therefore, seems to play a greater role than the NFI data show. Succession may become progressively more important, as the seed sources present in the surrounding areas build up and poor land is withdrawn from agriculture.

Nevertheless, planting will remain the most important means of establishing new broadleaf stands. This is the reason why the main focus of this Chapter 4.4 establishment of broadleaves is placed on planting and why planting and natural regeneration will be dealt with separately (see Chapter 4.4.3 and 4.4.5). It should be borne in mind, however, that in practice both issues are inextricably linked. This will be increasingly the case the more stands become uneven-aged in the future.

Presence of an overstorey above regrowth

The existence of an overstorey is often a precondition for natural regeneration. The data in Table 4.4-4 show that only 18% of the area, with young growth, is sheltered by an overstorey, and that the grant aided private forests have only a negligible proportion of old growth. This is quite understandable as most of these stands have been established only during the last two decades.

Table 4.4-4: Presence (%) of **overstorey** above regrowth by ownership. (Adapted from NFI, 2007)
(Basis: 450,000 ha stocked area with regrowth present)

Presence of	Ownership			
	public	private		Total
		grant aided	other	
Overstorey	*22*	*5*	*40*	***18***

4.4.2 Site conditions and forest establishment

Site conditions are the dominant issue for the selection of appropriate tree species. Site includes – as mentioned in Chapter 2 – climate, topography and soil.

The main issues are
(1) altitude,
(2) steepness and roughness of the terrain,
(3) soil type,
(4) moisture and drainage.

These will be discussed in the following paragraphs.

4.4.2.1 Altitude

The major influences of altitude on climate is dealt with in Chapter 2.2.3. Climatic stress increases exponentially with height above sea level which in the case of Ireland is mainly because of strong winds from the Atlantic. The data in Table 4.4-5 give an impression of the significance of this for broadleaves.

From these figures it can be concluded:

- The majority of all species and species groups – more than two-thirds of all broadleaf forests – are located in areas below 100 m above sea level. A further quarter is distributed between 100 and 200 m. Only 4% of all broadleaf forests grow at altitudes higher than 200 m, while there are few broadleaf trees growing above 300 m. This illustrates how severe the climatic conditions are in Ireland.

  Data from Continental Europe for comparison show a great difference: the tree line in the Black Forest is around 1,500 m and in the inner range of the Alps it is around 2,400 m.

- Only some short-living broadleaf species – probably willows – seem to tolerate higher elevations.
- Ash seems to be especially intolerant of higher elevations, even above 100 m, but this may be due to the limited availability of areas with suitable soils.
- Alder obviously tolerates these altitudes better than other broadleaf species, but again it is not possible to eliminate the influence of soil.

Table 4.4-5: Tree species groups (%) **by altitudes** – expressed in meters above sea level. (Adapted from NFI, 2007)

Species group		Altitude (m)				
		-100	101-200	201-300	301-400	>400
Oak		*64*	*34*	*2*	*<1*	-
Beech		*68*	*31*	*1*	-	-
Ash		*82*	*14*	*3*	-	-
Sycamore		*77*	*22*	*1*	-	-
Other long-living broadleaves		*70*	*29*	*1*	*<1*	-
Birch		*74*	*23*	*3*	-	-
Alder		*59*	*39*	*2*	-	-
Other short-living broadleaves		*67*	*25*	*6*	*2*	*<1*
Total area	%	***70***	***26***	***3***	***1***	***<1***
	1,000 ha	107	39	5	1	<1

It can be concluded from these data that broadleaf forestry is and will be confined predominantly to the lowlands. This is especially applicable to sub-Mediterranean species like wild cherry, Spanish chestnut and walnut, which should be grown only in sheltered areas.

4.4.2.2 Steepness and site roughness

Although some parts of the country are mountainous or even rocky, the actual forested area is generally not very steep (Table 4.4-6).

Almost two-thirds of the total forest area is on gently sloping ground (1-5°), and only about one-sixth on ground steeper than 10°. Compared with other countries, this is quite favourable, as generally forests have remained or are re-established on steep and stony ground that could not be used for agriculture.

This assessment is supported by the data given in Table 4.4-7.

Table 4.4-6: Forest area (%) **by slope** and ownership. (Adapted from NFI, 2007)

(Basis: 626,000 ha, weighted means)

Slope degree °	Ownership			
	public	private		Mean
		grant aided	other	
0- 5	*59*	*75*	*61*	***64***
6-10	*22*	*16*	*15*	***19***
>10	*19*	*9*	*24*	***17***
Total	***100***	***100***	***100***	***100***

The data show that more than half of the total forest area is level terrain and all types of ground preparation are possible. Furthermore, the uneven ground does not cause major obstacles for normal forest management. Only less than 10% may create difficulties especially for soil preparation. There are, however, slight differences between the different ownership areas, showing that the other private forests have a somewhat higher proportion of rough terrain. As these owners have a much smaller area than the others the actual area is not very large.

Table 4.4-7: Total forest area (%) **by site roughness** and ownership. (Adapted from NFI, 2007)
(Basis: 626,000 ha, weighted means)

Even = even terrain, no obstacles, suitable for ripping, pit planting, mounding or agricultural ploughing.

Uneven = Obstacles frequent, but these do not restrict normal forest management practices e.g. single or double mouldboard ploughing.

Rough = Obstacles occurring frequently of a size that may restrict or require modifications to normal forest management practices, like deep drains and boulders.

Site roughness	Ownership: public	Ownership: private – grant aided	Ownership: private – other	Mean
Even	*46*	*70*	*56*	***54***
Uneven	*45*	*27*	*28*	***38***
Rough	*9*	*3*	*16*	***8***
Total	***100***	***100***	***100***	***100***

4.4.2.3 Soil type

The percentage and actual total area of the main soil groups is given in Table 4.4-8. Again there is no distinction between the area of conifers and broadleaves.

Peats and gleys, with about 70% of the total forested area, are by far the two main soil groups. They are generally located in the public and grant aided private forests. Only in the other private forests do they comprise a smaller proportion (about 40%). These soils are not very suitable for broadleaves, and the data, therefore, explain the dominance of conifers.

Table 4.4-8: Stocked **forest area by soil type group** and ownership. (Adapted from NFI, 2007)

Great soil group		Ownership: public (%)	Ownership: private – grant aided (%)	Ownership: private – other (%)	(%)	Total (1,000 ha)
Peat	basin	*9*	*12*	*16*	***11***	67
	blanket	*36*	*33*	*7*	***32***	197
	cutover	*2*	*1*	*-*	***1***	7
Gley		*24*	*34*	*18*	***26***	164
Grey-brown podzolic		*1*	*3*	*5*	***2***	15
Brown earth		*5*	*7*	*25*	***8***	52
Brown podzolic		*5*	*4*	*6*	***5***	29
Podzol		*15*	*4*	*6*	***11***	67
Lithosol		*2*	*1*	*4*	***2***	14
Rendzina		*1*	*-*	*8*	***1***	8
Others [1]		*<1*	*<1*	*5*	***1***	6
Total	%	*100*	*100*	*100*	***100***	
	1,000 ha	359	187	79		626

[1] Alluvial, sand, limestone pavement

In the other private forests the proportion of better soils like brown earths, grey-brown podzolics and rendzinas is relatively high (about 40%), but as these forests cover only about 13%, their actual size is very limited (refer to Table 1.5-2). Only these soils are suitable for more site-demanding broadleaves like ash, sycamore and cherry.

The difference between peat and mineral soils is explained further in Table 4.4-9.

Around 40% of the forests are growing on **mineral soils**, which in general are relatively shallow, whereas the **peaty soils** comprise about 60%, and more than two-thirds of them are deep.

Outcropping rocks are of little relevance.

The other private forests grow – as mentioned – on the relatively better soils, because of a much higher percentage of mineral soils.

Table 4.4-9: Forest area (%) **by soil condition** and ownership. (Adapted from NFI, 2007)
(Basis: 626,000 ha, weighted means)

Soil condition	Ownership: public	Ownership: private – grant aided	Ownership: private – other	Mean
Mineral soil (no peat)	*30*	*42*	*69*	***38***
Mineral soil <20 cm	*2*	*1*	*4*	***2***
<30 cm of peat	*23*	*12*	*3*	***18***
>30 cm of peat	*45*	*45*	*23*	***42***
Outcropping rock	*-*	*-*	*1*	***-***
Total	*100*	*100*	*100*	***100***

4.4.2.4 Soil moisture and drainage

It is very noticeable that only a small proportion of all soils are dry. The vast majority are moist or even wet (Table 4.4-10).

A super-abundance of water, therefore, is a major disadvantage on most of the forest sites.

This becomes even more obvious when the data in Table 4.4-10 are analysed in relation to drainage conditions. Just over one-third of all forest soils are well to moderately-well drained, whereas almost two-thirds are imperfect to poorly or very poorly drained.

Table 4.4-10: Forest area (%) **by soil moisture** and ownership. (Adapted from NFI, 2007)
(Basis: 626,000 ha, weighted means)

According to the definitions of the NFI:

Dry soils have little or no moisture present like excessively drained coastal sand.

Moist soils have some moisture present like most mineral soils or drained peat.

Wet soils have a lot of moisture present like gleys or undrained peat.

ITEM	OWNERSHIP			
	public	private grant aided	private other	Mean
Soil Moisture				
Dry	*4*	*4*	*13*	***5***
Moist	*63*	*70*	*70*	***66***
Wet	*33*	*26*	*17*	***29***
Total	***100***	***100***	***100***	***100***
Drainage				
Well to moderately-well	*34*	*28*	*66*	***36***
Imperfect to poor	*66*	*72*	*34*	***64***
Total	***100***	***100***	***100***	***100***

Conclusions

Forest establishment in most cases has to deal with an oversupply of water and has to facilitate young plants to overcome this problem, often by soil preparation. Unfortunately, broadleaves in general – except alder, birch and willow – are more site-demanding and less tolerant of very wet soils than most conifers. Therefore, the availability of sites for many important broadleaf species is limited because of high moisture levels.

4.4.3 Establishment of broadleaves by planting

4.4.3.1 Arguments for and against planting

Planting is by far the most widely practised regeneration method in Ireland. This is logical as most forests were established on bare ground without mother trees to provide seed for natural regeneration. For a better understanding of the establishment of forests, however, it may be worthwhile to list the arguments for and against planting.

The main **advantages of planting** are:

- Opportunity to select tree species and provenances best suited to a site.
- Independence from previous stand and regeneration potential of the site.
- Independence from seed years.
- Improvement of performance and yield of selected plant material with regard to selected tree species and improved provenances.
- Shorter risk period for young plants.
- Shortening of production period.
- Less technical skill required when compared to natural regeneration methods.

There are also some **disadvantages**:

- High capital needed at beginning of regeneration.
- Possible risk of using wrong or unsuitable provenances.
- Risk of losses caused by planting-shock, as well as damage by weevils on reforestation sites, fire and competing vegetation.

4.4.3.2 Types of planting

Depending on the different conditions prevailing on the areas to be either planted or replanted, soil preparation may be necessary. The type of plant material and the planting technique must also be adapted to the specific conditions. Planting density and the protection of the young trees, as well as the tending of young growth, are further components of stand establishment. All of these are dealt with in this section.

Planting comprises a number of aspects:

- **Afforestation or reforestation** of larger areas predominantly with a single tree species or target species in mixture with a nurse. Filling-in or replacement of failures is also an important part of the procedure.
- **Enrichment planting** may take place where larger gaps occur within plantations caused by low survival rates or where there are gaps within naturally regenerated young stands. One or more additional species may be introduced in order to establish mixtures. This will grow in importance as natural regeneration becomes more common.
- **Completion** of homogenous dense regrowth. Individuals of the same species are used to fill in gaps in either plantations or naturally regenerated young stands.

The establishment phase is usually considered complete when the young plants have reached a height of approximately 2 m. Then they will have survived the planting shock and overcome weed competition, adverse climatic influences such as late frost and escaped damage by rabbits or hares as well as browsing by deer.

Crown contact usually follows shortly afterwards and the trees begin to compete with each other. This phase represents the onset of natural pruning and differentiation within the stand. This is also the time for tending and thinning to begin (see Chapter 4.5).

4.4.3.3 Preparation of planting site

Soil preparation may be necessary prior to planting in order to either eliminate obstacles to the planting procedure or to provide better growing conditions for the young plants. It can be time consuming and expensive and is, therefore, best undertaken by machine wherever site conditions permit. Tracked vehicles with a fork attachment can be particularly efficient in clearing scrub. However, on steep slopes and difficult terrain, or where the planting area is small or remote, manual methods may be the only option available.

The methods used are highly dependent on the site conditions and the different objectives (Table 4.4-11).

Table 4.4-11: Reasons for **soil preparation** prior to broadleaf planting.

Objective	Details	Method
Clearance of interfering slash or bushes	Elimination of shrubs, trees, weeds on planting site. Disposal of slash especially for ease of machine planting in the case of reforestation. Accelerating planting rates reduces planting costs.	Mechanical treatment depending on site conditions.
Elimination of physical barriers	Breaking up iron or plough pan in order to improve survival (root growth), drainage and later growth rates.	Ripping with tine plough.
Improving drainage	Sub-surface drainage; establishment of small drains to divert surface water.	Mole ploughing; mechanical or hand mounding; mouldboard ploughing.
Reducing weed cover	Improving survival rates of weed intolerant species such as ash and oak. Improving growth rates. Reducing weeds as a habitat for voles. Reducing risk of frost damage.	Strip ploughing before planting; herbicide application; agricultural ploughing.

Broadleaves are generally more intolerant of adverse planting conditions than conifers. Therefore, soil preparation becomes very important.

Table 4.4-12 contains outline information on the site preparation methods recommended in Irish forestry practice. For more detailed information refer to Forest Service: Forestry Schemes Manual (2011).

In general cultivation in some form is used for preparation of planting sites. On wetter and more difficult sites mounding is the most important site preparation and form of drainage. With mounding there is the added bonus of some weed control for a growing season or more. Where afforestation of broadleaves is on agricultural land, however, very little site preparation may be needed apart from control of competing vegetation such as grasses. Alternatively, ripping or single furrow agricultural ploughing gives a planting line which more than justifies the very small expenditure involved.

On such sites the application of pre-planting herbicides (e.g. glyphosate) gives good results (Plate 4.4-1). Generally herbicides are used in tandem with cultivation techniques. The mainstay of weed management in Ireland is still herbicides (Forest Vegetation Management in Europe, 2009), however, there is growing pressure for a reduction in the use of chemicals.

Figures derived from NFI data reflect the role of soil preparation in Irish forestry practice (Table 4.4-13). As the total forest area has been included in this survey the data also reflect the practices of earlier years and might not be current any more. Moreover, the data are not differentiated between site preparation methods for conifers and broadleaves.

Nonetheless, the data provide some important findings:

- In more than 80% of all forests some soil preparation has been carried out.
- Grant aided private forests have almost entirely been treated by some cultivation procedure, while less than a third of other private forests have been cultivated.
- Mounding was, and probably still is, the most important cultivation method; again with a clear dominance in the grant aided private forests.
- Double mouldboard ploughing has been important in the public forests in the past, but has been replaced by mounding.

On many former agricultural soils where

Table 4.4-12: Cultivation methods in Irish forestry. (Adapted from Forestry Schemes Manual, 2011)

Soil type	Recommended cultivation method
Carboniferous surface water gleys (pseudo-gleys) derived from carboniferous drift.	Mound on slopes less than 5 degrees.
Surface water gleys with adequate slope.	Mole; mound; agricultural plough.
Better old red sandstone (brown podzolic) soils.	Mound; rip.
Brown earths and other free-draining mineral soils with indicated plough pan.	Rip.
Brown earths and other free-draining mineral soils.	Rip; scarify; agricultural plough where ground permits.
Other suitable site conditions and soil types.	Mechanical planting.

Plate 4.4-1: Herbicide application prior to planting ash and sycamore.(Courtesy: Guest)

Table 4.4-13: Forest area (%) **by soil cultivation method and ownership for both conifers and broadleaves.** (Adapted from NFI, 2007)

(Basis: 626,000 ha, weighted means)

Cultivation method	Ownership			Mean
	public	private grant aided	private other	
No treatment	*12*	*3*	*71*	***17***
Mounding	*31*	*75*	*3*	***41***
Ripping	*2*	*7*	-	***3***
Pit planting	*19*	*7*	*21*	***15***
Ploughing	*4*	*2*	*2*	***3***
Double mouldboard ploughing	*25*	*4*	*2*	***16***
Single mouldboard ploughing	*7*	*2*	*1*	***5***
Total	*100*	*100*	*100*	***100***

drainage is not necessary an application of herbicide before planting will suffice (refer to Plate 4.4-1). Normally glyphosate (Roundup®) is used.

> **Conclusions**
>
> Most broadleaves are less responsive than conifers – especially Sitka spruce – to overcoming planting-shock, regeneration of roots and competing with ground vegetation. Soil preparation, therefore, is essential on most sites and can be regarded as standard practice in establishing new broadleaf plantations.
>
> As mentioned in Chapter 4.4.2.4 the majority of Irish forest soils have a super-abundance of water. Broadleaf sites, however, are generally drier. Therefore, drainage is generally not necessary on most former agricultural land and not on most former tillage areas.
>
> Mounding, as well as pit planting and the use of herbicides have been the preferred site preparation methods to date.

4.4.3.4 Fertilising to improve the establishment of young broadleaves

Most of the broadleaf species such as ash, sycamore, wild cherry, elm, Spanish chestnut and beech are more nutrient-demanding than broadleaf pioneers such as birch and willow as well as most of the conifers. These demanding species prefer soils with medium or high pH-values.

As shown in Chapter 4.4.2.3 (refer to Tables 4.4-8, 4.4-9 and 4.4-10) a substantial area of the forest soils in Ireland is moist, acid or peaty because of the humid Atlantic climate. Many of these sites are also of low nutritional capacity as a consequence of impoverishment by long-term loss of nutrients from former agricultural land-use. They are, therefore, not entirely suitable for most of the nutrient-demanding broadleaf species. Young plants on these sites may face problems. By adding the nutrients which are lacking through fertilising at the establishment phase they can be at least partly be helped to overcome this problem, provided the soil and climate conditions are reasonably favourable.

Fertilising can be applied with the following objectives:

- Improving the physiological resistance against abiotic factors such as frost and drought.
- Increasing volume growth and increment.
- Supporting nutrient-demanding species in mixture with less demanding ones so that they will not be overgrown by these competitors.
- Increasing the viability to overcome damage by insects or browsing by deer.
- Improving topsoil conditions in order to favour natural regeneration.

Fertilisers contain different nutrients which have the following effects:

- **Nitrogen (N)** is a very important nutrient since it influences the formation of chlorophyll.
- **Phosphorus (P)** has a central function for the energy balance of plants, and favours the generative development (flowering and fruiting), as well as root development.
- **Potassium (K)** influences the plant water balance, improves frost and drought resistance. It favours root development and may contribute to height growth on certain sites.
- **Calcium (Ca)** is an indispensable component of all cells. It neutralises organic acids, improves the humus status into better forms and favours nutrient uptake by several tree species. The uptake of other nutrients is restricted unless there is a reasonable availability of Ca.
- **Magnesium (Mg)** is fundamental for photosynthesis. It often acts together with calcium.
- **Trace elements** (copper, iron, boron, manganese, sulphur, zinc) are essential for physiological activities and influence the formation of chlorophyll and the growth of shoots.

Most of the major as well as the trace elements interact, which differs according to tree species and site conditions.

Fertilisers are available as compound fertilisers, as slow-release fertilisers and with or without trace elements. Compound fertilisers (NPK) are mainly used.

Throughout the 20th century fertilising has been carried out almost entirely to increase the volume production of conifers (Bruenig, 1959; Baule and Fricker, 1970; Fiedler et al., 1973; Schmid, 1977). As broadleaves in general were not so much the focus of forestry for a long time, little research has been undertaken on their nutritional requirements. Hybrid poplars are an exception as they have the capacity to produce high volumes. Nevertheless, only limited knowledge on the nutrient demands of most of the broadleaf species and their reactions to fertilisers has been established by experimentation and through on-site investigation (Table 4.4-14).

Table 4.4-14: Nutrient demand and response of some broadleaves to fertilising.
(Mainly according to Fiedler et al., 1973)

Tree species	Nutrient demand for enhanced growth	Response to fertilising
Willow	Generally low, but differing according to willow species.	CaO fertiliser improved volume production of goat willow by 300%.
Birch	Low	Improved root growth following CaP fertilising. In Scandinavia comparable growth increase by N and P fertilising as in Norway spruce and Scots pine. No growth response to liming.
Rowan	Low	No growth response to liming.
Aspen	Low	Little information. No growth response to liming.
Alder	Sensitive to Ca deficiency.	Strong response of height growth according to greater amounts of lime. Good reactions to P K fertiliser. N fertilising reduced formation of root nodule bacteria.
Red oak	Less demanding than ped. and sess. oak. High pH values not favourable, growing even on relatively poor and acid soils.	Faster growth out of the late-frost zone after P K fertilising.
Oak	Both oaks less demanding than beech. Sessile oak on dryer and poorer but warmer soils, slightly more demanding than pedunculate oak. Pedunculate oak in lowlands. Both oaks seldom on limestone soils.	Response to liming only on poor soils. Better height growth on bare land with high water table after N and P fertilising.
Beech	More demanding according to Ca, N and K contents.	Liming generally favours height growth of beech regrowth. N and K fertilising advantageous only on poorer soils.
Lime	More nutrient demanding than both indigenous oaks and hornbeam. K-demanding	Early height growth improved by liming on poorer soils. Good response to N fertilising on medium quality soils.
Sycamore	Medium lime content	Liming on poorer soils essential. Reacts positively to K fertilisers. Good response to NPK fertilisers on poorer soils, like beech.
Ash	Reasonably high lime content	Lime application on carbonate free soils very advantegeous.
Hornbeam	Ca-demanding	Profound increase of height growth after liming – much greater than with pedunculate oak. Little response to N fertiliser.
Elm	Nutrient demanding	Not documented
Wild cherry	Nutrient rich soils with medium to high lime content.	Little information. Obviously strong response to N fertilising.
Poplar	Very sensitive to Ca deficiency, minimum pH value 4.5; all sorts are very deman-ding and grow fast, only provided all growth factors are optimal. Great differences between clones.	High production only with regular NPK and Ca fertilising if not growing on nutrient rich alluvial soils.

The effect of fertilisers can differ greatly according to biological factors (tree species, provenance and age) as well as site conditions (climate, soil, exposure) and can alter the growth relations within tree mixtures.

Nevertheless, fertilising with lime has proven to be efficient for many broadleaf species especially on poorer soils. It is widely used on the Continent as a compensation for acidification caused by aerial pollutants. It is mainly spread by helicopter in the form of ground limestone containing variable proportions of calcium and magnesium. In contrast to liming, N-fertilising has been widely reduced because of an increased input of nitrogen by pollution. Deficiencies of trace elements have seldom been observed.

Another option to get young broadleaves established on less favourable soils (slightly acid), is to add ground limestone to the planting pit. This is especially appropriate in the context of converting pure conifer into mixed stands by underplanting with beech. Application of ground limestone to the pit, however, requires additional labour input.

Some experiments have recently been established by a number of German research organisations. The following example is taken from this programme and may illustrate the results observed so far.

Beech was established by sowing and planting under an approximately 100 year old Norway spruce stand with various levels of canopy cover. The site is located on pseudo-gley over quartzite around 600 m elevation in Osburg/SW Germany. This type of slightly acid soil is representative of large areas of former spruce stands that are gradually being converted into beech or beech/Norway spruce stands. To study the effect of soil improvement by addition of calcium, half of the beech plants remained without fertilising, the other half received 500 g/plant of ground limestone.

Results are shown in Table 4.4-15.

Table 4.4-15: Mean **heights** (cm) **of sown and planted beech.** (2,500 plants/ha; age of sown beech: 9-10 years (as counted from seed stage), age of the transplants: 14 years (at time of measurement).

(Huss and Csapek, 2011)

Canopy density	Seed sown: Lime application without	Seed sown: Lime application with	Seed sown: Diff.	Planted: Lime application without	Planted: Lime application with	Planted: Diff.
Dense	32	44	**+ 12**	86	146	**+ 60**
Slightly opened	46	59	**+ 13**	156	230	**+ 74**
	44	86	**+ 42**	130	211	**+ 81**
Lightly opened	84	166	**+ 82**	256	336	**+ 80**
Small gap	106	163	**+ 57**	286	512	**+226**
Large gap	125	281	**+156**	462	408	**- 54**
Mean	**73**	**133**	**+ 60**	**229**	**307**	**+ 78**

Results are as follows:

- The height growth of young beech, either sown or planted, was strongly (highly significant) influenced by the available light.
- Plants raised both from seeds, as well as those planted, benefited considerably and also significantly from lime application.
- One exception was observed: planted beech with lime application growing in a large gap suffered from heavy competition by naturally regenerated spruce seedlings and ground vegetation such as brambles.
- The beech transplants were able to increase their lead in height growth which they had retained from the nursery.

Similar results have been found in other experiments. It can, therefore, be concluded that the application of ground limestone on acid soils can effectively improve the height growth of nutrient-demanding species. The young trees, however, need sufficient light, to benefit fully from the treatment.

Conversely, it may happen that the ground vegetation or young growth of other tree species will also benefit from the light supply and compete with those of the target species depressing their growth. This is the normal dilemma: If one species is favoured, others may take advantage.

An additional result may be discerned: Seed sowing as compared with use of planting stock makes sense only if the environmental conditions are favourable as seedlings are much more prone to competition and other hazards compared with the taller and sturdier transplants (refer also to Chapter 4.4.4).

Lime acts slowly and does not damage roots even if they come into close contact with the ground limestone. This would not be the case for nitrogen and potassium as they often burn the roots. Nitrogen could be applied only by spreading round the plants. This, however, will normally have the adverse effect on the transplants as it favours the growth of the competing ground vegetation.

Conclusions

At present, the application of ground limestone seems to be a reasonable option to support the establishment of nutrient-demanding broadleaves on slightly acid soils. Liming, however, can only improve the growth conditions and compensate for poorer soil conditions for a short while. Therefore, demanding broadleaves should not be planted on very acid or wet soils.

If possible the site conditions should be investigated in advance of the application.

To date little information is available regarding the nutritional demands of broadleaf species on the different soil types in Ireland. This information deficiency needs to be addressed by future research.

4.4.3.5 Production and provision of seed and plant material

As mentioned in Chapter 4.1.2.5, the sourcing of suitable plant material is critical in determining the success of a broadleaf afforestation programme. In practice, however, problems may exist in obtaining suitable provenances for the following reasons:

- **Availability of site-adapted provenances for many of the broadleaf species**
  As indicated in Chapter 4.1.2.6, provenance trials and seed orchards have only recently been established. Reproductive material of site-adapted species will be available in the near future (Plates 4.4-2 and 4.4-3).
  Some details are provided in the descriptions of broadleaf species (Part II).

- **Origin of the seed material**
  In the recent past some of the broadleaf plant material available in Ireland has been provided by large continental nursery companies. The surge in demand for broadleaves during the past couple of decades has mostly been met by imports from France,

Plate 4.4-2: Native oak provenance trial.
(Manch Estate, Co Cork)

Plate 4.4-3: Birch provenance trial.
(Ballyredmond, Co Carlow)

In contrast to the other main broadleaf tree species, birch produces extensive quantities of seed because of its early flowering pattern. Thus it will be possible to supply the nurseries with improved seed in the near future and a limited supply has already commenced.

among other European countries. As the international trade in seeds, seedlings and transplants grew the control of seed and plant origin became increasingly problematic. Therefore, it is recommended that the Latin proverb *caveat emptor* (let the buyer beware!) should be adhered to by the forest owner in the purchase of seed and plant material.

On the Continent a number of forest enterprises have started either to produce plants in their own nurseries or to collect wildings from their forests in order to avoid being supplied with inappropriate plant material.

The following aspects for the long-term provision of plants should, therefore, be adopted:

- Establishment and management of certified seed stands (both the selection of suitable existing stands as well as the creation of new stands (refer to Table 3.3-13),
- testing the reproductive material from these stands and comparing their performance with best European sources (refer to Table 4.1-6),
- good control of seed collection, processing and transport to nurseries,
- better control of the sale of tree seed provenances and transport to the customer,
- continuation of the development of the seed orchard programme for the most important broadleaf tree species.

As genetic tests are becoming more widely available and affordable, the control of plant material will become more manageable and effective, but these are mainly aspirations at present.

4.4.3.6 Types of plant material

Broadleaf plant material consists almost entirely of bare-rooted stock which should preferably be produced from seed. The alternative macro- and micro-vegetative propagation methods are of little relevance in the immediate future. Only poplars and willows are produced from sets.

The various kinds of bare-rooted plants are described in Table 4.4-16.

It is essential that the following attributes are taken into consideration for the different plant types:

- **Seedlings**

  Tree species that form tap roots (e.g. oak) should be planted as young and as small as possible, preferably as seedlings. The lower costs of the smaller plants and their planting allow a higher density of individuals to be established per unit area which helps to improve later stand quality. They are especially suitable for simple planting machines.

  The disadvantage of using seedlings is that they can only be planted on vegetation-free

Table 4.4-16: Types of **bare-rooted and balled stock**, and their main characteristics.

Type of stock	Height cm	Age years	Tree species	Importance
Seedling	10- 30	0.5-2	Oak, beech, ash, sycamore	Plants tend to grow readily, but need almost weed-free ground; endangered by small mammals and birds. More susceptible than bigger plants to frost damage.
Transplant	30-100	2-4 (2+2)	All tree species	By far the most important stock even on problematic sites.
Wilding	30- 60	Often indeterminate	Preferably broadleaves	For transplanting; also used for underplanting pioneers (nurse crops).
Sapling	100-200	3-8	Only broadleaves	Currently unimportant; suitable for enrichment and completion planting.
Ball plant	30- 60	3-5	Oak, beech (and others)	Enrichment and completion planting on very weedy sites.

ground which increases the overall costs and raises ecological concerns regarding the necessity to use herbicides. Furthermore, seedlings are subject to a variety of threats and losses which incur additional replacement costs.

Because of the high costs involved in transplanting, there is a tendency to grow seedlings at lower densities in the seedbeds instead, and undercut them after one or two years in order to stimulate the growth of fine roots and thus favour the development of a compact root system.

- **Transplants**
  In keeping with their growth potential in the first year or two, seedlings of most species are transplanted after one or two years and left another one or two years in the nursery in order to grow taller, and sturdier, e.g. 2+2 in Table 4.4-16 for transplants 1^{st} numeral = years in seed bed and 2^{nd} numeral = years in transplant lines. They then form a more compact root system and are better able to withstand the often unfavourable conditions in the field. Transplants are the standard planting stock type, but they are more expensive than seedlings.

  Beech and sycamore seedlings and transplants are illustrated in Plates 4.4-4 and 4.4-5. They show the height development of both species with age and treatment. There are substantial differences in height between beech and sycamore at a given age.

- **Wildings**
  Wildings are collected from naturally regenerated regrowth in situations where they are progenies of high quality or site-adapted seed trees, or where there is a shortage of plants. Small wildings may be pulled out by hand if the soil is sufficiently wet, otherwise they must be dug out. Both actions may lead to root damage. Wildings tend to grow under the shelter of their mother trees and are, therefore, not adapted to exposed conditions. They have to be planted under the shelter of other trees or it may be necessary to transplant them for one year in a nursery.

  Though these procedures are time-consuming and expensive, the acquisition of plants of proven genetic quality has gained extra importance on the Continent because of the problems of purchasing reliable plant material of known origin. As these difficulties also exist in Ireland this method is to be recommended, especially for the supply of rare species such as wild cherry.

Plate 4.4-4: Bare-rooted beech seedlings and transplants as produced by nurseries.

Plate 4.4-5: Sycamore seedlings and transplants.
Because of their faster growth in the early years younger material can be used for most species except beech.

- **Saplings**
  Saplings are older, sturdier and taller than normal transplants. Oak, in particular, has been planted for centuries on agricultural land and in other open areas in order to establish single trees or small groups. Today, their main area of application is planting alongside roads, which is a common feature in the Netherlands, or in urban settings. Because of their size they are less susceptible to competition from weeds, browsing from deer and frost damage. However, they may suffer from droughts after planting.
  Moreover, their large root systems require the digging of large holes and laborious planting procedures, which are costly. But high costs and ecological constraints on chemical weeding, as well as control of deer have revived the use of saplings to some extent, especially for enrichment plantings.

- **Ball plants**
  Plants with an earth ball dug out in the field and transplanted almost immediately in the same locality may be used in order to infill patchy regrowth. This process can be advantageous when enrichment planting is aimed at closing gaps in young plantations with low survival rates or natural regeneration with irregular germination. In Ireland, such a procedure will be the exception as long as artificial establishment of young stands remains the norm.
  Production of **containerised stock** has become important in recent years, particularly for conifers. It is widely used in the boreal zones and in the tropics to some extent, but apart from certain exceptional circumstances, such as in high mountain areas in the temperate zone, broadleaves have not been produced for planting in this way to any significant extent.

According to the *Forestry Schemes Manual* (2011) transplants must have the following quality characteristics:

- A straight stem with a definite leader,
- well balanced foliage distribution with a good fibrous root system,
- a specified height to provide for size above ground when planted,
- a specified root collar diameter to provide for hardiness and good root/shoot ratio,
- an age not exceeding a specified maximum.

Broadleaf transplants should be within the quality limits as given in Table 4.4-17.

Table 4.4-17: Quality limits for broadleaf **transplants.** (Forest Service, 2011)

Species	Max. age yrs.	Min. collar diameter mm	Stem height cm
Alder	3	4	30-60
Ash	3 4	7 12	50-75 60-90
Beech, oak, Spanish chestnut	4 4 5	6 7 9	45-75 50-70 70-85
Sycamore	3	7	45-75
Other broadleaves	5	4	40-75

Conclusions

Two/three year old bare-rooted transplants are likely to remain by far the most widely used type of planting stock in Ireland, but some of the other stock types, in combination with special planting procedures, offer alternatives for particular conditions.
Plant size should be adapted to site conditions.

4.4.3.7 Lifting of planting stock and subsequent treatments

Between lifting in the nursery and planting in the field, plants are in danger of being exposed to many hazards. These all tend to reduce their water content through desiccation – i.e. reduce their freshness and induce a loss of vitality thus affecting their survival and growth.

The main risks are referred to in Table 4.4-18.

Table 4.4-18: Main steps and considerations from the time **of lifting of plants** in the nursery to their **planting**.

Sub-operation	Description	Critical issue
Lifting of plants	Lift with simple tools (spade/fork) or purpose-built machines when adequately hardened-off.	Possible injuries to roots through rough handling and dry, cohesive soils. Greatest risk on sunny, windy days if plants are not immediately protected.
Storage in refrigerated cold store facilities	Storage only after leaf fall when plants are fully dormant in conditions of high humidity.	Suitable opportunity for nurseries to spread work peaks; possible extension of planting period. Retardation of flushing favourable for planting at higher elevations or colder regions.
Sorting and grading	Sorting of plants into size classes. Selection and elimination of very small or damaged plants.	Drying out of roots because of inadequate protection. Rejection of inferior plants (culls) at planting recommended.
Transport to forest for planting	Wrapping of the plants in coextruded plastic bags or into boxes with straw or peat.	Special, relatively expensive but effective plastic bags. Danger of mildew developing if kept too long in the bags.
Heeling-in of young plants	Heeling-in of all plants, not used on day of delivery, under dense shelter in root-deep trenches. Light covering with earth. Regular watering.	Long-duration heeling-in harmless in winter. Frequent losses because of inadequate execution.
Pruning of roots and/or sprouts	Clean cut of long single roots in order to avoid compression when planting. Cutback of side branches to reduce transpiration (planting-shock).	Tap-roots of oak regenerate poorly and should not be much reduced. Cutting off large parts of roots in order to facilitate planting often leads to low survival and severe losses.
Transport of the plants to the planting site	Protection of the roots on site through wet sacking, moss or other material. Removal of plants only immediately before planting.	Carelessly handling on dry windy days causes serious desiccation and reduction in freshness, leading to high mortality.
Protection against insects	Dipping of plants in insecticide solution before planting or spraying at a later date.	More important for conifers (bark beetles), rarely necessary for broadleaves.

Conclusions

Most of the stages described above expose the plants to the risk of reducing the chain of freshness from the transplant bed to the planting site. Many forest owners and contractors tend to underestimate their importance. Severe losses in the young plants can be caused through negligence or carelessness at any one of the stages. The consequences lead to high mortality with subsequent expensive operations like filling-in, prolonged weeding, higher costs and irregular plantation growth.

It is, therefore, advisable to choose a reliable nursery company, to arrange the terms of lifting and transporting of plants and to observe all further handling procedures carefully. This offers an opportunity to save money, to prevent worry and avoid plantations of unsatisfactory quality.

4.4.3.8 Planting techniques

Several manual and mechanical planting techniques have been developed since afforestation first began, but only few are applied in practice today.

These are outlined in Table 4.4-19.

Notch planting methods are comparatively simple and relatively efficient. Yet problems may be encountered when inserting the roots of larger plants into the notch, causing distortions or bending. In recent years it has become evident that this causes long-lasting deformations of the root system, and leads to reduced physical stability. Species with tap roots like oak are especially sensitive to notch planting (Plate 4.4-6). They should preferably be **planted into pits**, even though this is both time consuming and expensive. Machine planting at present is of little relevance because of the small size of planting areas and the frequent stony nature of the soils.

On heavy clay and gley soils large transplants of sycamore are especially prone to becoming less stable and being blown over, as a consequence of poor root development which results in stem curvature (Plate 4.4-7). Therefore, it is generally recommended that young plants should be planted about 5 cm deeper than they were in the nursery. In this way, exposure of the upper roots to rain and wind can be avoided, and the danger of basal sweep is reduced.

Table 4.4-19: Relevant **planting techniques.**

Type of planting	Suitable plant types
Manual planting	
Notch planting	Bare-rooted seedlings and normal transplants
Pit planting	Plants with tap-roots
Planting auger	Plants with large root systems
Machine planting	
Hollow borer	Large containerised or balled plants or saplings
Furrow planting	Bare-rooted seedlings and normal transplants

Plate 4.4-6: Deformation of oak roots caused by notch planting.

Plate 4.4-7: Deformation of sycamore stems due to basal sweep possibly as a result of using plants that had a poor root:shoot ratio.

4.4.3.9 Planting time

Bare-rooted plants are usually planted in **spring** so that they can start to grow immediately. Another advantage is that they are not exposed to drought or damage caused by animals foraging during the winter months. Planting time, however, is very dependent on weather conditions, availability of labour and the size of the planting programme.

Planting in **autumn** offers the advantage of a longer period in which the roots can continue to grow after the lignification of the shoots. The mild Irish climate allows for planting throughout most of the winter.

Container-plants or wildings with earth balls dug up with a semi-circular spade can generally be planted throughout the frost-free period of the year. However, summer planting should be avoided because of the risk of longer periods of drought.

4.4.3.10 Density of plants and spacing

Few areas of silviculture have been the subject of more debate than plant density and spacing. As the two terms are often confused it might be helpful to define both before going into detail:

(1) **Plant density** refers to the number of plants per unit area – normally per ha. This is considered to be a most important aspect in stand establishment.

(2) **Spacing** characterises the arrangement of the plants, whether in squares, triangles or rows, e.g. 2x2 m or 3x1 m (the first digit refers to the distance between rows, and the second to the distance between the plants within the rows).

(1) Plant density

The main basis for determining the plant density is the natural pruning ability of the tree species. The degree of branching in the lower part of the stem determines the quality and consequently the price of the timber produced to a large extent (refer to Chapter 3.2.2.2).

Broadleaf species differ markedly in their capacity to self-prune. Three groups can be distinguished:

- Ash, sycamore, birch and alder lose their lower branches readily and relatively quickly and develop branchless stems.

- Beech, Spanish chestnut and especially oak self-prune much less quickly.
- Wild cherry and poplars prune very poorly and maintain dead branches for long periods. These dead branches form dead (black) knots in the wood, greatly reducing the quality of the timber.

Tree species belonging to the first group are often referred to as dead branch losers, whereas those from the third group are called dead branch keepers.

Natural self-pruning can be achieved for the first two groups by planting at appropriate densities. However, in some cases artificial pruning may be necessary.

Artificial pruning is essential for those species belonging to the third group.

For the production of high quality timber, the following plant densities are commonly recommended (Table 4.4-20).

Broadleaves like walnut, rowan, lime and plane are rarely planted in stands, but singly or in small groups mixed with other tree species. Therefore, no clear consensus exists about their appropriate densities. Usually the density is calculated according to the growing space they need.

The plant densities given in Table 4.4-20, however, have to be adapted according to the special conditions of an area to be regenerated. There is a number of arguments for and against choosing the upper or lower densities in practice. These are compiled in Table 4.4-21.

Table 4.4-20: Plant densities for broadleaf species as commonly recommended. (See also Table 4.4-21)

Species	Plant density recommended (plants/ha)	Plant density range (plants/ha)	Comment
Alder, ash, lime, maple, Spanish chestnut, sycamore.	3,300	2,000- 4,000	Good, rapid natural pruning, thus low densities possible.
Beech	6,600	4,000-10,000	Reasonable natural pruning, high densities necessary.
Sessile and pedunculate oak			Fair natural pruning, high densities necessary.
Wild cherry, poplar	750	500 - 1,000	Poor natural pruning, artificial pruning necessary, low densities possible.

Table 4.4-21: Reasons to **reduce or increase the plant densities** of broadleaves.

Criterion	Reduction	Increase
Site conditions	• Optimum conditions (good soils, sheltered and frost free), • poor soils: reduced availability of nutrients and water permit only a limited number of plants, • little competition from ground vegetation.	Where drought stress is to be expected, with consequential higher mortality rates.
Growing conditions for the young plants	• Plants placed under canopy of old stands, • regrowth of natural regeneration and/or root suckers suitable to fill up a plantation, • absence of deer, rabbits, voles, squirrels, cattle, sheep.	• Strong competition by ground vegetation, (e.g. thick grass cover, bramble, bracken, rhododendron). • Threat of browsing by game or grazing animals
Available plant material	Availability of • fresh, healthy plants from own nursery, • balled planting stock, • vigorous saplings over 1 m, which possibly will not be interfered with by competition from ground vegetation or by game.	Use of small plants such as seedlings. High losses to be expected because of • plant material of poor quality • loss of vitality during transport or plant storage.
Conditions during planting	Wet weather without winds, wet soil.	• Unsuitable weather conditions (hot, dry weather during planting), • inexperienced workers, • inappropriate machines or tools.
Objectives of management	Restocking of an area with little or no quality production goals.	• High quality timber production, • rapid cover of soil surface to suppress ground vegetation.
Possibility of later proper shaping and thinning procedures	• Existence of forest enterprise with experienced personnel. • Shaping, pruning and thinning in early phase probable.	• Owner with no helpers and with interests other than forestry.

The number of arguments clearly shows the complexity of the possible influences. In practice, however, many forest owners and contractors do not analyse the particular conditions, but tend to follow general guidelines on recommended plant densities for the different tree species.

Because of the great impact densities have on the development of the stand and plant qualities they are explored in more detail below.

Influences of plant densities on the development of individual trees and stands
Density has a defining influence on the development of plants collectively during youth. Later its effect is conditioned by the type and intensity of thinning. Nevertheless, density determines the development of the individual tree and stands up to the end of the production period – the age of harvest – as is described in Table 4.4-22.

Table 4.4-22: Influence of plant density on development of individual trees and stands.

Feature	Effects of plant density
Losses in young stands	Principally independent of density, but more rapid reduction in competition by ground vegetation through high densities.
Development of tree numbers	Earlier start of intraspecific competition in high densities, suppression of more individuals. Intensification of competition in the case of favourable water and nutrient supply. Early reduction of individuals with light-demanding attributes. Conservation of greater number of individuals in densely planted stands until the end of the production period compared with those widely spaced, if numbers not reduced significantly at an early stage.
Tree heights	Very little influence in the dominant classes. Reduction of height growth only through very low densities (like single trees) as well as by very high densities. Maximum heights at intermediate densities. Reaction more pronounced on poor, dry sites.
Diameter	Distinct and sustained influence of density: primarily intensive increase from high to low densities. Later decreasing effect. Stronger influence on dry soils. Continuation of influence the lower the density at time of planting.
Form and taper of trunk and crown	Taper, low with high plant numbers, abnormally high taper with low densities. Increase of taper after closure of canopy, but trees planted at low densities retain taper even when older. Crown: Retention of deep and wide crowns after establishment at low densities – precondition for enhanced diameter growth.
Volume	Volume production of individuals: high inverse correlation with growing space – increasing volume at decreasing densities. High positive correlation with diameter growth. Volume production of stand: reduction of total production with high densities towards the end of the rotation period (remaining trees not able to close canopy after elimination of dying or thinned individuals). Increase of production to a density optimum, then a falling off as increasing volume of individual trees cannot compensate for the decreasing number of trees per unit area.
Branch characteristics	Early and intensive self-thinning with high plant densities. Delayed dying of branches with low densities. Diameter: strong increase with decrease in plant density (negative correlation) because of greater crown expansion – like the stem diameters. Biggest branches produced by single trees. Length: elongation up to a maximum in reduced densities, then no further increase. Number: uncertain increase at lower spacing.
Timber quality	Timber from widely planted trees more knotty, but increase of tensile strength and bending properties – noticeably with beech and ash.
Structure of annual rings	Production of broad rings at low densities. May not fully meet the high visual requirements for furniture production, but much less important for broadleaves in contrast to conifers.
Deformation of stems	Increase of crooked and twisted stems at low densities for some species (beech, oak), but climatic factors and provenance differences may play a more important role.
Biotic threats	Increase of browsing pressure by deer (or cattle) at lower densities because of concentration on fewer plants.

Plates 4.4-8 to 4.4-11 give an impression of how much the available growing space determines the architecture and qualities of trees.

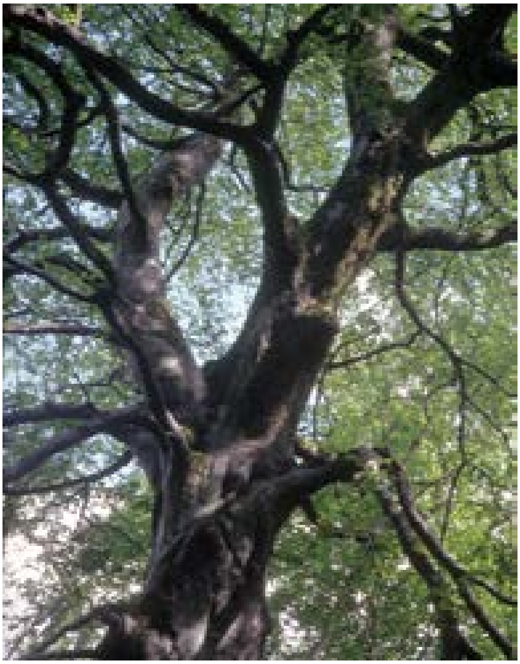


Plate 4.4-8: Architecture and quality of beech in response to available growing space.

Crown size and form, as well as stem diameter, especially of beech trees, are highly influenced by the available growing space.

Plate 4.4-9: Beech stand.

(Kilbora, Co Wexford)

Grown in dense stands, beech may, however, produce long straight, but slim stems.

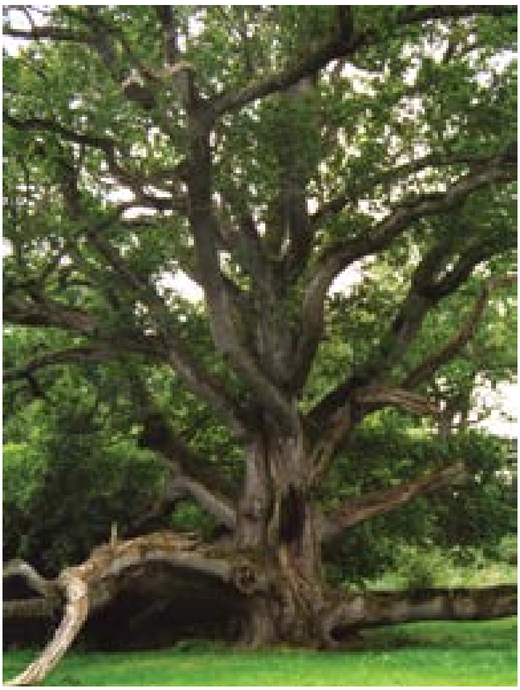


Plate 4.4-10: Architecture and quality of oak in response to available growing space.

(Charleville Estate, Co Offaly)

Under special circumstances even oak trees develop huge crowns provided they grow continuously in the open through their whole life.

Plate 4.4-11: Oak stand.

(Kilcooly, Co Kilkenny)

As with beech, oak forms long straight stems if growing densely from the time of establishment and onwards in a stand.

(2) Spacing

As mentioned, spacing denotes the spatial arrangement of plants on a planted area. It is expressed by the distance from one plant to the next. From these data the configuration of the growing space, for instance quadrangular, rectangular or triangular can be calculated. Configuration is, however, less important than the area of growing space per tree, assuming that extremes are avoided.

The following spacing variants are common in practice:

- Quadrangular,
- rectangular,
- row,
- cluster,
- irregular placement.

Square spacing is still used in many countries and is popular in Ireland. However, **row spacing** has begun to take over as it is less time consuming and, therefore, more cost effective. Several activities are cheaper when row spacing is adopted such as soil preparation, planting, filling-in, weeding, fertilizing, protection against animals and tending. This is illustrated in Table 4.4-23 and shows that the walking distance can be reduced remarkably.

By changing the quadrangular into row spacing the distance to walk to all plants is reduced to almost two-thirds in the first example and to half in the other.

Table 4.4-23: An example of **reduction of walking distance** while changing from square to row spacing demonstrated with two variants.

Initial plant density			Spacing	
plants/ha			quadrangular	row
6,666 (1)		m	1.25 x 1.25	2 x 0.75
	walking distance	m	8,000	5,000
		%	*100*	*62*
2,500 (2)		m	2.0 x 2.0	4.0 x 1.0
	walking distance	m	5,000	2,500
		%	*100*	*50*

(1) for example: oak and beech (2) for example: ash and sycamore

A special form of arrangement is groups or clusters which have been widely tested for oak during the past 20 years or so in east and central Europe (Figure 4.4-1). They follow from recommendations by Russian and Polish scientists and seem especially attractive in reducing time and costs. The groups may be planted irregularly into gaps within naturally regenerated young growth or on terrain with residual slash or other impediments (Plates 4.4-12 and 4.4-13).

A much favoured spacing type is planting oak in clusters of 21 plants spaced at 1x1 m within groups 10 m apart. It is assumed that at least 1 plant per group will develop vigorously and become a potential crop tree with reasonable stem quality. The open space between the groups may be filled with either naturally regenerated birch, willow or other tree species capable of providing some shelter, while not competing strongly with the oak groups. The alternative is to plant mixture trees like wild cherry. Even the use of hornbeam or beech is possible and these may eventually form an understorey, protecting the oak stems from the development of epicormics.

Compared with traditionally established plantations of 5,000-10,000 plants/ha, only 2,100 oak and possibly 500 cherry are required, about 2,600 plants/ha in total.

The pattern can be varied, of course. So it may be sufficient to plant oak only in situations where naturally regenerated seedlings or regrowth from stumps have not developed. Then the input will be reduced accordingly.

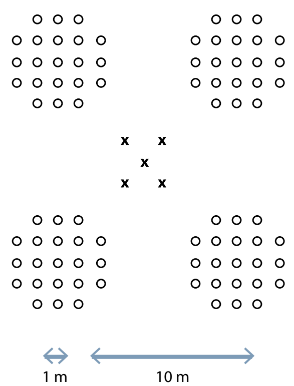


Figure 4.4-1: Example of **group planting pattern**

It is worth recording that variations of this system have been tried in Ireland:

- During the 1930s, Anderson (1953) recommended the establishment of broadleaf plan-

Plate 4.4-12: 15 year old groups of the early experimental phase.

(Simmern, Germany)

They have been spaced too densely (50x50 cm). Plant distance within groups has now been increased to 1x1 m.

Plate 4.4-13: A similar group showing great differences in diameter and quality within the group and furthermore, a typical flower bunch effect.

ations with conifer nurses. Clusters of 13 oak spaced at 60 cm apart within groups and with group centres at four and a half metres spacing, were recorded at Callan Forest, Co Kilkenny.

- Similar groups of oak, within a matrix of Norway spruce nurses, were established throughout the north midlands, but, due mainly to delays in thinning, the broadleaves were invariably suppressed by the conifers.
- More recently, groups of broadleaves were introduced into a 5-year-old Sitka spruce plantation at Ballyhooley, Co Cork (Horgan, 2004). Height growth and stem quality of the broadleaves remains good, but they will require regular attention to avoid suppression by the spruce.

The inference to be drawn from these trials is that groups are a comparatively inexpensive way of establishing broadleaves in certain conditions provided attention is given to subsequent management.

Groups are occasionally used for converting pure conifer stands into mixed conifer/broadleaf stands by underplanting (Plates 4.4-14 to 4.4-16).

Irregular placement of plants is common with enrichment plantings in gaps, as it is difficult to observe strict distances where young growth already exists.

As mentioned the configuration of the growing space on the development of the young trees is of less importance than its area. Nevertheless, some possible effects may be of interest and are, therefore, listed in Table 4.4-24.

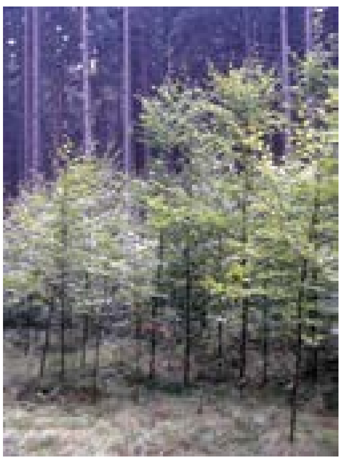


Plate 4.4-14: Gradual conversion of a Norway spruce stand into a mixed conifer/broadleaf forest by group underplanting with beech.

Plate 4.4-15: Single beech trees tend to become very branchy, thus group planting is essential.

Plate 4.4-16: Group regeneration of a former pure Norway spruce stand.

The beech groups (background, left and right) need some height growth advantage when young in order not to be overtaken by naturally regenerated Norway spruce (centre background).

(All photos from the Black Forest/ Germany)

Table 4.4-24: Influence of growing space on form of trees as generated by spacing.

Characteristic	Effect of growing space on form
Crown form	Quadrangular spacing: usually development of even crowns at all sides. Row spacing: slightly enlarged crown dimensions into the row interspace, but still reasonably balanced crowns. Irregular spacing: asymmetrical forms.
Stem form	Asymmetrical growing space: danger of stem sweep and bends because of light induction in some light-demanding (phototropic) trees like oak and alder. Row spacing: sometimes deformations in the early years which tend to disappear later.
Stem cross-section and annual ring structure	Possible oval stem cross sections because of irregularly formed crowns with resultant formation of reaction wood. Normally occurring only in trees along forest edges or larger gaps in the canopy. Oval stems may form eccentric annual ring structures, but reaction wood is a greater cause of wood deterioration.
Forming of branches	Row spacing: thicker and longer branches between as compared with within the rows. However, the competition within the rows influences the formation of branches between the rows.

Actual spacing in stocked forests with regrowth

The different pattern of plant distribution has been recorded by the National Forest Inventory. These specific data are summarised in Table 4.4-25.

On two-thirds of all regeneration areas regular spacing is the norm, but there are great differences between the stands of different ownership. Plantations in the grant aided private forests have regular planting in almost 90% of cases. In contrast, more than 80% of the other private forests have random distribution patterns. Group planting plays little or no role.

Table 4.4-25: Distribution of plants (%) within regrowth by ownership. (Adapted from NFI, 2007)

Definition of distribution:
Regular: uniformly, e.g. 2x2 m square spacing.
Random: no particular pattern.

(Basis: 450,000 ha stocked forest with regeneration; weighted means).

Distribution	Ownership			
	public	private		Mean
		grant aided	other	
Regular	*62*	*87*	*13*	***65***
Group	*2*	*2*	*5*	***2***
Random	*36*	*11*	*82*	***33***
Total	*100*	*100*	*100*	***100***

Conclusions

The density of trees in a stand at the time of establishment plays an important role with regard to production and quality characteristics of the individual trees. Moreover, it influences the stability, structure and yield of a stand until the end of the rotation period.

Close initial densities offer high probabilities of producing high quality timber. This is the

continued

Conclusions continued

reason why higher densities are recommended. However, wider spacing has been regarded as an opportunity to save money in recent years.

Excessive density in naturally regenerated young stands should be reduced by early respacing. Low densities may lead to heavily branched or misshapen trees and should be corrected by timely shaping, early thinning and artificial pruning. Within a wide range of spacings, the density of plants per unit area is more important than the spacing pattern.

4.4.3.11 Filling-in, completion and enrichment plantings

Afforestation or reforestation by planting seldom leads to complete success. Losses are almost inevitable. Their causes are mentioned in Table 4.4-22 and Chapter 4.4.7.

Losses have to be replaced in the case of serious plant failures or the quality of a young stand is likely to deteriorate.

The following considerations may help to decide whether filling-in (sometimes called beating-up) is necessary or not:

- **Losses of single plants** more or less evenly distributed over the whole plantation represent the normal risk. Provided they do not exceed about 10-15% filling-in is not necessary as losses of this order are usually anticipated in the plant density recommendations.

  Land owners tend to fill-in even small gaps as they cannot foresee how fast these gaps will be closed by the surrounding young trees. It is often less costly to remove some large branches from neighbouring trees than fill-in all losses.

- **Larger gaps** from losses of transplants, however, should be replanted.

- **Blank spots** are less serious when they are filled in naturally by pioneers like birch and willow. Filling-in, however, should be done only with vigorous plants, which are as tall as those in the plantation, one or two years after planting. Otherwise there is a danger that they will be overtopped immediately and have little or no chance to catch up with the others.

  Blank spots – provided they are large enough (greater than 100 m²) – can be used for **enrichment planting** with other tree species for mixtures. However, a sufficient distance (greater than 5 m) should be maintained from the already established plants in order to avoid overtopping from the sides (Plate 4.4-17).

Plate 4.4-17: Planting of an empty space in a regeneration area with tall sycamore transplants – enrichment planting. (Germany, 2002)

Conclusions

Planting is by far the most important method of establishing new broadleaf stands as long as afforestation is the main option.

Planting is normally the easiest and safest way to establish stands with a reasonable probability of reaching the expectations of the owner – especially that of high quality timber production.

continued

Conclusions continued

The most crucial aspect of all plantings is the availability of genetically improved, site adapted provenances, and this still remains problematic. As many of the broadleaf species have not been thoroughly tested and evaluated, much scientific and practical experimentation will be necessary in the future in this regard.

There are a number of methods and tools available for site preparation and planting which are appropriate for the wide range of sites and organisational conditions.

For the future a combination of planting and natural regeneration will, as in Central Europe, gain importance in Ireland, but for the present this is an aspiration.

After planting, tending of the young growth, like weeding, shaping and pre-commercial thinning, is similar to that necessary for stands established by direct seeding or natural regeneration. These aspects are jointly discussed in Chapters 4.4.7 and 4.4.8.

4.4.4 Direct seeding

In addition to planting, direct seeding is also an alternative method of artificially establishing a new stand.

Seeds are distributed by hand or machine in their designated locations in the field where they germinate and become established. This is the only difference from natural regeneration, where the seeds are distributed randomly by wind or animals. Once the seeds are in the ground all the subsequent processes are similar to those of natural regeneration. Direct seeding, thus, is an intermediate option between artificial and natural regeneration.

Direct seeding has almost no tradition in Ireland. However, on the Continent it has been practised for centuries, mainly with conifers, in times when transplants were not available because of lack of nurseries. Sessile oak acorns have also been sown in this way since time immemorial. This is still the common practice on relatively sandy sites where there is little or no competition from ground vegetation.

In parallel with the development of a more diversified forestry in Ireland it may be used occasionally in the future, which justifies a brief summary of the topic here.

4.4.4.1 Arguments for and against direct seeding

The main **advantages** of direct seeding are as follows:

- Undisturbed development of the root system.
- Avoidance of losses through seed storage.
- Reduced costs.
- Less time consuming than planting.
- Cost effective for filling gaps in naturally regenerated regrowth.
- Good quality of seedlings when growing densely and homogeneously.
- Chance to remove plants from dense regrowth for enrichment planting in gaps.

The following **disadvantages** apply to direct seeding:

- Dependency on seed years and seed availability.
- The need for large quantities of seed.
- Germination process dependent on weather conditions.
- High protection and tending costs.
- Weed competition can be problematic.
- Suitable seed bed conditions required.

4.4.4.2 Practice of direct seeding

In contrast to natural regeneration, soil preparation normally precedes direct seeding. This is necessary in order to create a favourable seed bed by opening up the mineral soil. Sometimes the seeds are even covered with soil for protection.

For the regeneration of oak especially, the following two advantages are worthy of note:
- Seeding normally provides a high density of even-aged young plants, ensuring early natural pruning within young stands.
- The acorns are sown in autumn shortly after seed fall as it is difficult to store them during the winter without loss of germination potential.

Acorns are normally sown in rows 1.5-2.0 m apart with 500-800 kg/ha. At present, however, it is unlikely that such quantities of seed are readily available in Ireland.

Of more importance will be the opportunity to fill in gaps in plantations or naturally regenerated young growth through spot seeding. This is a cheap method of introducing oak in mixture on many sites (enrichment seeding).

In the long-term sowing acorns may assume importance in Ireland and for this reason the procedure is outlined below:
- Small holes up to 5 cm deep are prepared with an iron bar; 1-3 acorns per hole are inserted and firmed in by foot.
- Alternately, hoes which are common in agriculture, can be used to prepare small slits, some acorns are inserted and then the slits closed as mentioned.
- The seed spots should be spaced 1-2 m apart in order to achieve a plant density of 5,000-10,000 plants/ha.

This method is ideal for making use of local seed sources of the mainly oak-dominated woodlots throughout the country – provided, of course, the genetic quality of the seed trees justifies their propagation.

Sowing of **birch** has gained some importance during recent years on the Continent in order to create nurse trees on large areas following damage due to pollution or windthrow. Seeds are preferably sown on snowy or wet ground late in winter in order to ensure sufficient humidity at time of germination (Plates 4.4-18 and 4.4-19). As there is a changing attitude towards birch in Ireland, especially regarding its nursing function, it may be worth considering establishment by direct seeding more often in the future, particularly on peaty sites.

Plate 4.4-18: 3-year-old birch sown in order to form a nurse crop.

Plate 4.4-19: 10-year-old sown birch nurse crop which is ready for underplanting with beech.

(Both plates from Ore Mountains, Germany)

4.4.5 Natural regeneration

4.4.5.1 Necessary preconditions and arguments for and against natural regeneration

To regenerate forests naturally, seed trees have to be present on the area or in the vicinity and these have to be well adapted to the site. In Ireland there are few broadleaf forests left of seed-bearing age and many are not indigenous, or their seed sources are at least unknown. However, there are some stands of reasonably good quality which can be naturally regenerated or used as seed stands.

Natural regeneration is not widely practised in Ireland, but it will gain some importance in the long-term as stands mature and as broadleaf stands become more extensive.

It may be worth noting that although there are certain **advantages** (Table 4.4-24), there are also some **disadvantages** (Table 4.4-25).

Table 4.4-24: Advantages of natural regeneration.

Benefit	Detail
Conservation of autochthonous or site-adapted populations	Eliminates the risk of being supplied with unsuitable provenances or even wrong species (e.g. brown bud ash).
Favourable adaptation to site variation	Effective adaptation of species mixtures to the micro-site differences.
Undisturbed growth of the young plants	Regular development of root systems; no root deformations as happens when planting species with tap roots (like oak) on heavy (compacted) soils.
Possibility for selecting more good individuals at later thinnings than in planted stands	High numbers of seedlings improve quality development of individuals and natural differentiation within stands; saving tending/thinning costs.
Opportunity to obtain wildings	Availability of site-adapted wildings for completion of heterogenous development of naturally regenerated young growth; for planting on other areas and for transplanting.
Saving costs of seed and plant material	Generally lower costs in the establishment phase, even if site preparation and fencing unavoidable.
Production of high quality timber through sheltering effects of old trees	Natural regeneration mainly takes place under shelter of old trees. Harvest gradually over a period of years.
Protection of young plants against climatic stress (frost, drought)	More related to the natural regeneration process although not necessarily limited to it. Planting under the shelter of old trees also possible.

Table 4.4-25: Disadvantages of natural regeneration.

Disadvantage	Detail
Dependence on seed production	Reduced economic flexibility of forest enterprises due to irregular seed years.
Unevenness of young plant distribution	Necessity of filling-in gaps and reducing overstocking. Possible deterioration of quality of edge trees beside gaps. Risk of neglecting early thinning due to variability in development within the stands.
Risk to survival of germinants and seedlings	Longer duration of exposure to damage by fungi, insects, deer, voles, snails especially at germination stage, as well as competition from weeds.
Technical problems of felling old trees over young plants	Risk of damage to young growth as natural regeneration mainly under shelter of old trees which are normally cut in several felling stages. Stumping back of damaged plants necessary.
Higher tending requirements in young stands	Special effort necessary for • elimination of undesired other species, • correction of irregular densities, • removal of wolves.
Long duration of regeneration process	Period between seed production and end of tending measures normally longer than for a plantation. Problems of ensuring continuity in the forest enterprise.

Despite the often-claimed advantages of natural regeneration as compared with planting it must be stated that natural regeneration is not cost free. In fact, specific treatments are often necessary at defined stages in the development of the young stands in order to secure the success of the whole process. This can include soil preparation, protection against browsing by deer and weeding. What is saved in reduced planting costs can also be offset by high early respacing or thinning costs. On the Continent there is agreement, that in general natural regeneration is economically more rewarding in the long-term.

In the following sections some procedures are described that may improve the potential of natural regeneration.

4.4.5.2 Promotion of seed production

The initiation of flower buds rather than vegetative buds is encouraged by sunny weather conditions when the flower and leaf buds are formed i.e. in the previous summer. The rarity of warm summers in Ireland is probably the cause for the rarer mast years than on the Continent, especially of oak and beech. Nevertheless, something can be done to improve the seeding ability.

Older trees with large crowns tend to fruit more often and more prolifically. Crown thinning from an early age, and continued at regular intervals, promotes earlier flowering, more frequent mast years and more copious seed production.

Even if early thinning has been neglected, the later release of crowns activates the lower part (shade-crown) and this will increase seed production. This is the reason why regeneration treatments, according to the traditional shelterwood system, always begin with a preparatory cut (also called seeding felling).

4.4.5.3 Improvement of topsoil conditions and germination potential

The state of the topsoil plays a decisive role in seed survival during winter and the conditions available for germination and the development of the young plants. On many regeneration areas the topsoil condition is often not favourable. In Table 4.4-26 some methods are listed which will improve conditions for successful germination and survival.

Table 4.4-26: Silvicultural methods for improvement of seed storage and germination on regeneration sites.

Type of treatment	Specification	Procedure	Evaluation
Conversion of litter layers inhibiting regeneration	**Opening canopy** to encourage soil activities by improving warmth and water supply.	Removing mainly strong shading and rain-intercepting trees. This ideally involves large-crowned, shade-tolerant sub-dominant individuals.	Essential part of the starting phase of several silvicultural systems with the aim of slowly improving the topsoil conditions. Threat of promoting competing vegetation if carried out too severely.
	Ground preparation to encourage soil activity.	Loosening topsoil and mixing of litter and mineral soil by machines/equipment suited to rotovate the topsoil.	Necessary in areas with retarded decomposition – mainly acid soils.
	Fertilising to activate litter decomposition.	Extensive and even distribution of lime or granulated complex fertiliser by machine or hand. Possibly in connection with opening the canopy.	Only appropriate if applied over a lengthy period on nutrient-deficient acid soils. Fertiliser effect improves increment on the old trees.
Elimination of litter layers inhibiting regeneration	**Opening up the mineral soil** by spot- or strip removal of the surface litter layer.	Shallow rotovation/scarification equipment, easily manoeuvrable within the stands.	Possibility to use seed years especially for beech.

Scarification is the easiest and most effective means of improving the condition of the topsoil for self-sown seed and subsequent seedling development.

Positioning the seeds on open mineral soil has proved to be most effective, because they are less likely to be attacked by mould fungi in the topsoil. This is especially the case in mild winters, on slightly to strongly acid soils, when moulds can be active (Plate 4.4-20).

Although most studies in this field have been carried out with beech there is evidence that the natural regeneration of other, mainly long-living broadleaf species can also be improved by soil cultivation. It has been found that regeneration success can be further increased by covering large seeds with mineral soil – to a depth comparable with direct seeding – in order to reduce the losses caused by frost, drought and predation by animals (Plates 4.4-21 and 4.4-22).

4.4.5.4 Establishment of germinants in the soil

Having successfully overcome the winter risks and successfully completed the germination phase, the young seedlings need sufficient water to develop further. Germinants that root only in the litter will wither and die if it dries out. Even in the wetter temperate zone a dry period of two to three weeks occurs almost every year and this plays havoc with newly germinated seedlings. Those that have rooted into the mineral soil have much higher survival rates.

4.4.5.5 Improving development conditions of seedlings

Survival of the young plants and their continued growth is mainly dependent on the amount of light available. This is influenced by the extent to which the canopy is opened in accordance with the light requirements of the species:

- Oak, for instance, has to be released from the shade of canopy trees after 5-10 years, whereas beech may grow for 20-30 years under shelter.
- Rapid openings will favour the proportion of light-demanding species, whereas slow progress will eliminate the light-demanders and favour the shade-tolerant species. Thus mixtures can be effectively controlled by the speed of removal of the overstorey.
- Rapid openings or overstorey removals may automatically encourage the ground vegetation to flourish and cause aggressive competition for the new established young forest trees.

The overstorey, however, must be opened further after the seedlings have become well established, that is when they have reached a height of 1-1.5 m. At this stage they should be able to withstand competing ground vegetation, otherwise the ground vegetation will win the race. In the latter situation planting is the only alternative for re-establishing the stand.

4.4.5.6 Minimising damage to seedlings after felling overstorey trees

Felling of overstorey trees will usually damage some young regrowth. This will happen even if the workers are skilled and careful. So, after felling is completed, some tending will be necessary to deal with broken and damaged seedlings.

Plate 4.4-20: Strip-wise cultivation of the mineral soil prior to seed fall in order to improve seed survival and germination conditions in a beech stand.

Plate 4.4-21: Densely established beech seedlings as a result of cultivation of the mineral soil – barely visible against the leaf-fall background.

Plate 4.4-22: Excellent strike and establishment of beech seedlings after soil preparation.

(All plates from central Germany)

Young broadleaves when stumped back have the potential to regenerate from the cut stump and catch up with their undamaged neighbours. If the crop is only 1-2 m high at time of treatment it is almost impossible to detect any difference between those treated, and those untreated, at a later date. Where the treatment has not been undertaken the damaged plants will retain their deformities to maturity. Furthermore, serious injuries to the bark may provide entry points for decay.

After stumping, the new sprouts normally grow up straight and without blemish. Moreover, there is no evidence that the cut surface provides a source of infection and decay.

4.4.5.7 Concluding the special treatments of natural regeneration

Compared with planting, the special attributes of natural regeneration are considered to have come to an end when the seedlings have reached approximately 1 m in height. At this stage their size corresponds to that of transplants established through artificial regeneration. From this time on the same tending principles apply to both and are discussed jointly in Chapter 4.4.8.

4.4.5.8 Overview of methods favouring natural regeneration of the major broadleaf species

In Table 4.4-27 a general view of suitable methods is provided.

Table 4.4-27: Overview of **conventional methods and conditions for natural regeneration** of the main broadleaf species

Species	Regeneration system	Preferable soils	Ground preparation	Relevance of natural regeneration
Beech	Uniform and irregular shelterwood, slow removal of shelter (15-30 yrs).	Nutrient rich soils, without ground vegetation.	Not necessary.	Most important natural regeneration tree species.
		Moderately nutrient rich soils.	Extremely important (before and after seed fall).	Improvement of natural regeneration through ground preparation important.
Hornbeam, elm	Naturally formed gaps in canopy; gap and shelterwood fellings.	Moderately nutrient rich, moderately wet soils.	Not necessary.	Easy to establish. Elm of no importance at present because of continuous Dutch elm disease attacks.
Lime	Shelterwood	Moderately-well supplied with nutrients and water.	Not necessary.	On the few lime sites usually naturally regenerated.
Oak	Shelterwood; usually rapid removal (~5 yrs).	Pedunculate oak: Moderate-rich in nutrients in lowlands (alluvial soils). Sessile oak: Moderate-rich soils in lower mountain ranges.	Slight ground preparation before and after acorn fall. Not necessary in case of sparse ground vegetation. Widespread ´seeding by jays.	Used in some countries. In Central Europe seldomly applied because of strong deer browsing.
Sycamore, ash, wild cherry	Naturally formed canopy gaps and light overstorey; gap and shelterwood fellings. As light-demanding and fast-growing, irregular removal in form of gaps after 2-5 yrs.	Rich, limey soils well supplied with water and of good depth.	Not necessary.	Easy to regenerate, locally only natural regeneration.
Birch	Edge or clear cuttings (pioneer).	Wide range of soils.	Necessary on soils with a dense grass sward.	Partly intensive natural propagation (succession on bare land).
Alder	Clear cuts.	Soils well supplied with water and nutrients. Regenerates only on mineral soil.	Not common, but very effective.	Distributed randomly along streams and forest edges.
Aspen	Edge or clear cuts. Because of high needs for light, no shelter (pioneer).	Low-moderate soil fertility.	Not necessary.	Often invades plantations and then becomes undesirable.

Conclusions

In general natural regeneration is an important option. Whether or not it will be used to a greater extent in future in Ireland depends on a number of factors:

- **Natural regeneration needs a long time period**
  Usually the period between seed fall and removal of the last overstorey trees requires much longer than that of plantation establishment. It is, therefore, not easy for many forest enterprises to provide experienced staff on a continuous basis that can devote time and that have the practical knowledge to promote regeneration.
- **Insufficient knowledge of natural regeneration conditions especially on problematic sites**
  Natural regeneration is easiest to obtain on moist sites. It is an open question as to whether oak and beech succeed in the lowlands where ground vegetation is an important factor of competition.
- **Ground preparation may be relevant**
  Mild climate and more or less acid soils are important conditions in Ireland. Therefore, ground preparation offers the best opportunity for increasing the numbers of seedlings. However, more detailed studies are needed.
- **Improved natural regeneration after rehabilitation of the forests**
  Studies have shown that restoration of degraded soils occurs under broadleaf tree cover through formation of nutrient and water storing humus layers. The trees of the overstorey also provide shelter and seeds. As long as the species and provenances are appropriate to the site the opportunity for natural regeneration tends to improve.
- **Lower costs**
  Forest owners generally have to work within economic constraints. Regeneration of forests needs high financial investment which can often be reduced by natural regeneration. Foresters complain about the irregular or patchy establishment and development of the seedlings, but ignore the fact that these groups reduce the size of area requiring artificial regeneration. The gaps can be filled-in with the same species, or enriched with other species.
- **Availability of seed trees and a suitable seed source**
  Retaining seed trees on-site or the availability of seed trees in the neighbourhood will ensure a seed source.
- **Site adaptation and naturalness**
  An added benefit is that the young stands are better adapted to that site and are more in keeping with the naturalness of the area.

In summary, an increase in the proportion of naturally regenerated forests can be anticipated – at least in the long-term.

4.4.6 Establishment of mixed forests

4.4.6.1 Role of mixed forests as an alternative to monocultures in management practice

Beginning in the first half of the 19th century large areas of bare land were planted with Norway spruce and Scots pine in Central Europe. At the end of the 19th century it became apparent that these monocultures suffered increasingly from storm damage, extensive snow breakage and attacks by many insect pests. Foresters then began to realise that mixed forests proved to be more stable physically as well as ecologically and recommended the adoption of mixtures:

- Gayer's book (1886) on mixed forests has become a bible in this respect and has been reprinted in 1998.
- Mortzfeldt in the 1870s in northern Germany began to plant oak groups into Scots pine stands in order to provide diversity and create seed sources for later natural regeneration. Some 3,500 of these groups, which are now up to 120 years old oak stands of around 0.1 ha in size, have been discovered by aerial photography and several of them have been studied by Bilke (2004).
- Others like Rebel (1922) in Bavaria followed the same trend and tried to improve the stability of Norway spruce stands by introducing groups of beech. Most of these endeavours were interrupted by the two world wars, but have been continued in recent years.

In keeping with the trend towards greater biodiversity in recent decades, mixed forests have now become popular worldwide. Apart from having greater stability they are regarded as being much more ecologically diverse than monocultures and are, therefore, better able to fulfill the social and public roles of forests.

An essential part of the close to nature movement, or nature-orientated forestry philosophy, is to increase the proportion of mixed forests, and so reduce the area of large even-aged monocultures. The dominance of Sitka spruce in Ireland, Scotland and Wales, as well as Norway spruce in Central Europe, has often been criticised by ecologists and nature conservationists. Mixed forests are, therefore, often viewed as an acceptable way to escape this dilemma.

4.4.6.2 Advantages and problems of mixed forests

Many foresters and nature conservationists are concerned about the regularity with which conifer forests are damaged by storms, snow and insect attacks. They believe that mixtures may provide a solution, or at least help to alleviate the problems. However, because not all foresters and land owners are in agreement on this issue, it is considered appropriate to explore the arguments, for and against the use of mixtures, before dealing with their establishment.

(1) Positive consequences and benefits of mixtures

The effects of mixtures have increasingly been studied during the past 20-30 years. For the greater part they deal with the benefits which can be achieved by the addition of broadleaves into conifer plantations. Although much of the information is still vague, and often emotionally driven, the following benefits are sufficiently apparent:

- **Improved physical stability of single trees and stands**
  Mixtures, especially those of broadleaves with conifers, influence crown size and form, which in turn alters stem form, taper and the height to diameter relationship (h:d ratio), thereby changing the oscillation behaviour in storms. The different rooting habits of the trees ensures that they anchor their roots at different soil depths. Both factors lead to greater stability and thus losses from catastrophic events like storms and snow are reduced. It has, however, to be admitted, that most of these positive experiences have been gained from mixtures of beech with Norway spruce, Scots pine, larch and Douglas fir on the Continent and cannot be transferred directly to Irish conditions. It is, moreover, debatable whether mixtures, as opposed to thinning, are more effective in favouring crown and stem form and thus improving the stability of individual trees.

- **Improved physiological resistance to disease and stress conditions**
  Vigorous trees resist stress conditions, such as drought, abrupt changes in weather conditions and insect attacks, better than suppressed trees. It is also well recognised that individual trees tend to grow more vigorously along forest edges than those in dense stands. With mixtures of varying growth potential the less vigorous trees within the stands provide edge conditions thus supplying their more dominant neighbours with more space and the opportunity to develop more vigorously. This is an important effect of mixtures within the main canopy. It is, however, debatable as to whether appropriate thinning procedures may be just as effective in providing these conditions. Nevertheless, improving the physiological resistance of trees, whether through mixtures or more intensive thinning, may become increasingly important with regard to climate change.

- **Shelter against exposure**
  Individual or groups of old trees, hedges or rows of pioneers provide effective shelter for less stress-tolerant species. This phenomenon can be observed all over the country wherever new plantations are established in the vicinity of such protection. If shelter does not already exist it can be provided by including nurse trees when planting with species sensitive to exposure.

- **Spatial separation of host trees**
  Compared with large pure stands, mixtures, especially if established in groups, reduce the food supply for insects or fungi and, therefore, inhibit the build up of infestations. They also create habitats for predators to allow the development of biological control.
  Mixtures, therefore, improve ecological stability and resilience which is the ability of the forest to recover more readily from stress conditions or damage.

- **Production of high quality timber**
  Stems of some broadleaf species, such as oak, ash, sycamore and beech, tend to develop epicormic branches if exposed to adequate light. Shade-tolerant trees that form an understorey and provide shade contribute to an improvement in the stem quality of the main crop.

- **Improving soil quality**
  Conifers (Sitka and Norway spruce, Scots pine and larch) produce relatively low quality humus. The admixture of broadleaves tends to improve the C:N ratio and thus helps to develop more diverse decomposition cycles which favours the uptake and absorption of nutrients resulting in a reduced nutrient depletion of the soil.

- **Diversity of tree species**
  A greater diversity of tree species provides the opportunity to create more ecological niches and may help to build up a diverse and versatile biocoenosis, the coexistence of plant and animal species. Greater biodiversity is a general objective in nature protection.

Most of these factors are interlinked. Many serve to benefit the forest owner directly by the long-term safeguarding of woodlands and income. The function of nature protection, however, leads to social benefits with far-reaching implications such as less damage to the forest by better protection of the soil and water resources and by erosion control, all of which ultimately protect the whole environment.

It will be apparent to the reader that most of the favourable aspects of tree mixtures are related to admixtures of broadleaves into coniferous crops. Therefore, it makes sense to pay more regard to this aspect in future.

(2) Disadvantages and problems of mixtures

From a management and silvicultural aspect there are numerous disadvantages and problems associated with mixtures that tend to discourage and restrict their implementation.

- **Problems of managing intimate mixtures**
  Mixed stands are very specific with regard to tending and thinning requirements. The more intimate the mixture, and the more diverse the growth behaviour of the various tree species included in it, the more sophisticated the treatments required in order to ensure that goals will be achieved. Random mixtures in particular need very specific procedures, adapted to mixture type.

- **Mixtures need just in time management**
  Light-demanding species respond strongly in their youth to the growing conditions (refer to Chapter 4.1.2.1). Shaping, pruning, tending and thinning treatments all have to be done in the relatively short early development phase. The time window is very short when effective structuring of the mixtures is possible. This means that most of the treatments have to be carried out at exactly the right time, otherwise one of the tree species may be suppressed by another, or the quality of all might deteriorate.

- **Mixtures are site specific**
  An additional factor is that site conditions may completely alter the growth relationship of the tree species in a mixture.
  For instance oak will tolerate competition from birch on sheltered sites and rich soils. On poor, water-logged and exposed sites, however, it has to struggle and will be overgrown by birch if not released in time.

- **Difficulties in managing mixed forests**
  In practice the following obstacles often lead to neglecting necessary treatments:
  - Managing mixtures needs well-trained and experienced forest managers and forest workers. These are not often available at the right time or at all.
  - Large stand units, that need to be treated at the same time, tend to complicate adequate treatment of mixtures.
  - The preliminary treatments, like mixture regulation and shaping, often have to be done at the early thicket stage when they are not easily accessible and difficult to see clearly.
  - Early tending operations are costly and the product from thinning is often not marketable and may even have to be undertaken at a net cost.
  - In some cases the plantations are established by farmers whose successors may not take an adequate interest in further management of the mixed stands.

Many stands throughout the country, which have been established in mixture show signs of lack of management, for example one species has taken over the lead and the other is suppressed or has been killed. As a consequence, the whole stand may fail to meet expectations, with regard to either volume and value production or other long-term goals. When establishing mixtures there is, therefore, a need to apply methods and procedures that ensure that mixed stands will remain intact, even if later management is neglected.

In this chapter, aspects of establishing mixed forests are introduced, including definitions which concern mixed forests, their values, the various types and establishment concepts. In Chapter 4.5.6 (Thinning of mixtures) the actual status of mixed forests in Ireland and the conclusions with regard to appropriate management procedures are discussed.

4.4.6.3 Naturalness and definitions related to mixtures

Before going into details some general explanations are given regarding the naturalness of mixed stands together with some of the many definitions that have been developed in this field.

Naturalness of mixed stands

Mixed stands are often regarded as the normal or even the only possible result of stand development under natural conditions. In fact, there is strong evidence that most of the

European forests have been mixed in earlier times, and that most of the man-made forests of today may again become mixed provided human interference ceases.

Under special circumstances, however, pure forests would also develop:

- **Temporarily:** after catastrophic events like fires, storms or insect attacks which lead to succession via pioneers.
- **Permanently:** under extreme climatic conditions as in the boreal zone, in higher mountains, on poor or wet soils along rivers or moors.
  Permanently pure forests can also develop where very competitive species dominate, like beech in Central Europe.

Mixed forests are, therefore, not necessarily the only ecological direction of natural forest development.

Definitions with regard to mixtures

Mixture is a rather imprecise term which requires further elaboration. It includes:

- Mixtures of **different species groups** (conifers and broadleaves as well as mixtures of broadleaves or conifers alone).
- Mixtures as a **result of natural succession** (refer to Chapter 4.1.2.6) as well as human interference according to various objectives.
- Mixtures in the **percentage of the tree species participating** (mixture grade).
  According to the NFI definition of mixed stands the dominant species occupies up to a maximum 80% of the canopy. Pure stands are consequently defined as those with the main species occupying 81% or more of the canopy.
- Mixtures are defined by the **horizontal texture** as well as the **vertical structure** (Table 4.4.28).

Table. 4.4-28: General **types and forms of tree species mixtures.** (Partly adapted from NFI, 2007)

Mixture type	Mixture form	Description	Relevance
Horizontal texture	single	Individuals of two or more tree species in an intimate mixture.	Intimate mixtures are problematic when trees are young as intensive management is necessary. In final crop stands, however, single tree mixtures are valued as an exemplary model.
	row	Row mixture of mainly two species: 1x1, 1x2, 1x3 etc. rows of the two species.	Common nurse crop mixture: one row of nurse species (Scots pine, larch) and one or more rows of the target species (oak, beech). One row at forest edge alongside a mono-textured stand (e.g. wild cherry alongside a beech stand).
	strip	Mixtures of two or more rows of mainly two species.	Transition stage between nurse crop mixture and group structure.
	group	Groups of a size of at least the crown cover area of a final crop tree (50-150 m²).	Precondition to establish stands with intimate mixtures in the final crop stage.
	area	Adjoining stands 0.1-0.5 ha in size.	Transition from mixture to neighbouring pure stands.
Vertical structure	mono-storeyed	Main storey comprised largely of even-aged trees, mostly of one species.	Typical especially for pure, even-aged conifer stands.
	two- or multi-storeyed	(1) Secondary storey beneath the main storey largely even-aged. (2) Multi-storeyed: No uniform differentiation in vertical structure.	(1) Main species (oak, ash, sycamore) with a serving tree species (beech, lime, hornbeam) beneath. (2) Typical consequence of management according to either the continuous cover system or multiple disturbances.

According to Table 4.4-28 many combinations of mixtures of two and more species are possible in theory. Only a few types, however, have gained importance and these are introduced in the next subchapter.

4.4.6.4 Main types of mixtures

In practice, the great variety of possible mixtures reduces to five fundamental types which are worthy of consideration (Table 4.4-29).

Table 4.4-29: Characterisation of the **most important types of mixtures** and their relevance for Irish broadleaf forestry.

MIXTURE TYPE	DESCRIPTION	RELEVANCE
(1) True mixtures of canopy species	Individuals of two (or more) species are represented in the upper canopy. In even-aged forests they normally jointly form the canopy of the final crop. When young they often differ in height growth.	Occur only on old estates at present, but their importance will possibly increase in future years. Most important mixture type on the Continent (e.g. as beech with other broadleaves or most of the conifers).
(2) Mixtures with species in serving function	Mixed species with different silvicultural objectives: shading of trunks to avoid development of epicormics; shading of soil surface to prevent development of ground vegetation as an obstacle to natural regeneration.	At present of minor importance, but will become relevant when oak and ash stands, established for high quality timber production, develop further. Serving species need to be shade-tolerant (beech, hornbeam, lime). However, they may, like beech, penetrate the canopy and compete with the less vigorous main species (e.g. oak, ash, sycamore).
(3) Temporary mixtures	One or two tree species reach maturity early. Often in context of natural forest development; pioneers with short life-span then drop out. Occasionally systematic introduction of fast-growing species that must be harvested earlier than main stand.	At present of minor importance to Ireland. High quality timber production of wild cherry, birch, Spanish chestnut, (and ash) in mixture with beech and/or oak. Distribution of single trees or small groups within stands which do not cause big gaps when harvested earlier than the main species.
(4) Protective nurse crop mixtures	One (or more) pioneer species for protection against late spring or early autumn frost, exposure, drought, seasonal excess water, over young growth of target species. The sheltering nurse species are removed when light becomes deficient for regrowth.	At present important for afforestation of susceptible species (e.g. beech or oak) in frost hollows. Protection purpose so far most important. Possibilities to keep some of the nurse trees (birch, aspen, alder over oak, beech) as intermediate crops, are increasingly discussed.
(5) Edge mixtures	Mixture of broadleaf species along forest edges for the enhancement of ecological and aesthetic diversity, often in front of conifer stands to assist wind stability. In urban areas for landscape purposes.	Ecological aspects tend to become more relevant as well as protection against windthrow. Aesthetic aspects may gain greater attention in the future.

These main mixture types are illustrated in Figure 4.4-2.

4.4.6.5 General considerations concerning establishment of mixed stands

The establishment phase offers the possibility of establishing mixed stands which, in most cases, is very challenging. Objectives that include the production of quality timber, and an understanding of the growth habits of the species to be combined in a mixture, are required to avoid trouble later on.

Mixed stands often develop unintentionally by planting another species into existing plantations or by filling-in small gaps in naturally regenerated regrowth. Usually these plants are younger and need time to overcome the planting shock, whereas the existing plants have already begun to grow. Those planted later, therefore, are in danger of becoming suppressed. Another consideration may be due to different growth habits. Individuals of the less vigorous species are liable to become suppressed if not released from competition. This involves additional costs.

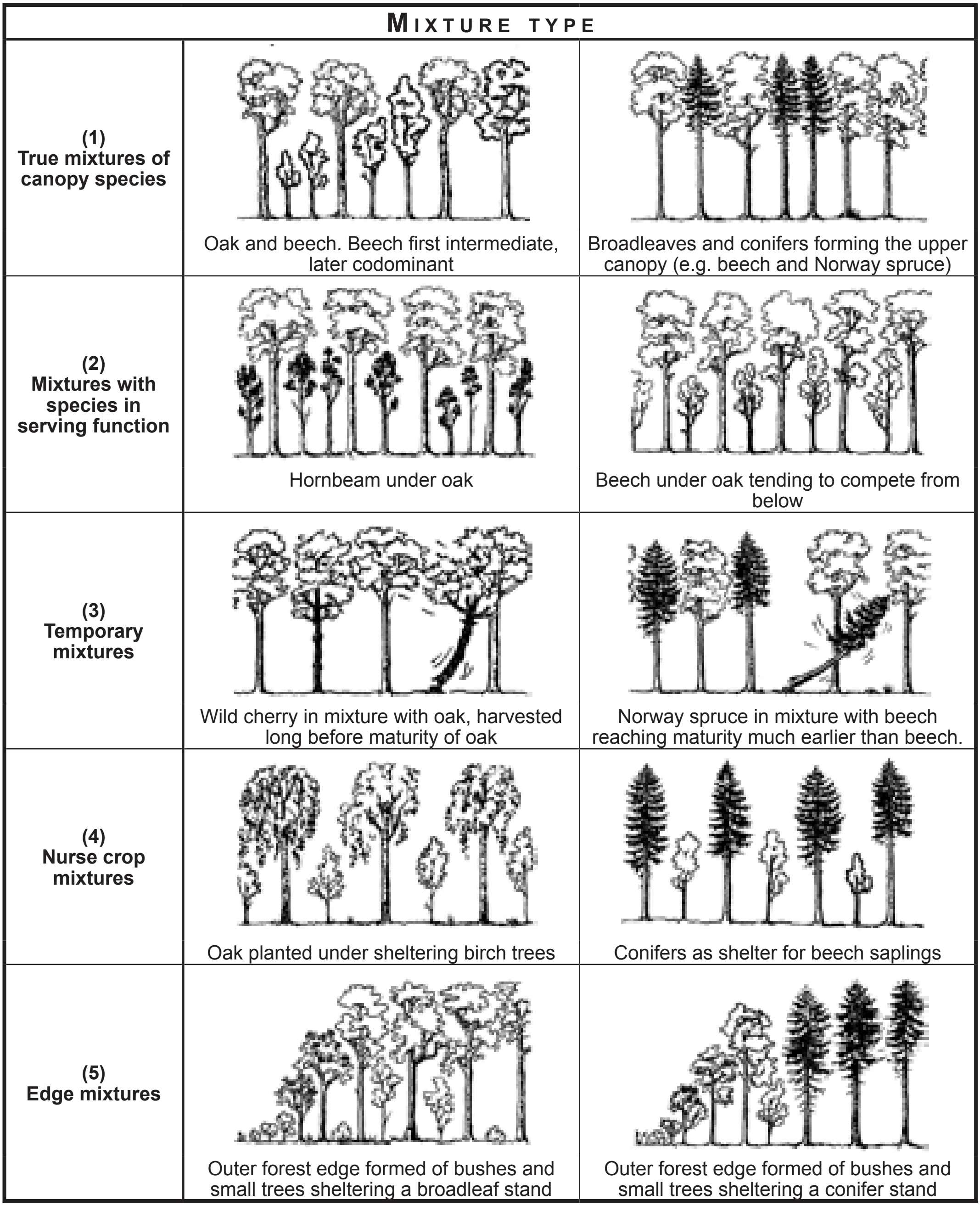


Figure 4.4-2: Illustration of the **most important types of mixtures**. (Drawings by A. Kuehnen)

The main considerations in the establishment of mixtures must, therefore, be to minimise the risk of losing the less vigorous species. The older mixed stands become, the less they can be manipulated with regard to composition and the productive capacity of the species involved. Managing mixed stands is a great challenge and is discussed in Chapter 4.5.6. The recommendations presented in the following sections are relevant according to the growth habits of the species involved, and their functions within the mixtures.

Mixed stands can be established in various ways. The order of the type of mixtures will follow that given in Table 4.4-29.

4.4.6.6 Establishment of mixed forests

Broadleaf management has been practised in old estates since historical times, but it is only recently that it has become relevant to the State's afforestation programme (refer to Chapter 1.4). Planting bare land has been the main focus of the latter and the establishment of mixed broadleaf/conifer stands was mainly incidental. In the *Code of Best Forest Practice – Ireland* mixtures with nurse crops are referred to and are eligible for State subsidy according to the *Forest Schemes Manual*. In the future, however, the other types of mixtures, listed in Table 4.4-29, may also gain some importance.

(1) True mixtures of canopy species

Objectives

It should be a primary objective that all target species of a mixture will form part of the upper canopy at the later stages of the rotation.

Guiding principle of establishment

As height growth increment tends to vary over time for different species, the individuals of at least one species in intimately mixed stands will be overgrown by the more vigorous companion species at some time in their development. For this reason species should be planted in groups. This makes provision for at least one individual within a group to grow to maturity without being suppressed or subjected to severe competition from the sides. The minimum area of groups should correspond to the crown area of a mature crop tree, and this depends on the species and the target diameter, as explained in Chapter 4.5.5.3. It varies roughly between 50 and 150 m^2 depending on species. A broad benchmark is 100 m^2, or an area of 10x10 m, which can be used as a starting point. This minimum group size can, of course, be increased to cover the crown size of several crop trees within the group.

Correspondingly, **bands** of one species alternating with another can be regarded as a series of groups. They should not be narrower than 10 m in width. Planting mixtures in **alternate rows**, with the intention of retaining them for the rotation, is generally not successful as one of the species will likely be suppressed.

In general, stands starting as group mixtures tend towards a more or less intimate or single tree mixtures as they approach maturity.

Procedure

Different establishment possibilities are common in practice:

- **Advanced regeneration**
  - Natural regeneration is encouraged by making openings of the upper canopy (refer to Chapter 4.2.2.5). This gives slow-growing species like beech an opportunity to gain a favourable start. Later, larger openings will meet the increasing needs of the other more light-demanding species.
  - Artificial regeneration by group planting into gaps in the canopy (refer to Chapter 4.2.2.3(2)).
- **Simultaneous planting on bare land**
  - Establishment groups as mentioned above (~100 m^2 in area or greater).
  - Establishment of bands in order to facilitate the use of planting machines, as well as tending and thinning procedures.
  - Supplementary planting of mixtures on bare ground: enrichment planting of areas that have failed, but only when each such area is at least the size of the crown cover of a final crop tree (~100 m^2).
- **Filling-in gaps in older stands**

  Group planting of fast-growing species in gaps created by snow, storm or insects in order to maintain stand productivity.

(2) Mixtures with species in serving functions

Objective
To provide shade for tree boles and the underlying soil by using shade-tolerant species in the lower canopy over the whole stand area.

Procedure
Planting the species mixture over the whole area at low densities (~1000 plants/ha).

There are two options:

- **Planting the nurse tree species simultaneously with the main species**
  The main advantage in this option is a cost reduction as planting is carried out in one operation, and only one fencing operation is necessary. In a mixture of a long-living pioneer species like oak and a shade-tolerant species like beech, the pioneer tends to grow well ahead of the nurse species. Later on, however, the nurse may begin to grow into the crowns of the main species and cause severe competition. Nevertheless, forest owners tend to prefer this approach as it ensures that the mixture has been established. Deferring the planting of the nurse species until later runs the risk that finance may not be available to undertake it in the future.

- **Underplanting some decades later**
  The converse argument applies: this type of establishment leads to higher costs, but excludes the risk of competition from below, interfering with development of the target species at a later stage.
  In Plates 4.4-23 and 4.4-24, underplanting at a later stage is illustrated. In Plate 4.4-11 (refer to Chapter 4.4.3.10) it is shown that oak without a serving tree species tends to develop epicormics and does not fully use the growth potential of a site – see also Plate 4.5-29 (page 257) for comparison as a very satisfactory example.

Plate 4.4-23: An oak pole-stage stand underplanted with beech which will act as serving trees to prevent epicormic development in due course.

Plate 4.4-24: Scots pine underplanted with beech which will gradually replace the pine when these have reached marketable dimensions.

(3) Temporary mixtures

Objective
To secure intermediate returns, by the production of saleable timber from the fast-growing trees through early harvesting, without disturbing the canopy of the main mixture trees.

Procedure
By planting fast-growing single trees or small groups into openings which can be harvested without causing big gaps. These gaps should be small enough for the neighbouring individuals of the remaining species to gradually close the canopy. In order to avoid damage to the residual trees, the fast-growing species should preferably be located near forest edges.

(4) Nurse crop mixtures

Objective
The protection of an initially slow-growing stress-intolerant species against adverse climatic effects and promote faster growth.

Procedure
Various establishment schemes are possible:

- Creating a relatively open canopy of a stress-tolerant (pioneer) species, either by planting at wide spacing or by opening up naturally regenerated young stands.
- Underplanting with the target species accompanied by later removal of the nurse crop.
- Establishing nurse and target species in two steps:
  The planting of widely spaced rows of a pioneer species, followed by planting of the target species in between, after the pioneer has reached 2-3 m in height and when it provides shelter.
- Simultaneous planting of nurse and target species.
  This procedure is less costly as it is done in one operation, which may explain its attractiveness. However, the individuals of the target tree species are afforded little shelter in the early years and may suffer from frost, drought or exposure.

Suitability of other broadleaves as nurse crops
In the past, where mixtures involved target species, broadleaves have almost invariably had conifers as a companion species (Plates 4.4-25 and 4.4-26). In recent years, however, the potential of other species, such as birch, alder and aspen as nurses, are being considered as they appear to have the appropriate attributes.

Birch, given its tolerance of poor soils, has been increasingly observed invading bare land in continental Europe (Plates 4.4-27 to 4.4-30). Some experiments have also been established which look promising (see box opposite).

Alder shows reasonable growth on wet ground if it is not too acid and the water is not stagnant. There is some evidence that it will be of greater importance in Ireland and may even be used for intercropping on some favourable sites.

Plate 4.4-25: Satisfactory 12 yr oak stand (3,330 pl./ha) with Scots pine (1,250 pl./ha) as a nurse.

(Camolin, Co Wexford)

The Scots pine has gained a slight lead of about 1 m and should be removed in 3-5 yrs. for further development of oak. As pines do not threaten to overgrow the oak, the mixture can be regarded as robust.

Plate 4.4-26: Band mixtures have been fashionable in various regions – here a Scots pine/red oak band mixture of the 1950s on sandy soils. (Central Germany)

Aspen has also been planted occasionally on storm-affected areas (Plate 4.4-31). Due to the great variation in plant quality, however, its growth rate is unpredictable. Sometimes it is very productive, sometimes not. Its role as a nurse crop species, therefore, cannot be predicted at present.

In 1990 hurricanes destroyed large stands, mainly of spruce, in S. Germany causing extensive bare land conditions. As many of these were on poorly drained level terrain (pseudo-gleys) and had problems with late frost, experiments were carried out to establish oak stands with the help of birch nurses. These were undertaken by the Freiburg Institute of Silviculture at Simmern SW Germany. One of the treatments was to compare the development of pure oak planted on bare land with oak planted with birch admixtures. Birch was planted at 4x4 m spacing (= 625 stems/ha). In the birch/oak mixture the density of the oak was halved as a positive birch-nurse effect was expected. 15 years later potential crop trees have been selected in the plots and measured.

The results are given in Table 4.4-30.

Table 4.4-30: Development of young **oak potential crop trees with and without a birch nurse**, 15 years after establishment. (Huss, 2007)
+ = significant, ++ = highly significant.

Establishment variant	Density at start	Number of PCTs	Top height	DBH	h:d ratio	Diam. of thickest branch
	pl./ha	trees/ha	m	cm		cm
Oak on bare land	10,000	252	6.2	6.4	*96*	1.9
	5,000	114	6.0	7.0	*85*	2.2
Oak with birch as nurse	5,000	180	8.2	7.0	*117*	1.4
	2,500	124	7.7	6.6	*118*	1.5
Statistical significance	Nurse	-	++	-	++	+
	Density	+(+)	-	-	-	-
	NxD	-	-	-	-	-

Results:

- The **quality of the oak potential crop trees** was substantially higher within the birch nurse crop. Thus half of the initial plant number was sufficient to produce roughly the same number of potential crop trees. Halving the density within each variant, however, reduced the number of pcts significantly.
- The **top heights** of the oak nursed by birch were about 2 m taller (= 30%) than the open grown oak, whereas the initial density of the respective planting did not have any effect. This is the most striking result of the whole experiment!
  The birch had reached around 10 m in height, but the oak crowns were still not fully over-topped at time of measurement.
- The **diameters at breast height** – surprisingly – were influenced neither by the establishment nor the density, but the birch-nursed oak had greater heights in relation to their diameters (greater h:d ratio) because they were taller. That means that stems were more slender and, therefore, less stable. Accordingly, they had to be released from the crown competition of birch.
- The **thickness of the branches** showed a clear beneficial influence of the birch nurse.

The main conclusion from these findings is that even widely spaced birch has a favourable nursing effect on the growth and development of oak in an area with difficult site conditions. It was also obvious that the initial plant density could be reduced. However, birch removal is immediately necessary when the birch crowns begin to overtop those of the oak.

(5) Edge mixtures

Objectives

Mixed trees alongside forest edges can serve different purposes: stabilisation against storms, improving aesthetic value and enhancing biodiversity (Plate 4.4-32).

All three goals should be integrated as far as possible.

Procedure

(1) Establishment of wind-firm broadleaves at wide and irregular spacing,

(2) planting broadleaves with striking autumn colour and unusual flowers, fruits, leaves or stem forms at very wide spacing to allow development of broad crowns; possibly mixed with some conifers,

(3) planting (or favouring existing) irregularly distributed individuals of indigenous trees and shrubs to create as many ecological niches as possible.

Plate 4.4-27: Naturally regenerated birch providing shelter for Douglas fir. (Ahlhorn, Germany)

After the older (approx. 8 yr) relatively dense birch cover has been opened, transplants of Douglas fir (4 yr old) have been underplanted and have started to thrive.

Plate 4.4-28: 7 yr old sessile oak planted on site cleared after storm damage, but now suffering from late frost.

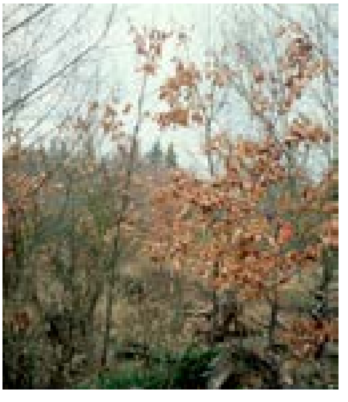


Plate 4.4-29: 7 yr old sessile oak planted with birch (4x4 m spacing).

Birch has provided perfect shelter, but has to be removed as soon as it begins to overtop the oak.

Plate 4.4-30: A further 5 years later the oak comes under pressure from the birch.

(All photographs from experiments at Simmern, Germany)

Plate 4.4-31: Hybrid aspen used as a nurse for Norway spruce. (Kattenbuehl, Germany)

Hybrid aspen may be gradually harvested as an intermediate crop when it starts to overtop the Norway spruce.

Plate 4.4-32: Forest edge with broadleaves sheltering conifers and providing habitat and cover for animals. (Grafing, Germany)

4.4.6.7 Overview of the main broadleaf species and their mixtures

In Table 4.4-31 the mixtures of primary broadleaf species and their accompanying species are listed as an aid for quick reference.

Table 4.4-31: Overview of the **main broadleaf species and their mixtures.** (The number of establishment types are those in 4.4.6.6)

Main mixture tree species	Second mixture species	Establishment type	Comment
Oak	Beech	(2) Acts as serving tree in mixtures.	Important mixture on the Continent. Beech tends to become a competitor on good sites.
	Birch	(4) Temporary mixture for a nursing effect.	Recently gaining attention throughout Europe.
	Hornbeam	(2) Acts as serving tree in mixtures.	Important on heavy soil; could become important in Ireland.
	Scots pine	(4) Temporary mixture for nursing effect.	Little nursing effect because of difficulty of establishment on grassy sites and slow height growth.
	Larch		Great variability in height growth. Often too vigorous and tends to lean away from prevailing wind thus causing damage to adjoining row.
	Norway spruce		Generally unsatisfactory as Norway spruce very competitive at older ages. Used extensively in Ireland in the past, but usually with little success.
Beech	Ash	(1) True mixtures of canopy species or (3) temporary mixtures.	Role of mixed species depends greatly on site quality: • On medium or slightly poorer soils develops into true mixture. • On favourable sites good growth of second mixture trees and, therefore, temporary mixture.
	Oak		
	Sycamore		
	Norway maple		
	Wild cherry	(3) Temporary and (5) edge mixtures.	Promising, but little experience mainly because of poor quality cherry stock (canker).
	Larch	(1) True mixtures of canopy species. (3) temporary mixtures or (4) temporary mixture for nursing effect.	Role of mixture depends greatly on site quality: • Larch and Scots pine suitable because of long production period, but often suppressed in the later phases. • Norway spruce in very variable forms of mixture. • Single specimens of Douglas fir gaining importance as perfect mixture tree.
	Scots pine		
	Norway spruce		
	Douglas Fir		
Ash	Hornbeam	(2) Mixed as serving tree.	No experience so far in Ireland, but both species seem to be appropriate and could have promising futures.
	Lime		
Sycamore	Beech	(1) True mixtures of canopy species or (2) mixed as serving tree.	Common mixture on the Continent, but problems if beech tends to compete.
	Lime		Comparable with the situation as mentioned under dominating ash.
	Hornbeam		

4.4.6.8 Broadleaf/conifer mixtures in Ireland

Plantations of mixed species are not new to Irish forestry. Many of the old estate woodlands of the 18th and 19th centuries were mixed plantations, often with combinations of conifers and broadleaves. Of more relevance to the present discussion on mixtures, however, are those broadleaf/conifer plantations established by the Forest Service from the mid-1930s onwards which, by design or otherwise, form the main broadleaf forests of today. Although the information available is sparse regarding their purposes, establishment configurations and subsequent management, planting records provide factual evidence of the species planted in respect of numbers, ages and spacings. These records, taken in conjunction with the stands as they exist today, allow inferences to be drawn as to the effectiveness or otherwise of the procedures adopted in the creation of a broadleaf crop.

Taken in chronological order the methods adopted may be categorised under three headings: spaced-group planting, row planting and band mixtures.

Spaced-group planting

Anderson (1953) claimed to be the originator of this method which he first suggested in 1928. He theorised that to produce first-class timber *trees must be grown as closely as possible, consistent with sound economy*. To achieve this he suggested planting widely spaced dense groups of broadleaves in symmetrical designs with each group having a fixed number of trees, 13, 21, 25 or 37, spaced 0.6 to 0.9 m apart within the group. The recommended range of spacings between unit centres was 3.6, 4.5, 5.4 and 6.3 m.

In his paper on the subject he referred to his service in Ireland where he tested its utility *in the growing of broadleaf trees with conifer nurses ... on a considerable number of small areas* over a number of years beginning in 1934. Many of these test areas were established in forests in the midlands e.g. Dartry Demesne in Cootehill Forest, Mooreabbey, Monasterevin Forest and Baronstown in Ballymahon Forest. Invariably, the broadleaf species was oak, in groups spaced approximately 6.3 m apart, in a matrix of Norway spruce. None of the mixtures survived as intended. Due mainly to a lack of attention to early management intervention, most of the oaks were outgrown by the Norway spruce and eventually died. The few that survived grew into etiolated trees with small crowns that never recovered.

Row planting

During the so-called economic war of the mid-1930s the acquisition of better quality land by the Forest Service prompted a widespread planting programme of broadleaves in mixture with conifers. Beech/European larch mixtures were very much in favour. Planting records show that equal numbers of both species were planted together and subsequent inspection of these stands in the 1990s provided irrefutable evidence that the planting configuration was alternate lines of beech and European larch. The larch was gradually removed in thinnings and these plantations now form the most extensive broadleaf forests of today (refer to Chapter 1.3). Mullaghmeen, Co Westmeath planted in 1935, Ballyarthur, Co Wicklow, planted in 1935 and Kilbora, Co Wexford are prominent examples of this method.

Although beech predominated as the target species, the method was not confined exclusively to beech. One of the best oak stands in the country, at Kilcooly Abbey, Co Kilkenny, was established in 1934-35 as an oak/larch mixture (Plate 4.4-11, page 186). Planting records show that oak (1+0) and European larch (2+1) were established in equal proportions at 1.2 m spacing. The larch has been removed in thinning.

Alternate row planting of Norway spruce and ash became popular for a period, but this mixture was not a success. The spruce grew too aggressively for the ash, depriving it of the necessary growing space to develop its crown.

Band mixtures

Learning from the difficulties experienced with spaced-group planting in the 1930s, foresters adopted a more robust approach in later years when Norway spruce/oak sites became available. One approach was to plant both the target and nurse species in alternate bands. Anecdotal evidence (Mulloy, 2009) suggests that the proportions were two-thirds Norway spruce and one-third oak. A stand of Norway spruce/oak planted at 1.5 m spacing in those proportions at Killane, Co Wexford, is today an almost pure stand of Norway spruce. Oak has only occasionally survived.

The best known example of this mixture is demonstrated in a plantation at Camross (formerly Ossory) Forest, Co Laois, where the soil is a fertile clay loam (Plate 4.4-33). Planting records show that the area was planted in 1960/61 with 2+3 year old Norway spruce transplants and one year old oak seedlings. Planting configuration was in alternating bands of five lines of spruce and three of oak. Spacing was 1.5 m.

Records of subsequent treatment are scanty, but evidence from spruce stumps indicates that by the thicket stage the lines of spruce adjacent to the oak had been removed. This suggests that even at this early stage the oak was coming under pressure from the spruce. The spruce received conventional thinnings and its growth rate and form was so good that it was designated a seed stand. The oak, in contrast, received little or no thinning and was generally spindly and of small diameter.

The spruce was harvested in 2007 leaving the bands of oak 9 m apart, roughly the conventional spacing of oak trees at maturity, although the oak is still only half way through its rotation. This had the effect of exposing the outermost rows of oak to increased light and wind with consequent epicormic growth and some windthrow (Plate 4.4-34). Its treatment now presents a serious challenge to the silviculturist (see Chapter 4.5.6).

Plate 4.4-33: Band mixture of oak and Norway spruce. (Camross, Co Laois)

Assessment of mixture types

Evidence from the three different mixture types described above serve to illustrate the combination of factors that come into play with mixtures, any one of which can be detrimental to the success of the nursed crop.

The interaction of diverse growth patterns with site conditions may lead to failure of either the target or the nurse species. There is, therefore, the need to choose both the target and the nurse to suit site conditions so that ideally the nurse will provide the necessary shelter. The issue is confounded by the lack of robustness of some types of mixtures and by their incompatibility as companion species over the rotation.

Plate 4.4-34: Oak remaining after harvesting of Norway spruce. (Camross, Co Laois)

From the evidence available the following points are considered to be relevant:

- Spaced-group plantings where the groups are too small demand constant attention if they are to succeed.
- Although the need is less acute for row spacing they too require attention at critical periods.
- It is questionable whether a species such as Norway spruce which reaches maturity long before oak is a suitable nurse when planted in band mixtures.
- The need for timely intervention is paramount with all mixtures.

In light of the relative success of the historical European larch/broadleaf mixtures, as shown by the evidence on the ground, this approach was adopted by the Forest Service in 1997 for grant purposes in the establishment of oak and beech mixtures with conifers. On sites unsuited to European larch, Scots pine was used as a substitute.

Current practice

At present mixtures of oak and beech with a conifer nurse (e. g. Scots pine and European or hybrid larch) are advisable when planted according to Forest Service recommendation (Table 4.4-32).

Current experiences with conifer nurses in broadleaf plantations

Data have been collected in recent years on the growth rates of some broadleaf species and conifer nurse mixtures. These are cited in the following sections:

- **Increase of height growth of broadleaves by admixtures of Japanese larch and Scots pine nurses**
  Compared with those of pure stands, the mean heights of 4 broadleaf species were increased by 20-50%, after 9 years growth, when grown in nurse crop admixtures of Japanese larch or Scots pine (Table 4.4-33).

- **Differences in height growth of oak/European larch and oak/Scots pine respectively when planted in alternate line mixtures**
  Height growth of oak/European larch and oak/Scots pine mixtures has been measured in plantations – not experiments with replicates – at various locations in Ireland.

  European larch showed an increase of 1 to almost 3 m over the first 5-9 years and, therefore, provided some shelter (Table 4.4-34). However, some of the individuals showed great differences in vigour which may be attributable to European/Japanese larch hybrids being planted instead of European larch.

  Scots pine growth, however, showed only a marginal increase on oak and, therefore, provided very little shelter (Table 4.4-35).

  In both cases it was decided that removal of the nurse crop rows of trees would be necessary in due course.

Table 4.4-32: Minimum stocking and spacing for broadleaves and mixtures.

(Adapted from Forestry Schemes Manual, 2011)

The recommended stocking density for pure oak and beech plantations is 3,300 plants/ha (refer to Table 4.4-20). Thus, the mixture leads to a reduction for oak and beech of 300 stems/ha (= 9%)

Species mixture	Line spacing	Plant spacing m x m	Stocking plants/ha
Oak/nurse mix	10 lines of oak or beech 1 line of nurse species	2.0x1.5	3,000 300 3,300
Beech/nurse mix			

Table 4.4-33: Mean h**eight of broadleaf species planted pure and in mixture** with Japanese larch or Scots pine at 9 years.

(Banteer experiment 30/96, 230 m asl, southerly aspect) (Adapted from Horgan, 2007)

Species	Stand pure	JL/ SP nurse	
	cm		%
Ash	394	+ 78	*+ 20*
Beech	342	+ 79	*+ 24*
Sessile oak	214	+ 108	*+ 50*
Sycamore	333	+ 164	*+ 49*

Table 4.4-34: Mean **heights (m) of oak/European larch in alternate line mixtures** as measured in spring 2007. (Adapted from Guest and Huss, 2010)

Location	Planting year	Species Oak	EL
Derrynahinch	1998	4.8	+ 2.3
Fordstown		4.4	+ 2.6
Inistioge		4.9	+ 1.4
Ballyhale	2000	3.6	+ 1.6
Lismore	2002	2.1	+ 1.1

Table 4.4-35: Mean **heights (m) of oak/Scots pine alternate line mixtures** as measured in spring 2007. (Adapted from Guest and Huss, 2010)

Location	Planting year	Species Oak	SP
Ballydermot	1998	4.2	± 0
Banteer		4.2	+ 0.4
Castlerea		4.2	+ 0.1
Killea	1999	4.2	+ 0.4
Virginia	2002	4.3	+ 0.8
Watergrasshill		2.4	+ 0.3
Freemount		1.7	- 0.8

- **Height growth of oak in band mixtures with European larch and Norway spruce respectively**
  In these slightly older plantations the height advantage of European larch was even more pronounced. Norway spruce was also well ahead of the oak (Table 4.4-36).

Table 4.4-36: Mean **heights (m) of oak/European larch and Norway spruce alternate band mixtures** as measured in spring 2007.

(Adapted from Guest and Huss, 2010)

Location	Planting year	Species	
		Oak	EL
Arklow	1995	5.6	+ 3.6
		Oak	NS
Moanmore	1992	6.2	+ 2.5

These data emphasise the point already made that the nurse species may become competitors. However, if the bands are of sufficient width, the oak in the centre of the interspace might not be fully overtopped.

Nurse crop trees are sometimes regarded as a potential financial investment. In practice, however, the nurse trees need to be removed early, when stems are usually relatively slender and, moreover, branchy, coarse and often crooked. Even if fuelwood becomes more marketable it is doubtful if this material can become economic.

It is often postulated that some of the nurse trees of reasonable stem form and quality should be retained until they produce timber as an intermediate return. At present, however, there is no way of testing any such hypothesis as there are no examples available for evaluation.

Conclusions

Because of the problems in managing more than two mixed species, generally only mixtures of one main and one secondary species are advisable. However, mixtures of more than two species are possible (e.g. beech/ash/sycamore/oak/cherry). But this will normally need sophisticated silvicultural management.

Mixtures of three or more species usually need suitable sites as some of the species are very nutrient-demanding or grow only in favourable climatic conditions.

Intimate mixtures of tree species are always difficult to manage as the individuals of the more vigorous species will out-perform the others. In practice it is clear that the more intimate a mixture is in its establishment phase, there is a greater likelihood that one species will be overgrown by another at a later stage. Group mixtures of adequate size are much less troublesome because of their robustness.

Little experience with broadleaf mixtures is available so far in Ireland. Therefore, experiments should be laid down for different mixture types, with necessary variations catering for the differing site conditions, different provenances and objectives of the forest owners as well as of society.

Mixtures with nurse crop trees are generally less costly to establish as lower plant numbers are required. However, they often need greater inputs for early tending, pruning or thinning. If this is not done in time the forest owner runs the risk that the mixtures will deteriorate.

European larch appears to be more suitable as a nurse crop than Scots pine, but Japanese and hybrid larch should be avoided as they grow too vigorously. Birch, alder and aspen are obviously promising, but need further investigation.

The role of broadleaves as a stabilising mixture in conifer stands has not been tested in Ireland and needs further investigation.

It can be expected that mixtures will gain greater relevance in the future. Therefore, further knowledge and experience should be derived by field trials. These may also serve as demonstration plots for the information and training of forest owners.

Mixtures normally need early and intensive management in order to fulfil their objectives. This will be discussed in Chapter 4.5.6.

4.4.7 Protection and aftercare of young broadleaves

Once plantations are established prevention of damage should be of the highest priority. Protection and aftercare of young broadleaves is an important component of all silvicultural systems and when damage occurs corrective measures are needed. Prevention and protection, however, are closely connected with each other and it is usually difficult to decide whether the necessary measures are silvicultural or damage remediation.

Newly planted forest crops are very vulnerable and require several years to become well-established. During this period the young plants are usually endangered by (1) abiotic hazards, (2) competition from vegetation and (3) damage by animals and other biotic causes.

4.4.7.1 Abiotic hazards

Frost is the most common weather-related cause of damage during the early years of the rotation, particularly by late spring and to a lesser extent by early autumn frosts. Frost occurs mainly in low-lying areas where cold air accumulates, particularly in the Midlands where frosts in June are not infrequent. Die-back of young shoots and increased forking are the consequence (Plate 4.4-35).

Plate 4.4-35: Repeated forking of a young oak tree caused by late spring or early autumn frosts. (Bailieboro, Co Cavan)

Although the damaging consequences of late spring frost are easily visible, the importance of the effects of early autumn frost have yet to be determined. The shoots, especially of young oaks, often do not harden off in time because of the generally mild weather conditions in autumn. It is likely that early autumn frosts will damage the leading buds, resulting in forking, however, this hypothesis still needs further study.

As mentioned in Chapter 4.1.2.1 frost tolerance is strongly linked to the succession type of the tree species – pioneer or late-successional. These are listed in Table 4.4-39 with special regard to late spring frosts.

As a precaution, therefore, frost resistant species should be selected for afforestation. Planting under shelter, if available, is helpful. Frost intolerant species such as beech can not be established in frost hollows or frost pockets without shelter, but ash or oak benefit also (Plates 4.4-36 and 4.4-37).

Nurse crops of frost hardy pioneers such as birch have proved advantageous as shelters in experiments in Ireland (Renou-Wilson et al., 2008) and on the Continent (refer to Chapter 4.4.6.5). The use of nurse crops, therefore, provides another option in Ireland, but more experience needs to be gained through experimentation.

Efficient vegetation control can reduce the risk of frost damage as it improves the temperature exchange between the topsoil and the air layer immediately above it.

The freezing zone generally extends up to 2 m at the maximum. It may be the case that young plants remain for years in this danger zone, and only after having grown out of it will they resume normal growth.

Die-back of young plants may necessitate filling-in while damage to the leaders and resultant forking usually require intensive shaping.

Table 4.4-39: Degree of **susceptibility to late spring frost.** (Partly derived from *Forest Protection Guidelines*, 2002)

SUSCEPTIBILITY TO LATE SPRING FROST			
high	moderate	low	very low
Beech, Spanish chestnut	Ash, oak, sycamore, wild cherry	Hornbeam, lime, rowan	Alder, aspen,birch, willow

Storms and wind are the most important damaging factors in older stands (Plates 4.4-38 to 4.4-40).
Basal sweep caused by steady winds, however, occurs in the early years after planting. Sycamore is particularly susceptible to it but, this may partly be due to a poor root:shoot ratio or bad planting practice or a combination of both (refer to Plate 4.4-7, page 183).

Young regrowth up to the thicket stage is less seriously threatened. Nevertheless constant winds reduce tree growth, add to instability, and may result in poorer tree quality. Some broadleaf species are especially intolerant of wind. Their strong response to shelter can be seen all over the country when trees are planted in unprotected areas in contrast to those in the shelter provided by hedgerows or other windbreaks.

Heavy rains can cause damage to unstable trees, whereas **wet snow** occurs rarely in this country and, therefore, does in general not play a significant role in damaging broadleaves (Plates 4.4-41 to 4.4-43).

Fire is not a serious threat to older forests in Ireland because of the humid climate. However, young plantations can be vulnerable to fire in spring when the ground vegetation has dried off and is highly inflammable. Areas with vegetation such as furze/whins, heather and purple moor grass (*Molinia caerulea*) present a greater risk than grassland. Broadleaves in general are much less prone to fire risk than conifers, especially older stands.

Access to forests and strategically placed reservoirs can be vital for fire prevention and control. Firebreaks should also be established around endangered plantations and important habitats, especially alongside roads and other potential sources of inflammable material. To be fully effective they have to be kept free of vegetation.

Plate 4.4-36: Young beech planted on an area regularly prone to die-back because of late spring frost. (Black Forest, Germany)

Only after the invasion of birch and other pioneers, which has already started, will the canopy eventually close and the beech may recover.

Plate 4.4-37: Late frost injury to walnut. (Black Forest, Germany)

Trees from warmer regions demand a warmer climate or sheltered conditions.

The risk of fires normally ends when the young stands have closed canopy and suppress the flammable ground vegetation. Higher plant density speeds up this development.

4.4.7.2 Vegetation competition

Competition from woody plants (willow, birch, bramble, heather, furze), herbs (bracken) and grasses and rushes represents one of the major difficulties in establishing broadleaf forests. Irish sites generally produce vigorous ground vegetation (Table 4.4-40).

Plate 4.4-38: Permanent exposure to wind stress shapes tree form and influences growth capacity. (Dungarvan, Co Waterford)

Plate 4.4-39: Entire loss of Norway spruce due to storm (foreground), while 120 yr. old oak remained standing (background). (Bitburg, Germany)

Plate 4.4-40: A sturdy oak withstood the storm whereas the surrounding conifers have all been windthrown. (Entenpfuhl, Germany)

Plate 4.4-41 (above): Storm damage to a young alder. (Tyrrellspass, Co Westmeath)

Broadleaves are more windfirm in general, as storms usually occur at times when they are leafless. However, they may be prone to wind damage in summer when the crowns are heavy with leaves.

Plate 4.4-42: Heavy rains have bent down slender birch with asymmetric and thus unbalanced crowns.

(Fuhrberg, Germany)

The same effect may be caused by wet snow.

Plate 4.4-43: Young pole stage alder bent and blown down by storm, in combination with heavy rainfall.

(Edgeworthstown, Co Longford)

Damage of this type is normally as a result of neglected early tending and thinning.

More than 80% of the forest floor is covered with vegetation in general. However, this coverage is slightly lower in public forests, presumably as a result of a higher proportion of conifers and generally less fertile soils. Grant aided private forests have higher percentages as canopy closure in the young plantations has yet to occur. Other private forests contain older broadleaves which are more open.

Heavy grass growth may prolong the period during which the young broadleaf plants are susceptible to late spring frosts and suffer from competition for light and nutrients.

Broadleaf establishment is often very slow if vegetation is not controlled. Therefore, adequate preplanting vegetation management of the planting site is essential and this should be carried out as early as possible. In many cases it is an essential precondition to prevent initial vegetation development. The use of tall and sturdy planting stock can be another precaution. Nonetheless, vegetation control is a usual requirement and as hand-weeding is very labour intensive and expensive, the current standard practice is to control weeds by using herbicides (Table 4.4-41).

Glyphosate is by far the most widely used chemical and it is one of the few herbicides that is still approved by the EU. The list of approved chemicals changes occasionally, but the most recent information is available from the Pesticides Control Service of the Department of Agriculture, Food and the Marine via its website <http://www.pcs.agriculture.gov.ie>.

Herbicides are applied spot-wise or row-wise with a knapsack sprayer, motor-manually or with a machine sprayer, depending on the area to be treated (Plates 4.4-44 and 4.4-45).

Table 4.4-40: Forest area by vegetation cover and ownership. (Adapted from NFI, 2007)

(Basis: 698,000 ha, weighted means)

Vegetation includes grass, herb, moss, fern, brush and shrub.

Vegetation cover	%	Ownership: public	private: grant aided	private: other	Mean
		%			
None to infrequent	*0-5*	*5*	*3*	*2*	***4***
Frequent to common	*6-50*	*16*	*9*	*11*	***13***
Common to abundant	*51-100*	*79*	*88*	*87*	***83***
Total		*100*	*100*	*100*	***100***

Table 4.4-41: Common herbicides used in Irish forestry according to competing species of ground vegetation.

(Adapted from Forest Service, 2000: Code of Best Forest Practice – Ireland; O'Shea, 2009)

Competing vegetation	Herbicide: Glyphosate 1)	Propyzamide 2)	Triclopyr 3)
Bracken	x		
Bramble	x		x
Broadleaf weeds	x		
Furze	x		x
Grasses	x	x	
Heather	x		
Rhododendron (stumps)	x		
Rush	x		
Scrub			x
Woody weeds	x		x

Trade names: 1) Roundup; Gallup; Glyphogan; Touchdown, 2) Kerb Flo, 3) Garlon; Nettlex Brushwood Killer.

Plate 4.4-44: Spot treatment of the ground vegetation with herbicide in an oak plantation (Roundup). (Shillelagh, Co Wicklow)

Plate 4.4-45: Strip-wise application of herbicide in an ash clone bank. (Kilmacurragh, Co Wicklow)

The application of herbicides needs special knowledge about their modes of action. Some are designed to be applied at pre-planting stage, others post-planting, while some are specific to the pre- or post-flushing stages.

The use of herbicides has also important health and safety considerations as well as environmental implications. Restrictions on their use have, therefore, to be observed, especially with regard to operator health, aquatic zones and other important habitats.

Details of the characteristics of the various herbicides are not dealt with in this section. Readers are referred to Ward (1998): Guidelines for the Use of Herbicides in Forestry, for a wider discussion of the subject.

4.4.7.3 Damage by animals and other biotic causes

Several biotic factors can cause severe damage to broadleaves. In Table 4.4-42 the main biotic agents are listed.

Deer have spread to almost all areas in recent years. They benefit from the developing forests which provide protection and more food than open pasture lands. Many broadleaf species, especially oak, ash and sycamore, are highly attractive to deer for browsing (Plates 4.4-46 to 4.4-50). Browsing, as well as bark stripping, has become a major problem, as in most countries on the Continent. Therefore, in regions with high deer populations it is almost impossible to establish broadleaves without adequate fencing combined with effective control.

Plate 4.4-46: Debarking by deer. (Hainich, Germany)

Plate 4.4-47: Young ash stems showing bark stripping by red deer in summer. (Hainich, Germany)

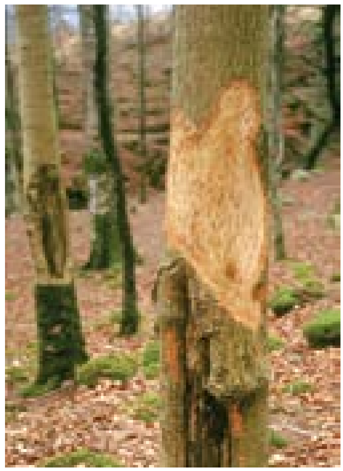


Plate 4.4-48: Older ash stems peeled by fallow deer. (Dundrum, Co Tipperary)

Domestic animals (cattle, horses, sheep and goats) (Plate 4.4-51) and other mammals can also damage trees, and expensive fencing is required to exclude them. Fencing is usually the most effective protection against deer as well as domestic animals, hares and rabbits.

For small-scale plantings, tree shelters (translucent plastic tubes), seem to be a good alternative to fences (Plates 4.4-52 to 4.4-54). They solve several problems concurrently: protection against hares and rabbits and partly deer, voles, competing vegetation. Moreover they provide shelter against frost and desiccating winds. They are easy to locate in the field and herbicides can be applied safely. According to the manufacturers claims, they do not need to be collected later on as they are biodegradable, but this has to be proved in practice. In large areas it is worth considering whether protection by fencing or by use of treeshelters is more economic.

As the plantations reach the thicket stage there is an increasing threat from **grey squirrels** (Carey et al., 2007) (Plates 4.4-55 and 4.4-56).

Table 4.4-42: Main biotic factors causing damage to young broadleaves.

Biotic factor	Regeneration type/ vulerable stage	Type of damage	Protection means	Comments
Deer: Red, Sika, Fallow.	Plantations as well as natural regeneration, until pole stage, particularly to broadleaves.	General reduction in plant numbers and health. Seeds: predation. Germinants and small seedlings: trampling and browsing – total loss. Seedlings: browsing with different preferences (high: oak, ash, rowan; moderate: beech, hornbeam; low: birch, alder, lime). Fraying. Saplings: debarking. Trampling soil surface and making it anaerobic.	Fences (or individual tree guards), tubes (tree shelters), chemical repellents. Hunting.	Proper fencing crucial. Fences very expensive. Sheep fencing standard. Difficulties to keep woodlands free of animals, when area larger than 1 ha. When population high, all tree species are vulnerable.
Domestic animals: cattle, horses, sheep, goats.			Fences	
Rabbits, hares	Plantations, broadleaves particularly vulnerable.	Browsing and stripping of bark, clipping of shoots, shoots cut back.	Fences, tubes, repellents. Shooting, trapping.	Rabbits concentrated on sandy, relatively dry soils, but increasing threat. Hares only locally damaging.
Grey squirrels	Thicket to large pole stage.	Bark stripping of viable trees mainly in crown. Prefer sycamore, but most other broadleaf species also. Wild cherry and ash least damaged.	Repellents, pesticide, selective poisoning, shooting, cage trapping.	Difficult to control. Distribution started from the Midlands, spreading throughout the country. Eliminates native red squirrel population. Suggestion that pine marten may control grey squirrel population.
Bank voles	Young plants	Debarking at root collar: ring barking.	Tubes. Suppression of vegetation reduces incidence of damage, as bank vole requires ground cover.	Currently confined to the south-west region. Mainly near brash and hedgerow vegetation.
Mice	Seed fall	Predation of seeds.	Selective poisoning.	Normally not very serious as natural regeneration has not played an important role up to now.
Insects: Large pine weevil	Newly planted transplants on sites with fresh (conifer) stumps.	Feeding on bark and underlying tissue.	Tubes. Insecticides (Cypermethrin): dipping or spraying main stem of newly planted trees, pre- and post-planting application.	Preferentially attack young conifers, also a problem if conifers have recently been felled (fresh stumps as breeding material).
Snails	Natural regeneration: germinants.	Losses through feeding on cotyledons and primary leaves.	Not possible.	At present of minor importance in Ireland.
Fungi: Honey fungus, *Phytophthora, rust*	Nursery: seedlings, medium sized trees.	Root and butt rot. Rust on leaves (loss of increment). Dying roots and then crown compartments.	(Selection of suitable provenances).	Disastrous damage to elms. Serious problem in nurseries. Mainly a threat to conifers, but also to adult broadleaves. Cherry susceptible to honey fungus.
Bacteria	Seedlings and taller trees.	Die-back, reduction of growth: canker of ash and wild cherry.	Selection of suitable provenances.	The general problem of planting wild cherry in Ireland.

Plate 4.4-49: Ash regrowth heavily browsed by deer has little chance to develop.

(Hainich, Germany)

Plate 4.4-50: Heavily browsed Norway spruce by fallow deer resembles bonsai.

(Kilcooly, Co Kilkenny)

If Norway spruce is browsed so heavily in this area then the oak in the neighbouring stand has not the slightest chance to regenerate successfully.

Attacks by **fungi and rusts** occur mainly on trees from the thicket phase onwards (Plates 4.4-57 to 4.4-60). While in general, fungal and rust diseases are regarded less serious for broadleaves compared with conifers, more recently a number of fungal and insect hazards to broadleaf tree species have emerged with major potential to cause serious damage (see Chapter 7.2).

The list in Table 4.4-42 and the following explanations give only an overview of possible damage by the different biotic factors. For further details refer to Forest Protection Guidelines by the Forest Service (2002).

Plate 4.4-51: Ash plantation which has been extensively debarked by horses. (Ferbane, Co Offaly)

Plate 4.4-52: Treeshelters used to protect planted seedlings.

Plate 4.4-53: Treeshelters are especially useful for small reforestation areas or areas which are difficult to access.

(Black Forest, Germany)

Plate 4.4-54: Treeshelters can also provide protection for larger areas such as experimental sites and provide a protective function against small mammals and weed competition.

(Manch Estate, Co Cork)

Plate 4.4-55: Bark peeling of sycamore by grey squirrel.

(Castledermot, Co Kildare)

The squirrels seem to be especially fond of selecting potential crop trees which results in damage to the most vigorous individuals.

Plate 4.4-56: Bark peeling of birch by grey squirrels.

(Ballyredmond, Co Carlow)

Plate 4.4-57: Elm killed by Dutch elm disease.

(Co Kilkenny, 1985).

In the late 1980s almost all elm trees were destroyed throughout Ireland.

Plates 4.4-58 to 4.4-60: Ash canker shows different forms of bark damage that seem to be related to provenance. These can lead to die-back of the leading shoots, to deformation of tree crown and various types of bark deformities. (Dungarvan, Co Waterford)

Conclusions

Irish forests have been regarded as being among the healthiest in Europe with relatively few serious forest pests and diseases (Cahalane, 2003). This is mainly attributable to the country's island status. There are, however, well-founded fears that various bark beetles and fungal pests may reach the borders and cause damage to conifer and broadleaf forests respectively. Ash dieback (*Chalara fraxinea*) is a threatening example.

continued

Conclusions continued

Nevertheless, there are various factors affecting the establishment and growth of young broadleaves, particularly animal damage and late spring frosts. However, every effort should be made to get the young plants out of the vulnerable frost stage as quickly as possible.

Deer numbers are generally increasing, even in areas where they have not been recorded before. They are mainly influenced by the hunting system and the attitude of the hunters. Often a land owner has little or no opportunity to control the populations effectively. This situation is the same in other countries and is one of the reasons why conifers are often preferred for afforestation purposes.

The growing deer population, therefore, needs to be addressed at national level. Otherwise the major investment in the broadleaves programme is in jeopardy.

In Britain damage by grey squirrels is regarded as being one of the major threats to broadleaves (Kerr and Evans, 1993) and this problem is also present in several areas of Ireland.

Deer and grey squirrel pressures, therefore, are becoming a major problem of broadleaf forestry.

4.4.8 Formative shaping of young trees

The establishment phase comes to an end when the young trees come into lateral contact and begin to close canopy – i. e. when competition begins. Depending on plant density and spacing, this occurs at a height of 2-3 m or 3-5 years after planting.

The establishment phase should result in an adequate number of straight, good quality and apically-dominant individuals in order to ensure value production at a later date (Plate 4.4-61).

Need for shaping

As mentioned in the previous subchapter some individuals may have already suffered from damage by late frost, deer and insects. They may have lost their leading shoots and have formed forks or developed disproportionately large lateral branches. Some may have suffered bark injury, which depreciates the future value of the stem.

Some of these deformations can be corrected in a relatively simple and inexpensive way by shaping interventions. By cutting forks, disproportionately large side branches, or by even stumping back damaged individuals with hand secateurs or small saws, their quality can be greatly improved. Only vigorous individuals of above average height and good stem form, which have the potential to dominate in the future stand structure, should be shaped.

Plate 4.4-61: End of the establishment stage: Good quality oak/ash mixture which has been shaped at an early age and does not need any further intervention at present. (Loughgall, Co Armagh)

Possible and recommended shaping treatments

Treatments as recommended are shown in Figure 4.4-3.

Formative shaping may be continued at annual or two-yearly intervals until the trees are 3 m tall. Then high pruning may be necessary.

Excessive branch removal should be avoided. Not more than 60% of the live crown should be removed in a single year.

The branch collar should remain intact in order to facilitate wound closure (occlusion).

Formative shaping should be confined to young trees of above average height with good form and vigour. As a general rule, 400-600 trees/ha, depending on overall crop quality and density, should be shaped. Should the number of suitable trees fall below 100/ha then the production of quality timber in the future is questionable.

Sometimes forest owners shape too many young trees of low vigour which have no chance of reaching dominance in the future stand. They should bear in mind that trees with badly deformed stems or those with coarse branching will normally be removed in tending and thinning (see Chapters 4.5.4 and 4.5.5). Shaping, therefore, should only be undertaken where insufficient stocking of potential crop trees is already obvious, otherwise the operation is wasteful of resources.

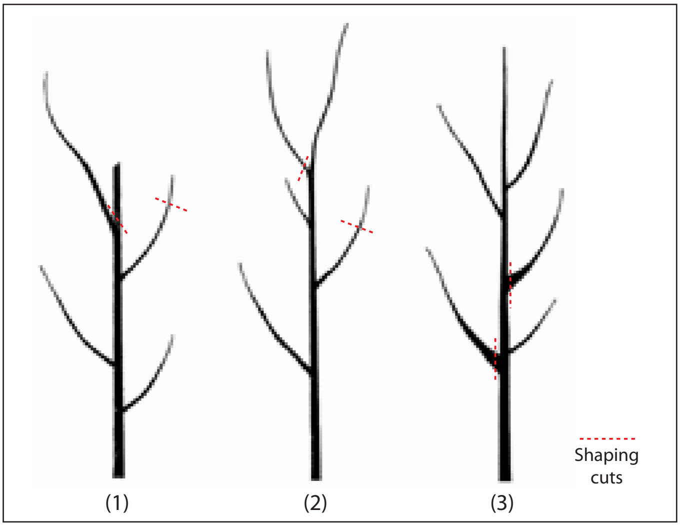


Figure 4.4-3: Illustrations of **removal** of damage, competing or mishapen tops and branches of young plants.
(1) Removal of damaged leading shoot,
(2) removal of fork,
(3) removal of heavy side branches.

Broadleaf crops should be inspected early after establishment in order to assess the need for formative shaping.

Shaping of poorly stocked young stands

Very early shaping in inadequately stocked plantations, or naturally regenerated young stands, sometimes offers a chance for regrowth which otherwise might have to be fully reforested or enriched by filling-in small gaps.

Elimination of young plants being damaged by felling or timber extraction operations

Young naturally regenerated trees damaged by felling or extraction operations will become malformed individuals if left unattended. If they are stumped back when small (1-3 m), they will sprout from the stool and catch up with neighbouring trees if these are not greater than 2 m in height.

Time of shaping

According to Forest Service (2000): *Code of Best Forest Practice – Ireland*, shaping is best carried out in June as by this time any frost-induced bud damage or forking – especially in ash – will have become apparent and lignification of new growth will not have taken place. Moreover, shaping in autumn can expose the fresh wounds to a greater risk of infection. According to Teagasc the optimum time for shaping broadleaves is given in Table 4.4-43.

For further information the reader is referred to a number of leaflets which have been published in recent years: Forest management tips: the importance of formative shaping; Forestry, a Teagasc Advisory Newsletter, Teagasc (2013); and Hemery et al., (no date): Formative pruning, Woodland Heritage, UK.

Table 4.4-43: Optimum time for shaping broadleaves. (TEAGASC, 2013)

Species	Best period	2nd best period
Ash	June-August	Mid winter
Beech		
Cherry		
Sycamore		
Oak	December	

Conclusions

Early and sometimes extensive shaping treatment during the establishment phase may prove necessary to ensure the production of high quality timber. As repeatedly emphasised in this book the main purpose of growing and managing broadleaves is to produce high quality timber – if timber production is the main objective.

Formative shaping at an early stage provides a seamless transition to the tending and thinning phase.

More details will be provided in Chapter 4.5.

4.4.9 Planning and record keeping of forest establishment operations

Advanced planning and documenting operations is an essential part of the establishment process. Moreover, it is recommended that records should be kept after the different treatments have been completed and finally after a plantation has reached the thicket stage.

Detailed planning and documentation should serve three important aspects:

- To avoid mistakes, delays, unnecessary costs and finally disappointments because of poor planning.
- To evaluate and understand the influences of several factors such as provenance, planting technique, time of treatments and protection measures on the success or failure of the respective activities.
- To collect data and information about the regeneration process as a basis for future planning.

In Table 4.4-44 the main items are listed which should be taken into account in both planning and record-keeping.

Table 4.4-44: Establishment plan and **check-list**. (Partly adapted from Dougherty and Duryea, 1991)

ITEM	DETAILS
Site preconditions	
Location and infrastructure	Name and area of afforestation/regeneration site accessibility. Location recorded on map.
Former land-use	Bare land: agriculture, pasture, shrubs. Former forest cover: stand characteristics.
Objectives	Timber production, wildlife protection (erosion control), expected revenues and costs.
Preparatory considerations	
Characterisation of site	Altitude, slope, aspect, geology, soil, water supply, major limiting factors: rock outcrops, wet areas.
Special considerations	Slash from previous stand, conservation of old trees or special soil pockets (biodiversity).
Species	Preferences (alternatives), provenances, seed sources.
Forest establishment procedures	
Afforestation/regeneration method	Planting, seeding, natural regeneration.
Site preparation	Soil preparation, reduction of weed competition.
Stocktype and planting procedures	Seedlings, transplants, hand planting (method), machine planting.
Plant density and arrangement	Spacing, row or group planting.
Seedling protection needs	Protection against weed competition, hare, rabbit or deer browsing.
Record keeping after establishment	
Regrowth evaluation	Losses, damage and injuries, causes of mortality, necessity for weeding, shaping.
Labour force, contractors	Experiences with workers and contractors.
Costs	Estimate/documentation of costs for site preparation, planting, plants, replanting, weeding, shaping.
Timetable	Schedule of time frame for all treatments. Options to change in case of enterprise constraints, unfavourable weather conditions.
Other observations	Documentation of all further observations associated with the regeneration procedures.

It is advisable to develop a record form for all afforestation/regeneration activities in order to be sure that no relevant details will be omitted and that all stands are regularly managed and recorded during the regeneration phase.

4.5 Silvicultural management: tending, thinning and pruning of broadleaf stands

4.5.1 Introduction

4.5.1.1 Establishment and management – the two main fields of silvicultural activities

When a plantation or naturally regenerated stand has reached a height of 2-3 m the young trees close canopy to form a thicket. The establishment phase is now complete and silvicultural treatments, such as, tending, thinning and pruning (implementing the production and function objectives), become relevant.

At the beginning of Chapter 4 it was shown that the establishment and thinning phases are the two main fields of silvicultural activity. They are usually clearly separated in even-aged stands that have been established through afforestation on bare ground or reforestation after clear-cutting (refer to Chapter 4.2). This is the general situation in most Irish broadleaf forests and is explored in more detail in the following paragraph.

4.5.1.2 Status of the Irish forests in relation to establishment type, ownership and age class

In Table 4.5-1 it can be seen that most of Ireland's forests have been established through afforestation (refer to Chapter 1.4).

Thinnings, therefore, will have to be carried out mainly in even-aged and mostly pure stands. This is especially the case in the grant aided private forests. Semi-natural forests which demand more sophisticated thinning procedures, covered just 13% of the area and occur mainly in the other private forest category. The data in Table 4.5-1, however, cover the whole forest area of the Republic.

In Table 4.5-2 information is presented specifically relating to broadleaves and their age distributions.

It can be seen that more than half of all broadleaf stands were less than 21 years of age at the time of inventory, and almost 80% were younger than 40 years. They are, therefore, mainly in the transition phase between establishment and thinning. The data also show great age differences between the tree species: only beech and oak stands were predominantly over 40 years. These are mainly located in the old estate woodlands. All others were younger and thinnings will have to be concentrated on these young stands in future years.

Table 4.5-1: Total forest area in relation to rotation type by ownership (%). (Adapted from NFI, 2007)

Basis: 626,000 ha, excluding the temporarily unstocked areas of approximately 2%)

Rotation Type	Ownership			
	public	private		Mean
		grant aided	other	
Afforestation	*61*	*95*	*22*	***66***
Reforestation	*32*	*1*	*13*	***21***
Semi-natural	*7*	*4*	*65*	***13***
Total	***100***	***100***	***100***	***100***

Table 4.5-2: Broadleaf species groups by age classes. (Adapted from NFI, 2007)

Species group		Age class				
		1-20	21-40	>40	Total	
		%			%	1,000 ha
Oak		*30*	*6*	*54*	*100*	14.6
Beech		*11*	*18*	*71*	*100*	8.7
Ash		*61*	*19*	*20*	*100*	19.2
Sycamore		*59*	*14*	*31*	*100*	8.1
Other long-living broadleaves		*53*	*22*	*25*	*100*	9.6
Birch		*52*	*32*	*16*	*100*	29.7
Alder		*61*	*27*	*12*	*100*	11.5
Other short-living broadleaves		*72*	*21*	*7*	*100*	50.6
Total area	*%*	***57***	***21***	***22***	***100***	
	1000 ha	**86**	**33**	**33**		**152.0**

4.5.1.3 Definitions of trees with regard to tending and thinning of stands

As a background to silvicultural treatments it is necessary to classify the individuals within stands, groups or even rows with regard to their potential to meet production goals. In literature, as well as in practice, considerable confusion exists about the precise meanings of the different terms that have developed regarding tending and thinning during the last few decades. Before going into the details of tending and thinning practice, therefore, it is necessary to provide an overview and explanation of these terms which are used (Table 4.5-3).

Table 4.5-3: Definitions of terms related to tending and thinning.

Term	Definition	Silvicultural treatment
Wolf	Very vigorous tree in thicket stage either with poor stem form, injuries or extreme branchiness. (Not to be confused with a predominant individual of good stem and crown form).	Removal of wolves, which impede slightly less vigorous, but well formed neighbours in thicket stage, that may become pcts. Often combined with shaping, however, shaping is usually undertaken earlier. These activities are also called cleanings, release cuttings or precommercial thinnings.
Potential crop tree candidate (pct candidate)	Tree, in thicket stage, with characteristics suitable for selection as a potential crop tree.	When stand is in transition between thicket and pole stage and differentiation into crown classes is not yet completed: provisional selection of dominant trees with suitable characteristics. Release (slight) from competitors in order to promote early crown development and stem diameter growth. Occasionally combined with 1st pruning.
Potential crop tree (pct)	Tree in pole stage with suitable characteristics (vigour, health, stem quality) which has the potential to become a (final) crop tree.	In pole stage selection of dominant trees with good stem and crown form that have the potential to meet the production goal when they reach the final crop stage. Release from crown competition of neighbours. Sometimes combined with 2nd pruning.
Competitor	Tree that competes with a neighbouring potential crop tree and has to be removed.	Removal of one or more of those competitors that cause crown competition for neighbouring pcts.
Indifferent tree	Tree which is unlikely to compete with a pct in the foreseeable future and has no serious defects.	Tree can remain in a stand as codominant, intermediate or suppressed individual and may act as a filler, shader against epicormic branches and ground vegetation.
Removed tree (thinnings)	General term for all trees that are removed during thinnings. Sometimes trees are included that die because of natural competition or abiotic and biotic influences.	During thinning, trees are removed for different reasons: competitor, poor stem form, injuries, high density, full wood production.
Intermediate crop tree	Tree that has reached an intermediate production goal (for example good quality stem of a short length) and provides the forest owner with an intermediate income.	Removal of a number of dominant trees which have reached a 1st production goal (for example small dimensional quality timber) and need to be removed in order to give (final) crop trees the opportunity to produce quality timber of large dimensions.
Final crop tree	Trees that have reached the production goal (target diameter) or remain at the end of the rotation period.	Final removal of crop trees in various forms: clear-cut or all forms of selective removals as explained under silvicultural systems (refer to Chapter 4.2)

In forest literature several expressions are applied to trees that have the potential to be among the final crop at harvest, such as potential crop trees, elite trees, future trees or potential final crop trees. In so far as the authors can ascertain potential crop trees or pcts has been widely agreed as the norm in the English speaking world. The term elite trees or plus trees is usually reserved for trees that are selected for regeneration purposes either through seed or vegetative reproduction.

4.5.2 Objectives of silvicultural treatments after the establishment phase

In Chapter 3.2.2.1 the economic superiority of high quality broadleaf sawtimber as compared with all other assortments has been discussed. In order to produce high quality timber, however, broadleaves need greater care during the management phase than conifers.

Stand establishment procedures are generally directed towards the production of high quality timber, and after the young stands have successfully become established, they have to be continuously treated so that the production goals are achieved. These treatments are normally included under the term thinning. They comprise the aims listed in Table 4.5-4.

This compilation shows that various silvicultural treatments are necessary for a target-oriented management of broadleaves. In the case of production of high quality timber they are essential. Some objectives can be indirectly achieved through the attainment of other targets. For instance, large individual trees that meet production goals may also contribute to aesthetic values. Mixtures managed to improve stability may also serve biodiversity.

If the target is the production of fuelwood only and no other functions or services are envisaged, no intervention will be necessary until the harvest of the stand. In general, however, it does not make economic sense to invest in the establishment of broadleaf stands for the production of fuelwood.

Table 4.5-4: Main **objectives for stand management** – thinnings.

Objective: general	Objective: detailed	Treatment
Economic	High quality timber production	• Selection of vigorous, best formed individuals. • Promotion of diameter growth, reduction of branchiness. • Elimination of misshapen, diseased or damaged trees. • Pruning.
Economic	Gain of intermediate yields	Harvesting timber through thinning.
Reduction of risks	Improving physical and ecological stability (resistance, resilience)	• Improving vigour of dominant individuals by heavy early thinning. • Favouring all kinds of mixtures (tree, shrub and ground vegetation). • Removal of diseased individuals.
Aesthetics, recreation	Improving mixtures and stand structure	• Favouring mixtures alongside forest edges (roads, foot paths and streams). • Increasing vertical structure and/or age diversity (for instance continuous cover through crown thinnings).
Bio-diversity	Improving mixtures and stand structure	• Maintenance and favouring high species diversity. • Low input forestry.

4.5.3 Main silvicultural intervention treatments of broadleaves

4.5.3.1 Development phases of broadleaves

As mentioned, forest regrowth results in the canopy closing at a height of 2-4 m, depending on the density of a stand. The individuals then have lateral contact and natural pruning begins with the lower, shaded branches dying. However, there are great differences between tree species in relation to natural pruning capacity (see Chapter 4.5.7).

Freedom from branches is an essential precondition for production of high quality timber and natural pruning is, therefore, important. In order to promote clean boles the stands should be kept dense until the branches have died up to a height of at least 5-6 m.

The minimum of 5-6 m of clean stem has been derived from the requirements of sawmillers and furniture makers: doors are generally around 2 m in height. A log should have a minimum length of 2.5 m to allow for losses due to stumps, cutting and waste in conversion. Two stem lengths of 2.5 m are a realistic option under Irish conditions.

In this first phase after establishment, intensive competition between the individuals begins, leading to a differentiation of dominant and more or less suppressed individuals. This phase is called **qualification phase** or **differentiation phase**.

High quality timber comes from large logs (refer to Figure 3.2-1, page 75). Only trees with large crowns can achieve large trunks, as crown size is a precondition for their development. Therefore, these individuals should get the opportunity for optimum crown growth which will allow them to develop into the **dimensioning phase** as soon as possible.

Here, foresters are faced with a management dilemma: in order to promote natural pruning they need to keep stands dense while, in order to promote crown development effectively, early and heavy openings of the canopy are necessary.

To overcome this dilemma the stands should be managed during these two phases in the following way:

- During the qualification phase stands have to be kept dense. Only dominating misshapen individuals (wolves) may be removed which would otherwise damage pcts. In the majority of stands, however, no intervention is necessary. As only low quality trees are removed, this type of intervention is termed **negative selection**.

- As soon as 5-6 m of stem has dead branches, the canopy should be opened, at least around the pcts in order to favour their crown development (dimensioning phase). As the best trees are favoured, this type of intervention is called **positive selection**.

At the transition point between the two phases, trees will have differentiated enough to make it possible to identify and select the most vigorous individuals that promise to produce large stems. They also have to be straight and defect-free to be able to produce high quality timber.

Where tree densities are low, or there are gaps in the canopy, natural pruning will be much delayed and insufficient. In these circumstances, it may be necessary to prune by hand to remove large branches (see Chapter 4.5.7).

According to earlier nomenclature negative selection was defined as the removal of the best individuals thus leading to a degrade of the whole stand.

There are two ways of looking at trees in a stand for the purpose of removal (thinning): (1) stand-wise and (2) tree-wise. Viewed standwise, removal of the best trees – often referred to as high grading – is called negative selection as it refers to the degradation of a whole stand. Viewed tree-wise, removal of the poorest trees is called negative selection as it refers to the stems removed. In this publication the authors have adopted the tree-wise approach, so negative selection in thinning always refers to removal of the inferior individuals.

4.5.3.2 Definition of the two intervention treatments: tending and thinning

The development phases mentioned above involve two different types of interventions: tending and thinning. Both need more detailed descriptions (see Chapters 4.5.4 and 4.5.5).

In practice, some confusion arises with regard to the definition of these two terms:

- From the **silvicultural** point of view, tending during the qualification phase is directed towards the removal of wolves and other treatments to improve the quality of the young stands by indirect means (see Chapter 4.5.4.1). Thinning, however, is aimed at favouring the best individuals in the dimensioning phase after they have differentiated sufficiently and can be identified as pcts (see Chapter 4.5.5.3). The transition point between each phase or between the tending and thinning, differs widely according to species, growth potential and establishment conditions. Nevertheless, the process of intervening in the stands is generally the same.

  For instance, fast-growing poplars may have to be thinned at an age of five years after no more than one tending operation, whereas beech on a poor site may be tended 2-3 times and thinning will not take place before 50-60 years.

- From the **utilisation** point of view thinning starts when the stems that are removed can be utilised – for example as fuelwood.

  The disadvantage of this definition is that it may change from one year to the next. So a treatment may be defined as tending when the stems cannot be used, but the same operation could be classified as thinning when markets exist.

- From an **economic** point of view, tending incurs a cost to the owner, whereas thinning is at least cost neutral or may result in a profit.

  Here again the definition largely depends on the specific circumstances of the operations as illustrated under the utilisation definition. Moreover, they may differ within the same forest enterprise. If, for instance, a forest owner starts a cutting operation by himself and calculates only the costs for his chainsaw and tractor he will make some money when selling the fuelwood. Then he might finish the same operation with the aid of workers, who need to be paid, resulting in a deficit. The first phase thus would be defined as thinning and the second as tending.

- In the Forest Service *Silvicultural Guidance for Tending and Thinning of Broadleaves* as part of the *Woodland Improvement Scheme* of 2009, both treatments are combined: Tending includes positive selection aspects. The background is economic considerations, based on the fact that tending operations as well as first thinning, are not covering the costs and, therefore, need subsidising.

To avoid misunderstanding, in this book the **silvicultural** definition of tending and thinning as described above is used consistently.

4.5.3.3 Characteristics of broadleaves as compared with conifers

Broadleaves, unlike most conifers, generally do not grow perfectly straight, and straight lengths are usually shorter. These differences can be illustrated clearly by data from the National Forest Inventory (Table 4.5-5).

These data show the considerable variation in the quality of timber produced between the two species groups:

- **Sitka spruce** for instance produces a high proportion of straight logs of over 5 m length – more than 75% of all the growing stock. As the minimum utilisable length of logs is 2 m, 97% of Sitka spruce logs are deemed to be straight.
- **Scots pine,** generally regarded as the conifer with the greatest proportion of crooked stems, still has more than 50% of the growing stock with straight logs of more than 5 m length.

Table 4.5-5: Proportion (%) of **straight logs of selected conifer and broadleaf species groups** (based on the standing volume). (Adapted from NFI, 2007)

Species group	Straight logs			
	none	2-5 m	≥5 m	**Total**
Sitka spruce	*3*	*21*	*76*	***100***
Scots pine	*10*	*32*	*58*	***100***
Oak	*38*	*47*	*15*	***100***
Beech	*54*	*40*	*6*	***100***
Ash	*60*	*34*	*6*	***100***
Sycamore	*46*	*47*	*7*	***100***
Other long-living broadleaves	*66*	*19*	*15*	***100***
Birch	*78*	*19*	*3*	***100***
Alder	*46*	*42*	*12*	***100***
Other short-living broadleaves	*93*	*6*	*1*	***100***

- All **broadleaves** are of much poorer quality in this regard. Most of them do not produce any straight logs, and no species group has more than 15% of the growing stock with more than 5 m of straight logs.
- Some broadleaves are especially poor: **Birch** and **the other short-living broadleaf species** – if of unimproved provenances and without management – produce hardly any valuable timber.

These data illustrate the great challenge forest managers have to meet when treating broadleaves. They have to select trees of sufficient straightness – provided high quality timber production is a goal.

It has to be borne in mind, however, that these broadleaf data are highly representative of the actual age-class distribution. Broadleaf stems tend to become straighter as they get older, and the average stem quality improves with age. Nevertheless, the problem of low quality timber production still remains.

It may also be mentioned that many recently established broadleaf stands consist of provenances that are not sufficiently site-adapted. Better and more suitable plant material may improve the quality of these forests in the long run.

Conclusions

Broadleaves are very demanding of management as they tend to grow less satisfactorily with regard to technical and economic aspects when compared with conifers.

From the technical point of view there is a great difference between conifers and broadleaves: conifers self-prune less easily. Their main product is construction timber. Freedom from knots as a quality factor is less important. This is especially the case with Sitka spruce timber. Therefore, it is not necessary to wait until they have passed the qualification phase, and thinning can start earlier than in broadleaves.

Most of the commercial broadleaf species such as oak and beech have much longer rotations than conifers, with the result that the initial investment is carried on for a greater number of years with increasing costs. Furthermore, thinnings come later and the material is less versatile or valuable than that of conifers. The main financial returns from broadleaves come towards the end of the rotation and in the final yield. This emphasises the need to produce high quality valuable timber, which demands a greater level of skill and management.

4.5.3.4 Intervention phases for broadleaves

There are two relevant indices for the classification of silvicultural management procedures according to the development status of a forest stand:
(1) growth stage and
(2) top height.

(1) Growth stage as a background for type of intervention

The growth stages are often used as a basis for classifying stand types and relating them to the type of silvicultural intervention that is required (Table 4.5-6). They are based on diameter ranges (dbh) which the majority of trees has reached within a stand.

The growth stages are often used in order to classify stands according to their development status. This gradation, which follows **diameter range** is, however, not very suitable for the deduction of specific silvicultural treatments. The reason is that stem diameter as an input variable is highly dependent on the growing space available to the individual tree.

For instance, slender stems may occur in old stands as a result of high initial density and later on due to neglect of thinning measures, whereas trees with thick stems may be much younger only because they have had sufficient growing space available from the start.

Table 4.5-6: Growth stages and **main silvicultural treatments.** (Adapted from NFI, 2007)

Growth Stage	Range age years	Range dbh cm	Main silvicultural treatment
Post establishment	≤4		Formative shaping
Pre-thicket	≥4	≤3	
Thicket		3-7	
Small pole		7-14	Tending, (thinning)
Pole		14-20	Thinning
Incoming high forest		20-30	
High forest *		30-40	
Overmature		>40	Harvesting, regeneration
Uneven-aged	Multi-storied		Thinning, harvesting combined

* High forest is a general term for forests derived from seeds or young plants as opposed to coppice forests, and should not be confused with diameter classes.

(2) Top height as a basis for silvicultural interventions

Top height is defined as the mean height of the 100 trees of largest diameter/ha. It is more suitable than mean height as a criterion. As it is usually not affected by treatment it mirrors the development of the stands much better. In general, forest stands, which have reached a certain top height, have also achieved a corresponding development phase. The top height classification is now the standard index and has also been adopted by the Forest Service (Table 4.5-7).

Table 4.5-7: Main silvicultural intervention phases and operations for pure stands of ash, sycamore and Norway maple.

Top height m	Main intervention phase	Description	Operation
Establishment phase			
1	**Filling-in**	Described in Chapter 4.4	Replacing failures.
2	**Weeding/cleaning**		Cleaning grasses, brambles etc. Removal of damaged or vigorous misshapen individuals in exceptional cases.
Qualification phase			
2-8	**Shaping and tending**	General improvement of a young stand, when the differentiation of individuals has begun, but has not progressed sufficiently for potential crop tree candidates or pcts to be finally identified. In general the canopy should be closed in order to guarantee natural pruning.	(1) Shaping = pruning of disproportionally large branches and forks, only on dominant trees. (2) Removal of pronounced wolves, dominant trees with defects, canker (= negative selection = indirect improvement of stand quality).
Dimensioning phase			
8-30	**Thinning**	Specific favouring of pcts in order to concentrate the increment of a stand on them to produce large dimensioned timber.	(1) Selection of vigorous well formed individuals (= positive selection). (2) Successive thinnings at 3-4 m height increment intervals depending on status and productivity (yield class) of stand.
8-12	**1st thinning**	As structural differentiation within stands is still in progress selection of pct candidates as a basis for later selection of pcts. Removal of competitors.	(1) Installation of racks for access and extraction of thinned material at approximately 20 m intervals. (2) Selection of up to 300 pct candidates/ha. (3) Removal of 2 or more competitors to each pct candidate.
12-15	**2nd thinning**	Selection of pcts from original pct candidates. Further removal of competitors. In practice often 1st thinning.	(1) Selection of 100-150 pcts/ha. (2) Removal of at least 1 competitor/ pct. In case of delay of 1st thinning comparable intervention, but selection of up to 150 pcts/ha.
~18 ~22 ~26	**Successive thinnings**	Continue release of pcts from competition to ensure further crown development and diameter growth.	Removal of ≥1 competitor/pct.
Harvesting phase			
~30	**Harvest** of final crop	Ideally only pcts remain which are then the final crop trees.	Clear-cut or successive removals of the crop trees to promote natural regeneration and use the remaining trees as shelter.

The development scheme is more or less the same for all broadleaf species. It may, however, be advisable to accelerate the procedures slightly with pioneers like alder, as they have a very rapid early growth, but tend to slow down on reaching a top height of 12-15 m. Beech as a shade-tolerant species, however, is able to react at even greater heights. Different silvicultural interventions, therefore, can be adapted at a later stage. Oak is somewhere in between.

4.5.4 Shaping and tending in young broadleaf stands

Having reached the crown contact stage, the canopy of the young trees closes at a height of 2-4 m depending on density. Now intraspecific competition between the individuals starts to influence their growth and form. In general, young stands should be kept dense in order to promote development of stem quality by natural pruning and differentiation (qualification phase). Some trees may, however, require light tending in order to avoid poor stem form.

According to the *Code of Best Forest Practice – Ireland* (Forest Service, 2000): *Tending encompasses a number of forest operations which take place between establishment and first thinning with the aim of improving final crop quality in terms of form and wood quality.*

4.5.4.1 Main fields of tending

Tending within the thicket stage includes:
(1) Shaping of defective or misshapen trees.
(2) Removal of wolves and damaged trees.
(3) Reduction of tree numbers in over-dense young stands.
(4) Regulation of mixtures.
(5) High pruning where necessary.
(6) Removal of diseased individuals.

These are explained below.

(1) Shaping of defective or misshapen individuals

Many young trees continue to form forks, produce disproportionally large branches or have a tendency to become crooked. If the number of misshapen individuals is high, there may be restricted options for the later selection of pcts. In these cases removal of forks and pruning of disproportionally large branches is advisable (Plates 4.5-1 and 4.5-2) – as described in Chapter 4.5.5.3.

In this context the term shaping is used for trees with diameters larger than 7 cm (Table 4.5-8).

The data in Table 4.5-8 illustrate that only limited shaping has taken place in ash and sycamore. All other broadleaves have received little or no shaping, but this may be a reflection of their development status.

(2) Removal of wolves and damaged trees

Young plants are often misshapen because of injuries by numerous factors such as windsnap, deer, frost, competing vegetation, birds, insects, damage through felling and extracting procedures. Vigorous individuals if misshapen may later develop into wolves and have a negative influence on stand quality (Plates 4.5-3 and 4.5-4). If not removed in time they may assume dominance and suppress their less vigorous, but possibly better formed, neighbours. Some

Plate 4.5-1: Young ash stand with many misshaped and forked individuals. (Grange, Co Kilkenny)

Plate 4.5-2: Young oak, very coarse.
(Shelton, Co Wicklow)

Both stands illustrate how necessary early shaping and tending may be in order to guarantee at least a reasonable quality at a later stage.

of the neighbours, if released early enough, may have the potential to replace the wolves by filling the gap caused by removal of the latter. This procedure will improve the opportunity to select pcts at a later date. In the case of low stocking in a young stand, the removal of wolves may cause bigger gaps which encourage the neighbouring trees to develop large branches. In this case it is better to girdle the wolves in order to keep them as a competitor for a while. By dying slowly during the subsequent years they will still act as stabilizers, but they gradually lose this function and give way to their neighbours.

Removal as well as girdling is normally a low cost operation if carried out before canopy closure.

Table 4.5-8: Shaping status of broadleaf species groups according to area and % area of species group of trees with a minimum dbh of 7 cm. (Adapted from NFI, 2007)

(Basis: 79,000 ha = total stocked broadleaf area with a minimum dbh of 7 cm)

Species group	Area	
	ha	%
Oak	200	*0.1*
Beech	-	-
Ash	1,220	*11.2*
Sycamore	430	*9.8*
Birch	40	*0.2*
Alder	30	*0.5*
Long-living broadleaves	40	*0.8*
Short-living broadleaves	20	*0.1*
Total	**1,780**	***22.7***

Some forest owners tend to remove too

Plates 4.5-3 and 4.5-4: Forks and wolves in young ash stands of reasonably good quality. (The Rower, Co Kilkenny)

These should be immediately removed in order to give their better neighbours an opportunity to fully develop. By this negative selection the mean quality of a stand will be improved.

many young trees – even the less vigorous ones with minor defects. This is counterproductive for two reasons:

- The costs rise with the intensity of thinning.
- The stands should be kept dense to encourage natural pruning up to 6-8 m. Only later should the canopy be opened.

Therefore, only obvious wolves should be removed. These are normally fewer than 200 trees/ha.

This type of intervention is termed differently depending on the point of view:

- From the silvicultural perspective the elimination of wolves is called negative selection. By removal of misshapen elements the quality of a stand is indirectly improved.
- From the economic viewpoint the terms pre-commercial thinning and non-commercial thinning are used. Whether the procedure is profitable or not depends on prevailing timber prices and labour and machine costs.

(3) Reduction of tree numbers in over-dense young stands
Recommendations about density and spacing at establishment provide for the normal development of young stands. Over-dense stands, however, may occur in naturally regenerated regrowth. Reductions in numbers may be necessary in conifers, especially to improve their physical stability. Broadleaves are much less endangered by abiotic threats, such as snow and storms, and should be kept dense in order not to interrupt the natural pruning process.

Silvicultural intervention may, however, be necessary when birch, willows or aspen seed naturally and compete strongly with the individuals of the target species.

Currently, reduction of over-density – or respacing– plays almost no role in Irish broadleaf forestry because of the very small amount of naturally regenerated broadleaf stands (refer to Table 4.4-3).

(4) Regulation of mixtures
The different types of mixtures have been discussed in Chapter 4.4.6. As mixtures are important, and tending as well as thinning procedures are strongly interlinked, they are discussed in more detail in Chapter 4.5.6.

(5) High pruning
High pruning is also strongly linked with thinning and is dealt with in summary in Chapter 4.5.7.

(6) Removal of diseased individuals
A special case involves cankered trees, mainly ash, which may later also cause serious deformations and infect their neighbours. Therefore, badly diseased individuals should also be removed and the slash burned. If the number of cankered trees is very high then only the most seriously infected ones should be removed in thinning. The situation can then be re-evaluated at the next thinning.

Currently the incidence and effect of ash canker are not fully understood. It may well be that opening up the stand through thinning will inhibit or reduce further canker infection.

4.5.4.2 Practice of shaping and tending

Shaping and tending can be very effective and are essential in order to produce high quality timber (Plate 4.5-5 and 4.5-6). Forest owners are, however, reluctant to undertake these measures as they are costly and time consuming, but the Forest Service launched a special shaping grant (Department of Communications, Marine and Natural Resources, 2003) to encourage this practice. In the 2014-2020 Programme the tending and thinning grant is part of the Woodland Improvement Scheme.

Tending is normally carried out with special or, more often, with light-weight chainsaws. This requires training and strict adherence to safety procedures. Forestry operators should be fully trained, adequately insured and always use purpose-designed protective wear.

As energy costs increase forest owners will be encouraged to undertake thinning for fuelwood. This can be profitable along with the production of wood chips under favourable conditions, i.e. in the vicinity of villages and towns with good infrastructure. It can be expected that this trend is likely to continue.

Plate 4.5-5: A young oak stand of poor quality. (Lismore, Co Waterford)

4.5.5 Thinning

While tending may enhance the stand characteristics, thinning is widely recognised as a direct promotion of quality. In this operation the most promising individuals are favoured.

Plate 4.5-6: An example of a high quality young oak stand. (Roosky, Co Roscommon)

By comparing both stands it becomes obvious that shaping, tending and pruning alone do not guarantee the quality of a stand, but that proven provenance also plays an important role. Nevertheless, early treatments can often improve the overall quality of the stand.

4.5.5.1 Recent status of thinning in Ireland

The NFI results contain a number of thinning-related stand attributes and characteristics which are of interest and are, therefore, presented in the following paragraphs:
(1) Thinning status and ownership,
(2) thinning status by growing stock,
(3) crown shape of broadleaves,
(4) form of broadleaf stems as an indicator of stability.

Branchiness is dealt with under pruning in Chapter 4.5.7 and social status within broadleaf stands in Chapter 4.5.5.3.

(1) Thinning status and ownership

The data on thinning status are given in Table 4.5-9.

The data in Table 4.5-9 show that a remarkable proportion of nearly 30% of all forests have not yet been thinned. Of much more importance, however, is the fact that 60% of all stands are in the juvenile phase and have yet to grow into the thinning phase.

Thinnings at the different ages so far account for only 12% of the total forest area, due partly to the youth of most stands in public and

Table 4.5-9: Thinning status of all forests by ownership. (Adapted from NFI, 2007)

Thinning status	Ownership: public	private: grant aided	private: other	Total	
	%				1,000 ha
No thinning	31	11	43	27	167
Juvenile forest	51	87	39	60	374
Respacing	-	-	<1	<1	<1
1st thinning	5	2	4	4	25
2nd thinning	3	-	2	2	12
Subsequent thinnings	7	-	13	6	37
Temp. unstocked	3	<1	<1	2	11
Total %	100	100	100	100	
Total 1,000 ha	359	187	79		626

in the grant aided private forests Although the situation is slightly less dramatic in the other private forests, even there 82% of the stands have never been thinned.

The data are not separated into conifers and broadleaves. Information about broadleaves, however, is presented in the next paragraph.

(2) Thinning status of broadleaf growing stock

Data in Table 4.5-9 are based on ownership, while those in Table 4.5-10 provide information on growing stock. The tables are, therefore, not fully comparable. Nonetheless, they provide an impression of the thinning status of broadleaf stands.

More than half of all broadleaf stands have not been thinned. From the data it cannot be determined whether the absence of thinning was due to the stands still being too young or whether thinning has just not been practised.

Lack of thinning is especially noticeable in the case of the short-living broadleaves, such as birch and alder, with only a few stands thinned for the first or second times. However, a much greater proportion of the long-living broadleaves are into the subsequent thinning stage.

Table 4.5-10: Broadleaf growing stock classified by species group and thinning status (%).

(Adapted from NFI, 2007)

Species group	Thinning status					
	none	juven.	1st	2nd	subsequ.	**Total**
Oak	59	8	4	-	29	**100**
Beech	35	3	16	3	43	**100**
Ash	43	17	9	2	29	**100**
Sycamore	55	6	5	2	32	**100**
Other long-living broadleaves	53	19	-	-	28	**100**
Birch	71	16	<1	<1	12	**100**
Alder	74	12	2	9	3	**100**
Other short-living broadleaves	59	32	2	<1	7	**100**
Mean	**55**	**14**	**5**	**2**	**24**	**100**

These data demonstrate the great challenge Irish forestry has to face in future years and how much work will be necessary to direct and improve the production potential of the developing broadleaf forest resource.

(3) Crown shape of broadleaves

The shape of the crowns is another indicator of the thinning status. When stands are intensively thinned most of the trees should have reasonably regular, almost circular crowns, with adequate growing space. In practice, however, the situation is very different from this ideal (Table 4.5-11).

Table 4.5-11: Crown shape (%) of broadleaf groups.

(Adapted from NFI, 2007)

Species group	Crown shape			No. of trees observed
	regular	one-sided slightly	one-sided strongly	
Oak	60	15	25	6,380
Beech	45	20	35	4,990
Ash	57	21	22	15,840
Sycamore	59	27	14	4,120
Other long-living broadleaves	34	26	40	8,930
Birch	42	27	31	28,770
Alder	45	25	30	11,860
Other short-living broadleaves	26	26	48	39,300
Mean/total	**40**	**25**	**35**	**120,190**

The data in Table 4.5-11 illustrate:

- Only 40% of all broadleaf trees have symmetrical crowns, and more than a third were strongly asymmetrical.
- There are great differences between the species groups: more than half of the oak, ash and sycamore have regular crowns: all the others have lower percentages. The other long- and short-living broadleaves show particularly low values.
- With approximately 120,000 individual trees evaluated the data seem to have a sound statistical base.

The overall impression from these data is that most of the stands are not being thinned adequately. It should be realised, however, that the evaluation was not primarily concentrated on pcts, which are ultimately the most important group with regard to future stand development.

(4) Form of broadleaf stems as an indicator for stability

The ratio of tree height to stem diameter (h:d ratio), also termed slenderness, is an indicator of the stem form, and indirectly the size of the crown and possibly the root system (Table 4.5-12). Trees with a slenderness ratio of less than 80 are relatively sturdy and, therefore, potentially stable. They are better able to withstand storms than those with values over 80 which are slender and unstable. The relationship between h:d ratio and physical stability is significant with conifers, like Sitka and Norway spruce, but less well known for broadleaves. Nevertheless, it is a good indicator of the thinning status of stands of all species.

Table 4.5-12: Slenderness of trees (%) within broadleaf species groups.

(Adapted from NFI, 2007)

Slenderness:
h:d ratio smaller (≤) 80 = relatively stable,
" bigger (≥) 80 = " unstable.

Species group	Slenderness	
	≤80	≥80
Oak	*88*	*12*
Beech	*68*	*32*
Ash	*35*	*65*
Sycamore	*33*	*67*
Long-living broadleaves	*70*	*60*
Birch	*40*	*60*
Alder	*49*	*51*
Short-living broadleaves	*52*	*48*

A satisfactory stability status was found for oak, beech and long-living broadleaves. Ash, sycamore, birch and alder, however, were relatively slender and are, therefore, potentially prone to wind damage. These stands need thinning urgently.

4.5.5.2 Thinning systems according to objectives of thinning procedures

Since forests are managed regularly and in a scheduled manner (refer to Chapter 4.1), several thinning systems have been developed to fulfill different objectives and are dependent on species characteristics (Table 4.5-13).

Throughout the book the authors have continuously tried to emphasise and substantiate the hypothesis that broadleaves should be managed predominantly with the aim of producing high quality timber. This can be achieved only if potential crop trees (pcts) are selected early. By releasing them from competition effectively, the increment of the stand is concentrated on these pcts. In general, therefore, we regard crown thinning as the only realistic thinning variant for broadleaves. All other thinning systems are of minor importance from this point of view. Crown thinning is also the only realistic thinning system for light-demanding pioneers. High thinning is possible for shade-tolerant species such as beech.

In practice, however, slight alterations may be possible:

- **A combination of crown and low thinning with pioneers**
  Pioneer stands tend to develop more or less mono-storeyed canopies. All trees that lose dominance and become suppressed eventually die. These suppressed individuals can be harvested separately from the selection of pcts and removal of their competitors. In cases where the number of pcts is low, there are always spaces between them which have not been thinned. These could be managed through heavy low thinning in situations where small material can be harvested and utilised. With the growing demand for fuelwood this may be an appropriate procedure.
- **A combination of crown and high thinning with shade-tolerant species**
  In mixed stands of long-living pioneers like ash and oak, an understorey of shade-tolerant species, such as hornbeam or beech, will require thinning to create openings in the upper canopy for the shade-tolerant species to survive and grow. This is a separate operation from crown thinning which favours the pcts. Therefore, the pcts will be

released and additionally the crown canopy will be slightly opened for the benefit of the intermediate and suppressed individuals of the understorey.

Table 4.5-13: Description and objectives of the **main thinning systems** and their importance.

Thinning system	Description	Purpose	Importance
Low thinning	Selection of individuals from below: • Moderate low thinning (Grade B)[1)]: removal of suppressed and poorly formed trees in the canopy. • Heavy low thinning. (Grade C)[2)]: removal of suppressed and some dominant trees without permanently opening the canopy.	Moderate low thinning: predominantly utilisation of codominant, suppressed and dying trees. Heavy low thinning: partly codominants and dominants also.	Moderate low thinning most widely used for conifers and partly for broadleaves; little effect on improving growing conditions for the most promising individuals in a stand. Recently less favoured.
Crown thinning	Selection of pcts; removal of competing dominant neighbours.	Concentration of increment on the most vigorous individuals with high stem quality.	Increasingly accepted as main thinning system for quality timber production, especially broadleaves.
High thinning	Release of pcts in the upper canopy and also lightly opening the remaining parts of the stand.	• Concentration of the increment on the pcts (like crown thinning), • favouring vertical structure (keeping suppressed individuals alive) as fillers (preventing epicormics and development of ground vegetation).	Main system in older beech forests and mixtures of pioneers and shade-tolerant understorey species (for example oak + beech; ash/ sycamore + hornbeam). At present not practised in Ireland.
Selection thinning	Thinning in selection forests thereby improving growing conditions for seedlings and saplings.	Favouring uneven-ageness and vertical structure.	Seldom practised as true selection forests are rare. Increasingly discussed in connection with continuous cover forestry.
Line thinning	Removal of trees according to a predetermined system (systematic thinning = every 2nd, 3rd row etc.). No consideration of the merits of individual trees.	Reduction of tree numbers (respacing). Often first opening of stands for further treatments.	Not thinning in a narrow sense. Mainly for conifers; less important for broadleaves.

[1)], [2)] International abbreviations for thinning grades

4.5.5.3 Criteria for the selection of potential crop trees

As shown in Table 4.5-13, crown thinning is increasingly accepted as the main thinning system for the production of high quality broadleaf timber through the promotion of pcts. Therefore, a detailed discussion of the selection criteria of the pcts and their release from competition appears necessary and is dealt with below:

(1) Ranking of the selection criteria.
(2) Determination of the number of the pcts.
(3) Decision on the commercial stem length of the pcts.
(4) Arguments for and against the selection of pcts.

(1) Ranking of the selection criteria

In practice there are three main criteria considered in the selection of pcts: vigour, stem quality and distribution (Table 4.5-14).

To be selected as a potential crop tree, an individual has to be dominant and vigorous in order to withstand the competition of its neighbours and be able to maintain growth up to the end of the production period. Therefore, **vig-**

Table 4.5-14: Main **criteria for the selection** of potential crop trees.

Criterion		Selection details
1	**Vigour**	Crown size: big, more or less symmetrical; canopy class: dominant tree; generally healthy status: vigorous; free of defects.
2	**Quality**	Absence of forks, crookedness, exceptionally large branches, diseases or injuries to the bark.
3	**Distribution**	As regular as possible: in older stands often not attainable because of differentiation and group structure.

our has to be the principal selection criterion.

In order to characterise vigour – that is the social status of a tree within the group of its neighbours – Kraft developed a tree classification system in 1884 which is still in use (Table 4.5-15).

Pcts should generally belong to tree classes 1 and 2, never 3 or 4. In practice, even experienced practitioners tend to prefer codominant trees, as these are well-formed with long boles free of branches, instead of selecting the most vigorous individuals which have the potential to produce large dimensioned trunks, albeit of shorter length. Thus they ignore the rule: vigour first!

Table 4.5-15: System of **social tree classes.** (According to Kraft, 1884)

Tree class		Description
1	**Predominant**	Predominant trees with healthy, well developed crowns.
2	**Dominant**	Main component of the upper crown canopy. Trees with reasonably well developed crowns.
3	**Codominant**	Marginally dominant trees with more or less normal crown forms, but relatively poorly developed and slightly deformed crowns.
4	**Intermediate**	Dominated trees with adpressed, rudimentary or one-sided crowns, not fully overtopped.
5	**Suppressed**	Fully overtopped trees with more or less viable crowns.

Of course a potential crop tree has to be of reasonable **quality**. There are, however, differences between V- and U-shaped forks (Figure 4.5-1).

V-shaped forks tend to break in high winds and destroy the whole crown (Plates 4.5-7, 4 to 4.5-9) while U-shaped forks are fully occluded as part of the stem and, therefore, normally stable.

From an economic point of view, it is generally best to select vigorous trees with larger, but shorter stems instead of codominants with longer straighter and clean, but slender trunks. This is explored in more detail in section (3) below.

Finally, **distribution** as a criterion is of lesser importance. The older the stands and the more variable the site conditions are, the more trees

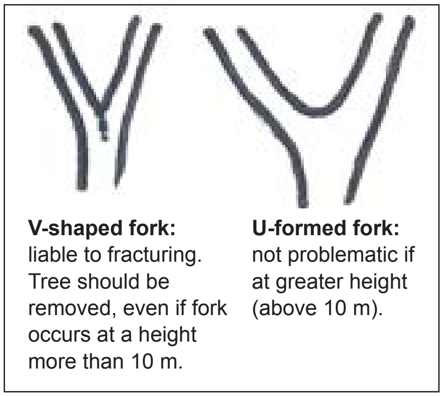


Figure 4.5-1: Sketch of **U- and V-shaped forks.**

Plate 4.5-7: A V-shaped fork with a fissure underneath in an ash stem.

Plate 4.5-8: V-forked ash with one branch broken by strong winds.

Moreover, the wound illustrates that fungi, causing rot, have already infiltrated the fissure.

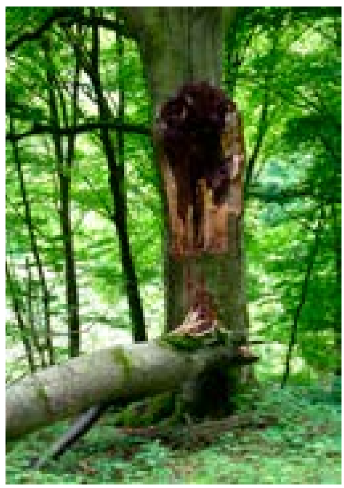


Plate 4.5-9: Old beech with a V-fork which survived for more than a hundred years, but finally broke in a recent storm.

tend to differentiate and develop a group structure; the practical consequences of this are discussed in Chapter 4.4.5.6.

Practitioners have a tendency to select too many pcts. Their rationale is to provide for the risk of eventual losses in later years, but, in doing so, there are implications for the expansion capacity of the crowns. Therefore, it seems appropriate to discuss the principles of selecting pcts, numbers, vigour, quality and distribution in greater detail in the following paragraphs.

(2) Determination of the number of potential crop trees

The question as to how many pcts to select has been a topic of much debate and controversy in recent years. To put this matter on a firm footing some calculations may be helpful.

The number of pcts/ha depends on the eventual crown width and stem diameter of the target crop trees at the end of the rotation (target diameter), and the tree species. In practice the calculations and considerations with regard to numbers have to be retrospective, starting with the crop trees at time of maturity and then trying to derive the numbers of vigorous young dominants that have the potential to reach the final stage and should, therefore, be selected.

There are two possible approaches to deciding their number:

- **Crown width** as an indicator
  A strong correlation exists between the diameter of crowns and that of stems. This can be used as an evaluation criterion. The crown diameters of a series of trees, that have reached the target stem diameter, can be measured and the average obtained. In an ideal situation the crown circumference will be circular and, therefore, of constant diameter, so the crown area can be calculated from the following formula:

  $$\text{Crown area} = 3.14 \times (\text{crown diameter})^2 \div 4.$$

  A crown with a diameter of 10 m, therefore, will cover an area of 78 m². Thus 128 crop trees will fill an area of 1 ha (10,000÷78) provided that they fully cover the area. In fact the number will be slightly less as circular crowns do not fully fill the space available.

  In practice, however, the tree crowns are of different sizes, asymmetrical and normally irregularly distributed within a stand. For this reason the crop tree number will differ more or less from this ideal value.

  The general problem with this type of calculation is that trees which represent the target trees are often not available. This is mainly the case in Ireland.

  Another obstacle to this approach is that trees which have developed in a wide growing space in their youth may later become suppressed by neighbours. These will show very different correlations between crown and stem diameters.

  To provide at least an idea about the possible numbers of pcts required, relevant data from SW Germany may be used (Table 4.5-16).

  These data show that the numbers of oak crop trees, at a target diameter of 60 cm, are just over 100 pcts/ha. The data from the two locations illustrate that age, as reflected in crown width, may also play a certain role. These data are presented as suitable for use as a first estimate for the decision as to how many pcts may be appropriate.

- **Basal area** and **target diameters** as indicators
  The main background to this type of calculation is the fact that the basal area of a stand is roughly the same whether it is derived from a small number of large stems or a greater number of smaller trees, so long as the canopy remains closed.

Table 4.5-16: Crown width and number of crop trees in two oak stands (SW Germany) at diameters (dbh) of 60, 70 and 80 cm. (Adapted from Spiecker, 1991)

LOCATION	AGE years	DIAMETER (cm) 60	70	80
Crown width (m)				
Müllheim	160	9.0	10.9	12.8
Johanniskreuz	256	8.3	9.9	11.6
Number of crop trees (individuals/ha)				
Müllheim	160	110	75	54
Johanniskreuz	256	129	91	66

The stand basal area is dependent on the tree species, the productivity of a stand and the age at time of harvest. These data can be taken from yield tables, provided they exist for the different species.

In Table 4.5-17 some relevant data are given.

To calculate the number of crop trees the **stand basal area (**B.A.) has to be divided by the mean **basal area of the crop trees** (b.a.), thus B.A. ÷ b.a. = number of crop trees.

Table 4.5-17: Stand basal area and mean diameter of some broadleaf species at a hypothetical harvest age and of a medium yield class. (From Hamilton and Christie, 1971: Yield tables, For.Comm.)

Item	Unit	Tree species		
		Ash	Beech	Oak
Age	year	80	100	120
Mean diameter	cm	35.4	48.1	50.8
Basal area	m²/ha	24.8	33.9	22.6
Mean annual increment	m³/ha/yr	5.0	7.9	5.5

The basal area of the crop tree (m²) is derived from its target diameter (cm) using the formula: 3.14 x target diameter²÷40,000.

For calculation purposes the basal area of trees with target diameters from 40-70 cm are shown in Table 4.5-18.

By using the stand basal area values – as given in Table 4.5-17 – the numbers of crop trees/ha are calculated to be between 270 and 75. They show how variable the numbers can be depending on the respective tree species and the target diameters.

Table 4.5-18: Number of crop trees according to target diameters (dbh) and tree species of moderate yield classes.

Item	Tree species	Unit	Target diameter (cm)			
			40	50	60	70
Basal area		m²/tree	0.13	0.2	0.28	0.30
Number of crop trees	Ash	trees/ha	195	126	88	82
	Beech		270	173	120	112
	Oak		180	115	80	75

At the outset, it is necessary to make an educated guess in relation to reasonable target diameters. These may vary between 50 and 60 cm for beech and oak in Ireland, and it is unlikely that ash can reach more than 50 cm on average. Thus the maximum numbers of crop trees/ha will vary roughly between 170 (beech) and 80 (oak). The numbers for ash may lie somewhere in between.

In Germany larger diameters are preferred, as can be seen from the data in Table 4.5-16, but it is doubtful if these are realistic in Ireland at present on a 120 year rotation.

These calculations need some critical considerations:

- So far it has been assumed that the number of pcts selected is the same as the number of pcts at time of harvest. It may be, however, that some of the pcts are lost during the life of the stand. Therefore, the numbers should be increased slightly at time of selection. This argument is discussed in section (4).
- The yield table data were collected from stands that were managed in a traditional manner, that is through moderate thinnings which started late. If modern management strategies, like early selection of pcts and a steady release from competition throughout their lifetime, are adopted much larger target diameters will be possible. Consequently, the numbers of pcts must be reduced.
- The results have been calculated for medium productivity rates. The number of final crop trees at maturity will be higher for stands with better yield classes and lower for inferior ones.
- The calculations have been based on diameters at breast height over bark. If mid-diameters underbark, which are standard in European markets, are adopted, then a

supplement of 3-5 cm for the bark thickness and taper (reduction of stem diameter according to height) has to be added to achieve breast height values: around 3 cm for a thin barked species like beech and 5 cm for oak with its thick bark. This adjustment will lead to a reduction in the numbers of pcts.

The above calculations are not intended to be definitive, but are meant to provide an in-sight into the approach that may be adopted in calculating the possible range of pct numbers and how these may be derived.

(3) Decision on commercial stem lengths of the potential crop trees

There have been long discussions in the field between foresters as to whether slender and less vigorous trees with long clean trunks are economically preferable to vigorous specimens with short stems. The answer requires information on two associated stand characteristics:

- **The price:size relationship for logs of different diameters**
  As shown in Figure 3.2-1 for all broadleaf species of sawntimber or veneer quality, the price for logs of equal volume and quality is greater for those of larger diameters: the price:size gradient. The steeper the price:size gradient the greater the price differential will be between logs of equal volumes, but different diameters. One would rightly conclude that growing trees with large diameters and short boles would be more economical. However, the second factor must be also taken into consideration.
- **The number of trees of different sizes to be accommodated in the stand**
  As stated, a strong correlation exists between stem diameter and diameter of the crown. Therefore, trees of large diameter have larger crowns and fewer can grow on a given area.
  In particular oak stems often achieve good prices when grown to large sizes.
  The price:size gradient is less steep for beech and an argument can be made for smaller diameters and a greater number of stems.

The main flaw in this type of decision-making is the long time-lag between the application of the decision and the time of harvest. In this period the price:size relationship may have altered radically.

(4) Calculation of economic value of potential crop tree logs according to number, diameter, length and price

To contribute to the above discussion, calculations on the following items may be helpful:
- Volume of the bottom log,
- number of crop trees according to target diameter and length of bottom log,
- prices of high quality timber by species and dimensions,
- prices of logs by mid-diameters and lengths,
- values of all bottom logs/ha by species, target diameters and lengths.

In the following the steps of the calculations and their combinations are presented for those readers who are interested in these deductions. Alternatively one may go directly to the conclusions:

- **Volume of the bottom log**
  The volume of a log is generally calculated by using the mid-diameter. As mentioned, this is also the basis for selling in the market. It may be sufficient to show the principle and to present only the volumes of three of the most common bottom log lengths: 3, 5 and 7 m (Table 4.5-19).
  The data illustrate that a large diameter stem with a short length (65 cm, 3 m long) has almost the same volume as a smaller one with a much longer clean bottom log length (45 cm, 7 m long). Thus, a 2 m gain in the bottom log length is roughly equivalent to an increase of 10 cm in diameter.

- **Number of crop trees according to target diameter and length of bottom log**
  The number of crop trees can now be calculated on the basis of the mid-diameters, though bark thickness and taper had to be considered (Table 4.5-20). Basal area values for stands of medium productivity, as presented in Table 4.5-17, have been used as the basis.
  These numbers differ not only depending on species and target mid-diameter. They are also influenced, but only slightly, by the length of the bottom log. The numbers of crop trees are reduced compared with those given in Table 4.4-18, which are based on diameters at breast height.
  These data are mainly needed for the further calculations.

Table 4.5-19: Volume of bottom log (m^3/log) according to mid-diameter and length ($\pi d^2/4$ x length).

Mid-diameter cm	Length of bottom log (m) 3	5	7
45	0.48	0.80	1.11
55	0.71	1.19	1.66
65	1.00	1.66	2.32

Table 4.5-20: Number of oak and beech crop trees (stems/ha) by mid-diameter under bark and length of bottom log.

Mid-diameter cm	Oak – Length of bottom log (m) 3	5	7	Beech – Length of bottom log (m) 3	5	7
45	120	115	106	195	187	173
55	83	80	75	133	128	120
65	60	59	56	96	93	88

- **Timber prices by species and dimensions**
  The next step is to get reasonable price information. As illustrated in Figure 3.2-1 the prices even for high quality timber vary remarkably between species and according to stem dimensions. The values given in Table 4.5-21 show the prices for high quality oak and beech. As detailed prices for high quality timber are not available in Ireland at present, data provided by the Bavarian Forest Service have been used to demonstrate the interrelationship. The oak prices may be taken as the optimum indicator for the high price segment of quality timber, and the beech prices as the poorest variant for the low price segment.
  These data again underline the great differences in values between the larger and smaller diameter logs. They also reiterate the fact that there are fundamental price differences between the species.

Table 4.5-21: Price of high quality oak and **beech** logs as related to mid-diameter.

(Adapted from Bavarian Forest Service,1994-2004)

Mid-diameter cm	Price €/m^3 Oak	Beech
45	330	170
55	425	225
65	580	250

- **Price of log by mid-diameter and length**
  A further step is the calculation of the price per log depending on mid-diameter and length (Table 4.5-22).
  Here it can be seen that the increase in mid-diameter leads to a much greater increase in value than the increase in length. Thus a log of 65 cm diameter, but only 3 m long, is worth more than one of 45 cm diameter and 7 m long. This is similar for oak and beech, despite their great difference in price.

Table 4.5-22: Price per log (€/log) as related to species, mid-diameter and length (data Table 4.5-19 x Table 4.5-21).

Mid-diameter cm	Oak – Length of bottom log (m) 3	5	7	Beech – Length of bottom log (m) 3	5	7
45	158	264	366	82	136	189
55	302	506	706	160	268	374
65	580	963	1,346	250	415	580

- **Value of all bottom logs/ha depending on species, target diameter and length**
  Finally, the value of all bottom logs in a stand is calculated – assuming that all stems within a stand have the same diameter and length characteristics (Table 4.5-23).

Table 4.5-23: Value of all bottom logs (€1000 /ha) by number of crop trees, mid-diameter and length (data Table 4.5-22 x Table 4.5-20).

Mid-diameter cm	Oak			Beech		
	Length of bottom log (m)					
	3	5	7	3	5	7
45	19	30	39	16	25	33
55	25	40	53	21	34	45
65	35	57	75	24	39	51

Now the economic superiority of the large diameter short stems over the small diameter long clean stems no longer exists, because of the much lower numbers of crop trees. Nevertheless, 60 oak crop trees/ha of 65 cm mid-diameter and 3 m long are only slightly less valuable (€35,000) than 106 crop trees of 45 cm mid-diameter, but 7 m long (€39,000).

Stands with rough, but vigorous individuals and, therefore, few pcts with a relatively short length of clean bottom logs, may have the prospect to generate almost the same value of high quality timber as those with perfectly formed, but relatively slender stems.

The question as to how many pcts/ha would be the absolute minimum that can still be accepted to form an economic crop remains open.

From these calculations the main results are:

- The number of pcts to be selected early in the rotation varies remarkably according to the target diameter of the crop trees.
- For logs of equal volume, the target diameter of the crop trees is greatly influenced by the price:size relationship for the species.
- Although the value of the logs is highly dependent on the tree species and productivity, the dominance of high prices for high quality stems seems to be relatively stable.

The practical consequences are therefore:

- A smaller number of vigorous trees with short log lengths, which have the potential to produce large dimensioned butt logs, are not necessarily inferior in economic terms compared with trees with slender, but long clean and straight stems of lower growth potential.
- Even if many pcts seem to be of minor quality, due only to relatively short log length, it makes sense to select them – provided they are vigorous and get adequate growing space to make use of their growth potential.

(5) Arguments for and against the selection of potential crop trees

In the beginning of the 1970s, it became more and more apparent that it was necessary to change the traditional thinning practice in Central Europe, which consisted mainly of moderate low thinning. Improving the stability of conifers and increasing stem dimensions of broadleaves were the main reasons for introducing crown thinning, which involved the early selection of pcts in a systematic manner. There have been intensive discussions since that time, and some practitioners are still reluctant to choose pcts in young stands for various reasons. Their arguments – together with the counter-arguments – are listed in Table 4.5-24.

In summary, it may be concluded that most of the arguments against the early selection of pcts listed in Table 4.5-24 do not stand up to a critical analysis. Nevertheless, the determination of the exact numbers of pcts will continue to be subject to debate concerning various issues such as target diameters, tree productivity, site variability and timber prices.

Table 4.5-24: Arguments for and against (early) selection of potential crop trees and early interventions in broadleaf stands.

Argument against selection	Counter-argument
It is doubtful that sustained superiority of pcts can be predicted when these are selected relatively early.	Observations in normal stands as well as in experiments show that vigorous specimens remain dominant and even expand their predominance, whereas less vigorous trees continue to grow slowly, even if fully released from the competition of their neighbours.
When thinnings are carried out at a very early stage the differentiation into dominant, codominant and suppressed individuals has not sufficiently progressed. Thus the selection of pcts should be postponed to a later age.	To avoid this problem a greater number of pct candidates than will ultimately be needed are selected when the 1st thinning is carried out early. In the 2nd thinning a reduced number of pcts will be chosen at which time it is usually easier to identify the really vigorous ones. Thanks to early selection the differentiation has been accelerated and the crown development of the pcts already encouraged.
A relatively small number of pcts does not include reserves. These, however, may be necessary to compensate for losses caused by abiotic or biotic hazards.	Initially the pcts are widely distributed in a stand. A sufficient number of reserve trees remains in the areas between the pcts. In the first thinning cycles reserve pcts can be selected from these parts. Later on the pcts are usually sufficiently stabilised and less prone to any risk.
Stands develop in an unpredictable way. Therefore, it is better to readjust the selection of dominant trees that should be supported at each thinning intervention.	The earlier dominant trees are favoured the more they tend to become predominant and remain in their tree class. It is wrong to assume that intermediate or even codominant individuals have the potential to ascend in tree class.
The selection of pcts is time consuming – especially in young stands with poor visibility – and needs experienced people.	There is no doubt that the selection of pcts is a challenging, laborious task, but it is a good investment for future interventions. Subsequent thinnings can be carried out much easier and faster!

4.5.5.4 Selection of competitors

As defined in Table 4.5-3 a competitor is a tree that competes with the crown of a neighbouring potential crop tree and has to be removed. Competitors are generally dominants or codominants. Their heights are at least two-thirds of those of the pcts and shade the crowns at least partially or will do so eventually. The closer the pct and competitor are, the stronger the competition or the crown tension.

From a number of neighbouring trees competing with a pct, those that are most dominant, or will become so during the next few years, have to be removed. Therefore, the forester needs some understanding of the growth habits of the species on a given site. Moreover, he has to decide whether a heavier or lighter thinning is appropriate according to the probable response of the species to the thinning treatment.

In order to be effective, usually no fewer than two competitors per pct should be removed at the first thinning treatment. In general, competitors should be taken from those sides where the crown of the pct is already slightly deformed or will be shortly. Pcts should retain or establish symmetrical crowns as these trees have greater stability and form less compression wood. Thus, the competitors should normally be removed at opposite sides. Whereas two or more competitors of a pct may be removed at the 1st or 2nd thinning, later the number will be reduced, as the main rivals have usually been already eliminated.

On exposed sites, or where thinning has been delayed for a significant period, thinning intensity should be reduced, and repeated more frequently.

4.5.5.5 Thinning cycle and intensity of thinning treatments

From the ecological point of view, and with regard to the acclimatisation of trees within a stand, it is best to thin lightly and frequently – at one or two years – however, this is normally impractical. The usual practice is for most forest owners to thin their stands at longer intervals. Unfortunately, this does not follow the trees growth cycle, which tend to show phases of accelerated and declining growth. This has been illustrated in Figures 4.1-2 and 4.1-3. It is, therefore, better to adjust the thinning intervals to the height growth and crown expansion potential of the tree species concerned. Height differences of 2-4 m should be used as a basis for the repetition of thinning intervals, with 3 m a reasonable recommendation. The degree to which the length of the time intervals changes for the different tree species and their varying height growth is illustrated in Table 4.5-25.

Thus, based on a height growth difference of 3 m, thinnings should be at 2-year intervals for the 10-year-old poplars, and at 30-year intervals for 100-year-old oak and beech. In practice, fast-growing stands should be thinned at height intervals of 4 m and slower growing stands at 2 m intervals. Moreover, it is realistic to use 3-4 m height intervals between two interventions in young vigorous stands and to reduce this to 1-2 m at later stages, in order to avoid excessively long thinning intervals.

The length of thinning cycles has an indirect influence on the intensity of thinning treatments. In the case of an early recurrence the treatments can be moderate. Long periods between consecutive thinnings may need heavier interventions, but this has consequences of increased instability for some years, and a profusion of epicormic growth with some tree species, especially oak (Plates 4.5-10 and 4.5-11).

Table 4.5-25: Length of thinning intervals (years) based on a height growth difference of 3 m as related to tree species, age and productivity. (From Hamilton and Christie, 1971: Yield tables. For. Comm.)

Tree species	Age (years)							Yield class
	10	20	30	40	50	75	100	
Poplar	2	4	6	10	20	-	-	14
Ash, sycamore, birch	6	6	9	14	21	43	-	12
Oak	-	6	7	9	11	19	30	8
Beech	-	5	6	8	11	19	30	10

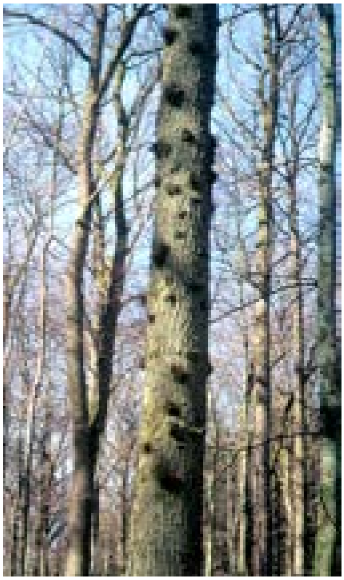


Plate 4.5-10: The development of epicormic shoots on oak stems is often an indication of insufficient thinning. (Freiburg, Germany)

Plate 4.5-11: Sycamore also tends to produce epicormic shoots if the tree has come under stress conditions in the crown. (Freiburg, Germany)

Conclusions

The result of these considerations show that the thinning cycles have to be adjusted to species, age and growth rate. Thinning cycles at constant time intervals of equally long duration are too rigid and do not satisfy the growth dynamics of trees.

The possibilities of enhancing the stand quality in its youth is not sufficiently availed of when thinnings are delayed or occur at infrequent intervals.

4.5.5.6 Successive thinnings

At present most owners of broadleaf stands in Ireland are concerned with the initial thinning phase, mainly in the selection of potential crop trees (pcts). This is especially the case in the grant aided private forests, but eventually later thinnings will become important. The other private, as well as state owned forests may need thinning treatments in later development phases.

Apart from the dependence of the thinning cycles on the growth characteristics of the tree species there are other aspects that may influence the type and timing of subsequent thinnings:

(1) Concentration of the stand increment on the pcts.
(2) Avoidance of stem decay.
(3) Maintenance of vertical structure of the canopy.
(4) Distribution of pcts and group thinning.
(5) Thinning interventions as a stimulation for natural regeneration.
(6) Thinnings as a means of favouring irregular stand structure and conversion to continuous cover management.

These are closely linked to the production targets in a wider sense and are described below.

(1) Concentration of the stand increment on the potential crop trees

Where high quality timber production is the goal and the pcts have been selected in a timely manner, the main task of the forest owner should be to concentrate on favouring these pcts so as to ensure their further enhanced growth. Permanent marking of pcts at the first selection operation facilitates the second thinning. After two thinnings, the pcts are usually easily identifiable because of their dominance (Plate 4.5-12).

As mentioned in Table 4.5-24 some owners hesitate to select pcts early. Nevertheless, they will favour those individuals which seem to be most appropriate at time of treatment and repeat the process at subsequent thinnings. Promotion of pcts, however, only makes sense if quality timber is the production goal.

Plate 4.5-12: Timely selection of potential crop tree candidates helps to concentrate stand increment on the best stems at an early stage. (Kilcock, Co Kildare)

(2) Avoidance of stem decay

Recent observations have shown that decay and stem discolouration often gain entry to the stems through large dead branches in the lower crown regions which have been shaded by neighbouring trees. These dead branches function as a means of entrance for fungi, especially in beech, oak, ash and wild cherry, and may cause serious deterioration of the stem quality and wood value.

Large branches in the lower crown should, therefore, be prevented from dying. At present broadleaf experts – at least on the Continent – recommend the release of pcts from competition by their vigorous neighbours after natural pruning has produced a branch-free trunk. Therefore, immediately after having passed the qualification phase, the crowns should be completely released from all competition so that no branch in the lower crown will die. Accordingly, only a relatively small number of pcts can be retained in a stand, and these will have the space to grow almost as single individual trees in a type of free growth. Their increment is greatly accelerated and they reach their production goal much earlier than would otherwise be the case. Little information is available so far on the volume increment in such stands, so the overall economic gain is, therefore, not quantifiable (Plates 4.5-13 to 4.5-17).

(3) Maintenance of vertical structure of the canopy

In general, stands that have reached the thicket stage tend to develop a single-storeyed structure. Individuals that are not able to keep pace with the others and become part of the lower canopy develop poorly or eventually die. This is the case with light-

Plate 4.5-13: Free growth of pruned ash. (Alsace, France)

Plate 4.5-14: Free growth of pruned wild cherry.
(Breisach, Germany)

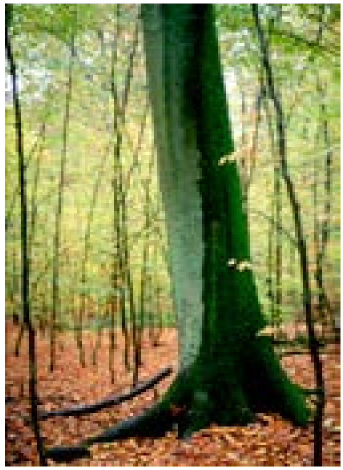


Plate 4.5-15: Free growth of beech. (Lorraine, France)

Plate 4.5-16: Free growth of oak.
(Kilcooly, Co Kilkenny)

Plate 4.5-17: Free growth of wild cherry.
(England; courtesy: Guest)
The bluebells add much to the aesthetic value of this fine stand.

demanding pioneers such as birch, ash and oak (Plate 4.5-18). Even shade-tolerant species, such as beech, tend to fade away if not sufficiently released from the shade of a closed canopy. Only in optimum site conditions – continuous water and sufficient nutrients – can stands of shade-tolerant species form multi-layered structures (Plate 4.5-19). Maintenance of a good vertical structure may be required to provide shelter for the trunks of pcts to prevent the formation of epicormic branches, to avoid the development of too much ground vegetation and to provide a diversity of habitats for various animals.

Crown or high thinnings will not only release the pcts from competition of their dominant neighbours, but also improve the light conditions in the lower storey. Beech forests, for instance are able to form multi-layered stands provided the canopy has been opened in time – as long as suppressed individuals remain alive. Pioneers, however, will never form multi-layered stands in the long-term as the suppressed individuals cannot survive. Shade-tolerant individuals beneath pioneers, however, may serve this function – like beech or hornbeam under oak. They also need some light to survive and to fulfil their function. Therefore, appropriate crown thinnings are imperative.

Treatments of this kind are especially a task of managing mixed stands and are discussed in Chapter 4.5.6.

Plate 4.5-18: Mono-storeyed birch stand.
(Freiburg, Germany)

Plate 4.5-19: Multi-storeyed beech stand.
(Freiburg, Germany)

(4) Distribution of potential crop trees and group thinning

As mentioned, the distribution of pcts within stands tends to be irregular. This is often the case in older stands. Two or three pcts may be standing relatively close together, while other parts of a stand may contain hardly any acceptable specimen that meets the minimum requirements of a pct.

Kato and Mülder (1978) found that pcts frequently form pronounced clusters in middle-aged beech stands. Breaking-up such clusters by thinning, would reduce the economic value. In such circumstances they, therefore, recommended that groups of two or three pcts should be treated as if they were just one tree by releasing the whole group from competition of the neighbouring competitors (Figure 4.5-2).

There is, however, no need to form groups of pcts in young stands with sufficient vigorous, well formed individuals. Here and there it may also happen that two trees of comparable vigour and quality stand beside each other, but only one can be selected as a potential crop tree. In this case the tree may be selected which is slightly superior in accordance with the adage: the perfect is the enemy of the good, or that which fits better into the distribution pattern.

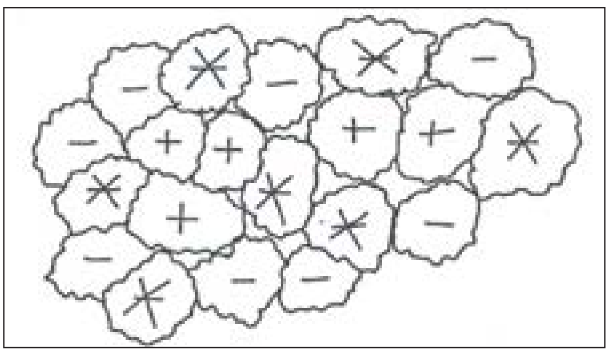


Figure 4.5-2: **Profile of a beech stand** with groups of neighbouring vigorous and well formed **potential crop trees** and **suggested competitors.**

Two examples for this type of group thinning are given: three potential crop trees (left) are released from three competitors and two pcts (right) from four competitors around the group.

+ potential crop tree
– competitor

(5) Thinning interventions as a stimulation for natural regeneration

Flowering and seed production are highly dependent on the size of the crowns. Sufficient space for crown development will, therefore, increase seed production effectively, and flowering will occur even after a few years. A crown thinning shortly before the end of the production period may, therefore, be helpful in stimulating and improving preconditions for seed production and natural regeneration.

(6) Thinning as a means of promoting irregular stand structures and conversion to continuous cover management

Various thinning intensities in heterogeneous stands offer good prospects for the transformation of even-aged stands into irregular uneven-aged stands. In several stands it can be observed that groups of larger trees exist beside those of smaller ones. This is mostly a result of different plant densities in the establishment phase. By heavier thinnings in the advanced groups, they may be encouraged to grow even faster. Later on they can be harvested much earlier than those with a somewhat delayed growth, which have been thinned only moderately. This will provide the possibility of regeneration over a long period as a precondition to create a final uneven-aged structure.

For various reasons thinnings are often delayed. The later they are carried out, the more ineffective they become (Plates 4.5-20 to 4.5-24). Moreover, because of the reduced reaction capacity of older trees, they will influence stand quality and structure very gradually.

Often selection of pcts may not make sense as wolves predominate in the stand and straight, knot-free individuals have been almost suppressed. In this case a type of free style thinning may be appropriate, with the aim to improve the quality of the remaining trees as much as possible. However, it is always essential to operate in the upper crown, as harvesting the intermediate and suppressed individuals has no silvicultural effect, but is acceptable in cases where the small material can be used – for instance as fuelwood – to cover the costs. Harvesting suppressed and intermediate individuals is irrelevant in pioneer stands, and counterproductive in stands of shade-tolerant species where a multi-layered structure is aimed at.

Thinning of mixed stands is a special case and of such importance that it is discussed separately in Chapter 4.5.6.

Plate 4.5-20: 40-50 years old neglected ash/sycamore/beech stand. (Freiburg, Germany)

The stand should have been thinned much earlier, but the more vigorous individuals may still respond to removal of competitors.

Plate 4.5-21: 90 year old ash/beech stand that has not been thinned for a long time. (Kelheim, Germany)

The crowns are reduced in size and consequently the diameter increment is minimal. It is unlikely that these trees will respond to any form of thinning.

Plate 4.5-22: View into the crowns of a fully closed oak stand canopy. (Kilcooly, Ireland)

Sometimes – especially in windy regions – oak and other species damage their outer fine branchlets.

Plate 4.5-23: Fully closed oak stand with slightly suppressed crowns.(Rathdrum, Co Wicklow)

Another example that illustrates the urgent need of a further thinning.

Plate 4.5-24: Sycamore in a later development phase after delayed thinning.

(Knocktopher, Co Kilkenny)

These specimens with fine stems have been selected as seed trees, but may not produce much seed because of their severely compressed crowns.

4.5.5.7 Ecological and economic implications of thinning

Thinnings have long and short-term effects, mainly ecological and economical. However, their results differ very much in relevance. This is explained in the next two sections.

(1) Ecological implications

Thinning modifies stand density at intervals. However, the influence is moderate as long as the impact is not severe. Moreover, the canopy tends to close again soon after moderate treatments, so that the changes are not long-lasting.

In Table 4.5-26 some of the possible ecological effects are listed.

Table 4.5-26: Ecological effects of thinnings.

Factor	Comment
Light	Improvement of light conditions on the ground after each thinning. More sunny locations, increase of diffuse light. Enlargement of area of crown available to light through movement of crown contact with neighbouring trees in deeper layers. Increase in increment in the remaining trees.
Temperature	Noticeable changes only after extremely heavy thinning.
Water regime	Decrease of interception losses through reduction of crown surface. Substantial increase of water supply, however, only after severe reduction of high densities or very heavy thinnings.
Soil	Mineralisation of raw humus and increased turn-over of nutrients possible, but only after heavy thinnings. Normally only minor influences shortly after the treatments.
Ground vegetation	In young stands no serious spread of ground vegetation occurs as the crown canopy closes rapidly even after heavy thinnings. Slow crown closure, however, in older stands after delayed thinnings. Therefore, development of vigorous ground vegetation cover, which will persist after later crown closure and may become a serious obstacle to natural regeneration at a later stage.

Generally, of all these factors only the stimulation of ground vegetation after late thinnings is of consequence.

(2) Economic implications of thinning systems

Systematic and stand adapted thinning have fundamental importance for stand stability and, therefore, reduction of wind risk. They improve tree quality and lead to concentrating the increment on the best individuals as well as favouring diversity. They thus have diverse, long-term and far-reaching economic consequences.

The transition from low to crown thinning may produce favourable economic results:

- The removal of only strong competitors of the pcts will reduce the number and volume of harvested trees per unit of area. The volume of each individual tree, however, is larger and more marketable. Felling and extraction, moreover, is less costly because of the greater volume of each log. Therefore, cost recovery is generally possible.

- Thinning of intermediate and suppressed individuals is normally not necessary from the silvicultural point of view. They may, however, be exploited if no extra costs arise. The trend in fuelwood demands suggests that this may be a more common scenario in the future (refer to Chapter 3.2.3).

The early selection and marking of pcts incurs slightly higher costs than marking trees in a free-thinning style. Careful examination and marking requires additional time and expenditure, but the great advantage of this measure is that subsequent thinnings can be executed much easier and faster. Moreover, it can be carried out by less skilled workers. The initial additional expenditure incurred will, therefore, be recouped at later thinning stages.

4.5.5.8 Practice of thinning

When implementing thinning procedures many mistakes are possible. Therefore, various aspects that seem to be worthy of attention are treated in the following three sections:

(1) Classification of individuals in stands

Instead of using sophisticated tree class systems in the field, as a preparation for identifying trees to be selected as pcts and competitors, it is generally sufficient – following Burschel´s recommendation (Burschel and Huss, 2003) – to group the individuals within a stand into three broad categories:

- Individuals which are **essential** for the management objectives,
- individuals that **interfere with** the management objectives,
- individuals which are **neutral** with regard to the management objectives.

The main advantage of this classification is that the forest owner has to clarify his management goals before starting to mark any trees.

(2) Selection of potential crop trees and competitors

The selection of the potential crop trees is a responsible task as it predetermines the development of a stand towards the production goal. It should be done carefully and by an experienced person. Many forest owners do not realise that this is the most important activity in the whole management phase to direct the structure and productivity of a stand during its life-time. As many forest owners are inexperienced in selecting pcts more training opportunities and other means of gaining and learning from experienced practitioners are required. Moreover, neighbours with forest properties could do the selection together and thereby discuss the management options, and so learn and gain experience from the process.

The selected pcts or potential crop tree candidates should be visibly marked with plastic bands or painted rings, so that they can at least be identified at the next thinning or even – if possible – for one or two thinnings after that (refer to Plate 4.5-14). The general experience is that the pcts favoured for two thinning treatments are then easy to identify and can be released from further competition.

Plastic bands last for some years, if not bound too tight, and as shown in Table 4.4-25 the first and subsequent thinnings will follow at relatively short intervals. Marking (spraying) with coloured paints may last longer, but is often disliked from the aesthetic point of view, yet, a visible marking of the pcts helps to ease the subsequent treatments.

In the first selection of pcts or pct candidates, the competitors should at least be marked by the forest owner or his representative in order to avoid an inappropriate selection. The authors of this book are realistic enough, however, to recognise that there is a tendency to delegate this work to the harvester driver or equivalent persons.

In many tests and trials it has proved advantageous to divide selection and marking of pcts and competitors into two operations:

- First, to identify and mark a group of pcts in a stand by asking: “where are the best trees that should be selected?” In this way the attention is focused on the cream of the crop.
- Second, to choose the competitors by asking: “which dominant trees interfere with the crowns of the selected pcts?” and, therefore, have to be removed. This approach is different, with attention being focused on trees interfering with the pcts.

This second traverse through the stand offers the opportunity to control the potential crop tree selection. Sometimes, faults like forks or injuries to a potential crop tree may have been overlooked and can be easily corrected by selecting a substitute.

(3) Thinning on slopes and alongside roads and racks
In sloping terrain trees tend to develop asymmetric crowns.

Therefore, on sloping sites competitors on the upper side of a potential crop tree should always be selected for removal first, rather than those with larger crowns on the downhill side.

Trees alongside roads and racks also tend to develop one-sided crowns into the open space, whereas they are often suppressed from the side of the stand. Therefore, they tend to form very asymmetric crowns (Plate 4.5-25).

Younger trees tend to bend down when hit by snow loads or heavy rainfall (refer to Plates 4.4-42 and 4.4-43). Older ones may form oval stems and compression wood.

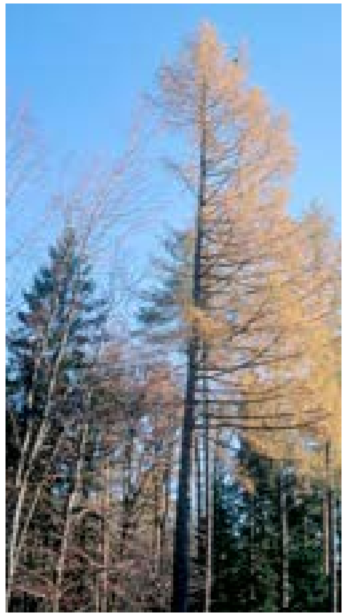


Plate 4.5-25: European larch showing remarkable crown development towards the road (open space) on the right and heavy suppression by beech on the left.
(Black Forest, Germany)

Conclusions

One of the main development features, especially in thinning practice of broadleaves during recent years, has been a remarkable change in approach. Traditionally whole stands were more or less intensively managed, but now the focus is much more on favouring individual trees with a potential for high value production and greater stability – little input per stand, but high input per tree has become the leading principle.

The more stands change over to the shelterwood or one of the other silvicultural systems, the more the fields of activities merge. Later, some more sophisticated systems, like the irregular shelterwood system, which integrate establishment and thinnings, may gain greater importance – but this is a vision for the future!

4.5.6 Silvicultural management of mixed stands

The establishment of mixed forests – as described in Chapter 4.4.6 – is always a challenging undertaking, but the subsequent management of the mixtures is even more demanding. Provided the mixed stands have been properly established, shaped and tended, the desired tree species should be sufficiently well-distributed not to cause problems in subsequent thinnings. Unfortunately, this is not the usual situation. Mixtures often develop more or less at random in naturally regenerated stands, or by self-seeding of pioneers in plantations. These rarely show appropriate configurations and structures for the tree species involved. In addition, planted stands often lack a satisfactory distribution to ensure that they have the potential to achieve all of the purposes and goals of mixtures (refer to Chapter 4.4.6). In those circumstances several interventions are usually required to maximise the potential of the mixture and achieve the best outcome.

Unlike pure stands, where the development of potential crop trees (pcts) is normally secured after the second thinning, mixtures often need repeated treatments to regulate the competition and interaction of the admixed tree species in order to achieve the desired outcome. Therefore, the management of mixed forests has to incorporate all thinning phases.

To provide an understanding of the task involved in managing mixtures in Irish forests, the extent to which they occur must first be examined, followed by details of the thinning procedures proposed.

4.5.6.1 Status of mixtures in Ireland

(1) Percentage of mixed forests in Ireland

Data illustrating the composition of high forests in Ireland with regard to mixtures are shown in Table 4.5-27.

These data show that almost two-thirds of the forest area consist of stands composed of almost pure conifers. Broadleaf and mixed stands together add up to roughly one-quarter in almost equal proportions.

There are, however, great differences between forest ownerships, which have been referred to earlier. The other private forests contain a much greater proportion of broadleaves, but the area of mixed forests in all ownership categories is relatively low at 14%. Nonetheless, the total of almost 90,000 ha of mixed forest is not inconsiderable, leading to the conclusion that the management of mixed forests deserves special attention.

Table 4.5-27: Stocked forest area by forest type and ownership. (Adapted from NFI, 2007)

Conifer high forest = ≥81% conifers.

Broadleaf high forest = ≥81% broadleaf.

Mixed high forest = >20% conifers or broadleaves.

Scrub = Semi-natural broadleaf forest, unlikely to become high forest.

Others: Felled, blown, burned, undeveloped, temporarily unstocked stands or forest areas.

Forest type		Ownership				
		public	private		Total	
			grant aided	other	Mean	Total area
		%				1000 ha
High forest	conifer	68	77	13	64	399
	broadl.	5	9	46	12	72
	mixed	16	12	11	14	89
Scrub		1	1	26	4	28
Others		10	1	4	6	38
	Total	100	100	100	100	626

(2) Number of species in mixed forests

The number of species within the mixtures varies considerably between forests of different ownership (Table 4.5-28).

According to these data, less than half of all forests are of one species (pure), whereas almost one-third contains two species. Only one-quarter of all forests incorporates three or more species. This leads to the conclusion that mixtures are generally not very complex.

It should be noted that a much lower proportion of forests with mixed species exists in the grant aided private forest sector compared with the other private forests. This may be due to the greater age profile of other private stands, perhaps resulting in natural regeneration and infiltration of other woody species into old stands.

(3) Forests according to structure of mixtures

Information on this category is based on stocked forest area with regrowth present. Its basis is 450,000 ha (that is almost three-quarters of the total forest area) and is classified according to the species structure of the regeneration (Table 4.5-29).

Slightly more than half of all forests with regrowth is homogenous. This implies that they are pure in species composition and even-aged. A high proportion of the remaining stands are mixed in an individual manner. Only 6% the total area of 450,000 ha is group- or line-mixed.

Table 4.5-28: **Tree mixtures** by **number of tree species** and forest ownership. (Adapted from NFI, 2007)

(Basis: 626,000 ha, but excluding 11,000 ha of temporarily unstocked area; weighted means)

Number of Tree Species	Ownership				
	public	private		Total	
		grant aided	other	Mean	Total area
	%				1000 ha
1	47	53	17	**45**	**281**
2	26	34	23	**28**	**177**
3	13	10	23	**13**	**84**
≥4	11	3	36	**12**	**73**
Unstocked	3	<1	<1	**2**	**11**
Total	100	100	100	100	**626**

Table 4.5-29: **Species structure** of total stocked forest area **with regrowth** by ownership. (Adapted from NFI, 2007) (weighted means)

Homogenous: only 1 tree species present.

Individually mixed: more than 1 tree species present, mixture in a random manner.

Group-mixed: groups of each species, line mixtures included.

Species structure	Ownership			
	public	private		Mean
		grant aided	other	
	%			
homogenous	57	52	30	**52**
individual	38	41	62	**42**
group/line mixed	5	7	8	**6**
Total	100	100	100	**100**

Conclusions

Based on NFI data, supplemented with data from other sources, it has been found:

- Although the proportion of pure stands is very high, there is a considerable area of mixed forests that will need intensive management during the next decades.
- The majority of young forests are mixtures of two or more species and therefore, most of them will need special care in order to keep the mixtures intact and provide benefits according to the goals.
- Irish forests comprise mainly three mixture types:
  (1) Nurse crop mixtures in plantations that have been established since the 1990s – mainly in grant aided forests. The main tasks here will be to remove the nurse trees at the appropriate time and with as little damage as possible to the target species. This will be an enormous challenge.
  (2) Mixtures of different age and species composition partly derived from natural regeneration – mainly in the other private forests. They will need more sophisticated procedures.
  (3) Maintaining and improving edge mixtures, especially in conifer stands with some broadleaf species.

4.5.6.2 Guidelines for the regulation of mixtures

The principles specified for the selection of potential crop trees (pcts) are as valid in mixed stands as in pure ones. Depending on the objectives of the mixture, however, it may be necessary to alter treatments slightly to favour individuals of less vigorous species at a certain development stage.

Most of the existing mixed stands in Ireland are young, having been established since 1990. This may be the reason why thinning, especially of mixed stands, has not been given much attention. However, there is now a grant for the tending and thinning of broadleaf:conifer mixtures. The Teagasc publication: Silvicultural guidelines for the tending and thinning of broadleaves (Short and Radford, 2008) should be consulted in this regard.

In the opinion of the authors, this field of silvicultural activity will gain increasing importance in the years ahead. Therefore, the essential thinning procedures required for the different mixtures are explained below – following the definitions and descriptions as already presented in Table 4.5-3 and Table 4.5-13.

(1) True mixtures

The goal of this type of mixture is to ensure that the constituent species participate equally in the upper canopy at the final phase of stand development (Plate 4.5-26 and 4.5-27).

Plate 4.5-26: A 130 years old highly productive ash/oak/beech stand with a successful true mixture. (Kelheim, Germany)

Plate 4.5-27: A view into the crowns of the same ash/oak/beech stand.
Now it becomes apparent that most of the ash trees have come under stress in past years because of insufficient thinning intensities.

From experience this can only be guaranteed if individuals of one species are not overgrown and suppressed by others. Therefore, they should be positioned in groups. The individuals in the centre of each group will then have the opportunity to maintain growth, even if the trees along the edge of the group are restricted by neighbours of a more competitive species.

In reality, it is unusual to find specimens of these species growing in groups of adequate size. Mostly, they are mixed either singly or in very small clusters (refer to Table 4.5-29). Consequently, they need intensive management or they will become suppressed. This situation arises from insufficient attention being given to the different growth patterns of the species at the outset.

Such problems are especially serious when light-demanding species, with rapid early growth, are mixed with shade-tolerant species, which show accelerated growth potential in the later phases. Typical examples are oak (especially sessile oak), ash, sycamore and larch in beech stands. They normally have accelerated growth in the first 20-30 years, followed by slower growth. Eventually, they struggle to survive against the resurgent beech (Plate 4.5-28).

The management of single specimens or small groups in this type of mixture is, therefore, frequently very demanding. It needs a clear-sighted view and a proactive management approach based on knowledge of the dynamics of the species involved. Unfortunately, due to lack of experience, this frequently does not exist in practice. When in doubt, it is better to relieve the constricted mixture trees more severely, than to do too little. When young they react strongly and will close the open space within short periods – generally much faster than most foresters expect.

(2) Mixtures with species in serving function

Serving trees, among other functions, can be planted to shade the trunks of the dominant species mainly to prevent the development of epicormics. They also shade the soil surface and reduce the growth of ground vegetation that may impede natural regeneration. Most importantly in this respect is the mixture of shade-tolerant trees in oak stands, which are essential if the production of high quality timber is the goal (Plate 4.5-29).

Most of the older Irish oak stands, however, lack this composition and consequently are somewhat unsatisfactory.

As mentioned, there is some uncertainty as to which species would suit best as a serving tree under Irish conditions. Beech, hornbeam and lime seem to be appropriate although, according to experience on the Continent, they tend to grow into the crowns of the oaks in later development phases. They become strong competitors and, therefore, need to be removed at that stage. In order to avoid this necessity, beech is often planted some decades later than the oak, after potential oak crop trees have been selected and released from competition.

Beech, hornbeam and lime are slightly more site specific than oak. In many areas hazel or holly are natural associates of oak, and it might also be possible to use them as serving trees.

As little or no experience is available in Ireland in this respect, experiments and critical observations are urgently needed.

Plate 4.5-28: European larch with only remnants of its former crown due to severe competition from beech.

Plate 4.5-29: High quality old oak stand with serving beech preventing the occurence of epicormics. (Bellême, France)

(3) Temporary mixtures

Trees of species that reach their production goal relatively early have to be removed long before the main stand can be harvested. Wild cherry, aspen, Spanish chestnut and alder in beech or oak stands, are examples.

The aim of management, therefore, is twofold:

- These mixed trees should have sufficient growing space to reach their target diameter at an early stage.
- Later, at the removal of the temporary mixture trees, the canopy gaps should be small enough to be closed by the remaining final crop neighbouring specimens.

  Unlike true mixtures, therefore, the task of the forest owner in this forest type is to make sure that the trees destined for early removal are distributed only singly or in very small groups. This is an essential difference to true mixtures.

(4) Nurse crop mixtures

Nurse crop trees are used for protection of susceptible tree species against climatic stress. Normally, they will be removed immediately after they have served their purpose, that is when the nursed trees have reached a height of 4-8 m. Nurse species which have gained a lead of some metres on the target species tend to develop branchy, coarse crowns and may cause damage to or even suppress the main crop. Therefore, they must be removed in time.

Felling problems are one of the main reasons why it is easier to remove complete rows instead of only selected individual nurse trees. This is the main purpose for planting nurse crop species generally in rows.

Band mixtures of at least two nurse rows are much less destructive than alternate line mixtures with regard to damage to the main species. Nevertheless, they may cause problems if well-timed removal is neglected (Plates 4.5-30 and 4.5-31; refer also to Plates 4.4-33 and 4.4-34).

Plate 4.5-30: Oak-Norway spruce bands (3x3 rows) with two outside rows of Norway spruce removed.

Plate 4.5-31: Same stand as in Plate 4.5-30 showing improved oak quality. (Calvertstown, Co Kildare)

Forest owners tend to retain the nurse trees for as long as possible in order to avoid undesirable strong branch development of the remaining trees along the nurse tree rows. It is, however, generally preferable to produce sturdy young trees with large branches than have to accept badly suppressed specimens. Large branches can be pruned, but suppressed individuals hardly ever recover. This is not a huge investment as only a moderate number of potential crop trees needs pruning.

Although the fuelwood market has improved to some extent in recent years, felling and extraction of the nurse crop material is generally not economic. Whether this will change in the future is difficult to predict.

Several forest owners have established plantations with nurse trees – mainly oak plantations with single rows of Scots pine or European larch as nurses (refer to Chapter 4.4.6.8). This was the standard procedure for establishment since the 1990s and it carried a generous grant and premium. However, as the time for tending and thinning approaches many owners are still unaware, feel indifferent or may be confused about further appropriate operations. Others are unsure of the economic climate and prefer to wait.

Whatever the reasons, a delay in the timely removal of nurse trees through deferral or neglect, will result in a deterioration of the potential development of these stands. This, of course, is totally counterproductive in regard to the overall goals of mixture management.

In cases where the nurse crop trees are properly removed within the first two decades, the mixture as such no longer exists and subsequent thinnings follow the standard procedures which apply to pure broadleaf stands. There is, however, an exception. Provided some of the nurse crop trees are of good growth and high quality and do not compete with those of the main crop, they may be retained until they have reached merchantable dimensions in order to provide an intermediate revenue. Preferably, these trees should be adjacent to roads or ridelines so that they can be felled without causing damage to the main crop. Then these mixtures correspond to temporary mixtures.

In the future other tree species, such as alder or birch, may be used as nurses and other mixture forms, such as bands or group mixtures. They may play an increasing role, but this is an open question. These types of mixtures may need alternative thinning approaches.

(5) Mixtures along woodland edges

Forest visitors have a greater appreciation of forest edges, mainly because of their high visibility. Therefore, they are an important design element for forests with recreational functions and they form essential habitats for flora and fauna.

Woodland edges are the fringes between open and closed parts of the landscape, i.e. agricultural and forest land. Edges within the forest serve the same purpose.

Generally edges should be relatively open and shaped with as little regular design as possible. A great variety of trees with large crowns, alternating with gaps, create habitats for ground vegetation and shrubs which provide both aesthetic and ecological services in an optimum way. It would be an advantage if such procedures could be taken into consideration at the time of early tending. In practice, however, measures to form and improve the forest edges are usually not taken into account until thinning has already started. Yet this may not be a great disadvantage, because individuals of even less competitive tree species growing in the edge zone will never become as suppressed as they might within a stand. They may also recover after being released.

Along edges the selection of pcts is not a goal. Specimens with rather crooked and gnarled stems and crowns are usually more highly valued by visitors than those with high quality timber-producing characteristics. Forest edge zones also offer an opportunity to support rare trees and other species and to preserve their seed production potential.

4.5.6.3 Practical implementation of the management of mixtures

Mixtures are at risk if adequate growing space is not provided for the different species according to their needs. It is especially important in the case of pioneers, which have been planted singly or in very small groups, and are inevitably threatened with suppression at a later stage of their development. An intervention before the stand reaches the thicket phase and canopy closure is desirable in this situation. It can be carried out without much difficulty as the relative growth performance of species can be readily assessed at this stage. Mixtures in this situation can best be regulated with hand and power driven cutting devices.

Larger machinery, like harvesters or processors, are normally not desirable for two reasons:

- The stands in need of management are usually heterogeneous, and distinguishing between species from the cab of a machine is not easy. It is very difficult to manage them individually.
- Trees for removal are slender and not readily marketable.

The machines are much too expensive to economically carry out the first interventions. Only in the later stages will the use of harvesters or chippers be economic. The more regularly spaced the mixtures (e.g. in the form of rows or bands), the easier it will be for mechanical harvesting.

It must be reiterated that the management of some mixtures demands considerable silvicultural skills and a good knowledge of the growth characteristics of the various tree species. The task should be undertaken by the forest owner or by experienced foresters and not delegated to the harvester driver or other machine operator. The procedures should be implemented rigorously, and be targeted towards the development of the normal crop species, otherwise they will not be effective as young stands tend to develop rapidly. This is especially so if self-seeded pioneers like birch, willow, and alder have to be removed.

To date very little thinning of this type has taken place so no reliable cost and time data are available.

Conclusions

For several reasons – especially from the ecological point of view – mixtures are regarded as essential for achieving a high degree of nature-oriented forests and greater biodiversity.

The management of mixtures is, however, a delicate task within the field of silviculture. In addition to needing a clear idea about the objectives of the mixtures, it requires a great deal of forestry vision, including good ecological knowledge and an intuitive understanding of the dynamics of the tree species involved, as well as the modifying influence of the site conditions.

These circumstances seldom exist. This problem was highlighted by Baader as early as 1938: *The establishment of mixtures is much easier than their maintenance and enhancement in the succeeding life phases of a stand as they are much more dependent on personnel than site condition*. Regrettably his words are still valid – not only in Central Europe.

Most mixed forests, that have been planted since 1990, need urgent management within the next few years. Therefore, this will become one of the main challenges of broadleaf thinning in the future. If not thinned properly and in time, there is a high probability that many mixed stands will ultimately not meet the objectives for which they were established.

4.5.7 Pruning

Artificial pruning of broadleaves is an important issue, but little has been carried out so far in Ireland, due mainly to the age structure of broadleaf forests.

Broadleaves are usually established with high plant densities in order to encourage natural pruning and improve stem quality. The high stocking also provides a wider choice in selection of potential crop trees (pcts). As most of the broadleaf species have good self-pruning ability, the general practice of forest owners was to rely on this process. This was supported by the often voiced argument that the wounds caused by artificial pruning might become a source of fungal infection and lead to wood discolouration or rot. Furthermore, production of high quality timber from broadleaves was not always the main focus of the forest owners, and it seemed questionable whether the pruning investment would ever pay – even at low rates of interest.

This situation has recently changed because of the following reasons:

- Quality production of broadleaves is now a primary objective.
- The plant densities have been substantially reduced.
- Often plantations are not homogenous, and even poor successional stands may produce valuable products.
- Dead branch stubs left from shed branches may be a source of infection.

Artificial pruning is, therefore, regarded as an important means to upgrade stem quality. Experience has shown that plants have a great ability to occlude the pruning wounds without causing deterioration of the timber.

In the following sections information will be provided about stem branch intensity and natural pruning of broadleaves, in addition to the different types of artificial pruning and the reasons for applying them. Some technical aspects, as well as the actual status of pruning in this country, will also be provided.

4.5.7.1 Branching intensity and natural pruning of broadleaves

As mentioned in Chapter 3.2, the value of broadleaf timber is determined mainly by the branch intensity and knottiness of the stems.

Broadleaf crops generally lose their lower branches naturally through suppression and subsequent death. The branches are then shed if the stands are established following the best management practice, including formative shaping, and carefully controlled thinning which does not encourage excessive branch formation.

Density and spacing in broadleaf plantations, as well as natural regrowth is strongly related to the ability of the tree species to naturally self-prune (refer to Chapter 4.4.3.10).

Broadleaf stands are usually kept sufficiently dense until the branches have died up to heights of 6-10 m on the stem, depending on the species and productivity. This was referred to as the qualification phase of a young stand (refer to Chapter 4.5.3.1). Only then should thinning begin.

The branch intensity of broadleaf stands was considered to be of sufficient importance to be recorded in the NFI (Table 4.5-30).

The data illustrate that on average approximately 20% of the broadleaves have light branches, 70% have medium ones and more than 10% have heavy branches.

There are, however, great differences between the species groups which are especially apparent in the heavy branch category: Ash has the least percentage of branches. Birch and alder are moderately branched, whereas beech and sycamore are more branched than other species.

Table 4.5-30: Branching intensity of broadleaves (tree species groups) (minimum diam. 7 cm) (Adapted from NFI, 2007)

Light: Small or medium sized branches which occur infrequently – for instance on trees growing at high densities.

Medium: Branches present in quantity and size neither light nor heavy.

Heavy: Large diameter branches occurring frequently. Common on trees with unrestricted growing space, for instance, edge trees.

Species Group	Branchiness light	medium	heavy	Total
	%			
Oak	*18*	*66*	*16*	***100***
Beech	*24*	*51*	*25*	***100***
Ash	*30*	*65*	*5*	***100***
Sycamore	*23*	*54*	*23*	***100***
Other long-living broadl.	*12*	*71*	*17*	***100***
Birch	*20*	*71*	*9*	***100***
Alder	*17*	*75*	*8*	***100***
Other short-living broadl.	*11*	*74*	*15*	***100***
Mean %	***19***	***68***	***13***	*100*
Total 1,000 ha	15	53	10	**78**

These statistics are to some degree surprising as broadleaves are generally regarded as less branchy than conifers. It should, however, be recognised that most of the broadleaf stands in the country are young and have not yet passed through the natural pruning stage. Nonetheless, these data are generally in accord with experience gained on the self-pruning ability of the broadleaf species (Table 4.5-31), which has been described in Chapter 4.4.3.10.

Table 4.5-31: Self-pruning ability of the main broadleaf tree groups

Self-pruning ability	Tree species
Good	Alder, ash, birch, sycamore
Medium	Beech, hornbeam, oak, rowan
Low	Poplar, wild cherry, Spanish chestnut

4.5.7.2 Types of artificial pruning and reasons for their application

Both of these topics are dealt with separately below.

(1) Types of artificial pruning

The main types of artificial pruning are presented below (Table 4.5-32).

Table 4.5-32: Types of pruning according to objectives, importance and tools

No.	Pruning type	Objective	Procedure and importance	Tool
1	**Access pruning** (up to 2.5 m)	Improving infrastructure in the thicket stage to provide access, i.e. creation of inspection paths.	Often the 1st treatment before tending, normally done only on one side of the tree in rows through the forest. Inspection paths (every 3rd to 5th row). Often called brashing or low pruning.	Handsaw (possibly with short stick); knives (smaller branches); hand secateurs; light weight chainsaw.
2.1	**Quality pruning** 1st step (low pruning) (up to 2.5 m)	Improvement of stem quality of trees with the potential of producing large dimensioned quality timber.	Important 1st step (1st lift) of quality pruning. Part of shaping. Often in combination with access pruning (No. 1).	
2.2	**Quality pruning** 2nd step (medium pruning) (up to 6 m)		Succeeding pruning treatment of No. 1. Practised in broadleaf (and conifer) stands where high quality timber can be expected. Often 2.1 and 2.2 combined to save costs. 2.1 and 2.2 most important variants of quality pruning.	Pole saw (with long handled saw); handsaw and ladder; by-pass top pruner; powered pruner (pruning machines).
2.3	**Quality pruning** 3rd step (high pruning) (8-12+ m)		Seldom and locally; wild cherry, poplar (and possibly other broadleaves). Appropriate only when highly productive. Becomes more important where concepts of free growth are practised (agroforestry).	Tree climbing device (tree monkey); special ladders.
3	**Partial whorl pruning**	Avoidance of formation of large branches acting as entrance for rot through pruning wounds.	Especially with wild cherry (oak), first pruning large branches in a whorl, and taking off the smaller ones 1-2 years later.	As No. 2.1
4	**Reduction of shading pruning**	Reduction of shading pressure by overstorey trees for (1) tree seedlings, or (2) agricultural crop (in agroforestry systems).	(1) Pruning of single trees (free growth) in agroforestry systems or hedges (poplar, ash, sycamore, maple, oak, wild cherry). (2) Conifers (silver fir, Norway spruce) in selection and irregular forests.	(1) Handsaw and ladder (-10 m). (2) as No 2.

Except for access pruning (1), which is often referred to as brashing, all other pruning types serve the purpose of improving stem quality.

(2) Reasons for artificial pruning
Normally, natural pruning will meet the objective of obtaining branch-free trunks. There are several reasons, however, why it may be advisable not to rely on self-pruning alone, but to undertake artificial pruning instead:

- **Shortening of the qualification phase**
  If the branches are removed in time with saws or other tools it is not necessary to wait until they have died. This shortens the duration of the qualification phase.
- **Securing stem quality of potential crop trees**
  Potential crop trees (pcts) tend to be dominant in the stand. They normally have larger branches than the average tree which take a longer time to die and be shed. This is especially the case with species that prune poorly. Artificial pruning, therefore, secures branch-free stems at an early stage.
- **Depleted stocking**
  Plantations often have under-stocked areas where trees have failed. In the case of natural regeneration it may have developed irregularly. Wide spacing or gaps lead to coarse growth of the trees around these open spaces. It may even happen that after crop failure, only very few specimens have developed and become wolves. In these circumstances, artificial pruning may improve their quality so as to be sufficiently acceptable.
- **Special objectives**
  Other goals include removing branches for aesthetic reasons, e.g. trees along forest edges may have developed disproportionately large and heavy side branches which have to be removed.
  In nurseries, also, tall trees need to be produced with clean stems for planting as saplings along roads or in urban green field sites.

4.5.7.3 Technique of artificial pruning

Despite various attempts to develop power-driven pruning devices, hand tools are still the standard implements. This is partly due to the cost and weight of the power-driven equipment and partly due to the variable nature of broadleaf stems and branches.

Some of the main tools used have been mentioned in Table 4.5-32. Catalogues of equipment suppliers will provide detailed information.

In earlier times only dead branches were pruned because of the reservations mentioned above. Today green branch pruning is common. However, the maximum diameter of branches that can be pruned is still debatable.

According to the Forest Service (2000) pruning should be done before branches reach 5 cm diameter (Plate 4.5-32). In Germany recommendations are different. The maximum diameter should not exceed 3 cm – at least for wild cherry and oak. Both species develop heartwood in the branches when these become older and thicker. Heartwood is prone to infection by fungi and provides an entrance for rot which may later spread to the whole stem. This is the background of the partial whorl pruning mentioned in Table 4.5-32.

Beech is even more delicate as wounds larger than 2 cm in diameter may cause stem rot (Plate 4.5-33). Delayed or improper pruning may cause large wounds, which will facilitate the entry of decay organisms and ultimately lead to the deterioration of the timber.

Pruning, therefore, should be carried out as shown in Figure. 4.5-2.

Only pcts should be pruned. Their number will rarely exceed 150 stems/ha. So expenditure is not great. Some forest owners, however, tend to prune even those trees that have already fallen behind in growth. These types of arboricultural procedures, where the individual tree is the sole focus, are not appropriate to a forest stand. They are unnecessary, time-consuming, expensive and wasteful of resources.

Plate 4.5-32: Cherry with a large occluded pruning wound – more than 5 cm in diameter.

(North Circular Road, Dublin)

Although the wound was occluded it may have provided a source for stem rot.

Plate 4.5-33: Insufficiently occluded pruning wound of beech.
(Schönbuch, Germany)

Pruning permits the use of single trees in incomplete young stands or in the landscape by improving their bottom log at least (Plates 4.5-34 and 4.5-35).

4.5.7.4 Time of pruning

For most species, pruning is best done in late spring, just before trees come into leaf. This ensures that wounds heal quickly. With the trees free of leaves, it is also easier to see the crown architecture and to choose the best branches to prune. However, cherry and walnut must be pruned in late June or early July. In cherry, this is to minimise the risk of bacterial canker and silver leaf disease, and in walnut, to avoid excessive bleeding.

4.5.7.5 Actual status of pruning in Ireland

Pruning of broadleaves has not achieved much attention in Ireland to date (Table 4.5-33).

According to the data, which were confined to trees with a diameter

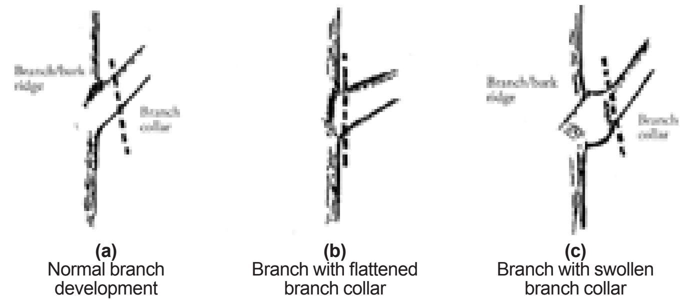


Figure 4.5-2: Positioning of pruning (and shaping) cut in relation to bark/branch ridge.

Table 4.5-33: **Pruning status** (ha) of broadleaves (dbh ≥7 cm) in Ireland. (Adapted from NFI, 2007)

Species Group	Pruning status		
	low ≤3 m	high ≥ 3 m	*% of species group area*
Oak	-	-	-
Beech	-	-	-
Ash	30	20	*0.5*
Sycamore	430	30	*11.5*
Other long-living broadleaves	20	-	*0.3*
Birch	-	210	*1.2*
Alder	10	160	*2.7*
Other short-living broadleaves	-	21	*1.3*
Total (ha)	**490**	**630**	
% of total area	*0.7*	*0.9*	

Plates 4.5-34 and 4.5-35: Free growing Spanish chestnut can be accepted as a potential crop tree after pruning (1st step). (Germany and Turkey)
Pruning can upgrade single trees of reasonable stem form. (see also Plate 4.7-1).

larger than 7 cm dbh, pruning has been carried out on less than 2% of the broadleaf area. High pruning was slightly more frequent than low pruning, and the area of pruned short-living pioneers, such as birch, alder and others, is larger than that of the long-living broadleaves. Moreover, in view of the dominance of ash planting, one could have expected that this species would have got preference in the pruning operation. Sycamore, however, is the species that had most pruning and this may reflect the large area that was planted in the earlier years of the current broadleaf grant scheme.

It should be noted that the data have been derived from very few inventory plots and are, therefore, subject to a large degree of statistical error. Nevertheless, they provide some useful information on how small an area has been pruned as well as the species involved.

Conclusions

Artificial pruning is an effective means of improving the quality of the lower and most valuable part of the trunk of potential crop trees. It is, however, a laborious and costly operation and a high investment at an early stage in the crop development. Because of the long time period to produce high quality trees the current forest owners will not profit from these endeavours. This may be the main reason why so little pruning has been carried out to date. However, pruning is an operation which can be carried out by farmers themselves at zero cost and should be recommended as best practice.

There is some evidence that high quality timber will be increasingly sought after by the market in the future.

4.5.8 Documentation on tending, thinning and pruning operations

As recommended in Chapter 4.4.9 (Planning and documentation of forest establishment procedures), it is important to record permanently all relevant details of the establishment treatments carried out. Thinning procedures and related activities should also be recorded by stands throughout the rotation as permanent records.

The documentation should generally include the following items:

- Number (name) and area of the stand,
- tending, thinning technique (selection of potential crop trees (pcts) and competitors),
- pruning activities (number of trees, location, height of pruning),
- time of procedure,
- amount of timber harvested (in total and per ha),
- costs and revenue of the operation,
- experience with labour force or contractors,
- timing of the next operation.

Besides documenting these details on stand-sheets, it is also helpful to record all thinning operations on an **overview map** and colour code the years of operation. Moreover, it may be advantageous to divide the stands into a maximum of ten block units and to always thin one block a year. Thus it will be easier to ensure that all stands will be thinned at least once in a decade. This ensures that no stand will be omitted and only those roads or extraction lines within the actual block are required to be in adequate condition for timber extraction.

Conclusions

The necessity for recording accurate and permanent data on stand management activities cannot be over-emphasised. Their value is twofold:

- to evaluate the past performance of the forest stands in order to understand the effect of previous silvicultural treatments, and
- to provide information for future planning.

4.6 Harvesting of broadleaves

4.6.1 Decision on the time of harvesting

When maximum volume production is the goal stands should be harvested when the current annual increment equals the mean annual increment volume (Figure 4.6-1).

However, trees are mainly harvested when they have reached a mature or exploitable size. This means that they have grown to dimensions that permit optimal utilisation and marketing. Often this is equivalent to achieving the target diameter. However, a target diameter is not necessarily a definitely predetermined size. It is highly dependent on species and the current market trends. These are much more varied for broadleaf timber than for conifers. As mentioned, broadleaf stems are of greatest value if straight, defect-free and large (Plate 4.6-1; refer also to Figure 3.2-1). In principle diameters are not subject to any upper limit. Occasionally

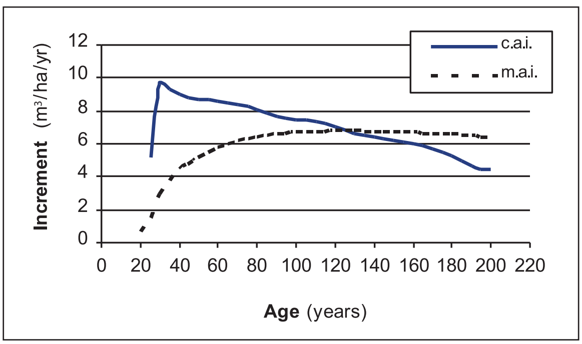


Figure 4.6-1: Current annual increment (c.a.i.) and mean annual increment (m.a.i.) of a productive oak stand.

(Yield class I equivalent to yield class 6.7 m³/ha at age 100 years – according to yield table, Juettner, 1955).

large dimensioned timber is devalued by discolouration, damage or rot. To avoid such occurrences stems should be harvested earlier. Beech for instance develops red heart, which may turn into brown rot later on. Ash often forms an olive-green heartwood which can be less valued by the market than white wood, and large oak stems may be subject to heart rot. This is the reason why forest owners often have to be content with maximum stem diameters of 40-50 cm.

The decision concerning harvesting time is, therefore, primarily based on current economic considerations.

Unlike many other land based products, standing timber has a unique flexibility in regard to harvest time. Once it has reached a certain size and quality it can be sold for a variety of products including sawtimber or veneer. Even more important is the extra dimension of time flexibility. Harvesting can be brought forward or delayed to suit market demand with little or no financial penalty.

When clear-cutting is employed, all trees are harvested at the same time when the majority have reached the target diameter. In these circumstances it is not possible to take into account the size of individual stems. Some may be too small, others may have already exceeded the target diameter threshold and wood quality started to deteriorate.

Plate 4.6-1: A perfect harvestable beech stem – large, straight and free of knots.
(Donadea Demesne, Co Kildare)

The situation is different with irregular silvicultural systems, where slender trees can be kept for variable periods over the regrowth. After having reached the designated dimensions they can then be harvested. In this way, it is possible to manipulate the harvesting process to achieve a noticeable increase in added value, though at the expense of greater harvesting costs than would be incurred in clear-felling.

In addition to these economic considerations, other issues should be taken into account. This is especially the case when regrowth already exists or natural regeneration is envisaged. Harvesting could thus be extended over a longer period. In Chapter 4.2.2.4, it has been shown that it may take 20-25 years between the first removals of canopy trees and the final cuttings if beech is managed under a shelterwood system. The stands are opened very gradually according to the need for shelter when the seedlings are becoming established and while they require more light at the sapling stage.

In the early stages these interventions resemble late thinnings, but they differ according to the objectives of the operation:

- During the thinning phase, the forester assesses the crowns of the canopy trees with the intention of improving the growing conditions of the best specimens: the main focus, therefore, is upwards into the crowns.
- During the harvesting phase in the shelterwood system, the main focus is downwards, assessing the growing conditions of the regrowth and how these can be improved. As a result, the forester will then decide which trees in the canopy have to be removed.

Totally different considerations apply to forests or forest edges that are important for recreation or nature protection. Old specimen trees, which are full of character and high aesthetic charm, have to be retained as long as possible. These are highly esteemed by visitors (refer to Chapter 3.4). Countless paintings, drawings, prints and photographs have conferred an iconic status on them and helped to form the European ideal of how nature should appear. They may be removed only in situations where the shedding of dead branches might endanger the public.

Old trees and deadwood provide important habitats for insects, birds and fungi (refer to Chapter 3.3.7). For this reason a small number should be excluded from harvesting.

4.6.2 Threat of damage to sheltering trees and regrowth by felling and extraction operations

Clear-cutting is the simplest and easiest system to implement as the existence of regrowth need not be taken into account. That is part of its attraction. However, felling large-crowned old specimen trees in shelterwood systems requires a high degree of skill and accuracy by well-trained forest workers. A system of racks, extraction lines and roads is also necessary – which are described in more detail in Chapter 4.8. Trees with asymmetric crowns are often felled with special felling support devices. Otherwise they may accidently fall into groups of regrowth or will cause damage to it during the extraction process. Damage tends to be worst on slopes as the boles are inclined to slide downhill. In the process they may cause bark wounds to standing trees, which later become entrances for rot or result in deformation of seedlings and saplings.

Felling damage is regarded as very undesirable in some enterprises, and old trees with big crowns are sometimes first debranched manually before the stem is finally felled (Plates 4.6-2 and 4.6-3). This, however, is an extreme and very expensive process.

Effective management of broadleaves is thus dependent on an appropriate network of roads and extraction tracks, skilled workers and suitable equipment.

Plates 4.6-2 and 4.6-3: Debranching an old beech over regrowth.

(Brussels, Belgium)

A worker has climbed up the main stem and started to debranch it with a small power saw as used in tree surgery.

After the crown has been removed the remaining stem can be felled without causing too much damage to the beech underneath.

4.6.3 Harvesting as an influence on the future forest structure

The choice of a silvicultural system has a deciding influence on the composition, structure and quality of the future stand:

- By clear-cutting any protection is removed against strong sun, evaporation or late frosts that may occur. The felled stand may however, have some indirect after-effects, such as seeds may have been distributed before felling or coppice shoots from the stumps may develop and influence the species composition. Pioneers will benefit from clear-cut conditions. In contrast, shade-tolerant species have restricted opportunities to grow because of their susceptibility to early autumn or late spring frost as well as to drought. Stands that have been reforested on clear-cut areas resemble new plantations being established on formerly bare ground. All will grow up as even-aged, pioneer-dominated and mainly single-storeyed stands, which is typical of the majority of all forests in Ireland.
- In all other silvicultural systems, including the strip-cutting and short-term shelterwood system, the old trees more or less influence establishment and development of the regrowth. In the continuous cover forest system they are especially important.

Apart from the ecological protection, the rapid removal of the sheltering trees from over the seedlings has some consequences. These have been mentioned in Chapter 4.2 (Silvicultural systems), but are repeated briefly here in view of their silvicultural and forest structure importance.

4.6.3.1 Development of species composition

Remaining old trees will produce more seed the longer they are kept, if they have the ability to extend their crowns. Where conditions are favourable, this will result in a certain level of natural regeneration. Empty gaps can be sown or planted where natural regeneration does not occur and as long as no impeding ground vegetation exists.

The faster the overstorey trees are removed, the more the light-demanding species will take advantage of the conditions. This is necessary if light-demanding species like oak are to be favoured. The opposite occurs with slow removal. Shade-tolerant species are then actively promoted.

Variable treatments within a stand – larger openings as well as more gradual removals – allow for increasing diversity of species composition and structure, which are features of continuous cover forestry with multiple objectives, or sites containing many different and variable soils.

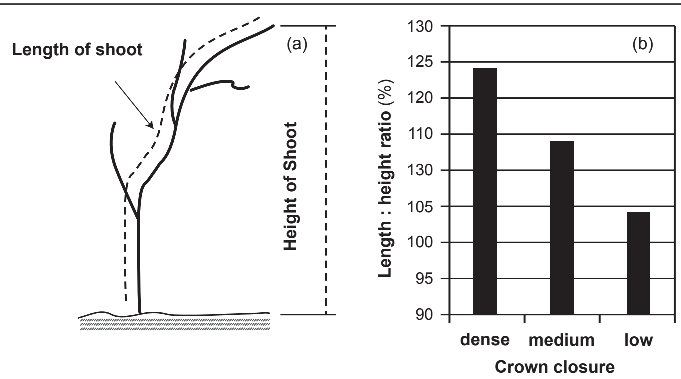
In all cases, the ordered structuring of harvesting over time offers an effective means of steering the composition of the succeeding stands.

4.6.3.2 Regulation of the quality of regrowth

Seedlings and saplings have more slender stems and lighter branches when they develop under the shelter of older trees. Hence their quality can be improved when they are kept for a longer time in shade. An added benefit is that less shaping and tending will be required in the early stages. Yet, at the same time they show less resistance to wind damage and snow breakage because of their lack of sturdiness. This, fortunately, is usually of relatively minor importance.

When kept too long in shade, however, young trees tend to grow towards the horizontal, seeking out any light source at the edge of the stand (Figure 4.6-2 and Plate 4.6-4). If released at this stage, they tend to become very branchy. Thus the opposite effect to that intended may be achieved.

Plate 4.6-4: Beech planted under Scots pine in forest conversion. (Schnaittenbach, Germany)
Because of poor light conditions the young trees tend to lack apical dominance and grow towards the available light.



(a) Measuring shoot length and shoot height as a basis for expressing stem form.

(b) Differences in the ratios of shoot length and height as influenced by the density of the canopy.

Figure 4.6-2: Sketch of **plant growth in dense shade**: total length is greater than height.

Conclusions

Sensitive light adjustments during the regeneration phase are an effective silvicultural means of influencing the quality of young plants.

Well regulated harvesting of old trees is, therefore, an additional, but challenging silvicultural procedure in order to support and safeguard the establishment and management of new stands.

It is evident that harvesting and regeneration are strongly interrelated in all silvicultural systems, except clear-cutting, as has been mentioned in Chapter 4.2.

4.7 Improvement of degraded or poorly stocked forests and enrichment of hedgerows

4.7.1 Challenges and objectives associated with improvement strategies

During the past two decades the majority of Irish broadleaf forests have been established by planting on former agricultural lands (Chapter 1.4). Young stands of a more or less homogenous nature were established which increasingly require thinning. This is the reason why this book was primarily dedicated to establishment of new forests mainly on farm land and their subsequent management.

In addition, the improvement and rehabilitation of degraded or poorly stocked woodlands will also become an increasingly important issue. Dealing with degraded and poorly stocked areas is a new challenge for which little experience exists up to now. There are, however, various types of land covered with trees or scrub which could be converted to high forest by more intensive management and in the process, become more productive and fulfil several different objectives:

- **Increase of productivity**
  Forests and woodlands represent national resources for the production of timber and fuelwood, which will be required in increasing quantities.
- **Improvement of native woodlands**
  Several poorly stocked woodlands exist which have little value with regard to biodiversity, recreation, soil protection or landscape architecture. If treated in a professional and appropriate manner, through proper improvement operations, these would become more productive forests capable of delivering multiple objectives.

The main types of degraded, or otherwise unsatisfactory woodlands will be described in the following sections, and possible silvicultural options are suggested. Finally, an estimation of the magnitude of the potential area suitable for forest improvement will be provided.

In practice, soil degradation and forest degradation are often treated as synonyms. This is incorrect. Soils become degraded for various reasons: as a result of erosion after clear-cutting in steep terrain, humus mineralisation because of exposure, soil compaction as a result of long-term pasturing by animals or mechanical compaction from operations within the forest area (refer to Chapter 2.5.3.1). Forest degradation on the other hand is mainly due to repeated over-exploitation and forest destruction. Afforestation or enrichment planting generally helps to rehabilitate the forest, and indirectly also helps to restore soil fertility. In the following subchapters the terms degradation and rehabilitation refer mainly to forests rather than soils.

4.7.2 Types of tree covered areas and optional improvement procedures

As indicated, there are very large differences in the types of areas with potential to be improved or developed in order to make better use of the resources. Because of their diversity, it is difficult to classify them. Nevertheless, the following approach is suggested as a help to illustrate the general possibilities.

4.7.2.1 Overview of degraded and poorly stocked areas and main silvicultural improvement procedures

In Table 4.7-1, the most important types of degraded and poorly stocked forest areas are listed and some relevant silvicultural methods for improvement are suggested. In all, nine types have been identified, based mainly on the NFI (2007) classification system. They represent a wide range of cover types, from fully stocked with poor quality trees to scrub types and finally to bare land. Because of their great variability they demand a wide range of silvicultural procedures: from thinning (the more advantageous) to a combination of thinning and enrichment planting and finally afforestation which is the less favourable option.

Table 4.7-1: Types of **tree or vegetation cover** according to relevance, availability and optional silvicultural improvement possibilities.

No.	Vegetation cover type		Description	Optional silvicultural activities
1	**Old depleted/ degraded woodlands**		Irregular distribution of over-mature broadleaf specimens of poor quality after repeated cuttings of the best stems (assortment cutting); regrowth of trees and scrub.	(1) If acceptable regrowth existing: **thinning (pruning) of pcts.** (2) In case of existence of suitable mother trees: **encouraging natural regeneration** (possibly after ground preparation). (3) If shelter of old crop existing: **enrichment underplanting**. (4) If poor young growth existing: **coppicing**.
2	**Depleted stocking**/ failure of plantation		Poor quality planted regrowth because of poor planting stock, damage by frost, deer, weeds.	Salvaging poorly growing established plantations: **shaping, thinning, groupwise enrichment planting or total replanting.**
3	**Closed birch, alder, willow stands**		Pure or mixed, mainly heterogeneous in structure from natural regeneration (succession). Partly on neglected pastures.	(1) Good quality birch: **selection of pcts**. Later underplanting with future target species (e.g. oak). (2) Opening up canopy; using existing **canopy as nurse**/shelter; **underplanting** with target tree species (in case of poor soil, also with conifers).
4	Poor quality **conifer stands** on good sites		Conversion into broadleaf or mixed broadleaf-conifer stands.	(1) **Underplanting** with shade-tolerant broadleaves under canopy. (2) **Planting** light-demanding broadleaves **into larger gaps** (>500 m²).
5	**Other woodlands**/ small (urban) woodlots		Groups of trees that do not meet the forest definition (>0.1 ha in area and >20 m in width). Sometimes closely connected with hedgerows.	(1) If some good trees present: **selection of pcts**, pruning, free growth management. (2) If low quality: **planting of single trees** (saplings) or **group**.
6	**Scrub/shrub**		Heterogeneous cover of scrub, reaching a height of >0.5-<5 m.	(1) **Single tree planting into gaps**. (2) Clearing of small gaps and **groupwise planting**.
7	**Cutover areas**, (partly with trees)		Heterogeneous distribution of single trees or groups of remaining poor quality broadleaves and/or young growth by succession.	(1) **Selection of pct**s. (2) Possible **coppicing** (birch) in order to improve stem form. (3) **Enrichment planting** into gaps.
8	**Hedgerows**		Increasing timber resource, improving shelterbelt function.	(1) **Selecting of single trees** of reasonable quality; pruning; removal of possible competitors. (2) **Planting of saplings** into hedges, later management as in (1).
9.1	**Bare land**	small scale (<1 ha)	Small patches of more or less open land within or outside forests.	Waiting for **natural succession** by scrub and pioneers, as in 5.
9.2		large scale (>1 ha)	Poor neglected pasture; cutaway peat; forest open area; bog and heath.	(1) As in 9.1. (2) **Establishment of nurse crop** (e.g. by sowing birch). (3) **Afforestation** as described (Chapter 4.4).

In the following subchapters, the silvicultural improvement possibilities will be described first (Chapter 4.7.2.2). Then the technical and ecological aspects and obstacles will be dealt with (Chapter 4.7.2.3) and finally the areas available for these improvement treatments will be calculated. For all these the NFI data will be used to provide information about the relevance of the respective vegetation cover types (Chapter 4.7.3).

4.7.2.2 Silvicultural principles of improvement treatments

As indicated above, the main silvicultural possibilities, options and principles of restocking and improvement measures are the following:
(1) Thinning rather than planting.
(2) Pruning of isolated high quality young trees.
(3) Coppicing of low quality broadleaves.
(4) Retention of trees and scrub for shelter.
(5) Planting in groups.
(6) Planting of transplants and saplings.
(7) Direct seeding.

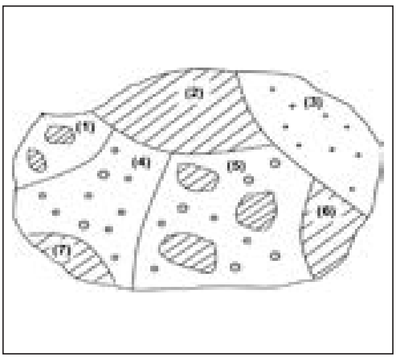
They will be described below.

(1) Thinning rather than planting

Experience has shown that the number of trees of reasonable quality is generally greater than that obtained from first impressions. This is even the case in degraded forests. In poorly stocked woodlands especially, the tendency is for foresters to focus on the poorer quality trees rather than the reasonably well-formed individuals. It is always a good exercise to start first by looking for trees of an acceptable quality and marking them. Even in the most extreme cases, usually some, or even groups of acceptable specimens, will be found in many woodlots.

The second step generally involves identification and selection of competitors (refer to Chapter 4.5.5.8 (2)). Although distances of 10-20 m between acceptable trees may appear excessive in young stands, their numbers will still be sufficient if gradually released from malformed competitors during the coming decades.

From studies in degraded forests it was found that the density and quality of trees within given areas differed remarkably. Groups of good stems beside those of very low quality were common. In such cases different treatments on a group basis are the best option: thinning in the good groups and planting in the others (Figure 4.7-1).



Sub-area No.	Condition/ status	Area		Rehabilitation
		ha	%	
(2), (6), (7)	Poorly stocked pole-stage parts with trees suitable for pcts.	7	*27*	Thinning, selection of potential crop trees.
(1), (5)	Thickets with few potential crop trees only.	8	*31*	Favouring some straight young trees, possibly by pruning; enrichment planting.
(3), (4)	Totally degraded wood with some scrub.	11	*42*	Planting; maintenance of the scrub for reduction of climatic bare land stress; natural succession.
	Total	**26**	***100***	

Figure 4.7-1: Subdivision of a degraded and poorly stocked forest area.
The recommended silvicultural procedures are given as in the table.

It is difficult to define exactly how many trees per unit area of reasonable vigour and quality are necessary to form a stand, or when thinning is reasonable, or afforestation seems to be necessary. Nevertheless, in case of doubt it can be confidently stated: thinning saves money compared with planting – and, therefore: **thinning should always be the first consideration!**

(2) Pruning of isolated high quality young trees

Pruning is a perfect method of improving free-growing trees with straight stems and no injuries, but with coarse branching. If not pruned, they could develop into wolves. However, when pruned, they may grow vigorously as single trees in a form of free growth, or later close canopy when their crowns come into contact with those of their neighbours (Plate 4.7-1, refer also to Plates 4.5-34 and 4.5-35).

Many trees in hedgerows or alongside roads could also qualify in this way (Plate 4.7-2).

As a general conclusion it can be stated: **pruning of single trees is much more cost effective than replanting large areas.**

(3) Coppicing of low quality broadleaves
After felling of conifers any remaining younger broadleaves, or even older broadleaves, can be coppiced and the gaps between the stools planted (Plate 4.7-3). It is, however, essential that the stool shoots are singled after a few years growth.

Another conclusion is: **coppicing may also reduce costs, but needs intensive subsequent management.**

(4) Retention of trees and scrub for shelter
Wherever feasible, trees and scrub should be left as a shelter against wind, drought and late frost. Scrub growth is often irregular in density, with gaps or empty pockets in between, into which single transplants or groups can be planted. The removal of only a few bushes may be required.

Keeping some scrubs and trees can be advantageous in many respects:

- The smallest possible clearings will reduce costs.
- They provide shelter for the young regrowth.

Plate 4.7-1: A single birch of reasonable stem form may act as a seed source for the development of a forest on a degraded site. (Ashford, Co Wicklow)

Plate 4.7-2: Single trees alongside roads or in hedgerows can be improved by pruning in order to produce a butt log of reasonable quality. (Ash in Montenegro)

Plate 4.7-3: Poor quality broadleaves remaining after harvesting mature conifers. (Cong, Co Mayo) If coppiced they could form a new stand, however, this area would also need enrichment planting.

- They will act as fillers for some years, thus reducing the need for high densities within the enrichment planting areas. Their removal at a later development stage is, however, essential.
- Willow especially may serve as fodder for deer and, therefore, indirectly, reduce browsing of transplants.

In 1886, Gayer, one of the most famous German silviculturists of the 19th century, strongly criticised the practice by many German foresters of clearing large afforestation areas of all vegetation in order to have neatly arranged compartments. In later years, they encountered great difficulty in getting their plantations established and growing, mainly because of late frost and desiccation.

As a conclusion, therefore, it is strongly recommended that there should **never be total clearance of felling areas!**

(5) Planting in groups

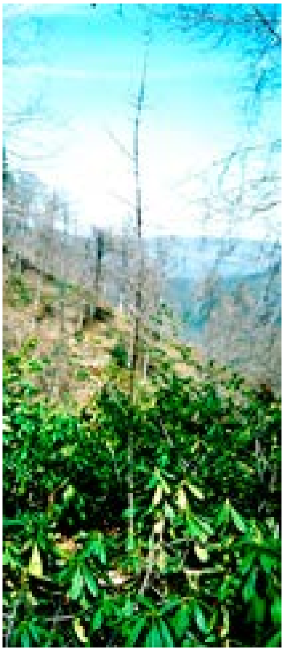
As indicated in Chapter 4.5.5.6, pcts may be treated in groups when they are scarce in other parts of the plantation. This practice may also be extended to planting in groups. The minimum size of group planting should be the equivalent of the crown size of one adult tree at the time of harvesting – 100 m^2 is a good average. Within groups of this size, there is a strong likelihood that at least one individual will reach the upper canopy and become a dominant crop tree. For smaller groups or single trees, this likelihood is greatly diminished without constant attention to ensure their survival.

Group planting may also increase biodiversity since parts of the original scrub and tree cover will be retained. It also creates favourable conditions for the establishment of multi-structural forests. Group planting is less worthwhile on bare land, unless the gaps between groups can be filled by natural regeneration (succession).

In conclusion: **introducing trees in groups will reduce the area to be enriched by planting and provides shelter for young plants being planted into the existing gaps in between.**

(6) Planting of transplants and saplings

Closed cover of ground vegetation on unplanted land as well as scrub in poorly stocked areas, may impede establishment of seedlings or transplants and their later development. Transplants are often too small and need repeated intensive weeding. Saplings – plants of more than 1 m in height – may overcome the competition more easily and do not need weeding (Plates 4.7-4 and 4.7-5). Although they are expensive, more difficult to plant, but future management costs are much lower.



Plates 4.7-4 and 4.7-5: Sycamore saplings planted in small gaps in rhododendron scrub illustrate the possibility to enrich scrubby vegetation with broadleaves. (Northern Turkey)

Saplings of ash, oak and wild cherry are also appropriate for inserting into hedgerows.

In conclusion: **saplings present options to establish a variety of trees in scrub areas or hedgerows.**

(7) Direct seeding

As mentioned (Chapter 4.4.4) failed areas and gaps have often been filled-in by dibbling (oak) acorns into the soil. This has worked satisfactorily in Central Europe. The main problem, however, is the threat from deer until the plants have grown out of the browsing zone.

Direct seeding of birch can help in the establishment of nurse crops for target species such as oak and beech (refer to Chapter 4.4).

Both techniques are worthy of trials in Ireland at an experimental level in order to gain knowledge on their viability.

4.7.2.3 Technical and ecological aspects: possible obstacles

Improvement operations in low quality stands may produce wood chips which can help to reduce costs. This opportunity will, however, be rarely available. Mixtures of tree groups of different species and genera, regeneration succession as well as plantations, could provide ecological advantages because of greater biodiversity and uneven-aged structure. However, the obstacles listed below will often impede, or even exclude, any silvicultural activity:

- Wet or stony sections which are difficult to restock.
- Severe exposure in uplands may exclude afforestation.
- Lack of accessibility may greatly complicate any forest establishment or management activity. Planting of broadleaves is greatly endangered by deer, especially when single trees are planted. Oak, ash and sycamore normally cannot be established without effective fencing.
- Natural regeneration is not possible in most places, because of lack of seed-bearing trees.

Because of these and other obstacles only a proportion of the existing degraded and poorly stocked forest land may be rehabilitated in practice. This will be discussed in more detail in the following subchapter.

4.7.3 Calculations relating to the possible improvement of forest and woodland areas

Some calculations have been made to provide a rough estimate of the possible area that could be improved by silvicultural treatments. The NFI data provide a separation of the respective poorly stocked areas **inside** the existing forest area, and those **outside**. This division is of relevance with regard to application in practice. It is much more realistic to carry out improvement measures in areas which are already part of forest areas than in those which are outside the forest area.

To get a rough idea about the size of rehabilitation areas concerned, three grades of improvement intensities have been calculated: low – moderate – high. These grades are based on the percentage of areas given for the land cover types. Low indicates that 10% of the respective poorly stocked area can be converted. Moderate is equivalent to 20%, and high to 30%.

In some cases these percentages have been modified where it seemed necessary. The figures are given in the next two tables (Table 4.7-2 and 4.7-3). These grades can be regarded as equivalent to pessimistic, realistic and optimistic scenarios.

4.7.3.1 Improvement of forests within the existing forest area

In Table 4.7-2, the areas of the main forest types and bare land within the forest area are listed. The table also contains area data according to low, moderate and high conversion rates.

Table 4.7-2: Areas related to forests and **estimated conversion areas** according to different scenarios. (Areas adapted from NFI, 2007)

Forest type	Objective	Area	Conversion area and percentage					
			low		moderate		high	
		1,000 ha	1,000 ha	%	1,000 ha	%	1,000 ha	%
Oak	Rehabilitation of degraded woodland	14.6	1.4	*10*	2.8	*20*	4.2	*30*
Beech		8.7	0.9	*10*	1.8	*20*	2.7	*30*
Ash		19.2	1.9	*10*	3.8	*20*	5.8	*30*
Sycamore		8.1	0.4	*5*	0.8	*10*	1.2	*15*
Other long-living broadleaves		9.6	1.0	*10*	1.9	*20*	2.9	*30*
Birch	Development of quality forest	29.7	3.0	*10*	9.9	*30*	14.8	*50*
Alder		11.5	1.2	*10*	2.3	*20*	3.4	*30*
Willow		50.6	16.8	*30*	25.3	*50*	42.1	*70*
	Subtotal	152.0	26.6	*18*	48.6	*32*	77.1	*51*
Conifers	Conversion	462.6	23.1	*5*	46.3	*10*	69.4	*15*
Forest open area	Improvement of timber resource	72.0	7.2	*10*	14.4	*30*	21.6	*50*
Bare land within forest		50.0	5.0	*10*	15.0	*30*	25.0	*50*
	Total	**736.6**	**61.9**	***8.4***	**124.3**	***16.9***	**193.1**	***26.2***

It is assumed that of the 152,000 ha of broadleaf forest, the rate of degradation is low for long-living species. Therefore 10, 20 and 30% may need rehabilitation. The only exception is sycamore, where the majority of stands have been established only in recent years.

Stands of short-living pioneers, such as birch and willow, may be transformed at rates of 10, 30, 50 or even 30, 50, 70%.

Thus, in total, around 25,000, 50,000 or 75,000 ha are available that would need rehabilitation. Oak, beech and ash stands, especially in the other private forests, have first class soils and are located mainly in the lowlands and would be suitable for improvement (Plate 4.7-6).

Plate 4.7-6: Unstocked plots in former conifer forests may be enriched by group planting of broadleaves. (Donadea, Co Kildare)

Birch, alder and willow are distributed in all forest ownership types. They cover a large area and should, therefore, be seen as a challenge and have potential for conversion.

If conifer stands were to be converted into mixtures with broadleaves, or into pure broadleaf stands, this would greatly increase the area for improvement because of the size of the conifer areas. By including the open area and bare land within the forests, around 60,000, 120,000 and 190,000 ha would be available for silvicultural activities. However, open space is an essential component for biodiversity, so that the low or moderate scenario only may be accepted.

4.7.3.2 Improvement and afforestation of areas outside the forest

Outside the official forest areas there are several other areas which could also – at least partially – be converted into forest of higher production or ecological value (Plate 4.7-7). These are given in Table 4.7-3.

Table 4.7-3: Other areas suitable for forest improvement and estimated conversion areas according to different scenarios. (Areas adapted from NFI, 2007, see also Tab. 1.5-1)

Land type	Objective	Area	Conversion area and percentage					
			low		moderate		high	
		1,000 ha	1,000 ha	%	1,000 ha	%	1,000 ha	%
Grassland	Improvement of timber resource	3,760	38	*1*	113	*3*	188	*5*
Hedgerow		272	27	*10*	54	*20*	82	*30*
Scrub		88	18	*20*	26	*30*	35	*40*
Other woodland		49	5	*10*	10	*20*	115	*30*
Cutaway peat		190	19	*10*	38	*20*	57	*30*
Bog and heath		870	43	*5*	87	*10*	130	*15*
	Total	**5,229**	**150**	***2.9***	**328**	***6.3***	**507**	***9.7***

With the exception of grassland, all land types and the optional silvicultural treatments have been included in Table 4.7-2.

Grassland is generally very suitable for afforestation and although farmers may show little willingness to sell pasture land at present, it is assumed that land availability will improve in the future. As part of this land is marginal for grazing, a small proportion has been included in the three scenarios.

In total, around 150,000, 330,000 or possibly even 510,000 ha seem to be available for rehabilitation.

Plate 4.7-7: Cutaway peat area that could be used for afforestation or will eventually be colonised by birch and willow if left unmanaged. (Boora, Co Offaly)

4.7.4 Critical discussion

Table 4.7-4 is an amalgamation of the areas given in the two previous tables.

Table 4.7-4: Total of rehabilitation areas according to conversion scenarios

Rehabilitation area	Conversion area low (1,000 ha)	moderate	high
Inside forest area	62	124	193
Outside forest area	150	328	507
Total	**212**	**452**	**700**

The main message of these calculations is that there are substantial areas that could – and should – be upgraded and converted into productive high forests as well as woodlands of higher ecological quality. There are obviously greater land area reserves in the country available for improvement than recognised so far. Even the potential of hedgerows has not been sufficiently valued to date.

The grading, of course, may be highly questionable. With the availability of better data, however, it is easy to change the estimates and adapt them according to new information. Nevertheless, the calculated values seem to be appropriate to provide at least an estimate of the approximate size of the area in question.

The conversion and improvement of these areas would mainly concern broadleaves. It is noteworthy that the figures of the lowest scenario exceed the current actual area of broadleaf forests. Thus the relevance of broadleaf forestry in Ireland could increase considerably in the long-term.

Conclusions

There are large areas of land that could be converted into forests of at least reasonable productivity and quality. These are estimated to be between 200,000 and up to 700,000 ha. The potential of these areas for timber production or natural habitats may gain increasing importance in the future. Broadleaves could play a dominant role in the rehabilitation of these areas, but as little experience has been gathered so far, intensive studies will become necessary.

Rehabilitation will often include a close combination of thinning and establishment measures, but the transition between both is always dynamic. This again is a great challenge to foresters and policy makers.

A difficult task will be to prioritise the most expedient steps to be undertaken. This is a task, however, not primarily for silviculturists, but for politicians or even for the whole of society.

Options for implementing rehabilitation activities will be discussed in Chapter 5.

4.8 Accessibility as a precondition for silvicultural activities

4.8.1 Introduction: Multifunctional role of access roads and racks

Proper silvicultural management of forests is only possible with adequate access. This is expressed in the saying: Silviculture is road building! In all cases, silvicultural activities depend on appropriate roads and racks so these need to be considered from the outset. Roads are generally regarded as necessary and need only be constructed for timber extraction when harvesting is imminent. However, it has become increasingly apparent that they are relevant in the initial planning and establishment phases of a forest enterprise.

Their role is manyfold as they serve various functions including:

- access to planting sites for ground preparation, transport of workers and plants,
- access for further management tasks like filling-in, weeding and vermin control,
- for thinnings and, of course, they are essential for harvesting of the final crop,
- access for inspection, fire control, hunting,
- serving the public for recreation, walking, hiking and other leisure activities.

They may also add to some aspects of biodiversity by providing open space and edge habitat within the forest.

Accessibility is, therefore, a pre-requisite for silvicultural activities, but these activities can also help to improve the overall conditions in a forest. Some aspects of roading, from the silvicultural point of view, are outlined below. However, road building in itself is not the subject of this book. For further information the reader should consult the *Forest Road Manual* by Ryan et al., (2005) and the *Forestry Schemes Manual* by the Forest Service (2011).

4.8.2 Accessibility

4.8.2.1 Access to forest stands and infrastructure within the forest

Access is normally provided by forest roads which are subject to low-intensity and slow-moving traffic.

While some forest roads are constructed to facilitate development and general management of large blocks, the majority will be for extraction purposes.

As stated in the Forest Road Manual, forest roads should have a tree clearance of 15 m (Figure 4.8-1).

In practice, forest roads are often too narrow, particularly with regard to the width of the verges on either side of the carriageway. These verges may serve the following purposes:

(1) Timber stacking and storage at time of thinning,
(2) facilitation of movement of machinery,
(3) provision of aesthetic values and biodiversity,

(4) reduction of windthrow through edge effect.

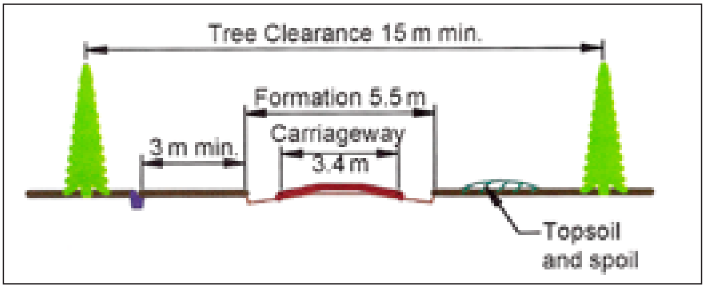


Figure 4.8-1: Typical forest road cross-section for flat to gently sloping mineral soil site. (From Ryan et al., 2005)

(1) Timber storage
Verges act as temporary storage areas for thinnings, where timber is brought from inside the stand by forwarder for later collection by the processor. These storage areas should be located at appropriate places and be of sufficient width.

(2) Adequate room for movement of machinery
Roads with sufficient open space along the sides provide an overview for the forest owner and all workers. Machines need turning spaces, which are often not given sufficient consideration.

(3) Zones of aesthetic value and biodiversity
Roads create edges which provide a great variety of aesthetic values and biodiversity, as mentioned in Chapters 4.4.6 and 4.5.6. This will be possible, however, only if they are wide enough to offer sufficient permanent space to allow the growth of a variety of ground plants, shrubs and small trees.

Many forest owners do not realise that the trees of the adjoining stands will also make use of the open space. Their crowns grow into these open spaces and develop branches several meters in length, thereby overtopping the banks, or even parts of the road, and shading out the roadside vegetation. Verges of 5 m width are normally recommended and, together with other forest edges, may add to the biodiversity of a forest.

However, roads are not always advantageous with regard to biodiversity. They can act as barriers for insects, amphibians and small mammals by restricting their movement. Afforestation projects greater than 10 ha in area must include space for biodiversity enhancement, comprising 15% of the total area. These areas can include open spaces (e.g. headlands, tracks, riverbanks), retained habitats, scrub, and existing trees. A minimum broadleaf species component is required.

Road building and timber transport may also damage tree roots and cause stem rot. Moreover, they may disturb the local water regime and cause run-off of precipitation and siltation. Therefore, details about road building near streams and riparian zones should be consulted in the *Forest Road Manual* (Ryan et al., 2005).

Plate 4.8-1: Forest road with a pavement capable of carrying heavy timber loads. (Lacken, New Ross, Co Wexford)
The trees alongside the road have used the open space for crown expansion and almost fully closed the canopy.

(4) Reduction of windthrow
Although windthrow is of greater significance for conifers, broadleaves with well developed crowns at the forest edges provide effective shelter for all types of adjoining forests.

While this lowers the planting costs, the productive area is not necessarily reduced, provided that the open space does not exceed around 5 m at each side of the road. The edge trees will take advantage of this growing space, but they will develop heavier branches (Plate 4.8-1).

Conclusions

Road density is highly dependent on a variety of factors. These include terrain and soil conditions, shape of the forest property, location of streams, riparian zones and lakes, historic features such as archaeological monuments and finally the type of machinery used.

Road building is the second largest investment for the forest owner and is grant aided by government. Grants of €800 per ha are currently available for road building up to a density of 25 m per ha (Forest Service, 2011, *Forest Schemes Manual*).

In larger afforestation areas it may be advisable to divide a forest enterprise into management units and build roads in blocks according to the priorities for tending.

4.8.2.2 Access within the stands

The spatial arrangement of plants may influence the task of planting and all succeeding operations on the regeneration areas. Racks that provide a permanent infrastructure are even more important than roads for the successive treatments (Plate 4.8-2).

The following arrangements should be considered:

(1) Spatial order of the plants to facilitate planting and the follow-up management procedures.
(2) Establishment of a pattern of extraction racks at time of planting.
(3) Infrastructure to enable tending and thinning operations in young stands.
(4) Sufficient width of racks to accommodate tractor access and to avoid damage to the edge trees.

Plate 4.8-2: Extraction rack, approximately 4 m wide in a young ash stand.
(Summerhill, Co Meath)
Racks enable early access for thinning operations and extraction of wood.

(1) Planting direction to facilitate work in the forest

Planting, whether by hand or with machine, is generally made easier by using row spacing (refer to Chapter 4.4.3.10). Long rows are best as they facilitate machinery and save expense.

On flat terrain, the rows should be oriented towards the main entrance and extraction direction. On hilly terrain, it is preferable to plant parallel with the contours and rows should, therefore, be directed in that direction. On steep terrain, timber extraction is increasingly downhill and the rows should face in this direction. The direction of planting lines will have a major bearing on the machinery involved in harvesting.

(2) Establishment of a pattern of extraction racks at time of planting

There are several arguments for and against the early establishment of extraction racks.

Arguments **for** early establishment of extraction racks:

- A clear structure for the planting area is established from the very beginning.
- Costs of 20% can be saved at planting time and later in tending operations (like

weeding) by using a system of racks 20 m apart and 4 m wide. At time of planting, rows can be left blank. With existing regrowth or thicket stage crops, racks have to be opened-up by hand or with a chipper.

- All heavy machinery causes soil compaction, which leads to a reduction of productivity that may last for decades. This is especially a threat on heavy soils, such as gleys, which are common in Ireland. Early establishment of racks helps to confine machine movement to defined areas from the beginning for operations such as spraying and distribution of materials throughout the site.
  Many forest owners may not be aware of the long-lasting effects of soil compaction on the forest ground. In some European countries, the state forest services allow distances of only 40 m between the racks, in order to keep the percentage of compacted soil as low as possible.
- Later tending and thinning treatments will not be delayed because stands are already accessible.

Arguments **against** the early establishment of forest racks:

- The edge trees tend to develop coarse branches and close over the racks before they are used. Natural pruning is somewhat delayed for trees along rack edges.
  Light-demanding species such as ash or oak do not, however, react strongly to the space available – as long as adequate space within the rows is provided (refer to Chapter 4.4.3.10). Occasionally, artificial pruning may be necessary, but this is less laborious than establishing the racks.
- Installing racks immediately before the first thinning allows the production of fuelwood. As dimensions are normally small, processing and transport of material may not be economic, though this depends greatly on prices of alternative energy sources and can change rapidly – as recent years have demonstrated.
  Consideration may be given to the laying out of a rack system before planting and the planting of more productive trees at closer spacing in these racks (for short rotation forestry). These can then be removed prior to the first thinning.
- In light of the rapid technical developments, it is doubtful that the racks installed at the establishment stage will be adequate for future needs.

Weighing up the possibilities **for** and **against** early rack establishment, and also taking central European experiences into account, the early establishment of racks is recommended. The cost savings involved in early rack establishment can be significant and the fact that they already exist when required, is an added benefit.

Finally, technical developments with regard to thinning have reached a level which may last for some time. The arms of existing processors can extend up to 10 m on either side, but greater distances will not be possible without increasing the weight of the machine considerably, and this does not make sense for small-dimensioned timber.

(3) Infrastructure to enable tending and thinning operations in young stands
Realistically, in most cases it is likely that a rack system will not be installed before the first thinning. Poor accessibility, therefore, will often be the cause of delayed tending and thinning. Accessibility may also be complicated by excessive weed growth, such as brambles, and by lack of visibility at the thicket stage. Brashing to gain access within the stand may be helpful. Its main function is to render thicket stage crops accessible for inspection, for marking trees, shaping, removal of wolves and measurement. Brashing is usually carried out with a light chainsaw.

The need for brashing has declined in recent years, primarily due to the mechanisation of thinning operations. However, it will still remain important, especially for owners of smaller woodlots in order to have access to their plantations.

As manual labour, however, has become very expensive, the only opportunity for many forest owners to carry out the necessary thinning treatments will be the timely opening up of the forest stands for machines like chippers, feller-bunchers or harvesters. It is expected that this situation will remain for the future.

(4) Sufficient width of racks to accommodate machine access and to avoid damage to the edge trees

Racks should be at least 4 m wide (refer to Plate 4.8-2) so as to provide sufficient space for tractors and even harvesters, so that they will not damage the lower, more valuable part of the stems. Several broadleaves have a thin and very vulnerable bark especially when young. Moreover, they are not able to close the wounds with resin like most of the conifers. Beech is particularly thin-skinned. Injuries caused by tractor wheels, cable ropes or careless felling operations are often the entrance for stem rot (Plates 4.8-3 and 4.8-4).

Plates 4.8-3 and 4.8-4: Beech stems damaged by careless timber extraction.
Narrow roads or extraction racks lead to damage to edge trees.

Conclusions

Access to forest areas and especially stands is a prerequisite for adequate implementation of silvicultural procedures. If possible, access for establishment, thinning and harvesting machinery should be provided at the establishment stage. This is particularly important for thinning – a prerequisite for the production of high quality timber.

For all silvicultural activities, access to individual stands, in the form of racks, is also important and should be provided at an early stage.

Providing access is an important investment by the forest owner which is often not carried out because of the high expense involved, therefore, grant aid is necessary.

5 Conclusions and outlook

5.1 Future role of broadleaf species in Ireland

5.1.1 Recent development of broadleaf forests

Forestry is a relatively recent national enterprise in Ireland in comparison with other European countries. Until the early 1990s it was an activity confined almost entirely to the state through the Forest Service and more recently, the state forestry company Coillte. As shown in Chapter 1.4 it was mainly conifer-driven and mostly confined to the uplands and poorer land types. Broadleaf afforestation is an even newer phenomenon, made possible through a new joint EU and Irish government policy, favouring a more diverse forestry programme and developed through a series of grants and premiums for private landowners (refer to Chapter 1.4). A new type of forest ownership consisting mainly of farmers has emerged as a result and some 18,000 farmers are now actively participating in forestry. Broadleaf forestry has, therefore, added a new dimension to the forest landscape of Ireland and the purpose of this chapter is to reflect on its development and the possibilities for the achievement of a critical mass and a resulting hardwood forest industry.

5.1.2 Changing role of primary production

For decades primary production sectors – mining, agriculture and forestry – have become less relevant from an economic perspective. This was partly due to the development of new technology which allowed higher production at lower cost. It resulted in producers needing larger areas, higher investments and more effective working methods to reduce unit costs, in order to achieve an adequate and sustainable income.

In agriculture, for example, the progress over the last hundred years serves to demonstrate these interrelationships: the steady decline in farm numbers, increased mechanisation and a reduction in the labour force combined with the need to increase the area per farm, all became necessary to maintain profitability levels. In all this change, however, the consumer was the benefactor: he/she had to allocate a steadily diminishing part of their income on food – at least in the countries of the developed world.

(In forestry – at least on the Continent – the situation was similar: in the 1960s the price of one cubic metre of sawn spruce timber was the equivalent of 40–50 working hours, that is a week's wage. At the end of the 20th century it was eqivalent to less than 2 hours, that is less than one-quarter of a day's wage.)

During this time people enjoyed an unprecedentedly prosperous lifestyle and improved living conditions. Now the era of cheap energy is past, and short of a breakthrough in nuclear fusion, is unlikely to ever be realised again. One of the consequences is the increased potential of renewable energy and wood as an important source. For thousands of years fuelwood was the main source of heat and this period was defined as the wooden era. Wood as a source of heat was gradually supplanted first by coal and then by oil and gas. Now, after less than a century of cheap energy from fossil fuel, fuelwood is once again beginning to gain a new relevance.

This is a timely occurrence, as most of the recently planted broadleaf stands in Ireland have begun to reach the pole stage and produce small dimensional timber which, although of low commercial value, can ideally be used for heating. It also supports the general acceptance of growing broadleaves as an economic alternative to agriculture, especially on land of low or marginal agricultural productivity.

Today, the rural population takes an increasing interest in broadleaf fuelwood as a highly relevant source of renewable energy. A recent audit by the Sustainability Institute suggested that biomass from existing forestry resources, and biogas from waste and other sources, offered a secure long-term alternative energy future (Siggins, 2009).

There is little doubt, therefore, that wood as a source of raw material for industry, as well as a source of energy, has excellent prospects. Although thinnings from broadleaves are less valued than those of conifers, because of the lower versatility in the wood-based panel product sector, they are highly valued as fuelwood.

5.1.3 Possible further increase of broadleaf forest area

According to the Strategic Plan (Department of Agriculture, Food and Forestry, 1996) Ireland had a challenging goal of increasing its forest area to 17% of the land surface by the year 2030.

The general economic climate, in agriculture as well as elsewhere, makes it unlikely that this goal will be realised for various reasons:

- There is increasing competition between different land uses. In recent years very little land could be acquired for afforestation due to excessively high prices. Prices in excess of €20,000/ha for broadleaves are far beyond economic justification (refer to Chapters 3.5 and 4.7). Although land prices have decreased substantially with the economic downturn they are still beyond those necessary for a profitable sustainable long-term broadleaf enterprise.
- Farmers are generally no longer willing to convert land, even marginal land, to forestry because of improved opportunities to produce food or other energy crops.

Nevertheless, as shown in Chapter 4.7, there are opportunities to improve broadleaf forestry within the existing areas of degraded, under-utilised or over-mature woodlands and marginal lands of different ownerships. In other private forests especially, there are possibilities to improve degraded broadleaf forests. A rough calculation suggests that the areas suitable for upgrading could be in excess of 200,000 ha.

5.1.4 Necessity of subsidising the further establishment of broadleaf forests

The economics of broadleaf forestry are questionable if high interest rates are applied to acquisition of land and afforestation over a long-term (refer to Chapter 3.5). The main revenue comes from the final crop and it is important that this is of the highest quality in order to secure the best price. There is the further problem of cash-flow. Even if the prices for fuelwood and small dimensional timber from thinnings increase, there is a long, lean period for each forest owner until the crop reaches merchantable size. This is encapsuled in the Chinese proverb: *Money grows on the tree of patience.*

Broadleaf forestry, therefore, needs strong commitment and perseverance while State support is essential to overcome economic constraints. Normally, it should be the role of the State to support these economic constraints in its own forests. When the public forests were reorganised and Coillte was established in 1989, however, the main emphasis was on a commercial enterprise and the maximisation of economic gain. This illustrates the priority of economic objectives over ecological and environmental matters which the State authorities imposed on the management of the public forests at that time.

Partly because of EU incentives, and for other reasons that have been dealt with in Chapter 1.4, broadleaves were established predominantly on farms. Farmers or other private landowners, however, will not invest in broadleaf forestry without support from the State.

The production of broadleaf timber, especially that of high quality, will deliver the raw material for a number of native industries such as furniture manufacture. Therefore, it is in the interests of the national economy to develop forestry as a renewable source of raw material.

In Germany for instance the contribution of forestry of all ownerships to the Gross National Product (GDP) is less than 1%, but the contribution of the timber processing industry is more than 4%. The difference in number of employees is even greater: around 60,000 in forestry compared to about 400,000 in the timber-based industries! Most enterprises in this industry would not exist without a supply of raw material from the indigenous forests.

At present there is very little in the nature of a broadleaf timber-based industry in Ireland. When more raw material becomes available, however, this situation will change and new industries will develop. Furthermore, high quality timber from the tropics will become less available, so homegrown broadleaf timber will serve as a substitute and become a much more valued resource. Consequently, apart from the aspect of developing a home-based industry, greater investment in establishing and managing our broadleaf forests will be required in order to secure a sustainable supply.

The Irish government has recognised this and has helped financially, not alone through grants and premiums for the establishment of broadleaves, but also for shaping, tending and thinning them to an acceptable standard. Furthermore, the many protective functions that broadleaf forests serve need to be supported by the State as they also benefit society.

Improving degraded forests and regeneration of over-mature stands are a further benefit to society, but they also involve a cost and their rehabilitation is unlikely without State aid. Other examples are the development of infrastructure such as forest roads, formation of cooperatives for marketing broadleaf timber, the establishment of Combined Heat and Power (CHP) plants and wood processing industries, especially in rural areas.

Recognising the deficit in exchequer finances at present, and possibly for some years to come, give reason to believe that financial assistance may be problematic for some time. Nevertheless, it is important that it becomes available. There are several reasons for this and these will be discussed in more detail below.

5.2 Potential to grow broadleaves for high quality timber

It has sometimes been argued that the potential to grow high quality timber is more difficult in Ireland when compared with conditions on the Continent. Relatively few older stands of high quality are found in Ireland, whereas in Central and Northern Europe stand quality appears to be better. This is partly attributed to the stress conditions caused by exposure to strong winds and to poorer soils. However, areas in Denmark, the Netherlands and western France are also subject to very windy conditions yet they are able to grow high quality trees. Therefore, the cause may be due to a combination of the following:

- **Excessive exploitation**
  Many of the older broadleaf forests are degraded because of the creaming off of better stems in the stand (positive thinning), leaving little other than low grade stems. After regeneration the stand quality will, therefore, improve.

- **Degradation of forest soils**
  It is a general experience that soils, which have not been under forest for a long time, deteriorate and need time to rehabilitate. This phenomenon was referred to by Cotta as early as 1816 in relation to forest sites on the Continent. After afforestation these soils tend to recover their structure so that the second forest generation grows better than the first. On this basis the newly afforested soils in Ireland should also improve gradually.

- **Need for appropriate provenances**
  The provenances of older forest stands are generally unknown. It is possible, and indeed probable, that proven suitable provenances could lead to further advantages such as greater productivity and better quality stems. Work in this area has already commenced with the registration of the best stands as future seed sources, with remedial work to improve their quality. Selection and tree breeding programmes are also in progress.

- **Absence of shelter against climatic stress**
  In the second generation the newly afforested stands will not need to be regenerated on large bare sites like the stands of today, but in the shelter of older trees. Forest blocks will also protect each other against exposure. As a result the new regrowth will be better formed and grow faster.

5.3 Options, challenges and objectives of broadleaf forestry

5.3.1 Silvicultural strategy

Despite the common reservations in relation to predictions, people participating in forestry need a vision. This also applies in other spheres.

It has been strongly argued in earlier chapters that broadleaf silviculture should be directed towards the production of quality timber (refer to Chapter 3.2). The price of such timber is much higher, and will be more in demand, so society will benefit from a larger and more valuable resource. It is, however, a valid criticism that nobody can predict the requirements of society in 100 or even 50 years.

While this is true, past developments in forest history and timber supply suggest the likelihood of some probabilities with regard to the needs of society. Moreover, doing something without a rational strategy makes little sense.

5.3.2 Options for future management

Some contemporaries argue that it does not make sense to formulate precise goals as all planning is faced with uncertainties. This is especially the case with forestry as its production horizons are so long (refer to Chapter 3.5). Therefore, long-term planning may become unrealistic, and following generations may find it more useful to be provided with options regarding management targets. This argument sounds reasonable at first glance. It takes account of the understanding that nobody knows today what the situation will be like in 50–100 years, the usual production periods of broadleaves.

The problem in forestry is, however, that future generations will not have the option to process high quality timber, if only material of inferior quality is available. High quality timber, on the other hand, can easily supply all markets, and can easily be transformed into lower value products such as chips, pellets and solid fuelwood, if this is the production goal at some future date. Providing options for future generations, therefore, means that one of the best possible options will be the production of high quality timber.

5.3.3 Reduction of risks

Avoiding risks is the soul of silviculture and forest economics (Otto, 1987).

Forestry is faced with a wide range of abiotic and biotic risks, pests and diseases. In general broadleaves are less at risk than conifers. This is especially the case with winds and storms. These are by far the greatest hazards for forestry and cause the highest financial losses. Sitka and Norway spruce are especially susceptible. They are also the main commercial trees of Ireland, Britain and the Continent. Most broadleaves root more deeply, have sturdier stems and during the period of excessive storms they bear no leaves. Apart from few exceptions, broadleaf stands are, therefore, much more stable with regard to physical properties as well as ecological features.

In 1990 southern Germany experienced one of the most serious cyclones on record. This resulted in around 80 million m^3 of blown and broken timber. When related to the annual cut allowances for the species concerned, the amount of damaged timber was almost five times for Norway spruce and less than one for oak (refer to Plates 4.4-39 and 4.4-40). The figures illustrate clearly the great differences in stability between the tree species.

Based on various sources of information and on personal impressions from field excursions, it is obvious that many broadleaf forests are mixed whereas conifers are mainly pure. Therefore, a further task in relation to mixtures will be to introduce broadleaves into conifer stands. This will help to stabilise the conifers and make stands more resilient.

5.3.4 Role of broadleaves in landscape planning

The structure of landscape is in many cases not regarded as a significant issue, although it is of considerable importance. The role of forests, woodlots, hedgerows and forest edges often seem not to be sufficiently well integrated with agricultural areas. Fields and forests are usually rather sharply delineated from each other. Moreover, the functions of wooded areas and especially of broadleaf forests with regard to soil erosion, flood control and water supply, are insufficiently considered or inadequately incorporated into landscape planning. In the light of the devastating floods of 2009 and 2014, this is a challenge that needs further thought and consideration.

5.3.5 Integration or separation of nature conservation

There are different approaches in the treatment of nature conservation in various countries:

- In New Zealand, for example, production is carried out in large plantations of Monterey pine (*Pinus radiata*) on the plains. Mountain forests are not regarded as production units, but are fully protected. In this way a total separation of timber production and nature conservation is assured.
- In most European countries settlements are distributed throughout the countryside and are integrated with agriculture and recreation. This involves considerable pressure on the landscape, resulting in an endangered flora and fauna. There have been attempts to designate some areas as national parks or nature protection areas, but they encompass only a small percentage of the total land area. It is, therefore, necessary to include nature conservation measures into normal forestry management.

As explained in Chapter 3.1.2, integrated multifunctional forestry instead of segregation is a major issue for consideration. This is an ever-increasing challenge for Irish forest owners as the requirements and demands for conservation within the forests increase. The Natura 2000 project of the EU is an example. Broadleaf forests are generally more appropriate in this respect and will, therefore, face even greater challenges.

5.3.6 Climate change

The future development of climate is a cause of great uncertainty. Forest planning may well be facing major new problems, as site conditions lose a degree of consistency that has existed in the past.

There seems little doubt that the world is undergoing a rapid climate change. According to different scenarios the temperature may rise between 2–6 °C by 2100. This rise will likely be combined with frequent extreme events, such as more severe droughts and storms. Central and western Europe, however, may escape the severity of climate change, as the model forecasts are moderate: summers will become only slightly warmer, but drier, and winters milder and wetter.

In this scenario the tree line will climb higher into the mountains. This will improve the growth conditions for forests there, but they will deteriorate in the lowlands. The climate may then resemble that of the Mediterranean. Therefore, tree species better able to withstand drought and heat may be preferred on sites prone to increasing stress. Broadleaves such as oak, hornbeam, lime and rowan as pioneers are likely to tolerate these conditions better than beech or alder. Also, some sub-Mediterranean species, like Spanish chestnut and walnut, may gain new roles for these changed conditions.

The main problem for forestry, however, is not the fact of climate change in itself. The climate has always changed in earlier times. The problem lies in the predicted speed of this development, which may cause serious difficulties for the slow-developing tree species which may not be able to adapt sufficiently quickly. Climate adaptive silviculture has become a new term that outlines this emerging challenge.

Carbon trading on the other hand may offer new opportunities for forestry, but the future role of broadleaves and conifers in this regard is unclear.

5.3.7 Ethics of forestry

Making provision for future generations is not a fashionable practice at present. A large proportion of society wishes to exploit today’s resources, but are not prepared to invest in the welfare of future generations. Forestry is very different in this respect. Its ethic is epitomised in the Chinese proverb:

One generation plants the tree, another gets the shade.

In a wider context this view was also expressed by the Irish statesman and philosopher, Edmund Burke, as mentioned in Chapter 3.1.1.2.

Welfare includes more than earning money by producing timber, it also includes supplying posterity with non-material goods such as aesthetic and ecological values.

The argument of securing options for future generations is often used as an excuse to save money and effort at the expense of these generations. In essence, the omission of silvicultural management, or intensive treatments which are required, are essentially a question of ethics: how much effort are forest owners or society willing to invest in the quality, effectiveness and multifunctionality of the forests mainly for the benefit of future generations?

The argument that later earnings, which will accrue from a specific treatment may not cover current costs, compounded at a certain rate of interest, points in the same direction. As an argument about the uncertainty of future events, it is usually used as an excuse to neglect more intensive investment in stand value at the present time.

5.4 Need for further development of broadleaf forestry

As described in Chapter 4.3, forestry practice tends to undergo a gradual development from concentration on afforestation to consideration of developing management issues such as thinning. Broadleaf forestry in Ireland is still mainly in this afforestation phase. Therefore, training of less experienced forest owners, field research and monitoring, as well as transfer of the knowledge acquired, are important issues.

5.4.1 Training needs

Managing broadleaves requires special skills and is more labour-intensive than for conifers. Field days and training courses with practical exercises have already been successfully employed (Plate 5.4-1). Their continuation is strongly recommended as the best way of transferring knowledge and practical experience to the forest owner.

Plate 5.4-1: Training in the field is an essential step in the introduction of a broadleaf silvicultural scheme. (Larch Hill, Co Meath)

Despite the best efforts of COFORD, the Forest Service, Teagasc and other institutions to provide technical and professional advice, as well as training opportunities, the majority of forest owners have yet to be reached. Therefore, a greater effort in dissemination of technical knowledge, information and know-how will be necessary in the future.

5.4.2 Further need of experiments and demonstration plots

At present, little knowledge is available in Ireland with regard to growth, development and silvicultural management of many broadleaves – especially the minor species. Therefore, the establishment of long-term experiments, examining aspects of broadleaf management, is desirable. They should contain several treatments, each differing in concept and planting density, including extremes, which may not be practical at present, but which will show the reactions of the tree species involved. Experiments of this type should also be well distributed within the country. Greater need for information on the growth performance and yield for all types of mixtures is also essential.

Even if the necessary experimental programmes are put in place immediately, many decades will have elapsed before these trials will deliver the required answers. Therefore, the sooner they start, the earlier these results will be available.

Established experiments could also serve as demonstration plots for future training courses. It is widely accepted that direct demonstrations in the field are much more successful and provide better understanding of ways to deal with a problem than theoretical information:

A picture says more than a thousand words or:
Silviculture cannot be learned only from the book.

5.4.3 Broadleaf forestry and future research needs

Irish forestry has now reached a stage of development and diversification, where simple and short-term actions are no longer appropriate. Therefore, a more sophisticated, integrated and far-reaching policy will be necessary. This cannot be provided by small single projects with restricted objectives, structures, time periods (usually five years) and finance.

Broadleaf forestry has raised a number of questions and highlighted special problems, which need long-term experiments. The main areas needing attention are as follows:

- **Identifying the role of tree species and the priority of research needs**
  The priority afforded to broadleaves over conifers is unclear, as is the role of the different species within the choice of broadleaves. For example, ash was the favourite choice among broadleaves, but this preference was based on the perceived early income from hurley material, but the possibility of a new and unexpected threat of ash die-back (*Chalara*) had not been taken into account.

- **Role of mixtures**
  Mixtures may be preferable because of their stabilising effects against storms (broadleaves in conifers), because they provide a higher resilience (to climate change), provide shelter (nurse crops), give better revenues (wider range of products) and provide greater biodiversity. However, questions remain concerning the circumstances when mixtures should be used, where they should be deployed and what species should constitute a mixture as well as the type of mixture.

- **Role of continuous cover forestry**
  Recent afforestation in Ireland has been predominantly tree-farming oriented. This is mainly grant aided and government support driven. In the older state forests the silvicultural system used has been clear-cutting followed by artificial regeneration. This approach is simple and economically efficient, but not always environmentally friendly. In the future, environmental considerations will gain greater importance, but methods to manage the main forest types, including even-aged Sitka spruce stands under continuous forest cover have not developed so far. Systems for broadleaf continuous cover forestry, which are only possible with older stands, are even less developed.

- **Role of hedgerows and minor species**
  They provide shelter and biodiversity. Their importance has been highlighted only recently, but should be explored.

- **Role of renewable energy**
  At present the role of renewable energy is important. There is evidence that normal (broadleaf) plantations produce nearly as much energy as short rotation coppice – provided all input:output-relationships are sufficiently taken into account. The role of conifers and broadleaves should be evaluated in this context.

- **Forest protection**
  Forests are threatened by a wide spectrum of abiotic and biotic threats. Some broadleaf species are especially susceptible to attacks by fungi, rusts and insects. Some of these hazards, such as ash die-back, have spread into Europe only recently and their future impacts are unknown.

- **Long-term scientific research versus practically-oriented investigations**
  Long-term experiments are often designed to provide detailed scientific information over a

wide range of site types. Alternatively, a few practically-oriented demonstration trials may more appropriately satisfy the needs of forestry practice.

Much long-term research has been carried out in other countries and it needs to be established whether such results can be transferred and applied to Ireland.

- **Objectives of farmers versus society**
  Many farmers have established plantations, but do not know how, or do not have adequate silvicultural knowledge, to manage them. This may result in much of the potential of these plantations being lost to the owner as well as to society as a whole. Moreover, the aims of thinning in the different type of forests are not clear. The owners may have specific objectives, but society in general may increasingly have objectives which conflict with those of the forest owner. This conflict of interest may not be urgent at present, but may become a much greater issue in future years.

This list is far from complete, but shows the main issues and illustrates the need for a comprehensive research policy for Irish forestry.

According to earlier experiences with the research branch of the Forestry Commission in Britain and similar institutions in other countries, long-term research can only be carried out by permanent, properly staffed and adequately funded national research units.

To achieve this objective the authors believe that it will be necessary therefore, to establish a permanent independent research unit for the following main fields of activities:

- Responsibility for long-term experiments.
- Record-keeping (data-bank administration) on forestry activities, ecological impacts, market developments, economy of forest enterprises.
- Continuation of the National Forest Inventory at periodic intervals (continuous forest inventory).
- Monitoring of climate and soils (site mapping, climate change, pollution).
- Become a general centre for all tasks of national research interest in forestry.

To develop well-balanced programmes this research unit should be advised and directed by an expert group, which understands the needs and is able to contribute to visions for Irish forestry, as well as the identification of urgent problems that need to be dealt with in the future.

Conclusions

People need to have a vision in order to be able to put their specific actions into practice. Hopefully, with this book it will be possible to contribute to the debate on the management of broadleaves and provide foresters and others with a background to broadleaf management according to the perceptions of the authors:

Silviculture creates values!

Never in the last fifty years have the conditions for forestry, and particularly the growing of broadleaves, been so promising. Timber as a source of energy and raw material is likely to increase substantially in importance. Moreover, broadleaves will contribute to the enhancement and diversity of the rural landscape and, therefore, add to the protective functions and biodiversity.

The problem of acquiring new areas for afforestation is a constraint on expansion at present. There are, however, great opportunities to improve broadleaf forest production by upgrading degraded woodlands and enriching hedgerows and underutilised unproductive areas. This could be more easily facilitated if new grants to support such activities were provided.

The outlook for growing broadleaves in general is optimistic. Nevertheless, a high degree of motivation is required and much work needs to be done to fully develop this renewable and valuable resource.

Part II

Description of broadleaf species

Beech alongside the Avonmore river, near Laragh, Co Wicklow.

6 Classification of broadleaves

6.1 Knowing the species

Silvicultural text-books usually contain detailed descriptions of the species and their requirements – often supported by botanical drawings (Plate 6.1-1). These descriptions provide the reader with information on specific characteristics of the different tree species. This knowledge is essential in identification of and in understanding the species, as well as their silvicultural and management requirements.

Many of the details on broadleaf species have been mentioned with regard to their characteristics and management objectives. However, they have not been described in complete detail or in any particular order.

The description of individual broadleaf species, therefore, forms the main content of Part II. Before commencing, however, a logical arrangement for their order and structure needs to be established.

Plate 6.1-1: Old silvicultural text-books provided students and practitioners with detailed descriptions of the main tree species.

6.2 Systems of classifying broadleaf tree species

There are different ways of grouping tree species according to subject-specific objectives. In practice authors use structures which differ according to their preferences.

These may be categorised as:
(1) botanical characteristics,
(2) ecological features and silvicultural characteristics,
(3) origin of species,
(4) wood properties,
(5) economic values,
(6) role as forest elements,
(7) role as landscape elements.

Each will now be addressed in the above sequence.

6.2.1 Botanical characteristics

In botanical classification, trees are divided into *Gymnosperms*, with naked seeds, and *Angiosperms*, with covered seeds. Most conifers belong to *Gymnosperms* while the broadleaves belong to the *Angiosperms*. In evolutionary terms the *Angiosperms* are more recent. They are, therefore, much more diverse and correspondingly comprise a greater number of species. The much acclaimed maidenhair tree (*Gingko biloba)* is a link between both classes, but, as it bears leaves rather than needles, it is usually regarded as a broadleaf by the public.

Most of broadleaf tree species growing in temperate zones are **deciduous.** This strategy obviously permits them to cope with winter cold. Only a few are **evergreen** – for example the native holly.

6.2.2 Ecological features and silvicultural characteristics

From an ecological point of view, trees are divided into pioneers, intermediate and late-successional groups (refer to Chapter 4.1.2). The National Forest Inventory (2007) uses the description short-living and long-living broadleaves, terms that have ecological connotations (refer to Table 1.5-7). Plants within these groups differ in many respects including seed production, growth patterns and timber quality.

With regard to silvicultural management, the **light requirement** of the species is usually the most important attribute:

- Pioneers tend to grow fast in their youth, develop mono-storeyed canopies, are harvested early and do not regenerate freely under the shelter of older trees. Birch, alder and aspen are examples.
- Late-successional species, by contrast, generally have problems establishing on bare ground. They need overhead or side shelter against stress conditions. Because of their shade-tolerance they are able to withstand shade from more dense canopies. Late-successional trees are able to form multi-storeyed stands together with the same or other species. The best known examples are stands in which beech or hornbeam form a component.

Very few species – like beech and hornbeam – are truly shade-tolerant. The majority of the broadleaves growing in Ireland are light-demanding or intermediate.

Another important feature of silvicultural management is the **coppicing ability** of the species (refer to Chapter 4.2.3). Most broadleaves sprout easily from stumps – a capacity that has been widely used for coppice forests.

Conclusions

Shade-tolerance varies, depending on the site conditions and the age of the individual trees. Moreover, not all species behave in an archetypal manner and as a result, the groups cannot be separated accurately. Coppicing ability is also not very important today and, therefore, not suitable as a criterion for classifying trees in this book.

6.2.3 Origin of broadleaves

Because of Ireland's geographic location, relatively few species managed to recolonise the country after the most recent Ice Age. Therefore, the number of **native or indigenous species** is unusually small (refer to Chapter 1.2) and except for yew, and possibly Scots pine, all are broadleaves (Table 6.2-1).

Because of the favourable climatic conditions of most parts of Ireland, many species have been introduced from the temperate zones of other parts of the world. They are referred to as **foreign, introduced**, or **exotic,** or more emotively as **alien species** – or scientifically expressed, **neophytes** (Table 6.2-2).

Many of the tree species found in Ireland today have been introduced from parts of the world including: North America, Far East Asia, as well as South America and Australia/ New Zealand.

The report of the National Survey of Native Woodlands lists 20 non-native broadleaves – excluding horticultural varieties – which have been introduced to Ireland, in contrast to 13 conifers. Exotic conifers have, however, become much more important from the commercial forestry point of view.

Native, as well as non-native broadleaves of some relevance, are described in more detail in Chapters 7 and 8.

Some of the introduced tree species are now fully **naturalised** and have become an integral part of the Irish flora. They occur in mixtures with the indigenous species, and they reproduce as in their home regions. Others, however, invade and may even suppress the local vegetation. This **invasiveness**, therefore, gives rise to some concern,

Table 6.2-1: List of **native species** and their **prevailing form** (tree or bush). (Adapted from Perrin et al., 2008)

Of these 31 species, the native status of Salix purpurea is questionable.

Two species are natural hybrids (Quercus petraea x Q. robur and Salix aurita x S. cinerea).

It is difficult to decide whether some species are bushes or trees. Trees are defined as woody plants that develop a single straight stem – they are thus 'monocorm'. Moreover, they reach a minimum height of 5 m.

Many species, however, normally form bushy types ('polycorm') and only under favourable conditions become trees. Thus, only 12 out of the remaining 28 species can be regarded as 'genuine' tree species. All the others form predominantly bushes, but a clear distinction is not possible.

Name: scientific	Name: common	Form
Alnus glutinosa	Alder	tree
Arbutus unedo	Strawberry	bush/tree
Betula pendula	Silver birch	tree
Betula pubescens	Downy birch	tree
Corylus avellana	Hazel	bush
Crataegus monogyna	Hawthorn	bush
Euonymus europaeus	Spindle-tree	bush
Frangula alnus	Alder buckthorn	bush
Fraxinus excelsior	Ash	tree
Ilex aquifolium	Holly	bush/tree
Malus sylvestris	Crab apple	bush/tree
Populus nigra ssp. betulifolia	Black poplar	tree
P. tremula	Aspen	tree
Prunus avium	Wild cherry	tree
P. padus	Bird cherry	tree
P. spinosa	Blackthorn	bush
Quercus petraea	Sessile oak	tree
Q. petraea x Q. robur	-	tree
Q. robur	Pedunculate oak	tree
Rhamnus cathartica	Buckthorn	bush
Salix aurita	Eared willow	bush
Salix aurita x S. cinerea	-	bush
S. caprea	Goat willow	bush
S. pentandra	Bay willow	bush
S. purpurea	Purple osier	bush/tree
Sambucus nigra	Elder	bush
Sorbus aucuparia	Rowan	bush/tree
S. devoniensis	French hales [x)]	bush/tree
S.hibernica	Irish whitebeam	bush/tree
Ulmus glabra	Wych elm	tree
Viburnum opulus	Guelder-rose	bush

x) Otherwise known as Devon whitebeam and found only in south eastern Ireland and south western Britain. (Nelson & Walsh, 1993)

Table 6.2-2: Non-native broadleaf tree species. (Adapted from Perrin et al., 2008)

According to this list, which has been published in the report of the National Survey of Native Woodlands 2003–2008, 20 species of clear non-native origin are mentioned.

In contrast to the native broadleaves, most of the non-natives form trees. It may be suspected that – apart from the willows – most of these species have been introduced mainly in order to produce timber.

With the exception of red oak, all exotics come from the European continent, partly Central Europe, partly from more southerly regions which show a climate comparable to that of Ireland.

Name: scientific	Name: common	Form	Location of origin
Acer campestre	Field maple	bush/tree	C. Europe
A. platanoides	Norway maple	tree	NE Europe
A. pseudoplatanus	Sycamore	tree	C. Europe
Aesculus hippocastanum	Horse chestnut	tree	SE Europe
Alnus incana	Grey alder	tree	C. Europe
Carpinus betulus	Hornbeam	tree	C. Europe
Castanea sativa	Sweet chestnut	tree	SE Europe
Fagus sylvatica	Beech	tree	C. Europe
Populus delt. x P. nigra	Hybrid black poplar	tree	Horticultural
P. nigra var. Italica	Lombardy poplar	tree	S Europe
Prunus laurocerasus	Cherry laurel	bush/tree	SE Europe
Quercus cerris	Turkey oak	tree	SE Europe
Q. ilex	Evergreen oak	tree	SW Europe
Q. rubra	Red oak	tree	NE America
Salix alba [x)]	White willow	tree	C. Europe
S. caprea x S. viminalis	-	?	Horticultural
S. fragilis [x)]	Crack willow	bush	C. Europe
S. triandra	Almond-leaved w.	bush	C. Europe
S. viminalis [x)]	Osier	tree	C. Europe
Sorbus aria	Whitebeam	bush/tree	C. Europe
Tilia cordata	Small-leaved lime	tree	C. Europe
T. cord. x T. platyphyllos	Common lime	tree	Horticultural
Ulmus procera	English elm	tree	W/C. Europe
U. x hollandica	Dutch elm	tree	Horticultural

x) origin questionable

especially from nature conservationists, and this invasive behaviour continues to be diligently observed. The worst example of invasiveness in Ireland and Britain is from *Rhododendron ponticum*.

For more than 100 years conifers have dominated planting activities in Ireland. This is mainly as a result of their higher rate of increment, their generally lower demands regarding site conditions and their greater versatility in industrial use. In the future an increasing interest in some rare broadleaf species may arise possibly because of climate change. They are therefore listed in Chapter 9.

Conclusions

The nativeness of the broadleaf species does not reflect their present importance, nor is their rarity a sufficient criterion for classification. Nevertheless, these attributes need to be considered in creating a classification structure.

6.2.4 Wood properties

The timbers of the various trees differ in technical characteristics, pore distribution, colour and value production. All these parameters have been used to group tree species in some books. This is illustrated and discussed in the following paragraphs.

6.2.4.1 Technical characteristics of timber of the main broadleaf species

In the timber trade, the terms **softwood** and **hardwood** have quite distinct meanings. Conifer timber is classed as softwood while broadleaf timber is regarded as hardwood. This categorisation, however, is too imprecise as many broadleaves have softer timber than that of some conifers and vice versa (Table 6.2-3).

Moreover, even within the two groups, the distinction is even more imprecise as the limits between both categories are poorly defined. This has been shown already in Chapter 4.1.2.2.

Table 6.2-3: Timber species as classified according to their **hardness**.

Hardness type	Species	
	Broadleaves	Conifers
Softwood	Poplar, aspen, willow, alder, birch.	Spruce, white pine, silver fir.
Hardwood	Oak, beech, hornbeam, elm, walnut.	Scots pine, larch, Douglas fir.

6.2.4.2 Pore distribution

The structure of the timber species also differs with regard to pore distribution (Table 6.2-4).

The majority of all timber species belongs to the diffuse porous category. This, however, influences neither their strength, their visual appeal nor their value.

Table 6.2-4: Pore distribution of the main broadleaf species.

Pore distribution	Species
Ring porous	Ash, elm, oak, Robinia, Spanish chestnut.
Diffuse porous	Alder, aspen and other poplars, beech, birch, wild and bird cherry, hornbeam, Norway and field maple, rowan, sycamore, walnut, willows.

6.2.4.3 Colour

In the market place, timber is often classified according to its colour as shown in Table 6.2-5.

Although this characteristic can be applied to summarise broadleaves and conifers, it is not suitable as a criterion for arranging broadleaves in a desired order.

Table 6.2-5: Classification of timber into **white and coloured species**.

Colour	Species	
	Broadleaves	Conifers
White	Ash, aspen, beech, birch, hornbeam, lime, Norway maple, poplar, sycamore, willows.	Spruce, fir.
Coloured	Elm, oak, Robinia, Spanish chestnut, cherry, walnut.	Scots pine, Corsican pine, Douglas fir, larch, yew.

Conclusion

Wood properties are considered inadequate for classifying species for the purpose of this book.

6.2.5 Economic values and marketability

Possibly the first attempt to classify trees according to their utility dates back to the 8th century. In the era of the Brehon Laws in Ireland – *Bretha Comaithchesa* (Laws of Neighbourhood) – tree and shrub species were grouped in an integrated order combining their value and relationship to the different canopy layers (Table 6.2-6).

At that time their use-value was predominant, as different fines were imposed for damage caused to the trees according to this value.

Today, the different physical properties, stem dimensions and quality, colour, workability and durability of timber species, are the basis for classifying timber in the market place according to their value (Table 6.2-7).

This classification is common in practice – at least on continental Europe. However, it is problematic for the following reasons:

Table 6.2-6: Classification of tree species in the early Middle Ages. (Adapted from Nelson and Walsh, 1993)

Role or layer in the woods	Species
Nobles	Oak, hazel, holly, yew, ash, Scots pine, crab apple.
Commoners	Alder, willow, hawthorn, rowan, birch, elm, cherry.
Lower divisions	Blackthorn, elder, spindle, whitebeam, aspen, juniper
Shrubs	Bracken, bog myrtle, furze, bramble, heather, broom, wild rose.

Table 6.2-7: Classification of broadleaf timber according to **value**.

Value	Species	Main use
High	Oak, Spanish chestnut, walnut, wild cherry.	Furniture, veneer, panels.
Medium	Ash, beech, sycamore.	Saw timber, furniture.
Low	Alder, birch, poplar, willow.	Saw timber, pulp, fuelwood.

- Almost all timber species can be used for most purposes. Even poplar can sometimes be processed into veneer, but it is generally used only for low quality plywood or matchwood.
- Generally, a certain proportion of all broadleaf timber is of low quality. Much is of small diameter, too crooked or flawed in some way. Even stands with high quality timber produce more than 70% of low value – calculated on the basis of total production of a stand during its life.
- Species undergo changes in fashion – illustrated by the variation of prices for the different timber species over time.

Nevertheless, this marketability classification has become popular. At least a small proportion of the timber of tree species can be sold at high prices, thus lifting the average price. This is especially the case with oak and cherry, as has been shown in Chapter 3.2.2.2.

Conclusion

As economic aspects are driving issues of forestry in general, they have to be reflected in the grouping system.

6.2.6 Role of broadleaf species as forest element

As stated, some 75% of the forest area in Ireland is stocked with conifers, and they account for more than 80% of the volume (refer to Table 1.5-3). Of the broadleaf species, only a small number are of importance. These are generally species that can be grown on a wide range of sites, such as oak, or are of great economic value like ash, sycamore and of course, oak Therefore, they are frequently classed as major species. These major species are often found in pure stands or in mixtures where they dominate the upper canopy.

All the others are minor species. They seldom form pure stands or groups of any great area. More often they occur as a small proportion of mixtures or act as service trees under the shelter of more dominant trees.

In the Native Woodland Scheme (2001), a slightly different grouping of acceptable species has been adopted (Table 6.2-8).

This system includes only native species. However, aspen, wild cherry and rowan (in part) are also overstorey species. On this account, this system is unsuited to the purpose of classification.

Table 6.2-8: Grouping of acceptable broadleaves under the Native Woodland Scheme. (2001).

Species category	Broadleaf species
Overstorey	Alder, silver and downy birch, ash, sessile and pedunculate oak.
Understorey and minor	Hazel, hawthorn, spindle, holly, crab apple, aspen, wild cherry, blackthorn, eared, goat and rusty willow, elder, rowan, guelder rose.

Conclusion

No system appears sufficiently comprehensive to meet the objective of grouping most of the aspects concerned.

6.2.7 Role of broadleaf species in the landscape

Trees – especially broadleaves – are important elements in the landscape. This is illustrated in Table 6.2-9.

Over the past century conifer planting has dominated State forestry. These forests have been confined largely to the poorer soils in more remote locations, often far from villages and towns (refer to Chapter 1.3). For this reason even the rural population have looked on forests as something alien to their everyday life. Indeed, most Irish people regard hedgerows and parks as being much more typical of the countryside and of far greater importance than forests.

Table 6.2-9: Classification of **trees** according to their **role in the landscape.**

Type	Description	Main objective	Main tree species
Woodland	A group of trees large enough to produce a special forest climate (>1 ha).	Timber production, erosion control; nature protection; recreation.	Conifers, ash, sycamore, oak, beech.
Isolated clumps	Small groups of trees within open land (<1 ha).	Timber/fuelwood production, shelter for animals.	Oak, beech, poplar.
Hedgerow	Rows of shrubs with some trees (mostly <20 m) 5-20 m in width; more-or-less regularly coppiced.	Marking of boundaries, shelter, fuelwood production.	Ash, hawthorn, lime.
Avenue	Generally 1-2 rows of tall specimens with large crowns.	Amenity, shelter.	Various broadleaves that form large trees (oak, lime, beech, plane)
Park tree	Magnificent single trees.	Amenity.	Oak, beech, lime, sycamore.

Conclusion

The authors concluded that since none of the above structures were suitable, they have decided to divide the species into two groups: the **main timber producing (major) broadleaf species** and the **minor broadleaf species.**

6.3 Structure of the following chapters

The **main timber producing broadleaf species** consist of alder, ash, beech, oak and sycamore – partly following the NFI classification – but also include birch, cherry and Spanish chestnut, as these have the potential to become major species in the future. They are described in Chapter 7.

All other species that are of some relevance to Irish forestry are classed as **minor broadleaf species** in Chapter 8.

Within the groups the species are arranged in alphabetical order by their common names.

The **rare species** are dealt with in Chapter 9. So far these rare species have not been planted on a forestry scale, but some may become important in the future. As some of the species have no familiar common name the scientific one is used – again in alphabetical order.

6.4 Sources of information and literature used for the species descriptions

6.4.1 Citation of literature

There are numerous books on trees, plants, woodland and forestry. The more recent generally contain information which reflects their current status. Most of the stated details, however, are not original findings of the authors based on their own scientific studies or experiments. They are usually derived by compilation from other sources, supplemented with information acquired through their own experiences. In this book, the authors were quoted only when their authorship was evident.

6.4.2 Growth potential of species

Little information is generally available concerning the **growth potential of most species**, especially the rarer ones.

The publication, *Champion Trees: A Selection of Ireland´s Great Trees* by the Tree Council of Ireland (2005), however, provides useful data concerning heights and girths of outstanding trees within the country. This information was partly used for the description of the major and minor species. It served especially as a basis for the evaluation of rare species.

According to the champion tree list, roughly 6,500 trees of over 860 species and varieties within the 32 counties have been measured. The criteria for the selection have been: *Trees that are remarkable for many reasons: their height, circumference and age provide the statistical information, but they may also have historical and folklore associations … Sometimes they are simply the most magnificent example of their kind on this island.*

7 Main timber producing broadleaf species

7.1 Alder

Family: *Betulaceae* - birch species.

Genus: *Alnus* (old Roman name of alder).

Alder is represented worldwide by 20–30 species, with about 15 species in Europe and Asia and the remainder in North and South America. Four species: (1) common, (2) red, (3) Italian and (4) grey are growing in Ireland, but only the common alder is of sufficient interest to be treated in detail. The other three will be described more briefly.

7.1.1 Common alder

Scientific name: *Alnus glutinosa* (L.) Gaertner.

English synonym: Black alder**.**

Irish name: Fearnóg**.**

Origin and geographic distribution: Common alder is indigenous throughout Europe except for northern Scandinavia and the north and south-east of Russia. Its range extends from Ireland to western Siberia and from Finland to north-west Africa and eastwards to northern Turkey and the Caucasus (Figure 7.1-1).

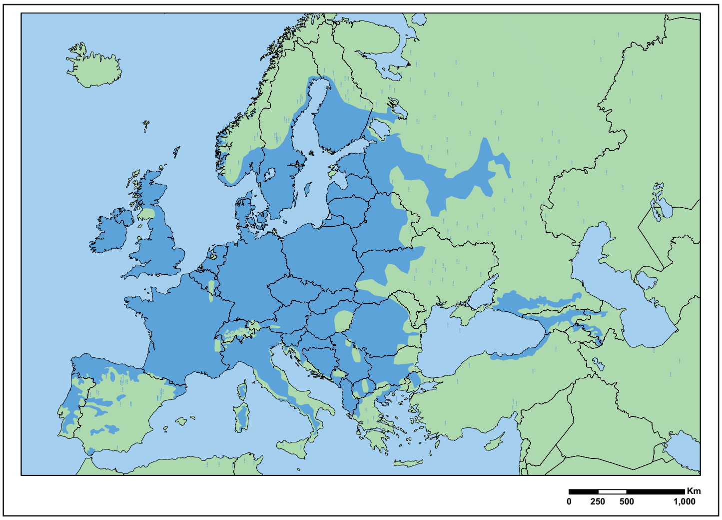


Figure 7.1-1 Natural distribution of common alder. (EUFORGEN, 2009)

Alder is recorded in over 2% of total forest stocked areas.

In recent years alder has played an increasing role in afforestation, mainly because of its ease of establishment and rapid early growth (Figure 7.1-2).

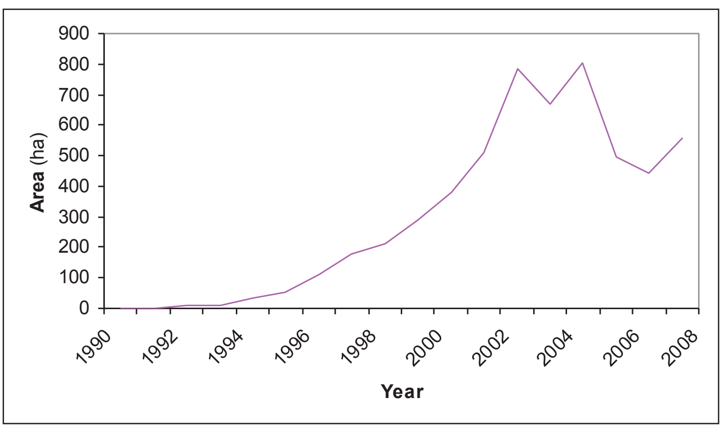


Figure 7.1-2: **Areas of alder plantings** 1990-2007. (Forest Service, 2008)

Botanical characteristics

Tree form: Pyramidal; crown conical and narrow in older trees; height 20–25 m.

Stem form: Straight and circular.

Bark: Dark grey and fissured.

Timber: Freshly felled logs develop a strong orange-brown colour on the end grain; this fades to a pinkish-brown and eventually

Key characteristics

- Shade-intolerant pioneer species,
- very rapid early growth and relatively short lifespan,
- resistant to damage by late frost,
- preference for moist sites with non-stagnant water,
- susceptible to lean and consequent stem deformation on exposed sites,
- good ability for natural pruning,
- prolific seed producer and good coloniser of moist disturbed mineral soil,
- fixes atmospheric nitrogen,
- versatile timber of poor natural durability except when immersed in water.

darkens to a greyish-brown on exposure to light.

The wood is diffuse porous, lustreless, with indistinct growth rings. Air-dried wood density is about 500 kg/m^3 and is relatively stable. It is soft and not very strong and has poor natural durability, but takes preservatives well. However, when immersed in water it is one of the most durable of timbers.

Typical strength values for dry (12% moisture content), defect-free British material are shown in Table 7.1-1.

Table 7.1-1: Strength values for alder.
(Fennessy, 2004)

Property		Value
Bending strength (modulus of rupture)	N/mm^2	80
Stiffness (modulus of elasticity)	"	8,800
Shear (parallel to grain)	"	12
Compression (parallel to grain)	"	41
Hardness	N	2,900

Root system: Common alder is usually found on fertile sites along rivers and streams where its roots penetrate deeply. It helps to stabilise river banks and reduces effect of erosion. On suitable sites it ranks among our deepest rooting native species. On peaty sites shrinkage sometimes leads to exposure of the root system (Plate 7.1-1).

Plate 7.1-1: Alder root system – visible because of shrinkage of peat. (Taylors Cross, Birr, Co Offaly)

Leaves: 4–10 cm long, almost circular in shape and sometimes notched at the apex; doubly toothed or wavy at the margins. They remain on the tree until late in autumn and darken before being shed.

Flowers: Each tree bears both male and female flowers (monoecious) which appear before the leaves in spring. Male catkins are yellow-reddish in colour, 5–10 cm long when mature and hang at the end of branchlets. Female inflorescences are 1.5–2.5 cm long, purplish-red, pedunculate, conical in shape and develop at the base of branchlets. They are pollinated by wind.

Fruits: Fruiting catkins are 1–3 cm long, dark-green turning to dark brown and persist until the following spring. Seeds have a small winged fringe which enables them to float and are disseminated by wind and water.

Ecological characteristics

Forest type: An important tree of riparian mixed forest and frequently occurs in mixture with ash, hazel and birch.

Successional type: A pioneer species, relatively short-living.

Light requirements: Strongly light-demanding.

Stress tolerance: Although alder survives it will not thrive on dry soils or those with stagnant water or those of high pH.

Climatic requirements: Prefers a moderate to cold climate and is confined largely to riparian environments in northern Europe. In central Europe it is a common species of the plains and of the mountains up to altitudes of 1500–1800 m.

Soil preference: Grows best in deep fertile soils with a moderately high water table in sheltered locations and thrives on moist humose deep loams where its roots have good access to ground water. While it tolerates flooding well it will not withstand stagnant water or high soil acidity. In waterlogged sites it can develop adventitious roots (Plate 7.1-2).

It does not grow well on limestone soils and nutrient-poor peats.

Strengths and threats: Frost-hardy and relatively storm resistant, but may suffer from leader breakage and stem lean on exposed sites (refer to Plate 4.4-43). It is browsed upon by deer. The most serious threat is a fungus (*Phytophthora spp.*) known as 'alder Phytophthora' (Gibbs et al., 2003) which attacks the inner bark of the stem, causing lesions, from which the tree normally dies. Another threat is crown dieback, which results in the tree dying from the top downwards.

Regenerative capacity: In open positions it may already start to fruit at 5 years or earlier, but trees growing in stands begin to fruit much later. Although it can produce seeds each year, abundant crops occur generally every 2–3 years. It regenerates naturally to form small pure stands on areas of exposed soil in wet localities, but seedlings often succumb to weed growth or drought. It coppices freely.

Provenances: Native seed and plant material is preferred and should always be the first choice. This also helps to protect against the introduction of *Phytophthora spp*. Native seed should preferably be sourced from registered seed stands of which there are 113 ha in Ireland (Fennessy et al., 2012).

In the absence of native material, British, northern French, Dutch, northern German and Danish sources are recommended.

Plate 7.1-2: Adventitious roots on alder stem.
(Taylors Cross, Birr, Co Offaly)

Growth characteristics

Height: In the first 15–20 years height increments of 0.5–1.0 m/year are typical of the species (Plate 7.1-3; refer to Figure 4.1-3).

With the exception of poplar, it surpasses all other native forest tree species in height growth for the first 20 years (refer to Figure 4.1-2), but by 45 years this will have markedly decreased and at 80 years height growth will have practically ceased. At maturity the tree can reach 20 m in height and up to 25 m in sheltered localities (Evans, 1984).

Plate 7.1-3: Young vigorous alder stand. (Shelton, Co Wicklow)

Age: Its maximum physical lifespan is about 120 years.

Total volume production: It is not as productive as its rapid early height growth would suggest and yield classes in excess of 10 m³/ha/yr are unlikely.

Values

Silvicultural values: Alder is mainly a niche species inhabiting moist to wet soils or in riparian areas where it occurs in small pure stands or in association with birch and other species of high moisture requirement such as ash. With regular crown thinning early mean diameters will surpass those of most other broadleaf species, but its shorter lifespan will militate against large diameter trees at the end of its rotation. Its role as a nurse in providing shelter and protection from frost is well recognised, but it tends rapidly to outgrow and suppress its companion species if left unattended.

Economic values: Alder wood is one of the most versatile in the manufacture of small dimensional produce. Inferior quality logs are used in the construction of models in factory applications. The wood is one of the chief sources of charcoal and it can be chipped for pulp. Along with oak it is the species extensively used in the smoking of fish and meat.

Larger and better quality logs (Plate 7.1-4) are used in the manufacture of musical instruments such as harmonicas and for cheaper veneer such as that used in plywood. It is excellent for turnery work when knot-free and is the staple timber of the clog-making trade: for this it is superior to any other. Its golden-red colour and light weight when seasoned make it a very acceptable wood for kitchen cabinets. Under water it is extremely durable and here its use is unlimited: it is widely used as piles in harbours and for the retention of unstable river banks.

Plate 7.1-4: Excellent middle aged pure alder stand on a rich wet soil. (N Germany)

Ecological values: It is noted for its capacity, in symbiotic association with the Actinomycete, *Frankia*, to fix atmospheric nitrogen at rates of 60–400 kg/ha/yr. Soil enrichment is further enhanced by rapid leaf decomposition. On this account it has the potential to benefit the growth of companion tree species (Savill, 2013).

Its foliage provides shade for fish species: its leaves decompose quickly in water and provide nutrients for invertebrates (caddisflies, stoneflies and water beetles), which form part of the aquatic food chain, and are eaten by fish including salmonid species (Featherstone, 2007).

Amenity value: It provides rapid plant cover along roadside embankments of newly built motorways.

Historical importance: While its durability when continually submerged in water is excellent, there is no record of it being used in building crannogs (lake dwellings) in Ireland during the Bronze Age (Nelson and Walsh, 1993).

It is listed among the *commoners of the wood* in the 8th century Irish law-texts judgements of neighbourhood, *Bretha Comaithcheasa*, for use in manufacture of shields, masts and tent-poles (Kelly, 1999). It was found in archaeological excavations at Wood Quay, Dublin, as posts and turned artefacts dating from the Viking period. It was the favoured species in the production of charcoal for making gunpowder.

Silvicultural management

Production of plant material: For planting, 1+1 or 1u1 plants should be used. These are produced in the nursery from seed broadcast sown during March-April at a density of 0.5–1.0 kg/100 m^2. Seed covering thickness is about 5 mm (Suszka et al., 1996). Soil moisture is important as alder seedlings tolerate a more humid soil than birch. Other methods include sowing in peat pots containing a mixture of peat and vermiculite inoculated with nitrogen-fixing bacteria from the root nodules.

Regeneration: Seed can be carried by wind for a radius of 30–60 m around the mother tree. Regeneration is efficient when seed falls on bare mineral soil, with adequate moisture and good light conditions and free of competing vegetation in the early years of growth.

Tending of young stands: Alder has good apical dominance and in sheltered locations is relatively free of stem forking. When established on suitable sites it will quickly dominate competing vegetation, so little tending should be required apart from removal of occasional 'wolf' trees and competitors to potential crop tree candidates. On exposed sites leaning trees may require early removal. Its good capacity for natural pruning should ensure an adequate number of clean boles at maturity.

Thinning: Alder is shade-intolerant and requires early and heavy crown thinning to achieve good diameter growth. When planted at conventional spacing (2 x 1.5 m), a selection of 350–400 potential crop tree candidates/ha (pcts/ha) should be made when branches in the lower stem have died up to a height of about 5 m and/or at a top height of 8–10 m and 1–2 strong competitors to these pct candidates removed. This should be followed, at a top height of 12–14 m, by a final selection of 250–300 potential crop trees/ha (pcts/ha) from these candidates and their release from competitors. Where natural pruning has not been fully effective, potential crop trees should be artificially pruned to 6 m. Subsequent thinnings should take place at top height growth intervals of about 3 m to remove competitors to the selected potential crop trees.

The three other alder species growing in Ireland – red, Italian and grey – have many similarities with common alder, but there are some important differences. In the description of those species reference will be confined mainly to those differences.

Conclusions

Common alder is an excellent tree for establishing shelterbelts, but its tendency to suffer leader breakage on exposed sites limits its potential in those locations. When grown for timber production it should be planted on moist fertile sites in a sheltered locality. For optimum growth its roots need access to an adequate water supply. Because of its shade-intolerance it requires early and heavy crown thinning.

As a nurse in intimate mixture with other species it tends to dominate at an early age so early intervention is needed.

Imported plants and seed should be avoided because of the danger of *Phytophthora spp.*

7.1.2 Red alder

Scientific name: *Alnus rubra* Bong**.**
The name derives from the colour of the inner-bark which turns a rusty-red when exposed to air.

Origin and geographic distribution: Native to North America from southeast Alaska to southern California. It grows in a coastal strip within 200 km of the Pacific coast except for an incursion inland across northern Washington into north Idaho (Figure 7.1-3).

Botanical characteristics

Tree form: Pyramidal crown when open grown, but becomes narrow and dome-shaped in forest stands.

Stem form: Moderately straight but has a strong tendency to grow towards the light or openings in the canopy (phototropic) (Hibbs, 1996).

Bark: Ashy-grey, generally smooth, but forming flat, irregular plates near base.

Timber: Ranges from white, when freshly felled, through pinkish to light brown; a soft hardwood with medium lustre. The wood has properties similar to that of common alder, but is less dense. When stained it is widely used as a substitute for more expensive traditional species like cherry (Mason, 2006).

Specific gravity is 0.37 for green and 0.43 for oven-dry timber. It is one of the easiest of North American wood species to dry. Shrinkage values are low.

Root system: Red alder forms extensive, fibrous root systems. In poorly drained soils most rooting is surface-oriented. On well-drained sites, root distribution is strongly influenced by water availability (Harrington, 2006). It can form adventitious roots when flooded like common alder (refer to Plate 7.1-2).

Figure 7.1-3: Natural distribution of red alder.
(Collingwood and Brush, 1979)

Leaves: Alternate, simple, ovate, 7–15 cm long with doubly serrated edges and a distinct point at tip. The leaf margins are tightly curled under at the edges (revolute), a diagnostic characteristic which distinguishes it from other alders.

Flowers: Red alder reaches sexual maturity at age 3–4 years for individual trees and at age 6–8 for those most dominant in a stand (Stettler, 1978). Flowering occurs in late winter or early spring. The tree is generally monoecious.

Fruit: Seeds are small, winged nutlets borne in pairs on the bracts of woody, cone-like strobili. Seeds are very light (770,000–3,000,000/kg) and can be carried long distances by wind. Seed may be stored for 5–10 years with little loss of viability when dried to less than 10% moisture content and stored in sealed containers in a freezer (Niemiec et al., 1995).

Ecological characteristics

Forest type: In its native habitat it is a common associate of coastal Douglas fir, western hemlock, western red cedar, grand fir and Sitka spruce forest types. Along streams it is mixed with willow, Oregon ash and bigleaf maple.

Successional type: A pioneer species that establishes rapidly in openings created by forest disturbance, but will not reproduce in the absence of exposed mineral soil (Niemiec et al., 1995). Rapid coloniser in moist clear-cut forest areas. Outgrows other species (including conifers) in early years and thereby prevents growth of conifers.

Light requirements: Very light-demanding. Full sunlight is required for good growth (Holmberg, 2006).

Stress tolerance: Sensitive to early spring and late autumn frost (Harrington, 2006).

Climatic requirements: Northerly through easterly aspects especially on steeper and drought-prone slopes (Holmberg, 2006). Growth can also be quite good on upland sites with adequate soil moisture and a favourable climate. Good sites are generally found along streams, in moist bottomlands and on lower slopes. Typical climate is mild and humid. It tolerates occasional flooding during the growing season, but sites with prolonged flooding are unsuitable (Niemiec et al., 1995).

Soil preference: Moist, but well-drained soils. The most productive stands occur on deep, well-drained loams and sandy loams derived from marine sediments or alluvium. Plentiful soil moisture during the growing season is essential for good development. Soils low in available phosphorus (P) greatly limit establishment and growth. Deficiency of P is indicated by a foliar concentration of less than 0.16%. Deficiency of soil nitrogen (N) is of lesser concern because of its symbiotic association with the actinomycete, Frankia.

Strengths and threats: Is fairly free of problems from insects and disease in its native habitat. It is browsed upon by deer and is sensitive to late spring and early autumn frosts.

Regenerative capacity: Like other alders it is a prolific seed producer, but seeds will only germinate in open areas of recently disturbed moist mineral soil. When young it sprouts vigorously from stumps and can be repeatedly coppiced (Harrington, 2006).

Provenance: In Britain the use of provenances from its northerly range has only been partly successful in overcoming sensitivity to frost (Evans, 1984).

Growth characteristics

Height/Age: Red alder has rapid juvenile growth. Growth slows after the juvenile phase, the decrease coming much sooner on poorer sites. Typical growth rate of red alder on good sites is shown in Figure 7.1-4.

It reaches heights of 20–35 m – the world's largest alder species – and has a lifespan of 40–70 years.

Production potential: Site index, as determined at base age 50 years, ranges from 18–37 m.

Production rates in young stands are estimated at 16 t/ha dry weight per annum.

Maximum volume typically occurs at age 50–70 years, ranging from 350–490 m^3/ha. On very good sites, annual volume growth rates average 20 m^3/ha for the first 10 years and 14 m^3/ha over 30 years (Niemiec et al., 1995).

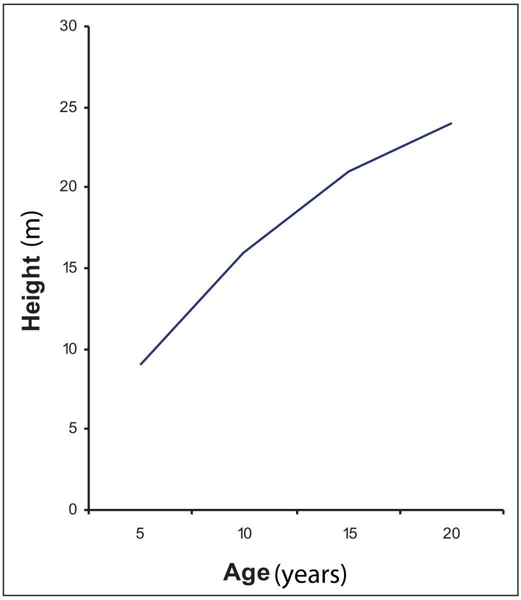


Figure 7.1-4: **Typical growth pattern of red alder on good sites.** (Harrington, 2006)

Values

Silvicultural values: In the past red alder was considered a weed species in forests of coastal Washington and Oregon and treated with herbicide. Now it is regarded as one of Western USA's most important broadleaf species.

Economic values: It is British Columbia's most important hardwood. In western Oregon, alder is chipped for pulp, peeled as veneer for plywood, sawn for lumber and burned to heat homes (Hibbs, 1996). In western USA and British Columbia it is being increasingly used in furniture and cabinet making.

Ecological values: As with other alders, it hosts the nitrogen-fixing actinomycete, *Frankia* spp.

Amenity values: Its rapid early growth makes it a useful tree for planting on disturbed ground such as spoil heaps.

Silvicultural management

Production of plant material: Plantations can be established with a variety of planting stock types. Best survival and growth rates for seedling stock is characterised by plants 30–90 cm in height and basal diameter of at least 4 mm (Niemiec et al., 1995).

Regeneration: Young red alder will sprout vigorously after cutting (coppicing). Trees more than 10 years old will not coppice well and regeneration of older stands by coppicing is not feasible.

Tending of young stands: Its rapid early growth makes cleaning unnecessary. Due to monopodial growth habit the crop will generally not require shaping. As a shade-intolerant species lower branches die and trees self-prune readily.

Thinning: Early crown thinning is essential to keep crop growing vigorously. As with common alder, self-thinning or mortality is rapid in overstocked red alder stands.

Conclusions

Red alder has many characteristics in common with Sitka spruce: a latitudinal range from Alaska to California and a likely similar range of provenances, susceptibility to late spring frost, and a preference for moist, but well-drained soils.

Its association with Sitka spruce within the range of habitats suggests that Washington

Continued

Conclusions continued

State provenances might be most suitable for Ireland, but this should be investigated through field research.

An unthinned stand in the John F. Kennedy Arboretum, growing on a dry site with a southerly aspect, initially showed a rate of growth superior to that of Sitka spruce, but its rapid early growth and promise was not maintained; it collapsed suddenly at 13–14 years. Similar phenomena have occurred in Britain, especially on poor sites, and this has discouraged further planting of the species.

In light of its increasing usage as a lumber species in the American North-West, and its excellent growth rates, its possible role in Irish forestry merits further investigation.

7.1.3 Italian alder

Scientific name: *Alnus cordata* (Loisel.) Duby**.** The scientific term *cordata* refers to the leaf outline which is heart-shaped.

Origin and geographic distribution: Italian alder has a very restricted natural range, being confined to Corsica, southern Italy and western Asia (Figure 7.1-5). It was first introduced to Britain in 1820 (Evans, 1984).

Figure 7.1-5: Natural distribution of Italian alder. (EUFORGEN, 2009)

Botanical characteristics

Tree form: Conical shaped crown of greater density than that of other alders.

Stem form: Upright form growing up to 25 m in height and 100 cm in diameter.

Bark: Greenish grey when young; smooth with numerous lenticels, which gives it a blistered appearance, changing to grey brown with age and becoming fissured.

Timber: Similar to common alder.

Leaves: Alternate, dark green and shiny on upper surface; heart-shaped (cordate) with small tufts of brown hairs in axils of veins on underside; 5–10 cm long and finely serrate at margin.

Ecological characteristics

Forest type: A tree of mixed birch and aspen forest in floodplains and riparian zones. It can also occur in dense thickets as a result of natural regeneration.

Successional type: Pioneer species.

Light requirements: Strongly light-demanding.

Stress tolerance: Susceptible to damage by late spring frost.

Climatic requirements: Prefers warmer sheltered sites, but withstands exposure once established; tolerates atmospheric pollution.

Soil preference: Grows well on a wide range of soil types from wet to dry; thrives on calcareous soils which are alkaline on the surface (Evans, 1984). It tolerates a pH range of 5–8 and will grow on drier soils than most other alders.

Strengths and threats: Not as frost-hardy as common alder; sensitive to late spring frost.

Regenerative capacity: Its ability to coppice is variable.

Growth characteristics

It grows more rapidly than common or grey alders with height increments of more than 1 m/year in youth and a greater volume production per ha. Horgan et al., (2003) recorded a top height of 22 m and a standing volume of almost 400 m^3/ha at 34 years for a stand at the John F. Kennedy Arboretum (Plate 7.1-5).

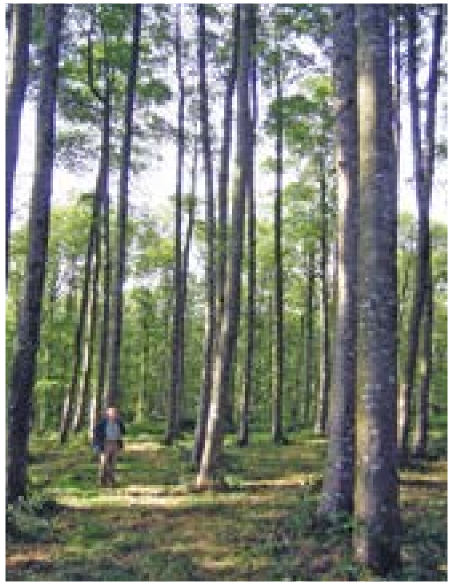


Plate 7.1-5: A fine stand of Italian alder. (John F. Kennedy Arboretum, New Ross, Co Wexford)

Values

Silvicultural values: Because of its tolerance of dry alkaline soils it is the species of choice on such soils. It is regarded as a valuable tree for landscape planting on difficult sites such as spoil heaps and compacted soils.

Conclusions

Its growth performance suggests that its potential as a forest species in Ireland has yet to be realised.

When planted in more exposed situations, albeit on a limited scale, it has performed poorly. This may be partly attributed to its rapid early growth and heavy crown development.

It is deserving of further trial plantings, but needs to be confined to the warmer parts of the country on sites not too exposed. On dry calcareous sites or where the pH exceeds 7 it is the alder species of first choice.

7.1.4 Grey alder

Scientific name: *Alnus incana* (*L.*) Moench (from Latin *incanus* = ash-grey).

Origin and geographic distribution: Grey alder has a much more limited distribution than common or black alder and is not native to Ireland or Britain (Figure 7.1-6).

It occurs in Europe, in the north and centre as well as in the mountains of the east and south and to the west of Siberia and in the Caucasus. In France it is found in the Jura, the Alps and the valley of the Rhine along the streams, rivers and mountain torrents.

It was introduced to Britain in 1780 (Savill, 2013).

Botanical Characteristics

Tree form: Crown is much less regular than that of common alder.

Stem form: On poor soils it remains shrub-like.

Timber: Similar in appearance to common alder, but inferior in quality.

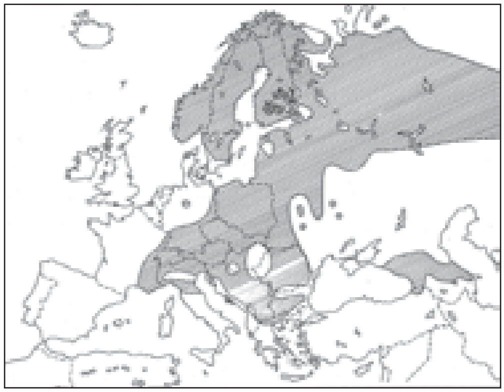


Figure 7.1-6: Natural distribution of grey alder.
(Suszka et al., 1996)

Leaves: It has longer more pointed leaves and their lower surfaces, as well as the young shoots, show a distinct silvery-grey down. The thick leaves are grey-green and double-toothed.

Flowers: Flowering takes place some two weeks earlier than common alder.

Fruits: Maturation of the conelets is also a little earlier. When both species are grown on the same site, hybridisation can occur.

Ecological characteristics

Forest type: Similar to common alder, but sometimes forms small pure stands along rivers on the Continent.

Successional type: Pioneer species with shorter life span than common alder. At about 60 years of age it goes into sharp decline and dies.

Light requirements: More shade-tolerant than common alder.

Climatic requirements: In the lowlands it grows in moist soils and in swamps. In the mountains it is found up to 1800 m and even to 2000 m in the Caucasus.

Soil requirements: It adapts to drier sites and heavy clays better than common alder.

Strengths and threats: Less frost-hardy than common alder.

Regenerative capacity: Grey alder shows a tendency to produce root suckers some distance from the tree at an early age (Horgan et al., 2003) and also after mature trees have been felled (Savill, 2013). It layers easily and can be propagated from cuttings.

Conclusions

Its tendency to produce root suckers some distance from the tree is an asset in some locations, such as roadside embankments, where the purpose is to colonise the site. In a managed plantation, however, this attribute can be a costly nuisance. As a nurse for other species on frost-prone sites it is inferior to common alder. It is more adaptable to a wider site range than common alder, particularly the drier sites where common alder will not thrive.

Grey alder is not an important species in Ireland and is unlikely to become so in the future.

7.2 Ash

Family: *Oleaceae* - Olive.

Genus: *Fraxinus* comprises some 43 species distributed throughout the northern hemisphere. Nearly half occur in North and Central America, and the remainder in Europe, North Africa and Asia. Three species of ash occur in Europe: (1) common ash, (2) narrow-leaved ash and (3) manna ash are of interest to Ireland, but each for a very different reason. Only common ash is native to Ireland.

Both common ash and narrow-leaved ash are large wind-pollinated trees, very closely related and known to hybridise where their distributions overlap. They are so similar in appearance that the latter has at times been mistakenly imported from the Continent in consignments of common ash planting material. The subject of their hybridisation is dealt with at the end of this chapter.

Manna ash is a smaller insect-pollinated, frequently multi-stemmed, tree of little or no forestry importance, but it too may have found its way into young ash plantations by a similar route.

Distinguishing common and narrow-leaved ash

Distinguishing common ash and narrow-leaved ash on the basis of bud, leaf and shoot characteristics is likely to be inconclusive due to the high degree of variability. The clearest practical distinguishing characteristic is the type of inflorescence and fructification.

Figure 7.2-1 shows key characteristics of the two species.

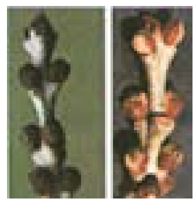
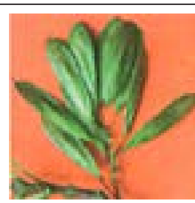
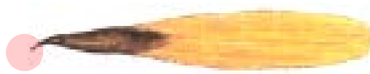
Criteria	Species	
	Common ash	Narrow-leaved ash
Buds	 Black to dark brown	 Brown (variable)
Leaflet	 Oval-shaped to spear shaped	 Narrower, spear shaped
Inflorescences and fructifications	 Branched (panicle with 50-150 flowers/fruits)	 Unbranched (raceme with 15-20 flowers/fruits)
Fruits (samaras): seed cavity	 Flattened	 Cylindrical

Figure 7.2-1: Key distinguishing characteristics of common ash and narrow-leaved ash.
(Adapted from Fraxigen, 2005)

Common ash (Figure 7.2-2 (a)) is a species of the temperate zone. Its northern limit is in Norway and it extends south to the Mediterranean, where its distribution overlaps that of narrow-leaved ash (Figure 7.2-2 (b)). Narrow-leaved ash is mostly confined to countries bordering the Mediterranean and the Black and Caspian Seas. It has a southern limit in Morocco and Algeria and extends northwards through Central Europe into Slovakia and southern Moravia.

7.2.1 Common ash

Scientific name: *Fraxinus excelsior* L.

Irish name: Fuinseóg.

The *excelsior* in its scientific name - which translates as taller, loftier or still higher – refers to its magnificent status among European broadleaves.

Origin and geographic distribution: Common ash has a wide natural distribution, occurring within climate zones as markedly different as oceanic and continental. It is indigenous throughout Europe from the Mediterranean to Norway and from Ireland to central Russia. It extends eastwards through northern Turkey to the Caspian Sea and the mountains of northern Iran (Figure 7.2-2 (a)).

Ash is recorded in about 3% of the total stocked forest area (refer to Chapter 1.5). More than half of this is under 20 years of age.

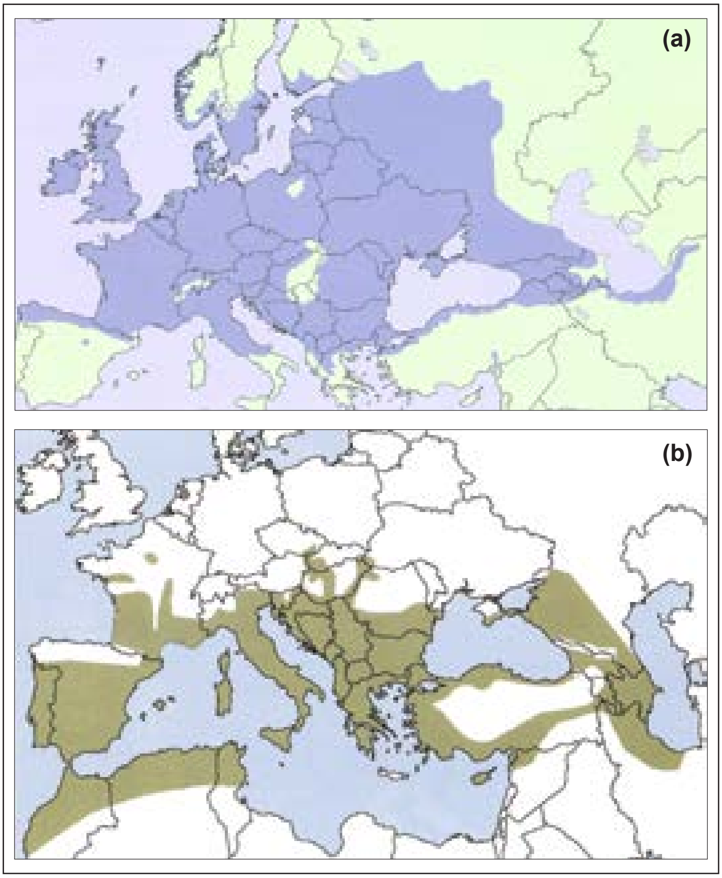


Figure 7.2-2: Natural distribution of common ash (a) **and narrow-leaved ash** (b). (Fraxigen, 2005)

Botanical characteristics

Tree and crown form: Ash has a light, domed crown, generally with steeply angled branches when young. Even as a solitary tree it never reaches a crown diameter comparable with beech.

Stem form and dimension: Common ash is one of the most magnificent trees of Europe, reaching heights of more than 40 m at its maximum, although 30 m is more the norm.

Bark: Pale grey and smooth on young trees, becoming fissured and ridged with age.

Timber: Ash is a markedly ring porous wood. Viewed in cross section the very large earlywood (springwood) pores of the annual ring, alternating with the strong, hard, dense latewood (summerwood) are easily discernible (Plate 7.2-1). This latter feature gives ash

Key characteristics

- Strong light-demander,
- very site specific,
- susceptible to damage by late spring frost,
- very responsive to vegetation control,
- susceptible to forking of leader,
- good natural pruner,
- prolific seed producer,
- very rarely attacked by grey squirrel.

its toughness after drying. The more rapid the growth, the greater is the proportion of latewood, resulting in greater flexibility and better bending ability.

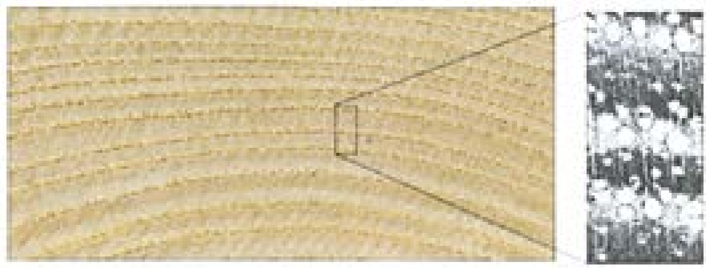


Plate 7.2-1: Cross section of common ash timber. X 40

Air-dried ash timber weighs 700–800 kg/m^3.

In the tree, the mechanical attributes of ash wood remain stable up to about 60 years of age, after which they tend to diminish. At 70–80 years the rapid diameter growth rate begins to decline and the onset of **black (brown or olive) heart** usually appears, giving a black or brown discolouration at the heart of the tree. Although its cause is unknown it is variously attributed to factors of site, origin of tree and age. Ash grown on wet or swampy ground is said to be more prone to black heart, as is ash originating from coppice origin.

In trees not affected by black heart there is little colour distinction between heartwood and sapwood: the general colour is white.

The wood is non-durable and perishable if exposed out-of-doors. The heartwood is moderately resistant to preservatives, but the sapwood is more permeable.

Root system: Is wide-spreading and consists of a taproot and long side roots, which provide stability against storms. Because of this wide-spreading root system, ash shows a high degree of stability and is rarely windthrown.

Leaves: Like most of the 60 ash species of the world, it has pinnately compound leaves. Leaves are dark green on the upper surface, 20–35 cm long with a stem-like axis carrying 7–13 leaflets each 5–12 cm long, oblong-lanceolate in shape with a pointed apex and toothed margins. Buds are black and conical, set in opposite pairs.

Flowers: Flowering is in April-May. Panicles of purple flowers develop from side buds before the leaves flush. The flowers are wind-pollinated, partly monoecious, partly dioecious. Flower structure is simple: two stamens, one ovary and a style and stigma. Often one of the two sexes aborts and so it is common to find individuals which are either male or female (Suszka et al., 1996). Seed production starts relatively early (at around 25–30 years), but solitary trees may bear seed much earlier. Mast years are usually every 2–3 years.

Fruits: Ash seeds (samaras) form large pendant clusters (panicles); each samara is about 4 cm long and 6–8 mm in width, lanceolate, green at first, becoming brown. They ripen on the tree during July to October and are shed over the winter and early spring, but most do not germinate until the following spring. However, if seed is collected as soon as it fills (before ripening), and is sown immediately, a high proportion will germinate in the following spring. Ash seed can be stored in the dry state for up to 10 years. The weight of 1,000 ash seeds varies from 65–100 g.

Ecological characteristics

Forest type: In its natural habitat ash is found growing both at low elevations and in mountain regions. Unlike oak and beech, it is rarely found in pure stands of any great extent. More usually it forms a component of broadleaf mixtures. In the higher parts of the riparian forest it will be found in mixture with oak and elm.

Successional type: It is classified as a long-living pioneer species.

Light requirements: Although ash is a strong light-demander in later years, it will tolerate considerable shade in youth, but will stagnate if not released within a few years.

Ash needs overhead space and light for the development of a large crown to attain rapid growth of the stem.

Stress tolerance: Although planting of ash in pure crops on bare land provides adequate light, and avoids the risk of competition from companion species, it presents a danger from frost and exposure. Ash is susceptible to damage by late spring and early autumn frosts. In late mild autumns it sometimes fails to harden-off completely before a sudden onset of winter. This can result in the death of buds and upper parts of the young branches and lead to forking of the shoots in the following year.

Late frost in spring, to which ash is extremely sensitive, may kill the opening buds or emerging leaves; this also leads to forking.

Ash, together with oak, is the last of the broadleaf species to flush. The strategy seems to be that it attempts to avoid frost damage by this behaviour.

Climatic requirements: Ash prefers sheltered locations found only in the lowlands. Good ash sites are almost exclusively former tillage or pasture. Afforestation on former agriculture land meets the high light demand for this species, but presents problems which can be ameliorated by shelter. For rapid growth, ash requires side shelter. This can be provided by topographic features or, where they are absent, by shelter from other species. On sites open to exposure, pure ash should preferably be intermixed in groups, of around 500 m^2, with groups of other species, such as sycamore or a suitable conifer, which will provide side shelter.

Frost hollows and other low-lying situations, where the emerging leaves and buds may be severely damaged by late frosts, should be avoided.

Soil preference: Ash is so site demanding that it accommodates very little room for error in terms of site selection. It is unlikely to achieve optimum growth unless it is grown on continuously moist, fertile soils. Soils that have been continuously cropped may need additional nutrients. For good growth ash needs soil conditions found mainly in the lowlands in areas that are frost-free. Such sites are not widely available for planting. Attempting to grow high quality ash on other sites is not likely to be successful, because it needs to be grown rapidly. It is probably better to grow species other than ash if this cannot be reasonably assured. Good ash sites are so limited in extent that ash should be the first option as the main species on such sites.

Compared with beech, sycamore and oak, ash has a high demand for nutrients, particularly nitrogen and phosphorus. To service this demand the soil has not only to be relatively high in nutrient levels, but also moist enough throughout the growing season to facilitate water-mediated transport of nutrients to the tree roots.

The best ash soils are found primarily amongst those developed on limestone parent materials, namely brown earths and grey-brown podzolics.

These are found mainly in the central area of the country, covering an area roughly encompassed by the counties Louth, Roscommon, Galway (east of Lough Corrib), Tipperary, Kilkenny, Carlow, Kildare, and Meath.

Good ash soils can also be found amongst the rendzinas and shallow brown earths of north Clare (Burren) and mid-Galway regions. Such areas tend to be very small, restricted to deeper pockets within the overall matrix of soils. Extreme care needs to be taken in selecting a site for ash in these areas due to the danger of the soils becoming too dry.

Ash grows well on some drumlin soils. The north-west drumlin belt, stretching from Strangford Lough westwards through Armagh, Monaghan, Cavan, Leitrim, Fermanagh and south Donegal, consists of a thick cover of boulder clay deposited by glaciers in the form of small hills. Gardiner and Radford (1980) have documented these drumlin soils. They explained that the poor drainage, which is often associated with these soils, is largely a function of parent material composition rather than an inherent feature. The soils of Leitrim, for example, are almost all poorly drained due to the heavy impermeable boulder clay of Upper Carboniferous shale composition. In contrast, the drumlin soils of parts of Monaghan and Cavan, where the boulder clay is formed from Palaeozoic shales and have a higher sand content, are free-draining and produce good conditions for the growth of ash.

Suitable ash soils can also be found in the Old Red Sandstone valleys of north Munster. These occur in those parts of the valleys – in or around the valley bottoms or footslopes – which have a significant component of limestone and/or shale glacial material in their soil parent material. The fine texture of the limestone and/or shale glacial material confers a clay-loam texture, thus allowing the soil to be water-retentive in dry spells. In addition, the limestone and/or shale material enables the soil to have reasonably high pH and nutrient levels for ash.

Ash has a wide tolerance of topsoil pH, which should not be less than 5, but it should ideally approximate neutrality (pH 7.0) in the lower parts of the soil profile. Although ash can be grown successfully on soils with a pH as low as 5, it develops best on deep, moist, free-draining and fertile soils of about pH 7.

Results from a soil study show that the brown podzolics and acid brown earths, covering large parts of Wicklow and Wexford, present problems for ash growth, although they are excellent for other tree species. Several factors are involved: low pH, low base status, excessive drainage (prone to drought), and low phosphorus availability in the soil.

While ash benefits from a good supply of water in the soil, it will not tolerate stagnant water conditions, swampy or compacted soils. Sites should be moist with a movement of water through the soil.

Strengths and threats: Ash is liable to suffer damage to its leading shoot and this, more often than in continental countries, leads to serious forking. Large areas of ash monocultures tend to be more prone to attack by ash bud moth and have the leaders broken by wind resulting in poor stem form.

Unusually late spring frost may kill the buds and newly flushed shoots, resulting in forking of the leader. It has been shown that death of emerging buds of seedlings will occur after 18 hours exposure to - 3 °C. Early autumn frost may lead to the same result. Planting ash with a nurse species does not necessarily overcome frost problems in low-lying situations. Such areas should, therefore, be avoided.

Ash suffers from leader breakage, even in relatively sheltered locations. This also results in forking.

It is susceptible to competition from grasses up to late in the rotation. This is particularly so on drier sites and is due to water deficiency and to competition for nutrients induced by the grasses.

Ash is prone to damage by hares and rabbits if left unprotected. Deer (fallow, red and Sika) tend to browse intensively on young plants and should be excluded, usually by fencing. Otherwise, seedlings and saplings will be destroyed. Large populations of fallow deer can wreak havoc in young plantations at the sapling stage through browsing and may also lead to heavy bark stripping of pole stage crops up to 20 cm diameter (refer to Plate 4.4-48).

Unlike other broadleaves, such as sycamore, beech and to a lesser extent oak, damage to ash by grey squirrels is rare.

As a forest tree, ash is susceptible to insect pests and fungi. The ash bud moth (*Prays fraxinella*) is the most serious insect pest and is regarded as one of the main causes of damage to the leading bud resulting in forking. It tends to be more of a problem on larger areas of pure ash.

Among the diseases that affect ash is canker of the stem and branches. The causal organisms are a fungus, *Neonectria galligena,* and a bacterium, *Pseudomonas syringae* subsp. *savastanoi,* which give rise to two different types of canker.

The canker caused by *Neonectria* is relatively symmetrical in shape. It often occurs where dead twigs or branches join the tree stem. From there, oval lesions develop which can reach up to 30 cm diameter after a number of years.

In contrast to those caused by fungi, bacterial cankers are very irregular in shape. The bacteria gain entrance through wounds and leaf abscissions and the damage to the cambium results in swelling and cracking of bark. This gives rise to a multitude of black necrotic lesions on the stem.

Although neither canker-causing organism is likely to result in death of the tree, they deform the stem and lead to considerable depreciation in wood value (refer to Plates 4.4-58 to 4.4-60). From a forestry point of view, the growing of ash on suboptimal sites should be avoided since bacterial canker, in particular, occurs on ash growing on acidic, boggy and extremely wet soils (Wulf and Kehr, 2009). Removal of affected trees is recommended to prevent the spread of the disease.

During the past decade a more destructive threat to ash, in the form of dieback, has emerged in eastern, northern and central Europe. The most visible symptom is top-dying, with 1- and 2-year-old shoots dying either before flushing or during dry periods in summer. Other symptoms include elongated cankers on the stem and branches, as well as dieback of the upper parts of the crown. The disease is most notable in young stands 4–10 m tall and appears to occur on trees of average to below average size.

Initially it was believed that adverse climatic factors were at least partially responsible for the dieback, but this was soon discounted. Thomsen (2007), reporting on the disease in Denmark, suggested that the pathogen might be *Chalara fraxinea*, a fungus first described by Kowalski (2006) on ash dieback in Poland. Although studies in Sweden by Bakys et al. (2009) isolated many different fungi from symptomatic tissues in trees with dieback, their role in tree mortality remained unclear.

Research work by Skovsgaard et al., (2010) on the associations among macroscopic symptoms of crown dieback, has indicated that dieback in ash due to *C. fraxinea* is a primary disease. Dieback and canker symptoms in the crown are strongly associated. The disease is also associated with symptoms of *Armillaria gallica* as a secondary damaging agent, but no associations were found with symptoms of *Neonectria galligena* or *Pseudomonas syringae* subsp. *savastanoi.*

More recent research (Sansford, 2013) has identified the disease-causing organism of ash dieback as *Hymenoscyphus pseudoalbidus* (anamorph *Chalara fraxinea*), but it is commonly referred to as 'Chalara dieback'.

From a silvicultural perspective, dieback is a very serious threat to ash stands. The fact that ash dieback appears to occur more frequently on trees of average to below average size within stands suggests that slow-growing or less vigorous trees are less resistant to the disease. This emphasises the need for appropriate site selection for ash.

In October 2012 the occurrence of ash dieback was confirmed in both Ireland and England. The outbreak in Co Leitrim was traced to a consignment of imported ash plants and in order to restrict spread of the disease some 33,000 young ash were destroyed. This was accompanied by a Ministerial order banning the importation of ash with immediate effect. Other stands of imported ash were being monitored by the Forest Service to determine the spread of the disease. By the spring of 2013 the disease has been identified on several more forest sites, horticultural nurseries, roadsides and farm plantings in both the Republic and Northern Ireland. Efforts are continuing to destroy all sources of the disease. A draft All-Ireland Chalara Control Strategy, developed by the relevant departments in both jurisdictions, outlines an approach to identify, control and eradicate the disease that causes Chalara ash dieback. The draft strategy includes joint policies on surveillance, destruction, research collaboration, general awareness, and advice. It is important that all stakeholders engage in the process to ensure that the best measures and policies can be identified to control and eradicate the disease from the island of Ireland.

Regenerative capacity: Ash regenerates freely on most soils in Ireland, but shows good growth only on fertile soils with sufficient rooting depth. The facility with which it regenerates naturally from seed ensures that it is one of the most common trees of the countryside and is the main tree species in many hedgerows. In most broadleaf woodlands ash will be found regenerating in small openings where it forms dense thickets. Although it regenerates freely on a variety of sites ranging from wet to dry, the presence of young ash trees should not lead one to assume that such sites are suited to the growing of ash for wood production.

Provenance: Ash is a native species that occurs abundantly throughout Ireland. Its abundance, fecundity and ability to remain viable in storage for up to 10 years has resulted in home-collected seed being used widely in the early planting programmes. Until the beginning of the 1990s only 5% of the seed sown was imported and most of that is attributable to one purchase of 225 kg from Denmark.

With the sharp increase in private planting from the 1990s onwards, demand for ash planting material outstripped supply and the shortfall was met by importations from the Continent, some of which inadvertently contained the related Mediterranean species, narrow-leaved ash.

Local provenance variation in ash is not known at this stage, nor is the performance of UK or Continental sources when grown in Ireland.

As a general rule, seed source studies have shown that when dealing with native species local provenances tend to out-perform those from other latitudes and climates. Where possible seed should be sourced from registered ash seed stands of which there are 156 ha currently registered (Fennessy et al., 2012). It should be collected from a minimum of 20–30 trees to obtain the full range of genetic variation available. The necessity to import seed and plants of ash is of lesser degree than for the large-seeded species of oak and beech. If imports are necessary then registered British and Dutch sources are recommended.

Growth characteristics

Height/age relationship: Like other pioneer species, ash grows very rapidly in the early years, enabling it to outperform competing ground vegetation. Current annual height growth increment culminates at around 20 years of age, averaging 50–60 cm. It diminishes to 25 cm around the age of 50 and to 8–9 cm at 100 years of age (Figure 7.2-3a). This is in contrast to the growth of beech, which culminates later and is more sustained.

Cumulative height/age growth of ash and beech follows a similar pattern (Figure 7.2-3b).

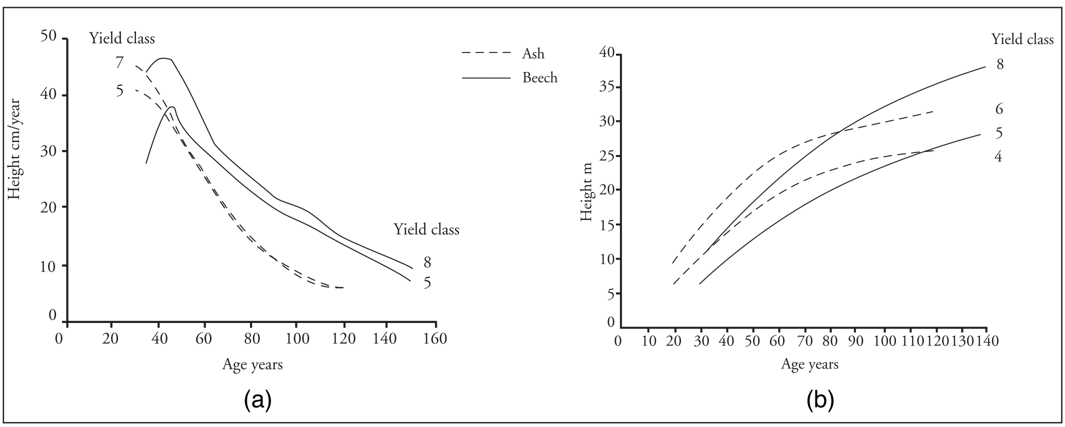


Figure 7.2-3 Current annual height growth (a) **for ash and beech**; height/age graph (b) **for ash and beech** (Volquardts, 1958; Schober, 1967).

British models (Edwards and Christie, 1981) are intermediate in height/age growth between the best two site classes in northern France (Nord-Picardie) up to the age of 40 years. Thereafter, the French models show much more rapid height growth and at 80 years have dominant heights of 34 and 30 m (Pilard-Landeau and Le Goff, 1996) compared with 26 m for the British model.

Total volume production: The British sycamore/ash/birch combined yield models show a maximum general yield class of 12.

Values

Silvicultural values: Ash is intolerant of competition and is a useful component in mixtures, but should be planted in groups rather than in intimate mixture (Savill, 2013). It is rarely completely successful when planted in large blocks as a pure plantation species.

Economic values: The primary objective in growing ash should be the production of logs suitable for sawtimber and veneer for the furniture industry, as this will generally provide the largest return to the grower. A by-product of this main objective may be butts from earlier thinnings suitable for the manufacture of hurleys and will include material for parquet flooring and fuelwood. It provides one of the best and most sought after firewoods.

Requirements for the production of the two commodities - logs for sawtimber and hurley butts - is described below:

- **Production of high quality logs for sawtimber**
  The normal dimensions required for sawing are logs with a minimum length of 2.5 m and a mid-diameter over-bark of 26 cm upwards (Plates 7.2-2 and 7.2-3). The objective should be the production of such logs with regular and large annual rings (4–5 mm in width radially or 0.8–1 cm annual diameter growth). Such growth also leads to excellent machining properties for furniture production.

Plate 7.2-2: High quality ash.
(Townly Hall, Co Louth)

Plate 7.2-3: Felled high quality ash.
(Britain; courtesy: Guest)

Large ring widths give mechanical properties favourable for products which require strength, flexibility and elasticity. Rapidly grown ash is very suitable for sports goods such as hurleys, hockey sticks and for tool handles, where shock absorbance and strength are required. For uses that require a handgrip, its smooth surface which rarely splinters, is a valuable quality.

Slow-grown ash with narrower ring widths leads to wood of lesser strength which tends to be brittle and breaks easily. Because strength is not required it can be used for veneer if logs are of a suitable size.

Ash is a popular timber for furniture because of its strength, clean white appearance and varied surface figure. It lends itself readily to steaming and bending without breaking or losing strength. This process is used to form curved parts of furniture and the ends of hockey sticks.

Black heart has very little effect on the mechanical properties of the wood, but it usually depreciates the merchantable value for sports goods. In France, the presence of more than 20% discolouration at the heart of the tree at stump level leads to a reduction in value of the order of 50%, but in Ireland it is often regarded as a novel feature by craft workers for cabinet making. Globally, however, the fashion trend is for white timber.

- **Growing ash for hurleys**

Currently, the main use for ash in Ireland is in the manufacture of hurleys (Plates 7.2-4 and 7.2-5). Specifications for hurley ash require a straight butt length of 1.5 m free of branches or defects such as extraction damage or other injury. Diameter at breast height should exceed 18 cm and ideally be in the range 28–32 cm. As stated above, the material most suitable for hurley manufacture will be fast-grown with large annual rings. Only the butt length with buttresses is used for hurleys.

The scarcity of hurley ash in the 1980s prompted an extensive study by the Forest Service into the prospects of future home supplies (Fitzsimons and Luddy, 1986). The study found that almost half a million hurleys of all sizes were required each year. Based on this figure, and assuming average production from good quality butts, it was calculated that an area of about 50 ha/yr would be sufficient to supply the hurley ash

Plate 7.2-4: Preparation of ash for hurleys. (Jenkinstown, Co Kilkenny)

Plate 7.2-5: Hurley butts prepared and ready for extraction. (Jenkinstown, Co Kilkenny)

market. On the assumption that hurley ash can be produced on a 25-year rotation, the total area of ash required for hurley production was then estimated to be about 1,250 ha.

Even allowing for a less optimistic rotation of 40 years, which is more in keeping with the requirements of stems of 28–30 cm diameter breast height, hurley requirements can be supplied from some 2,000 ha with a normal age class distribution, grown specifically for hurleys. This takes no account of thinnings suitable for hurleys produced under other regimes.

In the light of this study, and taking account of the large area (almost 12,000 ha) of ash planted over the past 20 years (refer to Chapter 1.5), which will begin to reach hurley dimensions within the coming decades, it seems reasonable to recommend that production objectives be directed towards much broader product requirements, such as sawlog and veneer.

Ecological values: Ash casts a light shade which permits the development of a rich ground vegetation. In the Burren, Co Clare, for example, where hazel and ash are the dominant woodland types, a ground flora develops which is rich in herbs and includes primroses, wild strawberries, bluebells, cuckoo spit and ferns in abundance.

On free-draining loam, ash and pedunculate oak may form the canopy with an understorey of holly, hawthorn and hazel and, less abundant, downy birch, rowan and spindle (Nelson and Walsh, 1993).

Amenity values: When grown in isolation in a sheltered parkland setting, ash shows its full potential and develops into a magnificent tree comparable in stature with oak, beech or sycamore, but more graceful in outline. It is the most abundant native tree species in Irish hedgerows.

Historical importance: In the Celtic Laws of Neighbourhood, it was listed among the noble trees, ranked even above oak (Kelly, 1999). Three of the five greatest legendary trees of Ancient Ireland were ash: *Bile Tortan, Craeb Daithi and Bile Uisneg*. *Bile Tortan*, which was credited with providing shelter for the men of Tortu, fell in 600 AD (Nelson and Walsh, 1993). Hayes (1822) referred to a magnificent ash *above 14 feet round, and carried nearly the same for 18 feet*, growing *nearly surrounded with water on the bank of the Avonmore*, which was blown down in a violent storm in 1776.

Silvicultural management

Production of plant material: For nursery plant production the seeds are harvested when they turn brown in October/November. When the moisture content has been reduced sufficiently the seeds are cold-stored until the following June. Ash seed, when ripe, is practically incapable of germinating and must be pre-treated by stratifying in a sand-peat mixture to break dormancy.

Seed production of ash in closed stands is generally poor (due to lack of thinning which results in small crowns). Therefore, collections have almost exclusively been from hedgerow trees. It is likely that these will continue to be the main source until seed stands are brought into production. For the longer term, seed orchards have been established with grafted material from trees intensively selected in plantations for good growth and form.

Plants normally used are 1+1 and 1+2 transplants. Recommended height ranges from 40–90 cm.

Regeneration: Ash shows a remarkable capacity for natural regeneration on many soils, even on those where it will not grow well, such as heavy gleys and on dry thin soils overlying limestone. Despite its capacity for regeneration, good quality ash stands in the production stage are few and far between. This may be partly due to the high demand for hurley ash material, which has often resulted in selective removal of the better stems, but it is also undoubtedly a reflection of site specificity and the general unsuitability for ash production of previously acquired state forest land.

Tending of young stands: Ash has the potential for better apical dominance than beech or oak, but forking of the stem may result from damage to the terminal bud by frost, wind and insects. In those circumstances formative shaping may be necessary.

Ash is one of the best natural pruners, yet artificial pruning may be necessary on some potential crop trees to obtain a branch-free bole of 6 m or more. Where the number of pcts candidates is low, it may be necessary to prune off heavy branches to obtain an adequate quota.

Thinning: The objective should be to maintain a sufficiently high stocking density up to a top height of 8–12 m, thereby taking advantage of the tendency for ash to prune naturally. At this height a heavy crown thinning is required to provide growing space for some 250–400 potential crop tree (pcts) candidates/ha to develop their crowns and encourage rapid diameter growth.

A second thinning at a top height of 12–15 m involves the selection of a quota of about 200 pcts from the originals and their release from competitors. Subsequent thinnings should follow at top height increments of 2–3 m by removing competitors to the selected potential crop trees (refer to Table 4.5-7).

The silviculturist will seek a branch-free bole of a minimum length of 6 m, preferably 8 m, with a diameter at breast height of 50–60 cm at maturity (Plates 7.2-6 and 7.2-7). A breast height diameter increment of 1 cm/year will be adequate for this purpose and diameter growth should not be allowed to fall below 0.6 cm/year if high quality timber is required. This necessitates timely thinning to provide adequate growing space for the pcts.

Like all ring porous woods (for example oak and Spanish chestnut) irregularities in ring width reduce quality and give rise to tension in the wood during kiln drying. Variations in ring width result from irregularities in thinning cycles, with alternating periods of stand competition and release. A large increment in diameter, consistent with good quality wood, is difficult to achieve without regular and consistent heavy thinning.

Early intervention is important. Although ash will tolerate shade in early youth it quickly becomes shade-intolerant and will not respond to or recover from delayed thinning.

Plate 7.2-6: Potential crop trees.
(Gosford Forest Park, Co Armagh)

Plate 7.2-7: Free growth of ash.
(Rhine Valley, France)

Conclusions

The criteria for successful growth and development of ash are the most demanding of all the broadleaves. The main features are:

- ash needs a deep, moist, free-draining, fertile soil, of about pH 6–7, for optimum growth conditions;
- ash is very site demanding and is rarely found over large areas for that reason;
- ash will benefit from side shelter provided by other species;
- ash needs to be kept free of grass competition in earlier years after establishment.

Evidence from plantations established during recent years suggests that some landowners have been encouraged by the apparent attractiveness of the hurley market into planting ash on sites where other species would have been more suitable.

Observations suggest that a number of ash plantations fail to conform to the above soil and stand size requirements: soil type in ash plantations ranges from peats to heavy clays, and from those with poor moisture retention to near swamp conditions. Large scale monocultures fail to take account of the variability that exist in fertility, moisture regime and soil structure over any large area. The result is often visible in unthrifty development of stands infected with stem canker. To compound the problem, poor quality stems provide limited opportunity for selection of pcts.

Thinning is sometimes neglected. Early and heavy crown thinning is essential to capture the rapid early growth of the species. If left too late the crop may not respond.

Great attention to site selection and management is required if high quality produce is to be achieved.

On suitable sites ash may be the first choice for the private grower, but if such sites are not available it is better to select a less site-demanding species.

7.2.2 Narrow-leaved ash

Scientific name: *Fraxinus angustifolia* Vahl.

English synonym: Narrow-leaved ash (colloquially known as brown bud ash)

The term *angustifolia* in its scientific name derives from the narrow shape of its leaves.

Origin and geographic distribution

Narrow-leaved ash is found throughout southern Europe, from Portugal in the west through southern France, the Balkans and eastwards to the Caucasus and Iran (refer to Figure 7.2-2 (b)). Forests of the species stretch along the large rivers and their tributaries or are associated with lakes and wetlands. Its distribution overlaps that of common ash in the Mediterranean part of this region.

Narrow leaved ash is a thermophilic species mainly occurring in southern Europe (Tutin et al., 1972). It is a smaller tree (up to 25 m high) than common ash (up to 40 m), and its wood is of lower quality (Picard, 1983).

It has many characteristics similar to those of common ash. Only those that are different are recorded.

Botanical characteristics

Tree and crown form: A tree of medium size with a tall irregular crown.

Bark: Has narrow and deep fissures, dark grey in colour and becoming warty with age.

Timber: In its native habitat it is an important timber species with properties similar to those of common ash. However, common ash has a higher proportion of heartwood and its wood is denser. The mechanical properties of narrow-leaved ash timber are also slightly inferior to those of common ash in terms of compression strength and tensile strength along the grain, as well as bending strength, impact bending strength and bending modulus of elasticity (Fraxigen, 2005).

Leaves: Narrow spear-shaped leaves are 15–25 cm long bearing 5–13 leaflets, each 3–9 cm long, oblong-lanceolate to linear-lanceolate, pointed at apex and with toothed margins.

Flowers: Are hermaphrodite, the axillary racemes appearing before the leaves. Flowering period is in May.

Fruits: Samara 2–4.5 cm long, glabrous, becoming brown when mature.

Ecological characteristics

Forest type: Commonly found in riparian forests, sometimes in pure stands, but more often in mixture with other broadleaves, e.g. oak, hornbeam, elm, maple, alder, poplar, plane, walnut, lime and cherry.

Stress tolerance: Likely to be susceptible to late spring and early autumn frost damage (Plate 7.2-8).

Climatic requirements: Narrow-leaved ash is a thermophilic species occurring mainly in Mediterranean climates.

Soil preference: It grows well on moist, rich clays and well-drained soils and on loams and sandy clay loams with pH in the range 6–8. It commonly occurs in riparian areas and will tolerate wetter sites than common ash and even tolerates temporary flooding. It also grows on sites similar to those preferred by common ash with which it is often found in mixture.

Strengths and threats: As a Mediterranean species, narrow-leaved ash is much more likely to be susceptible to frost damage than common ash and the degree of stem forking will be even more severe. Hybrids of the two species are also likely to inherit some of this trait.

Plate 7.2-8: Individual poor quality narrow-leaved ash in a stand of common ash.
(The Rower, Co Kilkenny)

Growth characteristics

Height/age: In its native habitat it grows rapidly in youth, but its growth rate tends to slow after 50 years. Rotation lengths are similar to those of common ash.

Total volume production: It has a reported mean annual increment of 12–15 m^3/ha/yr (Fraxigen, 2005).

Values

Amenity values: Narrow-leaved ash is being sold in Irish nurseries as an ornamental tree. A report of the Heritage Gardens Committee of An Taisce lists the species as occurring at

Birr Castle (Co Offaly), Kildangan (Co Kildare) and the John F. Kennedy Arboretum (Co Wexford), with cultivars at Castlewellan (Co Down), Illnacullin (Co Cork) and Malahide (Co Dublin). There is also evidence that the tree was grown at the Trinity College Botanic Garden, at Ballsbridge, Dublin in the 19th century (Scannell, 2007). This poses the question as to its possible occurrence in the wild in Ireland.

Silvicultural management

The poor growth and stem form of some ash species in young plantations in Ireland, where the plant material is known to have been imported, has been attributed to narrow-leaved ash. (A proportion show a very definite sinuous branching habit, but these may in fact be manna ash). The long term consequences of the retention of even a small number of these trees have become a concern for both forest geneticists and silviculturists because of the danger of gene pool contamination.

Although it is an important timber tree in its native habitat its performance as a forest tree in Ireland is so unsatisfactory that the Forest Service introduced measures for its eradication. In this way it is hoped to forestall hybridisation with common ash and so prevent contamination of the native ash gene pool.

Conclusions

Narrow-leaved ash has many disadvantages when compared with common ash. It is an exotic species from a Mediterranean climate, more prone to damage by late spring frost and consequent stem-forking. Its wood is inferior. The main threat, however, is that its continued retention in Irish woodland presents a serious risk of hybridisation with the common ash, resulting in contamination of its gene pool. For that reason alone it should be eradicated.

7.2.3 Hybrids of common ash and narrow-leaved ash

Both common ash and narrow-leaved ash are wind-pollinated. Therefore, the opportunity for natural hybridisation depends on the start and duration of flowering in the respective species. Within a given locality narrow-leaved ash will always start flowering before common ash, but in some years the end of narrow-leaved ash flowering may overlap with the beginning of that of common ash, allowing hybridisation to take place.

It is important to note that if hybridisation does occur the hybrid seeds are more likely to be found on common ash because of more overlap between female flower receptivity of that species and narrow-leaved ash pollen release. Therefore, it is much more likely that the common ash gene pool will be contaminated by narrow-leaved ash than the opposite case (Fraxigen, 2005). To avoid this happening it is important that any tree in the stand showing narrow-leaved ash traits, on the basis of leaf and/or bud characteristics, be removed in tending and thinning before they have the opportunity to flower. Seedlings of the two species and their hybrids are indistinguishable on the basis of their morphological characteristics.

The threat posed by hybridisation (of imported narrow-leaved ash or its hybrids) with native common ash is of major concern. It is of sufficient importance for COFORD to fund a study to determine whether hybrid trees can be more readily identified by the use of molecular markers, based on DNA, to distinguish hybrid individuals in unthrifty ash plantations. Furthermore, the capacity of 'hybrid' plantation trees to reproduce and spread in Ireland is being determined by paternity analysis of seeds produced in hybrid plantations and in native trees which surround those plantations. Two years of observation have shown that the flowering periods of imported trees in the hybrid brown bud ash plantations, had significant overlaps with the flowering periods of native hedgerow trees. Therefore, there is a potential for cross pollination of mature lines with plantation trees and vice versa (Douglas and Thomasset, 2013).

7.2.4 Manna ash

Scientific name: *Fraxinus ornus* L.

Origin and geographic distribution

Manna ash has a limited distribution being confined mainly to southern Italy, Greece, the karst region of the Balkans and western Turkey (refer to Figure 7.2-4).

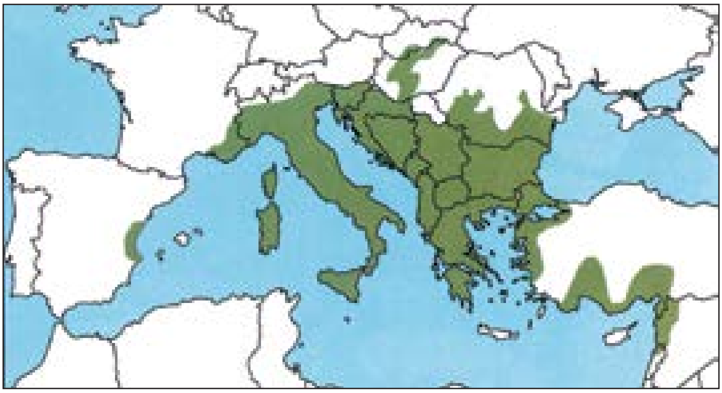


Figure 7.2-4: Natural distribution of manna ash. (Fraxigen, 2005)

Botanical characteristics

Tree and crown form: A tree of medium size with a domed or flattened crown.

Stem form and dimensions: Poor stem quality limits its use as an industrial wood.

Bark: Smooth and grey, sometimes dark grey.

Timber: Lighter than that of common ash and narrow-leaved ash with a density of 650 kg/m^3; used mainly for manufacture of tool handles and house implements.

Leaves: Pinnate, up to 30 cm long, with 5–9 leaflets each 3–10 cm long with pointed apex and toothed margins.

Flowers: Have four white petals and occur in creamy white and fragrant inflorescences, pollinated mainly by insects.

Fruits: Samaras 1.5–2.6 cm long, oblong in shape.

Conclusion

Because of its poor stem quality manna ash has no value as a forest species in Ireland, but may have a role as an ornamental tree in parks. As it is insect-pollinated, it presents no risk of hybridisation with common ash.

7.3 Beech

Family: *Fagaceae* – Beech family.

Genus: *Fagus* L. Of the 30 species of beech which occurred in the northern hemisphere during the Tertiary Period, only 10 now remain. Among them is the one beech species of the European continent, common beech.

Scientific name: *Fagus sylvatica* L.

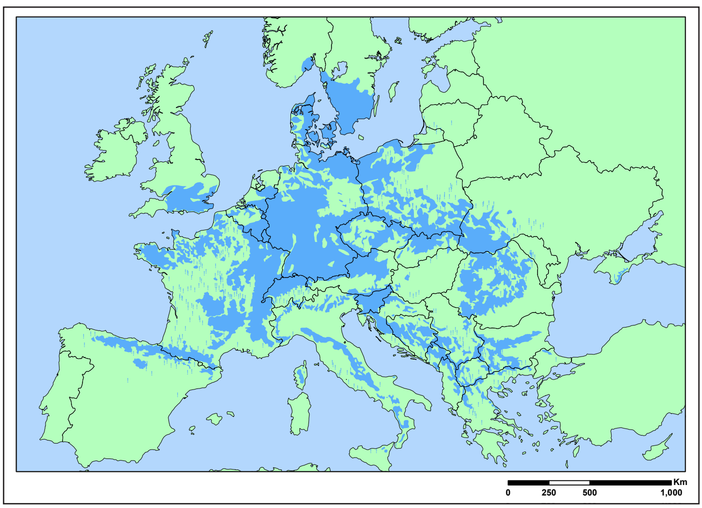


Figure 7.3-1: Natural distribution of beech. (EUFORGEN, 2009)

Key characteristics

- Good shade tolerance, the only significant shade-bearing broadleaf species,
- susceptible to damage by late spring frost,
- preference for moist, base-rich sites,
- prone to coarse growth and forking,
- medium ability to prune naturally,
- susceptible to grey squirrel damage,
- best established under the shelter of old stands or suitable nurse species.

Irish name: Feá.

Origin and geographic distribution: Beech is indigenous to most of the temperate parts of Europe, from Norway to the Mediterranean and from northern Spain to western Poland, the Ukraine and south to the Caucasus. In central Europe it grows both in the lowlands and in the mountains, while in southern and south-eastern Europe it is confined to mountainous regions. It is also native to the south of England (Figure 7.3-1).

Beech was by far the most dominant tree species of western and central Europe in early times, before being subjected to severe exploitation by human activity. Without interference by man, it would again assume that dominance.

Beech is not indigenous to Ireland. According to Nelson and Walsh (1993) it may have been brought here by the Normans, while Fitzpatrick (1966) was of the opinion that it was probably introduced from England sometime during the 17th century. Hayes (1822) seemed to support the latter date. Writing in 1794 he commented that the beech *at Shelton appear among the first which were brought into the kingdom, and from their mast most of our finest beech have been propagated*. Beech formed a substantial component of estate plantations for aesthetics and commercial use during the 18th century. State planting of beech began in the early 1930s and most of the beech plantations were established between then and 1955. It is now regarded as a naturalised tree of considerable potential.

Beech is recorded in 1.4% of the total stocked forest area in the Republic of Ireland (refer to Chapter 1.5). Age distribution is heavily weighted towards the older age classes with almost 60% of the area in the 51+ age category. This consists largely of the 1930s phase of beech planting in the public sector and the old woodland remnants of the private sector. Despite its undoubted potential beech has not featured prominently in grant-aided planting of recent decades, possibly because of perceived establishment difficulties and risks of serious damage from grey squirrel.

Botanical characteristics

Tree and crown form: The crown of the beech is of such remarkable plasticity that, in exceptional circumstances, it can reach diameters in excess of 20 m.

Crown development varies according to the growing space available; in youth, this can be greatly influenced by an overstorey (refer to Plates 4.4-8 and 4.4-9).

Beech may adopt a monopodial growth habit, with associated fastigiate branching, when competing with neighbours in even-aged and relatively dense stands (Plate 7.3-1). The greater the available growing space, the more the branches tend towards the horizontal (Plate 7.3-2).

Young beech will extend their branches into every gap in their vicinity, giving rise to irregularly shaped crowns.

Unfortunately, from a silvicultural point of view, beech stems are often deformed, and twisting is a common occurrence (Plate 7.3-3).

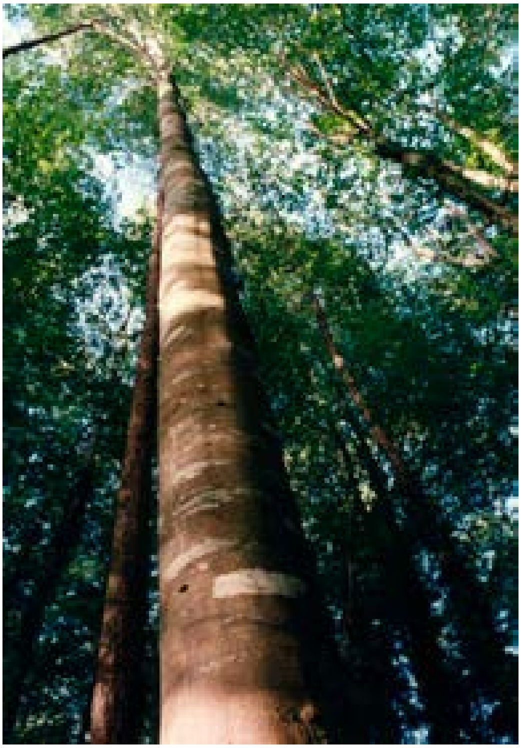


Plate 7.3-1: A very long beech stem with a now relatively suppressed crown.

Plate 7.3-2: This sturdy beech tree had sufficient growing space towards a neighbouring road. (Freiburg, SW Germany)

Bark: Smooth and grey, occasionally slightly rough. (Plates 7.3-4 and 7.3-5). Beech bark never recovers as seen on the autograph tree at Coole Park, Gort where George Bernard Shaw and others left their initials (Plate 7.3-6).

Timber: Beech is a diffuse porous wood - its pores are small and are spread uniformly throughout the wood. This feature and the absence of large rays or pronounced grain give it excellent woodworking properties. The average density of the wood at 15% moisture content is about 720 kg/m^3.

When freshly cut the wood is white, but it takes on a pinkish or reddish brown colour with age. There is no clear distinction between heartwood and sapwood (Plate 7.3-7).

Some trees show a reddish centre that may be mistaken for heartwood, but this is a defect known as red heart. It is thought to be age-related, but site conditions such as the moisture regime and high pH are probably contributory factors.

Beech timber has little natural resistance to decay, especially if it is in contact with water.

Root system: During the first three years young beech forms a sturdy taproot, but then starts to develop an intensively twisted heart-shaped root system. This root system varies according to soil properties and on gleys

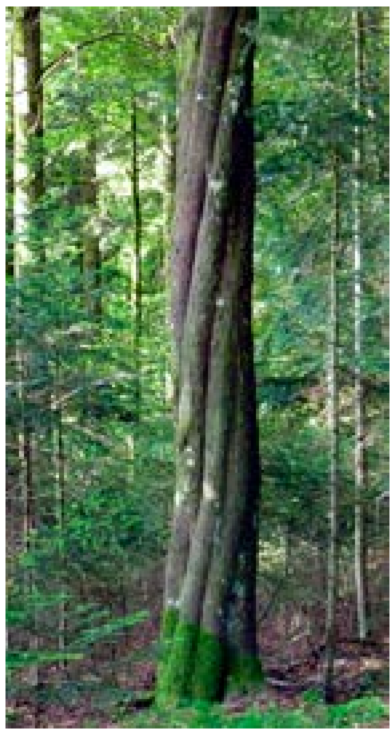


Plate 7.3-3: Beech stems often show spiral growth.
(Black Forest, SW Germany)

Plate 7.3-4: Beech bark is normally fine and thin.

Plate 7.3-5: Because of its fine bark beech is very susceptible to injury.

Plate 7.3-6: Beech bark shows the results of injuries even after a long time.

(GBS = George Bernard Shaw)

(Coole Park, Co Galway)

may resolve into a very shallow aggregation in the upper 10 cm. On fissured limestone sites a highly plastic root system can develop which penetrates deep into the fissures in search of moisture and nutrients.

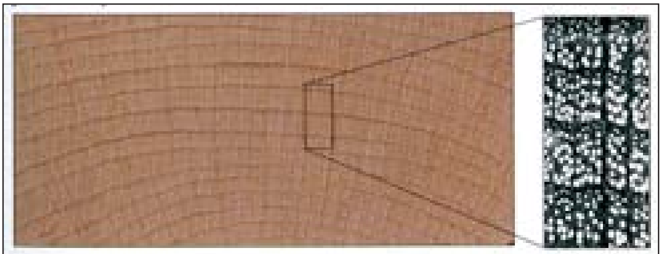


Plate 7.3-7: Cross section of beech timber. X 40

Leaves: The oval leaves are arranged alternately; shiny and dark green on the upper surface, with fine hairs along the edges. Buds are reddish brown, long and slender with tapering points, flushing mid-April to mid-May. Unlike oak a second flush in June is rare and consequently, beech has a somewhat limited capacity to replace young leaves damaged by late spring frost or insects.

Flowers: Beech is a monoecious species with separate male and female flowers on the same tree. Pollination is by wind. The female flowers are surrounded by a 4-lobed involucre and usually occur in pairs on a short stalk.

Its sepals develop into a cupule, which opens on ripening to release two triangular shaped nuts.

Flowering is induced by very warm and dry weather in July/August, when the new buds are formed. Mast years, therefore, rely on climatic conditions during the previous year's late summer.

The earliest age for trees to bear seed is 50–60 years, but the best seed crops are usually after 80 years and then only at intervals of 5–10 years or more. In recent years, however, there seems to be a developing pattern of more frequent seed years but whether this will be sustained is not yet known.

Fruits: Seeds ripen in September to October and fall up to November (Plate 7.3-8).

Mast can only be stored until the following spring without significant loss in viability. For over-winter storage the nuts are slightly dried and stored at 3 °C until spring. Storage at this temperature, combined with adequate moisture content, is sufficient to overcome dormancy and the seed can be sown in spring without any pre-treatment. Seed should not be allowed to become too dry or so moist as to encourage fungal development.

Beech nuts are relatively heavy, 1000 nuts weighing about 150–300 g.

Plate 7.3-8: Beech shows distinct mast years which have become more frequent during the past decades.

Ecological characteristics

Forest type: Beech is one of the most outstanding broadleaf trees of Europe with the potential to dominate on all but the most inhospitable soils.

Successional type: Beech is a late-successional species and is the most shade-tolerant of all European broadleaves (Plates 7.3-9 and 7.3-10). Even among conifers, only silver fir and yew are more shade-tolerant. These are, therefore, the only species able to compete with beech.

Light requirements: Beech is the most shade-tolerant of broadleaf species and when young its form is significantly enhanced by shade. However, later in the rotation beech breaks through taking advantage of full sunlight (refer to Chapter 4.6.3.2).

Plate 7.3-9: Illustrates an early stage succession. Beech colonises easily under Corsican pine. (Montenegro)

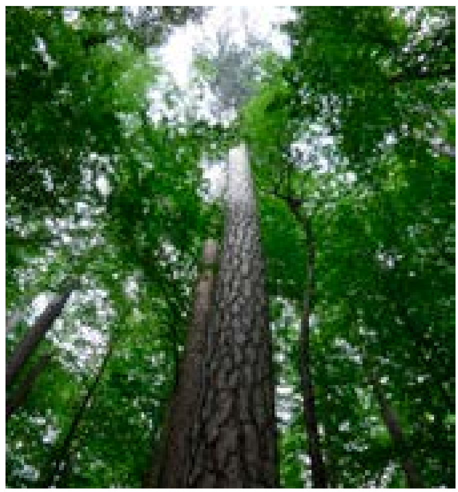


Plate 7.3-10: Beech become dominant. The last stage of development is shown: The mature old pine specimen still forms the upper canopy, but young pine cannot regenerate under the shelter of beech. (Montenegro)

Stress tolerance: Beech is a typical maritime species, well adapted to the climate of western and central Europe and to higher elevations in the east and south. It tolerates high temperatures only when not combined with long dry periods.

Young beech is very susceptible to damage by late spring frost, and may be killed because of its limited capacity to generate a second flush of leaves. Even if the trees survive, growth may be retarded for years.

Young beech benefits from the shelter provided by an overstorey (Plate 7.3-11).

In locations where the occurrence of late frost is frequent, such as hollows or flat terrain, young beech should be raised only under the shelter of old stands or introduced nurse trees. On clear-cut sites, reforestation with beech without the provision of shelter can lead to almost total failure (refer to Plate 4.4-36).

Moreover, late frost can inhibit seed production by destroying the young flowers even on large trees. Heavy winter frost can harm beech, but this applies only at the borders of its distribution in Eastern Europe. It is less inclined to lammas growth than oak, but this feature, when it occurs, makes it more prone to damage by early autumn frost, with consequent forking. This applies especially in maritime climates, where the shoots and buds have not had sufficient time to undergo a hardening-off process before the onset of frost.

Plate 7.3-11: Young beech showing good growth under the shelter of conifers. (Black Forest, SW Germany)

Climatic requirements: In Europe, beech adapts well to a maritime climate, while continentality determines its eastern boundary. In Mediterranean regions it occurs only at high elevations, where the climate is sufficiently oceanic.

It does best in a maritime climate with high humidity and precipitation exceeding 750 mm/year.

Soil preference: In Western and Central Europe it grows on a wide range of soils, from sandy to very rich soils, provided soil moisture or air humidity satisfies its water requirements (refer to figure 1.2-1).

Provided the moisture regime is satisfactory – not too much or too little – beech has the capacity to grow well under a wide range of soil conditions, from acid to alkaline. It will show its **best growth**, however, on soils with calcareous upper horizons, preferably having a pH status from slightly acid (pH 6.0) to moderately alkaline (pH 7.5). Such soils tend to be grey-brown podzolics or brown earths of high base status. It will also grow well on acid topsoils provided there is no waterlogging, and the pH and nutrient levels increase with soil depth. Soil studies in Ireland showed good growth of beech on acid top-soils where there was a rapid rise in pH towards neutrality (pH 7.0) with increasing depth.

It **does not do well** on wet sites such as swamps, moors and riparian soils on the one hand and dry sites, such as sands and shallow rendzinas, on the other.

Beech will **not grow well** if the topsoil is excessively calcareous when extremely high levels of free calcium carbonate are present. Such levels are more likely to exist if unweathered material from the subsoil or parent material is near the soil surface. Although establishment and early growth of beech may be reasonable on these shallow calcareous soils, they are predisposed to growth problems when they reach the thicket stage, due to an inability of the roots to absorb sufficient iron and manganese.

Experience in Ireland shows that high quality beech can be produced on a wide range of soils when adequate, but not excessive moisture conditions exist.

Strengths and threats: Beech, in common with ash, is very sensitive to **late spring frosts**, but, unlike ash, it lacks the early vigour to get its leader above the frost level. Furthermore, it flushes earlier and the risk of frost damage is, therefore, more acute.

Delayed hardening-off in autumn can also result in frost damage to the leading bud and lead to forking.

Beech is generally **windfirm,** but, when in full leaf, it may be damaged by summer gales or destabilised on soils which are waterlogged after prolonged heavy rainfall.

Beech ranks next to sycamore in terms of preference by **grey squirrels**. Stands may be attacked from the thicket stage up to 60 years of age by gnawing of the bark, usually near the base of trees, but often from larger branches in the crown. All such damage introduces a defect in the wood and may lead to fungal invasion (Plate 7.3-12. See plate 4.4.46).

Browsing, fraying and bark stripping by **red and fallow deer** can lead to serious damage where deer numbers are high. In continental European forests damage by deer is the major problem (Plate 7.3-13).

Many decay **fungi** attack beech, among them *Polyporus* and *Ganoderma* spp., which lead to

Plate 7.3-12: A mature beech with serious grey squirrel damage.

Plate 7.3-13: Young beech stripped by red deer.

branch and butt rot, particularly of old over-mature trees.

Young trees may be infested by the beech **woolly aphid**, which can lead to serious damage on some sites.

The one serious disease of beech reported from Britain and the Continent tends to occur on trees that have previously been subjected to stress due to long drought periods or other causes. The weakened condition of these trees makes them more vulnerable to attack by insects (including aphids) and fungi. The disease (beech bark disease) results from attack by a minute sap sucking insect, the **felted beech coccus**, followed by infection by a **parasitic fungus**, *Nectria coccinea*. The combined attack of insect and fungus may lead to the death of the tree from moisture stress (Evans, 1984).

Regenerative capacity: Beech regenerates freely and naturally in Ireland and an opportunity exists to restore lost genotypes by natural regeneration. The high numbers of plants/ha in naturally regenerated stands provide the opportunity for intensive selection of trees with good form which are well adapted and productive in Irish conditions. Where beech already exists, natural regeneration offers many benefits in terms of genetic improvement and silvicultural opportunities. Young beech trees show better stem form when developing under the light shade of the overstorey of mature trees. In such conditions high proportions grow up perfectly straight.

Provenance: Since its introduction, **importation of beech seed** is likely to have occurred on a regular basis, at least until the first plantings matured in the middle to late 19th century. It is likely that most of this was sourced from Britain, although imports from the 'classic' beech forests of France and Belgium, is a distinct possibility.

Forest Service records show that seed imports continued from the start of the state forestry programme over the 50-year period prior to 1980. During this time 34% of all beech seed sown was imported, mostly from Germany and Austria, in the years prior to World War II. During the 1960s imports were mainly from Romania, Bulgaria and Czechoslovakia. Recent studies in Britain suggest that there is a tendency for seed from these more continental south-eastern areas of Europe to perform less well when planted in the more oceanic areas such as northern France and Belgium (Wilson, 2008). The decline in performance would be even more pronounced in Ireland. During this 50-year period up to 1980, **home collections** amounted to 31,000 kg, or 68% of total sowings. Most of this material was collected in the 1940s and 1950s. Collections took place in many forests without rigorous selection of stands or seed trees. To what extent this practice has resulted in the poor stem form seen in many beech plantations is difficult to determine, but it is almost certain to have had some effect.

In 1998 an EU funded international beech provenance trial was established throughout Europe. Ireland was one of the 21 participants in this trial which consisted of 34 provenances from across the species range. While only preliminary results (after 9 growing seasons) are available at present, they show that reproductive material from eastern and south eastern Europe is the most vigorous, mainly because it breaks bud early, which could of course increase susceptibility to late spring frost. The results suggest that the use of home collected seed – individuals that have grown for one generation under Irish conditions, or material from British sources would be best suited to current Irish climatic conditions. Other low elevation sources from northern France and Germany as well as material from Belgium, the Netherlands and Denmark should also be suitable for use in Ireland (Thompson and Fennessy, 2010).

More recently, provenance trials have been established comparing the performance of home collected seed with imported origins. They are too recent to provide firm comparative data. Until results become available, seed from registered stands, of which there are currently 18 covering an area of just over 80 ha, should be the first choice. As with other major broadleaf species, knowledge of provenance variation in beech is limited, although there are recognisable differences in ecotypes with regard to time of flushing and leaf fall. Those from higher elevations flush earlier when brought to the lowlands and are, therefore, more susceptible to frost damage. In Britain, progeny obtained from plus trees in the 1945–1953 period initially showed a strong negative correlation between growth and stem form, but after 20–30 years it was possible to identify progeny that had desirable combinations of these traits (Wilson, 2008). This emphasises the need for continuity in long-term provenance studies.

Growth characteristics

Height and age: The tallest beech tree recorded in Ireland is 39 m with a diameter of 1.6 m (Tree Council of Ireland, 2005). Under suitable conditions of climate and soil, beech can attain good to very good production and on optimal sites reach a height of 40 m.

The physical life-span of beech is relatively short in comparison with oak and rarely exceeds 350 years.

Beech shows the typical growth pattern of a late-successional species: height growth begins relatively slowly, but continues more steadily and for much longer than pioneers such as ash (refer to Chapter 4.1).

Height increment is about 20–30 cm/yr for the first 15–20 years, but increases to about 60 cm/yr between 20 and 60 years, after which it tends to decrease gradually (Evans, 1984).

Beech is, therefore, often outgrown by other species in the early decades, but is usually able to survive under their canopies. During the second half of the rotation the roles are reversed and the resurgent beech begins to restrict the crown development of the companion species (see Chapter 7.8).

Comparisons between British and German models show slightly contrasting growth patterns. British growth models display a more rapid growth in youth and middle age than that of the German models, but both tend to converge at 120 years. Current height growth increment culminates around 35 years in the German model and somewhat earlier in the British one.

Total volume production: British yield models show a maximum yield class of 10, while German models indicate a yield class of about 9. Current and mean annual volume increments culminate at 60 years and 140 years respectively in Germany and at 45 years and 75 years respectively in Britain. In the past decades increment in continental beech stands has increased considerably, possibly as a result of aerial depositions of nitrogen, increase in CO_2 levels, extension of vegetation periods and rehabilitation of soils.

Values

Silvicultural values: Beech is the most versatile of broadleaf species, with the facility to form a crop or act as a species with a serving function (refer to Chapter 4.4.6.4).

Its ability to tolerate shade makes it the species of choice for underplanting an oak crop in order to curb the development of epicormic branching. It is used in mixture with all species on different sites.

Economic values: As a main crop species it produces a valuable timber which is widely used in furniture, flooring and plywood manufacture. The objective should be to produce material of high quality and of a size suitable for furniture manufacturing and veneer (refer to Figure 3.2-1). This will involve the production of straight, cylindrical, branch-free boles, 8 m or more in length and of a diameter 50–60 cm at mid-point. With rapid growth this objective should be achieved over a rotation of 80–100 years depending on yield class. Such a rotation will help to reduce the risk of red heart occurrence. Red heart usually develops between 100 and 120 years into the rotation and, although it does not significantly affect strength, it degrades the wood to the extent that it reduces the price of the product by half in Denmark, and even more so in Germany.

It is widely used in cabinet making, high-class joinery, solid and laminated furniture, desks and chairs, parquet flooring and plywood.

The wood is easily bent to form new shapes after steam treatment and this process is widely used in the manufacture of bentwood chairs. High quality logs can be rotary-peeled to give a serviceable veneer which is used in beech-faced plywood and medium density fibreboard. Alternatively, sliced veneer from the radial surface shows an attractive ray feature that is much more decorative. Beech makes excellent floor-blocks. It is the most widely used wood in the furniture industry, much of it out of sight in framing upholstery or as a base for more decorative veneer. Although it is often used for tool handles, its short fibres, which result in poor elasticity and brittleness attributes, make it inferior to ash for this purpose.

On the Continent beech, because of the facility with which it takes stains and its diffuse porous structure, is now regarded as the temperate species most likely to substitute for the decreasing supply of tropical hardwoods.

The timber is permeable to preservatives, which gives it excellent durability (railway sleepers for example).

Ecological values: Typically, beech dominates the stand to the extent that all other species are excluded and even the shrub and field layers are suppressed. As a species with serving function, it is usually found in association with oak where its main task is to curb the development of epicormic branching. Its tendency to dominate late in the rotation, however, makes it a threat in mixtures. To avoid such an occurrence it should be introduced under oak at a suitable time, when space and light allow it, usually after the 2nd or 3rd thinning. Alternatively, hornbeam or lime may be substituted as serving species instead of beech as they tend to remain in the understory.

Amenity values: Beech was one of the main species planted for aesthetic purposes in demesnes during the 18th century. It was also favoured for shelterbelts on estates. Many of the older beech trees of today date from that period. The aesthetic appeal of beech is such that it still forms a large component of planting in urban parks in the form of standards.

Historical values: As a non-native species beech has little historical significance. Hayes (1822) referred to *six beech from 11 feet* [3.35 m] *to 12 feet* [3.66 m] *round* growing on the Earl of Desart's estate in Co Kilkenny, but did not list any outstanding specimen. This is in contrast to other species, many of them non-native.

The report of the Royal Scottish Arboricultural Society, which visited Powerscourt demesne, Co Wicklow in 1897, referred to *The beech avenue was voted the best that could be seen* *anywhere* and equal *in girth and length of stem to the splendid beeches seen by the Excursionists of the Society, in 1895, on the Deister Hills, Hanover, Germany* (Annual Excursion Report, 1897) (Plate 7.3-14).

Plate 7.3-14: Beech avenue at Powerscourt in 2013.

Silvicultural management

Production of plant material: Forest Service recommendations for bare-rooted beech are for plants 3, 4 and 5 years of age with corresponding heights varying from 50–80 cm. These plants best meet the requirements on most sites (refer to Plate 4.4-4).

On the Continent, 2+0 undercut seedlings are frequently used on vegetation-free ground.

Wildings can be used to supplement plant supply, but should never be planted into open ground, only under the shelter of existing stands. They are especially suitable for underplanting and can be used after being transplanted in a nursery for at least one year. Preferably, they should be collected from registered seed stands,

Beech is generally regarded as the most sensitive of the broadleaves in its inability to withstand rough handling prior to planting.

Regeneration: Young beech is very sensitive to exposure to wind. If planted on open exposed land without shelter, it suffers more than most other broadleaf species and is prone to leader damage by late spring frosts. For that reason beech is usually established in mixture with species which provide the necessary shelter. This has been the procedure with beech afforestation by the State which began in the early 1930s. The conventional approach was to plant the beech in mixture with European larch or Scots pine, at a stocking density of 4,400–5,200 plants/ha, either in 50/50 line mixtures or occasionally 75% conifer and 25% beech (one line in four). Over time the conifers were removed and these plantations are now essentially pure beech stands.

Beech is especially well adapted to natural regeneration under the shelterwood system. As a shade bearer its preferred environment in youth is one of partial shade, protected from frost and desiccating winds, and free of competition from grass and weeds. Such conditions are best obtained by regenerating from seed under cover of the existing stand (refer to Chapter 4.2).

Although the ability of beech to regenerate from coppice shoots is much less than other broadleaves, including oak and ash, it is coppiced in mountainous regions of continental and southern Europe on a moderate scale (Plate 7.3-15 and 7.3-16).

Plate 7.3-15: After being felled older trees may still sprout. (Kaiserstuhl, SW Germany)

Tending young stands: Beech has poor apical dominance and a strong propensity towards coarse growth. These characteristics are much more apparent in crops established on bare land and are particularly prevalent in Irish beech plantations. Some of the poor quality that exists may be attributable to provenance, when insufficient care was taken in seed collection from good quality sources, but lack of early management through tending is undoubtedly a contributory factor.

Plate 7.3-16: Beech coppices freely as long as it is not cut several times and its sprouts are not permanently overtopped. (Sicily)

Without formative shaping, beech has a tendency to produce a crop lacking in the attributes needed for high quality timber production. This operation should begin when the crop is about 2 m in height and be confined to the 400–600 trees/ha of best stem form which have the potential to become crop tree candidates at a later stage. Formative shaping should continue if necessary on the selected trees until the crop is about 6–7 m in height. It should be followed by a tending operation at 7–10 m by removing any wolves, if present.

Establishing beech under a shelterwood system would significantly reduce the need for shaping or pruning.

Pruning of beech is not generally recommended. Pruning scars do not occlude quickly without rapid diameter growth and present a danger of infection by fungi (refer to Plate 4.5-33).

Thinning: At a top height of 12–14 m some 250–400 potential crop tree candidates/ha should be selected and their competitors removed through a crown thinning. This is followed by a further crown thinning at a top height of 15–16 m when a final selection of 100–200 potential crop trees should be made. Other thinnings will follow at top height increments of 3–4 m by removing competitors to the best potential crop trees (refer to Table 4.5-7).

Beech responds much better than other broadleaves at an advanced age to crown thinning, and is, therefore, regarded as one of the most adaptable tree species. Compared with all other broadleaf species in Europe it has the unique ability to adopt a more horizontal branching habit, even at a great age, and, thereby, to enlarge the volume of its crown.

If well-managed it offers the opportunity to produce high quality stands of large areas throughout Europe (Plates 7.3-17 to 7.3-19).

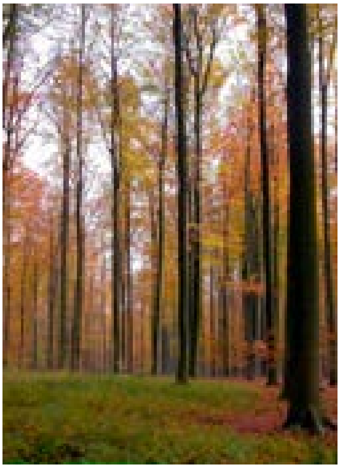


Plate 7.3-17: High quality beech seed stand near Brussels. (courtesy: van der Aa)

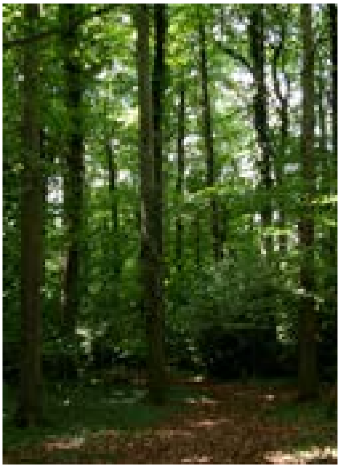


Plate 7.3-18: Excellent quality beech stand. (Dollardstown, Co Kildare)

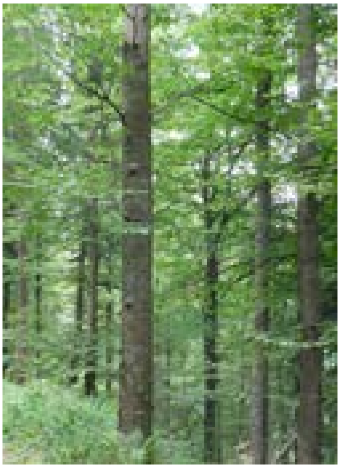


Plate 7.3-19: A well-managed multistoreyed beech stand. (Freiburg, SW Germany)

Conclusions

Beech has the capacity to grow well under a wide range of soil conditions, from acid to alkaline, provided the moisture regime and nutrient status are satisfactory. It will not tolerate waterlogging and is subject to windthrow on gleyed soils.

Economic considerations indicate that beech should be restricted to free-draining soils of pH 6.0–7.5, with a good to moderate base status. Soils at the extremities of the range (wet heavy clay soils and very dry sandy soils) should be avoided. Beech has an economic rotation of 100–120 years.

It does best in a moist climate with annual rainfall exceeding 750 mm.

Beech is difficult to establish on open exposed sites without overhead shelter and is prone to damage by late spring frosts. This leads to forking and results in poor stem form. Once established, however, it is relatively easy to manage. It is the most shade-tolerant of the broadleaf species and forms an excellent understorey to other species. It is the broadleaf species best suited to our maritime climate, and when planted on suitable sites, it has the potential to create stands of high quality if protected from grey squirrel. In mixture with other species it will begin slowly, but later in the rotation it will outgrow and dominate most species if corrective action is not taken.

Beech produces a highly versatile wood. In continental Europe it is regarded as the timber most likely to substitute for the decreasing supply of tropical woods. It has excellent woodworking properties and forms the mainstay of the furniture industry. Good quality logs are used in high-class joinery and veneer, but beech timber is not as highly valued as that of oak (refer to Figure 3.2-1) or cherry.

7.4 Birch

Family: *Betulaceae* – birch species.

Genus: *Betula* L. Silver birch (*Betula pendula* Roth) and downy birch (*Betula pubescens* Ehrh.) are but two of the 50 or so species of the genus *Betula* which occur in the northern temperate zone. Both are indigenous to Ireland, where they have been a feature of the Irish landscape since the last ice age.

Distinguishing silver birch and downy birch

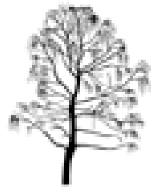
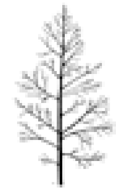
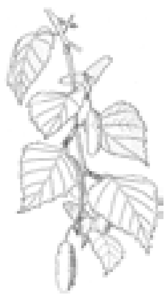
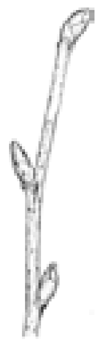
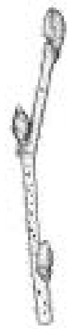
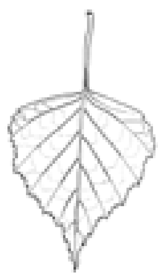
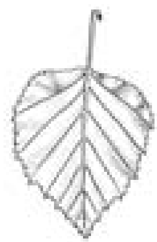
Distinguishing the two species is not straightforward because of overlapping characteristics. A practical guide suggests that if there is doubt about identification it is probably downy birch (Worrell, 1999).

A summary of identifying characteristics for the two species is shown in Figure 7.4-1.

Key characteristics

- Silver birch shade-intolerant; downy birch more shade-tolerant,
- rapid growth and relatively short life-span,
- both are extremely frost-hardy,
- both will grow on a wide range of soils: silver birch preferably on mineral soils, downy birch on peat,
- greater tolerance of exposure than other broadleaf species,
- good ability for natural pruning,
- prolific early seed producers and good coloniser of moist disturbed mineral soil.

Table 7.4-1: Key distinguishing characteristics for silver birch and downy birch.
(Adapted from O'Dowd, 2004 and Harmer et al., 2010)

	Silver birch		Downy birch	
Tree, crown and stem form	Up to 30 m high; crown columnar in older trees; in young trees conical or irregularly oval; stem form is much superior to that of downy birch.		20-25 m high; crown rounded or irregular; stem more prone to forking.	
Branches and twigs	Branches pendulous. Young twigs brown, with numerous white resin glands giving them a wart-like feel to the touch. 		Branches upswept. Twigs brown/black, lack resin glands, pubescent especially when young. 	
Bark	Smooth and silvery-white on upper stem occasionally with scaly dark patches; older silver birch 'diamond' fissured at base of stem, forming rectangular plates.		Bark of downy birch is brown or greyish in colour, usually not fissured at the base of older trees, but smooth or with a faint pattering.	
Leaves	No hairs; shape generally triangular; extended tip; base angular; double serrated margin; primary teeth curve up to apex; lighter green.		Pubescent, at least on lower veins; underside with white hairs in the axils of the veins and the leaf stalk; shape more rounded or oval; short tip normally; base rounded to angular; generally single toothed margin; teeth don't curve up to apex; duller green.	
Soil type	Almost exclusive to mineral soils.		Common on peat soils.	

Other methods for distinguishing the species

The morphological approach outlined in Table 7.4-1 will generally distinguish silver birch, but downy birch is less easy to categorise and may be mistakenly identified as silver birch. Failing a definitive identification by morphological methods, resource may be had to the chemical test developed by Lundgren et al. (1995) or to the more sophisticated chromosome count test.

The chemical test helps to distinguish the two species by detecting a chemical which occurs in the inner bark of silver birch and its hybrids, but not in the bark of downy birch. The test cannot differentiate between silver birch and its hybrids, but it will screen out downy birch. It is quick and cheap and is particularly useful when leaves are not available for morphological analysis.

Chromosome counting is probably the most reliable approach for differentiating between the two species (O'Dowd, 2004). Silver birch has 28 chromosomes (diploid) and downy birch has 56 (tetraploid). As a diagnostic tool for differentiating between the two species, however, chromosome counts are of doubtful utility to the field practitioner, requiring as it does fairly sophisticated laboratory equipment. Yet, they are very relevant in choosing a species for genetic research and breeding programmes.

The difficulty in distinguishing the two species has led to the belief that hybridisation is common. Individuals that show confusing characteristics of both silver birch and downy birch are supposed to be either spontaneous hybrids or resulting from extra chromosomes. Yet studies indicate that there are incompatibility barriers between the two species and that hybridisation is very rare (O'Dowd, 2004). On the rare occasions when it does occur, the hybrid is sterile due to the difference in chromosome level between the parents. In a recent survey of open-pollinated free-growing silver birches in Finland, a possible 0.2% of hybrids was found (Koski and Roussi, 2005).

7.4.1 Silver birch

Scientific name: *Betula pendula* Roth. (formerly *B. verrucosa* Ehrh.).

Irish name: Beith.

Origin and geographic distribution: Silver birch is found over most of Europe with the exception of the southern parts of Italy and Greece. In Spain it is confined mainly to northern Catalonia. Its range extends into Asia as far as central Siberia, and from the Caucasus to northern Iran (Figure 7.4-1 (a)).

The distribution of birch species has been heavily influenced by the activities of man. Silver birch is recorded in 3% of the total stocked forest area (refer to Chapter 1.5).

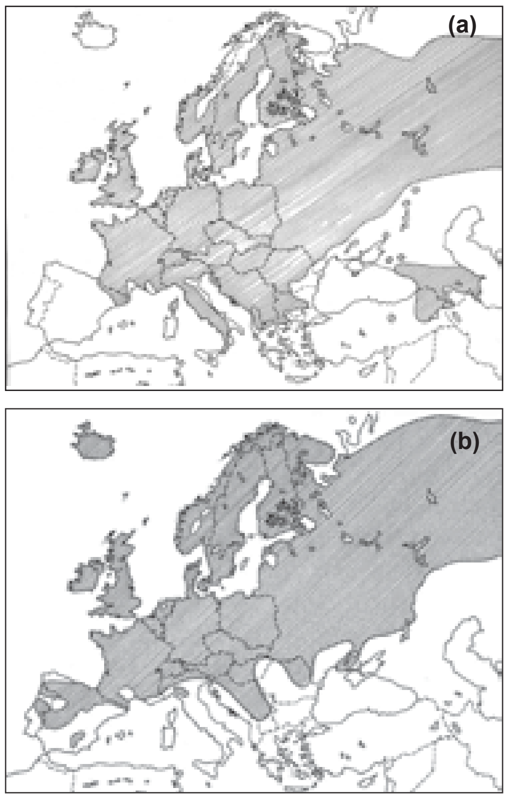


Figure 7.4-1: Natural distribution of silver birch (a) **and downy birch** (b).
(Suszka et al., 1996)

Botanical characteristics

Tree form: Crown is columnar in older trees; conical or irregularly oval and lightly branched in young trees. Young twigs brown and slender, pendulous, with numerous white resin glands giving them a warty feel.

Stem form: Shows a tendency to fork with poor stem circularity (fluting); pendulous branching habit; has potential to produce good straight stem from selected provenances. For commercial purposes, stem form is much superior to that of downy birch, which is much more inclined to stem-forking and heavy branching.

Bark: Bark of older silver birch fissured at base of stem, forming rectangular plates; smooth and silvery-white on upper stem, occasionally with scaly patches showing darker grey (refer to Table 7.4-1).

Timber: White to light brown in colour, diffuse porous of fine texture with good working qualities: perishable and moderately resistant to impregnation by preservatives (TRADA, 1991).

Root system: Tends to occupy the upper humus layer on sandy soil; presents strong competition for species selection on such sites.

Leaves: Ovate-triangular, pointed at apex with double toothed margins; lighter green than downy birch.

Flowers: Male catkins 3–4 cm long formed in autumn; elongate in spring at time of leaf burst. Female flowers on short branches develop in spring as cylindrical catkins covered with overlapping scales.

Fruits: Female catkins form cylindrical conelets turning brown in autumn and disintegrate shedding their winged fruits (achenes). The seeds are very light and can be dispersed over long distances by wind or transported by water.

Ecological characteristics

Forest type: Silver birch is commonly associated with oak and pine woodland on better drained soils, but usually forms only a small component of these woodlands (Worrell, 1999). In the northern part of its distribution it is a tree of both lowlands and uplands, but in the southern part it is exclusively a mountainous species.

Successional type: Birch is a relatively short-living pioneer species. It occupies a transitory stadium to late-successional woodland following soil disturbance (Plates 7.4-1 and 7.4-2).

Light requirements: Is very light-demanding and will not survive under the canopy of other trees.

Plate 7.4-1: Natural colonisation of a former industrial land covered with mineral soil.

(Shelton, Co Wicklow)

Plate 7.4-2: Natural regenerated birch stand after clear-cut of a Norway spruce stand. Some selective thinnings have taken place.

(Kilbride Wood, Co Wicklow)

Stress tolerance: Tolerates exposure better than other broadleaf species, but stem form is poor in such situations. In hot dry summers it is one of the first species to show stress in the form of premature browning of foliage (Evans, 1984). It is considered frost-hardy.

Climatic requirements: It grows well in a wide range of climates from warm to extreme cold.

Soil preference: Birch makes little demand on soil nutrients and although it will colonise sites with an unfavourable moisture regime its growth and stem form can be sensitive to many environmental factors. Heavy soil, high ground water level, competition from grass and shrubs retard growth and can degrade stem quality. Silver birch tends to inhabit drier sites than downy birch with a preference for well-drained lighter mineral soils, such as brown earths and podzols, but it will also be found on heather sites, shallow peats and gravels. Like all other species it will grow best on brown earth soils, but will inevitably meet strong competition for species selection on such sites. Other suitable soil types are the podzols and the drier surface-water gleys.

Strengths and threats: Tolerates **browsing** by deer better than other broadleaves, but browsing is the main reason for poor regeneration in upland woodland.

On heavy wet soil it often develops **root rot** at 40–50 years of age. Birch species are among the most susceptible of broadleaves to honey fungus, *Armillaria* spp. (Savill, 2013).

Birch dieback has recently become a problem in many new native woodland planting schemes in Scotland. The causal agents have been identified as the pathogenic fungi *Anisogramma virgultorum* and *Marssonina betulae* which cause deterioration in crown health, starting about 5–10 years after planting. The latter occurs more frequently on the silver birch than on downy birch and the reverse appears to be true for *A. virgultorum* (Green, 2005).

Regenerative capacity: Birch produces vast quantities of seed which are carried on the wind over long distances. According to Swedish sources, a large birch can produce 10 million seeds in a single year (Suszka et al., 1996), but seed germination is low at 40%. Seed germination is heavily dependent on an adequate soil moisture status and freedom from competing vegetation.

Provenances: Birch had for long been regarded as a weed species in forestry, to be eradicated in plantations because of its invasiveness, poor stem form and aggressive growth habit.

Stem form is a highly heritable trait and the continued selective exploitation of better stems throughout the centuries led to the gradual erosion of its gene pool. Because of its status as a weed, birch did not have the benefit of silviculture to counteract this decline of its genetic base.

Within the past decade birch has come to be accepted as a valuable species, not only for amenity, biodiversity and its timber properties, but also as a nurse for broadleaf species sensitive to frost and exposure (Plates 7.4-3 and 7.4-4).

Although good stem form is not a requirement for amenity and nursing purposes, it is essential for timber production. For this to be achieved a rigorous selection of quality stems coupled with a breeding process is required.

Attempts to import high quality Scandinavian, and particularly Finnish birch, met with no success. They showed low survival rates and poor growth when compared with Irish origins. In the late 1990s, therefore, a COFORD funded research programme for improvement of Irish birch was undertaken. Phenotypically superior stands of silver and downy birch, in the Republic and Northern Ireland, were identified and a seed collection made from plus trees in these stands (O'Dowd, 2004).

In addition, scion material was collected from the plus trees and used to establish an indoor seed orchard/gene bank. Breeding seed orchards were also established in 2001, based on the original seed collection, augmented by controlled crosses from the grafted material (O'Dowd, 2004). Pollinations were carried out with both species of birch in 2000 and the seed was sown in spring 2001 for field testing.

Plate 7.4-5 shows a 6-year-old first generation birch plantation in one of the trials. Even at this young stage the improvement on wild birch is striking. Progeny testing is expected to lead to further genetic gain. Selection of plus trees follows the same aim (Plate 7.4-6).

Growth characteristics

Height-age growth: Birch shows very rapid height growth up to 15–20 years of age, often growing 1 m/yr for the first decade. Thereafter, growth declines slowly and essentially ceases at 50–60 years of age (Figure 7.4.2). Silver birch can attain heights of up to 30 m, but rarely exceeds more than 20 m.

Its biological lifespan is about 100 years.

Plate 7.4-3: Scandinavian birch stands like this one are usually regarded as being superior, which is, however, not always the case. (S Sweden)

Plate 7.4-4: Birch sometimes shows good stem form which allows the production of high quality timber. (E Germany)

Plate 7.4-5: Progeny trial of native birch. (Coolbawn, Co Tipperary)

Plate 7.4-6: Birch plus tree selected by Future Trees Trust. (Pitlochry, Scotland)

Total volume production: The rapid early height growth of birch does not translate into high yield classes. Silver birch will attain yield class 6–8 or 10–12 on the best sites (Figure 7.4.2). Maximum mean annual increment culminates between 40 and 50 years (Evans, 1984). Its silvicultural rotation usually varies from 45–60 years, but can be extended up to 80 years if required.

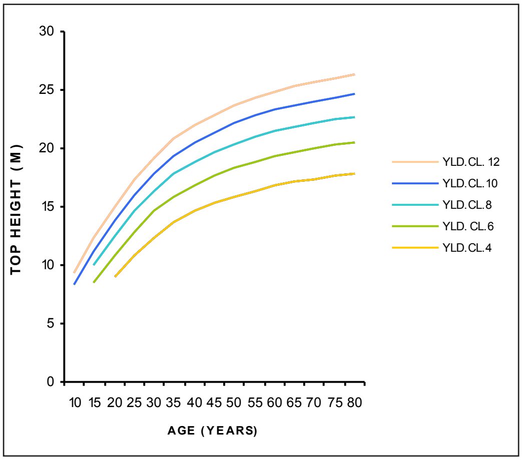


Figure 7.4.2. Top height – age graph and yield classes for sycamore/ash/birch.
(Edwards and Christie, 1981)

Values

Silvicultural values: Because of its hardiness birch can be grown as nurse species for other broadleaves, such as oak and beech, and frost-tender conifers on sites liable to early frost, but care must be taken to ensure that the nurse does not outgrow and suppress the main crop species (refer to Chapter 4.4.6.5(4)).

Sometimes birch is a welcome filler of gaps in conifer stands (Plate 7.4-7).

Economic values: Silver birch is the preferred birch species for timber production. Its timber is widely used for plywood, furniture and turnery, e.g. brush backs and flooring. The potential of the species for sawtimber is often limited, due to poor stem quality, but it makes good firewood.

Ecological value: Forms a component of the ancient oak-birch woodland. Birchwoods provide shelter in exposed locations and form excellent habitats for birds which feed on seed and insects.

Amenity value: The form and colour of birch is a defining feature of the landscape (Plate 7.4-8). The autumn colour of its foliage is particularly appealing. It is often planted along the visible edges of conifer stands to alleviate the monotony of large blocks. Where it regenerates in small groups, it can be a welcome addition to biodiversity in the stand, and an enhancement to its visual amenity, for there are few trees of superior autumn colour.

Historical importance: Birch was given the rank of a 'commoner of the wood' under the ancient Brehon Laws of Neighbourhood, probably because of its timber. Its Irish name – *Beith* – is still recalled in the names of towns, e.g. Ballybay, Co Monaghan and Kilbeheny, Co Tipperary (Nelson and Walsh, 1993).

Plate 7.4-7: Birch of reasonable stem form in mixture with Norway spruce has filled former storm induced gaps. (Kilmacurragh, Co Wicklow)

Plate 7.4-8: Typical silver birch, valued as an avenue tree. (N Germany)

Silvicultural management

Production of plant material: Seed may be collected from August to end of September. Generally the bracts are not separated from the seed and this mixture is used for sowing (Suszka et al., 1996). 1 kg of the mixture contains about 500,000 seeds capable of germination.

Birch can be grown as both bare-rooted and containerised stock. Seedlings are transplanted and sold as 1+1 plants (Worrell, 1999).

Regeneration: It will readily colonise areas of disturbed mineral soil in open woodland, but will usually fail to establish itself where there is a litter layer or existing ground vegetation other than heather.

Tending of young stands: Open extraction racks, remove wolves and some competitors to potential crop trees. Some pruning may be required if stem form of potential crop trees is poor (refer to Chapter 4.5).

Thinning: Because of its strong light-demanding nature, silver birch requires heavy crown thinning before canopy closure takes place (refer to Chapter 4.5). Even if thinning is commenced soon after canopy closure, birch is generally unresponsive (Evans, 1984).

Conclusions

Because of its poor stem form and bole fluting, both birch species have long been regarded as weed species in forestry. Within the past decade, however, silver birch has come to be accepted as a valuable tree species for its timber production. Birch is also an important element of biodiversity and amenity. Growth performance and stem form is being addressed in a research programme funded by COFORD which has started to produce genetically improved material, but only in limited quantities.

For timber production silver birch is preferable to downy birch.

7.4.2 Downy birch

Scientific name: *Betula pubescens* Ehrh.

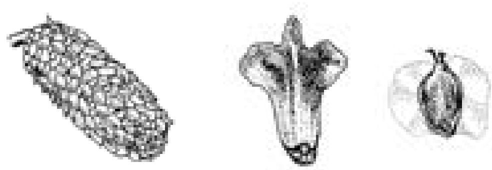
Downy birch has many similarities with silver birch: only the differences are recorded here.

Origin and geographic distribution: Downy birch has a more restricted range than silver birch within Europe, being absent from much of the region bordering the Mediterranean. It is found throughout Iceland, Scandinavia and extends into Russia beyond the Urals (refer to Figure 7.4-1 (b)). It can be found at high altitudes, up to 2,200 m in the Alps.

Downy birch was thought to be much more abundant than silver birch in Ireland (O'Dowd, 2004) although NFI (2013) data give a roughly similar figure at about 3% of the total stocked forest area (refer to Table 1.5-5).

Botanical characteristics

Tree and crown form: Can attain a height of 20–25 m: crown rounded or irregular with branches dense and twisted; shoots lack resin glands, but have a covering of soft white hairs (pubescent), especially when young.



Stem form: More prone to forking and poor stem form than silver birch (Plate 7.4-9).

Bark: Bark of downy birch is brown or greyish in colour; is not fissured at the base of older trees, but is smooth or with a faint pattern.

Leaves: Leaves are similar to those of silver birch, but usually more rounded or oval; duller green than silver birch with toothed margins which are coarse and equal. The underside of the leaf has white hairs in the axils of the veins and the leaf stalk is hairy.

Flowers and fruits: Flowering of downy birch and seed ripening are a little later than that of silver birch, but generally the seeding process of the two birches is similar.

Plate 7.4-9: Birch stands from natural colonisation – possibly downy birch – are often of poor quality, but this may also be a matter of provenance and site conditions.
(Portarlington, Co Laois)

Ecological characteristics

Forest type: As a pioneer species birch was strongly represented in the postglacial forest. Its capacity for and frequency of seeding makes it the principal pioneer tree species of the Irish countryside. Downy birch is often an important constituent of oak-birch-holly semi-natural woodland, that occurs on acid or base-poor soils that are dry or moist, and in some situations may even be the dominant tree.

In Ireland downy birch is more common on peat whereas silver birch is almost exclusively found on mineral soils. In northern Europe it is the typical species of peaty soils and gleys.

Light requirements: Downy birch is more shade-tolerant than silver birch and can survive as an understorey tree in many woodland types (Worrell, 1999).

Stress tolerance: In hot dry summers birch is one of the first species to show stress. It is extremely frost-hardy.

Climatic requirements: Downy birch is more suited to northern Europe climates as it can withstand extreme cold. Both birch species are frost-hardy, but downy birch in particular can tolerate very low temperatures.

Soil preference: Downy birch is more associated with the wetter sites and marshy locations. It also grows well on mineral soils, but tolerates wet conditions and deep peat much better than silver birch.

Growth characteristics

Height/age growth: Downy birch can grow to a height of 25 m. It is generally slower growing than silver birch.

Volume production: It is not very productive and is more likely to grow at yield class 4 or less.

Values

Sivicultural values: On peaty soils its role as a nurse is well recognised, where it provides shelter to species susceptible to late spring frost.

Silvicultural management

Thinning: It is relatively more shade-tolerant and will tolerate delayed thinning better than silver birch.

Conclusions

Downy birch is considered even more frost-hardy than silver birch, but is less important as a timber producing tree, mainly because of its slightly inferior stem form. Ongoing provenance and breeding trials, however, should improve stem quality.

7.5 Cherry

Family: *Rosaceae* – Rose family. There are roughly 900 species in North America and 90 in Europe and Asia.

Genus: *Prunus*, roughly 200 species in the temperate zones, which are trees or shrubs with undivided leaves and small stipules.

7.5.1 Wild cherry

Scientific name: *Prunus avium* L. (Latin from *avis* = birds which eat the fruit as it ripens). The common name 'bird cherry' for *Prunus padus* is, in a certain way, misleading.

Irish name: Crann Silíní Fiáin

Origin and geographic distribution: Its natural range includes western Eurasia and the northern extremity of Africa (Figure 7.5-1). It is thought to have originated in the Caucasus, but its distribution has been influenced by man for thousands of years so that it is impossible to reconstruct its geographical spread. It is native to Ireland and its distribution is very scattered in woods and hedges and extended natural populations are rare.

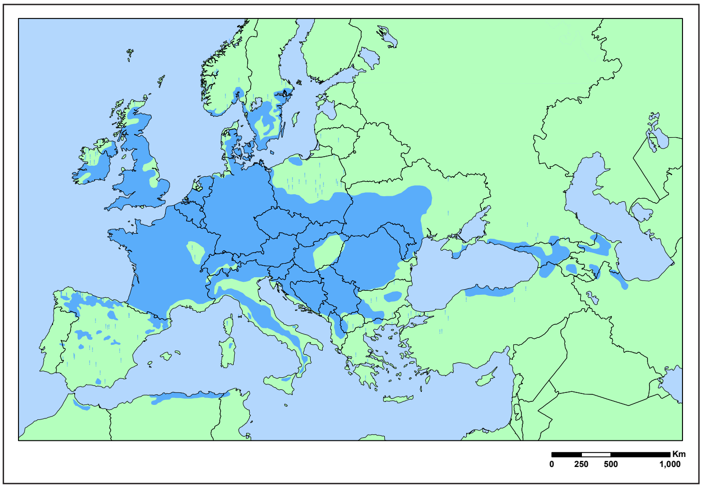


Figure 7.5-1: Natural distribution of wild cherry.
(EUFORGEN, 2009)

Wild cherry is the most important of all *Prunus* species that are distributed in Europe and is the origin of all cultivated sweet cherry species and flowering ornamentals in gardens and orchards.

Botanical characteristics

Tree and crown form: Fast-growing tree with strong apical growth, broadly conical, later with spherical-shaped crown of medium height. Deep broad crown when growing in the open, but long stem with low taper and high crown when growing in stand conditions.

Stem form, branches: Usually it has a straight trunk. Most of the branches are arranged in annual whorls – comparable with conifers. This is an unusual feature in a broadleaf tree, however, this characteristic disappears with age.

Cherry has the tendency to produce forks and big branches. Branches larger than 3 cm tend to show heartwood and sapwood. The heartwood acts as an entrance for rot into the stem.

Key characteristics

- Strong light-demander, except when young,
- site specific,
- susceptible to damage by late spring frost,
- responsive to vegetation control,
- good apical dominance,
- poor ability for natural pruning,
- producer of high quality timber,
- not susceptible to damage by grey squirrel,
- susceptible to bacterial canker and heart rot.

Bark: Smooth, rose-grey, shiny with large, light lenticels when young. When older it peels horizontally; blackish.

Timber: It has a fine grain and with a yellowish-light reddish heartwood colour which will become reddish-golden brown under light influence with a slightly shiny surface. Sapwood is slightly lighter. The colour sometimes turns to greenish which reduces its value. The timber is semi-diffuse porous and of medium weight (dry weight: 0.49–0.67 g/m^3). Hard and resistant, it is easily workable and can be bent with steam. Its hardness is not affected by the width of the annual rings. It is as strong as oak, but not very durable.

Root system: Extensive shallow root system with root suckers**.**

Leaves: Alternating, oval-lanceolate (2–5 cm in length, 1–2 cm in width); margins with rounded teeth; dull and glabrous above, hairy on the veins below.

Flowers: Masses of pure white flowers, 1–1.5 cm in diameter, appear singly or in small umbels before flushing of leaves in early spring (March-April). It is one of the first trees to flower in spring. Flowering starts early, from about 4 years of age under optimum conditions. It is insect-pollinated and self-incompatible.

Fruits: Small red or black, edible fruits, sweetish-bitter with a stone, ripening in July and germinating in the following spring, but can remain dormant for another year.

Ecological characteristics

Forest type: Cherry is an element of open mixed broadleaf woods with sycamore, ash, beech and oak. It is an important component of hedges and road-sides in Ireland, Britain and central Europe. It inhabits hedges and scrubland, very often in mixture with hawthorn.

On the Continent it is a member preferably of oak-hornbeam forests and beech-maple-lime tree forests on steep slopes. In other forest types it occurs sporadically.

As a thermophilic slightly shade-tolerant species it is also abundant in hedges of various types.

Successional type: Pioneer and intermediate stages (Plate 7.5-1).

Light requirements: Apart from a short period in its youth, it is very light-demanding and needs open space for crown development.

Stress tolerance: Relatively drought-resistant.

Climatic requirements: Warm climates from lowlands to low mountain altitudes.

Soil preference: Cherry has a relatively wide amplitude, but grows best on light, loose-packed humus and loamy soils, rich in nutrients, preferably not too dry. It also does well on stony and calcareous soils where climate is suitable. It is often found, though not growing vigorously, on dry stone-barriers, rocky sites, gravelly sites in valleys where other tree species are less competitive. However, compacted soils with high clay content and standing water are unsuitable because of the low rooting capacity of this species.

Plate 7.5-1: Cherry is not very competitive. Therefore, it benefits from release by coppice fellings and can be found in coppice-with-standards forests. (Alsace, France)

Strengths and threats: Because of its shallow rooting it is susceptible to storms and should not be planted on exposed sites.

Cherry is moderately resistant to browsing and fraying, but needs fencing in areas with high deer populations. It is considered immune to grey squirrel damage.

Many cherry provenances and hybrids are particularly susceptible to canker which affects stem growth. Infections by gummosis may penetrate to the centre of the stem. It shows early stem rot which tends to enter through branches larger than 3 cm which have developed heartwood.

Regenerative capacity: Its seeds are widely distributed through bird droppings by pigeons, thrushes, starlings, jays and by small mammals.

It also regenerates frequently by root suckers and has the ability to cover larger areas through far-spreading roots. Vegetative recovery after coppicing is strong. The root suckers may form dense clonal clumps of trees. These suckers can be dug out and planted in other places.

Provenances: Wild cherry can hybridise with various other cherry species. Therefore, it shows a great variety of forms. Distinct differences have been detected between trees from different locations during the last 2–3 decades, and on the Continent has led to the selection of plus trees and seed production in seed orchards. This has resulted in a sufficient supply of site-adapted forest-specific cherry seedlings which are now available commercially.

An extensive study of Coillte (State owned) forests identified very few individual plus trees of quality which could be suitable for inclusion in a breeding programme for this species. Experience from this programme indicated that native material may not always be as vigorous as some Continental sources. However, extensive field testing is still required to determine the adaptability of foreign provenances to the Irish conditions.

The main problems associated with the species are the many crossings with horticultural breeds which are often susceptible to stem canker.

Growth characteristics

Height: Cherry grows up to 20–25 m, rarely higher. It is precocious, which means that it is fast-growing in the first decades. Height growth is around 1 m/yr in the early years, but growth rates decline and almost ceases at an age of 50–60 yr. Cherry resembles sycamore in height growth at both the start and end of its development.

Diameter: 40–50 cm (sometimes even up to 70 cm). Diameter growth also has to be facilitated in the first 30 years by intensive early thinning.

Age: 70–100 yr.

Volume: Cherry has never been grown in large stands, therefore, no yield data on a stand basis are available.

Values

Silvicultural values: As one of the producers of highest quality timber, cherry deserves greater consideration in forestry. It is especially suited for enrichment of forest edges and for planting in rows or single trees in hedgerows. Small groups or solitaires may also be planted on ridges or stony locations.

Economic values: The timber is very decorative with distinctive characteristics and elegance. When planed the wood is shiny. It is used for a wide variety of purposes: sawtimber, veneer, turnery, small furniture, picture frames, wood-carvings.

Fruits collected from the wild form are used for the production of brandy. The importance of fruit production from the horticultural varieties does not need to be emphasised.

Ecological values: Provides nutrition for birds and small mammals.

Amenity values: Because of its early and rich flowering it is very attractive along forest edges, in hedgerows and mixed forests (Plates 7.5-2 and 7.5-3).

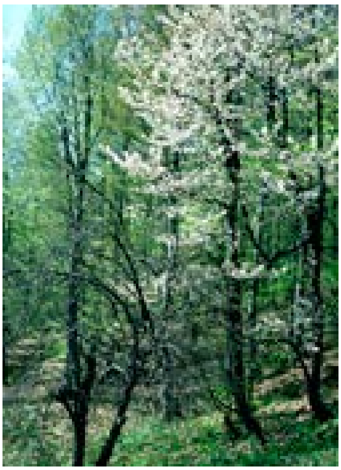


Plate 7.5-2: Wild cherry is ideally suited as an edge tree, where it cannot be overgrown, for instance by other species such as beech. It adds to the beauty of the landscape. (N Turkey)

Plate 7.5-3: The cherries have become visible, even from long distances, since they are sufficiently and timely thinned in order to develop big crowns. (Freiburg, SW Germany)

Historical importance: It was the main furniture timber in the period between 1770–1830 (Louis XVI to Biedermeier-style). In the 19th century it was of greater value than walnut. Parquet floors of cherry were very fashionable in earlier times, but are no longer affordable.

The tough timber has been used for tools, turnery and straight branches for walking sticks.

Silvicultural management

Production of plant material: Seeds should be pretreated by a combination of cold and warm stratification. Cherry seedlings are easily raised from seeds and produced as 2- or 3-year-old transplants (30–120 cm in height).

Seeded young plants are used as rootstock for all flowering cherries.

Regeneration: There are few locations in Ireland where cherry regenerates naturally because of lack of mother trees. Therefore, it has to be planted. Survival and early growth of young plants is sometimes unreliable: some individuals starting to grow immediately while others slowly fade away. This is due to poor root development after planting.

Establishment should always be in mixture with other broadleaves in the form of small groups and lines or single trees along forest edges. As cherry will normally be harvested earlier than the other species, its removal should not cause large gaps that cannot be closed by the surrounding trees (refer to Chapter 4.5.6.2(3)).

Tending and thinning: Given suitable growing conditions, cherry is very vigorous in the early years and it tends to outgrow most other broadleaf species up to an age of 25 years. Later, other species start to overtake it (Plates 7.5-4 and 7.5-5).

A key issue is the early release of the crown. However, thinning is often delayed and the crowns will not respond if released too late. Having reached a stem length of 8–10 m free of living branches, the crown should be given sufficient growing space so that at this stage natural pruning is not required.

Wild cherry is a poor natural pruner, therefore, artificial pruning (up to 8 m) is highly recommended (Plate 7.5-6). This is necessary when grown in lines or as single trees for production of high quality timber. Small branches can be pruned at any time without adverse reaction, however, pruning of larger branches is best done in June. Epicormic

Plate 7.5-4: Very poor quality cherry tree which had not been pruned and released from competition in time.

(Freiburg, SW Germany)

Plate 7.5-5: A cherry tree that had been dominant in its youth, but later was overgrown and killed by its competing neighbours – a typical result of delayed thinning.

(Freiburg, SW Germany)

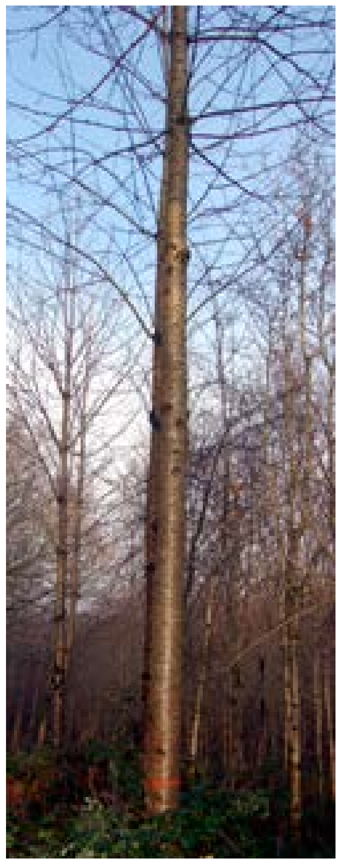


Plate 7.5-6: A perfect potential crop tree of cherry, 16 years old, timely pruned and thinned, and now with potential to produce a high quality log.

(Clonmel, Co Tipperary)

branches may develop where cherry has not formed a big crown.

Hazel, holly, lime and hornbeam may serve as understorey species.

Harvesting: This is normally dictated by the appearance of rot in the stem and should, therefore, be undertaken when the stems have reached diameters of 50–60 cm.

Conclusions

Wild cherry is one of the most valuable timber species in Europe. For centuries it has been used in the manufacture of high-class furniture and is still highly valued today (refer to Table 3.2-4). Demand is much greater than production. Despite the high value of its timber, little attention has been paid to its regeneration and management. This is partly due to insufficient knowledge of its provenances and possibly its susceptibility to hybridization with cultivated varieties.

Wild cherry grows very rapidly in youth and develops large crowns. Therefore, it needs continuous thinning from early development stages onwards. Artificial pruning is essential because of its poor natural pruning ability.

Its characteristic early and spectacular flowering is highly valued by the public as 'a thing of beauty' in the landscape, especially along woodland margins. It is also an ideal tree for mixtures in small woodlands and along forest edges because of its rapid growth and ability to produce high quality timber over short rotations.

Its fruit is considered to be a source of sustenance for birds and insects.

Cherry should be used by owners of small woodlands as a possible additional source of income. It can be planted in small groups, lines or solitaires. In this way it offers a great opportunity to be grown in small woodlands, in hedgerows and along field edges.

A number of other cherry species play a limited role, but mainly as ornamentals or fruit trees. Some of these species also produce high quality timber. They, however, do not play any significant role because of their infrequent occurrence and because of their production possibility of only small dimensions.

7.5.2 Bird cherry

Prunus padus (Greek name for wild cherry) has **flowers and fruits in bunches** similar to *P. serotina*. It is widely distributed over Europe (except the Mediterranean and the Balkans) into N Asia and Japan. It is also native to Britain and Ireland.

Bird cherry grows fast in its youth and reaches heights up to 15 m. It has a relatively straight stem with a densely foliated slim conical **crown**. Its **roots** have good sprouting ability.

Because of its large water demand it is mainly found along streams and rivers. It does not grow well on dry soils and those with high lime content.

Its glossy, dark grey **bark** smells unpleasantly like sharp vinegar when damaged.

The **leave**s have a velvety dark-green surface and are grey-green underneath. In autumn they turn yellow-red. The slightly fishy smell attracts insects and the fruits attract birds. By spreading the seeds they help to regenerate it over wide areas. It is of special ecological value.

Bird cherry reaches around 60 years of age. Its timber is of low value and, therefore, has never been propagated for forestry purposes.

Ornamental breeds with characteristic yellow flowers are found in gardens and parks (Plate 7.5-7).

7.5.3 Black cherry

Plate 7.5-7: Flowering bird cherry.

Prunus serotina, (from *serotinus* = late-ripening fruit) has shiny leather-like leaves and white flowers in bunches. It ranges in various forms from Nova Scotia to Guatemala (Mitchell, 1989) and is a fine tree up to 35 m in height in all parts of the USA. It is scarce as a garden tree in Britain and was originally planted as cover and food for pheasants on several estates.

On the Continent, it has been intensively seeded and planted in order to improve poor sandy soils. In those locations, it has tended to spread mainly as a bush and become a very troublesome, invasive species.

Its strong shoots can grow 2 m in a year when cut back.

Where it reaches tree size it can produce one of the most valuable timbers as in the USA. Its timber is sometimes devalued by gum enclosures. This, however, is a problem of the selection of adapted provenances which have not been studied fully.

Being relatively site-unspecific it could have some prospects as a forest tree species in Ireland, but its invasiveness may create future problems.

7.5.4 Cherry laurel

Prunus laurocerasus (*laurocerasus* = laurel-like) has often been planted in woods and demesnes and is extensively spreading as an invasive species in many areas.

It is an evergreen bush and sometimes small tree that comes originally from the Near East. It is tolerant of winter frost to -20 °C and is able to sprout from the roots.

Cherry laurel is valued as a hedge plant because of its fast growth in the early years and its sheltering effect even in winter as well as its ornamental value (bunches of white flowers in spring and of dark fruits in autumn). Its seed are widely spread by birds. Cherry laurel has developed as a dense undergrowth in some forests, similar to rhododendron. It is, therefore, listed as a neophyte and, therefore, should not be planted outside of urban areas.

Prunus lusitanica (from old name of Portugal: *Lusitania*) is somewhat similar to cherry laurel, but smaller and with pointed, sharply toothed leaves and red petioles. Often planted, but rarely naturalised, it may be used as a substitute for cherry laurel.

7.5.5 Wild plum and sour cherry

Wild plum (*Prunus domestica*) is thought to be native to Ireland, but could have been introduced in earlier times. It is a small tree up to 15 m, but mostly as a bush growing in hedgerows and alongside forest edges.

It sometimes resembles blackthorn because of its thorns, but its leaves are much bigger (3–8 cm in length and 2–5 cm in width), dark green on the surface and light green underneath.

Wild plum shows a great variety of forms as it has often escaped from gardens and orchards.

Sour cherry (*Prunus cerasus*) originally from SE Europe may be found also occasionally in hedgerows, mainly spread by birds. Its leaves differ from those of wild cherry being harder and without glands. The flowers are smaller. Sour cherry is neither of silvicultural nor ecological value.

Blackthorn (*Prunus spinosa*) will be dealt with in Chapter 8.1

7.6 Oak

Family: *Fagaceae* - beech family.

Genus: *Quercus* L. Of the large number of oak species distributed throughout the north temperate zone only two, sessile and pedunculate, are of commercial relevance in Irish forestry.

Both species colonised Europe soon after the ice sheets receded. In the oak-mixture period they covered the warm lowlands and extended much higher into the mountains than they do today. Because the pollen of the two species are indistinguishable it is now impossible to determine the extent of their respective distributions at that time.

Key characteristics:

- Strong light-demanders,
- very long-living species,
- accommodating in regard to site,
- susceptible to late spring and early autumn frosts,
- excellent stability to wind,
- susceptible to damage by grey squirrels,
- medium ability for natural pruning,
- prone to development of epicormic branches,
- susceptible to shake.

Although they have many characteristics in common they have important botanical and ecological differences which help to distinguish the species. The botanical differences are highlighted, but they are often blurred by the tendency of the two species to hybridise.

Following a description of the key characteristics of both species a short tabular presentation of the differences is provided. This is followed by a detailed description of the characteristics of sessile oak. In order to avoid repetition, characteristics which are common to both species are not repeated for pedunculate oak.

Non-native oak species such as (3) red oak, (4) Turkey oak and (5) holm oak are treated briefly.

A summary of distinguishing characteristics of sessile and pedunculate oak is presented in Table 7.6-1.

According to Ducousso and Bordacs (2004), hybrid foliar characteristics resulting from controlled crossings resemble more the female parent and are not intermediate between the parental forms. They also state that hybridisation is asymmetric in European white oaks: sessile oak preferentially pollinates pedunculate. This suggests that trees with pedunculate oak leaf characteristics may often be hybrids.

7.6.1 Sessile oak

Scientific name: *Quercus petraea* (Mattuschka) Liebl.

Irish name: Dair Ghaelach. The *Ghaelach* indicates that this is regarded as the Irish oak. It is the National Tree of Ireland.

Origin and geographic distribution: Sessile oak has a much more limited distribution range than pedunculate. It is concentrated in the more sub-atlantic regions where its climatic requirements resemble those of beech (Figure 7.6-1). Its southern extent includes the Mediterranean

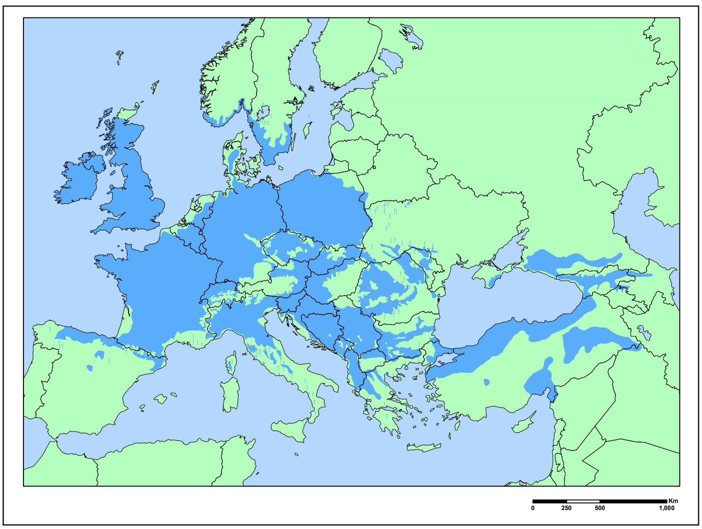


Figure 7.6-1: Natural distribution of sessile oak. (EUFORGEN, 2009)

For comparison purposes the distribution maps of the two species are inserted here.

countries, with the exception of southern Spain and Greece. To the north it inhabits the coastal regions of Norway and Sweden and extends eastwards to north-east Poland, reaching the Crimea through the Ukraine. It is also present in regions south of the Black Sea, in the Caucasus and in the south and east of Turkey.

It is native to Ireland and was widely distributed in the uplands where it began its colonisation around 9,000 BP (refer to Chapter 1.2). It is recorded on 1% of the total stocked forest area (NFI, 2013).

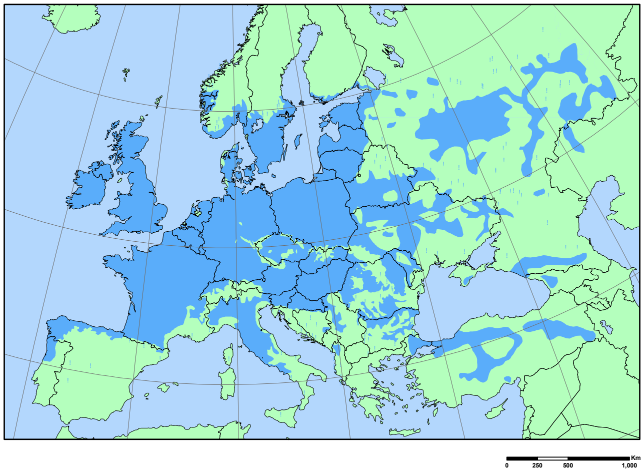


Figure 7.6-2: Natural distribution of pedunculate oak. (EUFORGEN, 2009)

Botanical characteristics

Tree and crown form: The crown is regular and compact; branches are straight and spread out widely.

Table 7.6-1: Key distinguishing characteristics of sessile and pedunculate oak.

	Sessile oak	Pedunculate oak
Leaf It may not always be a defining characteristic.	 More symmetrical; base tapering (cunate) to cordate; bright green on upper surface, grey-green beneath with fine hairs in the axils of the veins; longer petiole (1.8-2.5 cm).	 More elongated to oval; base with pair of rounded lobes (auricles); dull green on upper surface, pale bluish green beneath; shorter petiole (0.4-1 cm).
Acorns	In groups, stalkless (sessile) or on a peduncle up to 1 cm.	In groups, on stalks (peduncles) 3-8 cm.
Bark	 Generally finer	 Generally coarser

Stem form and dimension: Sessile oak usually keeps to a straight monopodial structure, although it attains less imposing dimensions than pedunculate oak.

In contrast to pedunculate oak the stem is usually clearly visible at the top of the tree.

Bark: Fissured, forming longitudinal narrow grey ridges.

Timber: The wood is strongly ring porous and within the annual ring the circles of large vessels (each up to 0.3 mm diameter, and easily visible to the naked eye) which characterise the softer, less dense earlywood that stands out clearly from the harder, denser latewood (Plate 7.6-1). Average density of the wood at 15% moisture content is about 720 kg/m^3.

A distinctive feature of oak timber is the broad (medullary) rays radiating from the centre of the stem. When sawn radially (quarter-sawn) these show up as large silver coloured plates, giving the ornamental feature known as 'silver grain', which is also a highly valued characteristic of oak veneer.

Plate 7.6-1: Cross section of oak timber. X 40

The wood is normally light tan in colour when freshly cut; it dries slowly and has a tendency to split and check unless care is taken in drying. The heartwood is very durable and resists penetration by preservatives. Sapwood, which is usually confined to the outer 10–20 rings in the tree, is perishable but more permeable.

Root system: Sessile oak has a definite taproot often penetrating to a depth of 2 m in youth. Later in life the root system develops into a heart-shaped form. On that account it is exceptionally windfirm (refer to Plates 4.4-39 and 4.4-40).

Leaves: Leaves are set alternately, usually with a tapered (cuneate) base and have 6–9 pairs of tapered lobes (refer to Table 7.6-1).

Flowers: Flowers are monoecious; the male flowers are grouped in pale green catkins 4–6 cm long; the female flowers are solitary or on a spike of 2–5 flowers. Pollination is by wind and the two species can hybridise. The flowers appear at time of leaf flushing in May, slightly earlier for sessile than for pedunculate. Flowering starts relatively late, at an age of 20–30 years for isolated trees and much later, 50 years, in stands. Mast production is very uncertain, even when flowers form they may be damaged by late frost or by insect attack.

Fruits: The acorns are sessile (stalkless) or have a short stalk (up to 1 cm). Acorns are usually produced in clusters of up to 6 (refer to Table 7.6-1). They are among the heaviest fruits of all native European trees: 1,000 acorns weigh 2,000–3,500 g. Seeds of a very wide range of plants including trees fall into two main groups, orthodox and recalcitrant, which is a reflection of their true sensitivity to moisture content and subsequent storage. Seed of oak is classified as recalcitrant meaning they cannot be dried below a certain moisture level and, as a result are difficult, even impossible to store without damage to their viability.

Mast years occur at intervals of 5–10 years and are obviously, like beech, partly dependent on the weather conditions in late summer of the previous year.

Ecological characteristics

Forest type: In continental Europe, sessile oak inhabits the hills and lower mountain ranges and can rightfully be regarded as the 'oak of the mountains'. It forms the main constituent of the oak/mountain ash/holly/birch woodland of upland acidic soils. In Ireland, it is still the predominant species where woodlands occur in the uplands of Wicklow and Kerry.

Successional type: Sessile oak has many of the characteristics of a pioneer species and in natural conditions regenerates by species alternation. It has, however, the ability to outlive most competitors, as it grows on a wide range of soils, has a good seed dispersal by birds and mammals and remains because of its longevity, predominant in many forests. Savill (2013), therefore, regarded oak in a certain way as a climax species.

Light requirements: Sessile oak is a strong light-demander.

Stress tolerance: It is less tolerant of flooding than pedunculate oak and can withstand **flooding** for less than a few weeks so wet sites should be avoided.

Sessile oak may suffer from frost crack during deep winter frosts and is very susceptible to damage from **late spring frosts**. In normal years, however, it avoids damage by flushing relatively late, at the end of April and in early May, normally after beech and at about the same time as ash.

Damage from **early autumn frost** occurs after long and warm late-summer periods, which encourage oak to produce lammas shoots (a second growth of the shoots in August). If this is then followed by a sudden onset of freezing temperatures it can cause damage to terminal buds which have yet to harden-off. Both types of frost, early autumn and late spring, cause forking of leaders in the growing season following the occurrence of damage (refer to Plate 4.4-35).

Climatic requirements: Sessile oak is a tree of the uplands where it tolerates drier sites than pedunculate. It grows best on south-facing slopes which provide sufficient summer warmth for good growth.

Soil preference: The optimum soil conditions are deep, fertile fine-textured soils, but it has the capacity to to grow on a wide range of soil types.

Sessile oak grows on the freer draining, less fertile soils of the hills, but will show its best growth on deep, acid brown earths on sheltered sites in these locations. In contrast to other broadleaf species (e.g. ash, beech, sycamore and wild cherry) oak is relatively indifferent to site conditions. Good, or at least moderate, growth of oak was recorded in studies on most of the major soils throughout Ireland, ranging through the upland podzols and brown podzolics to the lowland brown earths, grey-brown podzolics and gleys.

Strengths and threats: Oak is the most **storm resistant** of all tree species and rarely suffers from windthrow.

One of the major defects in newly felled oak is a condition known as **shake**. Shake is a longitudinal splitting or separation in the wood, radiating from the centre of the log (star shake), or around the annual ring (ring shake).

Studies in Britain have linked the occurrence of shake to trees growing on light, free-draining soils, but variability between trees on the same site indicates that there may be some genetic linkage. More recent work at Oxford University suggests that oaks with larger than average sized earlywood vessels are likely to have a greater predisposition to shake (Savill and Mather, 1990). These shake-prone trees can be recognised by their tendency to flush slightly later in springtime.

Deep fissures or longitudinal ribbing along the stem are usually a sign of **frost crack**, which occurs occasionally in Ireland, but is much more common on the Continent.

Deer, where present, tend to browse intensively on broadleaves and must be excluded by fencing. With increases in deer populations, growing oak will become more difficult. Acorns are extremely attractive to herbivores, such as deer, and to mice, a factor that must be taken into consideration during natural regeneration, when partial covering of the seed considerably reduces predation.

Stock and rabbit fencing will be necessary to exclude domestic **livestock, rabbits** and particularly **hares**, which can cause considerable damage to newly established plantations by snipping off all plant stems in their path.

Damage by **grey squirrels** is much more widespread in Britain than in Ireland, where they do untold damage to oak. Without good control measures damage is expected to become much more severe in Ireland.

In continental Europe, and occasionally in Britain, the larvae of the **oak leafroller moth** (*Tortrix viridana*) cause defoliation and consequent reduction in volume increment. Of the fungi that attack oak, two are of significance: *Polyporus sulphureus*, causing brown **cubical rot**, and *Stereum gausapatum* causing **pipe rot** (Evans, 1994). These enter the tree through branch stubs in which heartwood has developed. The formation of heartwood inside branches occurs when they exceed 3 cm in diameter at the stem. To avoid infection, side branches should not be allowed to develop heartwood. This is best achieved by ensuring that branch diameter is kept small by close spacing. The alternative is early and continuing pruning. Rot is more prevalent in overmature trees.

Mildew is more serious in the nursery stage, but in woodland it is confined almost entirely to coppice shoots and rarely does lasting damage.

Regenerative capacity: Oak can be regenerated by the shelterwood system, but this can be achieved only where measures are taken to protect the seed from predation. Acorns are very attractive to mammals, such as deer and mice, as well as birds and without protective measures regeneration is not possible, even in mast years. The current method of regeneration in Ireland is exclusively by planting. This is partly due to the long intervals between seed years.

Both oak species have a good ability to sprout from stools. The oaks have, therefore, been widely used in the coppice silvicultural system since early times and it is still an important feature of French and Italian forests. Sprouting potential declines gradually with age of the stool and volume production decreases after a number of coppice rotations, but reliable data are unavailable.

Provenance: Sessile oak is a native species and in times past it constituted a significant part of the native woodland. Today, only a very small area of this ancient native woodland has survived.

Until recent decades most of the seed used in establishing oak plantations in Ireland was of home collected origin. The National Tree Seed Register shows that during a 50-year period, from the start of the State Afforestation Programme in the late 1920s to 1980, only 25% of oak seed was imported, mostly from Germany and the Netherlands.

With the upsurge in private planting since the 1990s, demand for planting stock far outstripped the available harvestable supply of acorns, and led to the import of large quantities of both acorns and plants. Concern about the quality of some imports has prompted a renewed effort to source home supply and in 2007 over 30,000 kg were collected from registered seed stands (Doody, 2007). This was sufficient to meet national requirements for that year, but the periodicity of good mast years, and the difficulties involved in storing acorns for more than six months, remains.

For centuries it has been common practice in oakwoods on this island to remove the better quality trees thereby resulting in genetic impoverishment because those of poor quality produce most of the seed for the next generation. To safeguard the threatened genetic resource and identify the best sources of native oak for commercial purposes an oak provenance trial was established in 1988. More recently these have been augmented by three new provenance trials.

An early assessment of the provenance trials is fully reported in Felton et al., (2006). Results from the progeny testing, however, will not be available for many years.

In the absence of data from field trials, material from registered Irish stands should be a first choice. Currently, there are 1,381 ha of sessile oak registered in the Republic of Ireland (Fennessy et al., 2012).

If seed and plants must be imported then it is recommended that material should come from registered seed stands growing in the UK, Netherlands, Belgium and the northern parts of France and Germany, regions which have a climate not too dissimilar to Ireland.

Varieties of oak: There are several varieties of oak recorded in both sessile and pedunculate, however, one worth mentioning is *Fennessii* which according to Elwes and Henry has leaves varying greatly in shape, some are lanceolate and entire, others are cut at the edges or deeply laciniate, but all are cunate at the base. It has received a variety of names. It was first raised by Fennessy and Son of Waterford around 1820. It was put into commerce as *Q. pedunculata fennessii* (Elwes and Henry, 1906–1913).

Growth characteristics

Height and age: Like all light-demanding tree species oak grows rapidly in height in the early years.

According to German yield models (Jüttner, 1955), oak reaches 31 m at 100 years and 40 m at 200 years on very good sites. Comparison with poorer sites shows that the differences in height growth occur during the first 30 years (Figure 7.6-3) .

Current annual height increment culminates between 10 and 20 years for the best yield classes (yield class 9) and later than 30 years on poorest sites (yield class 3) (Fig 7.6-4).

British (Edwards and Christie, 1981) and French models (Jarret et al., 1996) follow similar growth trends for both cumulative height and annual height increment.

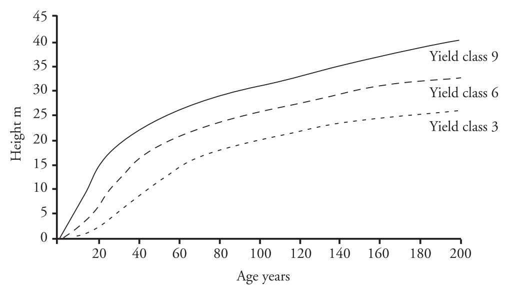


Figure 7.6-3: Cumulative height growth of oak for yield classes 3, 6 and 9.
(from German yield tables, Jüttner, 1955)

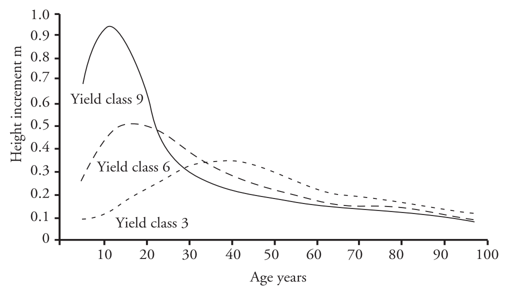


Figure 7.6-4: Annual height increment of oak for yield classes 3, 6 and 9.
(from German yield tables, Jüttner, 1955)

Values

Silvicultural value: Because of its deep-rooting ability oak has a great resistance to summer drought and good stability in winter storms. As a long-living species it outlives most other trees and the wood does not suffer from deterioration. With a suitable understorey to curb the development of epicormic branching a high quality product can be realised (refer to Plate 4.5-29).

Economic value: The timber is used for veneer, furniture manufacture and joinery (Plates 7.6-2 and 7.6-3).

The proportion of earlywood to latewood determines the ease of working and strength properties of the timber.

Earlywood width tends to remain constant irrespective of growth rate, so rapidly growing trees will contain a high proportion of latewood relative to earlywood. This results in high strength properties, greater shrinkage and somewhat poorer workability, but is very suitable for furniture manufacture and support beams. Conversely, in slow-growing trees the annual ring will consist almost entirely of early wood resulting in poorer strength properties, lower shrinkage, but good workability. This timber is very suitable for high class joinery and veneer.

Oak is one of the most highly priced timbers (refer to Chapter 3.2) and high quality veneer logs can fetch exceptional prices. The determining factors are diameter, colour and uniformity of growth. Site factors and species characteristics ensure that sessile oak grows slowly, resulting in average ring widths of 2–2.5 mm. High quality veneer logs are mostly oak.

The criteria for high value oak are:
- large diameter dimensions,
- straight cylindrical stem,

Plate 7.6-2: Oak butt of veneer quality. (Tullynally Estate, Co Westmeath)

Plate 7.6-3: Oak stem of excellent quality suitable for furniture manufacturing. (Denmark)

- absolutely blemish-free stem,
- a light clear colour,
- concentric rings of uniform growth.

To meet those criteria, management should ensure that the stems are branch-free from an early age and that uniform growth is achieved through regular thinning.

Medium dimensions of approximately 60 cm in diameter are specified in Germany, but larger diameters command much higher prices. In France, even larger dimensions, 70 cm minimum at breast height (optimum 80 cm), are specified for sessile oak.

Ecological value: From a biodiversity viewpoint, oak is reputed to play host to more species of insects than any other British tree (Savill, 2013). This is reflected in the high ecological value placed on oak by nature conservationists (Plate 7.6-4).

Its acorns are particularly relished by deer and many other animals.

Amenity value: For amenity purposes, oak has few if any equals. Its longevity, durability, wind firmness and attractive profile ensure that it is the species of choice for parks and amenity woodland. There is a mystique attached to gnarled old oak that is unequalled in any other tree (Plate 7.6-5).

Historical importance: In Ireland, oak is irrevocably linked to the ancient woodlands and the number of place names with derry point to its previous widespread distribution. The largest surviving oak artefact from these ancient woodlands is a huge logboat shown in Plates 7.6-6 and 7.6-7.

The old oak forests were extensively exploited over the centuries, although trees of exceptional quality seem still to have remained into the 15th century.

Following the Tudor and Cromwellian conquests, oak was widely used for fuel to service the ironworks and glassworks that proliferated during the 17th century. It was used for shipbuilding, and in the period between 1778 and 1800 alone, *515 ships … are known to* *have been built in Ireland.* (Neeson, 1991). Oak bark was extensively used for tanning and the timber used for cask staves. According to Mc Cracken (1971) Irish oak barrel staves were exported to France and Spain to cask their wines during the Cromwellian period of exploitation.

Plate 7.6-4: Oak woodland in the neighbourhood of pasture land. (Ballykilcavan, Co Laois)

Silvicultural management

Production of plant material: The acorns ripen in October and are able to produce a radicle immediately (not a shoot, which must await a period of winter chilling), but they very soon lose this capacity. This makes it difficult to store acorns for longer than a few months without employing special handling measures.

In the nursery, sowing is usually done in March after soaking in water for 48 hours to return the moisture content to the desired level.

Forest Service nursery stock specifications are for 3, 4 or 5 years old plants with heights of from 20–85 cm. To avoid losses plants should have a good root/shoot ratio.

Regeneration: Oak can be regenerated under the shelterwood system. This system is widely used for regeneration of oak crops in the more maritime regions of the Continent. In central Europe, with its more continental climate, a system of acorn sowing is practised. Both are feasible in Ireland although, with infrequent mast years, the system of acorn sowing may be considered wasteful of a limited resource.

In Ireland, planting is the main method of regeneration. Sessile oak should be planted on the lighter upland soils. Light drought-prone soils should be avoided because of the risk of shake.

Tending of young stands: Formative shaping is important because of damage by late spring frosts. The terminal bud is often damaged or killed, particularly in low-lying locations. Damage to lammas shoots by early autumn frost, and to emerging shoots by late spring frost, contribute substantially to forking in oak. This necessitates corrective action through **formative shaping**.

Formative shaping should take place when the top height is 2–3 m. It encourages the tree

Plate 7.6-5: The 'Squires Walking Stick'. (Tullynally Estate, Castlepollard, Co Westmeath)

Plate 7.6-6: The Lurgan logboat was unearthed from Addergoole Bog, Lurgan, Co Galway. It dates from the Earlier Bronze Age (ca. 2,500 BC). In 1902 it was brought to the National Museum of Ireland. (Photo: Courtesy of the National Museum of Ireland)

Plate 7.6-7: Lurgan logboat measures 15.25 m in length and was made from a straight tree trunk. It can be seen in the archaeological department of the National Museum of Ireland. (Kildare Street, Dublin)

to revert to a single leader and thereby improves stem form. Shaping should be confined to 400–500 potential crop tree candidates/ha.

In pure oak crops, removal of wolves is necessary during the tending stage. With oak/conifer mixtures, removal of the conifers should begin when they start to interfere with the development of the oak, but not later than a top height of 8–9 m – when wolves, competitors to potential crop trees and dominating conifers are removed.

Pruning is an operation that is rarely cost effective, especially over long rotations, but in oak/conifer mixtures the process of natural pruning may be so inadequate that artificial pruning is required. Even in pure oak crops or oak/broadleaf mixtures, situations may arise where some potential crop tree candidates still have live branches in the lower half of the stem at time of first thinning. In such circumstances it may be desirable to prune potential crop trees on a limited scale. The branches of candidates for pruning should not have been allowed to form heartwood and, therefore, should not exceed 3 cm in diameter at the stem.

Thinning: Traditionally, oak has been thinned cautiously; frequent, and moderate interventions have been the norm. This has inevitably resulted in slow diameter growth and long rotations. Recent research on the silvicultural treatment of oak in France and Germany favours a dynamic rather than a gradualist approach. It is predicated on the need for more rapid stem diameter growth and shorter rotations. Close spacing is maintained in youth to effect natural pruning and one or two early tendings ensure that wolves and poorly formed dominants are removed.

First thinning

When an adequate stem length free of live branches has been obtained, thinning of the upper canopy ensures good crown development. This should take place at about 12 m top height and involves the selection of 250–300 potential crop tree candidates/ha and their release from competitors where necessary (refer to Chapter 4.5.5).

The rationale is that early crown thinning allows optimisation of the potential in the juvenile growth phase for crown development when the crop is most likely to respond. In turn, crown response to increased growing space helps to curb the stresses generated in the tree to produce epicormic branches. Furthermore, the increased light favours the growth of the understorey.

Subsequent thinning

The second thinning should take place at about 15 m top height, by the selection of about 150 potential crop trees/ha from the previously selected candidates and the removal of competitors (refer to Chapter 4.5.5). In this final selection tree vigour and quality of stem take precedence over uniformity of spacing (in that order). Thereafter, thinning should take place at height growth increments of 1.5-2 m and should always be directed towards the removal of competitors to the potential crop trees.

Delayed thinning

If tending or thinning has been delayed, the provision of growing space for the selected potential crop trees should be approached cautiously, particularly if the crowns are small. Unlike beech, oak can only enlarge its crown upwards and needs more time for crown development. Therefore, thinnings should be lighter and more frequent. Thinning must also have regard to developing the understorey, e.g. beech or hornbeam, and must be of sufficient intensity to encourage its development, but not too heavily. Thinning intervention must tread a fine line between the danger from epicormic branching (from too heavy thinning) on the one hand, and the light requirements of the understorey (the fear of damage to the understorey by shading) on the other.

Epicormic branches

More than any other broadleaf species, oak has a strong propensity to develop epicormic branches. In stands without an understorey species with a serving function (e.g. beech or hornbeam, that shade the stems) a majority of stems will exhibit some tendency in this regard. Thinning practice should avoid exacerbating this situation over the long term (Plate 7.6-8).

Epicormic branches arise from adventitious buds on the stem, which are activated by increased light within the stand, such as that resulting from heavy thinning. Conversely, small compressed crowns, which result from neglect of thinning, also induce epicormic branching as the trees struggle for survival.

Provided light conditions are favourable, the epicormics continue to grow and will eventually form large branches if not shaded out by neighbours or an understorey.

Even in the juvenile stage they give rise to clusters of small knots, or catspaws, in the wood, which makes it unsuitable for veneer or high-grade furniture.

The smaller the crowns the greater is the risk of epicormic branches developing. Even light thinning may trigger the development of epicormic shoots when the crowns are small or restricted. This presents the silviculturist with a dilemma. Light thinning will curb epicormic branching, but will do little to develop the crowns and this in time may lead to the development of epicormics. Heavy crown thinning will allow the crowns to develop, but may give rise to epicormic branching in the short term.

Plate 7.6-8: Oak stands without serving trees to protect their trunks from developing epicormic shoots. (Ballygannon Wood, Rathdrum, Co Wicklow)

Understorey

In pure oak stands and in oak/conifer mixtures (from which most, if not all, conifers will have been removed), preparations should be made for the establishment of an understorey by planting 600–800 beech/ha after the second thinning.

Subsequent thinnings should take place at 1.5–2 m increments in top height. These interventions take the form of selective crown thinnings of medium intensity to favour the development of the potential crop trees by removing competitors. Thinning should continue to promote the development of the understorey, gradually and cautiously.

Free growth

Attempts to circumvent the problem of epicormic growth have given rise to experimentation with free growth in Britain (Jobling and Pearce, 1987; Kerr, 1996) and in Denmark, where some 50–60 final crop trees/ha have been isolated in youth by heavy thinning and the epicormics removed annually by pruning. The rapidly grown, large diameter and knot-free stems are said to be much sought after by timber merchants in Denmark. While the procedure is feasible it requires a firm commitment to annual pruning for a long time. Any lapse in annual pruning will result in renewed epicormic growth and deterioration in timber quality.

Conclusions

Both sessile and pedunculate oak are accommodating in regard to site, with sessile growing on the lighter soils of the hills and uplands. The deep-rooting habit of both species makes them extremely windfirm.

In localities where they grow together they tend to hybridise. Sessile preferentially pollinates pedunculate and the hybrid may show the foliar characteristics of pedunculate oak.

Oak is intolerant of shade and will stagnate if the crown is not provided with sufficient light. It is the most difficult of the broadleaves to grow successfully because of the production of epicormic shoots. Without a suitable understorey to shade the stems, the production of high quality veneer trees will not be possible. Estimated economic rotation for sessile is 160 years.

High quality oak veneer logs command the best price of all the broadleaf timbers, with the exceptions of wild cherry and walnut. Most high quality veneer logs are of sessile origin, but these are unlikely to exceed 20% by volume of the best stands.

Oak timber is widely used for furniture manufacture and joinery where strength, durability and good looks are required.

Notwithstanding the mystique associated with oak in Ireland, it must be concluded that the commercial growing of oak can be economically justified only on good sites. The production of high quality timber is imperative for the profitability of the enterprise.

Oak management inevitably involves long rotations. Taking into account the long payback period, this may well make the planting of oak for commercial purposes less attractive to small forest owners with an early return on investment in mind.

7.6.2 Pedunculate or common oak

Scientific name: *Quercus robur* L.

Irish name: Dair ghallda. Although it is native to Ireland, much of the pedunculate oak growing here today is thought to have originated from imported seed. This is indicated by the appellation *ghallda*, meaning foreign, in its Irish name.

As already mentioned, sessile and pedunculate oak have many characteristics in common, but there are some important differences. Only these differences are recorded.

Geographic distribution: Pedunculate oak is found throughout most of Europe, with the exception of the more northerly regions of Scandinavia and the southern parts of Spain, Italy and Greece. Scattered populations extend eastwards into Asia Minor, the Caucasus and as far as the Caspian Sea (Figure 7.6-2). In Ireland it is recorded on an area greater than that of sessile oak, slightly more than 1.6% of the total stocked forest area (NFI, 2013, refer to Table 1.5-5).

Botanical characteristics

Tree and crown form: Pedunculate oak has a large irregularly domed crown, which usually divides into big, often crooked branches (Plate 7.6-9).

Timber: The wood is similar to that of sessile oak, but usually has wider annual rings.

Root system: It has the most intensive root systems of all broadleaf species, especially on heavy soils.

Leaves: Leaves are set alternately, each with 3–7 pairs of rounded lobes and a pair of small rounded lobes (auricles) at the base (Table 7.6-1).

Flowers: The flowers appear at time of leaf flushing in May; flowering is slightly later for pedunculate oak than for sessile.

Fruits: Pedunculate oak acorns are carried on stalks (peduncules) 3–8 cm long. Acorns are usually produced singly or in small clusters (Table 7.6-1)

Plate 7.6-9: Pedunculate oak beside a river. (Schwerin, E Germany)

Ecological characteristics

Forest type: Pedunculate oak is more a tree of the lowlands and foothills. In Ireland, it is most frequently found on fertile soils in the Midlands in association with hazel and birch. Unlike sessile oak, today it is infrequent outside large estates (Little and Cross, 2005). Evidence suggests that oak occurred in association with elm on fertile soils in ancient Ireland.

Stress tolerance: It tolerates flooding for up to 4 months during summer and can grow on soils with a high water-table, such as ground-water gleys, and those with a fluctuating water table, such as surface-water gleys.

Climatic requirements: Pedunculate oak tolerates a more continental climate than sessile oak and is, therefore, less susceptible to damage by heavy winter frosts. Both pedunculate and sessile oak have wide climatic ranges and need sufficient summer warmth for good growth.

Soil preference: Pedunculate oak is very accommodating in regard to soil, and grows on acid soils as well as on very basic ones. It is usually associated with the heavy clay soils of the lowlands. Because of its better ability to grow on heavy soils, like surface-water gleys, pedunculate oak is even found on very compacted soils.

Growth characteristics

French tables indicate much more rapid growth rates for pedunculate oak than for sessile (Duplat et al., 1996) with a dominant height of 35 m at 100 years.

Because it usually grows on better soils, its annual diameter increment is greater with ring widths of 2.5–4 mm/yr.

Silvicultural management

Its silvicultural management is similar to that of sessile oak. Tending and thinning should follow the same procedures. Since pedunculate oak is more favoured for the wetter sites, hornbeam may be substituted for beech in the establishment of an understorey after the second thinning.

Conclusions

Pedunculate oak usually occupies the heavier soils of the lowlands, but is accommodating in regard to site. Because of its strong taproot, it is the only broadleaf species with the capacity to penetrate heavy gley soils. This deep-rooting habit of the species makes it extremely windfirm.

It is strongly light-demanding and, like sessile oak, has a tendency to develop epicormic branches. Therefore, it needs an understorey to shade the lower part of the stems. If it grows on the wetter soils, hornbeam will be the most suitable understorey species.

Estimated economic rotation is 120–130 years.

Pedunculate and sessile oaks tend to hybridise and the hybrids will often show the foliar characteristics of pedunculate oak.

Although less preferred for veneer, because of harder wood and darker colour, large blemish-free logs will still command excellent prices. Its timber is widely used for furniture manufacture and joinery where strength, durability and good looks are required.

In other respects the statements in regard to sessile oak apply to pedunculate.

7.6.3 Red oak

Scientific name: *Quercus rubra* L. **(**formerly *Q. borealis* Michx. F.**)**

English synonyms: Northern red oak; champion oak

Origin and geographic distribution: Red oak is a native of North America and is the most northerly growing of the red oak group. It is widely distributed throughout the eastern states of the USA and southeast Canada. To the north it is found from the Great Lakes, through Ontario and Quebec, east to Nova Scotia. To the west it extends as far as Minnesota, Iowa and the extreme east of Nebraska, Kansas and Oklahoma. Its southern limit includes parts of the states of Alabama, Georgia and the Carolinas (Figure 7.6-5).

Figure 7.6-5: Natural distribution of red oak.
(Suszka et al., 1996)

It was introduced to Britain in the early

1700s and into Europe in 1724. It is an important tree on the Continent, especially in France (Savill, 2013). In Ireland it is planted on a limited scale.

Botanical characteristics

Tree and crown form: Open-grown specimens form large spreading crowns rounded at the top.

Stem form and dimension: In its native forests it grows straight and tall. In Britain the stem is reported to have a tendency to fork rather badly.

Bark: Smooth and light grey on young trees, becoming dark brown and lightly fissured on older trees. A distinguishing feature is the appearance of shiny stripes all the way down the trunk.

Timber: Pale reddish brown with darker sapwood. A defining microscopic feature which distinguishes the wood from that of the white oaks (which include sessile and pedunculate) is the absence of tyloses in the vessels. These are outgrowths of parenchyma cells which invade the vessel through the pits in its wall and have the effect of blocking the passage of liquid. The absence of tyloses in red oak makes the wood permeable.

Like native oaks, the timber suffers from occasional shake and is also inclined to check on drying.

Specific gravity is 0.66 and the average density of the wood at 15% moisture content is about 790 kg/m^3.

Leaves: 12–22 cm long and 15 cm wide, with 7–11 lobes tapering from a triangular base and terminating with irregular, long, bristle-pointed teeth. Lobes are deeply serrated, up to one quarter the width of the leaf. The upper surface of the leaves is dull green, the lower surface greyish to whitish or yellowish green. Petioles are 2–5 cm long, often red in colour.

Flowers: The tree flowers in May when the leaves are about half-grown. The male flowers form catkins in the axils of the leaves of the previous year's growth. Female flowers are either solitary, or grouped in twos or more, and form in the axils of the current year's growth.

Fruits: Acorns are solitary or in pairs, either sessile or on short stalks; oblong-ovoid with a broad flat base and lightly held in a cupule which has small oval and pointed reddish-brown pubescent scales. They do not ripen until the spring of the second year – about 18 months after pollination – and attain complete maturity in September/October of that year.

Fruiting begins from the age of 25 and reaches its maximum from 50 years onwards. Frequency of seed crops is 2–4 years and yields are extremely variable.

Ecological characteristics

Forest type: Red oak is a major constituent of the broadleaf forest of eastern North America, growing along well-drained borders of streams in valley bottoms and up to mid-slopes of hills.

Light requirements: Red oak will endure more shade than native oak and will even form an understorey in some situations.

Stress tolerance: In Poland it is resistant to freezing and to drought (Suszka et al., 1996). Although it is regarded as hardy in Britain, it is occasionally damaged by late spring frost (Savill, 1996).

Climatic requirements: As one might expect for a species with such a wide geographic distribution there is great variability in the climatic conditions and the length of photosynthesis period under which it grows. No studies have been conducted in Ireland in this connection.

Soil preference: It is tolerant of many soil types and grows rapidly even on the poorest soils, but it will not grow well on calcareous soils or peats. Its best growth, however, is on fertile soils that are moist and free-draining.

Strength and threats: Epicormic branching is less profuse than on native oaks. In North America its acorns are often subject to attack by weevils and larvae of cynipid wasps, but are relatively free of insect pests in Europe.

Regenerative capacity: Like native oak it has the ability to coppice.

Growth characteristics

Height/age: In North America it grows up to 35 m with a trunk of up to 1 m diameter. The height in Europe is less, at 21–27 m with a diameter of 60–90 cm.

A single red oak specimen at Altamount, Co Carlow is 21 m in height and 3.85 m in girth and is the Irish growth champion (Tree Council of Ireland, 2005).

Total volume production: Levels of production are much greater than those for native oaks. They range up to 9 m^3/ha/yr for the Netherlands and Belgium, and similar production rates have been found in Britain (Savill, 1996).

Values

Silvicultural values: In forests, it is the oak species of choice on dry, acid soils which are unsuited to other broadleaf species.

Economic values: It is regarded as one of the most important oaks in North America for timber production and is considered to be superior in quality to other related oaks.

In Britain it is regarded as inferior to the native oaks for furniture manufacture, because of its less attractive colour and texture. In France, however, it is much in demand for making furniture and for flooring and interior joinery (Savill, 1996). It is now being planted more widely in Germany and the wood is used for sawtimber and parquet. Because of the absence of tyloses and the consequent permeability of its wood, it is rejected by coopers for making wine casks and by shipwrights for boat-building.

Ecological values: Although the kernels of acorns are bitter they are, like those of native oaks, an important source of food and are eaten by birds, squirrels and deer as well as other mammals. Young red oak plants are, however, less palatable to herbivores.

Amenity values: In autumn the leaves turn a magnificent rich red or reddish brown. This makes it a most attractive species for planting along forest edges and in parkland.

Silvicultural management

Tending and thinning: Shaping and pruning should follow the recommendations for native oak. As it is more shade-tolerant thinning may be slightly later than for these oaks if natural pruning is required. Like the native oaks it will benefit from heavy crown thinning.

Conclusions

Red oak is a fast-growing species with greater volume production/ha than native oak. It will tolerate a wide range of soil conditions including poor, dry soils unsuited to other broadleaf species. The rich red autumn foliage makes it a valuable tree for amenity purposes.

7.6.4 Turkey oak

Scientific name: *Quercus cerris* L.

Origin and geographic distribution: Turkey oak is native to southern Europe and Asia Minor. Before the previous ice age, about 120,000 years ago, the range of the species extended to northern Europe. It is now widely planted throughout the Continent. It was introduced to Britain and Ireland in the 18th century and is naturalised in southern England.

It is planted mainly in parks for amenity purposes.

Botanical characteristics

Tree and crown form: A broadly domed deciduous tree growing to 25–35 m in height.

Stem form and dimension: Stem form is usually superior in form to native oak and can attain diameters of up to 2 m. If a supposed native oak has exceptionally good form, it should be suspected of being a Turkey oak!

Bark: Dark grey and deeply fissured.

Timber: Superficially, the wood has many of the characteristics of native oaks, but it is brittle and inferior in durability, strength and particularly seasoning properties (Evans, 1996). It is prone to warp, shrink and split during seasoning and is usually relegated to such uses as fencing or firewood. Its density varies between 800–880 kg/m^3 at 15% moisture content.

Leaves: Leaves alternate, 5–10 cm long and 3–5 cm in width, slightly tapering at the base. The leaf margins have 6–10 lobes on each side; blunt, or rarely with a small point.

Flowers: Male and female flowers are in separate clusters on the same tree (monoecious) and appear with young leaves in May and June. Male flowers are in dense bunches on drooping catkins 5–8 cm long. The female clusters are inconspicuous, with 1–5 flowers.

Fruits: Acorns are 2.5–4 cm long and 2 cm wide, maturing in the second year after pollination. The acorns develop in cupules which are covered in scales up to 1 cm long.

Ecological characteristics

Strengths and threats: Turkey oak plays alternate host to the knopper gall wasp, *Andricus quercuscalicis,* which requires the presence of both Turkey oak and pedunculate oak to complete its two-phase life cycle. The wasp lays its eggs in the fruiting buds of pedunculate oak (or occasionally sessile oak) and the galls develop as a contorted distortion between the acorn and the cupule.

The knopper gall wasp appeared in Britain during the 1950s and is now found throughout England, Wales and as far north as Scotland. An outbreak of galls on pedunculate oak in Britain in 1979 caused much concern that this would seriously reduce acorn fertility and consequent regeneration. Control measures were considered, but were eventually found to be unnecessary.

Regenerative capacity: In Britain it produces seed regularly and natural regeneration is common. Like other oak it coppices well (Savill, 2013).

Values

Economic value: Turkey oak has very limited economic value. Although it grows more rapidly than native oak, and has usually much better stem form, its wood is much inferior.

Amenity value: It is grown in parks mainly for its relatively fast growth. It is used as an ornamental, and as a coastal windbreak.

Conclusions

Turkey oak grows more rapidly than native oak and has better stem form, but has little commercial value. Its wood is much inferior to that of native oak and is prone to warp and split on seasoning. It has little potential as a forest species in Ireland.

7.6.5 Holm oak

Scientific name: *Quercus ilex* L.

English synonyms: Evergreen oak; holly oak. Its common name 'holm' comes from the ancient name for holly. The *ilex* of its scientific name derives from the similarity between its leaves and those of holly (*Ilex aquifolium* L.).

Origin and geographic distribution: Holm oak is a native of the Mediterranean region.

Botanical characteristics

Tree and crown form: An evergreen tree of medium size with a domed crown.

Bark: Brownish-black with finely rectangular-fissured plates.

Timber: The wood is hard and tough.

Leaves: Dark green on the upper surface and whitish grey below; margins entire or with toothed or spiny teeth on young trees. They are 4–10 cm in length and 1–3 cm broad, oblong to lanceolate in shape with a pointed tip.

Flowers: The flowers are catkins which are produced in June.

Fruits: The fruits are acorns and mature in late autumn.

Ecological characteristics

Forest type: It grows in pure stands or mixed forest in relatively arid climates, at low or moderate elevations. It is found growing in the holm oak/Atlantic cedar forests of the Atlas Mountains.

Climatic requirements: Holm oak will grow in the maritime climate of Europe, but it is intolerant of cold continental winters.

Growth characteristics

Height/age: It grows up to 20–25 m in height.

Values

Economic values: The wood has been used since ancient times for general purposes, such as the construction of wagons, wine casks and for household vessels as well as for firewood. The acorns are an important food for free-range pigs reared for serrano ham production in Spain. In France the holm oak is one of the most important tree species for the cultivation of truffles which grow in a mycorrhizal association with the tree's roots.

Amenity values: Its size and evergreen character makes it a valuable tree in urban woodland and parks.

Conclusions

Holm oak is the most prominent of the evergreen oaks. It is planted in parks for ornamental purposes, but it has no forest significance in Ireland.

7.7 Spanish chestnut

Family: *Fagaceae* - beech family.

Genus: *Castanea.* Of the 12 species of *Castanea* that inhabit the north temperate zone only one, *Castanea sativa* – the Spanish or sweet chestnut – is native to Europe.

Scientific name: *Castanea sativa* Miller.

English synonym: Sweet chestnut.

Irish name: Castán.

Origin and geographic distribution: Spanish chestnut is indigenous in southern Europe, along the Mediterranean, and eastwards into Turkey to the Caucasus and northern Iran. It also occurs in parts of N Africa (Figure 7.7-1).

As a native of a warmer climate it has not been widely planted in Ireland. In the National Forest Inventory (2007) it is recorded on 0.07% of stocked forest area. Planting of Spanish chestnut has been confined almost exclusively to the warmer parts of the country, in the south and southeast, generally in group mixtures with other species such as oak, ash or beech. Some plantations planted pure show good growth potential (Plate 7.7-1).

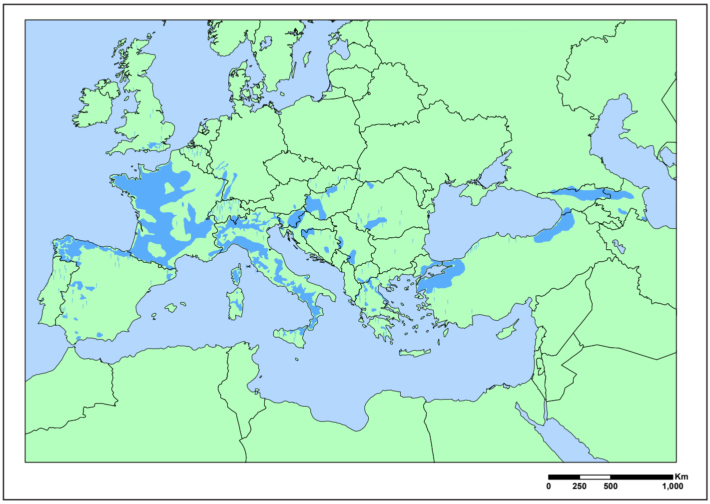


Figure 7.7-1: Natural distribution of Spanish chestnut.
(EUFORGEN, 2009)

Botanical characteristics

Tree and crown form: A deciduous tree up to 30 m in height with domed crown (Plates 7.7-2 and 7.7-3).

Stem form and dimension: When grown for timber production, Spanish chestnut produces a straight stem (Plate 7.7-4).

Bark: Smooth and silvery-grey becoming dark brownish-grey with longitudinal fissures, often in twisted spiral form.

Timber: Yellowish-brown in colour, ring porous, of medium texture and good

Key characteristics

- Better volume producer and a much shorter rotation than oak,
- good ability to reproduce from stools, even when old – excellent coppicing ability,
- wood has very good natural durability,
- shade-tolerant in youth, but becomes more light-demanding later,
- more site specific than oak and does not thrive on heavy calcareous soils,
- very frost tender,
- intolerant of exposure,
- prone to ring and star shake.

Plate 7.7-1: A small stand of good quality Spanish chestnut. (Ballycullen, Co Wicklow)

Plate 7.7-2: A magnificent Spanish chestnut at Avondale. (Co Wicklow)

Plate 7.7-3: Spanish chestnut can grow for many hundreds of years and still produce large amounts of fruit. (S Turkey)

Plate 7.7-4: Young to middle-aged Spanish chestnut stand of good quality.
(Ballycullen, Glenealy, Co Wicklow)

working qualities. It is naturally durable and impermeable to preservatives. It stains in contact with iron in damp conditions. The timber resembles oak, but without the broad (medullary) rays. It is lighter and less strong than oak. The sapwood is narrow, rarely exceeding about 1 cm or about 3 growth rings (Savill, 2013). Ring shake can be a major defect. Shake makes the timber unsuitable for use other than for firewood or pulp.

Root system: It develops a deep-rooting system with a strong tap-root, similar to that of oak. It is claimed to be storm-resistant, but Irish experience of the species shows a tendency for individual trees in stands to be wind-thrown, even when growing on relatively sheltered sites, in soils of good rooting depth. However, large trees growing in hedgerows, and along ditches often in exposed situations tend to be reasonably wind-firm. This is due to the provision of adequate growing space. On poorly drained or indurated soils it is subject to root rot.

Leaves: 10–25 cm, oblong-lanceolate, dark green, smooth and glossy. The margins have large spine tipped teeth.

Flowers: It flowers in June and July, later than almost all other trees except the limes. Flowers are in erect bunches of insect-pollinated catkins. The male flowers are a mass of whitish-yellow stamens; female flowers have 7–9 white styles, usually in threes, in a rosette of bright green spines at the base of the catkins.

Fruits: In bunches of 2–3, the outer cupule with radiating spines, splitting into four lobes to release usually three large shiny nuts in October-November. The weight of 1000 seeds is about 5 kg. Its nuts are edible and much sought after, but, unfortunately, rarely viable in Ireland.

Ecological characteristics

Forest type: In its native habitat Spanish chestnut is a tree mainly of the lower hills and mountains and is rarely found in the lowlands.

Light requirements: It is shade-tolerant in youth, but becomes more light-demanding as it grows older, although less so than oak.

Stress tolerance: It is frost-tender and very intolerant of exposure.

Climatic requirements: Sheltered, preferably north-facing, frost-free slopes. The species requires a mild climate for good growth and is sensitive to spring frost and low winter temperatures.

Soil preference: Chestnut does not require high fertility, but grows best on a deep, porous, fresh and reasonably fertile soil. It can grow in rather dry soils if deep, but wet localities should be avoided. A loamy sand suits it best. It does not grow well in heavy or calcareous soils.

Strengths and threats: Spanish chestnut suffers from ring and star shake. While the factors which cause shake are not fully understood, studies indicate that ring shake is more prevalent in trees suffering a high level of competition. Shake occurs mostly in older trees growing on light soils liable to dry out, but its occurrence is impossible to predict.

Chestnut blight caused by the fungus *Cryphonectria parasitica* (Murr.) Barr is potentially a serious threat, but so far has not reached Britain or Ireland.

Spanish chestnut coppice suffers from ink disease (*Phytophthora cinnamomi* and *P. cambivora*), a root rot which shows as a violet or blue-black stain around infected roots and the base of a tree or stump. The disease is prevalent on wet, poorly drained soils, especially shallow compact clays (Evans, 1984).

Regenerative capacity: It begins to produce seed at about age 30 and reaches full production after the age of 50 years. Full seed years occur every 2–3 years. Production of viable seed in Ireland is sporadic and only occurs in the warmest summers, although natural regeneration on a limited scale has been observed in some stands (Plate 7.7-5). Currently there are 8.6 ha of registered seed stand of Spanish Chestnut (Fennessy et al., 2012)

Provenance: French seed orchards, where trees have been selected for wood production (not for the production of edible nuts) are preferred.

While no provenance trials have been established in Ireland, work on genetic improvement started in 2007 with the selection of seed stands and plus trees (Plate 7.7-6) by the then British and Irish Hardwood Improvement Programme (BIHIP), now the Future Trees Trust.

Plate 7.7-5: Spanish chestnut natural regeneration.
(Ballycullen, Glenealy, Co Wicklow)

Growth characteristics

Height-age relationship: It grows rapidly in youth surpassing the growth rate of oak on suitable sites.

Volume production: Savill (2013) regarded it as one of the most productive broadleaf species with a mean production of 8 m^3/ha/year in parts of England. There are no volume production data available for Ireland.

Values

Silvicultural values: It is reasonably shade-tolerant and is sometimes planted as a 'soil improver' on lighter soil (Savill, 2013). On sheltered, frost-free sites it exhibits good apical dominance and grows very erect. When planted on less favourable sites it frequently adopts a bush-like form.

Economic values: Good quality logs, free of shake, are used for the production of high quality furniture and craftwork. Larger logs of high quality are used for veneer. Spanish chestnut timber may also be used for flooring and, while it is not as hard wearing as beech and oak, it is particularly stable and has an attractive grain when flat sawn.

Lower grade logs are used for fencing, outdoor wooden cladding and other uses where durability is required.

The facility with which it produces stool shoots makes it an excellent species for coppice production.

The size of material required generally determines the length of rotation. Because the timber is one of the most naturally durable of the temperate broadleaves it is much in demand for support poles in hop growing and in the split fencing trade in southern England.

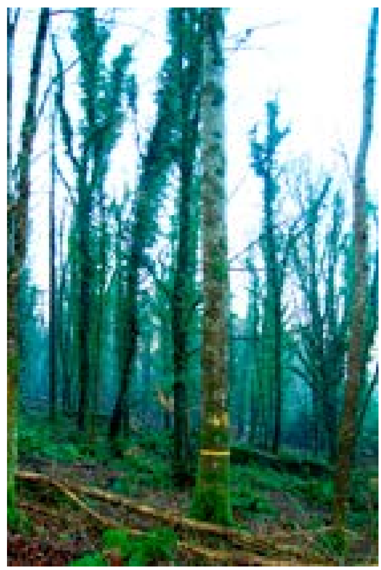


Plate 7.7-6: Plus tree of Spanish chestnut in the foreground.
(Gurteen La Poer, Co Waterford)

Ecological values: The nuts are an important food source for squirrels, deer and other mammals.

Amenity values: As in its native habitat it is also a decorative tree in Ireland where it is planted as a specimen in large gardens, arboreta and parkland settings. It exhibits strong autumn colours.

Historical importance: It was introduced into Britain, probably by the Romans, and is naturalised in southern England where it is cultivated under the coppice system. There is no record of its introduction to Ireland, but Samuel Hayes (1822) referred to an *old avenue of Spanish chestnuts*, then 110 years old, being felled at Dunganstown in 1793.

Silvicultural management

Production of plant material: Chestnut plants are frost-tender and need to be protected against late spring and early autumn frosts either by artificial means or by raising them in sheltered localities. Plants 60–80 cm tall and having a root collar diameter of at least 1 cm should meet the requirements of most sites.

Regeneration: Its ability to coppice is superb, even when old, and its role in this regard is recognised in the south of England where it is the last remaining coppice species, worked on a rotation of 12–16 years (Savill, 2013). Spanish chestnut is also suitable for layering as its shoots readily produce adventitious roots, but the frequent failure of its fruit to ripen fully in our climate limits its ability for wide-spread natural regeneration. Spanish chestnut is generally an easy tree to establish artificially. Given suitable growing conditions, early growth is rapid and normally requires little attention after the second growing season.

Tending of young stands: Spanish chestnut has a poor ability to shed its branches naturally and may require artificial pruning. It stands pruning well.

Thinning: Thinning schedule is similar to that for oak.

Conclusions

As a Mediterranean species, Spanish chestnut should be planted only in the warmer parts of Ireland in sheltered locations.The predicted climate change scenarios suggest that conditions favouring Spanish chestnut cultivation will be significantly enhanced.

When grown on suitable sites it will establish itself rapidly and produce a greater volume than other long-living broadleaves such as oak.

For coppice production it has few, if any, equals.

7.8 Sycamore and maples

Family: *Aceraceae.* There are about 150 species in the northern hemisphere, mainly in E Asia. Most are deciduous. Many are ornamental or timber trees. Some North American species are of extra commercial value as they produce maple syrup which is a major industry of the New England states of USA and Ontario in Canada.

Genus: *Acer* (from celtic *ac* = tip/point). There are two explanations to the acer name: one refers to the pointed tips of the leaf lobes and the other that the wood can be pointed and can be used for skewers.

Three *Acer* species are of some importance in Ireland: (1) sycamore is by far the most relevant, as it has been planted on large areas since the 1990s; (2) Norway maple and (3) field maple play only very minor roles. According to NFI (2012) sycamore is now recorded in 1.5% of the stocked forest area and is, therefore, ranked joint third of the major broadleaf species with beech, after ash and pedunculate oak (refer to Table 1.5-5).

The three species are described separately below.

7.8.1 Sycamore

Scientific name: *Acer pseudoplatanus* L. with reference to the similarity of the leaves with those of plane.

Irish name: Seiceamar.

Origin and geographic distribution: Sycamore is a European/West Asian species, but not native to Ireland, Britain, NW Germany, Denmark and other parts of Scandinavia, southern Spain and southern Greece (Figure 7.8-1).

Sycamore is a tree of the temperate zone in mountainous areas of Central Europe. The German name 'Bergahorn' (mountain maple) underlines this preference. It is found up to 1,700 m in continental mountainous regions, and is naturally less abundant in the lowlands. It has, however, been extensively planted, especially in urban areas and has become naturalised far beyond its original range.

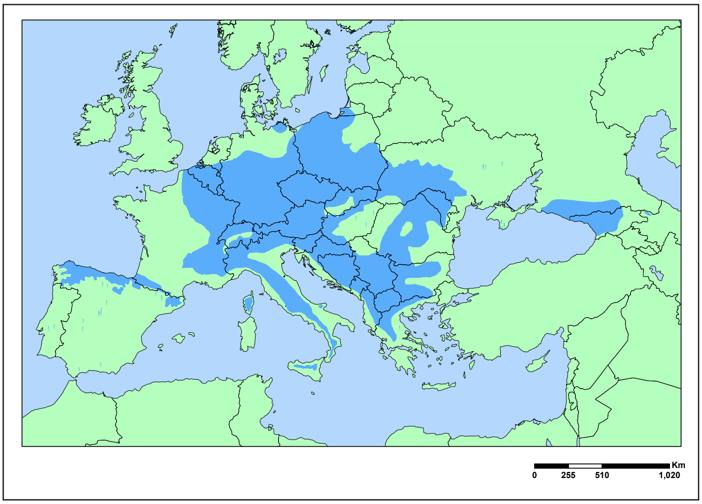


Figure 7.8-1: Natural distribution of sycamore. (EUFORGEN, 2009)

Sycamore was first recorded in Ireland in 1632, but it was probably introduced at an earlier date. It was planted originally as a mixture in shelterbelts and along avenues on estates. Today, it is mainly found as a common species in shelterbelts on farms and in hedgerows.

Planting in woodlands began about 1700.

Key characteristics

- Prefers cool, humid sites,
- tolerant of exposure,
- tolerant of late spring frost,
- tolerant of shade in early youth but light-demanding later,
- positive response to weeding,
- susceptible to forking,
- moderate natural pruning ability,
- more susceptible than any other tree species to damage by grey squirrels,
- prolific producer of seed and natural regeneration.

Botanical characteristics

Tree and crown form: Sycamore is one of Europe´s most impressive broadleaf species, reaching a height of up to 35 m in stands. It is the tallest member of the *Acer* species in Europe.

The wide-spreading crown is often broader than high. This is especially the case with isolated trees (Plates 7.8-1 and 7.8-2).

Stem form and dimension: Sturdy upright stems can reach up to 3 m in diameter.

Bark: It peels in a characteristic fashion (Plate 7.8-3), slightly resembling that of common plane (Plate 7.8-4).

Timber: The whitish, hard and dense sycamore timber, with no distinction between sapwood and heartwood, is relatively supple and elastic and easy to split (Plate 7.8-5). It is naturally shiny and provides a smooth surface when processed. Ripple marks and bird´s eye maple are especially attractive and valuable.

Root system: Its root system is intensively twisted and heart shaped, with marked verti-

Plate 7.8-1: Individual sycamore are highly valued in avenues, parks and gardens. (Mount Merrion, Co Dublin)

Plate 7.8-2: An isolated sycamore on a forest edge is of particular beauty in the landscape. (Black Forest, Todtmoos, Germany)

cal development. Therefore, it is very windfirm and, on this account, frequently compared with the oaks.

Leaves: Opposite leaves, 10–15 cm long, with 5 coarsely toothed lobes. Plates 7.8-6 to 7.8-8 compare the leaves and fruits of the other two maple species.

Flowers: Greenish-yellow, appearing with the leaves and hanging in separate male and female clusters, 6–12 cm long, male and female (monoecious), sometimes hermaphrodite, with 5 sepals and 5 petals. Sycamore flowers in April-May, almost annually and is insect-pollinated.

Fruits: The winged fruits (samaras) form in pairs, 3.5-5 cm long, and the grey-brown wings are set at an angle of 90° (Plate 7.8-6). The fruits ripen between mid-September and end of October, normally in large quantities.

Seed can be stored for up to 6–7 years without loss of viability.

Plate 7.8-3: Sycamore stem with peeling bark scales.

Plate 7.8-4: For comparison: common plane.

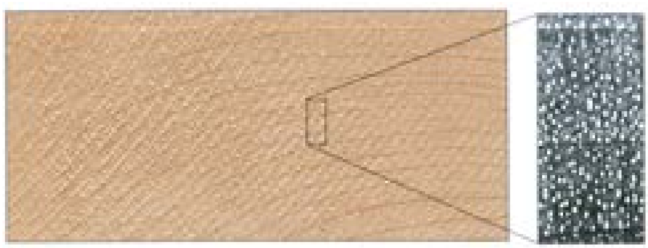


Plate 7.8-5: Cross section of sycamore timber. X 40

Plate 7.8-6: Leaf and fruits of sycamore.

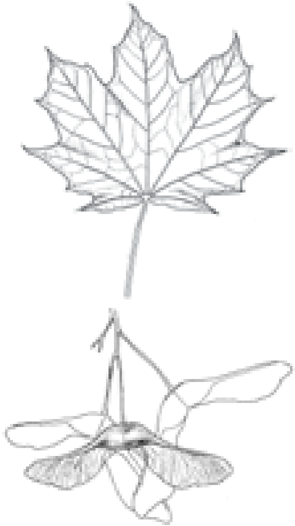


Plate 7.8-7: Leaf and fruits of Norway maple.

Plate 7.8-8: Leaf and fruits of field maple.

Ecological characteristics

Forest type: Mainly as a companion to beech, ash and other site demanding broadleaves, sycamore is usually found on richer soils, but seldom forms pure stands. It is especially adapted to steep slopes in ravines where beech is not so competitive. As it is more tolerant of exposure than beech, it can also grow in higher mountainous regions, mainly because of reduced competition from other species, including beech and spruce.

Successional type: Intermediate to late-successional according to site conditions.

Light requirements: In terms of shade tolerance it is regarded as an intermediate species: tolerating a considerable amount of shade in its youth, much more than ash and almost as much as beech. At a height of around 1 m, however, it largely loses this tolerance. It, therefore, withstands over-shading by old trees for only a few years before it needs to be released in order to achieve its full growth potential.

Stress tolerance: Mature trees are frost-hardy, tolerant of exposure, industrial pollution and salt spray along the Atlantic seaboard. When young it is relatively immune to damage by late spring and early autumn frost.

Climatic requirements: It does best on cool, humid sites, such as those normally found in mountainous regions. This preference is indirectly expressed by the fact that it does not occur on the dry and warm Hungarian plains or in the inner Alps, which are characterised by a continental climate.

In Denmark, the best production is in coastal regions. In central Jutland, with a slightly more continental climate, the growth rates are markedly reduced.

Soil preference: Alkaline and other base-rich soils. It requires a permanent and good water supply for adequate growth, but does not tolerate excess water, for instance in riparian zones. Good water storage capacity can compensate for low precipitation. In Ireland, it is sometimes planted on heavy compacted soils like gleys and pseudo-gleys. This results in reduced growth rates and basal sweep because of poor rooting (refer to Plate 4.4-7).

It responds well to increased nitrogen levels.

Strengths and threats: Sycamore has strong invasive tendencies, owing to its wide ecological amplitude, a short generation time and prolific production of widely dispersed seeds.

Young sycamore is susceptible to competition from grasses for moisture and this may sometimes result in complete failure of plantations. Like ash, older stands also suffer from competition from grass swards. Therefore, a shade tolerant tree species like beech, hornbeam or lime in the understorey is needed to control the competing ground vegetation by shading.

It is heavily browsed by deer, sheep, goats and cattle. Deer like to peel the bark of the lower trunk, while grey squirrels debark the crowns of dominant trees in young stands, causing severe losses (Plate 7.8-9). Damage by squirrels is the greatest hazard to this species.

Plate 7.8-9: Young sycamore debarked by grey squirrel.

Regenerative capacity: In central Europe sycamore has benefited from the gradual rehabilitation and eutrophication of the soils which has resulted from atmospheric pollution. This has led to prolific regeneration on many sites and has been termed 'acerification'. The phenomenon is also attributed to more intensive thinning in recent times which provides less competition. In common with other broadleaf species, such as oak and ash, sycamore has the ability to coppice and to sprout from the stem (Plates 7.8-10 and 7.8-11) and even finds an ecological niche on eroded rocky material, as beech cannot grow there (Plate 7.8-12).

Its invasiveness and exotic origin are the main reasons why it has caused controversy with conservation bodies in Ireland and Britain, especially where it threatens to take over remnants of ancient woodlands.

Provenances: Sycamore was originally introduced to Ireland for ornamental reasons, and perhaps the present naturalised specimens may not be the best provenances for this country.

Plate 7.8-10: Sycamore's sprouting capability made it a common element in coppice forests.

(Hainich, Germany)

Plate 7.8-11: Sycamore has a great ability to colonise rocky sites vegetatively.

(Swabian Alps, Germany)

Plate 7.8-12: Sycamore can grow on rocky sites which are prone to erosion.

(Black Forest, SW Germany)

Little is known of seed source variation in the species.

Most of the high quality sycamore stands in Ireland have already been harvested. Therefore, conservation of the existing gene pool of this naturalised species is considered an imperative.

Provenance trials have been established only very recently. Work on species improvement commenced in 2003 and was initially focused on identifying seed stands and plus trees in both Britain and Ireland. The target was the selection and registration of 150 plus trees and 10 seed stands by 2007. By 2006 approximately 100 plus trees and eight seed stands had been selected in the two countries and there was every confidence the target would be met.

The focus was then directed towards ensuring that only seed from the certified seed orchards reached nurseries and that there was a conservation collection of the plus trees in both Britain and Ireland. As part of this initiative, Teagasc, Kinsealy Research Station, Dublin, engaged in the propagation of scion material. This initiative, combined with an existing clonal seed orchard at Rathluirc, Co Cork, (based on an earlier EU collection of plus trees) and the clone bank at Kilmacurra, Co Wicklow, means that there will be an excellent collection safeguarded (Carey, 2006).

The group is considering the establishment of breeding seedling [seed] orchards (BSOs) and/or clonal seed orchards (CSOs).

A selection from the coastal regions of Denmark is also being considered for inclusion in the programme. To date four stands with an area of 7.0 ha have been registered as seed stand (Fennessy et al., 2012).

Greater numbers of plants, however, have been imported, mainly from the Netherlands, for afforestation since the 1990s. Besides Dutch sources, those from Northern Germany, Britain and Northern France are possible alternatives.

Growth characteristics

Height and diameter growth: At the end of the 18th century, Samuel Hayes recorded a sycamore near Rathdrum, Co Wicklow, which was *15 feet in circumference* (145 cm in diameter) *with the most beautiful head in proportion; this was the largest sycamore I ever saw.*

Since then, specimens of greater height and diameter have developed. After oak sycamore has the greatest number of champion trees in the country (Table 7.8-1).

Table 7.8-1: Number, height and diameter of sycamore champion trees in 13 counties.

ITEM	NUMBER OF		MEAN	MAXIMUM	MINIMUM	VAR. COEFF.
	champions	counties	m			%
Height	21	13	24	30	20	±*14*
Diameter 1.3 m			1.9	2.4	1.3	± *7*

There are more than 20 champion trees which have reached heights greater than 20 m, some even 30 m. Their diameters are also impressive being almost 2 m on average. The low coefficients of variation, under both headings, show little deviation from the mean, i.e. they lie close together.

As sycamore is usually mixed with other broadleaves, and seldom forms pure stands, there are few data on continuous measurements of experimental plots. Where it has been planted outside its natural habitat, however, as in Schleswig-Holstein in northern Germany, Denmark and England, some yield models have been developed (Figure 7.8-2 and 7.8-3).

In the most productive stands, sycamore reaches 15 m in 20 years and slightly over 30 m in 80 years. The Danish and the British models show a slower increase in height development than the German ones, possibly because of the greater windiness in these two countries.

Age: Experience on the continent has been that sycamore tends to live up to 500 years.

Total volume production: The trends in volume production, for northern Germany and Britain, are illustrated in Figure 7.8-4.

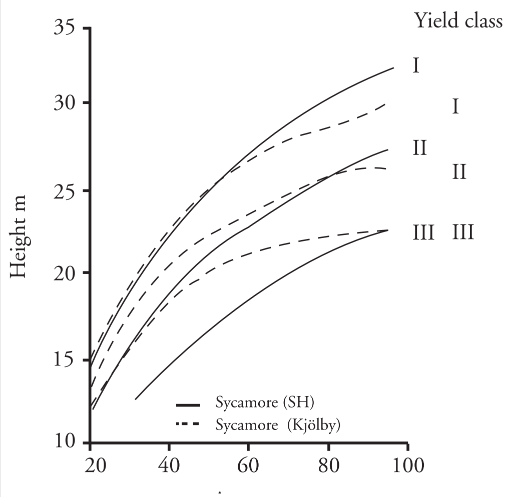


Figure 7.8-2: Height-age graphs for sycamore from German and Danish growth models.

(Nagel, 1986; Kjölby, 1958)
(SH = Schleswig-Holstein)

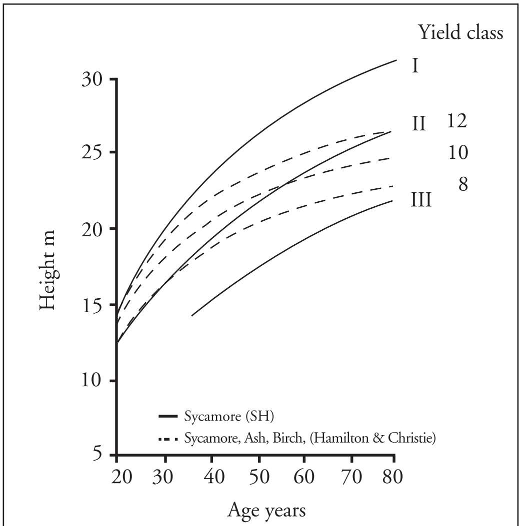


Figure 7.8-3: Height-age graphs for sycamore from British and German growth models.

(Hamilton and Christie, 1971; Nagel, 1986)

According to the German yield model, cumulative volume production (including thinnings) is estimated to be around 800–1,000 m³/ha at 80 years. At this age British models show slightly lower volume production (770 m³/ha), which may be due to higher wind stress conditions in Britain.

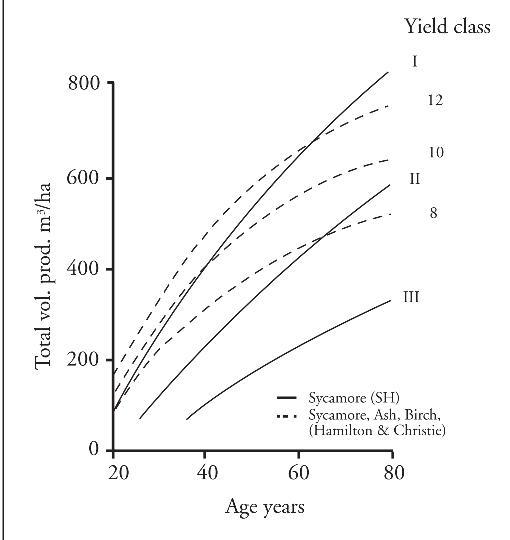


Figure 7.8-4: Total volume production for sycamore in N Germany and Britain.

(SH = Schleswig-Holstein, from Nagel, 1986; Hamilton and Christie, 1971)

Values

Silvicultural values: Sycamore grows well in mixture with ash, with which it has much in common in terms of site requirements, growth rate and silvicultural treatment. Beech is also a natural companion species with which it will compete successfully up to about 50 years. Then it needs silvicultural interventions or it tends to be overtaken later in the rotation. This is illustrated in Figure 7.8-5.

Sycamore is of special value as a tree in mixtures, even with conifers and at higher altitudes, because of its tolerance to exposure.

In Ireland these mixtures have not played any role to date.

Economic values: Big dimensioned logs free of knots command exceptionally high prices (Plate 7.8-13).

The objective, therefore, should be the production of high quality logs suitable for veneer and sawtimber. Veneer material requires boles of 40–60 cm DBH – the bigger the better – which have been branch-free from an early age.

High quality timber, especially if it shows a ripple effect, is much sought after by musical instrument manufacturers, for making the sides and backs of violins, cellos and guitars.

As a diffuse porous wood and in terms of its utilisation requirements, there is little or no deterioration in wood quality with rapid diameter growth.

Sawtimber – even of small dimensions – is sought after for furniture, boards (finger jointed), panels and parquet flooring.

Ecological values: Sycamore is a valuable constituent of mixed broadleaf stands on the better soils. Its leaves decompose rapidly and produce a good humus. Its relatively open crown when older permits shade-tolerant trees to grow underneath.

Amenity values: As illustrated in Plates 7.8-1 and 7.8-2, sycamore is highly appreciated as a single tree in urban areas, as a hedge tree and along forest edges and avenues.

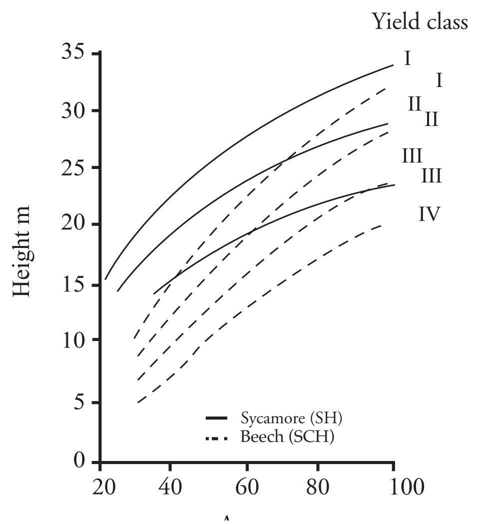


Figure 7.8-5: Height-age graph for sycamore and beech from German growth models

(SH = Schleswig-Holstein/N. Germany from Nagel, 1986; SCH = Schober, 1971)

Historical importance: In the early years of the 18th century sycamore wood was among those used for making barrels for the export of meat, butter, tallow and fish, which suggests that there was a substantial supply then available. On the Continent, its twigs were used in mountainous regions to feed domestic animals in late winter in periods of fodder shortages. It was often fully exploited and, because of its relatively low heating potential, its regeneration was neglected.

Plate 7.8-13: This sycamore stem was sold for € 28,000 at a high quality timber auction at Muellheim, Black Forest, Jan. 2007.

Dimensions: diameter 72 cm, length 6.1 m, volume 2.48 m³. The price per m³ was €11,340.

The representatives of the forest-owning community and the foresters advising the community drinking champagne show that this is not a regular event.

Silvicultural management

Production of plant material: Sycamore seedlings can easily be raised in the nursery. Their rapid growth in the early years permits planting of 1-year-old seedlings, with a height of about 30 cm, in grass-free soils. Normally, however, 1+1 year old transplants 50–80 cm tall are used (refer to Plate 4.4-5).

Regeneration: Planting in weed-free ground is recommended (after pre-planting herbicide application or soil preparation) at a density of 3,300 plants/ha, equivalent to a spacing of 2x1.5 m.

Tending of young stands: Weed control in the first two years is essential.

Because of its tendency to fork, singling forked leaders of the dominant individuals may be necessary. Often, however, this procedure is overdone and the subdominant and intermediate less vigorous specimens are also included.

Thinning: To achieve large dimensions, sycamore should be thinned immediately after having reached a butt log length of 5–8 m free of live branches (at a height of 10–12 m). This should be followed by continuing release from competition of neighbouring trees, at 2–3 m height growth intervals, to ensure a diameter growth necessary for high quality timber and to avoid the development of epicormic branches as well as development of poor crowns (Plates 7.8-14 to 7.8-16).

The target diameter should be 50–60 cm.

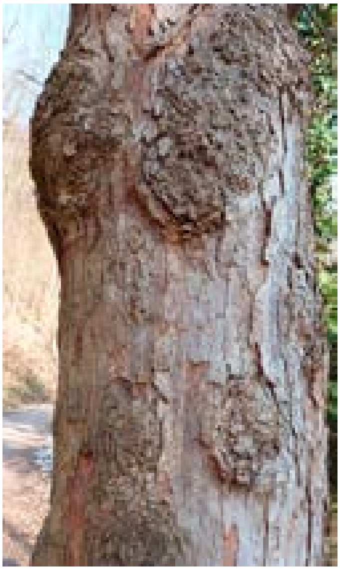


Plate 7.8-14: Sycamore tends to develop epicormics which produce figured veneer timber, especially bird´s eye wood.

(Black Forest, Germany)

Plate 7.8-15: Epicormics are formed especially if sycamore grows under competition.

(Freiburg, SW Germany)

Plate 7.8-16: A sycamore seed tree with a suppressed crown because of delay of thinning.

(Ballyredmond, Co Wexford)

Conclusions

Sycamore is one of the broadleaf species that has the potential to produce medium quality, even high quality, timber and this potential should be encouraged by early and effective thinning. However, it should be restricted to better soils. Apart from its value for shelter or as an ornamental tree, the objective should be the production of high quality logs. Even single trees in hedgerows may be pruned in order to get a butt log of 5–6 m of good, or occasionally outstanding, quality.

With its ability to withstand exposure it can be grown at higher exposed elevations.

Although introduced at least four centuries ago, it has gained greater relevance as a forest tree after extensive planting since the 1990s. From these seed sources it will eventually regenerate naturally and increase its area in the long term. Rigorous squirrel control is necessary.

7.8.2 Norway maple

Scientific name: *Acer platanoides* L. (= like the plane leaf).

Origin and geographic distribution: Norway maple is indigenous to most parts of Europe, including S Sweden, the Caucasus and Near East, but is mainly concentrated in the moderately continental parts of Central and Southern Europe. It is not native to Britain or Ireland and was introduced to Britain before 1693 (Figure 7.8-6).

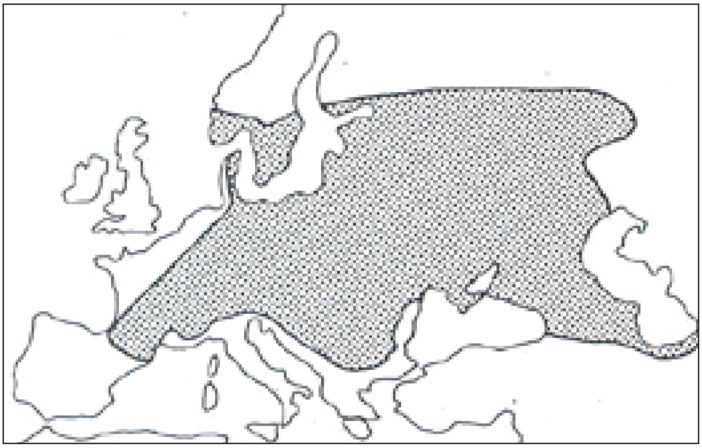


Figure 7.8-6: Natural distribution of Norway maple. (Evans, 1984)

Botanical characteristics

Tree and crown form: It is a tall tree, sometimes with heights up to 30 or even to 35 m, but generally smaller than sycamore. Its crown is regular shaped. If grown in the open it develops a uniformly large oval crown.

Stem form and dimension: In the open it produces a straight stem divided rather low down into branches. In dense woods, however, it will produce a tall cylindrical stem with a small crown restricted to its upper part.

Bark: Light grey for the first few decades, later dark grey-blackish, with vertical fine fissures similar to middle-aged oak, but not peeling like sycamore (Plate 7.8-17).

Timber: Comparable to sycamore, but less valued because of a slightly more yellow or even reddish colour, slightly coarser fibres, and harder and heavier timber (specific gravity 0.74 g/cm^3, sycamore 0.67 g/cm^3). Fairly durable when kept under cover, but not in the open. It can be easily polished.

Root system: Deep, intensive heart shaped and layered root system.

Leaves: Buds wine-red (important identification feature in winter). Leaves with 3–7 pointed tips and round indentations (distinct from sycamore); more colourful both in spring and in autumn (refer to Plate 7.8-7).

Flowers: Yellowish in straight panicles (3.5–5 cm), flushing before or together with the leaves, insect-pollinated.

Fruits: The wings of the seeds are almost horizontal. The seeds ripen in September and October and fall in October and the winter months.

The minimum seed-bearing age is 25–30 years; seeding intervals are 1–3 years.

Plate 7.8-17: Bark of Norway maple resembles young oak or ash rather than sycamore. (Freiburg, SW Germany)

Ecological characteristics

Forest type: Norway maple is a typical component of mixed, but less commonly occurring broadleaf woodland (oak/hornbeam, oak/elm riparian forests, lime/maple/sycamore woods in ravines). It may also occur in beech forests, but is generally suppressed by the beech. Originally much rarer, it has been widely planted in gardens, parks and avenues and spreads naturally from there.

In Britain it is a component of ash-maple woodland (wet ash-maple woods, ash-maple woods on light soils, dry ash-maple woods) and maple-ash-lime woods (Evans, 1984). It is rare in Irish woodland.

Successional type: Pioneer to intermediate.

Light requirements: Light-demanding to slightly shade-tolerant (intermediate between light-demanders and shade-bearers).

Stress tolerance: Suffers somewhat from late frost, but is hardy as regards winter cold. Tolerant to temporary drought – more so than sycamore – but intolerant to excessive summer heat.

Site requirements: Lowlands to middle mountain sites (N Alps, up to about 1,000 m), preferably on summer warm mountainous slopes with a moderately continental climate. It is more a tree of the plains than sycamore.

Soil preference: Moderately wet to wet soils with sufficient nutrients *including calcareous ones on chalk downland* (Evans, 1984). More tolerant of stagnant water than sycamore. Grows poorly on very dry, very acid and gleyed soils as well as infertile soils, but is able to grow on rocky and gravel soils.

Strengths and threats: It is storm-firm. Maple, when young, requires some protection against late frost, and is less tolerant to exposure than sycamore.

It is browsed by deer and sometimes peeled, and it is very susceptible to squirrel damage.

The Norway maple dieback in the Rhine valley in the 1970s was obviously caused by different fungi, but they have never been fully identified (Schuett et al., 1992). It is susceptible to honey fungus (*Armillaria* spp.) (Evans, 1984).

Regenerative capacity: Regenerates naturally over longer distances as seeds are distributed by wind.

Provenances: Norway maple has been brought to areas outside the forests for centuries and has been cultivated in many forms. These differ especially in terms of autumn colour.

Irish and British stands and material from northern French, northern German and Danish stands are preferred (Forest Service, 2011).

Growth characteristics

Height and diameter growth: Maple grows rapidly in the early years, but slows comparatively early so that it is overtaken by beech, though it ultimately reaches the same height. According to Evans (1984), on sheltered sites it will often grow faster than sycamore. At 40 years it can reach a diameter of 40 cm.

Seven champion trees in seven counties have been listed with an average height of 23 m (max. 30 m) and a mean diameter of 110 cm (max. 160 cm). Three of these are ornamentals (Schwedleri, Stolli) and may distort the values slightly. Nonetheless, the data correspond with continental values.

Age: According to German sources it can live for 400 years or longer. According to Evans (1984), over-maturity is reached at an age of 120 years or more, although trees older than

100 years are rare. This may, however, be the result of the special history of this species in Britain.

Total volume production: Norway maple is never grown in pure stands. Therefore, no yield tables are available. Generally, growth is regarded as more or less equivalent to sycamore and even beech and is calculated accordingly.

Values

Silvicultural values: Norway maple is a welcome component of mixtures on suitable sites. It can be used for enrichment plantings in degraded woodlands and scrub because of its fast growth in the early years.

Economic values: The timber is used for furniture (including veneer) such as tables and kitchen tools, for joinery, carvings, music and mathematical instruments, as well as parquet flooring.

As a general purpose hardwood it is often regarded as a substitute for sycamore, but, because of its slightly more yellow colour and coarser structure, it is less valued in the market.

Ecological values: It is very suitable for road sides as it is relatively tolerant of salt, compaction and air pollution.

It is a good pollen and nectar producer and flowers early. On that account it is an important source of honey for bees in spring.

Amenity values: Masses of yellow flowers in April, broad domes in parks, and the colours of leaves in autumn are the basis for its general popularity. For that reason it is widely planted as a street or park tree.

Historical importance: Because of its minor importance in comparison with sycamore, no special information is available.

Silvicultural management

Production of plant material: The most effective method is to stratify the seeds. As it grows fast in the early years, it is produced as 1+0 seedlings (20–40 cm) and 1+2 transplants (60–140 cm), except for landscape planting where special assortments are required.

Regeneration: Norway maple is generally planted, but recently it has increasingly reproduced naturally – probably as a result of improved seed beds. When planted, it withstands desiccation better than many other species.

Tending and thinning: As mentioned, it is fast-growing in the early years, but like sycamore becomes less competitive, especially in mixtures with beech. Therefore, it should be given sufficient growing space in time to develop a large crown and later steadily released from intensive crown competition.

Conclusions

Although sycamore and Norway maple often grow together in mixed stands, Norway maple occurs preferably in a more continental climate, while sycamore grows more often in the wetter, but less cold regions of the mountains. The main value of Norway maple is its suitability for avenues and parks. It can be a highly valued component of hedges – as standards – and along woodland boundaries.

7.8.3 Field maple

Scientific name and English synonyms: The scientific name *Acer campestre* (belonging to fields) corresponds with 'field maple', whereas its other English name, 'hedge maple', reflects its common occurrence in hedges.

Origin and geographic distribution: Europe, N Spain and N Africa and in western Asia; native to Britain, but not Ireland, though it has frequently been planted in Ireland (Figure 7.8-7).

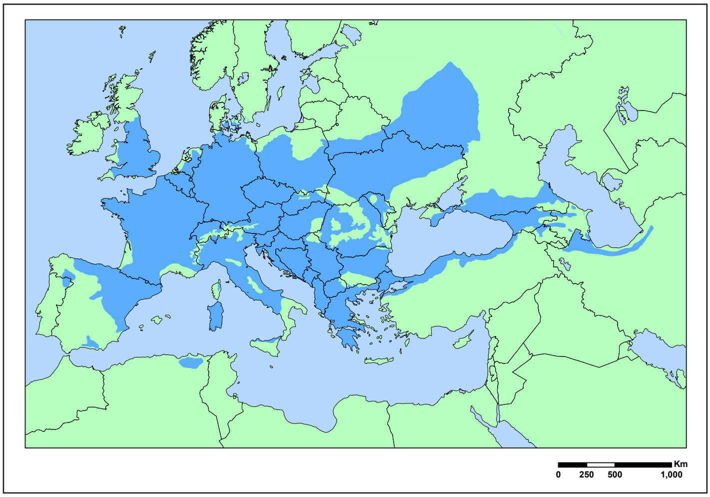


Figure 7.8-7: Natural distribution of field maple.
(EUFORGEN, 2009)

Botanical characteristics

Tree and crown: It is a small tree, normally reaching 10–15 m, but seldom exceeding 20 m. Sometimes it is only a large shrub. The crown forms an irregular, broad dense dome of straight shoots curving up towards their tips. On poorer sites it develops multiple stems.

Stem and branch: The stems are normally very short and often bent or twisted. Twigs are brown with fine hairs and when cut, often develop thick corky wings (comparable with wych elm – *Ulmus glabra*). This is a helpful feature for distinguishing the species in winter.

Bark: Pale to dark grey-brown with narrow fissures.

Timber: Reddish white and slightly darker than that of sycamore and Norway maple. It is the hardest, toughest and most elastic of the *Acer* species.

Root system: Deep-reaching, dense heart root, easily sprouting from the stumps and also producing root suckers.

Leaves: Opposite; 4–7 cm long (smaller than those of its two related species), usually 3-lobed, the outer lobes often further lobed, all with rounded teeth towards the tip. New unfolding leaves are pinkish or red on late sprouts. Slightly lighter underneath. In autumn they turn bright yellow, often with some red and dark purple (refer to Plate 7.8-8).

Flowers: Only 3 mm long in 10–20 line-spaced erect umbels. Males and females together in erect clusters, appearing with the leaves. Field maple is the last of the maple species to flower in May.

Fruits: Horizontally oriented, 3 cm, brown when ripe. Sets viable seeds in most years. Seeds often germinate in the second year after falling.

Ecological characteristics

Forest type: Contrary to what the names field or hedge maple suggest, this species is a typical part of mixed forests on richer soils in relatively open beech, oak-hornbeam or ash riparian woods. It can also be found in mixture with many other broadleaves (wild cherry, wych elm, small-leaved lime, whitebeam, wild service tree, rowan, hawthorn, even birch).

Its use as a hedge tree is very old as it tolerates cutting, trimming and pruning. It has always been an important component of coppice forests, especially on warm sites, where it was also raised as standards. Today, it is often found on the margins of woods and along boundaries.

Successional type: Pioneer to intermediate.

Light requirements: Moderately shade-tolerant, more than sycamore and Norway maple.

Stress tolerance: More robust and resistant to drought than sycamore and Norway maple.

Climatic requirements: Plains and lower mountains (in central Europe up to 900 m); does better in warmer climates than the other two *Acer*s.

Soil preference: Often on chalk soils, but less demanding than sycamore and Norway maple. Grows best on heavy soils which are often calcareous in the lower soil horizons. Fairly tolerant of free calcium carbonate.

It does not tolerate very wet and acid soils. This is the reason why it is not common in N Germany.

Strengths and threats: Relatively free from disease. Less liable to be browsed by deer.

Regenerative capacity: Regenerates freely.

Provenances: Many cultivars have been produced. Some may have escaped from urban areas into the wild.

Growth characteristics

Height and diameter growth: Grows with moderate vigour for the first 20–25 years and reaches 10–15 m in height. Maximum diameters are 60–70 cm.

Age: Up to 100 years.

Total volume production: No data are available.

Values

Silvicultural values: As a small tree, field maple is unable to compete with dominant forest trees. It is a typical species of hedgerows, woodland edges and scrubland types, and has no special silvicultural values.

Economic values: The timber has limited economic value as it was never normally allowed to grow to reasonable dimensions. At present, only small amounts of timber are merchantable. Perfect stems, however, are used for veneer and are much valued for their beautiful texture.

It is used for turnery, marquetry, carvings, craft work, furniture, parquet, as well as for special purposes, such as music wind instruments (e.g. recorder).

Its firewood and pulpwood are of good quality.

Ecological values: Apart from general enhancement of biodiversity, no information is available on the special ecological value of field maple.

Amenity values: The reddish colour at time of flushing and its bright yellow leaves in autumn make it an attractive component of many woodland edges.

Historical importance: Field maple was an important element of coppice and coppice-with-standards forests and still is in some parts of France. Its timber – apart from its main function as firewood – was much used for tools, shoe nails and making music instruments.

Silvicultural management

Production of plant material: As the seeds tend to stay dormant for one year, special stratification procedures are necessary in the nurseries.

Regeneration: Since it regenerates freely on appropriate sites, planting is not normally necessary.

Tending and thinning: In order to form valuable, as well as aesthetically attractive specimen trees, young straight-growing field maples have to be selected very early and continuously isolated from competition.

Conclusions

Field maple is another example of a tree that could increase the variety of Irish woods in many instances. If sufficiently thinned, it has the potential to add some more valuable timber to the market. Moreover, it raises the attractiveness of many broadleaf woods, forest edges and hedges. It should be favoured in those locations in order to form conspicuous standards, which are attractive eye-catchers in autumn.

It is relatively resistant to climatic stress and little affected by browsing. Nevertheless, its distribution will always be restricted to the better sites because of its intolerance to wet and acid soils. Because it does best in warmer localities, it will be mainly suitable to the southern parts of Ireland.

8 Minor broadleaf species

8.1 Blackthorn

Family: *Rosaceae* – Rose family. There are roughly 900 species in North America and 90 in Europe and Asia.

Genus: *Prunus,* roughly 200 species in the temperate zones.

Scientific name: *Prunus spinosa* L.

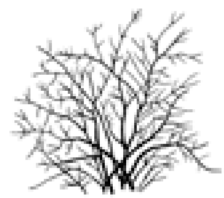
Common names: blackthorn, sloethorn.

Irish name: Draighean.

Origin and geographic distribution: Widely distributed all over Europe, except for the far north and Iceland. It grows in hedges and thickets, often propagating itself by means of suckers. According to Scannell and Synnott (1987) it is found all over Ireland.

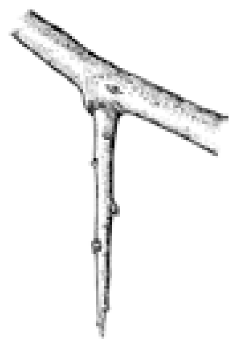
It is a typical component of hedgerows as well as many types of broadleaf-dominated forests, especially small woodlots.

Botanical characteristics



Tree and crown form: Bush; rarely a tree, occasionally up to 6 m in height.

Stem form, branches: Very crooked, mainly multi-stemmed; branches numerous, dense and widespreading. Thorny twigs are downy when young, becoming glabrous and smooth with age.



Bark: Sooty blackish colour, splits into stripes when old.

Timber: Reddish-brown heartwood and reddish sapwood; very hard and resistant with a slightly gleaming surface.

Root system: Extensive root system with root suckers and creeping roots.

Leaves: Alternating, ovate (2–5 cm in length, 1–2 cm in width); margins with rounded teeth; dull and glabrous above, hairy on the veins below.

Flowers: Pure white flowers, 1–1.5 cm in diameter, single or in small umbels; appear before flushing of leaves in early spring (March–April); high production of nectar.

Fruits: Blackish-blue fruits with a stone, ripening in September/October, remaining on the branches during winter (Plate 8.1-1). The pulp has a bitter taste and is edible after the first frost. It contains high amounts of vitamin C.

Ecological characteristics

Forest type: Open mixed broadleaf woods with hornbeam, sycamore, ash and alder and even in riparian forests. It is an important component of hedges and road-sides in Ireland, Britain and central Europe. Inhabits hedges and bush land, very often in mixture with hawthorn.

Successional type: Pioneer and intermediate stages.

Light requirements: Light-demanding to medium shade-tolerant.

Stress tolerance: Very drought-resistant.

Climatic requirements: Climates prevailing from plain to mountain altitudes (up to 500 m in Britain; 1,400 m in central European mountains).

Soil preference: Light, loose-packed humose soil, rich in nutrients, preferably dry, stony and calcareous on sunny slopes. Often on dry stone-barriers, rocky sites, gravel in the valleys.

Strengths and threats: Moderately resistant to browsing.

Regenerative capacity: Natural regeneration through bird droppings. Ability to cover large areas through far-spreading roots and root suckers.

Provenances: Old element of the European flora and possibly influenced by man.

Growth characteristics

Slow-growing; fully developed after 20 years. Reaches an age of approximately 40 years.

Values

Silvicultural values: Protecting seedlings of other broadleaves from browsing.

Economic values: Timber not marketable because of its small dimensions.

Leaves, flowers and fruits of some medicinal importance (sudoriferous treatment against springtime lethargy, acne). Used for the production of marmalades, fruit juice and especially brandy.

Ecological values: Because of its extensive rooting habit it is often used to fix unstable slopes. Its early flowering makes it the first source of honey for bees.

Important as part of woodland protection also for birds and small mammals, as well as providing nutrition. Provides cover and protection also for game birds; it forms impenetrable hedges and wind barriers.

Amenity values: Produces a rich scent in the landscape in springtime through its intensive flowering (Plate 8.1-2).

Plate 8.1-1: The fruits are notable because of their bright blue colour. Today they are occasionally used to produce brandy or sloe gin.

Plate 8.1-2: Blackthorn often forms large hedges. They offer a good habitat for small mammals and birds. Moreover, they are attractive in spring.

(S Germany)

Historical importance: The tough timber has been used for tools, turnery and straight branches for walking sticks. Brushwood was widely used for fencing and for the protection of single trees against cattle and sheep.

Hedges, mostly of blackthorn, form a defence like a wall which cannot be penetrated or even seen through (Rackham, 1986).

From the bark a non-fading and water-proof ink has been extracted. In times past the thorns have also been used as a substitute for nails.

Silvicultural management

Production of plant material: Easily raised from seed and produced as 2– or 3-year-old transplants (30–120 cm in height).

Regeneration: Planting difficult because of the thin root system with long single roots.

Thorny, dense and tough blackthorns make access for weeding of forest plants difficult. Because they resprout easily from the stumps they are difficult to eradicate.

Conclusions

Blackthorn is of little economic value and normally not planted (except for game and bird protection hedges). It is, however, an important element of the landscape and especially along forest edge zones. Because it is widely spread by birds, it regenerates easily in woods as well as in hedgerows. It will continue to remain a common companion of all types of bush land and open forests. Because of its higher demands regarding soil quality and light it will, however, remain less important than hawthorn.

Blackthorn is an important invader of degraded land and unused forest ridelines as emphasised by Rackham (1986): *Blackthorn has a nasty habit of growing on disused highways and powerfully induces passers-by to go round some other way*.

8.2 Crab apple

Family: *Rosaceae.*

Genus: *Malus* (Latin *malum* = apple) with some 25 species and numerous hybrids and cultivars.

Scientific name: *Malus sylvestris* (L.) Miller (= *Pyrus malus* L. = *M. communis*), *sylvestris* = (Latin) forming forests or belonging to an unknown place. (Wild) crab apple = a tree that produces sour apples.

Irish name: Crann fia úll.

Origin and geographic distribution: Crab apple is a Eurasian sub-Mediterranean species distributed over almost the whole of Europe, but never very abundant. It is native to the whole of Ireland (Scannell and Synnott, 1987; OCarroll, 2004) (Figure 8.2-1).

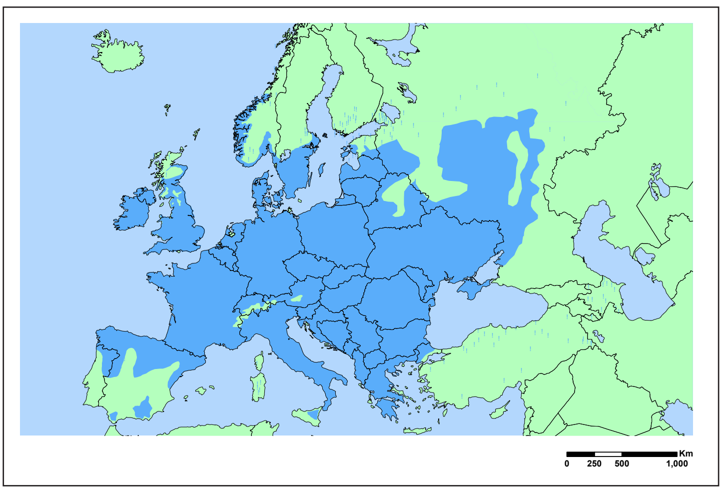


Figure 8.2-1: Natural distribution of crab apple. (EUFORGEN, 2009)

According to Rackham (1986) it was documented in the late middle-ages in Britain, but even then it was rare. There is some ev-

idence that it was planted into hedges in the 18th century. Many names suggest that it often occurred in open-land situations.
It is regarded as one of the ancestors of more than 1,000 breeds and cultivars.

Botanical characteristics

Tree form and dimension: It is a small, sometimes bushy tree up to 10 m in height, sometimes with thorny branchlets. Slow-growing, often with a flared and fluted stem form and with a broad branchy, dense crown.

Bark: Reddish-brown when young, later grey-brown with fissures and peeling in small plates.

Timber: Hard and heavy, elastic, fine textured; sap-wood reddish-white, heartwood reddish-brown; not very durable.

Root system: Shallow rooting.

Leaves: Oval, shallow toothed, hairless even on the underside when mature.

Flowers: Small umbels of flowers on long pedicels, white on inside, pink outside. Flowering in April/May.

Fruits: Characteristic apple form, 2–3 cm in size, yellowish green, bitter tasting.

Ecological characteristics

Forest type: Scattered in forests from the plains to the mountain regions (1,100 m in the Alps). Found in oak-elm riparian, oak-hornbeam and downy oak woods as well as in forest edges and hedgerows in the open fields and on stony ridges.

Light requirements: Light-demanding to slightly shade-tolerant.

Stress tolerance: Very resistant.

Climatic requirements: Sunny sites from lowlands to mountains.

Soil preference: Grows on almost all soils, but preferably on deep lime-free soils.

Strengths and threats: Heavily browsed by cattle and deer.

Regenerative capacity: Natural regeneration by seeds and by root suckers.

Growth characteristics

Height and diameter growth: Seven champion trees in six Irish counties are mentioned as having reached heights of 14 m maximum and 12 m on average. Their diameter at breast height was 110 cm at maximum and 90 cm on average.

Age: not documented.

Total volume production: As crab apple was never managed as pure stands no data are available.

Values

Crab apple has neither any special **silvicultural** nor **economic value** as the stems are normally crooked and very short. However, it adds to aesthetic value especially of hedges and its fruits are sought after by many animals.

Historically its timber has been used for special tools, and its fruits were of some importance for food (jelly) and health (vitamins).

Silvicultural management

Production of plant material: Young plants are raised from seeds, but vegetative propagation from shoot or root cuttings is also possible.

Regeneration: Planting is the normal way of introducing the species in the forests. Normally it is planted as a single tree or in small groups preferably along forest edges.

Tending and thinning: Young crab apple trees have to be protected against browsing and damage by fraying. As they are not very competitive they must be released consistently from all types of overshading and suppression by weeds and neighbouring trees.

Conclusion

Crab apple has mainly ecological values (biodiversity, food for animals), but may also add to the beauty of the forest edges – blossom locations within an otherwise pure, homogenous forest.

Feral apple breeds (*Malus domestica* Borkh. – Irish: Abhaill) occur in a few regions of Ireland. Tree leaves are hairy. It is a very variable species.

8.3 Elms

Family: *Ulmaceae.* Some 20 elm species occur in the temperate zones of the northern hemisphere. Four are native to Europe. The elms hybridise freely and make it difficult to differentiate between the species. Linnaeus regarded all of them as only one species.

Genus: *Ulmus.*

Species: (1) Wych elm, (2) English elm, (3) Small-leaved elm, (4) Dutch elm; many hybrids and local varieties.

Distribution: The European elm species (*U. glabra, U. campestris, U. laevis, U. procera*) show only slight differences in size, leaf dimensions and site demands.

All of them are almost extinct because of the Dutch Elm disease (refer to Plate 4.4-57). It is caused by a fungus (*Ceratocystis ulmi*) which blocks the trees' conductive tissues. The disease was introduced – probably from China – first to France in 1918 and then to the Netherlands – therefore, the name. A mild form was common during 1920–1945, but a virulent form was brought here from N America in the mid-1960s. Originally the spores of the fungus were distributed by the elm-bark beetle (*Scolitus scolitus*). The aggressive form (*Ophiostoma novo-ulmi*), however, often spreads without this carrier.

The elms are at present reduced to poor remnants, but some specimens will survive because of their isolation – not found by beetles or spores.

Trials to breed resistant trees were of little success.

As the wych elm is the only one native to Ireland it will be described in more detail.

8.3.1 Wych elm

Scientific name: *Ulmus glabra* Hudson (= *U. scabra* Mill. = *U. montana* With.).

Irish name: Leamhán sléibhe.

Origin and geographic distribution: Native to most of Europe, even far north in Norway, but absent from Mediterranean zones, reaching far into Asia (Plate 8.3-1). wych elm is the only elm that is certainly native in Britain and Ireland. Rare as a native, chiefly in mountain glens, it was planted frequently throughout the country. It has been very common and widespread especially as a component of hedgerows, partly also because of being widely planted in parks and alongside roads.

It was almost entirely killed by Dutch Elm disease in the 1980s.

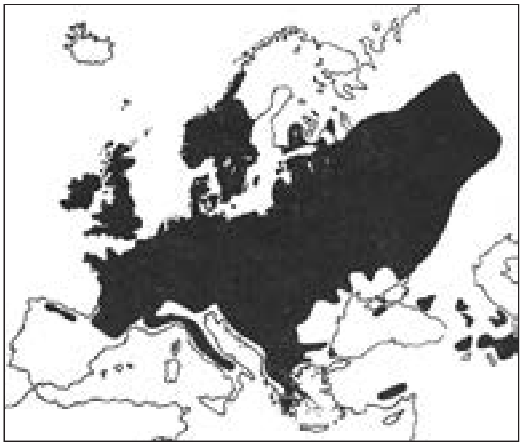


Figure 8.3-1: Natural distribution of wych elm. (Mette and Korell, 1982)

Botanical characteristics

Tree and crown form: A large tree up to 40 m with spreading branches, broader than other elms, but narrower in a stand.

Stem form and dimension: Young rust-coloured twigs, stout and stiffly hairy.

Bark: Unlike other elms, smooth when young, silver-grey, later fissured and dark-grey.

Timber: Ring-porous with reddish-brown heart and pale-yellowish sapwood. Tough, moderately hard, with high compressive strength and perfectly workable, but prone to shake.

Root system: Deep-rooting with a tap-root when young, later with a heart root system.

Leaves: Alternate, rounded to elliptical and long-pointed leaves, 10–18 cm in length, toothed, stiff hairs above, softer hairs beneath; each leaf has 10–18 pairs of veins; asymmetric leaf-base.

Flowers: Purplish-red flower clusters appear before the leaves in February to March. Every 2nd year rich fruiting is usual, starting at an age of 20–30 years in the open and 40 years in stands.

Fruits: 1–1.5 cm, papery winged in clusters, ripening in May/June distributed by wind. Germination capacity only for three weeks.

Ecological characteristics

Forest type: In mixture with sycamore and large-leaved lime it is a typical tree for shady and wet glens.

Successional type: Intermediate to late-successional.

Light requirements: Moderately shade-tolerant.

Stress tolerance: Very resistant to pollutants.

Site requirements: Preferably in hilly areas up to the mountain zone (1700 m in Italy).

Soil preference: Found on rich, moist soils.

Strengths and threats: It is said to be slightly more resistant to Dutch Elm disease – unlike the other elm species. Nevertheless, little has remained of the original vast number of elm trees in Ireland.

Regenerative capacity: Wych elm does not produce root suckers unlike other elms. It sprouts from the stump and, therefore, was often an element of coppice forests.

Provenances: Several local varieties.

Growth characteristics

Height and diameter growth: Twelve champion trees in nine counties reached a mean height of 23 m, but 35 m at maximum. They had a mean diameter of 125 cm and 150 cm at maximum.

Age: 400–500 years.

Total volume production: As elm was never managed as pure stands no data are available.

Values

Silvicultural values: Wych elm was an important and typical element of forests in glens, partly replacing beech.

Economic values: Very valuable timber for veneer, furniture, panels, parquet, intarsia; the root wood, because of veining, highly valued for turnery and intarsia.

Ecological values: Relatively shade-tolerant companion to beech on wet (but rich) soils.

Amenity values: As single trees in hedgerows elms made a positive contribution to the appearance of the landscape in the past.

Historical importance: Because of its strength the timber was widely used for wheels, spokes, the framework of carriages. Leaf fodder was highly valued for its food quality and for improving physical health of domestic animals. Bark cut into pieces and then soaked produced a liquid used as medical remedy, especially for burns.

Silvicultural management

Production of plant material: Because of the disease threat little is planted and plant production is unimportant.

Regeneration: Spread by seeds, usually not suckering, like other elm species.

Conclusions

The almost total loss of this very common species in Ireland is one of the greatest tragedies of its kind in the recent past. Almost no planting of the species has been carried out since the outbreak of the aggressive form of the Dutch Elm disease, and there is little hope that resistant provenances will be successfully selected and developed in the foreseeable future.

8.3.2 English elm

Scientific name: *Ulmus procera.*

Irish name: Leamhán gallda.

Origin and characteristics: It is thought to have been brought to Britain and Ireland by early tribes from southern Europe. Common in hedges and at roadsides, but always planted.

English elm is also a tall tree, but the crown is narrower than wych elm. It has, however, a rough and furrowed bark and often corky twigs. Stem and branches are persistently hairy, the leaves slightly smaller than those of wych elm (shorter than 9 cm). The greenish flowers have red anthers. The greenish fruits are 1–2 cm long and set near the tip of the wing.

Whereas the mature elms have been mainly killed by Dutch Elm disease, shoots from rootstocks, especially in hedges, remain unaffected for 10–15 years until the shoots have grown thick enough to support breeding populations of elm bark beetles.

8.3.3 Small-leaved elm

Scientific name: *Ulmus carpinifolia* Gleditsch (= *U. minor* Mill. = *U. campestris* Z.T.).

Irish name: Leamhán mion.

Origin and geographic distribution: Native to most of Europe except Scandinavia (Figure 8.3-2). It was brought in by pre-Roman tribes to Britain and also widely planted. It is a very variable species with many distinctive local populations and sometimes divided into several separate species. Hybrids with wych elm are often planted for ornament. In Ireland it was less frequent than English elm. Only very few isolated trees have survived.

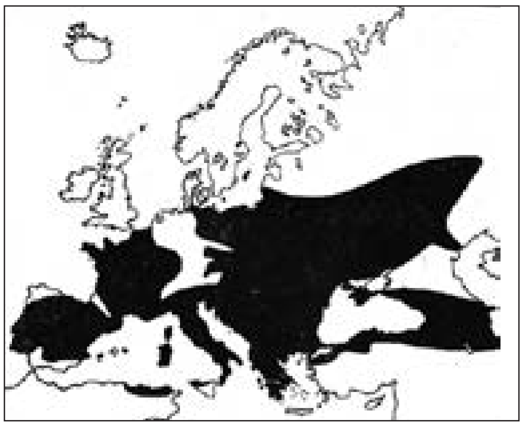


Figure 8.3-2: Natural distribution of small-leaved elm.

(Mette and Korell, 1982)

Botanical characteristics

The small-leaved elm is a slightly smaller tree than the other elms of up to 30 m with a narrower crown of very varied form and sharply ascending branches. The branches are long pendulous with glabrous young twigs. The bark is soon fissured (Plate 8.3-1).

The alternate leaves are 6–8 cm in length, usually widest above the middle, pointed, and smooth on both sides; 7–12 pairs of veins; long side of the asymmetric leaf-base makes a 90 ° turn to join the stalk. The leaves slightly resemble those of hornbeam, therefore, the Latin name *carpinifolia*. The clusters of small flowers open before the leaves appear in March. The fruits, 0.7–1.8 cm long, contain a seed near the top of the papery wing.

Ecological characteristics

Because of its greater preference for a warmer climate it was mainly distributed in the lowlands and riparian hardwood forests (‘beech of the riparian forest’). Thus it favours deep, moist soils along roadsides and hedgerows. It suckers freely.

Growth habit

A few champion trees have reached heights around and slightly over 20 m and diameters around 100 cm and 110 cm at maximum.

Values

Small-leaved elm was an important element of lowland and riparian forest. However, it lost substantial areas before the arrival of the Dutch Elm disease because of anthropogenic destruction of its preferred habitats. The timber is, because of its deep red colour, even more valued than that of wych elm.

Small-leaved elm was valued because of its strong and extensive suckering for purposes of marking boundaries and for its foliage for cattle fodder.

Plate 8.3-1: The bark of small-leaved elm could be mistaken for oak, but the fissures are longer and the bark ribs are less subdivided.

(Paris, France)

Conclusion

Because of its high susceptibility to Dutch Elm disease, it is unlikely to become common again in Irish forests in the foreseeable future.

8.3.4 Dutch elm

Names: Several hybrids of wych elm (*U. glabra*) and the very variable small-leaved elm (*U. carpinifolia*) are covered with the general name Dutch elm (*U. x hollandica*). Some breeds have special names like Commelin elm (*U. x hollandica* Commelin).

Origin and characteristics: Dutch elm was the last one of the elms introduced into Britain just before 1700 (Evans, 1984). It was commonly planted in northern Europe, but it was much reduced by disease in recent years.

Tree form and crown are very similar to wych elm, but the few rust-coloured hairs present are confined to the buds and leaves. It is said to be more productive than the other elms. The timber works well, but appears to be prone to butt rot.

As it often suckers freely it has the opportunity to survive at least up to the pole stage and then to sucker again.

European white elm (*U. laevis*), is native to central and south-eastern Europe (Figure 8.3-3), and in former times was of great importance in river valleys and floodplains, but not distributed in Ireland. Belonging to a different section of the genus it does not hybridise with the other European elm species.

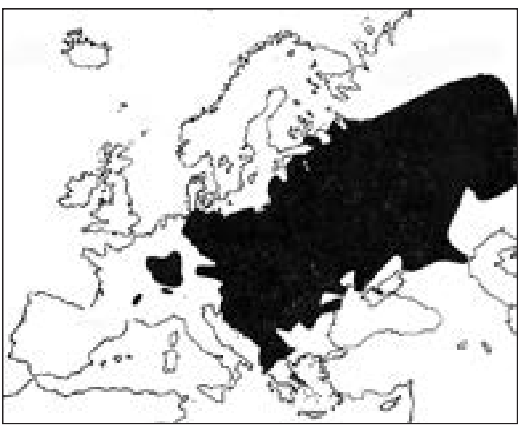


Figure 8.3-3: Natural distribution of European white elm.

(Mette and Korell, 1982)

8.4 Hawthorn

Family: *Rosaceae* – Rose family. There are about 900 species in North America and some 90 in Europe and Asia.

Genus: *Crataegus* – classical Greek name for hawthorn; a complex group across the northern hemisphere with a number of varieties.

Species: (1) Common hawthorn, closely related to (2) may whitethorn and (3) hybrids.

Origin and geographic distribution: Both common hawthorn and may whitethorn have a wide distribution in Europe. They are typical constituents of hedgerows and many types of broadleaf-dominated forests, especially small woodlots. Both are widely distributed in Ireland. As their botanical background is different they will be treated separately. Hawthorn is by far the most common and will, therefore, be described first.

8.4.1 Common hawthorn or whitethorn

Scientific name: *Crataegus monogyna* Jacqin emend. Lindm. (*monogyna* = one style).

Irish name: Sceach gheal.

Origin and geographic distribution: All over Europe east to Siberia and to North Africa. Very common in woods and thickets. Often seen as a hedging plant in northern Europe, and in hedges and copses all over Ireland.

Botanical characteristics

Tree and crown form: Naturally forming a dense tree up to 18 m high (Plate 8.4-1), but is often cut back to form hedges and prevented from reaching its full height (Plate 8.4-2). Very variable in shape and form. Formless, wide deep-reaching crowns.

Plate 8.4-1: Whitethorn as a fully developed single standing tree. (Virginia, Co Cavan)

Plate 8.4-2: Whitethorn – here in combination with gorse – is a common element of hedges and an eye-catcher in spring. (Delgany, Co Wicklow)

Stem form, branches: Often crooked and with fluting (Plate 8.4-3). Twigs with numerous thorns, up to 1.5 cm long; whitish thorns in contrast to those of blackthorn (refer to Chapter 8.2).

Bark: Pale grey to dark brown with rectangular fissures and cracking into small plates.

Timber: Flesh-coloured reddish, very tough, elastic and hard, difficult to split.

Root system: Long with poor fibrous root formation.

Leaves: Alternate, shiny, 1.5–4.5 cm long, 1½ times as long as broad; divided into 3–7 deep lobes; lobes entire or toothed near the tip; base of leaves with the lobe acute (Plate 8.4-3).

Flowers: Masses of white to pale pink flowers, each with one style (important differentiation character). Flowering in April-June. Has a particular smell that attracts insects. Cultivars with red flowers.

Fruits: Red and berry-like with only one stone; floury pulp; ripening in September (Plate 8.4-4).

Plate 8.4-3: Hawthorn usually has a fluted stem with spiral grain. (Freiburg, SW Germany).

Ecological characteristics

Forest type: Occurs in mixed broadleaf/conifer woods, mainly with oak. Forms lower canopy in riparian forests and in old pine forests on richer soils. Locally frequent. It is a very important part of hedges and road sides in Ireland, Britain and central Europe, where it is mixed with almost all broadleaves such as hazel, ash, field maple, birch, wild cherry, wych elm and briar. Together with sallow and elder it is an important part of poor quality woodland in Britain.

Successional type: Intermediate.

Light requirements: Light-demanding to medium shade-tolerant.

Stress tolerance: Tolerant of drought and temperature extremes.

Climatic requirements: From lowland to mountain climates (up to 500 m in Britain; 1,600 m in central European mountains).

Soil preference: Very adaptable to all soils, but prefers alkaline soils (limestone); largely confined to heavy soils in southern England (Evans, 1984).

Strengths and threats: Moderately resistant to browsing.

Regenerative capacity: Seed dispersed by birds. Good natural regeneration and coppices well.

Provenances: As it has been cultivated since time immemorial, a great variety of forms have been developed, but no selection or breeding was ever carried out.

Plate 8.4-4: Reddish fruits of whitethorn provide food especially for birds. (N Switzerland)

Growth characteristics

It is slow-growing. In Ireland, three champion trees have reached 12 m maximum. The maximum diameter was 85 cm. Hawthorn is said to reach an age of some hundreds of years.

Values

Silvicultural values: Can form a type of protective nurse especially for young oak, shielding them from browsing by cattle or deer. Beech, however, has great difficulty in coming through hawthorn thickets. Often the hawthorn needs to be cleared.

Economic values: Timber is not marketable, but is excellent for turnery. It has a high fuel value. Leaves, flowers and fruits are of medicinal importance (for high blood pressure, sleeplessness, depression).

Ecological values: Highly important as part of woods for protection of birds and small mammals as well as for their nutrition. It is particularly advantageous for game birds. Makes a useful wind barrier.

Amenity values: Relatively early flushing and flowering makes it a conspicuous and welcome constituent of hedges (Plate 8.4-5). The red cultivar is especially appreciated as a tree along avenues.

Historical importance: Great hedge planting activities took place between 1750 and 1850 in Britain. Fences were replaced by hedges. In the 19th century straight boundaries were established with flimsy hawthorn hedges (Rackham, 1986). Its branches were used to protect trees, gardens, fields against browsing of household animals and deer.

Its tough timber has been used for tool handles. Fruits have been used as fodder for pigs, goats and hens and in emergencies also by man. It is of high medicinal importance.

It has been associated with many public beliefs, customs and traditions: *Ireland still has many sacred thorns* (Rackham, 1986).

Plate 8.4-5: Whitethorn is a common component of hedgerows, especially at the edges, where it can avoid competition from other tree species. (N Germany)

Silvicultural management

Production of plant material: Easily raised from seeds, but cuttings are quicker. 2- or 3-years-old transplants, 30–120 cm tall, are standard.

Regeneration: Hedge planting is familiar and well documented.

Tending of young plants: It tolerates cutting and trimming very well (hedges).

Conclusions

Hawthorn is of limited economic value and is planted mainly in gardens and urban areas for amenity and protection purposes. Because the seed is widely spread by birds, it regenerates easily in woods as well as hedgerows, and will remain an important element of all types of land and open forest. It is sometimes planted in the landscape for game conservation, and the establishment of wind-breaks and this practice is likely to accelerate in the future.

8.4.2 May hawthorn, also Midland or English hawthorn

Scientific name: *Crataegus laevigata* Poir. (= *Crataegus oxyacantha* L.) (= *C. oxyacanthoides*). (*laevigata* = smooth, flattened; *oxyacantha* = with sharp thorns).

Irish name: Sceach choille.

Origin and geographic distribution: Midland hawthorn, native to Europe as far west as France and Britain. It has a narrower ecological range and does not occur in Scandinavia. According to Scannell and Synnott (1987) it is not native to Ireland, but is locally frequent and rare elsewhere. They suggest it is highly probable that the Midland hawthorn is an introduced plant, imported as nursery-stock to supply the Irish market for 'quicks' possibly as early as the 18th century. It is very similar to common hawthorn in many respects. Therefore, only some differences need to be mentioned.

Red double-flowered forms are common street trees.

Botanical characteristics

Like common hawthorn it is a variably shaped bush (2–5 m) and tree, sometimes reaching a height up to 12 m. Stem form, bark and leaves are very similar. Only the branches tend to be thorny. It is, therefore, less thorny than common hawthorn. It differs from common hawthorn in its leaves, which are shallowly lobed to about half-way with broad, round-tipped basal lobes and 2–3 carpels. The essential difference is that the flowers have 2 styles.

Ecological characteristics

Forest type: In mixed mainly broadleaf woods, like common hawthorn.

Light requirements: Slightly more shade-tolerant than common hawthorn.

Climatic requirements: Grows from lowland to mountain climates (up to 500 m in Britain; 1,600 m in central European mountains). It is slightly more demanding with respect to temperature than common hawthorn (narrower amplitude).

Soil preference: Heavy clay soils, but very adaptable. Soil should not be too acidic. It does poorly on pure limestone soils, but grows on waste disposal sites.

Growth characteristics

Slow-growing; crooked stems with maximum diameters of 70 cm. It may even reach a diameter of 1 m and live for approximately 500 years.

Values and management

Similar to common hawthorn.

Conclusion

See common hawthorn.

8.4.3 Hybrids

C. laevigata x monogyna (*C. x media* Bechst.) is a naturally occurring widely distributed hybrid, resembling may hawthorn, 1–2 styles.

8.5 Hazel

Family: *Betulaceae;* sub-family*: Corylaceae.*

Genus: *Corylus* (classical Roman name of the hazel nut) comprises 15 mainly shrub species in the northern temperate zone of North America, Europe and Asia.

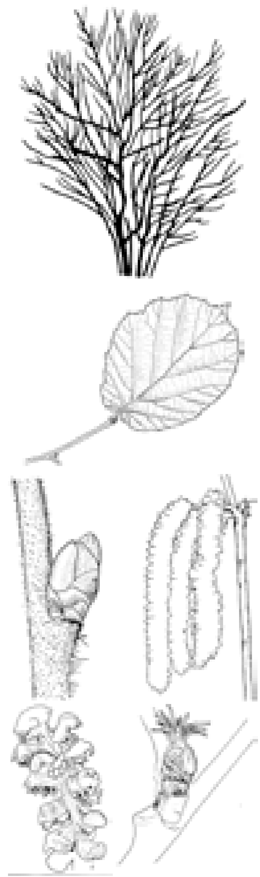
8.5.1 Common hazel or hazel nut

Scientific name: *Corylus avellana* L. (from Avella, near Naples).

Irish name: Coll.

Origin and geographic distribution: It is found in most parts of Europe, as far north as Norway and extending to the Near East and Caspian Sea. In the south it occurs only in higher mountain areas and is absent in the Mediterranean region. It was more widely distributed during the warm period after the ice-ages. It is native to both Britain and Ireland, where it is spread all over the country and is locally abundant. According to NFI (2013) data, hazel – which is recorded on 1.7% of the total stocked forest area (refer to Table 1.5-7) – is by far the most important of the other short-living broadleaves category, after willow.

Botanical characteristics



Tree and crown: Bush (shrub), seldom a tree.

Stem and branches: Normally upright straight multiple stems. Twigs are very flexible with reddish, glandular hairs. Winter buds are without stalks, short, rounded and greenish-brown.

Bark: Shiny grey-brown, curling off in flakes. It is smooth with whitish horizontal lenticels and becomes fissured with age.

Timber: Reddish white, tough and flexible, soft, easy to split, with poor durability.

Root system: Shallow rooting with good sprouting capacity.

Leaves: Leaves are alternate, 5–10 cm in length, almost circular with a heart-shaped base, sharply double-toothed at the margins and pointed at the tip; medium green on the upper side, light green beneath; hairy on both sides. The leaf stalk is 0.5–1.5 cm long.

Flowers: The male catkins open early in spring (January to April). The female flowers are bud-like, with only their styles exposed. Both male and female flowers appear long before flushing of leaves. Monoecious, wind-pollinated.

Fruits: Oil-rich, hard-shelled (wooden) tasty nut, long-enveloped with ragged, leafy, cup-like involucre about as long as the nut; ripening in August/September. Fructification starts at about 10 years; nuts remain alive only until the following spring. They are often damaged by the grubs of weevil and nuts may be eaten by squirrels.

Ecological characteristics

Forest type: In hedges, scrub and as an understorey in open mixed-broadleaf woodlands and in riparian woods. It is a typical companion of oak and of hornbeam-oak woods. It forms a component of hedges and scrubland (together with blackthorn and others) at the fringe of forests, and is a common element of many coppice stands. In mountainous areas it forms a patchy cover on rocky slopes covered with boulders. Often planted in pasture areas.

Successional type: Pioneer.

Light requirements: Light-demanding to slightly shade-tolerant.

Stress tolerance: Resistant to traffic pollution.

Climatic requirements: Wide range of climate from the lowlands to mountainous regions (up to 1,800 m in the southern Alps).

Soil preference: Demanding with regard to nutrient status; intolerant of poor sandy soils and peats.

Strengths and threats: If left uncut, the hazel becomes dense and shades out most vegetation and wild flowers. In addition to that of birch the pollen of hazel is the greatest nuisance for an increasing number of people suffering from allergies.

Regenerative capacity: Spread mainly by seed which is taken by birds, squirrels and mice. Its distribution is irregular. Bushes enlarge their size by layering. It coppices well (Plate 8.5-1 and 8.5-2).

Plate 8.5-1: Hazel in bushy form is often a reminder of former coppicing. (JFK Arboretum, Co Wexford)

Plate 8.5-2: Hazel is almost omnipresent on warmer and rich soils with no overshading by more competitive tree species. (SW Germany)

Provenances: There are many cultivars for amenity (weeping, red leaved) and for nut production.

Growth characteristics

Slow-growing during the 1st decade, then slightly faster. One champion tree in Ireland has reached 10 m in height and 85 cm in diameter. Usually, however, it grows to diameters of only 6–8 cm. Its normal lifespan is 60–80 years.

Values

Silvicultural values: Hazel can provide some shelter and be useful as a nurse crop for enrichment plantings. It could possibly provide shading for the lower stems of oak and other broadleaves, to avoid the development of epicormic branching, but this has not been proven.

Economic values: Nut production is probably its most important asset. Apart from being edible they are used for the production of nutritious oils as well as for other special purposes (paint, lubricating oil). The timber, however, is generally not merchantable.

Hazel charcoal is of limited value for gun powder production, as well as for drawing crayons. Its usefulness as a firewood is minor. The catkins, bark and young twigs are used for several medicinal applications, both internal and external.

Ecological values: Dense hazel scrub or underwood is important as a protection for birds and game and provides a valuable source of food for wildlife. Its pollen is collected by bees in early spring.

Because of its tolerance of traffic pollution it is increasingly used along road verges. In dense thickets it suppresses all ground vegetation.

Amenity values: Apart from special cultivars it has no special attributes.

Historical importance: It has been used extensively in the past for firewood, fencing material, wickerwork for half-timbered houses and sticks for different purposes as well as for gunpowder production. In prehistoric times, before the cultivation of cereals, it was an important food source. This may be the background for its high mythological reputation and role in superstition. It is still used as divining rods.

Silvicultural management

Seeds should be sown in autumn and covered with sand.

No special silvicultural aspects are known.

Intensive resprouting in former broadleaf woods after clear-cutting may cause competition problems. In such cases stumps may have to be treated with herbicides.

Conclusions

On favourable sites and without human interference hazel is and will remain a common component of mixed broadleaf woods. It easily colonizes bare ground.

Although of no real economic value today – at least in Ireland – it plays an important role for wildlife and to a certain extent also as an element in the landscape – along the roads and forest edges.

8.5.2 Turkish hazel

Scientific name: *Corylus colurna L.*

Corylus colurna is a sturdy tree up to 22 m in height with a conic crown. It is native to south-eastern Europe, but has been introduced to many other parts of Europe. Its distribution overlaps with that of pedunculate oak. Because of its resistance to pollution it is planted mainly along avenues (Plate 8.5-3). The timber is useful for furniture and carving (Plate 8.5-4). One champion tree in Ireland has attained 65 cm in diameter.

Plate 8.5-3: Turkish hazel is an increasingly valued tree in cities because of its tolerance to air pollution and salt contamination.

Plate 8.5-4: The straight stems and good timber quality of Turkish hazel make it additionally attractive.

(Both plates from Freiburg, SW Germany)

8.6 Holly

Family: *Aquifoliaceae:* Holly family. There are about 400 species mainly in the tropics and subtropics of both hemispheres.

Genus: *Ilex* – from the Roman name of the holm oak (*Quercus ilex*).

Scientific name: *Ilex aquifolium* L. – (the Roman name for holly) **–** the only *Ilex* species in Europe.

Irish name: Cuileann.

Origin and geographic distribution: Holly is indigenous throughout western and southern Europe, mainly in Atlantic climatic conditions. It is native to Ireland and distributed all over the country; common in scrub, hedgerows and as a shrub layer in woods. Often planted.

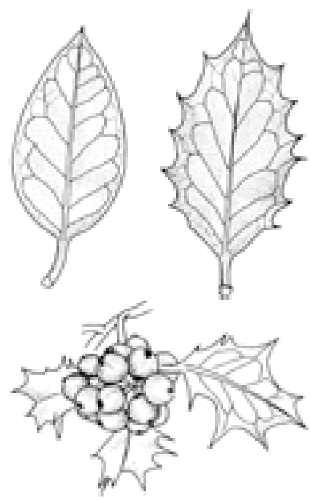
Botanical characteristics

Tree and crown: Usually a small, conical tree (Plate 8.6-1), but often only a shrub as an understorey under oak which has been often cut for fuelwood or removed as a weed and, therefore, had no opportunity to adapt tree form (Plate 8.6-2). However, it can reach dimensions of up to 15 m in height and more than 50 cm in diameter (Plate 8.6-3).

Plate 8.6-1: Conical shape of a young holly crown and straight stem. (Freiburg, SW Germany)

Plate 8.6-2: Impenetrable holly undergrowth in old oakwood. (Dromore, Co Kerry)

Plate 8.6-3: A holly stand of old specimens. (Sicily, Italy)



Stem and branches: Tips of young branches curve upwards.

Bark: Smooth, silver grey, becoming fissured eventually.

Timber: Smooth, whitish-green, hard, strong and heavy, fine-grained.

Leaves: Evergreen, alternate, glossy dark green above, dull green underneath, with very prickly foliage (5–12 cm long), stiffly leathery, waxy, wavy and spiny on the margins. Old trees often with glazed, spineless leaves. The older leaves are shed around midsummer.

Flowers: White flowers about 0.6 cm in diameter, 4-petalled, in small auxiliary clusters. Males and females on different trees (dioecious). Only the males are fragrant. Trees growing in deep shade are often sterile. Flowering May-August.

Fruits: Berries 0.7–1.2 cm long; bright scarlet, poisonous (Plate 8.6-4). The seeds germinate in the 2nd year.

Plate 8.6-4: Fruiting holly in Kilsheelan Forest. (Co Tipperary)

Ecological characteristics

Forest type: Widespread mainly as underwood in open mixed broadleaf forest and at forest edges. It is a common shrub in oak and beech woods everywhere and in rocky areas along streams in the hills.

Light requirements: Slightly shade-tolerant.

Stress tolerance: Slightly frost-intolerant.

Climatic requirements: Mild maritime or humid mountainous climate; in the north in lowlands, in the south in the montane region (up to 1,600 m in the Alps).

Soil preference: Moderately wet, sandy, loamy to limey soils.

Strengths and threats: Tolerates smoke and exhaust gas pollution. Very tolerant of hedge clipping.

Regenerative capacity: Sprouts readily from stumps (Plate 8.6.5). Seeds are spread by birds.

Provenances: Many horticultural breeds and local varieties.

Plate 8.6-5: Holly has good sprouting ability from root suckers. (Sicily, Italy)

Growth characteristics

Height and diameter growth: Slow-growing; in southern Europe and in the Orient it reaches 15–20 m in height and a diameter up to 1.5 m. In Ireland two champion trees have attained 21 and 16 m in height and 75 and 60 cm in diameter.

Age: 300 years at maximum.

Values

Silvicultural values: It has not been used in a systematic manner so far, but it may provide protection against the development of epicormics in oak woodland.

Economic values: Timber is used for turnery, marquetry and veneer to a minor degree. It makes good kitchenware and chess figures. Twigs with berries are sold as ornamental material (Christmas).

Ecological values: Not known.

Amenity values: Many cultivars with leaves variegated green and yellow. Highly valued in gardens and as a hedging plant.

Historical importance: Young leaves have been used as a tea to counteract gout, rheumatism and diarrhoea.

Silvicultural management

Production of plant material: Easily raised from seed for planting in gardens and parks.

Regeneration: Spread naturally by birds.

Tending and thinning: No management treatments have been used to date.

Conclusions

Holly is by far the most important tree species in the group of other long-living broadleaves, according to NFI (2013) data (refer to Table 1.5-5). Yet it has never been managed as a forest tree. As an understorey tree in oak forests it has potential as a tree species which protects the bottom logs from the development of epicormic shoots. On favourable sites it could produce small valuable stems if it were artificially pruned. Its slow growth and production of only slender stems, however, limits its silvicultural management for any forestry purpose at present. As it regenerates freely it is not an endangered species.

8.7 Hornbeam

Family: *Betulaceae:* Birch family.

Genus: *Carpinus* (from ancient Roman = hornbeam). There are some 35–40 species of this small-to-medium-sized deciduous tree, related to birch and alder, in Europe, Asia and N America.

Scientific name: *Carpinus betulus* = hornbeam-like birch.

Irish name: Crann sleamhain**.**

Origin and geographic distribution: Native to most of Europe including SE England, but not to Ireland (Figure 8.7-1). It is a common hedgerow and woodland species and was obviously introduced during past centuries. According to Webb et al., (1996) it was occasionally planted in demesne woods and possibly naturalised in several places.

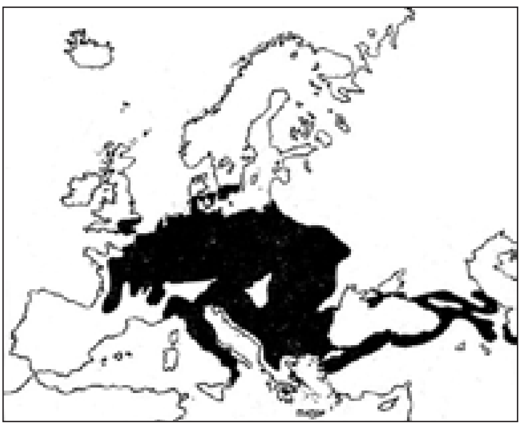


Figure 8.7-1: Natural distribution of hornbeam. (Mette and Korell; 1982)

Botanical characteristics

Tree form: Pyramidical, later irregular shaped crown; medium size (height up to 20 m, crown diameter up to 15 m), but more often seen as a shrub.

Stem form: Often crooked and with a tendency to fork. Its ability to resprout from the stump made it an important element of coppice forests on the Continent in earlier times (Plate 8.7-1). Frequently it has stem fluting, buttressing and spiral grain which reduces its value considerably (Plate 8.7-2). There are, however, provenances with straight stems and circular, regular cross-sections (Plate 8.7-3).

Plate 8.7-1: Hornbeam sprouts from stump.

(Freiburg, SW Germany)

Plate 8.7-2: Large hornbeam with fluted stem.

(Freiburg, SW Germany)

Plate 8.7-3: Perfectly circular hornbeam stem.

(Hainich, E Germany)

Bark: Smooth and thin, sometimes fissured, pale grey in colour.

Timber: Greyish-white, without a coloured core; very hard and tough. It is the hardest of all European hardwoods (= hornbeam). Does not splinter; very difficult to split, but good workability.

Root system: Deep-rooting, later heart root system.

Twigs: Densely covered with hairs.

Leaves: Alternating, oval shaped, sharply pointed, irregularly serrated, 4–12 cm in length (length:width = 2:1), rounded at the base with sharply double-toothed margins; medium green with autumnal tints yellow-orange. The undersides of leaves have about 15 pairs of prominent, hairy, parallel veins. It retains its rich brown leaves throughout the winter, thus making a good hedge.

Flowers: Pendulous yellow male catkins up to 5 cm long; female catkins up to 12 cm, green; flowering April-May.

Fruits: Each pair of nuts is attached to a leaf-like, 3-lobed involucre up to 4 cm long.

Ecological characteristics

Forest type: Occurs all over Europe as part of mixed broadleaf forest; characteristic species of oak/hornbeam forests. It is a part of floodplain (riparian) forests together with pedunculate oak, ash and elm.

Successional type: Medium- to late-successional.

Light requirements: Shade-tolerant, but less so than beech.

Frost tolerance: Frost-hardy.

Climatic requirements: Preference for warmer areas (flat and upland zone, rarely montane).

Soil preference: Great range: an ability to grow on waterlogged as well as dry sites, but grows best on loamy medium-rich soils.

Threats: Relatively storm-resistant; not damaged by insects or fungi; often not browsed by deer, but this depends greatly on the occurrence of accompanying tree species and herbs.

Regenerative capacity: Seeds have a dormancy period of 1–2 years; normally easy to regenerate naturally; sprouts very readily from stumps.

Provenances: There are obviously great differences in stem quality according to local strains, but no studies have been carried out on this characteristic.

Values

Silvicultural values: Being shade-tolerant and less competitive than beech – as a result of its generally lower height growth – it has proven an ideal understorey tree species to prevent the growth of epicormics in oak forests. Because of its great site adaptability it can grow on waterlogged soils, together with pedunculate oak, as well as being an understorey tree to sessile oak on dry soils.

Economic values: Hornbeam has been widely used for tools, cogs, spokes of wheels, work benches, butcher's blocks, piano hammers and parquet. Because of its good working characteristics there is an increasing demand in the market and the prices have risen slowly provided the quality is reasonable. It makes good firewood, but is less preferred than beech because of difficulty in splitting.

Ecological values: Important and very tough member of hedgerows in some areas because of its easy sprouting and shade-tolerance.

Amenity values: Excellent tree for hedging: extremely tolerant of trimming and cutting. Many horticultural breeds, especially *fastigiata*, a columnar growing variety widely used in parks and gardens.

Historical importance: Used for mill-cogs and the hubs of cartwheels. For many centuries it has been a very important part of coppice forests, especially in France, for fuelwood. In Central Europe often used to mark – after pollarding – the boundaries of forest properties.

Growth characteristics

Its height growth after overcoming planting shock is very vigorous. It may even compete with oak when planted at the same time. Sprouts from stools reach 0.5–1 m in the first two years, but fall back later.

Seven champion trees in Ireland have attained maximum heights of 34 m and an average of 21 m. Their diameters reached up to 1.75 m and all of them exceeded 1 m.

Life span is around 150 years.

Silvicultural management

Production of plant material: Raised from seed, but dormancy period has to be recognised.

Planting: Mostly 1+2 transplants are used with a height of 60–100 cm.

Weeding: Is normally not necessary because of its great tolerance of competition from grasses and brambles.

Thinning: Normally no thinning is necessary because its main function is as a serving tree for oak. There is a tendency, however, to select and to favour straight specimens with circular shaped stems.

Conclusions

To date hornbeam has been a species of limited interest to foresters, but this will likely change gradually as the market demand increases (hard and tough timber, flooring). Its use, however, will be mainly restricted to its role as an understorey tree species against epicormics, used to improve the quality of stands of oak and other light-demanding broadleaf species such as ash and sycamore. As it suppresses the ground vegetation it indirectly improves the opportunity for natural regeneration of various tree species.

As long as it is not possible to select provenances with straight circular stems it will be used mainly as fuelwood.

Hornbeam may yet become one of the more important of the minor species in Ireland.

8.8 Horse chestnut

Family: *Hippocastanaceae.*

Genus: *Aesculus* (probably a Roman name of an oak species). There are ca. 25 deciduous species of tall or medium size from the northern hemisphere and some hybrids. A few are of interest: horse chestnut, which is highly valued as an ornamental, and other horse chestnuts, which have limited relevance as ornamentals.

8.8.1 Horse chestnut

The characteristic pattern of the leaf-scar, resembling that of a horse-shoe, is believed to be the background to the name.

Scientific name: *Aesculus hippocastanum* (*hippo* = Greek: horse, *castanum* = Latin: sweet chestnut).

Irish name: Crann cnó capaill.

Origin and geographic distribution: Native only to a few mountain and valley forests of the Balkans (Greece, Albania, Macedonia) but naturalised in western Europe after 1600 (Figure 8.8-1). Now distributed and common to the whole of Ireland. Planted mainly for ornament and occasionally self-sown in hedges.

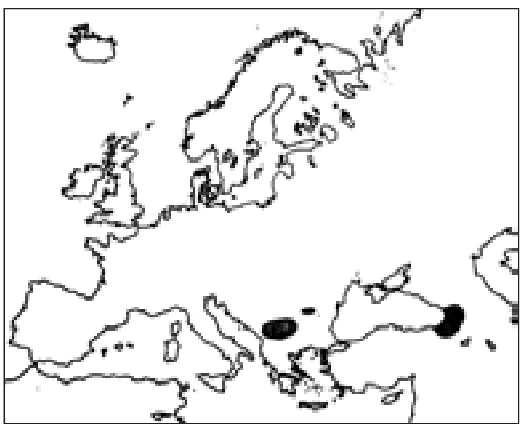


Figure 8.8-1: Natural distribution of horse chestnut. (Mette and Korell, 1982)

Botanical characteristics

Tree and crown: A medium sized to tall tree up to 35 m, handsome widespreading, broad-headed tree.

Stem and branches: Stout trunk (diameter maximum 1.0 m); reddish-brown twigs in winter, bearing large buds, very sticky in spring.

Bark: Brown-grey, scaling and cracking into plates (Plate 8.8-1).

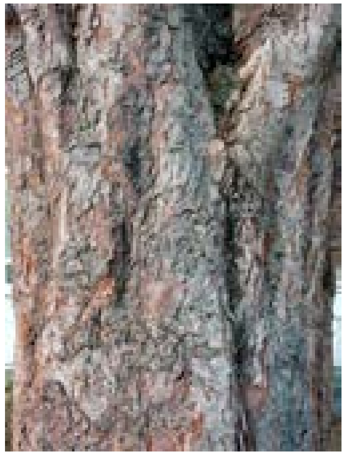


Plate 8.8-1: Cracking bark of horse chestnut. (Dublin)

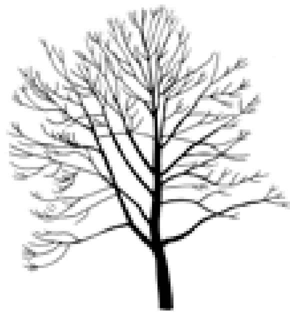
Timber: Pale, soft, weak and light, brittle and with very little durability; often with spiral grain, homogenous structure, fine-grained.

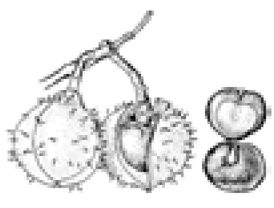
Root system: Forms a taproot initially, which becomes flat later and develops into a far-reaching root system.

Leaves: Opposite, palmate, with 5–7 leaflets up to 20 cm long, lacking petioles.

Flowers: Are in tall erect panicles (candles) with 5 petals and white with pink or yellow spots at the base; flowering period April-May, yearly, starting at 10–15 years.

Fruits: Large (6 cm across), spiny, leathery husks with 1–2 big brown nuts, ripening September/October. They frequently germinate subterraneously, but rarely mature. High contents of starch and saponins. Germination capacity: 6–7 months.





Ecological characteristics

Forest type: Rarely found in woodlands, but occasionally mixed in broadleaf forests.

Successional type: Not known.

Light requirements: Moderately shade-tolerant.

Stress tolerance: Not very temperature-demanding. Frost-tolerant. Wind-stable. Not very tolerant of pollution by traffic.

Climatic requirements: Found growing from the lowlands to submountain regions, comparable with hornbeam. As it grows outside its native habitat under very diverse conditions it can be regarded as a species with great ecological adaptability.

Soil preference: Deep, rich valley soils, but grows quite well on any soil that is not too acid or dry.

Strengths and threats: It may shed large branches during summer gales. A leaf-moth (*Cameraria ohridella*) was first detected in 1984 around Lake Ohrid in Macedonia and has since spread throughout the Continent. Its larvae mine the leaves, which develop ugly brown spots in early July and cause premature leaf-shedding in August. These attacks, however, do not kill the trees (Plate 8.8-2). Red horse chestnut and some other varieties with thicker cuticles (outer surface of leaves), are not attacked.

A new disease, bleeding canker of chestnut, caused by *Pseudomonas syringae pv aesculi* has caused serious problems in Britain.

Regenerative capacity: Surprisingly poor in the forest, but develops freely when raised in seedbeds.

Growth characteristics

It grows fast in youth. Fifteen champion trees in Ireland show remarkable height growth with 29 m maximum and 25 m on average. They attained diameters up to 2.0 m and a mean of 1.7 m. As horse chestnut has never been grown for production purposes, no respective volume data are available.

Some of the specimens planted at the beginning of the 17^{th} century still survive, so an age of 400 years seems feasible.

Values

Silvicultural values: Not known.

Economic values: The timber, because of its weakness, spiral grain and poor durability (resistance to decay) is of little value for industrial purposes and fuelwood, but sometimes it is used for carving.

Saponins are used for production of detergents, but may also have other health benefits such as inhibition of cancer cells, reduction of cholesterol levels and strengthening the immune system. Starch and oil have served as fodder for animals and even food for humans after extraction of bitter constituents through industrial processing in times of need. Tannic acid and other ingredients are used for medical purposes.

Ecological values: Fodder for deer in winter. The flowers produce large amounts of honey and pollen and are attractive to bees. Birds make use of hollows in trees where branches have broken off.

Amenity values: Planted throughout Europe for its shade. It is **the** tree in beer-gardens on the Continent. Moreover, it is a very common ornamental tree in parks and streets. This use may be the reason why it is probably the best known of all broadleaf tree species by the public (Plate 8.8-3).

Silvicultural management

Plant material is raised by seed directly after seed fall or after stratification procedures. It is propagated by grafting, especially for ornamental varieties.

Plate 8.8-2: Horse chestnut attacked by leaf-moth. (Freiburg)

Plate 8.8-3: Free grown horse chestnuts form magnificent specimens with diameters of more than 1.5 m. This explains their presence in parks and avenues. (Paris, France)

Conclusions

Horse chestnut is rarely found as a tree in forest stands and this is unlikely to change. It is, however, one of the best-liked ornamental trees and often forms a border along forest roads, especially in old demesnes.

8.8.2 Other horse chestnut species

Red horse chestnut or red Buckeye (*Aesculus x carnea* Hayne = *Ae. x rubicunda*).
This is a hybrid of *A. hippobastanum* and *A. pavia* (from southeast USA). A slightly smaller tree, with smaller dark coarse leaves and red flowers. These characteristics explain why it is often planted as an ornamental.

Indian horse chestnut (*Aesculus indica*)
Native to the Indian Himalayas, it resembles horse chestnut, but is a smaller, more delicate tree (up to 20 m). Leaves are much smaller, and flowers are like horse chestnut. It is often planted in parks or as a garden and street tree.

8.9 Lime

Family: *Tiliaceae*. It comprises some 400 species mainly in the tropics.

Genus: *Tilia* is one of five genera with some 30 tree species in the temperate regions of the northern hemisphere. *Tilia* comes from the Greek *ptilon* = wing (the flower bract). The name was also used in classical Roman times (Virgil, 70–19 BC).

Common names: Lime, linden/linden tree from Anglo-Saxon 'lind(i)a'.

Irish name: Teile.

Species: Three lime species (small-leaved, broad-leaved and silver lime), and one hybrid (common lime), are of some importance in Europe and partly in Ireland also. The small-leaved lime is by far the most important and will be described in greater detail. For the other species only the differences will be mentioned.

Origin and geographic distribution: All three species are found throughout Europe. During the warm Neolithic period (8,000–4,000 BP), the small-leaved lime reached as far north as middle Scandinavia and the broadleaf species covered most of central and southeast Europe. When the climate became colder they moved further south (Figures 8.9-1 and 8.9-2).

According to Rackham (1986) their presence was much more frequent even after the Middle-Ages and has been greatly underestimated. This may be partly attributable to insect-pollination and shedding very

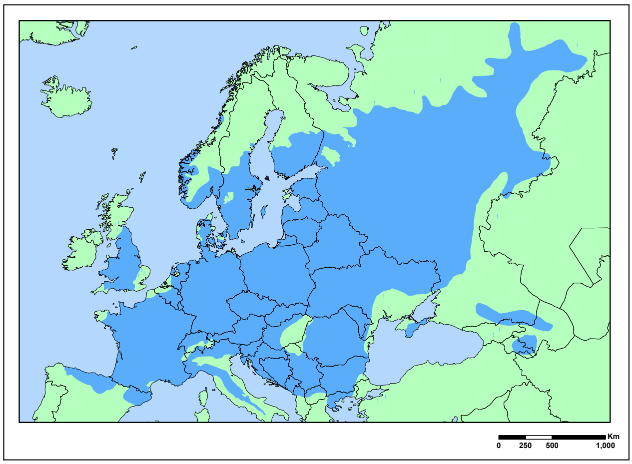


Figure 8.9-1: Natural distribution of small-leaved lime
(EUFORGEN, 2009)
For comparison purposes the distribution map of broadleaved lime is inserted here.

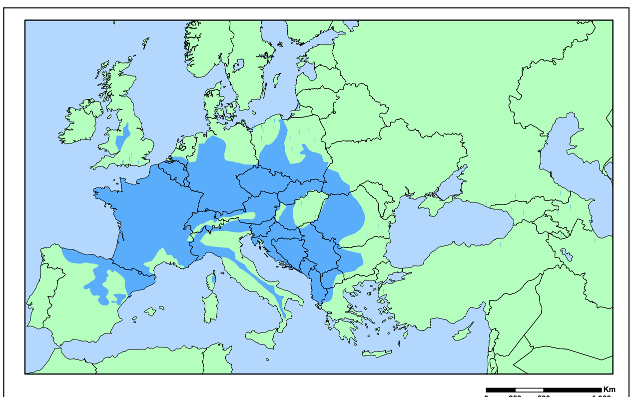


Figure 8.9-2: Natural distribution of broad-leaved lime
(EUFORGEN, 2009)

little pollen. As a result there are little or no pollen records that can be traced in bogs or stratified mud-layers in lakes.

8.9.1 Small-leaved lime

Scientific name: *Tilia cordata* Miller, derived from Latin *cor* = heart, the heart-shaped leaves.

Scientific synonym: *T. parvifolia* Ehrh., from the Latin *parvus* = small, and *folium* = leaf.

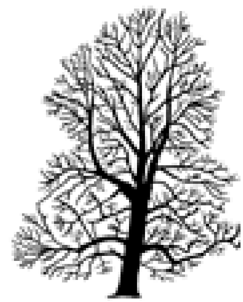
Common names: Small-leaved lime, linden, pry tree, basswood.

Irish name: Teile.

Origin and geographic distribution: Occurs in Europe up to 63° north latitude (Figure 8.9-1). It is native to the limestone areas of Europe, except for the far north and south. Native in England and Wales: *… is a living link with Mesolithic times. In prehistory lime had been the commonest tree of Lowland England. It is still the commonest tree of ancient woods in certain small and sharply defined areas in Lowland England* (Rackham, 1986).

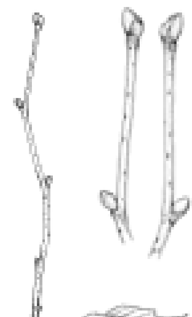
Not native to Ireland, but is often planted as a street tree.

Botanical characteristics



Tree and crown form: Forms a tall tree (big domes) up to 32 m in height, with a rounded well-shaped dense crown in the open, and side branches reaching low down the stem. It is, however, less imposing than broad-leaved lime.

Stem form and dimension: Develops tall cylindrical stems with reduced crowns in closed stands. It can attain large diameters (up to 2 m) as a solitaire, and has downwardly arching branches on older trees.



Bark: Smooth, grey/grey brown, when young, later brown/black brown with vertical fissures and cracks comparable with that of oak. The bark contains strong bast fibres.

Timber: Dense, with soft wood of relatively low weight (0.52 g/cm^3); tough, but with a high shrinkage rate; diffuse porous; with little durability, although remarkably rot-resistant in old standing specimens. Colour is light yellowish. Its fine texture and uniform grain make it workable in all directions.

The wood is of low calorific value.

Root system: Deep-rooting with a taproot in the early decades. Later with a strong lateral root system.

Leaves: Heart-shaped, light green (linden green), alternating, with long stalks. 3–9 cm long and broadly heart-shaped, finely toothed, dark shiny green above, paler with tufts of pale red-brown hairs in the vein-axils beneath.

Flowers: Whitish/yellowish with 5 petals; fragrant, in a pendulous cluster of 4–15 attached to a pale green, wing-like bract. Pollinated by bees, flies, bumble bees. Flowering period in July.

Fruits: The seeds ripen late October/early November and fall at end of November/early December. Thin-shelled, globose nuts 0.6 cm long; downy at first, becoming glabrous, usually ribbed. The seeds are extremely small and light (up to 20,000 seeds/kg). Production of viable seeds is highly dependent on warm summers. Seeds remain dormant for one year and retain their viability for two years.

Ecological characteristics

Forest type: Lime occurs naturally (in England) on silty gleys and soils derived from chalk and limestone and succeeds best wherever there is good drainage. It is a common mixture species in many oak-dominated forests, together with ash, field maple, hawthorn, birch, wild cherry, wych elm. Generally the proportion of lime is small.

It is a common component of mixed as well as pure coppice.

Successional type: On the Continent, lime normally belongs to an intermediate successional stadium suffering competition from beech on sites appropriate to this species. Because of its great lifespan, however, it is able to survive even in mixture with beech for centuries. In ravines, on rocky locations and relatively warm and dry sites, it can be part of late-successional forest types.

Light requirements: Moderately tolerant of shade, but casts a heavy shade itself. Some consider it a shade-bearer, others a light-demander. In practice it occupies a middle position in this respect.

Stress tolerance: Relatively frost-hardy, but somewhat tender to late frost. It is far more sensitive to drought.

Climatic requirements: Intolerant of high exposure; prefers sheltered sites.

Soil preference: Prefers nutrient-rich brown earths and limestone soils (rendzina, brown calcareous soil). For good growth it requires a deep, fresh, if not moist soil. An acid surface is acceptable, but a base-rich soil (with pH greater than 5) at depth is essential. Fairly tolerant of free calcium carbonate and does not show chlorosis on chalk or limestone. All infertile sites are unsuitable.

Strengths and threats: As it is slightly sensitive to frost, it is mainly planted in sheltered conditions (underneath old trees or into gaps) and, therefore, frost damage is minimised. It is hardier than broad-leaved and silver lime as regards climate and soil. Fairly windfirm.

Lime is obviously very sensitive to grazing as cattle like its leaves (Rackham, 1986). High populations of deer cause severe browsing on young seedlings, but bark-peeling of older stems is infrequent.

As far as can be observed, it is rarely damaged by grey squirrel. Insects and fungi are of little importance, except for the buff-tip moth (*Phalera bucephala*), whose larvae often strip it bare. It is less susceptible to attack by aphid than the common lime.

Regenerative capacity: Seed production commences at 20–30 years of age and continues about every other year. Production of viable seed is dependent on warm summers. Flower bracts permit seed to be dispersed over long distances. According to Rackham (1986) it now grows with difficulty from seed as the climate has obviously turned against it. Reproduction from stools is excellent, and the stools last a long time (Plate 8.9-1).

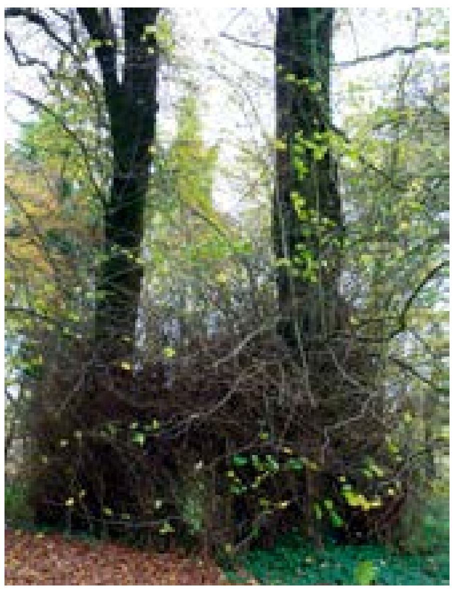


Plate 8.9-1: Lime species produce prolific sprouts at the base of trunks.
(New Ross, Co Wexford)

Provenances: According to OCarroll (2004) Irish, British, French, Belgian, northern German and Danish stands are preferred.

Growth characteristics

Height and diameter growth: Usually vigorous. In youth it shows medium-rapid height growth, but later the growth is similar to that of beech, reaching about the same height (Table 8.9-1). Over a rotation of 50–70 years it reaches a height of 25–30 m with a stem diameter of 30–45 cm (Evans, 1984), but has very little height growth after an age of 200 years.

Table 8.9-1: Height development of lime species on favourable sites as well as their value for parks and gardens.
(Adapted from Mitchell, 1989, Schütt *et al.*, 1992 and Tree Council of Ireland (2005))

Lime species	Height (m) at year			Value for parks and gardens	Champion trees		Height (m)		Diameter (cm)	
	10	20	final		number	counties	mean	max.	mean	max.
Small-leaved	6	12	30-35	high	3	3	22	25	180	190
Broad-leaved	8	12	35-40	medium	1	1	-	17	-	200
" 'laciniata'					3	3	-	17	65	90
Common	8	11	40-50	low	10	9	28	42	220	330
Silver	7	12	30	high	2	2	20	22	105	130
" 'petiolaris'					4	3	23	26	95	130

Lime grows better in Britain than in Ireland, although the common lime has reached equivalent height values in both countries. The varieties of broad-leaved and silver lime are more often used as the basic species.

Age: It reaches a greater age (more than 1,000 years) than any other European broadleaf tree species.

Total volume production: As lime is almost never grown in pure stands no yield tables are available.

In Germany, beech yield tables are used whenever the production capacity of lime has to be estimated.

Values

Silvicultural values: As a rule it is found mixed with other broadleaf trees. Owing to its dense foliage lime is also suitable for pure plantations. In parts of Britain it is a gregarious tree and occurs as patches of pure lime rather than mixed with other species (Rackham, 1986).

Because of its medium shade-tolerance it is able to grow in older oak and ash stands, and form an understorey, as well as participating in the canopy. This gives it the ability to reduce the growth of epicormics and increase the mainly low volume production in the stands of light-demanding species.

According to Mitchell (1989) it has the potential to replace elms as a species of similar structure and need.

Economic values: At present the market for its timber is very small and special. Its lustreless uniform grain and insipid colour lack the appeal of most other broadleaf timbers.

It is not fit for building purposes and is only used for tool handles, joinery and carvings. Minor products are toys, cigar boxes, drawing tablets, picture frames and model making. Because of its softness it is not suitable for parquet flooring. Therefore, the prices for its sawtimber are low. Its sale is possible only because the amounts of timber marketed are small. Small dimension material especially is not marketable as sawtimber. It can, however, be used for pulp.

Non-wood forest products: dried flowers for tea (against cold, flu and catarrh), in salves for external use on open wounds, as charcoal in the treatment of diarrhoea.

The production of linden honey is still highly valued, but forest owners normally are not able to make money from it.

Oil prepared from the seed is said to have a quality comparable to olive oil.

Bark fibres have been used as binding material for strings and ropes.

Timber for tools and household goods such as spoons, dishes, bowls. It was and still is important timber for wood carving and especially sculpting.

Ecological values: It is a good soil protection species. The leaves decay easily and form a good humus, thus providing a good supply of nutrients. Even if not native it is naturalised and now adapted to local ecosystems. It is an important part of coppice forests and hedgerows. Coppice-with-standards as occurring in England provides favourable habitats for many game animals and other wildlife.

Amenity values: Small-leaved limes form magnificent trees with elegant foliage and bright starry flowers. Their sweet smell at time of flowering is a further attraction. Magnificent trees as focal point in the villages (venues for public representatives of the village and as a place of jurisdiction, trees with dancing platforms); as landmarks at road junctions and other remarkable places and shelter for animals in the field.

Historical importance: Until the end of the Middle Ages the small-leaved lime was a very common and widespread tree in Britain and central Europe. According to Mitchell (1989) it was the dominant tree in the Saxon period in most forests of England and Wales. It played a considerable role – probably the most important one of all broadleaves in Europe for reasons already listed above.

Silvicultural management

Production of plant material: As seeds rarely ripen in Britain and Ireland they are mostly imported from the Continent. It is easy to transplant up to a considerable size. Young plants can be propagated from cuttings.

Regeneration: There is little or no natural regeneration because of the poor ripening of seed and because of the absence of mother trees even if the site conditions are favourable.

Tending and thinning: It should follow along the principles already mentioned. There are no special recommendations.

Conclusions

Small-leaved lime is a valued component of mixed broadleaf woodland, where it still exists. According to Rackham (1986), it is *the lovely and uncommon tree of ancient woodland*.

It has the potential to play a certain role as a mixture tree with oak and ash in order to protect their stems from epicormics and to increase volume production. Because of this special silvicultural value, it should be given more attention in the future.

At present its timber is not highly valued, so forest owners may not be encouraged to grow quality lime. Yet, it is possible that its non-wood products may be prized again in the future.

Continued

Conclusions continued

Lime has many ecological and aesthetic values. Moreover, it is favourable as a tree in lowland shelterbelts. These aspects also justify some more planting.

It is relatively easy to manage. Apart from browsing by deer, there are no dangers against which the tree needs special protection.

As the most tolerant species of all the limes, regarding climate and soil, the small-leaved lime seems to be the only one which may gain some importance in the Irish woods in the long term.

8.9.2 Broad-leaved lime

Scientific name: *Tilia platyphyllos* Scopoli from Greek *platys* = broad and *phyllon* = leaf.

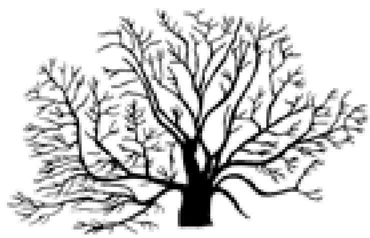
Scientific synonym: *T. grandifolia* Erh., from Latin *grandis* = big and *folium* = leaf.

Common name: Broad- or large-leaved lime.

Origin and geographic distribution: Native to hills in central and southern Europe (refer to Figure 8.9-2). It is today distributed in central and southeast Europe, in the Ukraine and the Caucasus and is found up to 1,000 m. There is uncertainty as to whether or not it is native to England. It is not indigenous to Ireland, but was introduced some centuries ago.

As in England it has been planted mainly for amenity purposes along streets, but less so than common lime.

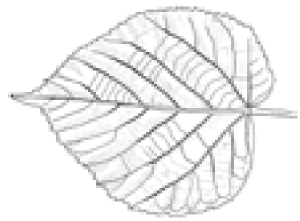
Botanical characteristics



Tree and crown: A magnificent tall tree (up to 40 m) with a dense, regular and rounded crown.

Stem and branches: Like the small-leaved lime its branches may reach down to the bottom of the stem.

Bark: Dark grey and fissured.



Timber: Its timber is slightly lighter than that of small-leaved lime (specific gravity 0.49 g/cm^3) and of lower quality.

Root system: It is intensively deep-rooting and is able to penetrate even compacted soils.

Leaves: Alternate, heart-shaped leaves 6–9 cm, noticeably larger (5–15 cm) than those of the small-leaved lime; some hairs remaining near the tip of the shoot; sharply toothed; hairy on both sides, but especially beneath.

Flowers: Flowers with 5 petals, yellowish and fragrant in a long-stalked, pendulous cluster of 2–6, attached to a whitish, wing-like bract. Flowering in June and 1–2 weeks earlier than small-leaved and other limes.

Fruits: Globose nuts 0.8–1.2 cm long; hairy with 3–5 prominent ribs. The seeds ripen and fall about two weeks earlier than those of small-leaved lime (i.e. mid October-mid December). Some fruits remain in winter on the lower branch shoots.

Ecological characteristics

Forest type: It is found dispersed in lime-sycamore, beech-lime and ash-elm-sycamore forests, mainly in ravines and on steep slopes. It occurs in pure stands in eastern regions of its distribution.

Light requirements: Shade-tolerant.

Stress tolerance: More susceptible to late frost than small-leaved lime.

Climate and soil requirements: From upland to sheltered mountain ranges. More demanding with regard to temperature, humidity and nutrients.

Strengths and threats: More subject to attack by aphids.

Growth characteristics

As shown in Table 8.9-1, broad-leaved lime and its varieties do not seem to be superior to the small-leaved lime.

Values
No general difference to small-leaved lime, only its shape is more magnificent.

Conclusions

Broad-leaved lime has no advantages compared with that of small-leaved lime. It may be planted for amenity purposes only in the milder regions of southeast Ireland.

8.9.3 Common lime

Scientific name : *Tilia x europaea* (= *T. x vulgaris* = *T. intermedia* = *T. hollandica*)

Origin and geographic distribution: Natural hybrid of small- and broad-leaved limes, which has been introduced to Britain about 1600. In many respects it shows characteristics intermediate to its parents. All specimens are planted and not native.

Botanical characteristics

Tree and crown: It is the tallest tree (up to 46 m) in most areas of the UK (Evans, 1984). This magnificent tree, however, can often be badly misshapen.

Stem and branches: Frequently with dense sprouting on lower stem. Branches arched on older trees.

Bark: Dull grey with fine fissures.

Timber: Its timber is also slightly softer and lighter than that of small-leaved lime.

Root system: Its roots are invasive; it sprouts around the base.

Leaves: Broad alternate leaves 6–10 cm long, also intermediate in size between those of both parents; base heart-shaped or cut straight across; dull green above, paler with tufts of white hairs in vein-axils beneath. Often sticky with sap; no autumn colour.

Flowers: 5 petals, yellow-white and fragrant, 5–10 in a pendulous cluster attached to a yellowish-green, wing-like bract. Flowering period July.

Fruits: Thick-shelled, ovoid to globose nuts, 0.8 cm long; downy and weakly ribbed; rarely fertile.

Ecological characteristics

The common lime tends to be strongly infested by greenfly. These produce a fine rain of honeydew, which pollutes cars and garden furniture located underneath. Sitting under those limes is unpleasant.

Values

Common lime has been planted along streets and avenues, mainly because of its magnificent appearance.

Conclusions

Because of honeydew production, the problems with abundant root suckers and the often misshapen crowns, common lime merits little attention.
Some authors refer to it in somewhat pejorative terms:

- *The worst tree known for either purpose* (Mitchell, 1989),
- *.. the sticky lime tree of avenues and municipal parks* (Rackham, 1986).

Nowadays, it is being replaced as a street tree by more fungal- and insect-resistant species.

8.9.4 Silver lime

Scientific name: *Tilia tomentosa* Moench (= *T. argentea* DC). *tomentosa* = dense woolly, felty; *argentea* = silver, refers to the green silvery underside of the leaves and the young shoots.

Common name: White/silver linden or Hungarian lime.

Origin and geographic distribution: A tree of southeast Europe, the Black Sea and Caucasus from the Balkans to western Ukraine and northern Hungary, eastwards to Asia. According to fossil records, it was widely distributed in central and eastern Europe during the Neolithic Period (8,000–4,000 BP), but retreated to the warmer parts later. It was introduced to central and western Europe in the past 200 years and is often planted for its handsome foliage.

Botanical characteristics

Tree and crown: Medium to tall (up to 30 m), an impressive tree with strong healthy growth.

Stem and branches: Ascending branches give this compact tree a broadly domed crown. Young twigs are downy white, becoming glabrous and green.

Timber: White-yellowish, light and very soft; very suitable for carving.

Leaves: Alternate, 8–10 cm long, heart-shaped with asymmetric base and sharp-toothed margins; very attractive because of its dark green leaves above and densely silvery white with stellate hairs beneath. Shoots and underside of leaves are densely woolly.

Flowers: With 5 petals, yellow or whitish, fragrant; 6–10 in a pendulous cluster attached to a yellowish, wing-like bract. Flowering July-August.

Fruits: Ovoid nuts 0.6–1.2 cm long, downy with 5 dominant ribs. Fruiting yearly, starting at an age of 20–25 years. Fruits ripen September/October.

Ecological and growth characteristics
It forms a component of downy oak/Turkey oak/sweet chestnut/hornbeam forests. It is tolerant of winter frost, drought and less in need of humidity than other limes. The hairy

leaves prevent attack by lime aphids. Therefore, no 'honeydew' is produced and this makes it more suited for parks and streets. It is slightly faster growing in the first decades than broad-leaved lime. Compared with other lime species silver lime produces the greatest amounts of honey.

Conclusions

Stress-tolerant, winter-hardy and of vigorous growth, the impressive silver lime could be a welcome substitute especially for common lime, but also for broad-leaved lime, in city parks, streets and avenues.

8.10 Pear (wild)

Family: Rosaceae

Genus: *Pyrus* (Roman name of pear) comprises 20–30 mainly deciduous pear species in Eurasia and Northern Africa; in Europe three species as well as numerous hybrids and cultivars.

Latin name: *Pyrus pyraster* (Burgsd.) Borkh. (= *Pyrus achras* Gaertn.) wild pear. Together with Asian species parent of ~1,000 cultivars (*Pyrus communis* L. = *P. domestica*).

Irish name: Crann piorraí.

Origin and geographic distribution: Occurs from Europe to West Asia, but never very abundant. According to Evans (1984) it was introduced to UK pre-1600. According to Rackham (1986) wild pear was occasionally mentioned in medieval documents, and pear charcoal is widely recorded from the Neolithic era onwards. It may, therefore, be regarded as native in the UK. Scannell and Synnott (1987) classified it as native to Ireland, but occurs in some regions only (Figure 8.10-1).

Botanical characteristics

Tree and crown form: Bulky-branched, diversely shaped bush, but mainly small tree 5–15 m high, exceptionally up to 20 m, with branchlets transformed into spines. It reaches an age up to 150 years.

Stem form and dimension: The slim, sometimes curved stem can reach more than 50 cm in diameter.

Bark: Light to dark grey, cracks into cube- or dice-formed pieces.

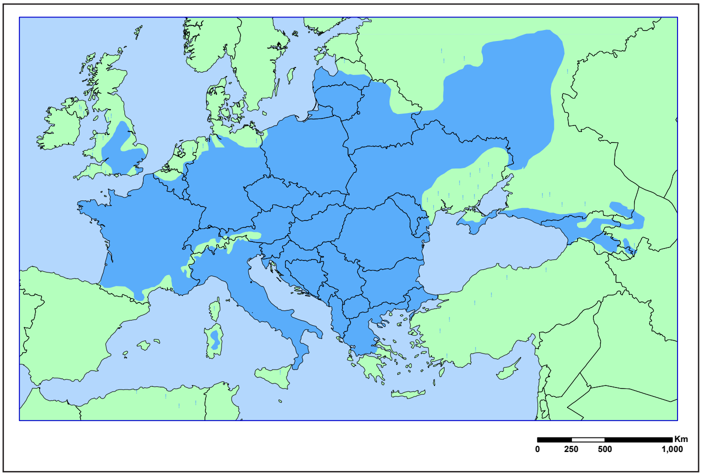


Figure 8.10-1: Natural distribution of wild pear. (EUFORGEN, 2009)

Timber: Sapwood and heartwood hard (imperfect heartwood); light brown-reddish in colour, old trees have a darker centre; very durable if dried, easy to work, takes polish well and has low shrinkage.

Root system: Deep-rooting.

Leaves: 3–7 cm long, 2–6 cm wide, with 3–5 cm long stalks.

Flowers: White flowers, occasionally pink, 3–9 in an umbel. Flowering period is April/May.

Fruits: Fruits ripen in August-October. They have an astringent acid taste and do not keep as well as crab apple.

Ecological characteristics

Forest type: Scattered in poorly stocked broadleaf woods, oak forests on dry soils, in bushes on rocky sites and oak-elm or ash-elm riverside and oak-hornbeam woods.

Light requirements: Light-demanding to slightly shade-tolerant.

Site requirements: Plains to sub-montane regions, but prefers warm sites.

Soil preference: Prefers fresh to moderately dry, nutrient-rich, deep, calcareous soils. It is much more site-demanding than crab apple.

Strengths and threats: Subject to heavy browsing by cattle and deer.

Regenerative capacity: Flowering starts at age 6–8 years.

Provenances: Cultivars tend to revert to wild forms. Therefore, even seeds from cultivated varieties may be used when seeds of wild pear are unavailable.

Values

Silvicultural values: Pear trees do not have a special silvicultural value.

Economic values: One of the most valuable timber species, even in small dimensions, if straight and free of branches. Used for veneer (panels), furniture, toys, music instruments (piano, recorder, resonance timber), turnery and carvings, model making, marquetry and as a substitute for ebony. On the Continent almost all timber comes from old big trees in pastures and gardens. But tall trees are becoming scarcer as new plantations, with trees grown on an espalier, are replacing the old garden trees.

Ecological values: Pear trees in forests increase diversity in many respects. The fruits are eaten by many animals, such as deer, as well as birds. Even foxes like them.

Amenity values: Pear trees are especially visible when flowering and add a favourable appearance to forest edges.

Historical importance: Apart from being one of the ancestors, for breeding the fascinating variety of cultivars, timber has been used for many purposes in the households and for tools as well as machinery. Furthermore, the fruits and leaves have been used in the treatment of bladder, gout and rheumatism complaints.

Growth characteristics

Four champion trees in Ireland have reached a mean height of 13 m, with a maximum of 15 m. Diameters had a mean of 60 cm and a maximum 70 cm.

Silvicultural management

It corresponds with that recommended for wild crab apple. Only the need for better site conditions need to be taken into account.

8.11 Plane

Family: *Platanaceae.*

Genus: *Platanus* is the only genus of the family. *Platanus* is derived from Greek: *platys* = broad, plain, flat. The genus comprises 7–10 species in North and Central America, Southern Europe and Asia towards the Himalayas. Three species deserve a short description: (1) Common or London plane, (2) Oriental plane and (3) American plane (*P. occidentalis*).

None is indigenous to Ireland or Britain. Oriental plane is an early introduction to Britain, but American plane came rather late.

Common plane plays a certain role in Ireland. Therefore, the main focus will be on this species.

8.11.1 Common or London plane

Scientific name: *Platanus x acerifolia* Att. Willd. (= *P. x hispanica* Münchh. = *P.x hybrida* Brot.) (*acerifolia* = maple-leaved).

Irish name: Crann plána.

Origin and geographic distribution: In many aspects common plane seems to be a cross between *P. orientalis* and *P. occidentalis.* It is, therefore, usually regarded as a hybrid of the two, but it is also possible that it might be a form of *P. orientalis*. Its real origin is unknown. Around 1650 it was found in southern Europe and was introduced to Britain about 1695. It is planted all over Europe as a park and avenue tree and is one of the commonest street trees.

Botanical characteristics

Tree and crown form: Trees of up to 35 m in height, occasionally 40 m, with a broad spreading crown of big branches.

Stem form and dimension: Mainly straight with diameters of 1–2 m. The old branches are twisted and horizontal.

Bark: Grey and smooth when young; when older, small round-shaped parts regularly flake away from the trunk to reveal a mosaic of large buff and yellow patches. This is a very typical aspect of the tree (refer to Plate 7.8-4).

Timber: Sapwood yellowish white or reddish, only vaguely distinguishable from the heartwood. A very typical feature is its distinctive silver grain when quarter-sawn. It has little weather resistance.

Root system: Deep-rooting.

Leaves: Large alternate, up to 25x25 cm, palmate, divided to less than halfway to the midrib into 5 triangular lobes with forward-pointing teeth.

Flowers: Male inflorescences are in 2–6 yellowish-green heads of flowers. The females usually are in 2–5 crimson heads.

Fruits: Fruiting heads 2.5 cm long, brown, remaining on the tree until the following spring, before breaking up to release abundant, white-haired seeds. 1–2 (3) fruits per peduncle.

Common plane: Lobes as wide as long, 1-2 (3) fruits per peduncle.

American plane: Lobes wider than long, 1 fruit per peduncle.

Ecological characteristics

Forest type: Almost exclusively used as a park and roadside tree.

Light requirements: Light-demanding.

Stress tolerance: Very resistant to pollution and urban climate; winter frost-hardy. It tolerates long periods of drought provided it has contact with groundwater. Very storm-resistant; it is hardly ever known to blow down.

Climatic preference: Light, sunny place in protected locations.

Soil preference: Best growth on fresh, deep soils, but gravelly ground is also suitable provided contact with groundwater is possible.

Strengths and threats: Vigorous, very tolerant of cutting and pollarding. The fungus *Ceratocystis fimbriata* has spread throughout Europe during past decades and attacks all three plane species. It causes a type of cankerous stain, mainly after mechanical injuries, and may kill the infected tree. Common plane sometimes suffers in central Europe from a brownish leaf disease (*Apiognomonia veneta*).

Regenerative capacity: Sprouts readily.

Growth characteristics

It shows hybrid vigour and even the largest and oldest trees will still add rapidly to their girth.

In Table 8.11-1, some height and diameter values of Irish champion trees are combined for comparison.

Common plane is one of the most magnificent broadleaves in Europe. This explains its high reputation. Oriental plane is slightly inferior and less often planted.

Table 8.11-1: Heights and **diameter** of common and oriental plane champion trees.

Species	Number of		Height		Diameter	
	trees	counties	mean (m)	max. (m)	mean (cm)	max. (cm)
Common plane	8	6	26	38	195	240
Oriental plane	7	6	20	29	85	210

Values

Silvicultural values: Common plane has not been used to any extent in forestry, therefore, no experiences can be provided.

Economic values: Common plane produces an attractive timber, which is sometimes used for veneer or inlay work, turnery and carving, but only very small amounts are available to the market.

Ecological values: Avenue specimens and solitaires are much appreciated for providing shelter and shade in summertime.

Amenity values: One of the most common street trees in Europe. This function is by far the most important aspect of this species (Plate 8.11-1).

Plate 8.11-1: Planes have become the most widely used tree in urban areas, especially for avenues. (Paris, France)

Silvicultural management

Production of plant material: Reproduction by seed is possible, but, despite their poor survival rates (about 10%), cuttings are mostly used.

Regeneration: By planting at the end of the vegetation period. Seedlings will then have reached a height of 30–40 cm and cuttings about 60 cm.

Tending and thinning: No experience available.

Conclusions

Despite its relatively early introduction into Britain, its good growth and its high timber quality, common plane has not been considered for forestry use. Evans (1984) argued that it merits further trials in forest plantings, but clearly its main value will be as an urban tree. The general attitude towards broadleaves and even rare species has, however, altered somewhat in the meantime. It may now be worthwhile considering its planting alongside streams, forest edges and prominent places, for example at road junctions in forests, to increase their aesthetic diversity where site conditions are suitable.

8.11.2 Oriental plane

Platanus orientalis L. is a tree of southern Europe (Greece, Macedonia), the Near East and northern Iran. It was introduced to Britain ca.1500 and is the oldest plane species there. It is often planted as an ornamental and park tree.

Botanical characteristics

Oriental plane forms a big tree with a large relatively open crown of remarkable diameter when growing in the open. It reaches heights up to 30 m. The stems are mainly straight and attain diameters of 1–2 m. It often has a rather low crown which makes it unsuitable for city streets. Its bark is less colourful than that of the common plane. It produces an attractive wood of medium density, easily workable, but not very durable. Its leaves are slightly deeper-curved than those of American plane, but less than those of common plane; they are cut into 5–7 narrow lobes, and the lobes are usually coarsely toothed. In this respect there is a striking difference to the common plane. Flower-heads hang in clusters of 3–6. Flowering period is April-June, starting at an age of 3–4 years.

Ecological characteristics and forestry use

Oriental plane grows in broadleaf mixtures (together with oak species) in the south eastern parts of Europe, preferably on wet soils along rivers, streams and lakes in the plains. It is reputed to grow well also on alkaline soils. It is relatively light-demanding and, according to some authors not very winter frost-hardy, while others mentioned that it can withstand winter frost as low as -20 °C.

Although showing good growth as a solitaire, it has – although introduced early into Britain – never been used as a forest tree on any scale (Evans, 1984). This may be due to its requirement of a warmer temperature and limited tolerance to winter frost. In western-Europe it is almost entirely planted in urban areas along avenues or as solitaires. The scenery in many cities and villages, for instance in southern France, cannot be imagined without the presence of intensively pollarded or shaped oriental planes. Its main importance is amenity and shelter against the sun. Nevertheless, its timber is also of some value and is sometimes used for veneer or inlay work, turnery and carving.

8.11.3 American plane

Platanus occidentalis L., also called American sycamore or American plane tree, occurs in almost all North American states, except those immediately west of the Great Plains. It is the only American plane species of any forestry importance. With heights up to 50 m and diameters of about 3 m, it is one of the largest broadleaves of North America.

It grows throughout most of the eastern half of the country from southern Maine to southeastern Nebraska, south into Texas and along the Gulf of Mexico to northern Florida (Collingwood and Porush, 1979). It is found – sometimes as a pioneer on fallow land – from sea level to about 1,000 m on moist alluvial sites alongside rivers and streams, together with other broadleaves like *Fagus grandifolia, Acer saccharum*, *Fraxinus americana*, *Betula nigra* and others. It is fast-growing and produces a hard and heavy timber, which is used for furniture, boxes, barrels, paper and is tolerant of industrial and traffic pollutants. It has never gained any importance in Europe including Britain and Ireland.

8.12 Poplar

Family: *Salicaceae* (= Willows).

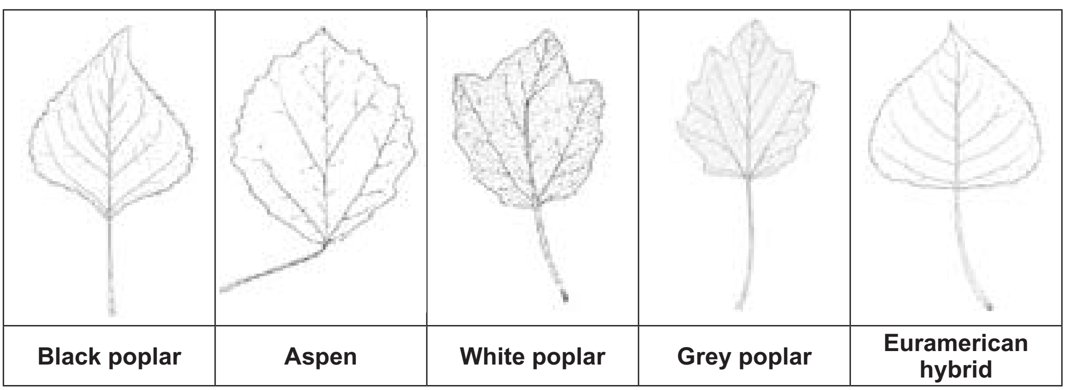
The family consists of deciduous trees or shrubs, many of them are arctic or alpine species. They are extreme pioneers.

The genus poplar is the favourite for genetic research and breeding because of its early flowering habit and easy hybridisation of its species. The first modern tree improvement programme began with poplar (*Populus* spp) in the USA in the 1920s, (Fennessy et al., 2013), and one of Ireland's earliest tree breeders was Augustine Henry who specialised in poplar breeding.

Genus: *Populus* (Latin from Roman times = poplar).

Species: Three main species are of relevance to Ireland (black and white poplar, aspen), as well as many hybrids. Balsam poplar from North West America is also worth consideration.

Form and size of the leaves help to differentiate the species.



Origin and geographic distribution: In all countries where poplars are native they received little attention during past decades. More recently, however, due to the degradation of riparian forests, the gradual decrease in populations of black poplar, and to a lesser extent white poplar, has led to increasing concern among nature conservationists.

According to NFI data (2013) poplar is recorded in only 0.1% of the stocked forest.

In the chapters below, the poplars are discussed in the following order: (1) black poplar, (2) aspen, (3) white poplar, (4) hybrids and (5) balsam poplar.

8.12.1 Black poplar

Scientific name: *Populus nigra* (nigra = black).

Irish name: Poibleog dhubh.

Origin and geographic distribution: Black poplar is widely distributed from Spain to far into Russia, but is absent from Scandinavia. It is also indigenous to the southwest of England (Figure 8.12-1). As black poplar was propagated by man in Eurasia for thousands of years, it is now difficult to reconstruct its local natural distribution.

It is not listed by Scannell and Synnott (1987) as native to Ireland, but according to Webb et al., (1996) it is *possibly native in the south and centre.*

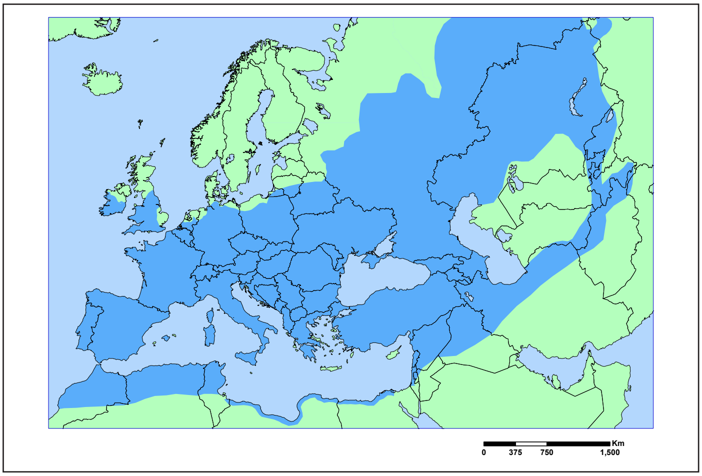


Figure 8.12-1: Natural distribution of black poplar.
(EUFORGEN, 2009)

Botanical characteristics

Tree and crown: A tall tree with rounded crown, but irregular branching. Old solitaire specimens may resemble old oaks.

Stem and branches: Large burrs and rough swellings on the stem, branches curving downwards, often bearing large, corky bosses. Twigs are glabrous and shiny orange-brown.

Bark: Old specimens show coarse, dark grey-blackish bark disturbed by veins and curls as well as epicormics.

Timber: Heartwood is light brown; sapwood is whitish-grey with clear annual rings, macroscopically resembling willow timber; soft and light (dry weight 0.34 g/cm³). It is of limited suitability for industrial use, mainly because of its curved stems, epicormics and poor natural pruning.

Root system: Primarily with a tap-root, but develops stronger main lateral roots later.

Leaves: Leaves alternate, pointed, somewhat rhombic, without glands.

Flowers: Poplars are wind-pollinated. Male and female catkins occur on different trees (dioecious). The male catkins are red, the female green. Flowering occurs early in March, long before leaves flush.

Fruits: Fruiting starts early, at around 10 years, and continues each year provided late frost does not damage the flowers. Seeds are tufted with hairs. The seeds, ripening in May/June, are viable only for some days.

Ecological characteristics

Forest type: Companion species of riparian forests together with willows (Plate 8.12-1).

Successional type: Pioneer in riparian zones.

Light requirements: Very light-demanding.

Stress tolerance: Tolerates deep winter cold and late frost.

Climatic requirements: Warm riparian zones in the lowlands.

Soil preference: Very demanding, growing best on soils well supplied with nutrients and water.

Strengths and threats: Little is known about biotic impacts. By far the most important threat is the destruction of its habitat by drainage and cultivation for agriculture.

Regenerative capacity: Under natural conditions, regenerating mainly by seeds, but is easily propagated from cuttings.

Provenances: Black poplar tends to hybridise with other poplars.

Plate 8.12-1: Black poplar in floodplain forests along the river Rhine. (Karlsruhe, SW Germany)

Growth characteristics

Height and diameter growth: In Ireland, five champion trees are listed reaching heights between 22–30 m with a mean of 27 m. Their diameters were 140–210 cm and a mean of 170 cm.

Age: 100, up to 300 years.

Total volume production: High volume producer, but, like its hybrids (see Chapter 8.12.4), very much dependent on site quality.

Values

Silvicultural values: Because of its generally poor stem quality, black poplar has been generally replaced by the Euramerican hybrids wherever timber production was the objective.

Economic values: Pulpwood; also used for match production and for window blind timber.

Ecological values: The decreasing area of black poplar has become an indicator of the diminishing riparian habitats which has gained international attention. Its conservation or – better still – its recapture of floodplains and riparian zones has, therefore, become a specific issue for ecologists and nature conservationists.

Amenity values: Magnificent old solitaires can be an attraction, but in general the Italian black poplar (Lombardy poplar), which has a more columnar growth habit, is much better known.

Historical importance: Black poplar timber has been used for the production of clogs and household goods (cutlery), boxes, turnery and small furniture items. Different extracts (salicine, oils, tannin) have been and are still obtained from the tree.

Silvicultural management

Production of plant material: Mainly from cuttings or even long sets.

Regeneration: On mineral soil, especially on fresh alluvial soil.

Tending and thinning: Poplars do not tolerate competition, even from the side, and need permanent free-crown growing space. As they are poor natural pruners, they have to be artificially pruned when quality timber is the goal.

Conclusions

Black poplar in recent times has gained more and more ecological importance. There is little likelihood, however, that it will gain any relevance in economic forestry because of the much higher production of many of its hybrids.

The columnar shaped variety, *Populus nigra Italica*, with straight upright branches, is the best known poplar for planting along roadsides and in urban areas (Plates 8.12-2 and 8.12-3). Many people regard it as the real poplar. Indeed, with the exception of horse chestnut, it seems to be the most popular tree species of all for this purpose.

Two champion trees in Ireland have reached heights of 30 and 31 m and diameters 110 and 160 cm.

Apart from its amenity value in towns, parks and avenues it is widely used for shelterbelts. As it is less site-demanding, it should be used more often in Ireland to protect forest plantations from wind exposure.

Plates 8.12-2 and 8.12-3: The 'Italian' or 'column poplar' is a mutant of black poplar. It has been planted everywhere in Europe and parts of Asia. (Plate left: Ankara, Turkey; right: Dresden, E Germany).

8.12.2 Aspen

Scientific name: *Populus tremula* for the fluttering motion typical of aspen leaves.

Irish name: Crann creathach.

Origin and geographic distribution: Aspen is native and common on poor soils throughout Europe, Russia, the Far East and as far as the Pacific Ocean, but restricted to mountains in the south (Figure 8.12-2).

It is by far the most important indigenous poplar species in Europe.

According to Webb et al., (1996), it is native to Ireland and fairly frequently found in glens and other wild or rocky places in the west and north, but rare in hedges in the east and south-east. It is also sometimes planted.

Botanical characteristics

Tree and crown: Pale looking tree 20–35 m, but often less. Narrow crown in its youth, later broad and flimsy, often irregular.

Stem and branches: Generally straight, sometimes slightly bent stem with little taper. Young twigs are thinly haired, becoming glabrous and dull later; grey-brown. Lower branches horizontal, upper branches directed steeply upwards.

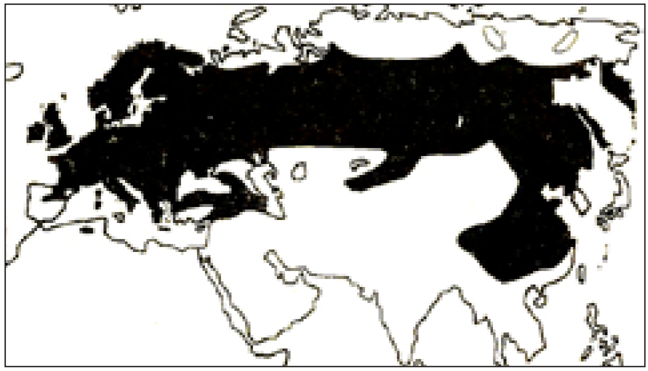


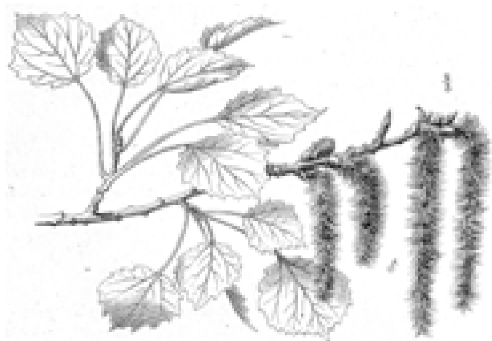
Figure 8.12-2: Natural distribution of aspen.
(Mette and Korell, 1982)

Bark: Smooth and greyish in earlier years. Later with deep fissures, greyish-black.

Timber: In contrast to all other poplars, aspen has only sapwood. The whitish, diffuse-porous, soft and lightweight timber has low shrinkage.

Root system: Primary with a tap-root, later stronger main side roots.

Leaves: Leaf buds narrow sharply cone-shaped. Leaves broadly oval to almost circular (1.5–8 cm); bluntly and coarsely toothed, dark green above, but pale beneath. The light, fluttering motions accentuate the flashing of their pale undersides. Leaves of suckers more heart-shaped and thinly hairy.



Flowers: Flower buds much bigger than leaf buds. Catkins (5–8 cm), often crowded on the tips of the twigs, appear before the leaves; males with reddish-purple anthers, females with pink stigmas. Capsules 0.4 cm long. Flowering period February-March/April.

Fruits: Inflorescence ripens at end of May, consisting of long-stalked greenish-brown slim capsules containing very small yellowish round seeds with white woolly hairs.

Ecological characteristics

Forest type: Open forests, on clearcut areas, fallows, rock piles, on forest fringes and alongside roads, as well as in hedgerows. Often mixed with birch, willow and oak.

Successional type: Pioneer; often following gorse, broom, blackthorn.

Light requirements: Very light-demanding.

Stress tolerance: Tolerates deep winter cold and late frost.

Climatic requirements: Very adaptable.

Soil preference: Not very demanding, but – as with most tree species – growing best on slightly moist soils, well supplied with nutrients, slightly basic to slightly acid sands or loams.

Strengths and threats: Almost no pest and insect problems. The leaves are disliked by deer and livestock, although palatable to sheep. Under certain circumstances, this gives aspen a survival advantage. Improves the soil by its easily decomposable litter. Has little storm-resistance.

Regenerative capacity: Seeds have a very short time-span for germination, needing to germinate within 8–10 days. Fruiting starts at age 20 years and is then generally on an annual basis. It suckers freely, but is very difficult to propagate from cuttings (in contrast to white and black poplar).

Provenances: Little tested. Tends to hybridise with other poplars (for instance grey poplar – see Chapter 8.12.4).

Growth characteristics

Height and diameter growth: Fast in the first 30–40 years, but height growth is finished at about 50–60 years. Diameter is 1 m at maximum. No champion tree has been recorded.

Age: 100 years maximum, but tends to develop rot in the centre of the stem much earlier.

Total volume production: Medium; lower than some other poplars. Production is very dependent on site quality.

Values

Silvicultural values: Ideal pioneer with soil improving properties. Sometimes used for timber production. Suitable as intermediate mixture. It is increasingly used as a nurse crop and for renewable energy plantations. This is especially the case with hybrid aspen (Plate 8.12-4).

Economic values: Pulpwood; also used for match production and for window blind timber. Because of its consistently whitish timber, it is often preferred by saw millers and other consumers.

Ecological values: Not specific.

Amenity values: Its trembling leaves are a special feature in hedgerows and forest fringes. Autumn colouring can be very bright (Plate 8.12-5).

Historical importance: For clog and feeding trough production, also as construction timber. Leaves and bark have been used in traditional medicine for their anti-inflammatory and fever-reducing properties, especially for bladder infections and scurvy.

Plate 8.12-4: Hybrid aspen grows vigorously on bare land, in storm affected areas – and on difficult soils – here on a waterlogged pseudogley. (Refer to Plate 4.4-22). (W Germany).

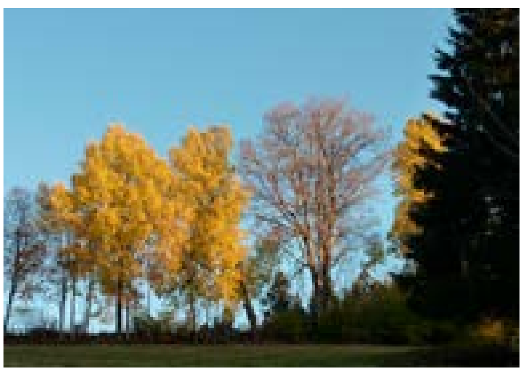


Plate 8.12-5: Autumn colouring of aspen can be especially flamboyant with bright yellow leaves. (Black Forest, SW Germany)

Silvicultural management

Production of plant material: Partly from seeds, partly from suckers. In contrast to other poplar species there is little possibility to raise it from cuttings.

Regeneration: On mineral soil, especially on burned-over land.

Tending of young stands: It will benefit from singling of root suckers and respacing of over-dense groups of regrowth.

Thinning: Where timber production is the aim, early release from competition is necessary.

> **Conclusions**
>
> Aspen regenerates freely, but very irregularly on various sites. Through early tending and thinning, its proportion could be increased without any planting. Nevertheless, its relevance will remain limited.

8.12.3 White poplar

Scientific name: *Populus alba* L., (alba = white).

Irish name: Poibleog gheal.

Origin and geographic distribution: A Eurasian species, native and common to central and east Europe as far as west Siberia, the west part of Asia and north Africa. It has been introduced to many areas, such as western and northern Europe (Figure 8.12-3). According to Rackham (1986), it is native to Britain or has been a very early introduction. Although it is found in many areas of Ireland, it is not native (Scannell and Synnott, 1987). It was most likely introduced as an ornamental.

As it is of very limited importance in Ireland, it will be described only briefly.

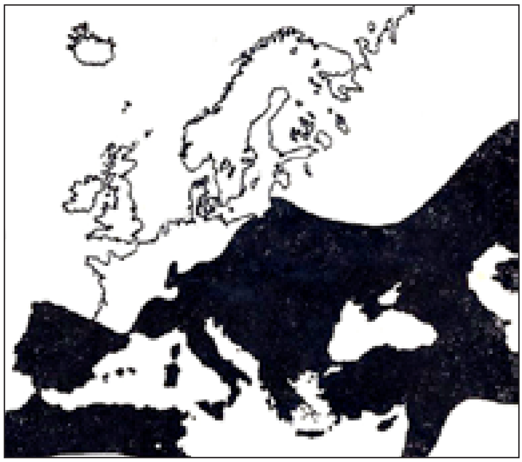
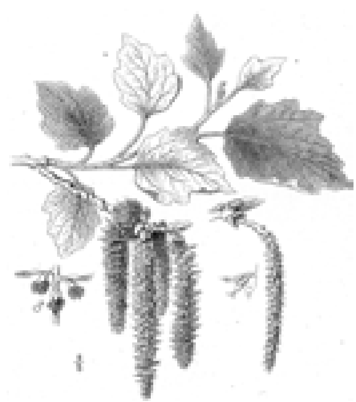


Figure 8.12-3: Natural distribution of white poplar. (Mette and Korell, 1982)

Botanical, ecological and growth characteristics

White poplar is a spreading tree of 20–40 m height, often with leaning trunk suckering at the base. It often occurs in groves. Like other poplars, it is a fast grower in the first 30–40 years. Two champion trees have reached heights of 26 and 30 m and diameters of 85 and 140 cm.



Twigs have white hairs for the first years, then become glabrous. The fissured grey bark with horizontal rows of black lenticels is typical of the species. Its timber resembles that of black poplar. The bicoloured leaves are conspicuous, forming another typical element for identification.

White poplar is also a pioneer and prefers a warm climate, but tolerates deep winter cold and late frost, as well as exposure. It suckers strongly on sand dunes.

It grows best on soft, wet ground, but is not specific and will grow on poorer ground also. Plant material can be easily propagated from cuttings. It tends to hybridise with other poplars (for instance grey poplar).

White poplar is also one of the endangered species. This is partly due to the fact that its hybrid, grey poplar is superior in growth and less site-demanding. There is little likelihood that it might gain more relevance.

8.12.4 Hybrid poplars

Grey poplar (*Populus x canescens*) is a natural hybrid of *P. alba x P. tremula*. It differs from aspen chiefly in the somewhat palmate lobed leaves, and the grey hairs on the buds, young twigs and lower side of the leaves, but can easily be mistaken for white poplar (Plate 8.12-6).

New foliage makes the crown appear silver-white, but by summer it is dark grey-green.

It was probably brought to the UK with white poplar, and this would also seem to be the case in Ireland. According to Webb et al., (1996) it is often planted in woods and hedges and spreads by suckers. It is moderately resistant to sea-winds.

It forms a magnificent tree of remarkable height and diameter: three champion trees have reached heights of 33, 40 and 42 m with diameters ranging from 165–190 cm.

The finest specimens tend to be in limestone country, but it can grow on sandy soils also, which means it is not very site-specific.

Its main value is ornamental and for use in shelterbelts. Because it is less site-demanding and more productive it will generally be preferred to white poplar.

Plate 8.12-6: With grey poplars, not only are the leaves grey underneath, but also the bark. (Paris, France)

Hybrids of European and N American poplars (*P. x euramericana* or *P. x canadensis*) were highly recommended for planting along agricultural field margins in the 1950s. They promised to be fast-growing and productive (Table 8.12-1).

These data show that hybrid poplars can reach almost 30 m in the first 20 years. At 40 years of age, they get up to 40 m. At that stage they may have a diameter of more than 60 cm and an average production of 26 m³/ha/yr. These figures are unique when compared with the performance of all other broadleaves growing in temperate zones (Plate 8.12-7). The data of the lower yield classes, however, reveal that the production decreases rapidly. In actual fact, poplars in the many plantations established at that time proved to be very site-demanding with regard to temperature, nutrient supply and steady water-flow. Most of them grew slowly, showed top dieback and were attacked by canker or other diseases. In general, these plantations were a disaster and caused much disappointment to the farmers involved.

Table 8.12-1: Yield table for euramerican hybrid poplars.
(Adapted from Blume, 1949)

Parameter	Unit	Yield class I		II		III	
		Age (years)					
		20	40	20	40	20	40
Height	m	29	39	24	34	18	28
Diameter	cm	31	63	22	49	-	-
Mean annual increment	m³/ha/yr	26	26	12	14	11	8

Some poplar hybrid champion trees in Ireland also have the potential to reach impressive dimensions: *P. x canadensis Serotina* with 44 m in height and 170 m in diameter and *P. canadensis Robusta* with 35 m height and 110 cm diameter are examples.

Hybrid poplars have gained great, in some cases even forestry-dominating, importance in warmer climates and on appropriate riparian soils. This has been the case in a wide belt from southern Europe (River Po in Italy) to Near East (northern Turkey), Asia (River Indus and Ganges) and finally China. In some of these situations they are especially relevant as a green belt against wind erosion.

In recent years, poplars and willows are under consideration in **r**enewable **e**nergy **m**anagement (REM) experiments in the form of **s**hort **r**otation **c**oppice (SRC) (refer to Chapter 4.2.3.2). As mentioned, they also need adequate sites (lowland, agricultural fields, sufficient water supply), and their cultivation often has to compete with agricultural or other renewable energy crops. It is difficult, therefore, to forecast their future relevance in the temperate western and northern parts of Europe. An increase in temperature, because of climate change, could possibly expand the opportunities to grow them successfully, even on areas which are cooler today.

Plate 8.12-7: Euramerican poplar hybrids are very productive, but mainly on alluvial sediments in the vicinity of flowing water, where nutrient conditions are also very favourable. (Dresden near the River Elbe, E Germany)

8.12.5 Balsam poplar

Balsam poplar or black cottonwood (*P. trichocarpa* Torr. & Gray), because of its superior growth rates, has been planted at a moderate scale in Central Europe. It is less site-demanding – with regard to climate as well as soils – than the native and euramerican poplar hybrids, but it is still restricted to a limited area of suitable sites. Nevertheless, it may gain some relevance in Ireland in the long term and is, therefore, described here (Plate 8.12-8).

According to Niemiec et al., (1995) balsam poplar is the tallest, fastest-growing hardwood in the western USA (Kodiak Island – 62 °N to Northern Baja, California – 31 °N and eastward to the Rocky Mountains). There it grows in a wide range of climates (from humid to arid), but best on deep alluvial soils with good aeration and abundant moisture.

It develops narrow, cylindrical crowns with long clear boles. It matures as early as 60 years and lives for at least 200 years. Its nondurable, soft, light timber with uniform texture is used for pulp and paper, successfully sawn into lumber and peeled for veneer (for core plywood or interior furniture parts). The heartwood is less penetrable by preservatives. As a pioneer, it is intolerant of shade and, therefore, commonly occurs as scattered, emergent trees, with crowns far above associated species in stands of very different mixtures.

Regeneration is common after logging on more upland sites. It sprouts easily from stumps or fragments of branches. Newly planted balsam poplar is extremely sensitive to vegetative competition, but early growth of densely stocked balsam poplar suppresses competing vegetation easily. It must maintain a dominant crown position to survive and grow.

Young trees are susceptible to damage from early or late frost.

Plate 8.12-8: Balsam poplar, as well as the very soil-demanding euramerican poplar hybrids, shows good growth even on suboptimal sites. (Castlemorris, Co Kilkenny)

High numbers of wildlife are typical in riparian areas, where deer can devastate plantations through browsing and antler rubbing. Wind breakage is common sometimes as a result of decay caused by fungi.

Sawlog can be grown in 20–25 years.

Balsam poplar has outstanding potential for genetic improvement and manipulation with superior clones and hybrids (*P. trichocarpa x P. deltoides*).

Conclusions

Poplars have gained publicity for various reasons at different times:

- Black and white poplar are endangered species as a result of the deterioration of their habitats (riparian regions with alluvial soil). Their retreat is an indicator of the destruction of a highly sensitive type of ecosystem. Therefore, they have come into focus for nature conservationists.
- The impressive growth potential of hybrid and balsam poplars was overemphasised some decades ago, as the great demands of these species with regard to warm temperatures, perfect nutrient and water supply was under-estimated. The result was poor growth and disappointment for growers. Only recently they have gained new attention as potential species for fast-growing, short rotation coppice woodlands. However, it is reasonable to expect that there will be few sites available that meet their demands. Moreover, poplar planting competes directly with agricultural uses and objectives.

8.13 Rowan, whitebeam and service trees

Family: *Rosaceae*, Rose family, subfamily *Maloideae* (apple trees).

Genus: *Sorbus* (classical Latin for rowan or whitebeam); 80–100 species of deciduous trees and bushes in the northern and temperate regions, which tend to hybridise freely and form many hybrids, causing problems of identification and classification. The genus *Sorbus* is closely related to *Pyrus* and *Malus* (pear and apple). Leaves are partly simple, partly imparipinnate. This is the most important feature for distinguishing between species within the genus *Sorbus*.

Species: Four species will be described: (1) rowan (*Sorbus aucuparia*), (2) whitebeam (*S. aria*), (3) wild service tree (*S. torminalis*) and (4) true service tree (*S. domestica*).

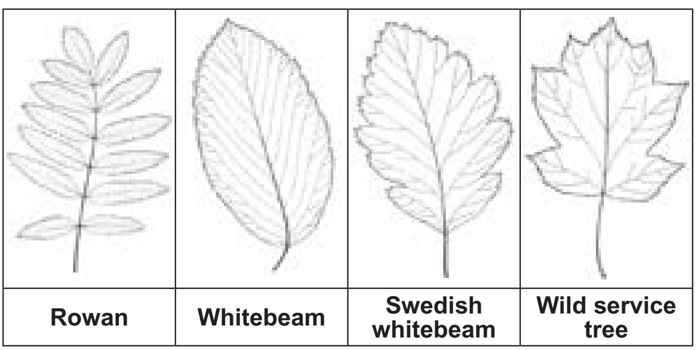
The shape of leaves helps to distinguish between them. True service tree leaves, however, resemble those of rowan.

8.13.1 Rowan

Scientific name: *S. aucuparia* (*au>avis* = bird, *cuparia>capere* = to catch). Shoots have been used to make birdlime and berries to catch birds.

Synonymous common names: Mountain ash, quicken tree.

Irish name: Caorthann.



Origin and geographic distribution: Native to most of Europe and frequently planted as a street tree (Figure 8.13-1). Occurring as several subspecies. According to the NFI data (2013) rowan is recorded on 0.6% of the stocked forest area and is, therefore, one of the more important species within the other short-living category (refer to Table 1.5-5).

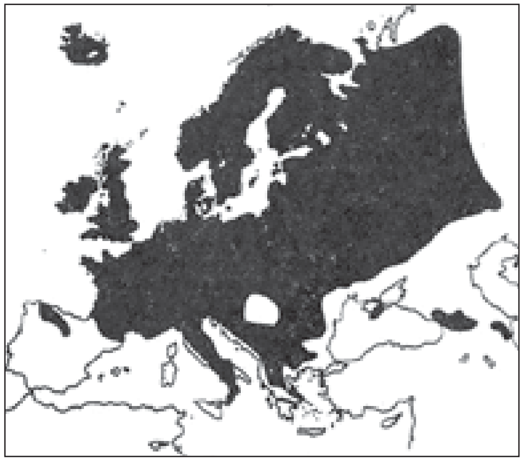


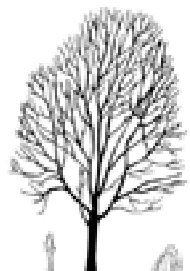
Figure 8.13-1: Natural distribution of rowan.
(Mette and Korell, 1982)

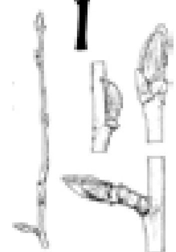
Botanical characteristics

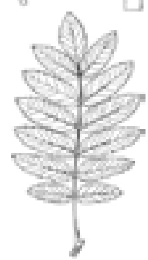
Tree and crown form: Smallish to medium sized (5–20 m), with an irregular-formed, often rounded, open crown. Under climatic stress conditions, it exists only in bush form.

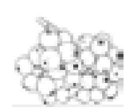
Stem form and dimension: Slim, roller-formed, up to 40 cm diameter. Spreading branches partly ascending.

Bark: Smooth, yellowish green-grey with fine fissures. Blackish when old.









Timber: Dense, hard, of yellowish light brown colour, diffuse porous.

Root system: Heart-root system with long sideshoots.

Leaves: Alternate, pinnate leaves, about 20 cm long and 8–12 cm wide, divided into 5–10 pairs of oblong leaflets, each 3–6 cm long; leaflet blades are toothed in the upper part, asymmetric at the base with grey hairs below. They are fresh to dark green above, grey-green below, turning to bright yellow on dry soils, becoming blood red in autumn. This is more spectacular at high elevations than in towns.

Flowers: With 5 petals and 3–4 styles; 0.8–1.0 cm in diameter. The white flowers occur in clusters; flowering period May-July.

Fruits: Clusters of globose or oval fruits, 0.6–0.9 cm long, yellow at first then turning to bright scarlet, embedded in orange pulp; ripening in August-September. Fruiting starts at an age of about 10 years and continues yearly with a rich crop. They remain dormant for a period and germinate after 2–8 years.

Ecological characteristics

Forest type: Rowan has an extremely wide distribution within the whole of Europe. It is a companion species of almost all forest types in the establishing phases, in woods or open places. In Central Europe, it is the typical tree of higher elevations with an extreme climate, up to the tree line – therefore, the name 'mountain ash' (Plate 8.13-1). It means that it can grow in severe climatic conditions near the tree line in Ireland. It also grows well at lower elevations, but here it is usually suppressed by more competitive species.

Successional type: Pioneer species on a wide variety of sites.

Light requirements: Light-demanding to slightly shade-tolerant. Therefore, it is able to form an understorey in old open stands, like those of Scots pine.

Stress tolerance: Exceptionally hardy to all types of frost, very tolerant of drought and especially of wind.

Climatic requirements: Grows higher in the hills and mountains than almost all other European broadleaf tree species, and partly forms the tree line (above 1,000 m in Scotland, 2,400 m in the Alps).

Soil preference: Rowan is not very site specific and tolerates a wide variety of soils from acid to calcareous, but excluding waterlogged conditions. It can be found on dry and wet sand, stone and peaty soils, poor in nutrients. It grows best – like almost all other species – on light textured brown earths or fertile peat, but it is – like Scots pine – one of the least site-demanding tree species of Europe.

Strengths and threats: Subject to intensive browsing and bark-peeling by all deer species and, therefore, it is often totally stunted into bush form.

Plate 8.13-1: Rowan occurs at high elevations – here at 1800 m in Montenegro, together with Norway spruce and mountain pine.

Regenerative capacity: Because of its yearly fruiting and wide distribution by birds rowan is easily spread over large areas. It coppices strongly and produces root suckers. Even if heavily browsed, it is able to resprout from the stumps.

Provenances: Not specifically tested.

Growth characteristics

Young rowan grows fairly fast, but falls back at a later age and stops growth as an intermediate tree species. Three champion trees have been recorded in three counties. They showed a mean height of 14 and a maximum of 18 m. Diameters were between 50 and 95 cm.

Age-span is normally around 80 years. As a pioneer rowan seldom exceeds 100 years.

Rowan has never been managed to date and never been grown in pure stands. Therefore, no data on volume production are available. Its production would appear to be relatively low in comparison with other pioneer species.

Values

Silvicultural values: Rowan has been neglected over long periods of forestry practice. The common practice has been to remove it as a weed from forest plantations. Its useful function as a shelter tree during the establishing phase of young stands has only recently been realised. It is now increasingly used as a nurse crop, especially in higher elevations. Furthermore, it makes a useful component of upland shelterbelts. It is also one of the species used in the restoration of soils which have been subject to erosion.

Economic values: Dense, hard timber that is good for turnery, carving and small furniture. It makes a good firewood. The edible fruits contain sorbitol (from *Sorbus*), which can be used as a sugar substitute by diabetics. After elimination of bitter constituents it can be used for stewed fruit, marmalade, juice and brandy. The variety, Moravian or sweet rowan (*S. aucuparia var. dulcis*), is often planted along roads for fruit production.

Ecological values: Well liked by many birds, especially by the thrush, but also by deer, foxes and badgers (Plate 8.13-2).

It improves the soil because of its easily decomposable litter.

Amenity values: Due to its early fast growth, it is often planted as a park and avenue tree. Both the clusters of white flowers in late spring and bunches of red fruit in autumn are a conspicuous attraction.

Plate 8.13-2: Rowan 'bundles' of fruits are both aesthetically pleasing and food for birds and small mammals. (Central Sweden)

Historical importance: The fruits and dried leaves have been used since time immemorial against scurvy (rowan = lemon of the north). Rowan was associated with superstitious traditions in the Middle Ages.

Silvicultural management

Production of plant material: Germination is delayed because of dormancy. Even after stratification, problems can arise in raising seedlings in the nursery. Wildings can be easily collected in areas where they have developed naturally.

Regeneration: Mostly naturally regenerated from seeds that are widely dispersed by birds (Plate 8.13-3).

Management: Trees are often multi-stemmed because of browsing. In such cases, shaping, singling and pruning are recommended. Early thinning is necessary to prevent its crowns being overtopped by other dominating tree species.

Plate 8.13-3: Rowan, although a pioneer species and tolerant of exposure, benefits from shelter – seen here in a gap in a Norway spruce stand. (Black Forest, SW Germany)

Conclusions

Long regarded as a weed, rowan has only recently gained attention as a valuable broadleaf component in conifer woodlands, especially on poor soils and in regions with extreme climate. Even the value of its timber was not recognised. Evans (1984) argued that rowan … *is unlikely ever to become a timber tree*. At that time, the assessment was also the general view of most continental foresters, but more recently this attitude has changed totally.

On the Continent rowan regenerates impressively wherever the deer population is drastically reduced, demonstrating that rowan could play a possible role, provided the

Continued

Conclusions continued

main regeneration problem was solved. In the future, rowan may also gain importance in Ireland, as a nurse crop and shelter tree, as well as a component of forest fringes. By shaping and pruning single hedgerow trees, rowan has the potential to produce some small dimensional quality timber.

8.13.2 Whitebeam species

Scientific name: *Sorbus aria* (L.) (from Greek: whitebeam)

English Synonym: Chess-apple.

Irish name: Fionncholl

Origin and geographic distribution: Is native to woods in most of Europe, mainly in the mountains of the south, but absent in northern Europe (Figure 8.13-2).

Whitebeam is very rich in forms. It includes several species, subspecies and hybrids which are difficult to differentiate. Many are native to Ireland and – especially *S. aria* – are most common in the south of Ireland (OCarroll, 2004). They are listed in Table 7.13-1. All are relatively similar. According to Webb et al., (1996) further investigation of Irish material is needed. *S. hibernica* is classed as the commonest species. Only Swedish whitebeam (*S. intermedia*) is not native.

Figure 8.13-2: Natural distribution of whitebeam. (Mette and Korell, 1982)

Table 7.13-1: Whitebeam species and hybrids in Ireland. (Adapted from Webb et al., 1996)

NAMES			CHARACTERISTICS	OCCURRENCE
English	**Scientific**	**Irish**		
Irish whitebeam	*Sorbus hibernica*	Fioncholl gaelach	Leaves oval, teeth symmetrical. Fruit red.	Woods, cliffs, rocky places usually on calcareous soils; occasional.
Whitebeam	*S. aria*	Fioncholl	Leaves sometimes shallowly lobed. Often densely white-hairy beneath.	Rare as native, locally frequent (Galway), scattered as an obvious introduction elsewhere.
Rock whitebeam	*S. rupicola*	Fioncholl creige	Leaves toothed only in the top two-thirds.	Mainly in the west and north; occasional.
-	*S. anglica*	Fioncholl gallda	Leaves shallowly or moderately lobed.	Killarney only.
-	*S. devoniensis*	Fioncholl Domhnann	Leaves usually shallowly lobed near the base. Fruits orange-brown.	Rare, known only from the south-east corner of Ireland.
Swedish whitebeam	*S. intermedia*	Fioncholl Lochlannach	Leaves with large, deep lobes at least at the base.	Known only from counties Galway, Dublin and Wicklow.

Obviously, one needs to be a specialist to identify the differences between the species. Nevertheless, whitebeam as a group is easy to identify (Plate 8.13-4).

In the following sections the whitebeam group (*S. aria* agg.) will be described in general.

Botanical characteristics

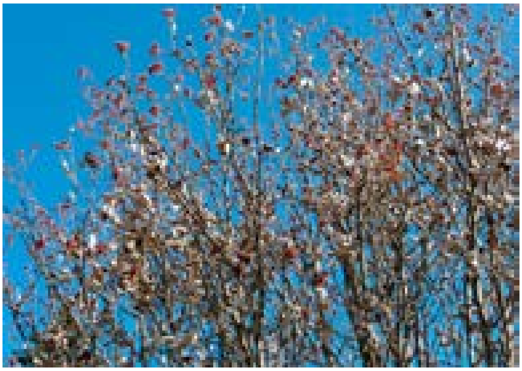


Plate 8.13-4: Whitebeam has a typical white floury underside to the leaves.
(1400 m in Black Forest, SW Germany)

Tree and crown: Bush or medium-sized tree standing out from its surroundings, 5–25 m in height. It is most noticeable because of its leaves, which have white undersides. Very rich in different forms: irregular, upwardly directed or flattened crowns.

Stem and branches: Trunk is often multi-stemmed, frequently bent and flared. The coarse twigs are hairy at first, becoming glabrous later.

Bark: Young trees with a glossy, greyish-silver bark, later with parallel fissures.

Timber: Hard, with a white-yellow sapwood and a reddish-brown heartwood.

Root system: Deep-reaching, with a high capacity for sprouting and production of suckers.

Leaves: Alternate, green above with white dense felty undersides; 5–14 cm long, oval with irregular teeth curving towards the rounded tip, with 8–14 veins.

Flowers: White in branched clusters, each flower 1–1.5 cm in diameter. Flowering time May-June.

Fruits: Ovoid fruits, 0.8–1.5 cm long, scarlet with many lenticels. Ripening in August-September, but remain for long – until winter – on the tree. Slightly toxic because of parasorbinic acid content, but this is decomposed after the first frost.

Ecological characteristics

Forest type: Native to woods, mainly in oak and beech forests on dry sites.

Successional type: Pioneer

Light requirements: Very light-demanding.

Stress tolerance: Frost- and drought-resistant. Poorly competitive, therefore, able to grow in mixture with other broadleaves only in open, slow-growing, woodlands or on rocky ground, where it cannot be overtopped by neighbours.

Climatic requirements: Preferably warm southerly slopes; often on rocky soils at altitudes over 1,000 m in Central Europe.

Soil preference: Wide range from mild acid, sandy and stony soils, but preferably those originating from limestone.

Regenerative capacity: Seeds are widely dispersed by birds and squirrels.
Regenerates well from sprouts and root suckers (Plate 8.13-5).

Growth characteristics

The whitebeam species are slow-growing. Two champion trees were 12 and 20 m high and 40 and 85 cm in diameter respectively.

The Swedish whitebeam had four champion trees in four counties. These reached heights between 12 and 14 m and diameters between 70 and 95 cm respectively.

Whitebeam has a lifespan up to 200 years. There are no data in regard to volume production available as it is always growing in mixture with other broadleaves.

Plate 8.13-5: Whitebeam coppices easily and is often used for fuelwood. Therefore, it seldom forms real trees. (1400 m at Black Forest, SW Germany)

Values

Silvicultural values: None specific to whitebeam.

Economic values: Timber is used for turnery and for manufacture of small furniture items by carpenters. It is similar to rowan, but without much market relevance because of low production.

Ecological values: Important as winter food source for birds and small mammals.

The felty hairy leaves filter out aerial dust. This is the main reason why whitebeam has become a common street tree.

Amenity values: The silvery underside of the leaves provides a very special visual appeal.

Historical importance: Uses are comparable with those of rowan in traditional medicine. Fruits have been widely used as pig fodder and, in times of need, mixed with flour for baking bread. On a small scale, the berries are still used in central Europe for production of marmalade, juice and brandy.

Silvicultural management

No measures for regenerating or managing whitebeam have been undertaken so far.

Conclusions

Whitebeam and its many subspecies, varieties and hybrids, add specific aspects to the biodiversity of open woodlands, rocky areas, hedgerows and forest edges in warmer regions. Furthermore, they provide winter food for many animals and birds. They even produce a small amount of sawtimber.

They should be favoured wherever possible and released from competition of dominating neighbouring trees.

8.13.3 Wild service tree

Scientific name: *Sorbus torminalis* (= relieving abdominal pain or colic).

Synonymous English name: Chequer tree.

Irish name: Crann soirb.

Origin and geographic distribution: Indigenous to south east Europe, reaching as far as North Africa and Asia Minor. It is native to England (south eastern region and extending locally to the limestone areas of the southern Pennines and Cumbria) (Figure 8.13-3). It is often associated with the warm temperate climate of wine growing areas and is widely planted alongside roads in more northerly regions of Europe. Not native to Ireland.

Botanical characteristics

Tree and crown: Large spreading bush or domed tree up to 25 m in height, with a round crown and spreading branches (Plate 8.13-6).

Stem and branches: Twigs are shiny brown.

Bark: Flat-grey when young, later dark brown-grey with vertical fissures.

Timber: Whitish-reddish, later brownish sapwood and red-brown heartwood. Very dense, elastic, heavy and hard timber.

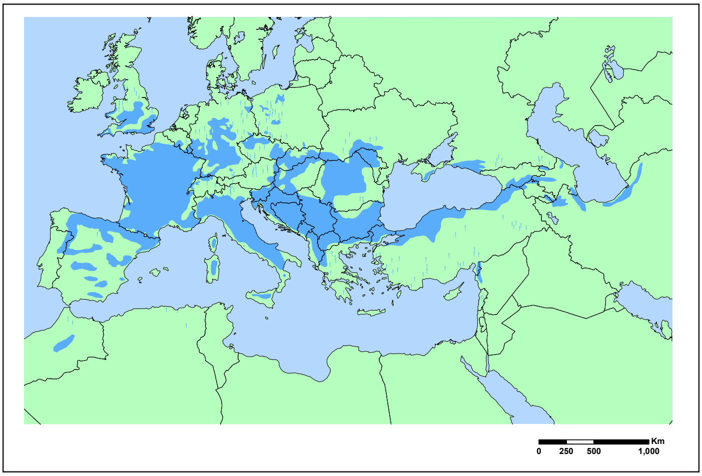


Figure 8.13-3: Natural distribution of wild service tree. (EUFORGEN, 2009)

Root system: Tap-root in youth, later heart-root system. Poor sprouting ability, but grows from suckers.

Leaves: Oval with 3–5 pairs of toothed, pointed deep lobes, 5–10 cm long, 4–8 cm wide. Dark green above, hairy beneath when young and almost glabrous when mature. In autumn they turn a luminous yellow and/or deep red.

Flowers: 1–1.5 cm in diameter, white, borne on woolly stalks in branched clusters. Flowering May-June.

Fruits: Brown berries (different from other *Sorbus* species), up to 1.5 cm in diameter, fleshy and dotted with numerous lenticels. Fruiting starts at 20–30 years and continues annually. When over-ripe become pasty and are then edible.

Plate 8.13-6: A wild service tree with a straight trunk will produce a very valuable high quality log. (Lorraine, France)

Ecological characteristics

Forest type: Scattered and widespread in deciduous woodlands of birch-oak. Preferentially associated with dry sessile oak woodlands.

Successional type: Pioneer to intermediate tree species.

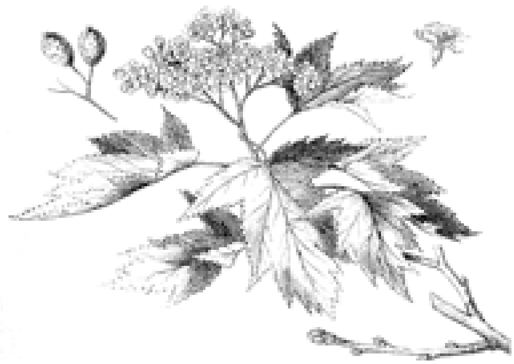
Light requirements: Light-demanding to reasonably shade-tolerant.

Stress tolerance: Relatively drought-tolerant.

Climatic requirements: Dry, moderately warm shallow (stony) sites of lowlands and submontane regions.

Soil preference: Preferably alkaline soils.

Strengths and threats: Not documented.



Regenerative capacity: Regenerates well from root suckers.

Provenances: Wild service tree is the only *Sorbus* species that does not hybridise.

Growth characteristics

The wild service tree is slow-growing and reaches an age of over 100 years. As it always grows in mixture, no volume production data are available.

Values

Silvicultural values: The wild service tree can be a valuable admixture with sessile oak on appropriate sites.

Economic values: The very valuable timber is used mainly for furniture and fine woodwork and is traded under the name 'Swiss pear wood'. Together with high quality veneer oak and wild cherry, it has commanded outstanding prices in France and Germany for decades.

Ecological values: It provides food for birds and small mammals in late autumn.

Amenity values: In Britain it is considered as one of the most attractive of the few native species (Mitchell, 1989).

Historical importance: The timber was always highly valued by carpenters, joiners, turners and coach builders. Its fruits, both fresh and dry, have been used to counteract diarrhoea and cough.

Silvicultural management

Production of plant material: Seeds are dormant and need special treatment in the nursery.

Regeneration: It regenerates naturally, provided seed trees are available.

Management: Because of its slow growth it is always liable to be overtopped by individuals of other tree species and, therefore, needs effective and continued release from competition.

Conclusions

Like the other *Sorbus* species, the wild service tree has been overlooked for a long time. Its high site demands limit its opportunities for good growth in Ireland, but there are some areas of alkaline soils on warmer sites, especially in the south, which would suit its requirements. Its relevance, therefore, as a welcome mixture tree could be substantially improved. As a single tree in hedgerows, and an element of forest edges, it can be a valuable supplement to the native flora.

Its extremely high timber value may act as an incentive to support its propagation in the future.

8.13.4 True service tree

Sorbus domestica L. is native to south central Europe, extending as far as North Africa and Asia Minor. Like the wild service tree, it is associated with the warm temperate climate of wine growing areas, but it was also widely planted mainly in gardens and orchards in more northerly regions. Its leaves are very similar to those of rowan. The bark, however, is raw and scaly. Its bitter tasting fruits have been used as an admixture especially for cider.

The true service tree is slow-growing, seldom exceeds a height of over 20 m and is said to be able to reach an age of 500–600 years. Its timber is very hard and heavy and was used for technical installations subject to abrasive wear.

Conclusions

The true service tree could add to the diversity of the Irish forests and landscape, although its propagation and management is problematic.

8.14 Southern beech

Family: *Fagaceae*

Genus: *Nothofagus* (Greek: false beech, probably meant to be 'Notofagus' = southern beech). The genus is confined to the southern hemisphere. It contains around 40 species which are partly distributed in the temperate zone of New Zealand, Australia and South America. Most are evergreen, but seven species are deciduous, of which six are from Chile and Argentina.

Leaves and twigs are alternate. Their seed cups with 3–7 nuts resemble those of European beech, but are smaller.

Species: According to Tuley (1980) 17 *Nothofagus* species have been tried in Britain and Ireland. Roble beech (*N. obliqua*) and rauli (*N. procera*) have to date been the most promising in Ireland and the UK, and seem to have the greatest potential as forest trees. Therefore, only these are described in the following sections. Comments on the growth of other *Nothofagus* species are made in Chapter 9.5.

Roble and rauli were only introduced to the UK as late as the first quarter of the 20th century.

The frost hardiness of seedlots of both species was measured experimentally in a trial in Britain over three winters. All seedlots hardened very slowly in the autumn and were damaged to some extent by temperatures below – 14° C (Murray et al., 1986). Having examined records of previous temperatures in the UK, the authors suggested that both species had a high risk of suffering severe frost damage at least once in their rotation in all but the mildest regions. Spring and autumn frosts were considered to be more damaging than winter frosts.

According to NFI (2013), *Nothofagus* species occupy around 140 ha in Ireland, but no information is provided in regard to species.

Origin and geographic distribution: Both species (roble and rauli) are native to South America, from Chile to northern Argentina (see distribution map in Chapter 9.5).

Tuley (1980) has documented experiences gained on the two species in Britain, and the following text is partly based on his Forest Record.

8.14.1 Roble beech

Scientific name: *Nothofagus obliqua* (from Latin: the slightly oblique leaf).

Common name: Roble (from Spanish: oak).

Origin and geographic distribution: Native to Chile (see distribution map in Chapter 9.5). It was planted for timber in Britain and became increasingly popular as an ornamental. It is – possibly because of its greater climatic tolerance – more often seen than rauli.

Botanical characteristics

Tree and crown: A remarkable fast-growing, deciduous tree with an open crown of arching branches, up to 30 m in height.

Stem and branches: Slender raised branches, rather brittle and fine willow-like shoots hanging from the upper crown.

Bark: Grey bark, initially smooth, later rough and cracked.

Timber: Dark reddish brown with a lighter coloured sapwood. It is reported to be extraordinarily resistant to decay.

Root system: Roble has shown poorly developed root systems when grown in plantations at close spacing and on wetter sites.

Leaves: Buds are 4–5 mm in length and shorter than those of rauli. The leaves, dark green above and paler beneath, turn yellow or red in autumn. They are similar to those of European beech, but asymmetric at the base, tips less pointed, margins irregularly toothed and veins in 7–11 pairs.

Flowers: Male and female flowers borne in axils of leaves. Males solitary, females usually in threes, enclosed by a single stalkless, deeply fringed, 4-lobed involucre. Flowering February-March.

Fruits: Fruiting involucre reaches 0.8 cm long; the lobes spreading to release the 3 nutlets, each 0.5 cm long. The ripening seeds change from green to pale brown, and ripe nuts fall throughout August and September. Because of the frequently large numbers of empty seeds, their quality in general is low. The nuts are seldom dormant and germination is not improved by pre-chill treatment.

Ecological characteristics

Forest and successional type: Roble grows mainly in mixture with several other broadleaves in its natural habitat. In Chile it also reinvades bare abandoned land forming a type of pioneer forest. It can be classified as a long-living pioneer.

Light requirements: It is light-demanding.

Site requirements: Roble generally occurs on warmer, drier sites than rauli, but – as found in the southern part of the Chilean central valley, where cold air collects from the surrounding mountains – it is able to withstand frostier locations. Therefore, seed from these regions is preferable for areas with low winter temperatures. Roble, however, is not suitable for exposed sites.

Soil preference: Roble grows well on soils ranging from deep sands to fairly heavy clays and does better on drier soils than rauli. Nevertheless, it is relatively demanding with regard to nutrients.

Strengths and threats: Roble is susceptible to drought as noted after the 1976 drought period. Late spring and early autumn frost may also cause problems. A number of native

British insects have been found feeding on *Nothofagus*, but appear not to have seriously affected timber growth as the trees recovered rapidly. In 2009, at a site in Cornwall, 12 – 18-year-old trees of roble and rauli were reported with extensive dieback and mortality. Trees had bleeding lesions on trunks and branches and the causal agent was identified as *Phytophthora pseudosyringae*. During 2010 and 2011 *P. pseudosyringae* was isolated from mature and semi-mature trees of both species in England, Scotland and Wales, all showing similar symptoms (Scanu et al., 2012).

Grey squirrels rarely attack roble and rauli, although sycamore and beech in the vicinity were seriously damaged.

Regenerative capacity: No information is available about the natural regeneration possibilities of roble.

Provenances: In Chile, roble covers a large area from the definitive Mediterranean climate to the relatively warm temperate zone. Because of its frost-intolerance, only provenances from the southern border of its distribution should be used.

Growth characteristics

Height and diameter growth: Roble is fast-growing, but slightly less so than rauli. According to Tuley (1980), 26– to over 70-year-old roble trees have reached heights of 21–29 m and diameters of 47–105 cm. For five champion trees in Ireland the equivalent data are 17–32 m in height and 90–110 cm in diameter. The ages of these trees, however, were not recorded.

Age: In its natural habitat it lives for several hundred years.

Total volume production: According to British experiences and studies, these two *Nothofagus* species are much superior to all European broadleaves in regard to yield class and height development (Table 8.14-1).

Table 8.14-1: **Growth comparisons between *Nothofagus* and some European broadleaf tree species.**
(Tuley, 1980)

Species	Yield class (m³/ha/yr.)		Height (m) at age 10 years	
	mean	range	mean	range
Oak	6	4- 8	3.9	2.5- 5.1
Beech	7	4-10	3.8	2.1- 5.5
Ash	6	2-10	6.8	4.1- 8.9
Sycamore	8	4-12	6.8	4.1- 8.9
Nothofagus	14	10-18	9.2	6.8-10.8

Values

Silvicultural values: Its fast growth in youth ensures that it will not be overgrown by other broadleaves and is, therefore, a perfect mixture tree species.

Economic values: Slightly less valuable than rauli.

Ecological values: Roble did not suffer from frost during recent decades as there were not any particularly severe winters.

Amenity values: Roble has high ornamental values, but it should be kept in mind that it is able to reach remarkable dimensions and should not be planted in small gardens.

Silvicultural management

Production of plant material: According to Tuley (1980), seed supply was scarce at the beginning of its introduction, but now this should not restrict planting. The nuts of European beech can be successfully stored for only 2–3 years, if kept dry and in a cold store. In sharp contrast, the seeds of both *Nothofagus* species can be stored for up to 20 years, if kept dry at 2 °C.

Regeneration: Planting with 1+1 year old transplants of around 60 cm height is the normal procedure.

Tending and thinning: Roble should always be given sufficient space in order to be able to use its capacity to become a tall tree with a wide crown. Moreover, intensive thinnings could provide the possibility that development of the root system might be improved, thereby stabilising the tree against wind-throw.

> **Conclusions**
>
> Roble may have some potential to become a companion species in Irish broadleaf forests and hedgerows. However, caution needs to be exercised due to its susceptibility to frost damage and *Phytophthora pseudosyringae.*

8.14.2 Rauli beech

Scientific names: *Nothofagus procera* (from Latin: long, high, protruding) – syn. *N. alpina*.

Origin and geographic distribution: South America, especially Chile (see distribution map in Chapter 9.5). Planted in parks and gardens.

Botanical characteristics

Tree and crown: A remarkably fast-growing tree with open crown of arching branches, up to 40 m in Chile.

Stem and branches: The branches are sturdy, the shoots stout and warty. The bole soon becomes large.

Bark: Brownish, many lenticels, becoming fissured.

Timber: Fine structured, straight fibred, reddish-brown, slightly heavier than that of roble, but softer than European beech, and partly comparable with wild cherry.

Root system: Comparable with that of roble.

Buds and leaves: Buds are 8–10 mm long – roughly twice as long as those of roble. Leaves are finely toothed, with wavy margins and 14–20 pairs of veins. Buds open early, but cold spells will delay their expansion.

Flowers: Cupule with three dark nuts.

Fruits: Nutlets about 1.0 cm long, comparable with beech, but much smaller.

Ecological characteristics

Both species are relatively closely related in many aspects. Therefore, only the characteristics specific to rauli will be mentioned.

Forest and successional type: Slightly less ability as a pioneer on bare land.

Light requirements: Rauli is also light-demanding, but slightly less so than roble.

Stress tolerance: Intolerant of deep winter frost. Therefore, it is distributed in Europe only near the Atlantic coast (for instance southern England).

Site and soil requirements: In Chile, rauli occurs on sloping sites with deep soils which are permanently moist. In Britain, it is less suitable for drier sites than roble.

Strengths and threats: Comparable with those of roble, but even more frost-intolerant.

Provenances: Preferably those from southern ranges of its distribution.

Growth characteristics

Height and diameter growth: Rauli is exceptionally fast-growing, – even slightly faster than roble – and, therefore, including eucalyptus and poplar, it is one of the fastest growing broadleaf in Europe. On suitable sites it may achieve 2 m/yr and in one case has reached 15 m in 9 years (Mitchell, 1989). At different locations in Britain, it has reached 20–26 m in height at ages between 40 and 60 years. The respective diameters were 65–93 cm. A 22-year-old stand at Rehill Property, Clogheen Forest, had a mean height of 23 m and mean diameter of 35 cm (Plate 8.14.1). The data in Table 8.14-1 are also valid for rauli.

Annual volume production: In Chile 10–15 m^3/ha.

Plate 8.14-1: Specimen tree of *Nothofagus procera* growing in a 27-year-old pure stand. (Rehill Property, Clogheen Forest, Co Tipperary)

Values

Silvicultural values: Even more so than roble, the fast growth of rauli in youth ensures that it will not be overgrown by other broadleaves and is, therefore, a perfect mixture tree species.

Economic values: Easily workable and machinable, and therefore, a valuable timber for veneer, furniture, panels, parquet and frames. It is sometimes sold under the trade name Chilean mahogany.

Tuley (1980) calculated the financial returns from rauli at 1970 price levels and at a discount rate of 5%. This showed that the revenue was substantially greater than that from oak or beech. It should be mentioned, however, that at present only a small number of logs come to the market and, therefore, no real price structure has been developed.

The normal economic rotation for *Nothofagus* would be 40–50 years compared with 70 years for beech or oak.

Ecological and amenity values: They are equivalent to roble.

Silvicultural management

Production of plant material: Seed supply and plant production are no longer a problem.

Regeneration: Establishment is by planting only.

Management: Thinning is very important in order to ensure attainment of high quality timber production and stability.

Conclusions

Rauli could provide a valuable enrichment of the Irish flora, but should be confined to favourable sites and soils. Because of its ornamental beauty, and its high quality timber, it is the most valuable of all *Nothofagus* species.

Continued

Conclusions continued

In sheltered areas it might be a profitable mixture species with other broadleaves. Even solitaires within hedgerows are possible, but experience is lacking.

Its fantastic timber quality and growth capacity, therefore, warrants more research on this outstanding species.

8.15 Strawberry tree

Family: *Ericaceae.*

Genus: *Arbutus* comprises 12 mainly shrub species in the northern hemisphere of Europe/Asia/Africa (3) and N America (9).

Common name: Strawberry tree, referring to the distinct shape and colour of its fruits.

Scientific name: *Arbutus unedo* (unedo = I eat one).

Irish name: Caithne (cuinche).

Origin and geographic distribution: It is the most widespread *arbutus* species, found in most parts of the Mediterranean zone (including Turkey, Syria, Lebanon, Israel, Morocco, Algeria, Iberia and W France). It is native to Ireland in counties Cork, Kerry (frequent near Killarney) and Sligo and perhaps native, now extinct in Clare, Mayo, Waterford, but not native to Britain.

According to NFI (2013) data, the strawberry tree belongs to the long-living broadleaves and has an occurrence comparable with horse and Spanish chestnut as well as large- and small-leaved lime, Turkey oak and southern beech.

Botanical characteristics

Tree form: A bushy shrub or small tree that reaches 10 m in height (seldom up to 15 m).

Stem: Often with multiple stems.

Bark: Reddish-brown to grey-brown, on mature shoots and trunk. It is rough, fissured, usually not peeling. Young twigs green or with red tinge, with glandular hairs.

Timber: It is hard, reddish-brown, tending to split and crack.

Root system: It spreads widely if not hindered by any obstacle in the soil and is susceptible to damage.

Leaves: The evergreen and leathery leaves alternate. Variable in size and shape and are 5–10 cm long, narrow, oval, toothed, hairless and short stalked with glandular hairs. Above they are dark green, below pale green.

Flowers: *Arbutus* produces masses of creamy-white or pale flesh-coloured translucent flower-bells hanging in clusters. They occur in small, terminal, drooping panicles and open in September-November.

Fruits: They are tubercle berries with pulpy flesh, 15–20 mm across. At first they show orange-scarlet, but dark-crimson when quite ripe. As they need a year to ripen, flowers and fruits are borne together in late autumn.

Ecological characteristics

Forest type: Found in the margins of oak woods and rocky sites where the vegetation is open and shrubby.

Successional type: Pioneer.

Light requirements: Very light-demanding. Thus, it is never found growing in woodlands, under other trees in the same way that holly does.

Stress tolerance: Not documented.

Climatic requirements: Sheltered, sub-Mediterranean conditions.

Soil preference: Individual plants prefer rocky slopes, where excellent drainage is assured. It appears to be indifferent in terms of nutrient demands, as it is found on rocky lake-shores and islands with almost no soil cover, but will grow also in gardens with lime-rich or acid soil.

Strengths and threats: In the first years after planting it is liable to be killed by frost, especially deep winter frost.

Regenerative capacity: Several trunks often spring from a broad lignotuber, i.e. a woody structure usually buried in the ground. It contains dormant buds. The strawberry trees can survive fire when the trunk is killed and the buds are stimulated to sprout new shoots. In this way a well-established old strawberry tree can live for an undeterminable time. In this regard it does not behave like a pioneer. Because of its ease of vegetative propagation, annual regeneration from seed is not necessary to maintain populations.

Provenances: There are some red-belled cultivars in cultivation.

Growth characteristics

Strawberry trees grow relatively slowly. In ideal conditions they will reach 2 m in height within a period of 10 years. One specimen in Co Wicklow is reported to have had a stem diameter of over 1 m.

Values

Silvicultural values: The strawberry tree has never been an object of silvicultural management and possibly never will.

Economic values: In the past, in the Killarney area, arbutus was used for furniture making, making toys and ornaments and as an inlay in furniture (Farmer, J. (1992). The Oakwoods of Killarney. Stationery Office, Dublin).

Ecological values: No special function is reported.

Amenity values: The strawberry tree is regarded as one of the most beautiful and perplexing of the native tree species.

Historical importance: It has been used extensively in the past for fuelwood. Charcoal production for iron-smelting furnaces played a certain role during the 17th and 18th centuries. In the 19th century the destruction of native woodland provided wood for marquetry. Small dimensions have been used for coloured marquetry. This may be the reason why it became extinct in some counties. The fruits have been used on a minor scale for alcohol production, but of themselves are not palatable.

Silvicultural management

Seed should be removed from the ripe fruit by careful maceration and the pulp washed away. A thick layer of chopped sphagnum moss scattered over a peat compost provides the best seedling bed. When sown, seed must be kept moist, but not waterlogged, and unshaded.

No special silvicultural aspects are known.

Conclusions

Strawberry trees will remain (without human influence) a rare sub-Mediterranean element on special sites. It is of no economic value, but adds to the beauty of the wild on rocky slopes. It needs protection due to the fact that it is one of the rarest native species.

Provided global warming will continue then the strawberry tree may extend its distribution.

8.16 Walnut

Family: The *Juglandaceae* have eight genera and around 60 deciduous, mainly tree species in the northern hemisphere and the subtropics (Central America, Argentina, Java and New Guinea).

Genus: *Juglans,* derived from Latin Ju = Jupiter and glans = acorn, has 15 deciduous tree species in the regions of southern Europe to Southeast Asia, North and Central America.

Species: The two species of interest to Ireland are (1) common and (2) black walnut.

8.16.1 Walnut (common)

Scientific name: *Juglans regia.*

Common names: Common or Persian walnut.

Irish name: Gallchnó.

Origin and geographic distribution: Native to the Balkans and parts of Asia. Its original distribution is thought to have included south-eastern Europe, northern Turkey, Iran, western India and eastern Asia (Figure 8.16-1). It is difficult, however, to authenticate its true original distribution as it has been widely cultivated since the Neolithic period. It was introduced to Britain in pre-Roman times (Evans, 1984), but Rackham (1986) considered it *an exotic* of *respectable antiquity* in Britain because it showed *no sign of becoming wildlife*. He claimed it had never become fully naturalised, but was distributed solely by planting at *random on all soils at the whim of growers*. According to Press (1992), however, it is widely naturalised.

It can grow reasonably well in some (southern) parts of Ireland.

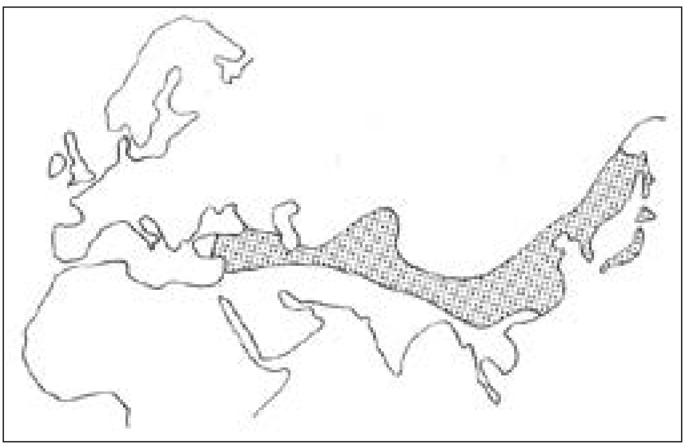
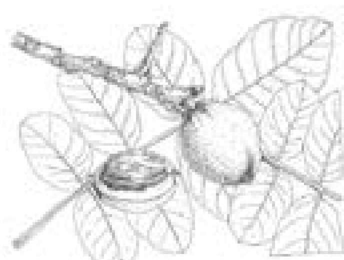


Figure 8.16-1: Natural distribution of common walnut.
(Evans, 1984)

Botanical characteristics



Tree and crown: A tree of up to 25 m in height, with a broad spreading crown, if growing in the open. The large branches are often twisted.

Stem and branches: Open grown trees have thick trunks of large diameter, up to 2 m. In forest stands, the crowns are smaller and the stems long and straight. The twigs are smooth with well discernible leaf scars. Twigs have a central pith divided into chambers and distinctly Y-shaped scars where leaves have fallen.

Bark: Silver-grey, at greater age dark grey with bigger smooth particles divided by deep fissures.

Timber: It has a yellowish sapwood and dark heartwood, is hard and tough, but not very elastic with a fine grain, moderately resistant to decay. It is easy to work and very decorative.

Root system: Deep-rooting (taproot).

Leaves: Alternate, pinnately divided into 7–9 entire leaflets each 6–15 cm long; those towards the tips of the leaves larger than the others. Divided, leathery and aromatic leaves, the only species of the family with smooth leaf edges.

The leaves contain tannins and after they decompose they have an allelopathic effect on competing ground flora.

Flowers: Male flowers in solitary, pendulous catkins 5–15 cm long on old wood; female flowers in spike-like clusters of 2–5. Wind-pollinated. Flowering May-June.

Fruits: Roughly globular, green fruit 4–5 cm long, contains an oval, wrinkled kernel, the familiar walnut. Nuts are distributed by animals.

Ecological characteristics

Forest type: Generally as a solitaire in fields. Sometimes growing wild in central European high quality broadleaf (ash, sycamore, elm) forests. In central Europe walnut is regarded as a tree species best suited to and typical of a wine climate.

Successional type: Long-living pioneer.

Light requirements: Light-demanding to slightly shade-tolerant.

Climatic requirements: Warm sheltered sites, preferably with south or southwest aspects. Exposed sites and especially frost hollows must be avoided. In central and southern Europe it grows only up to 800 m.

Soil preference: Deep fertile loams with good drainage. Very sandy and very clayey soils as well as infertile soils and those with seasonal water-logging are unsuitable.

Stress tolerance, strengths and threats: Tolerates drought periods. Is relatively winter frost-hardy, but is extremely susceptible to late and early frosts. Therefore, sheltered sites are required. It is susceptible to damage by honey fungus (*Armillaria* spp.)

Regenerative capacity: It rarely regenerates naturally. Its decaying leaves produce chemical agents which prevent germination of other seedlings (allelopathy).

Provenances: Many horticultural varieties, but little is known about special forest provenances. An autochthonous provenance, with small hard nuts, is believed to exist in central Europe. In Ireland no provenance trials have been established, but the Future Trees Trust Walnut Group has established provenance trials in the UK.

Growth characteristics

Height and diameter growth: It is fast-growing in its early years and so it quickly outgrows the threat from late spring frost. If given sufficient growing space, it is capable of producing an annual diameter increment up to 8 mm. In mixture with other broadleaves, however, an increment of this size is not possible. On good sites walnut trees reach 30 cm diameter at about 40 years (Evans, 1984).

Ten champion trees – mostly in the more southern counties – had heights between 16 and 24 m, (average 19 m) and diameters between 100 and 190 cm (average 140 cm).

Age: Life span is about 200 years.

Total volume production: As walnut has never been grown to any extent in pure stands no data are available.

Values

Silvicultural values: There is nothing to indicate that walnut offers any special advantages compared with other broadleaves.

Economic values: One of the most highly prized timbers of Europe. It is regarded as the most beautiful and, therefore, the most valuable of all European timbers. Used for furniture (including veneer) and many small items like boxes, picture frames, rifle and pistol butts, carvings, turnery and high class joinery. Even small pieces of wood (parts of branches) are used. Walnut also makes a very good firewood.

Large horticultural plantations in Sub-Mediterranean regions of Europe and North America serve primarily for the production of nuts. These are used for direct consumption and for the production of nut oils. In rural areas of warmer climate, solitaires in and on the outskirts of villages, mainly serve the same purpose.

The leaf tannins are used for medical purposes, and leaves and the fruit husks are the basis for dyes.

As very little walnut is grown in forests, most of the timber comes from the orchards.

Ecological values: Broad crowns of walnut trees outside of forests provide shelter for livestock. Their role in providing shade for people in villages and house gardens should also not be underestimated. The nuts provide a source of food for several birds and small mammals.

Amenity values: The profile of solitaires in fields and around houses is a welcome addition to the landscape.

Historical importance: The fact that walnut trees have been distributed and planted in areas with a slightly favourable climate for thousands of years demonstrates its value for human needs. It is, however, difficult to establish and grow. This factor is indirectly referred to by Rackham (1986: 224): *Walnuts were much planted in field hedges, but are rarely heard of again and may not have survived.*

Silvicultural management

Production of plant material: Because of their frost intolerance walnut transplants should be 50–80 cm in height, which means they should be 1+2 or even 2+2 years old. They are, therefore, relatively expensive.

Regeneration: Walnuts in the Irish climate rarely produce fertile seed and, on the occasions that they do, predation by squirrels and birds is very common. Therefore, natural regeneration or direct seeding is not promising. Planting is the only method to ensure establishment.

Tending of young stands: Stumping back saplings that have suffered from late frost or browsing may enable them to get above the frost level. Single walnut saplings tend to develop large side branches and to fork easily. Therefore, shaping and pruning is essential to produce a reasonably long stem of high quality (at least 5 m). According to Evans (1984), pruning should be done only when in full leaf during July or August.

Thinning: It has to start very early to ensure sufficient growing space, as walnut is not very competitive in later years. Overtopping by neighbouring trees is not tolerated by walnut of any age.

Conclusions

Walnut produces one of the best timbers of all the tree species that grow in Europe and even small dimensions can be used. For this reason it is being increasingly planted as a forest tree in southern Germany in recent years. It should be grown in Ireland wherever possible, but suitable sites are limited. Nonetheless, in the south of the country on sheltered sites it should be possible to grow it in hedges, near houses and other urban areas, in small woodlots and along forest edges. The harvest of nuts provides a further incentive.

8.16.2 Black walnut

Species: *Juglans nigra* L.

Origin and geographic distribution: Black walnut occupies an extensive range in the Eastern part of the USA (Figure 8.16-2). It was introduced to Europe in the 17th century and widely planted for timber, mainly in the eastern parts of central Europe (Press, 1992).

Figure 8.16-2: Natural distribution of black walnut. (Evans, 1984)

Botanical characteristics

Tree and crown: Large, fast-growing tree similar to common walnut, but reaching greater heights (more than 40 m). Domed crown.

Stem and branches: Twigs have a central pith divided into chambers and large Y-shaped leaf-scars.

Bark: Black or brown, deeply fissured into diamond-shaped ridges.

Timber: Dark to black brown, comparable with common walnut.

Root system: Deep taproot.

Leaves: Alternate, pinnately divided into 15–23 leaflets, each 6–12 cm long, oval to lance-shaped, pointed and irregularly fine-toothed and hairy beneath. Terminal leaflet often absent. Finer, more abundant foliage than common walnut.

Flowers: Male flowers in catkins 5–15 cm long. Female flowers in spike-like clusters of 5. Flowering May-June.

Fruits: Globular or slightly pear-shaped fruit, 3.5–5 cm long, green and hairy, containing an oval, ridged kernel, not edible.

Ecological characteristics

Black walnut is a typical long-living pioneer: light-demanding and intolerant of autumn and late spring frost. It is very site-demanding, as it requires a mild climate and deep, moist, mineral rich soils, easily penetrable by roots. Good ash sites, if not too wet, are favourable. No diseases or other abiotic threats are known.

Growth characteristics

Height and diameter growth: Fast-growing, at least in its youth. Data for six champion trees show its good growth (range 20–30 m in height, mean 24 m; diameter range 70–140 cm, mean 120 cm).

Total volume production: Volume and value production is higher than for oak.

Values

Black walnut is more suitable at forest edges than common walnut or as small groups within broadleaf forests. Like common walnut, it produces one of the highest priced timbers, even in small dimensions, and is more productive.

Silvicultural management

Black walnut is established only by planting and should be managed in a way comparable with common walnut.

Conclusions

On very good sites it is preferable to common walnut, provided nut production is not the aim. Its timber production and economic return is higher. Black walnut is more suited as a forest tree than common walnut.

A hybrid of both walnut species, *Juglans x intermedia* Dipp., seems to be of special interest for forestry as it is more vigorous than its parents.

Japanese walnut (*Juglans ailantifolia*) has reached only 15 m in Cork – according to the Tree Council of Ireland (2005) – and, therefore, is not of any interest for further planting.

8.17 Willow

8.17.1 General characterisation of willow species

Taxonomy and distribution

Family: *Salicaceae.*

Genus: *Salix* (from Latin: willow). The genus consists of 300–500 species, which are often intermediate between trees and shrubs. According to various authors, this wide range presents problems of identification, as many produce natural hybrids and varieties. Indeed, it is sometimes argued that there are no true willow species.

Only a few willow form straight long stems. Therefore, in some cases, it is difficult to decide whether they should be classified as trees or bushes (Plate 8.17-1 to 8.17-3).

Origin and geographic distribution: Willow species are distributed mainly in the northern hemisphere. Many of them are arctic or alpine species, widely dispersed throughout Europe. Around 30 species are indigenous to the Continent; approximately ten are found in Ireland.

As willows have much in common, it seems appropriate to describe their general characteristics first and then to specify some of them that are common and important in Ireland.

Botanical characteristics

Tree and crown: No broadleaf genus is as variable as the willow in producing forms, from creeping bushes to straight high trees as shown in Plates 8.17-1 to 8.17-3.

Stem and branches: A great variety of bush and tree forms.

Bark: Willows tend to have bark with deep fissures when older.

Timber: Soft, light timber and often thin or crooked stems are mainly of low or no value. The timber of white willow (*S. alba*) is very elastic and can be used for different tools.

Plate 8.17-1: Willow, in Connemara illustrating the bush type.

Root system: Most willows have a shallow rooting system, but white willow roots are deeper.

Plate 8.17-2: Goat willow half shrub/half tree (with many stems and no clear differentiation into crown and stem). (N Germany)

Plate 8.17-3: White willow with clear tree form. (E Germany alongside river Elbe)

Leaves: Alternate and simply formed leaves often have large stipules at the base of the petiole. The winter buds are always covered with a single hood-formed scale. This is a helpful characteristic to distinguish willow from other broadleaf species.

Flowers: All willows are dioecious. Some species are wind-pollinated, but most are insect-pollinated. They flower early in spring, mainly before flushing.

Fruits: Extremely tiny seeds with fine woollen hairs allow them to be distributed by wind over large distances – up to 50 km. They can germinate immediately, but lose this capacity within a few weeks.

Ecological characteristics

Forest type: Willows grow on a wide variety of sites – from high alpine areas down to riparian forest zones. Many of them are mixed with birch or alder.

Successional type: All willows are typical pioneers with fast growth in early years. They often form a riverine belt alongside lakes where other tree species cannot grow because of the high water table. There the willows cannot be overtopped and succession towards more diversified forests does not take place (Plate 8.17-4).

Plate 8.17-4: Belt of willow along a lake shore. (National Park Biogradska Jezero, Montenegro)

Light requirements: Willow is generally very light-demanding and does not tolerate any shade, thus it dies off immediately when overtopped by other trees. Only white willow (*S. alba*) is slightly shade-tolerant. Willows are, therefore, never represented in late-successional forest types.

Stress tolerance: As typical pioneers, willows are very tolerant of all types of frost and drought.

Site and soil requirements: Many willows have a wide climatic amplitude. Most of them grow on wet soils.

Strengths and threats: Most willows do not suffer from abiotic or biotic threats. Some are, however, browsed by deer, especially osier (*S. viminalis*).

Regenerative capacity: Apart from the closely related poplar genus, no other broadleaf species group sprouts as easily and can be propagated so simply by cuttings as the willow.

Growth characteristics

Height and diameter growth: Some willow can grow up to 2 m/yr in the early years. This is unequalled by any other European species.

Age: As short-living pioneer, willow normally has a somewhat short life-span of 50–80 years. White willow, however, is said to reach an age of up to 200 years.

Total volume production: Willow has not been managed for timber production over any length of time, so no volume data exist. Recent investigations in modern short-rotation coppice forests, however, show that they are capable of producing more than 10 t/ha/yr. This is one of the reasons why individual species – like *S. viminalis* – have gained some importance in this regard.

Hybrids are – as usual – often more productive than their parents.

Values

Silvicultural values: For a long time willow has been regarded as a weed in forest plantations and was removed. It colonises bare land, even on very poor soils or with excess water. By doing so it prepares the ground for more demanding species by improving the soil and water conditions and providing shelter against wind. By retaining some willow or other pioneers on former bare land it is, therefore often possible to opt for enrichment instead of full planting. This opportunity to reduce planting effort and mitigate establishment problems, especially on exposed sites, has gradually changed their reputation in forestry.

Economic values: Willow timber in general has a low oven-dry density. It is of minor quality and low energy content, but, when the stems are big enough, they can be used for veneer (plywood), wood carvings, household tools, clogs, chip baskets and pulp.

The high biomass production of some varieties has recently increased interest in them for the production of fuel.

Purple willow is used for producing salicin for the pharmaceutical industry.

Ecological values: Willows that form trees or pollarded stumps about 2 m in height are an important habitat for several bird species (ducks, owls) and a biotope for insects (willow species, such as *S. alba, aurita, caprea, cinerea, fragilis*).

Some willow species (*S. alba, caprea, cinerea, purpurea, viminalis*) have honey-producing glands, which are very attractive to bees in early spring when other food is scarce.

Willows contribute to species diversity mainly on unmanaged land.

Amenity values: In general only tree willows enjoy popularity, weeping willows especially (*S. alba, var. vitellina* Tristis; *S. caprea*, Kilmarnock, syn. Pendula; *S. purpurea* Pendula) are of great ornamental value and are often planted along rivers and streams.

Historical importance: For thousands of years shoots of willow species (mainly *S. alba, S. viminalis*) were, and still are locally of great importance for the production of baskets, fences, fascine poles and brushwood revetments, wattles, wicker-work and binding material. There are innumerous paintings and drawings illustrating pollarded willows as elements of the landscape (Plates 8.17-5 to 8.17-7).

Pollarded willows, according to the *Très Riches Heures du Duc de Berry* of the 15th century, have been very common. (From reprint by Pognon, 1979/1987)

Plate 8.17-5: Detail of the painting for the month of June.

Plate 8.17-6: October in front of the Louvre, Paris.

Plate 8.17-7: April in front of the castle in Dourdon.

Special osier groves and regularly pollarded willows have been widely established and managed on wet ground to meet the need for this type of material (Plate 8.17-8 and 8.17-9).

Plate 8.17-8: Willow osiers are still to be found at many places although they have lost much of their former importance. (Montenegro)

Plate 8.17-9: The perfect ability of most willow species to root from cuttings was and still is used to stabilise eroded soils and river banks. (Alpine region in Switzerland)

Roots of white willow were popular for the production of red colour (dye), and its bark was used for tanning leather.

Their sprouting ability guaranteed that willows were a component of coppice forests.

Silvicultural management

Production of plant material: With the exception of ornamental willows, they are almost never planted, as it is easy to propagate them by cuttings. Goat willow, however, sprouts less easily from cuttings.

Regeneration: Seed viability is low and they need a good moisture supply when germinating. Because of their shade-intolerance, they also need weed-free (mineral) soils. Nevertheless, their natural regeneration, especially on bare and wet land, is normally not a problem.

Tending and thinning operations: Willows are usually removed whenever they interfere with the target species in a forest plantation or naturally regenerated young stand.

Tree willows are sometimes pruned, but only in agroforestry or along roadsides and are given sufficient space to develop big and evenly shaped crowns.

Conclusions

Willow contributes remarkably to broadleaf diversity, mainly in scrub and on bare land. Moreover, they act as nurses on exposed sites and offer the opportunity to gradually convert such sites through enrichment planting, into productive forest.

On a limited area, they may be used for short rotation coppice forests. Here, however, they compete to some extent with poplar, which is usually more site-demanding.

Willow has tended to be sidelined in forestry for a long time. There is some indication, however, that they might gain more attention in future.

8.17.2 Willow species and their importance in Ireland

Species occurring in Ireland

As compared with the number of willows living in the northern hemisphere, only a relatively small number are common in Ireland (Table 8.17-1).

Table 8.17-1: Native and introduced willow species in Ireland. (Adapted from Scannell and Synnott, 1987)

Name			Status	
Scientific	English	Irish	native	introduced
S. alba, var. alba	White w.	Saileach bhán		x
S. aurita	Eared w.	Crann sníofa	x	
S. caprea	Goat w.	Sailchearnagh	x	
S. cinerea, subsp. cinerea	Grey w. (sallies)	Saileach liath	x	
S. cinerea, ssp. oleifolia	Rusty w.	“ rua	x	
S. fragilis	Crack w.	“ bhriose		x
S. herbacea	Dwarf w.	Camshaileog	x	
S. hibernica	Irish w.	“ ghaelach	x (sub-species of Tea-leaved W.)	
S. myrsinifolia (*S. nigricans*)	Dark-leaved w.	Saileach dhubh	x	
S. pentandra	Bay (leaved) w.	“ labhrais	x (in the northern counties)	
S. phylicifolia	Tea-leaved w.	“ ghaelach	x	
S. purpurea	Purple w.	“ chorcra	x (probably in the centre)	
S. repens	Creeping w.	“ reatha		x
S. triandra	Almond w.	“ na dtrí bhall	x (probably in S-E counties)	
S. viminalis	Osier	Saileánach	x	

Of these 14 species, 11 are regarded as native. As all of them carry Irish names so it must be a long time since they were introduced.

It should also be mentioned that there is a number of indigenous hybrids.

Frequency of occurrence of willows

According to NFI (2013) data (refer to Table 1.5-5) willows have been recorded on approximately 5% of stocked forest area. Grey willow (sally - *S. cinerea oleifolia*) is a common willow in Ireland and is very similar to the goat willow (*S. caprea*) which is by far the most important willow species. White willow (*S. alba*) and crack willow (*S. fragilis*) seem to be the next important willow species in Ireland, however, their occurrence and that of the other willow, is not documented.

Distribution of main willow species

As willows have never been a preferred tree species for botanists, ecologists or foresters, distribution maps have been prepared only for the most important willow species (Figures 8.17-1 to 8.17-3).

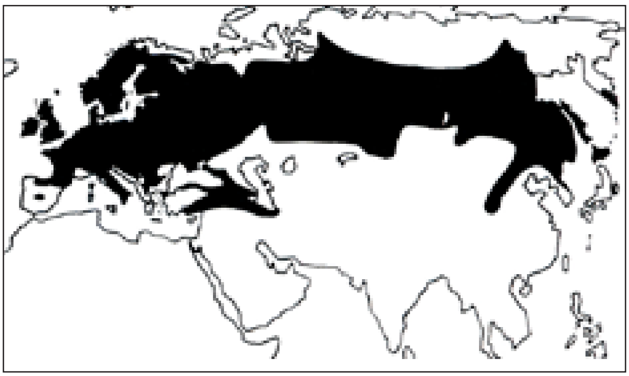


Figure 8.17-1: Natural distribution of goat willow.
(Mette and Korell, 1982)

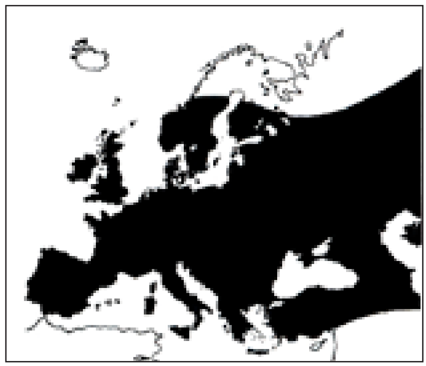


Figure 8.17-2: Natural distribution of crack willow.
(Mette and Korell, 1982)

As shown in Figures 8.17-1 and 8.17-2 goat and crack willow occur throughout Ireland, whereas white willow (Figure 8.17-3) occurs only in a small area of the country.

Botanical characteristics and site preference

The botanical characteristics of the most important species and a short version of their ecology are listed in Table 8.17-2.

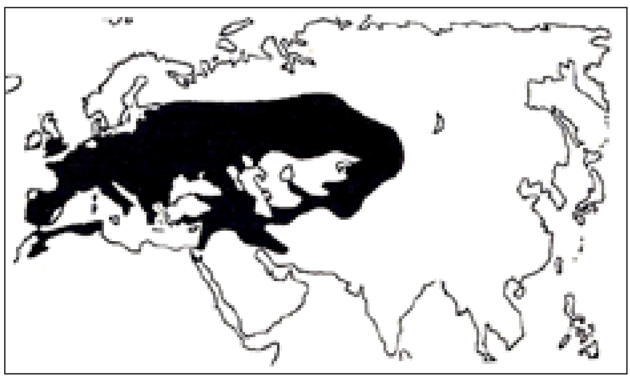


Figure 8.17-3: Natural distribution of white willow.
(Mette and Korell, 1982)

Figure 8.17-4 shows some illustrations of morphological characteristics of the most important willow species.

Table 8.17-2: Botanical and ecological characteristics of the main willow species in Ireland.

Species	Tree form and size	Branches	Leaves	Flowers	Flowering month	Site Demands and distribution
White w. *S. alba*	Slim, densely branched crown (-25 m). Best of all willows.	Big branches, upright oriented, twigs flexibly hanging. Yellowish/ reddish.	Lanceolate (5-10 cm long), sickle-shaped leaf scars. (Figure 8.17-4)	Male flowers silvery coloured, later yellowish.	2-5	Pioneer, usually found in alkaline riverine zones with running water. Most important species of softwood floodplain forests. Partly on heavy soils. Tolerates longer flood periods. Widespread throughout Europe.
Eared w. *S. aurita*	Up to 2 m, A shrub species.	–	Characterised by presence of stipules and similar to grey willow.	–	4-5	Lowlands – high mountainous zones. Moors free of alkalinity.
Goat w. *S. caprea*	Small tree or tall shrub with round crown; rarely single stemmed (max. 10 m).	Rich, stiff twigs, thinly haired when young, soon yellowish brown.	Broadly oval to elliptical (5-12 cm), pointed. Hairy on underside. Biggest buds of all willows. (Figure 8.17-4)	–	3-4	Fast-growing pioneer. Preferably at places with high water table, but also often in quite dry places. Light as well as heavy soils. Pioneer on bare land. From lowlands to alpine zones. Along hedgerows and edges of woods.
Grey w. *S. cinerea*	Broad bush (6 m). Resembles goat willow.	Twigs felted with grey hairs.	Leaves oval and waxy. Tapered at base.	Male flowers brick-red before flushing.	3-4	Wet fenland, marshes in most of Europe; preferably light, but also on gley soils. Lowlands – mountain zones.
Rusty w. *S. cin. oleif.*	Tall shrub or small tree.	Twigs red brown.	With stiff, rusty hairs below.	Catkins 3-5 cm, appearing before leaves.		Native to a wide range of habitats in Atlantic Europe; pioneer. Referred to as grey sally in Ireland and is very common.
Crack w. *S. fragilis*	Stout tree (up to 20 m) with a short, thick often leaning, trunk and broad, rounded crown. Resembles white willow.	Twigs brittle where they join the branches. Twigs break easily. No hairs on twigs.	Lance-shaped, long-pointed, hairy at first, soon completely glabrous and dark shiny green above, bluish-grey beneath (9-18 cm); margins with coarse, even, gland-tipped teeth. (Figure 8.17-4)	Male and female catkins similar looking, (4-6 cm) with short, hairy stalks.	4-5, much later than white willow.	Found on deep, wet, lime-free lowland soils. Often planted on the fringes of farmland. Hybrid between crack and white willow (*S. x rubens*) more common and widespread, often cultivated on light soils. Used for river bank stabilisation.
Bay (leaved) w. *S. pentandra*	Small or tall with spreading branches (rarely up to 15 m).	Glossy yellow – reddish-brown.	Elliptical to oval (5-12 cm) less than 3 times as long as wide; highly glossed; leathery, dark, very shiny above, paler below. (Figure 8.17-4)	Hairy-stalked catkins appear with the leaves. Dense, cylindrical male catkins (2-5 cm) pale yellow, greenish females shorter. Honey smell.	5-7, latest of all willows.	Riparian to alpine zone. Common along waterways and on wet soils most of Europe, moors, lime-free, sandy-gravelly soils. Uncommon in south, frequent in north.
Purple w. *S. purpurea*	6 (-10) m	Branches long and slender.	Leaves often opposite (-12 cm long). Red buds on sun oriented twigs.	Catkins reddish with a purple tinge.	–	Widespread, but scattered throughout most of Europe. Preferably on wet sites, but also grows on poor dry sands. Not native to Ireland.
Osier *S. viminalis*	Bushy (3-10 m). Resembles grey willow.	Greyish felted. Especially fast-growing in the first 2 years.	Lanceolate (-20 cm long).	Catkins crowded on short tip.	3-4	Pioneer; widely distributed (floodplains), partly artificial: mainly planted for withies or twigs, sometimes a relict of cultivation in the west and some river valleys (Blackwater (Munster) and Bride).

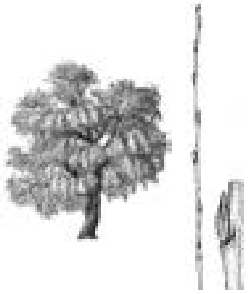
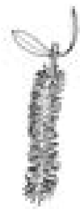
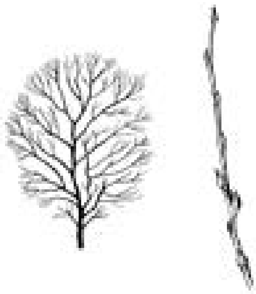
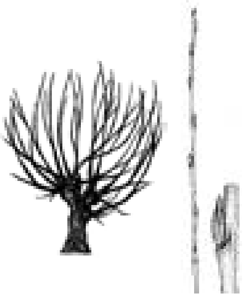
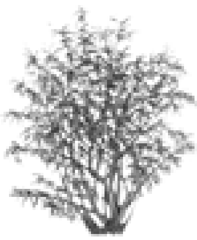
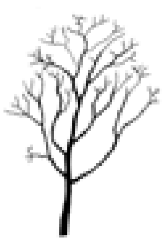
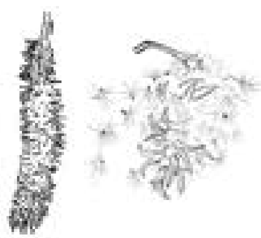
Species	Crown	Leaves	Flowers
White willow *S. alba*			
Goat willow *S. caprea*			
Crack willow *S. fragilis*			
Osier *S. viminalis*			
Bay willow *S.pentandra*			

Figure 8.17-4: Morphological characteristics of the most important willow species.

Growth characteristics

As mentioned, most willows are intermediate between bushes and trees. The main exception is white willow (*S. alba*), the tree willow species. Three champion trees in Ireland have reached heights of 18–22 m and diameters of 175–185 cm. A variety (*S. alba, var. vitellina* Britzensis) has reached up to 29 m. Grey willow (*S. cinerea*) is normally a bush, and the only champion tree of this species reached 10 m.

Regeneration and management

All willows recorded in stands throughout the country have probably come into existence through natural regeneration. Planting has never been carried out and tending and thinning is not practised.

Conclusions

Willow is present over a much greater area than most foresters, farmers and ecologists realise. Although their economic value is low and will probably be so in the future, they offer ecological advantages relating to afforestation, rehabilitation of degraded forests and enrichment of existing tree crops. This may be an argument worthy of consideration in the effort to increase the area of productive broadleaf stands in Ireland – as mentioned in Chapter 5.

9 Rare broadleaf species

9.1 Origin of rare species

Only tree species from temperate zones can survive and grow over most of Ireland. However, Ireland's favourable climatic conditions, with mild winter temperatures in the south and sheltered lowlands, sometimes permit the growing of less stress-tolerant trees from Sub-Mediterranean and even subtropical regions.

Broadleaf species have been introduced from many parts of the world from the temperate zones of the northern and southern hemispheres. Only Africa – except for the northern Mediterranean regions – has not provided species suitable for Irish conditions.

Five regions have been identified from which rare exotic trees have been established successfully:

- Europe and Near East
- Far East-Asia
- North America
- South America
- Australia and New Zealand.

Tree species from these regions that have been planted in Ireland are described below.

All data have been abstracted from *Champion Trees of Ireland* (Tree Council of Ireland, 2005), supplemented by information about growth data from other sources for comparison and comments on the importance of the species (refer to Chapter 6.4).

9.2 Species from Europe and the Near East

Europe has no defined climatic border to the East. The climate of the chain of mountains, beginning with the Pyrenees in the west and the Alps and Carpathians in the south, is relatively similar to that of the Caucasus and the Himalayas. Within this wide geographic range species like walnut and yew occur. Others are closely related, like horse- and Indian chestnut or silver and Pindrow fir. The western Himalayan region and Far East-Asia, however, seem to have little in common.

For this reason the species introduced from Europe are combined with those from the near Near East ranging into the Himalayas (Table 9.2-1). It contains 24 species. Almost two-thirds come from SE Europe and the Near East. Three are typical Mediterranean species. Northern and Central Europe do not, however, contribute any rare species of note. Only one species, *Acer cappadocicum*, occurs in both spheres: Eastern Europe/Himalayas and Far East/China.

None of the species has more than four champions. Six trees reached heights over 20 m, which is more or less equivalent to the heights the trees reach in their native habitats. Ten species achieved diameters of more than 1 m.

Conclusions

Apart from naturalised species like beech and sycamore, which have been recorded in Table 6.2-2, no outstanding rare broadleaf species of European origin can be recognised. The species listed in Table 9.2-1 come predominantly from warmer parts of Europe and the adjoining Asian mountains and may be of some importance for the more southerly parts of Ireland. In the event of global warming they could become more relevant, some may even become important in the future.

Table 9.2-1: Exotic trees from **Europe and Near East** (adjoining Asia). (Mainly adapted from *Champion Trees of Ireland* – refer to Chapter 6.4)

Name: Scientific	Name: Common	Location of origin	Number of champions	Height: at origin (m)	Height in Ireland: max. (m)	Height in Ireland: mean (m)	Height in Ireland: CV (%)	Diameter: max. (cm)	Frost hardiness[1)]	Importance growth habit products
***Acer** cappadocicum*	Cappadocian maple	Caucasus, N Turkey, Iran, Himalayas , China	2		17	16		105		
A. capp. ssp. lobelii	Lobell´s maple		2		18	12	-	65		
A.opalus	Italian maple	S Europe	2	15	20	18		90		
A. velutinum var.van volxemii	Van volxen´s maple	Caucasus, N Iran	1		16			110		
***Aesculus** indica*	Indian chestnut	NW Himalayas	4		20	16	*18*	70		
***Arbutus** x andrachnoides (A. andrachne x A. unedo)*	Hybrid strawberry tree	SE Europe, Near East	2	8	14	11		60		
***Betula** utilis*	Himalayan birch	W Himalayas	1		17			80	3	
***Buxus** sempervirens*	Box	Europe, Turkey, N Africa	1	5	12			15		Evergreen
***Clethra** arborea*		Madeira	2		15	13		65		Evergreen
***Corylus** colurna*	Turkish hazel	SE Europe - Himalayas	1					65	3	
***Cotoneaster** frigidus*		Himalayas	1	10	15			60		
***Ficus** carica*	Common fig	E Mediterranean, W Asia	1	10	8			25		
***Laburnum** alpinum*	Laburnum	S Centr. Eur., Italy, W Balkans	1	8	8			120		
L. anagyroides	Laburnum	SE France - Balkans	2	8	10	9		110		Ornamental
***Laurus** nobilis*	Sweet bay	Mediterranean, Near East	2	12	12	11		70	1	Ornamental; Highly valued turnery timber.
***Magnolia** campbelli*	Campbell´s magnolia	Nepal, Sikkim, Bhutan	3	15	22	20	*6*	130	3	
***Morus** nigra*	Mulberry	Near East	2	12	8	7		50		
***Prunus** cerasifera*	Cherry plum	SE Europe - SW Siberia	1	10	13			65		
P. laurocerasus	Cherry laurel	SE Europe, Near East	1	8	11			70		
P. lusitanica	Portugal laurel	SW Europe	2	20	13	13		85	2	
***Pterocaya** fraxinifolia*	Caucasian wingnut	Caucasus, N Iran	4	25	20	17	*14*	160	3	
P.x rehderana (P. fraxinif.x P. stenoptera)	Hybrid wingnut	Horticultural	2	25	25	23		120		
***Quercus** canariensis*	Mirbeck´s oak	SE Europe, N Africa	2	30	25	23		100	3	Easily workable timber
Q. castaneifolia	Chestnut-leaved oak	S Caucasus,N Iran	2	25	24	24		110	3	Highly valued timber
Q. macranthera	Caucasian oak	Caucasus, Iran	1	20	15			55	3	
Q. pyrenaica	Pyrenean oak	France, Spain, Potugal, Morocco	1		22			100	3	
***Zelkova** carpinifolia*	Caucasian elm	NE Turkey, N Iran	1	30	28	24		130	3	

CV = coefficient of variation   1) **Frost hardiness** (mean minimum temperature): 1 = limited frost-tolerant (0 °C), 2 = relatively frost-tolerant (-5 °C), 3 = totally frost-tolerant (-15 °C).

9.3 Species from Far East-Asia

The temperate zones of Far East-Asia stretch mainly into northern China, Korea, Japan and Siberia.

According to Table 9.3-1, roughly 30 tree species from the Far East are regarded as champions. This is almost the same number of introduced broadleaf species as those from Europe and the Near East. It should be noted that the Himalayas are regarded as having climatic conditions closer to those of E Europe than that of the Far East.

Maidenhair tree (*Gingko biloba)* was added as a broadleaf tree species, as it bears typical leaves, although it is a gymnosperm.

Most of the species have been recorded as champion trees only once, but maidenhair tree achieved this status more than 10 times.

Seven species have reached heights over 20 m, sometimes taller than in their native countries. Japanese beech and Chinese tulip tree seem to grow especially vigorously. Almost a third of the champions have reached a diameter of 1 m and more.

Most of the species are frost-hardy.

Conclusions

Some of the broadleaf species from the Far East have obviously been introduced mainly as ornamentals because of their flowering patterns. There are, however, some that show promising growth and produce valuable timber and some of them may deserve further studies and research trials in order to ascertain their suitability for forest use in Ireland.

9.4 Species from North America

North America is the third region that contributed roughly 30 species as champions (Table 9.4-1). These come mainly from the eastern parts of the subcontinent. Almost half reached heights well over 20 m, but trees with diameters greater than 1 m are less abundant.

From the forest management point of view, most of the important exotics come from the north-west of the United States and Canada. These are mainly conifers like Sitka spruce, Douglas fir and lodgepole pine. There are also some broadleaf trees with good height growth originating from the eastern USA: tulip tree, red oak, black walnut and locust tree.

Conclusions

North America, especially the east coast, is the home of a variety of broadleaves which suit Irish growing conditions. Some are valued as ornamentals, others are productive and produce quality timber. They also deserve further scientific investigation to identify suitable provenances for Ireland and increase broadleaf diversity.

9.5 Species from South America

The landmass of the temperate zones of the southern hemisphere is relatively limited. A boreal zone does not exist. In contrast to the larger parts of the temperate zones in the northern hemisphere, the climate of its southern equivalent is highly influenced by the surrounding oceans. This is the reason why the winter temperatures, even at higher altitudes, seldom fall below -15 °C. Therefore, only a few species from mountainous regions are sufficiently frost-hardy for growing in sheltered locations in Ireland.

In Table 9.5-1 (see page 470) some species from southern Chile and southern Argentina are listed. Winter´s bark is the outstanding one. The Chilean firebush would be a welcome

Table 9.3-1: Exotic trees from **Asia (Far East)**. (Mainly adapted from *Champion Trees of Ireland* – refer to Chapter 6.4)

Name: Scientific	Name: Common	Location of origin	Number of champions	Height at origin (m)	Height in Ireland max. (m)	Height in Ireland mean (m)	Height in Ireland CV (%)	Diameter max. (cm)	Frost hardiness 1)	Importance, growth habit, products
***Acer** cissifolium*	Vine-leafed maple	Japan	1	8	9	-		20		
A. palmatum	Smooth Japan. maple		1		8	-		50		
***Aesculus** turbinata*	Japan. horse chestnut	Japan	1	20	23	-		90		
***Ailanthus** altissima*	Tree of heaven	China	1	25	15	-		70		
A. altissima Duclouxii	"		1		20	-		110		
A. vilmoriniana	Downy tree of heaven	SE Asia	2		17	14		80		
***Betula** albosinensis var. septentrionalis*	Chinese red-barked birch	China	1		16	-		100		Decorative broadleaf tree.
***Castanea** henryi*	Chinese chestnut	China	1		10	-		40	3	Tallest chestnut in E Asia
***Cercidiphyllum** japonicum*	Katsura	Japan	4	30	22	18	*28*	25		In Japan, one of the most important forest tree species; very valuable timber
***Cinnamomum** camphora*	Camphor tree	Trop. SE + E Asia, Japan, Malaysia	1	20	17	-		35		Evergreen; very valuable timber; spice.
***Cornus** capitata*	Bentham´s cornel	China, Himalayas	1	12	11	-		60		Ornamental
C. controversa	Table dogwood	Japan, China, Himalayas	1	15	8	-		40		Highly valued turnery timber.
***Corylus** tibetica*			1		17	-		40		
***Davidia** involucrata*	Dove/handkerchief tree	W China	2	15	21	21		80		In Europe mainly used as ornamental
***Eucommia** ulmoides*	Gutta-percha tree	Central China	1	12	12	-		30		
***Fagus** crenata*	Japanese beech	Japan	1		28	-		100	3	Economically not important.
***Gingko** biloba*	Maidenhair tree/gingko	S China	12	30	24	15	*29*	110	3	
***Juglans** ailantifolia*	Japanese walnut	Japan	1	15	15	-		160	3	Fast growing; very valuable timber; tasty nuts; dye from bark.
***Laurelia** serrata*	Chilean laurel	Chile	1		20	-		100		Easily workable timber.
***Ligustrum** lucidum*	Chinese privet	China, Korea, Japan	1	10	12	-		100		Highly valued timber.
***Liriodendron** chinense*	Chinese tulip tree	China, Vietnam	3	25	28	23	*19*	100	3	
***Magnolia** delavayi*	Chinese evergreen m.		1		14	-		50		
***Paulownia** tomentosa*	Foxglove tree/Paulownia	Central China	3	35	20	18	*22*	85	(3)	Fast growing; beautiful flowers.
***Phellodendron** sachalinense*	Phellodendron	N China, Amur region, Korea, Japan	2	14	20	16		80	(3)	
***P** chinense*	"	Japan	1	10	16	-		60		
***Populus** maximowizcii*	Japanese poplar	NE Asia, Japan	1	30	28	-		75	3	Important tree of Japan and NE Asia.
***Sophora** japonica*	Pagoda tree	China, Korea	1	30	16	-		130		Minor forestry importance though producing valuable timber; bee pasture.
***Sorbus** commixta*	Japanese rowan	Japan, Korea	1	10	9	-		30	3	
***Ulmus** pumila*	Siberian elm	E Siberia, N China, Korea	1	20	16	-		55		Shelterbelts; parks, gardens.

CV = coefficient of variation 1) **Frost hardiness** (mean minimum temperature): 1 = limited frost-tolerant (0 °C), 2 = relatively frost-tolerant (-5 °C), 3 = totally frost-tolerant (-15 °C).

Table 9.4-1: Exotic trees from **North America**. (Mainly adapted from *Champion Trees of Ireland*–refer to Chapter 6.4)

Name: Scientific	Name: Common	Location of origin	Number of champions	Height at origin	Height in Ireland max. (m)	Height in Ireland mean (m)	Height in Ireland CV %	Diameter max. cm	Frost hardiness[1)]	Importance growth habit products
***Acer** macrophyllum*	Oregon maple	N WEST	0	-20	26	22	*23*	165		
A. negundo	Boxelder maple		0		12	12	-	70		
A. pensylvanicum	Moosewood m.	N EAST	0	12	9			40		
A. rubrum	Red maple	N EAST	0		22	18		95		
A. saccharum	Sugar maple	N EAST	0	25	22	21	*7*	110		
***Aesculus** flava*	Yellow buckeye	EAST	0	30	18			70		Tallest and most important of the American chestnut species;timber for furniture, boxes, tools.
A. glabra	Ohio buckeye	C EAST	0		20			50		
***Betula** nigra*	River birch	EAST	0		14			50		
B. papyrifera	Paper bark birch	-	0		20			90		
***Carya** glabra*	Pignut	EAST	0	25	17			65		Most important hickory species in N America; very valuable timber; important pig mast in earlier times.
***Catalpa** bignonioides*	Southern catalpa	S EAST	0	15	18	13	*40*	100	2	Ornamental
C. speciosa	Northern catalpa	EAST	0	(30)	12			70	3	Ornamental; very durable timber.
***Fagus** grandifolia*	American beech	EAST	0		29			95		
***Fraxinus** americana*	White ash	EAST	0	25	22			70		Most abundant and important ash of N America; valuable timber.
***Gleditsia** triacanthos*	Honey locust	CENTRAL + EAST	0	30	17			85		Ornamental
***Halesia** monticola*	Snowdrop tree	S EAST	0	12	10			35	3	Ornamental
***Juglans** nigra*	Black walnut	EAST	0	30	30	23	*17*	145	2	
***Liquidambar** styraciflua*	Sweet gum	S EAST	0	25 +	16	14	*14*	70		
***Liriodendron** tulipifera*	Tulip tree	EAST	0	30 +	34	24	*21*	210		Fast growing; easily workable timber.
***Magnolia** acuminata*	Cucumber tree	EAST	0	20	22	16	*23*	95	2	In many parks; highly valued timber.
M. grandiflora	Southern magn.	S EAST	0	18	12	10	*21*	60		
M. macrophylla	Bigleaf cucumber tree	-	0		16			35		
***Populus** fremontii*	-	WEST	0	25	34			95	3	
***Quercus** palustris*	Pin oak	CENTRAL + EAST	0	20	17	16		75		Fast growing; furniture timber, but less valuable than *Qu. rubra*.
Q. phellos	Willow oak	S EAST	0	20	11			30	3	Valuable, versatile multi-purpose usable timber.
Q. rubra	Northern red oak	EAST	0	30 +	24	20	*27*	120	3	Fast growing; most important exotic broadleaf species in central Europe;very valuable timber.
Q. velutina	Black oak	EAST	0	30	23			85	3	Timber less valuable than *Q. rubra.*
***Robinia** pseudoacacia*	Black locust	EAST	0	25	22	18	*21*	120	(3)	Fast growing pioneer; second most important broadl. spp. in Central Europe; very valuable timber; soil improver; nutrition for bees.
***Umbellularia** californica*	Californian laurel	WEST	0	18	18			105	3	

CV = coefficient of variation [1)] **Frost hardiness** (mean minimum temperature): 1 = limited frost-tolerant (0 °C), 2 = relatively frost-tolerant (-5 °C), 3 = totally frost-tolerant (-15 °C).

ornamental addition to many forests, but as with most of the species from this region, it is not very frost-hardy.

Some southern beech species are most promising as they come from regions with comparable climates (Figure 9.5-1). Roble and rauli (*Nothofagus obliqua and N. procera* have been described and evaluated in Chapter 8.14. Some others, such as Dombey´s southern beech, would appear to have prospects, but there are more southern beech species that show adaptability to Ireland (Table 9.5-1).

Surprisingly, *Nothofagus pumilio,* with the widest distribution in Chile and Argentina, has not been tested in Ireland so far.

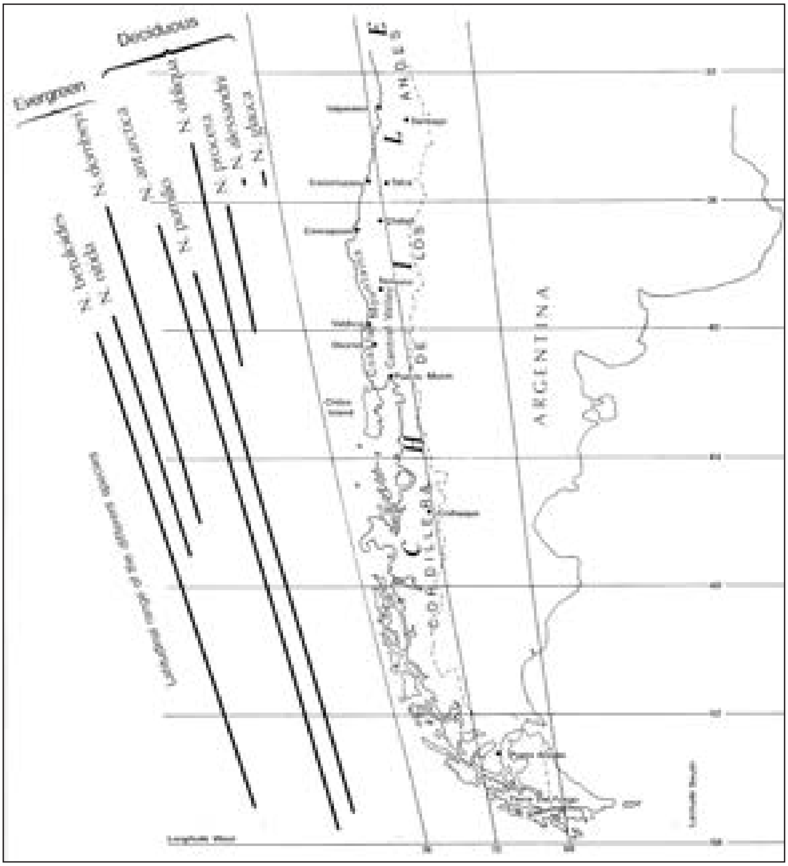


Figure 9.5-1: Natural distribution of southern beech species in S America.
(Evans, 1984)

Table 9.5-1: Heights and diameter of **southern beech champion species**.
(Adapted from Tree Council of Ireland, 2005)

NAME		HEIGHT	DBH	COUNTY
Scientific	English	m	m	
N. antarctica	Antarctic beech	12	0.7	Laois
N.dombeyi	Dombey´s southern beech	16	1.0	Antrim
		28	1.1	Down
		32	1.5	Wicklow
N. glauca		12	0.2	Derry
N. obliqua	Roble beech	32	1.0	Cork
		23	1.0	Down
		29	1.0	
		26	1.1	Tyrone
		17	0.9	Wexford
N, solandri var. cliffortioides	Mountain beech	16	0.5	Donegal
		20	0.7	Dublin
N. cunninghamii	Southern beech	18	0.7	Galway
N. menziesii	Silver beech	20	0.7	Westmeath
N. nervosa	Southern beech	32	1.3	Wicklow

Conclusions

South America provides only a small number of broadleaf species for Ireland because of its limited land area within the temperate zone. Nevertheless, some of the southern beech species may be successfully grown in the future. Provenance studies would be the first requirement to establish potential and suitability.

9.6 Species from Australia and New Zealand

The situation in regard to the land area in the temperate zone of Australia and New Zealand is even more problematic, from the point of view of species suitability, than in South America (Table 9.6-1).

Australia hardly stretches into the real temperate zone. Almost all tree species from there and from New Zealand are not very frost-hardy. Nevertheless, some of them have proved to be very fast-growing in sheltered areas in Ireland.

The champion trees from Australia and New Zealand are clearly dominated by the eucalypts.

Of the 500 or more eucalyptus species from Australia and Tasmania, at least 15 grow successfully in Ireland. Two-thirds have reached maximum heights well over 20 m (Table 9.6-2).

Table 9.6-1: Latitude extremes for Europe and regions in the southern hemisphere

Region	Latitude (°)
Norway	71 north
S America	57 south
New Zealand	46 south
Australia	39 South

Tasmanian blue gum has been the species most widely investigated. It has shown a remarkable growth with heights up to 44 m.

Two *Acacia* species have grown vigorously also and some other species like southern beech and *Pittosporum* did reasonably well.

Conclusions

In the south of Ireland, eucalypts in gardens and parks demonstrate their growth potential. Consideration should be given to other species which might be more widely used, for instance in mixtures. Little is known about any of these species' potential in the Irish climate.

Information on the growth potential of many of the species also seems to be non-existent.

Further studies are necessary to assess their possibilities in this respect.

Overall conclusions

Until recently there has been relatively little interest in broadleaves in Ireland. They have not been the main focus of forestry. Nevertheless, many species from temperate zones around the world have been planted in arboreta and parks. Quite a large number of them show remarkable growth and seem to offer the opportunity to increase the aesthetic and ecological diversity in Ireland's forests as well as to contribute valuable timber crops.

Therefore, it seems desirable that in the future some of these might become the subject of more detailed studies in regard to provenances, site demands and silvicultural characteristics, especially in respect to mixtures. It is important to remember, however, that a problem of possible future invasiveness always exists with exotic species.

Table 9.5-1: Exotic trees from **South America**. (Mainly adapted from *Champion Trees of Ireland* – refer to Chapter 6.4)

NAME		LOCATION OF ORIGIN	NUMBER OF CHAMPIONS	HEIGHT				DIAMETER	FROST HARDINESS[1)]	IMPORTANCE GROWTH HABIT PRODUCTS
Scientific	Common			at origin	in Ireland max.	mean	CV	max.		
				m	m	m	%	cm		
Crinodendron *hookerianum*	Chilean lantern tree	Chile	1	16	13			20		
Drimys *winteri*	Winter´s bark	S Chile, Argentina	5	15	20	16	*19*	150	1-2	Fast growing
Embothrium *coccineum*	Chilean firebush	S Chile	2	10	16	16		65	2	Ornamental
Maytenus *boaria*	Mayten	Chile	1	20	14			70		

Table 9.6-2: Exotic trees from **Australia and New Zealand**. (Mainly adapted from *Champion Trees of Ireland*– refer to Chapter 6.4)

NAME		LOCATION OF ORIGIN	NUMBER OF CHAMPIONS	HEIGHT				DIAMETER	FROST HARDINESS[1)]	IMPORTANCE GROWTH HABIT PRODUCTS
Scientific	Common			at origin	in Ireland max.	mean	CV	max.		
				m	m	m	%	cm		
Acacia *dealbata*	Silver wattle/mimosa	SE Australia	5	30	25	16	*38*	60	1	Planted worldwide in subtropical climates; timber valuable; cut-flowers; tannin.
A. melanoxylon			2	35	27			100		Planted at great rates worldwide in subtropical climates. Best furniture timber in Australia; in Europe mostly for amenity.
Eucalyptus *aggregata*	Black gum		1		17			85	1-2	
E. bridgesiana	Apple gum		1		40			130		
E. coccifera	Funnel-fruited gum		1		16			160		
E. dalrympleana	Mountain gum		1		29			105		
E. delegatensis	Gum-topped stringybark		1		24			105		
E. globulus	Tasmanian blue gum	SE Australia, Tasmania	9	55	44	36	*11*	245		Most important eucalypt worldwide, planted in subtropical and tropical regions. Timber hard, heavy, durable: good for construction, paper and fuel. Eucalyptus oil.
E. gunnii	Cider gum		2		25			120		
E. johnstonii	Tasmanian yellow gum		2		38			160		
E. macarthurii	Paddy´s river box		1		23			80		
E. racemosa	Snappy gum		1		18			75		
E. regnans	Stringy gum		1		26			60		
E. nitida	Peppermint gum		1		20			70		
E. pauciflora	Weeping gum		1		20			65		
E. urnigera	Urn gum		2		34			130		
E. viminalis	Manna gum		1		37			140		
Nothofagus *cunninghamii*	Southern beech		1		18			73		
N. fusca	Red beech		1		24			110		
Pittosporum *tenuifolia*	Pittosporum	New Zealand	2		20			60		Not hardy; planted because of amenity (blue flowers).

CV = coefficient of variation   1) **Frost hardiness** (mean minimum temperature): 1 = limited frost-tolerant (0 °C), 2 = relatively frost-tolerant (-5 °C), 3 = totally frost-tolerant (-15 °C).

Glossary

A

Abiotic factors: Non-living chemical and physical factors in the environment.

Achene: A dry indehiscent, one-sided fruit, formed from a single carpel, and with the seed distinct from the fruit wall.

Acidophilic: Thriving in or requiring an acid environment.

Actinomycete: A member of the *Phyllum Actinobacteri*a with a hyphal morphology, which contributes to the biological buffering of soils and has a role in organic matter decomposition conducive to crop production.

Adaptation: The process(es) whereby individual (or parts of individuals) such as populations or species change in structure, form or function in such a way as to survive under changing environmental conditions.

Adventitious roots: Roots that develop from parts of the plant other than a pre-existing root (e.g. from a stem or leaf).

Afforestation: The establishment of trees in an area that has lacked forest cover for a long time.

Age: The number of growing seasons since planting. The age of a crop is calculated to a whole year; the 1st July is taken as the operative date for increase in age. For example a crop planted over the winter of 1970/1971 is 29 years old if measured on or before 30 June 2000, but is 30 years old if measured on or after 1 July 2000.

Alkaline/calcareous: An alkaline soil is one that has pH levels greater than 7 in any part of the soil profile; calcareous soils contain sufficient calcium carbonate (free or excess lime) to effervesce visibly with dilute (10%) hydrochloric acid. Free lime contents are normally related to pH levels, ranging from none or slight at around neutral (pH 7) to extremely high at pH 8+. (It should be noted that the terms are sometimes used as if they mean the same thing – an example of where this would be inappropriate is calling an alkaline soil with no free lime a calcareous soil.)

Allele: Any of the alternative forms of a gene that may occur at a given locus.

Allelopathy: A biological phenomenon by which an organism produces one or more biochemicals that influence the growth, survival and reproduction of other organisms.

Angiosperm: A division of the plant kingdom that includes all flowering plants; vascular plants in which double fertilisation occurs resulting in development of fruit containing seeds; composed of two classes, *Monocotyledonae* and *Dicotyledonae*.

Anthropogenic: Caused or produced by human activity.

Apex: The end of an organ or plant part remote from its point of attachment or organ (e.g. the root tip or shoot tip).

Apical dominance: Height growth dominated by a leading shoot, which over a period of years, tends to produce a straight stem and conical crown.

Auricle: An appendage, which may resemble the ear of an animal, occurring at the base of a leaf-blade.

Autecology: The ecology of an individual organism.

B

Bare-root stock: Plants lifted from the nursery and despatched to the planting site with their roots bare of soil.

Basal area: The cross-sectional area of a tree stem measured at 1.3 m (breast height) above the ground surface.

Biodiversity: The variety of all life forms at all levels, including genetic diversity, species diversity, and landscape diversity within an ecosystem.

Biotic factors: Living factors such as those related to presence, behaviour and/or interactions to neighbouring organisms.

Boreal: The forests of the Northern Temperate Zone that are dominated by conifers such as spruce, fir and pine.

BP: Before present – a measure of time in years from the present to the occurrence of a past event.

Bract: A leaf, often modified or reduced, which subtends a flower or an inflorescence.

Brashing: The removal of lower branches up to a height of about 2 m to facilitate access for inspection or thinning.

Broadleaves: Trees with broad, flat leaves, e.g. oak, ash, beech and sycamore. Growth is not in whorls, but almost always diffusely branched. Usually deciduous.

C

Calcareous soil: Soil containing sufficient calcium carbonate to effervesce visibly when treated with 10% hydrochloric acid.

Canker: Fungal or bacterial attack that causes lesions on branches or stems.

Canopy: The mass of foliage and branches formed collectively by the crowns of trees.

Carpel: A female organ in a flower, bearing and enclosing one or more ovules, and forming singly or with others the gynoecium.

Catkin: Elongated crowded inflorescence of wind-pollinated flowers.

Cellulose: A complex carbohydrate composed of glucose units that form the main constituent of the cell wall in most plants.

Chromosome: A discrete physical unit of the genome carrying many genes.

Clearfelling: A silvicultural system in which the full crop is felled over an area, usually over a short period.

Climax species: Former expression for species in the final stage of plant succession which reaches a state of equilibrium with the environment.

Cline: A geographical gradient in phenotypic characters.

Clone: A group of genetically identical individuals.

Co-dominant trees: Trees in the upper canopy, but below the crown level of dominants.

Coline zone: Upland.

Compatible species: Species that grow at about the same rate.

Conelet: An immature conifer cone.

Conifer: Trees or shrubs that have needle-like leaves and bear cones. Mostly evergreen.

Coppice: Trees felled close to the ground so as to produce shoots from the resulting stools, giving rise to successive crops of biomass and/or timber.

Coppice system: Crops, in part at least, originating from stool shoots.

Coppice-with-standards: Crops consisting partly of vegetative shoots and partly of trees (standards).

Coupe: An area of woodland that has been designated or is planned for felling.

Crown: The living part of the top of the tree, including branches and leaves.

Crown length: The vertical length of the crown of a tree measured along the main axis of the stem, from a point halfway between the lowest live branch or lowest live whorl to the tip of the tree.

Crown thinning: The removal of dominant trees to provide growing space for the potential crop trees (pcts). It includes the removal of some of the well-formed dominants where they are grouped, and part of the co-dominants. The sub-dominant and suppressed trees are retained. The standard thinning recommended for broadleaves.

Cultivar: A variant of a species that has been selected by gardeners or nurserymen. Cultivars are often loosely termed varieties.

Cupule: Cup-like structure at the base of a fruit, composed of bracts, such as the acorn cup of oak.

Current annual increment (CAI): The basal area or volume increment put on a tree or area of a forest over a given period, usually a single year.

D

DBH: Diameter breast height – diameter of a tree stem measured at 1.3 m above ground level. (Mean stand diameter is the quadratic mean of all trees in a stand, the diameter corresponding to the mean basal area tree (see above).)

Deciduous: Trees that shed their leaves or needles in the autumn. Most broadleaves are deciduous, whereas only some conifers are deciduous, e.g. larch.

Diffuse porous: Wood in which the pores are of a fairly uniform or only a gradually changing size and distribution across a growth ring.

Diploid: A cell or organism with two complete sets of homologous chromosomes.

Dioecious: Possessing male and female flowers on separate unisexual individual plants.

Direct seeding: A process whereby tree seed is sown by hand or machine into a prepared seedbed at the site designated for woodland creation.

DNA: The macromolecule which is the carrier of genetic information in all cells.

Dominant trees: The tallest and the most vigorous trees in a crop - usually have a large proportion of their crowns free.

Dormancy: A period in an organism's life cycle when growth and development activity is temporarily suspended.

E

Earlywood: Thin-walled cells with large spaces within the cell walls, formed in the annual ring at the commencement of growth in spring.

Economic rotation: The age at which the net discounted costs revenues from a forest are at a maximum.

Ecosystem: An ecological system; a natural unit of living and nonliving components that interact to form a system in which cyclic interchange of materials takes place between living and nonliving units such as in a forest.

Elite tree: A phenotypically superior tree; plus tree.

Enrichment planting: A system of planting trees of desirable species into an existing regeneration or an understorey to improve chances of achieving adequate stocking.

Epicormic branches: Small branches originating from adventitious or dormant buds on the stem. They are found on most broadleaf species, and can reduce stem quality in oak.

Eutrophic peat: Flushed (with mineral-rich ground water) peat with a high nutrient content relative to peat generally.

Exotic species: Species that occur in a given place as a result of deliberate or accidental actions by man.

F

Fastigiate branching: Branching sloping towards the vertical, making an acute angle with the stem, and with generally parallel branches.

Filling-in: The replacement of plant failures, also known as beating-up. Usually carried out before the beginning of the second growing season.

Final crop trees: The trees which remain after successive thinnings and are finally felled at maturity.

Flushing: The commencement of above ground growth, characterised by the swelling and bursting of buds.

Forking: The occurrence of two or more leaders in a tree. Usually occurs when a leader or terminal bud is damaged.

Free growth of oak: A system to enable the rapid growth of individual oak trees: a small number (usually between 70/100 ha) of the best and most vigorous potential crop trees in the stand are selected at an early stage; they are pruned and their crowns are allowed full growing space through the regular removal of all adjacent competing trees on a regular basis. Epicormic growth is also removed through annual interventions.

Frost damage: Damage to the soft tissue of a tree by sub-zero temperatures (-5 °C), which can occur in the nursery and in young plantations. Trees are most vulnerable when freshly flushed in late spring or early summer and again in early autumn, prior to hardening off.

Frost hollows: Low-lying concave area where cold air collects, causing frost damage.

Fungi: A group of organisms, which contain no chlorophyll, and are either parasitic or saprophytic on other plants and animals.

G

Gene: The hereditary unit containing genetic information.

Genetic diversity: The diversity among, within and between populations based on the frequencies of shared genes.

Genotype: The genetic constitution of an organism, as opposed to its physical appearance (phenotype).

Genus: A taxonomic group covering more than one species.

Germplasm: The genetic material that forms the physical basis of inherited qualities that are transmitted from generation to generation by the germ cells.

Gley soil: Soil developed under conditions of poor drainage due to presence of slowly permeable layer(s), through materials having disproportionately high clay/silt content and/or through materials that are compacted or indurated. Gymnosperms: Woody vascular seed plants that produce naked seeds not enclosed in an ovary (e.g. conifers).

Gymnosperms: Woody vascular seed plants that produce naked seeds not enclosed in an ovary (e.g. conifers).

Group system: A shelterwood system of successive regeneration fellings in which the canopy is opened by removing trees in discrete groups.

H

Habitat: Any place or type of place where an organism or community of organisms normally lives and thrives.

Haploid: A cell or organism having a single set of chromosomes.

Haplotype: The combination of alleles, at more than one locus, that an offspring receives from one parent.

Heartwood: The inner, older layers of wood in the trunk or branches of a tree or shrub.

Heritability (H): The ratio of genetic variance to phenotypic variance.

Hermaphrodite: Trees possessing functional male and female parts.

Humus: Organic soil matter that remains, after the major portions of added plant (and animal) residues have decomposed (see mull, moder and mor).

Hybridization: The crossing of different races of species; also sometimes used to denote the crossing of individuals.

I

Inflorescence: Flowering branch (or portion of the shoot above the last stem leaves) including its branches, bracts and flowers.

Imparipinnate: Pinnately compound leaves in which there is a lone terminal leaflet rather than a pair of leaflets, also called odd-pinnate.

Indigenous species: Species which have colonised an area naturally, without deliberate human assistance.

Indurated soil: A soil which has strongly compacted material, and which is low in organic matter. It normally occurs at depths of 30-75 cm and extends for 30-50 cm or more.

Invertebrate: Collective term for animals other than those in the *Phylum Chordata* - all those animals that do not exhibit the characteristics of vertebrates.

Involucre: Joined bracts, usually surrounding the base of a short dense inflorescence.

J

Juvenile instability: The leaning or overturning of young trees (2-5 years old) due to the fracture or weakness of the root or base of the stem just below ground level. Trees rarely topple , but continue to grow sometimes resulting in in stems with a bend above the base.

Juvenile period: The period during which juvenile wood is formed.

Juvenile wood: Core, immature wood, which often distorts on sawing.

K

Karst: A landscape formed from the dissolution of soluble rocks such as limestone in the Burren area. It is characterised by sinkholes, caves and underground drainage systems.

L

Lammas growth: Annual shoot growth that can occur a summer pause in growth.

Late-wood: Thick walled cells formed in the annual growth ring during the early autumn period.

Leaching: The removal of materials – including nutrients – in solution from the soil by percolating water.

Leader: The main or leading shoot of a tree.

Lenticel: One of many raised pores in the stem of a woody pant that allows gas exchange between the atmosphere and internal tissues.

Lesion: Damage, injury - morbid change in functioning or texture of organ.

Lichen: A symbiotic association of fungi and algae.

Light-demanders: Trees which only thrive when allowed unimpeded access to light.

Loamy: The textural class name for soil having a moderate amount of sand, silt and clay.

Locus: The position or site of a particular gene on a chromosome.

M

Marginal thinning intensity: An intensity of thinning, taken to be the rate up to which overall volume production is not reduced, sometimes taken as 70% of the maximum mean annual increment, or 70% of the yield class.

Mast year: A year in which seed is produced in exceptionally large quantities. Refers mainly to beech and oak in which mast years occur at intervals of approximately 5-15 years. The quantity of seed produced is usually determined by the accumulated temperature in the previous summer.

Maximum mean annual (volume) increment (MMAI): The maximum annual average volume increment for the crop.

Mean annual (volume) increment (MAI): Total volume production to date, divided by age, i.e. the average rate of volume production over the life of the crop to date.

Mesophytes: Land plants - such as grasses, corn, clover and other field crops - that are adapted to conditions that are neither too dry nor too wet.

Mesotrophic peat: Slightly flushed peat with an intermediate nutrient content.

Micropropagation: The propagation in culture by axillary or adventitious means; general term for vegetative *in vitro* propagation.

Moder humus: Intermediate between mor and mull. The current litter layer overlies partly decomposed material which is not matted as in mor humus.

Monoculture: A stand in which only one species or cultivar is present or predominant.

Monoecious: A plant which bears separate male and female flowers.

Monopodial: A plant with a single axis or stem and extension growth from the apex.

Monopodial growth: Indefinite, indeterminate growth.

Mor: Raw humus; type of forest humus layer of unincorporated organic material, usually distinct from the mineral soil. Comprised of current litter layer overlying a matted layer of partly decomposed material.

Mounding: Formation of discrete mounds of soil, usually 20-30 cm in height, distributed at the intended planting spacing.

Mull: A humus-rich layer of forest soil consisting of mixed organic and mineral matter. A mull blends into the upper mineral layers without an abrupt change in soil characteristics.

N

Natural regeneration: The regeneration of a crop through natural seeding from mother trees.

Nemoral: Of or pertaining to a wood or grove.

Neophyte: Newly introduced plant species.

Nurse species: Species that shelter more delicate species from late or early frost, wind, desiccation and drought.

O

Oligotropic peat: Unflushed peat with a very low nutrient content.

Ortet: The initial individual that is vegetatively propagated to produce a clone.

Orthodox seed: Seed which conform to normal seed storage principles relating to moisture content and temperature.

Osiers: Species of willow usually grown on very short rotations to provide shoots for basket weaving.

P

Pannage: A traditional practice, mainly in Europe, of turning out domestic pigs into a wood or forest to feed on fallen acorns or beech mast.

Panicle: Strictly, a branched raceme with each branch bearing a raceme of flowers.

Parent material: The unconsolidated and more or less chemically weathered mineral or organic matter from which the overlying topsoil and subsoil is developed by soil-forming processes.

Pedicel: A stalk bearing one flower.

Petal: A member of the corolla, often brightly coloured and conspicuous.

Petiole: The stalk of a leaf.

pH: A value on a scale 0-14 that gives a measure of the acidity or alkalinity of a soil. A neutral soil has a pH of 7. Acidic soils have pH values of less than 7 and alkaline soils greater than 7. The lower the pH the more acidic is the soil; the higher the pH the more alkaline.

Phenotype: The observed characteristics of a tree, produced by the genotype in conjunction with the environment and in response to management.

Phototropic: Orientation in response to the stimulus of light.

Pinnate: Of leaves, compound, with leaflets displayed on either side of a central stalk.

Pioneer species: Species that first colonise a physical environment sequentially until more shade-tolerant species take over.

Plus tree: (see elite tree).

Pollen: The partly developed male gametophyte produced by the anthers of seed plants.

Pollarding: A woodland management method of encouraging the re-growth of lateral branches by cutting a tree stem or minor branches close to ground level, or 2-3 m above ground.

Polyploid: A plant possessing more than two sets of chromosomes.

Precocious: Flowering or producing fruit in the life of a tree.

Progeny: The offspring of a particular parent or a particular combination of one female and one male organism.

Provenance: A geographical area of occurrence of a particular species with specific adaptation to site conditions, for example Spessart oak from south-central Germany.

Pruning: The removal of branches from a tree stem by artificial or natural means.

R

Raceme: A simple (unbranched) racemose inflorescence in which the flowers are visibly stalked.

Ramet: An individual member of a clone descended from the ortet.

Recalcitrant seed: Seed that does not survive drying or freezing during *ex situ* conservation, for example acorns.

Refugium: An area that provides protection/escape for species from adverse ecological conditions occurring elsewhere.

Revolute leaves: Leaves having a rolled-back edge.

Ring-porous wood: Wood in which the pores of the earlywood are distinctly larger than those in the latewood, and form a well-defined zone or ring.

Riparian zone: The area, above and below the ground surface that borders a river/stream.

Ripping: The deep cultivation of a soil with a long tine, mounted on a machine tool bar, to depths of 30-100 cm for the purpose of shattering compacted/indurated layers, including plough pans.

Riverine: Located in the vicinity of a river (usually in the floodplain).

Root sucker: See sucker shoot.

Rotation: The number of years required to establish and grow a crop to a specified condition of maturity, at which stage the crop is felled (clearfelling), or regenerated under the shelter of the existing crop (shelterwood), which is then gradually removed.

S

Samara: A dry, indehiscent fruit of which part of the wall forms a flattened wing, for example an ash key.

Sapwood: The outer, younger part of the wood of a tree or shrub, pale in colour, with living tissue (parenchyma cells), and still conducting sap.

Sawlog: Logs, usually of at least 14 cm top diameter, which are intended for conversion in a sawmill.

Scarification: A method of site preparation that disturbs the ground and allows the mixing of organic and mineral layers of the soil thus improving the conditions for growth for the next tree crop.

Scion: Any unrooted portion of a plant used for grafting or budding on to a rootstock.

Scionwood: Shoots or woody plants from which scions are collected.

Selection system: A silvicultural system in which trees are removed individually, across a large area each year.

Selective thinning: Removal of individual trees in favour of trees of at least as good growth form and condition.

Sepal: A whorl of modified leaves in angiosperms that encloses and protects the flower bud before it opens.

Serving species: A species whose function is to remain in the understorey and perform a shading role, which assists in natural pruning and suppresses ground vegetation. The species must have shade-bearing characteristics.

Shade-bearers: Understorey species (not always grown in the understorey) which are adapted to growing with limited access to light.

Shake: A defect in timber, consisting of cracks either radiating from the centre of the stem (star shake) or following an annual ring (ring shake).

Shaping: Removal of forks and large branches (usually from broadleaves) with the object of producing straight single stems.

Shelterwood system: A silvicultural system of successive regeneration fellings in which the young crop is established under partial shade, overhead or lateral, of the old crop.

Silvicultural system: The process by which forest crops are regenerated, tended, thinned, removed and replaced by new crops, resulting in stands of distinctive form.

Silviculture: The science of establishing, growing and managing forest crops.

Singlestorey: Woodland with a single canopy.

Soil aeration: The process by which air in the soil is replaced by air from the atmosphere. In a well-aerated soil, the soil air is similar in composition to the atmosphere above the soil. Poorly aerated soils usually contain more carbon dioxide and correspondingly less oxygen than the atmosphere above the soil.

Soil permeability: The ease with which gases or water penetrate or pass through a mass or layer of soil.

Soil profile: A vertical section through the soil and its horizons extending to the parent material.

Soil texture: The relative proportions of the various soil separates (clay, silt, sand) in a soil.

Solitaire: A single individual tree.

Sprouting: Beginning to grow; producing shoots or buds.

Stalk: The main stem of a herbaceous plant or the slender attachment or support of a leaf.

Stamen: The pollen-producing male reproductive organ of a flower.

Stand structure: The distribution of trees within a stand by species and size.

Stipule: A small leaf-like appendage to a leaf, usually at the base of a leaf-stem.

Strobilus: The reproductive structure of most gymnosperms and some pteridophytes.

Stumping-back: The cutting-back of plants which are usually malformed, within a few years of planting, to within 5-10 cm of ground level. This stimulates regrowth of multiple shoots, which can then be singled.

Sub-dominant trees: Trees not in the upper canopy, but with leaders having free access to light.

Sucker shoot: An underground shoot arising adventitiously from the roots or lower stem of a tree and emerging from the soil to form a new plant, initially nourished by its parent.

Suppressed tree: Tree whose leader has no direct access to light and is overtopped by the crowns of adjacent trees.

Sympodial: Branching in which an apparent main axis is made up of many lateral branches, each arising from the one before.

T

Taproot: A vertically descending central root.

Tending: The removal of wolves and trees of defective stem form which would adversely affect the growth and quality of the crop. Usually done when trees are 5-8 m high.

Thinning: The removal of a proportion of trees from a crop in order to improve the growth and form of the remainder.

Thinning cycle: The interval in years between successive thinnings.

Thinning intensity: The proportion of the standing volume removed.

Top height: The average height of the 100 trees of largest diameter breast height per hectare.

Till: Glacial drift deposited directly by ice and consisting of clay, silt, sand, gravel and boulders.

Transplants: Barerooted plants usually 1-3 years old, grown in a nursery and transplanted

Tylosis: An outgrowth from an adjacent ray or axial parenchyma cell through a cell cavity in a vessel wall, partially or completely blocking the vessel lumen. Tyloses may be few or many crowded together; thin- or thick-walled; pitted or unpitted or without starch, crystals, resin, gum etc.

U

Understorey: Any plants or shrubs growing under a tree canopy.

Uniform system: A shelterwood system in which successive regeneration fellings are uniformly distributed over a full stand, resulting in a more or less even-aged crop.

V

Vessel: An axial series of cells that have coalesced to form an articulated tube-like structure of indeterminate length.

W

Waterlogged: Soil saturated with water.

Water table: The upper surface of groundwater or that level below which the soil is saturated.

Wildings: Self-sown plants.

Windfirm: Stable trees or plantations that, because of species, soil, rooting or relative exposure, are unlikely to suffer windthrow.

Windthrow: Uprooting or breakage of trees caused by strong winds.

Wolves: Trees in the upper canopy (dominants/co-dominants) with defective stems and large, rough lateral branches.

Y

Yield class: The potential or actual yield. In Britain and Ireland it is the potential maximum mean annual volume increment, derived from top height over age for different species. (In Germany yield class is defined in a different manner: it is the potential mean annual volume increment (m^3/ha) at 100 years of age. Thus, yield class 9 is equivalent to a cumulative volume production of 900 m^3/ha at 100 years of age.)

Bibliography

Anderson, M.L. 1953. Spaced-Group Planting. Unasylva 7: 55-63.

Anonymous. 2006. Annual Excursion Report, 1897. Scottish Forestry 60 (1): 44.

Baader, G. 1938. Betriebstechnische Grundsaetze fuer eine waldbauliche Planung unter besonderer Beruecksichtigung der Mischbestandfrage. Der Deutsche Forstwirt 20: 701-713.

Bacon, P. 2004. A Review and Appraisal of Ireland's Forestry Development Strategy. Stationery Office, Dublin.

Bakys, R., Vasaitis, R., Barklund, P., Thomsen, I.M., Stenlid, J. 2009. Occurrence and pathogenicity of fungi in necrotic and non-symptomatic shoots of declining common ash (*Fraxinus excelsior*) in Sweden. European Journal of Forest Research 128 (1): 51-60.

Barry, J. 2009. Personal communication.

Barry, P. 1986. Potential of Irish Climate for Agriculture. In: Keane, T. (ed.). Climate, Weather and Irish Agriculture. Agmet Group, Dublin.

Baule, H., Fricker, C. 1970. The fertiliser treatment of forest trees. BLV, Muenchen.

Bilke, G. 2004. Waldumbau in Nordostdeutschland durch Eichennachzucht in Mortzfeldtschen Loechern. Diss. Universitaet Freiburg.

Boerner, F. 1989. Taschenwoerterbuch der botanischen Pflanzennamen (4th edn. revised by Kunkel, G). P. Parey, Hamburg.

Bossemal, I. 1979. Jays and Oaks: an Eco-Ethological Study of a Symbiosis. Behaviour, Volume 70:1-117

Bruenig, D. 1959. Forstduengung. Neumann Verlag, Radebeul.

Bulfin, M., Radford T. 1998. Effect of early formative shaping on newly planted broadleaves – Part 1: Quality. Irish Forestry 55 (2): 35-51.

Bulfin, M., Radford, T. 1998. Effect of early formative shaping on newly planted broadleaves – Part 2: Height and diameter. Irish Forestry 55 (2): 52-61.

Bulfin, M., Radford, T. 2000. Studies in the Planning, Location and Management of Farm Forestry: Formative Shaping of Broadleaves. End of Project Report, Project 4125, Horticulture and Farm Forestry, Series No. 20, Teagasc.

Bulfin, M., Radford, T. 2001. A review of historical literature on the pruning (formative shaping) of broadleaved trees, from the sixteenth to the nineteenth century. Irish Forestry 58 (1-2): 30-45.

Burschel, P., Huss, J. 2003. Grundriss des Waldbaus: Ein Leitfaden für Studium und Praxis (3rd unmodified edn.). Verlag E. Ulmer, Stuttgart.

Cahalane, G. 2003. Threats to Irish forests from exotic pests and diseases. The Farm Forest: 54-55. Teagasc, Athenry.

Cahalane, G., Doody, P., Douglas, G., Fennessy, J., O´Reilly, C., Pfeifer, A. 2007. Sustaining and Developing Ireland´s Forest Genetic Resources: An Outline Strategy. COFORD, Dublin.

Carey, M. 2006. Personal communication.

Carey, M. 2009. If trees could talk: Wicklow's trees and woodlands over four centuries. COFORD, Dublin.

Carey, M., Hamilton, G., Poole, A., Lawton, C. 2007. The Irish squirrel survey. COFORD, Dublin.

Caslin, B. 2009. Personal communication.

Church, R.J.H., Hall, P., Mead, W.R., Mutton, A. 1973. An Advanced Geography of Northern and Western Europe (2nd edn.). Hulton Educational Publications, Amersham.

Claessens, H. 2003. The alder populations of Europe. In: Gibbs, J., van Dijk, C., Webber, J. (eds.). Phytophthora Disease of Alder in Europe. Forestry Commission Bulletin 126. Forestry Commission, Edinburgh.

Clark, J. 2010. Personal communication.

Clinch, J.P. 1999. Economics of Irish Forestry: Evaluating the Returns to Economy and Society. COFORD, Dublin.

COFORD. 2008. The National Catalogue of Seed Stands. COFORD Annual Report. COFORD, Dublin.

COFORD. 2009. BROADPROV project report (p 14). COFORD Annual Report. COFORD, Dublin.

Coillte. 1991. Coillte's Broadleaf Experimental Programme. Information Note. Unpublished.

Collier, P., Dorgan, J., Bell P. 2002. Factors Influencing Farmer Participation in Forestry. COFORD, Dublin.

Collier, P., Short, I., Dorgan, J. 2004. Markets for non-wood forest products. COFORD, Dublin.

Collingwood, G.H., Brush, W.D. 1979. Knowing your Trees. Butcher, D. (ed.). The American Forestry Association, Washington, D.C.

Collins, J.F., Cummins, T. (eds.). 1996. Agroclimatic Atlas of Ireland. AGMET (Joint Working Group on Applied Agricultural Meteorology). Agrometeorological Memorandum No. 5. Meteorological Service, Dublin.

Connaughton, M.J. 1969. Air frosts in late spring and early summer. Agrometeorological Memorandum No. 2. Meteorological Service, Dublin.

Connaughton, M.J. 1973. The grass growing season in Ireland. Agrometeorological Memorandum No. 5. Meteorological Service, Dublin.

Convery, F.J. 1979. Irish Forestry Policy. National Economic and Social Council, No. 46. National Economic and Social Council, Dublin.

Cooney, G. 1993. Forestry and the Cultural Landscape: Understanding the Past in the Present. Irish Forestry 50 (1): 13-20.

Cotta, H. 1816. Anweisung zum Waldbau. Dresden and Leipzig.

Cregan, M., Murphy, W. 2006. A review of forest recreation research needs in Ireland. COFORD, Dublin.

Cross, J.R. 2006. The potential natural vegetation of Ireland. Biology and environment: Proceedings of the Royal Irish Academy 106B (2): 65-116.

Cubbage, F.W., Siegel, W.C. 1985. The Law Regulating Private Forest Practices. Journal of Forestry 83 (9): 538-545.

Curry, J.P. 2004. Factors affecting the abundance of earthworms in soils. In: Edwards, C.A. (ed.). Earthworm Ecology: 91-113 (2nd edn.). CRC Press, Boca Raton, Florida.

Curry, J.P., Byrne, D., Schmidt, O. 2002. Intensive cultivation can drastically reduce earthworm populations in arable land. European Journal of Soil Biology 38: 127-130.

Davis, L.S., Johnson, K.N. 1987. Forest Management (3rd edn.). McGraw-Hill Book Company, New York.

Department of Agriculture and Food. 2007. Annual Review & Outlook for Agriculture & Food 2006/2007. Department of Agriculture and Food, Dublin.

Department of Agriculture, Food and the Marine. 2014. Forests, products and people - Ireland's forest policy - a renewed vision. Department of Agriculture, Food and the Marine, Dublin.

Department of Agriculture, Food and the Marine. 2015. Afforestation Scheme (Leaflet No. 1). Department of Agriculture, Food and the Marine, Dublin.

Department of Agriculture, Food and the Marine. 2015. Forestry Standards Manual. Department of Agriculture Food and the Marine, Dublin.

Department of Agriculture, Food and Forestry. 1996. Growing for the Future: A Strategic Plan for the Development of the Forestry Sector in Ireland. Stationery Office, Dublin.

Department of Communications, Marine and Natural Resources. 2003. Forestry Schemes Manual. Forest Service, Dublin.

Department of Lands, Forestry Division. 1972. Forest Research Review 1964-1970. Stationery Office, Dublin.

Doody, P. 2007. Personal communication.

Douglas, G.C. (ed.). 1995. Strategies for Improvement of Forest Tree Species. COFORD, Dublin.

Douglas, G., Thomasset, M. 2013. Identifying and characterising hybrid 'brown bud' ash in Ireland. COFORD Connects, Reproductive Material No. 20. COFORD, Dublin.

Dowding, P. & Smith, L. 2008, Forest Fungi in Ireland, Coford Dublin.

Ducousso, A., Bordacs, S. 2004. EUFORGEN Technical Guidelines for genetic conservation and use for pedunculate and sessile oaks (*Quercus robur* and *Q. petraea*). International Plant Genetic Resources Institute, Rome.

Duplat, P. avec la participation de Champagne, P., Chollet, F., Ginisty, C., Jarret, P., Nouveau, M., Reteau, F., Sevrin, E. 1996. Sylviculture du Chêne pédonculé: 15-19. Bulletin Technique No. 31. Office National des Forêts, Fontainebleau.

Durand, J.F. 1969. The Evolution of State Forestry in Ireland. Unpublished Ph.D. thesis. University College Dublin.

Dussart, G. 1999. The ecological implications of loss of alder trees. Appendix 3, Consolidated Progress Report of the EU Concerted Action FAIR5-CT97-3615. Cited in Claessens, H. 2003.

Edlin, H.L. 1968. Know your Broadleaves. Forestry Commission Booklet No. 20. HMSO, London.

Edwards, P.N., Christie, J.M. 1981. Yield Models for Forest Management. Forestry Commission Booklet 48. Forestry Commission, Edinburgh.

Elwes, H.J., Henry, A. 1906-1913. The Trees of Great Britain and Ireland. Edinburgh, Scotland. Privately published in seven volumes with index.

Evans, J. 1984. Silviculture of Broadleaved Woodland. Forestry Commission Bulletin 62. HMSO, London.

Farrell, E.P., Kelly-Quinn, M. 1992. Forestry and the environment. In Feehan, J. (ed.). Environment and Development in Ireland: 353-357. The Environmental Institute, UCD, Dublin.

Farrelly, N. 2007. The farm forest resource in Ireland: opportunities and challenges for rural development in Ireland. Small-scale Forestry 6: 49-64.

Farrelly, N., Gallagher, G. 2013. Classification of Lands Suitable for Afforestation in the Republic of Ireland. COFORD, Dublin. Unpublished report.

Featherstone, A.W. 2007. Trees for Life-Species Profile: Common or black alder. http://www.treesforlife.org.uk/forest/species/alder.html

Feehan, J. 2005. The woodland vegetation of Ireland, past, present and future. Irish Forestry 62 (1&2): 73-87.

Felton, D., Thompson, D. 2008. Seed source influences growth, form and silvicultural management of oak. COFORD Connects. Reproductive Material No. 16. COFORD, Dublin.

Felton, D., Thompson, D., Nieuwenhuis, M. 2006. An early assessment of Irish oak provenance trials and their implication for improved seed production. Irish Forestry 63 (1-2): 6-25.

Fennessy, J. 2004. Common alder (*Alnus glutinosa*) as a forest tree in Ireland. COFORD Connects. Reproductive Material No. 8. COFORD, Dublin.

Fennessy, J., Doody, P., Thompson, D. 2012. A review of tree improvement programmes in Ireland – historical developments, current situation and future prospects. Irish Forestry 69 (1&2): 184-203.

Fiedler, H.J., Nebe, W., Hoffmann, F. 1973. Forstliche Pflanzenernaehrung und Duengung. G. Fischer Verlag, Stuttgart.

FitzGerald, J., Johnson, J. 1996. The Economics of Biomass in Ireland. The Economic and Social Research Institute. Unpublished paper. Cited in Clinch, J.P. 1999.

Fitzpatrick, H.M. 1966. The Forests of Ireland. Society of Irish Foresters, Dublin.

Fitzsimmons, B., Luddy, W.B. 1986. Growing Ash for Hurleys. Irish Forestry 43 (1): 32-55.

Forest Service. 2000. Code of Best Forest Practice – Ireland. Forest Service, Dublin.

Forest Service. 2000a: Forestry and Water Quality Guidelines. Department of the Marine and Natural Resources, Dublin.

Forest Service. 2000b. Forestry and the Landscape Guidelines. Department of the Marine and Natural Resources, Dublin.

Forest Service. 2000c. Forestry and Archaeology Guidelines. Department of the Marine and Natural Resources, Dublin.

Forest Service. 2001. Native Woodland Scheme. Department of the Marine and Natural Resources, Dublin.

Forest Service. 2002. Forest Protection Guidelines. Department of the Marine and Natural Resources, Dublin.

Forest Service. 2006. Forest Recreation in Ireland: A Guide for Forest Owners and Managers. Department of Agriculture and Food, Wexford.

Forest Service. 2006a. Forest Statistics – Afforestation. Forest Service, Wexford.

Forest Service. 2007. National Forest Inventory, Republic of Ireland – Results. Government Publications, Dublin.

Forest Service. 2007a. Current standard costs (Exclusive of VAT) for each GPC [Grant/Premium Category] (€/ha). Forest Service, Wexford.

Forest Service. 2011. Forestry Schemes Manual. Department of the Marine and Natural Resources, Dublin.

Forest Service. 2013. The Second National Forest Inventory – Republic of Ireland – Results. Department of Agriculture, Food and the Marine, Wexford.

Forestry Commission. 2012. Chalara dieback of ash (*Chalara fraxinea*). http://www.forestry.gov.uk/chalara

Fraxigen. 2005. Ash species in Europe: biological characteristics and practical guidelines for sustainable use. Oxford Forestry Institute, University of Oxford.

Gardiner, M.J., Radford, T. 1980. Soil Associations of Ireland and Their Land Use Potential. Explanatory Bulletin to Soil Map of Ireland 1980. Soil Survey Bulletin No. 36. An Foras Talúntais, Dublin.

Gayer, K. 1886. Der gemischte Wald, seine Begruendung und Pflege, insbesondere durch Horst- und Gruppen-wirtschaft. Parey, Berlin.

Gibbons, J. 2008. Green issue gains support as political climate changes. Irish Times 20.11.2008.

Gibbs, J., van Dijk, C., Webber J. 2003. Phytophthora Disease of Alder in Europe. Forestry Commission Bulletin 126. Forestry Commission, Edinburgh.

Gray, H.J. 1963. The Economics of Irish Forestry. Journal of the Statistical and Social Enquiry Society of Ireland 21(2): 18-24

Green, S. 2005. Birch dieback in Scotland. Information Note. Forestry Commission, Edinburgh.

Guest, C., Huss, J. 2011. Quantifying the Development of Oak/European Larch and Oak/Scots Pine Stands in Ireland. COFORD Connects, Silviculture and Forest Management No. 21. COFORD, Dublin.

Hamilton, G.J., Christie, J.M. 1971. Forest Management Tables (Metric). Forestry Commission Bulletin No. 34. HMSO, London.

Hammond, R.F. 1979. The Peatlands of Ireland. Soil Survey Bulletin No. 35. An Foras Talúntais, Dublin.

Hannan, D.E., Commins, P. 1993. The impact of forestry on rural communities. The Economic and Social Research Institute, Dublin. Cited in Kearney, B. 2001.

Harmer, R., Kerr, G., Thompson, R. 2010. Managing Native Broadleaved Woodland. Forestry Commission, Edinburgh.

Harrington, C.A. 2006. Biology and Ecology of Red Alder. In: Red Alder: A State of Knowledge: 21-43. General Technical Report PNW-GTR-669. USDA Forest Service.

Hassenkamp, W. 1959. Review of contributions by kjölby, Sabroe and Moltesenon on Acer (*Acer pseudoplatanus*), in Dansk Skovforening. 1958. Forstarchiv. 138 - 140.

Hayes, S. 1822. A Practical Treatise on Planting and The Management of Woods and Coppices (3rd edn.). Dublin.

Heaney, S. 2008. Personal communication.

Hemery, G., Savill, P.S., Kerr, G. 2003. Formative pruning. Woodland Heritage, Haslemere.

Herries Davies, G.L., Stephens, N. 1978. The Geomorphology of the British Isles: Ireland. Methuen, London.

Heurtz, M. 2003. Population genetic structures in common ash: A focus on southeastern European genetic resources. Free University of Brussels, Public Research Centre-Gabriel Lippmann.

Hibbs, D.E. 1996. Stand Management – Managing Red Alder. The Woodland Workbook. Oregon State University Extension Service.

Holmberg, P. 2006. Red Alder – Regeneration and Stand Initiation: Techniques and Field Craft as Related to Final Returns on Early Investments. In: Red Alder: A State of Knowledge: 137-149. General Technical Report PNW-GTR-669. USDA Forest Service.

Horgan, T. 2004. Shelter is key to successful broadleaf silviculture. Forestry & British Timber, June 2004.

Horgan, T. 2009. Personal communication.

Horgan, T., Keane, M., McCarthy, R., Lally, M., Thompson, D. 2003. O'Carroll, J. (ed.). A Guide to Forest Tree Species and Silviculture in Ireland. COFORD, Dublin.

Huss, J. 2007. Zur Begruendung von Eichen auf Sturmwurfflaechen. Proceedings German Union of Forest Research Organisations, section silviculture, 2006 in Tharandt: 98-113.

Huss, J., Csapek, G. 2011. Zum Umbau von Fichtenreinbestaenden in Mischwaelder mittels Direktsaat und Planzung – darstellt anhand eines Versuchs im rheinland-pfaelzischen Forstamt Osburg. Freiburg Forest report.

Iremonger, S., O´Halloran, J., Kelly, D.L., Wilson, M.W., Smith, G.F., Gittings, T., Giller, P.S., Mitchell, F.J.G., Oxbrough, A., Coote, L., French, L., O´Donoghue, S., McKee, A.M., Pithon, J., O´Sullivan, A., Neville, P., O´Donnell, V., Cummins, V., Kelly, T.C., Dowding, P. 2007. Biodiversity in Irish Plantation Forests (BIOFOREST Project <http://bioforest.ucc.ie>). Environmental Protection Agency, Wexford.

Jarret, P. avec la participation de Duplat, P., Hoyau, H., Kiefer, E. 1996. Sylviculture du Chêne sessile: 21-28. Bulletin Technique No. 31. Office National des Forêts, Fontainebleau.

Jobling, J., Pearce, M.L. 1987. Free Growth of Oak. Forest Record No. 113, Forestry Commission. HMSO, London.

Jones, M. 1986. Coppice Wood Management in the Eighteenth Century: an Example from County Wicklow. Irish Forestry 43: 15-31.

Joyce, P.W. 1905. The origin and history of Irish names of places. Volumes 1-3. McGlashan and Gill, Dublin.

Jüettner, O. 1955. Ertragstafel Eiche. In: Ministerium für Laendlichen Raum, Ernaehrung und Forsten. Baden-Wuerttemberg (edn. 1993). Hilfstafeln für die Forsteinrichtung, Stuttgart.

Kato, F., Muelder, D. 1978. Ueber die soziologische und qualitative Zusammensetzung gleichaltriger Buchenbestaende: Ein Beitrag zur Rationalisierung der Buchenwirtschaft. Schriften a. d. Forstl. Fak. Univ. Goettingen u. d. Nieders. Forstl.Versuchsanst. Bd. 51. Sauerlaender´s Verlag. Frankfurt.

Keane, T. 1986. Meteorological Parameters in Ireland. Chapter 3 in Keane, T. (ed.). Climate, Weather and Irish Agriculture. AGMET Group, Dublin.

Keane, T. 1992. Irish Farming, Weather and Environment. AGMET Group, Dublin.

Kearney, B. 2001. A Review of Relevant Studies Concerning Farm Forestry Trends and Farmers Attitudes to Forestry. COFORD, Dublin.

Kelleher, C.T., Hodkinson, T.R., Kelly, D.L., Douglas, G.C. 2004. Characterisation of chloroplast DNA haplotypes to reveal the provenance and genetic structure of oaks in Ireland. Forest Ecology and Management 189: 123-131.

Kelly, F. 1999. Trees in early Ireland. Irish Forestry 56 (1): 39-57.

Kerr, G. 1996. The effect of heavy or 'free growth' thinning on oak (*Quercus petraea* and *Q. robur*). Forestry 69 (4): 303-317

Kerr, G., Evans, J. 1993. Growing broadleaves for timber. Forestry Commission Handbook 9. HMSO, London.

Knaggs, G., O'Driscoll, E. 2012. Woodflow and forest-based biomass energy use on the island of Ireland. COFORD Connects, Processing/Products No. 29. COFORD, Dublin.

Knaggs, G. and Xenopoulou, S. 2004. Guide to Irish hardwoods. COFORD, Dublin.

Koski, V., Rousi, M. 2005. A review of the promises and constraints of breeding silver birch (*Betula pendula* Roth) in Finland. Forestry 78 (2): 197-198.

Kraft, G. 1884. Kraft, G. 1884. Beiträge zur Lehre von Durchforstungen. Schlagstellungen und Lichtungshieben, Hannover.

Larner, J. 1992. The Oakwoods of Killarney. Stationery Office, Dublin.

Little, D., Cross, J. 2005. Realising Quality Wood from Ireland's Native Woodlands. Woodlands of Ireland, Dublin.

Lundgren, L.N., Pan, H., Theander, O., Eriksson, H., Johansson, U., Svenningsson, M. 1995. Development of a new chemical method for distinguishing between *Betula pendula* and *Betula pubescens* in Sweden. Canadian Journal of Forest Research 25 (7): 1097-1102.

MacConnell, S. 2008. Marginal drop in price of farm land. Irish Times 18.01.2008.

Malone, J. 2008. Factors Affecting Afforestation in Ireland in Recent Years. A report to the Minister of State with responsibility for Forestry. Internal report, Department of Agriculture, Food and the Marine, Dublin.

Mason, C.L. 2006. Red Alder Market Implications for Management; Reasons for Optimism. In: Red Alder: A State of Knowledge: 133-136. General Technical Report PNW-GTR-669. USDA Forest Service.

Matthews, A. 2008. IFA's scare campaign damages Ireland Inc. Irish Times 20.07.2008.

McCracken, E. 1971. The Irish Woods since Tudor Times. David & Charles, Newton Abbot.

McWilliams, B.E. (ed.). 1991. Climate Change – Studies on the implications for Ireland. Stationery Office, Dublin.

McWilliams, B.E. 2005. The development of our climate – The Climate of Ireland: Yesterday, Today and Tomorrow. Climate Change Conference in Botanic Gardens, Dublin.

Mette, H.J, Korell, U. 1982. Richtzahlen und Tabellen für die Forstwirtschaft. VEB Deutscher Landwirtschaftsverlag, Berlin.

Mitchell, F. 1986. Shell Guide to Reading the Irish Landscape. Country House, Dublin.

Mitchell, A. 1989. The Trees of Britain and Northern Europe. Collins, London.

Mitchell, F., Ryan, M. 1997. Reading the Irish Landscape. Trinity House, Dublin.

Mitcherlich, E.A. 1945. Lebenserinnerungen. Deutsche Akademie d. Naturforscher, Halle.

Mortzfeldt, J. 1896. Ueber horstweisen Verjuengungsbetrieb. Zeitschrift fuer Forst-und Jagdwesen 28: 2-31.

Mulloy, F. 2008. Personal communication.

Murray, M.B. Cannell, M.G.R., Sheppard, L.J., Lines, R. 1986. Frost Hardiness of *Nothofagus procera* and *Nothofagus obliqua* in Britain. Forestry 59 (2): 209-222.

Nagel, J. 1986. Wachstumsmodell für Bergahorn in Schleswig-Holstein. AFJZ. Forst- u.J.-Ztg 157:31-36

National Catalogue of Seed Stands in Ireland. 2011. List of species. Department of Agriculture Food and the Marine, Dublin.

Neeson, E. 1991. A History of Irish Forestry. The Lilliput Press, Dublin.

Nelson, E.C., Walsh, W.F. 1993. Trees of Ireland: Native and Naturalized. The Lilliput Press, Dublin.

NFI. 2007 see Forest Service 2007.

NFI. 2013 see Forest Service 2013.

Ní Dhubháin, Á., Fléchard M.C., Moloney R., O'Connor D., Crowley T. 2006. The socioeconomic contribution of forestry in Ireland. COFORD, Dublin.

Niemiec, S.S., Ahrens, G.R., Willits, S., Hibbs, D.E. 1995. Hardwoods of the Pacific northwest. Research

Contribution 8, Forest Research Laboratory. Oregon State University, Corvallis.

OCarroll, N. 2004. Forestry in Ireland: A Concise History. COFORD, Dublin.

O'Connor, E. 2006. Progress in the Selection and Improvement of Birch. COFORD Connects, Reproductive Material No. 10. COFORD, Dublin.

O'Dowd, N. 2004. The improvement of Irish birch. Phase I: Selection of individuals and populations. COFORD, Dublin.

O'Reilly, G. 1992. In: Keane, T. (ed.). Irish Farming, Weather and Environment. AGMET Group, Dublin.

O'Sullivan, M. 2009. Land auction prices crash to 5-year low. Irish Independent 6.01.2009.

O'Sullivan, M. 2010. Land values drop further. Irish Independent 19.01.2010.

O'Shea, D. 2009. Personal communication.

Otto, H.J. 1987. Wiederaufforstung von Windwurf- und Immissionsschadflaechen. Allg. Forstzeitschrift: 913-914.

Perrin, P., Martin, J., Barron, S., O´Neill, F., McNutt, K., Delaney, A. 2008. National Survey of Native Woodlands: 2003-2008. Vol. I: Main Report; Vol. II: Woodland Classification. Unpublished report to the National Parks and Wildlife Service, Dublin. http://www.npws.ie/researchprojects/woodlands

Phillips, H. 2005. Initial Economic Analysis, Future Species Scenarios and Impacts on Coillte Teoranta. Version 1.3. Coillte internal report. Coillte, Newtownmountkennedy.

Phillips, H. 2011. All Ireland Roundwood Production Forecast: 2011-2028. COFORD, Dublin.

Picard, J.F. 1983. A propos du frêne oxyphylle. *Fraxinus angustifolia. Forêt-enterprise* 83:9.

Pilard-Landeau, B., Le Goff, N. 1996. Sylviculture du Frêne. Bulletin Technique 31: 9-14. Office National des Forêts, Fontainebleau.

Pinay, G., Labroue, L. 1986. Une station d'épuration naturelle des nitrates transportés par les nappes alluviales: l'aulnaie glutineuse. Compte rendu de l'Académie des sciences 302 (17): 629-632. Cited in Claessens, H. 2003.

Polunin, O., Walters, M. 1985. A guide to the vegetation of Britain and Europe. Oxford University Press.

Press, B. 1992. The Field Guide to the Trees of Britain and Europe. New Holland Publishers, London.

Pryor, S.N., Jackson, T.J.F. 2001. The cost of restoring plantations on ancient woodland sites. An analysis of the economics of future management options for plantations on ancient woodland sites. Woodland Trust and Oxford Forestry Institute. Cited in Phillips, H. 2005.

Rackham, O. 1986. The History of the Countryside. J.M. Dent & Sons, London.

Rau, H., Brandl, H. 2000. Zwei Jahrhunderte Forstgeschichte Baden-Wuerttemberg – von der Koeniglich-Wuerttembergischen Forstdirektion zur Forstdirektion Stuttgart. Freiburger Forstliche Forschung. Berichte Heft 19.

Rea, T. 1985. Irish State Forestry: Government Policy 1948-1959. Irish Forestry 42: 7-15.

Reader's Digest Association, in association with the National Trust. 1986. Woodland Trees and Shrubs. National Trust, London.

Rebel, K. 1922. Waldbauliches aus Bayern. Jos. C. Huber´s Verlag, Dissen vor Muenchen.

Redmond, J. 2014. Personal communication.

Renou, F., Keane, M., McNally, G., O´Sullivan, J., Farrell, E.P. 2008. Developing a forest resource on industrial cutaway peatland: The BOGFOR programme. COFORD, Dublin.

Review Group on Forestry 1985. Report to Minister for Fisheries and Forestry. Stationery Office, Dublin.

Rohan, P.K. 1975. The Climate of Ireland. Stationery Office, Dublin.

Rohan, P.K. 1986. The Climate of Ireland. Stationery Office, Dublin

Royal Horticultural Society. 1996. A-Z Encyclopaedia of Garden Plants (German version, published in 1998). DuMont Buchverlag, Koeln.

Ryan, T., Phillips, H., Ramsay, J., Dempsey, J. 2005. Forest Road Manual: Guidelines for the design, construction and management of forest roads (2nd edn.). COFORD, Dublin.

Ryle, G. 1969. Forest Service – The first forty-five years of the Forestry Commission of Great Britain. David & Charles, Newton Abbot.

Sansford, C.E. 2013. Pest Risk Analysis for *Hymenoscyphus pseudoalbidus* (anamorph *Chalara fraxinea*) for the UK and the Republic of Ireland. Forestry Commission, Edinburgh.

Savill, P.S. 1996. The Silviculture of Trees used in British Forestry. CAB International, Wallingford.

Savill, P.S. 2013. The Silviculture of Trees used in British Forestry (2nd edn.). CAB International, Wallingford.

Savill, P.S., Evans, J. 1986. Plantation Silviculture in Temperate Regions with Special Reference to the British Isles. Clarendon Press, Oxford.

Savill, P.S., Mather, R.A. 1990. A Possible Indicator of Shake in Oak: Relationship between Flushing Date and Vessel Sizes. Forestry 63 (4): 355-362.

Scannell, M.J.P. 2007. Is *Fraxinus angustifolia* Vahl. (Narrow-leaved ash) naturalised in Ireland? Irish Botanical News 17: 5-14. The Committee for Ireland, Botanical Society of the British Isles.

Scannell, M.J.P., Synnott, D.M. 1987. Census Catalogue of the Flora of Ireland (2nd edn.). Stationery Office, Dublin.

Scanu, B., Jones, B., Weber, J.F. 2012. A new disease of *Nothofagus* in Britain caused by *Phytophthora pseudosyringae*. New Disease Reports 25, 27. http://dx.doi.org/10.5197/j.2044-0588.2012.025.027

Schmid, R. 1977. Forstduengung. Grundsaetzliche Betrachtungen und Ergebnisse aus 6 mehrjaehrigen Versuchen. Mitteilungen Nr. 16 der Kali AG Bern.

Schmidt-Vogt, H. 1991. Die Fichte. Vol. II/3. Verlag Paul Parey, Hamburg.

Schober, R. 1957. Ertragstafeln wichtiger Holzarten bei verschiedener Durchforstung. Verlag M. u. H. Schaper, Hannover.

Schober, R. 1971. Die Rotbuche. In: Nagel, J. 1986.

Schober, R. 1967. Ertragstafel Buche. Forest Service, Baden-Wuerttemberg.

Schuett, P., Schuck, H.J., Stimm, B. (eds.) 1992/2002. Lexikon der Baum- und Straucharten: Das Standardwerk der Forstbotanik. Nikol Verlagsgesellschaft, Hamburg.

Schuett, P., Weisgerber, H., Schuck, H.J., Lang, O., Stimm, B., Roloff, A. (eds.). 2006. Enzyklopaedie der Laubbaeume. Nikol Verl. Ges., Hamburg.

Serup, H., Kofman, P.D. 2005. Wood for Energy Production (Irish edn.). COFORD, Dublin.

Short, I., Radford, T. 2008. Silvicultural Guidelines for the Tending and Thinning of Broadleaves. Teagasc, Athenry.

Skovsgaard, J.P., Thomsen, I.M., Skovgaard, I.M., Martinussen, T. 2010. Association among symptoms of dieback in even-aged stands of ash (*Fraxinus excelsior* L.). Forest Pathology 40 (1): 7-18

Smyth, W.J. 1997. The greening of Ireland – tenant tree-planting in the eighteenth and nineteenth centuries. Irish Forestry 54 (1): 55-72.

Society of American Foresters. 1983. Terminology of forest science, technology practice and products. Authorized by Joint FAO/IUFRO Committee on Forest Bibliography and Terminology. Society of American Foresters, Washington D.C.

Spiecker, H. 1991. Zur Steuerung des Dickenwachstums und der Astreinigung von Trauben- und Stieleichen (*Quercus petraea* (Matt.) Liebl. und *Quercus robur* L.). Schriftenreihe der Landesforstverwaltung Baden-Wuerttemberg. Band 72.

Stettler, R.F. 1978. Biological aspects of red alder pertinent to potential breeding programs. Cited in Harrington, C.A. 2006.

Stinglwagner, G.K.F., Haseder, I.E., Erlbeck, R. 2005. Das Kosmos Wald- und Forst- Lexikon (3rd edn.). Kosmos, Stuttgart.

Suszka, B., Muller, C., Bonnet-Masimbert, M. 1996. Seeds of forest broadleaves–from harvest to sowing. Translated by Gordon, A. Institut National de la Recherche Agronomique, Paris.

Sweeney, J., Brereton, T., Byrne, C., Charlton, R., Emblow, C., Fealy, R., Holden, N., Jones, M., Donnelly, A., Moore, S., Purser, P., Byrne, K., Farrell, E., Mayes, E., Minchin, D., Wilson, Jim, Wilson, John. 2003. Climate Change, Scenarios & Impacts for Ireland. Final Report (project 2000-LS-5.2.1-M1). Prepared for the Environmental Protection Agency by the Department of Geography, National University of Ireland, Maynooth.

Teagasc. (no date). Shaping Young Broadleaves for Quality Timber. Farm Forestry Series, No. 3. Teagasc, Athenry.

Teagasc. 2000. Wood Energy from Farm Forests: A Basic Guide. Teagasc, Athenry.

Teagasc. 2007. Wood Energy from Farm Forests – A Basic Guide (2nd fully revised version). Teagasc, Athenry.

Teagasc. 2013. Forest management tips: the importance of formative shaping. Forestry Newsletter.

Thompson, D., Fennessy, J. 2010. Beech (*Fagus sylvatica*) in Irish Forestry. In: Frýdl, J., Novotný, P., Fennessy, J., von Wuehlisch, G. (eds.). Evaluation of beech genetic resources for sustainable forestry. Cost Action E52. Communicationes Instituti Forestalis Bohemicae 25. Forestry and Game Management Research Institute, Jiloviště.

Thomsen, I.M. 2007. Ash dieback. University of Copenhagen.

TRADA. 1991. Timbers - their properties and uses. High Wycombe, Buckinghamshire.

Tree Council of Ireland. 2005. Champion trees: A Selection of Ireland´s Great Trees. Tree Council of Ireland, Dublin.

Troen, I., Petersen E.L. 1989. European Wind Atlas. Riso National Laboratory, Denmark.

Tuley, G. 1980. Nothofagus in Britain (2nd edn.). Forestry Commission, Forest Record 122. HMSO, London.

Tutin, T.G., Heywood, V.H., Burges, N.A., Moore, D.M., Valentine, D.H., Walters, S.M., Webb, D.A. (eds.). 1972. *Flora Europaea, Vol* 3. Cambridge University Press, Cambridge.

Volquardts, G. 1958. Ertragtafel Eiche. In: Yield Tables of Forest Service. Baden Wuerttemberg, 1993.

Ward, D. 1998. Guidelines for the Use of Herbicides in Forestry (2nd edn.). Coillte, Newtownmountkennedy.

Webb, D.A., Parnell, J., Doogue, D. 1996. An Irish Flora. Dundalgan Press, Dundalk.

Westhoff, V., van der Maarel, E. 1973. The Braun-Blanquet approach. Cited in Cross, J.R. 2006.

Wiedemann, E. 1931. Ertragstafeln Rotbuche. In: Weidemann-Schober. 1957: Ertragstafeln wichtiger Holzarten bei verschiedener Durchforstung. Hannover.

Wiedemann, E. 1957. Ertragstafeln Buche. In: Schober, R. (ed.). Ertragstafeln wichtiger Holzarten bei verschiedener Durchforstung: 36-57. Verlag M. u. H. Schaper, Hannover.

Wilson, S.McG. 2008. Potential to produce improved beech planting stock in Britain. Quarterly Journal of Forestry 102 (1): 34-43

Wimmenauer 1919. Ertragstafel Esche. In: Bayer. Staatsmin. E. L. F. (ed.) 1981: Hilfstafeln für die Forsteinrichtung pp. 165 and 365. Muenchen.

Worrell, R. 1999. The Birch Woodland Management Handbook. Highland Birchwoods, Rossshire.

Wulf, A., Kehr, K. 2009. Diseases, Disorders and Pests of Selected Valuable Broadleaved Tree Species. In: Spieker, H., Hein, S., Makkonen-Spieker K., Thies, M. 2009. (eds.). Valuable Broadleaved Forests in Europe. European Forest Institute Report 22. Brill, Leiden.

Wüst, C. 2008. Bäume zu Autofutter. Der Spiegel (29):144-146

Zentsch, W. 1982: Forstsaatgut. In: Mette H.-J., Korell U. (eds.). Richtzahlen und Tabellen fuer die Forstwirtschaft. VEB Deutscher Landwirtschaftsverlag, Berlin: 234-249.

Index - Broadleaves

Index - General

A remarkable growth in the level of planting of broadleaf woodlands has taken place in Ireland over the last quarter of a century, to the extent that broadleaves are now a significant component of Irish forestry. As well as providing biodiversity and other environmental services, they are an increasing source of wood products, including fuelwood. The longterm objective is to establish broadleaf forests as a sustainable, indigenous supply of high quality hardwood timber.

Broadleaf Forestry in Ireland provides owners and managers with a comprehensive suite of silvicultural and management guidelines to grow high quality trees to meet market demands. The material is presented in an accessible, easily-understood and well-illustrated format.

The authors begin with the policy background and the development of forests and forestry practice in Ireland. They continue with a description of soils and sites suitable for broadleaves, ecological and social values of broadleaf forests, as well as an extensive review of silvicultural strategies and procedures. Other aspects addressed include an examination of the future role of broadleaves, together with a detailed discourse on individual species. They conclude with a brief description of some lesser-known broadleaves, which may increase in use due to climate change.

Juergen Huss studied forestry at the universities of Göttingen, Vienna and Edinburgh. He began his career in the Lower Saxony Forest Service. After his PhD in silviculture at Göttingen he moved to the University of Munich as Professor of Forest Management and Remote Sensing, before taking up the post of Director of the Institute of Silviculture at the University of Freiburg. He has worked on projects in Turkey and in many other regions worldwide. His publications include *Aerial Photo measurement and Remote Sensing in Forest Management* and co-authorship of *Foundations of Silviculture* (both in German), as well as *Management of Broadleaves in Turkey*, and the COFORD publication *Growing Broadleaves*.

Padraic M Joyce is Emeritus Professor of Forestry at University College Dublin, where he took primary and Masters forestry degrees. He holds a PhD in forest mensuration from the National University of Ireland. Before becoming a lecturer in forestry he had extensive forest management experience in Ireland and Wales. During the course of his career he spent periods at Yale University and in Germany. He has many scientific papers to his name, and is a co-author of *Growing Broadleaves* and *Sitka spruce in Ireland*, both published by COFORD. He maintains close contact with developing trends in silviculture and forest management in both Ireland and Europe.

Richard (Dick) MacCarthy took his primary and Masters (in soil chemistry and survey of forest lands) forestry degrees at UCD, and his PhD (in forest nutrition) at North Carolina State University, USA. In 1973 he joined Research Branch in the Forest Service, later part of Coillte. His main work includes research into the establishment and growth of tree species on poor soils, which has led to specific guidelines for the major site types, particularly relating to methods of site preparation and the use of fertilisers. He is a co-author of *Growing Broadleaves* and *A Guide to Tree Species Selection and Silviculture in Ireland*, both published by COFORD.

John Fennessy holds a Masters degree in forestry from University College Dublin, and is an alumnus of the programme in Forest Gene Resource Management at the University of British Columbia. He spent his early career in research in conifer tree improvement, later concentrating on broadleaves, and developing the Irish element of the Future Trees Trust (FTT). In 2002 he joined COFORD, with responsibility for the development of forest genetic resources. In addition to publishing a number of scientific papers, he is the co-author of *Sustaining and Developing Ireland's Forest Genetic Resources - An Outline Strategy* and *Forest Genetic Resources in Ireland*. He is a current Trustee of FTT, and chairman of its Oak Group.

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