Impact of land-use change on greenhouse gas emissions

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Abstract

Changes in land use are thought to be one of the most critical factors in determining the future atmospheric greenhouse gas budget. Our understanding, however, of how different land-use changes impact on the emissions of carbon dioxide, and trace gases (CH_4, N_2O) is still unclear. As part of two projects examining land-use change, one involving the conversion of unimproved grassland to forest, the other the conversion of a conventional tillage system to non-inversion tillage with the introduction of a cover crop, we have assessed their impact on soil carbon dioxide and trace gas emissions. Conversion of grassland to forest show time, or stand-age-dependent, impacts on GHG emissions, with soil N_2O emissions increasing as a result of afforestation. Soil CO_2 emissions decreased as a consequence of afforestation. These results were driven by both soil moisture status and temperature due either to changes in the diffusion characteristics of the soil and/or soil microbial activity. For the agro-ecosystem, non-inversion tillage practices had relatively small effects on CO_2 and N_2O fluxes, with most of the gains associated with an enhanced carbon sequestration attributable to an increased carbon uptake by the cover crop. These results emphasise the potential complexity of current and future land-use changes on greenhouse gas emissions and argue for a more comprehensive assessment of the range of likely scenarios.

Site description

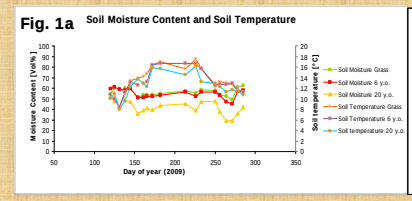
Forest site Dooary

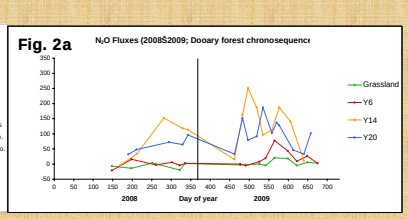
In Dooary, four sites were selected to represent the typical land use change from grassland to forest (*Picea sitchensis* (Bong.) Carr.) using stands of different ages ("chronosequence"). This chronosequence included a semi-natural grassland, a 6, 14 and a 20-year-old Sitka spruce forest. The Dooary forest (52°57' N, 7°15' W) in the Irish midlands (elevation of 260 m) is a first rotation plantation established on former grassland.

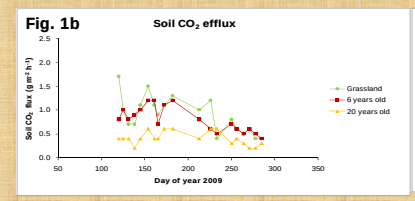
Arable site Carlow

The arable site at Carlow is situated in the TEAGASC research centre Oak Park, Carlow (52° 52' N, 6° 54' W, 56 m asl.). The site includes two large plots (~2.5 ha) subjected to different tillage practices. The first plot is managed using conventional tillage practices, the second one by non-inversion tillage featuring mustard (*Brassica juncae*) as a winter cover crop. On both plots spring barley (*Hordeum vulgare* cv. Tavern) is the main crop in summer and after harvest the residues are left on the field.

Results







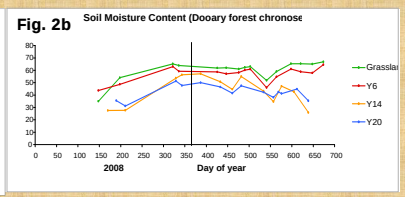


Figure 1a-b: The data collected from April to October 2009 suggest that the highest soil CO_2 emissions are in the grassland and lower in the 6 and 20 year-old forests. **The conversion from grassland to forest decreases the emissions of CO_2 to the atmosphere.** The differences in fluxes between the grassland and the 20-year-old sites were highly significant.

Figure 2a-b: The data collected from May 08 to November 09 suggest that **the conversion from grassland to forest increases the emissions of N_2O to the atmosphere.** The differences in fluxes between the grassland and the 14/20 year-old sites were highly significant. With the conversion a decrease in soil moisture content was also observed.

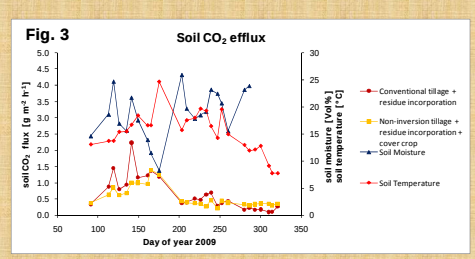


Figure 3: The differences in soil CO_2 efflux between the two different tillage pactices vary over the year following the cropping period. In the growing period of the main crop, **conventional tillage shows higher values than non-inversion tillage.** In contrast, non-inversion tillage causes higher soil CO_2 effluxes in autumn due to growing of the cover crop.

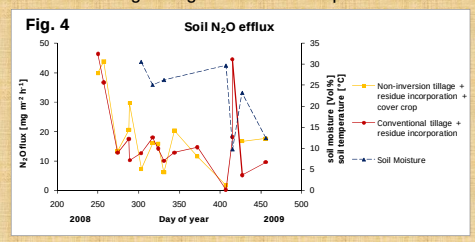


Figure 4: In Carlow the emissions of N_2O varied with time. The highest N_2O emissions were recorded in September in both the conventional and non-inversion tillage treatments. However, **no significant difference was found in N_2O emissions between the two plots investigated.** A negative correlation between soil moisture and N_2O flux was observed.

Discussion

In Dooary the decrease in soil CO_2 emissions associated with afforestation could be a reflection of differences in decomposable biomass between the grassland and the forest. The higher herbaceous plant biomass in the grassland compared with the forest, presumably combined with a higher microbial activity could have resulted in an increase in CO_2 emissions. Moreover temperature and soil water content could also have had an important influence on soil respiration; measurements of water content between the sites were significantly different, with lower water contents in the afforested sites. The increase in N_2O emissions associated with afforestation could be due to a reduction in soil water content due to increased evapotranspiration. Records of soil moisture content made in conjunction with gas sampling are consistent with this hypothesis. The high water content present in the grassland soil and the higher water table level could favour the reduction of N_2O and the production of N_2.

At the arable site, annual patterns of soil CO_2 efflux are driven by cropping period and associated climatic parameters that also vary seasonally. Both tillage practice and the extended period of vegetation cover associated with the cover crop define the differences between the two measurement plots; the presence of vegetation increased the soil CO_2 efflux. Although disturbance due to ploughing increased N_2O fluxes, this was only transitory and the values fell below those of the unploughed treatment. As the soil moisture decreased, the N_2O flux also increased.

Conclusions

Changes in land-use are likely to have complex impacts on greenhouse gas emissions that may be related to alterations in a number of factors, including temperature, water availability and vegetation cover; these are also likely to be site and/or region-specific. This argues for a more comprehensive assessment of the effects of a range of land-use changes on greenhouse gas emissions.

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