CARBIFOR II

Carbon sequestration by Irish forest ecosystems

PROJECT TEAM

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BACKGROUND

The overall objective of CARBiFOR II is to provide information for quantifying the influence of disturbance, land use change, soil type and forest age on carbon budgets that are relevant to the Land Use, Land Use Change and Forestry (LULUCF) reporting requirements under the Kyoto Protocol of the Climate Change Convention. CARBiFOR II builds directly on the achievements of CARBiFOR, by extending the time span of flux measurements to include an analysis of stand age, as well as the influence of disturbance caused by afforestation and thinning operations. The project will also attempt to characterize changes in biomass, decomposition, CO_2 and non-CO_2 greenhouse gas (GHG) flux associated with different soils and tree species, providing a more comprehensive assessment of the total greenhouse gas budget of Irish forest ecosystems. The project intends to study three complete chronosequences (a series of sites representing the development of forest plantations):

Chronosequence 1: Sitka spruce growing on a mineral soil;

Chronosequence 2: Sitka spruce growing on a peat soil;

Chronosequence 3: Ash growing on a mineral soil.

OBJECTIVES

- Biomass allocation and stock measurements.
- Above- and below-ground coarse wood decomposition study.
- Using ground penetrating radar to estimate below-ground biomass.
- Measuring the surface exchange of CO_2, H_2O and turbulent energy over several forest age classes using permanent and mobile Eddy Covariance towers.
- Estimation of C losses associated with thinning, associated vegetation and land use change.
- Measurement of non-CO_2 greenhouse gas emissions associated with land use change and forest stand age.
- Assessment of net GHG budget associated with afforestation.
- Project chronosequence soil characterisation and C stocks.
- Soil sampling of NFI plots and chronosequence sites.
- C inputs and parameters for Century model.

PROGRESS

Enough data have been collected to construct small tree biomass equations covering ash, alder, larch and Sitka spruce. These will be used to estimate biomass in younger forest stands where the dbh is not measurable. The height range varies from 30 cm to 11 m. These young forests often fall outside the range of biomass equations/yield models.

Photo from the top of the permanent tower at Dooary. The average dbh and height were 17.6 cm and 13.9 m, respectively, in the 20-year old stand. Snow fall in February 2009 brought air temperatures above the forest canopy to -2.7°C. Temperatures at ground level were over a degree higher because of the sheltering effect of the tree cover.

Stock estimates derived from biomass surveys of the Sitka chronosequence were used to examine age-related changes in forest increment (Figure 1). Productivity was greatest between years 16 to 18 when stand canopy competition was greatest. Annual litterfall amounts (needles and twigs) varied across the Sitka chronosequence from 0.31 (6-year old), to 2.1 (14-years), to 1.33 t C ha^{-1} (21 years). The larger amount corresponds to the period of forest development where the forest stocking is still high (two thinnings have substantially reduced the stocking of the 21-year old forest) and the growth of the tree crowns has begun to be limited by competition.

Brash, buried root bags and the trenched root experiments continue to be sampled every six months. Following mass loss and density measurements, samples have been homogenised and ground for CHN analysis, which has just begun. First results show an expected correlation between the C:N ratio and density of decay class samples. As decay progressed, both the C:N ratio and density decrease (Figure 2). Surveys of coarse woody debris stocks (CWD; Figure 3) show an abundance of abandoned logs following thinning at the 35 year old stand. This may be atypically high due to difficulties in harvesting because of a steep slope at this site.

Eddy covariance measurements have shown that the carbon sink strength of Sitka spruce forest plantations increases with age after afforestation of semi-natural grassland to a 21-year old forest stand (Figure 4). Thinning has been shown to have both neutral and negative impacts on carbon assimilation (Figure 5). The Dooary forest was thinned in 2007 (line and selection) and 2008 (selection). The results show an increase in Net Ecosystem Productivity (NEP) of the stand after the first thin due to a small reduction in gross primary productivity (GPP), coupled with a significant decrease in ecosystem respiration (Reco). The results of the second thinning show a decrease in NEP due to a reduction in both GPP and Reco.

Soil carbon dioxide (CO_2) efflux has been measured at the grassland, 6-year and 21-year chronosequence sites. The results show that CO_2 efflux decreases with forest stand age although these results are not significant ($p>0.05$). Precipitation exclusion shelters (Figure 6) have been constructed at each site to investigate the impact of changing soil water conditions on soil CO_2 efflux.

Trace gas data collected at the Dooary forest chronosequence suggest the conversion of grassland to forest increases the emissions of nitrous oxide (N_2O) to the atmosphere, while methane (CH_4) emissions tend to decrease. These results are largely due to changes in hydrology, the waterlogged conditions at the grassland site lead to anoxic soil conditions enhancing the production of methane. The lower water content at the afforested sites resulted in a decrease in CH_4 emissions but an increase in N_2O emissions.

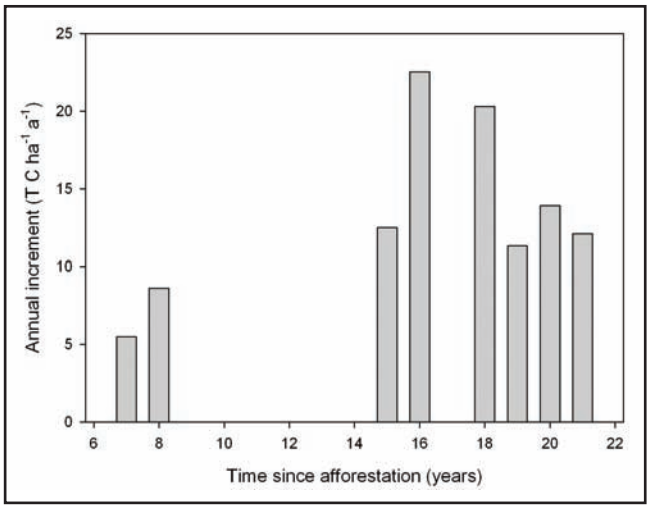

Figure 1: Increment across the Sitka spruce chronosequence at Dooary, Co Laois. Stock estimates were generated from stand surveys (on some sites since 2005) and the increment calculated as the difference between one year and the preceding one. Although thinning operations took place in years 18 and 20, the removed was added back to make stand productivity comparable with years where there was no thinning.

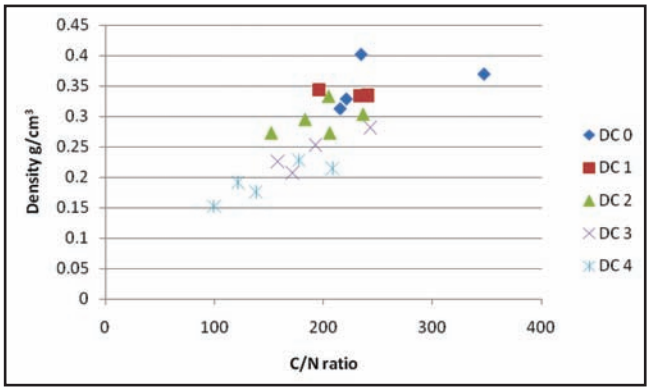

Figure 2: The relationship between C/N ratio of Sitka spruce deadwood and the basic density in different decay classes (level of decay increases from DC0 to DC4).

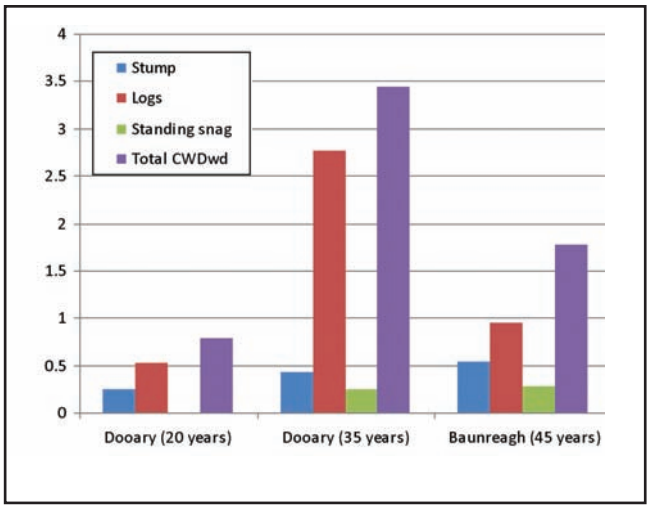

Figure 3: Above-ground coarse woody debris (CWD) stocks across a series of older Sitka spruce sites. Belowground dead roots are not included.

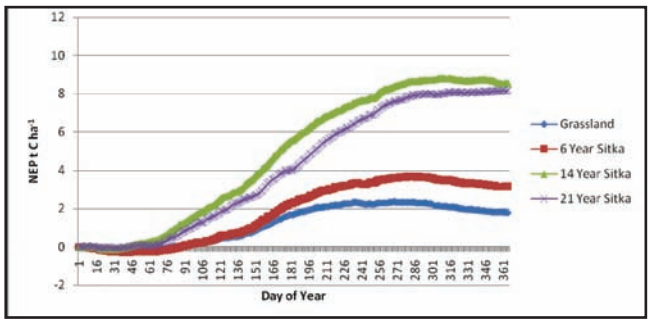

Figure 4: Net Ecosystem Productivity in 2009 of a Sitka spruce chronosequence, ranging from a semi-natural grassland (pre-afforestation) through to a 21-year old stand.

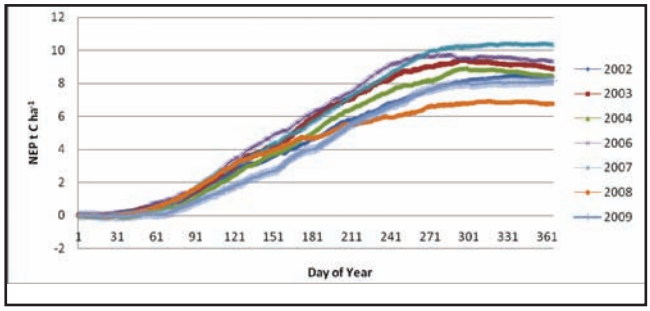

Figure 5: Inter-annual variation of Net Ecosystem Productivity of the Dooary forest, Co Laois.

Figure 6: Rain exclusion shelter located at the Dooary grassland chronosequence site.

The sampling of mineral and peaty mineral soils has been completed. These were prioritised over peat soils using a detailed sampling protocol, which was agreed with the ForesSoilC project in December 2008. Peat sampling equipment was shared with ForestSoilC. There are currently three peat sites remaining to be sampled. If these sites are not suitable, backup sites will be selected from a reserve list. The first chronosequence was sampled.

Three quarters of the sampled sites have been processed for Soil Organic Carbon (SOC). Bulk Density (BD) has been measured and calculated for over half the sites. Analysis of SOC has begun using CHN analysis. Once the SOC and BD work finishes texture analysis will begin.

Commencement of modelling will take place shortly as SOC data becomes available. The primary modelling exercise will be carried out using Century, and Yasso will also be investigated.

A peat auger at 6 m extension used to collect samples from varying depths through the soil profile.

ACTIVITIES PLANNED

- Biomass sampling of pine, larch and ash will continue in 2010.
- Surveys will be made of new chronosequence sites to establish biomass and CWD stocks.
- Above-ground CWD decomposition experiment sampling (brash bags).
- Below-ground decomposition measurements (includes decomposition bag and stump excavation).
- Continue litter collection, tree ring analysis from disk samples, ground-vegetation sampling and decaying log respiration measurements.
- The mobile eddy covariance tower will rove chronosequence 3 sites during 2010.
- Continuous soil respiration and canopy profile CO_2 measurements at the Dooary forest will continue.
- Decomposition, litterfall and fine root turnover experiments will be continued.
- Measurements of N_2O and CH_4 and soil respiration will be undertaken at chronosequence three sites in 2010.
- Continue NFI paired plot sampling and processing.
- Commence analysis of samples.

OUTPUTS

Meetings/conference attendance

COST Action FP0803. 2009. Belowground carbon turnover in European forests. Kick-off meeting to start the Action, Brussels, 25 May 2009.

ECHOES COST Action FP0703. 2009. Expected Climate Change and Options for European Silviculture. 2-3 November 2009, Thessaloniki, Greece.

ANAEE (Analysis and Experimentation on Ecosystems). 2009. Final Meeting, 24-26 November 2009, Exeter, UK.

Saunders, M., Tobin, B., and Osborne, B. 2009. *Assessing the impact of forest age on net ecosystem carbon exchange.* Irish Plant Scientists Meeting 20-21 March 2009, Trinity College Dublin.

Tene, A., Tobin, B., Ray, D., Black, K. and Nieuwenhuis, M. 2009. *Adaptability of forest species to climate change.* Ppaper presented to the Annual conference of the Association for tree-ring research, Octocec, Slovenia, 16-19 April 2009. Submitted as an article in ITF (Vol. 18, No. 2, 2009).

Wellock, M., LaPerle, C., Kiely, G., Reidy, B. and Bolger, T. 2009. *The Carbon Stocks of Peatlands under Forestry in the Republic of Ireland.* [Poster Presentation.] European Geosciences Union General Assembly 2009, Vienna , 19-24 April 2009.

Tene, A., Tobin, B., Ray, D., Black, K. and Nieuwenhuis, M. 2009. *Assessment of tree response to severe climatic occurrences.* Annual European Dendrochronology Meeting. [Poster presentation.] Majorca, 26-30 October 2009.

Albanito, F., Saunders, M. and Jones, M.B. (2009) The Irish contribution to an infrastructure for measurements of the European carbon cycle (IMECC). [Poster presentation.] AGMET meeting, Dublin, 7th December 2009.

Benanti, G., Cacciotti, E., Helmy, M., Saunders, M. and Osborne, B. 2009. *Impact of land use change on greenhouse gas emissions*. [Poster presentation.] AGMET meeting, Dublin, 7 December 2009.

Osborne, B. 2009. *Use and performance of cover crops for increasing carbon sequestration and greenhouse gas mitigation in arable ecosystems.* AGMET meeting, Dublin, 7 December 2009.

Tene,A., Tobin, B., Dyckmans, J.,Ray, D.,Black, K. and Nieuwenhuis, M. 2009. *The growth response of Sitka spruce forest stands to sever drought events*. [Poster presentation.] AGMET meeting, Dublin, 7 December 2009.

Tobin, B., Gardiner, P., Olajuyigbe, S., Saunders, M. and Nieuwenhuis, M. 2009. *Forest carbon stocks and the effect of thinning.* [Poster presentation.] UCD School of Agriculture, Food Science and Veterinary Medicine Research Day, 8 December 2009.

Publications

Luyssaert, S., Reichstein, M., Schulze, E-D., Janssens, I., Law, B., Papale, D., Dragoni, D., Goulden, M., Granier, A., Kutsch, W., Linder, S., Matteucci, G., V, M., Munger, J., Pilegaard, K., Saunders, M. and Falge, E. 2009. Towards a consistency cross-check of eddy covariance flux based and biometric estimates of ecosystem carbon balance. *Global Biogoechemical Cycles* doi:10.1029/2008GB003377.

Field study

The Dooary chronosequence sites were used to host a silviculture field day for the UCD third year forestry class in October 2009.

Project networking

- Dooary site, together with some additional work tasks, now included in a new EU funded project GHG Europe, starting January 2010.
- Forest research work included in ANAEE (analysis and experimentation on ecosystems, an EU project with preliminary funding).
- Discussions are also continuing in relation to participation in ICOS (International Carbon Observation System), its Irish equivalent IGOS-I, and LifeWatch (long-term monitoring of ecosystems).
- Dooary site now included in the EU FutMon project (long-term monitoring of forest ecosystems) as a Level 1 site.