Creating “Climate-smart” soils to optimize carbon sequestration through land management (Ref IAP2-18-191)

University of Stirling, Biological and Environmental Sciences
In partnership with University of Glasgow and Forest Research

Supervisory Team
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Key Words
1. Carbon cycle
2. Land use change
3. Forestry
4. Grassland
5. Climate Change mitigation.

Overview

Background
In their Special Report on Global Warming of 1.5 °C (IPCC, 2018), the Intergovernmental Panel on Climate Change has recently outlined the clear case for reducing net CO$_2$ emissions globally. The report explicitly covers land use change as a pathway to achieving net CO$_2$ emission reductions, so the creation of climate-smart soils (Paustian et al. 2016) becomes a new challenge to society.

Forests have a high potential for carbon sequestration, particularly in young, rapidly growing stands. However, to understand the full benefit of tree planting for long-term sequestration of CO$_2$ from the atmosphere, we also need to account for changes in the underlying soil carbon (C) stock, as a loss of soil C following afforestation can potentially offset any gains in aboveground C stock.

There are a number of knowledge gaps that have to be addressed in order to manage soils under forestry in a climate-smart fashion:
- Where within the soil does C sequestration occur, and what are turnover times of different fractions?
- What is the role of microbial communities (including mycorrhizal associations with roots) in the formation and the decomposition of soil organic matter?
- What are interactions between climate, underlying geology and vegetation that can optimise climate-smart land management?
- What is the significance of soil erosion and transport of dissolved organic matter on the net C balance of afforested sites?

Aim
This studentship is to address these key uncertainties in order to provide robust insights for land management. A strong focus will be placed on process studies to better understand the ecological and...
biogeochemical processes that produce observed changes under a range of soil types, vegetation cover and environmental conditions.

**Methodology**

Through the collaboration with Forest Research, the student has access to forest sites of different ages since plantations were established, and with recorded land use and management history. By selecting plantations on land previously used for pasture in Scottish uplands, the aim is to create a data set of chronosequences for which soil C stock can be established. Where possible, control sites where pasture has been continuously grazed will be used to verify potential changes in C stock and other soil parameters (e.g. pH or bulk density changes).

Transplanting soils between geographical locations is a powerful tool to separate influences of climate, geology and vegetation type. Nylon netting of different mesh size will be used to selectively allow or block access to transplanted soils by roots and/or mycorrhiza (e.g. Subke et al., 2011). Measurement of CO₂ flux from these transplanted soils will then identify increased or decreased decomposition, whilst addition of common substrates (e.g. wood or plant litter) are options to focus on specific forms of organic matter affected by root and mycorrhizal priming. A novel aspect of the methodology is the measurement of natural abundance radiocarbon (¹⁴C) in soil organic matter pools and respired CO₂ to determine the changes in turnover and age of carbon emissions following a transition between vegetation types. ¹⁴C determinations are subject to approval by the NERC Radiocarbon Facility, and the student would be involved in writing this application, providing valuable experience in composing and managing scientific grant applications.

Field experiments will be supplemented by lab studies using mesocosms of different plant/mycorrhizal assemblages in soils of contrasting management origins. In collaboration with Prof. D. Johnson (University of Manchester), the student will develop his/her abilities to culture plant/fungal assemblages and set up novel experiments to investigate mechanisms of organic matter formation as well as decomposition. The student would also have access to Prof. Johnson’s state-of-the-art mobile laboratory to monitor gas flux from soil cores at field sites, enabling novel short- and long-term responses to manipulations in aboveground and belowground C dynamics.

The student will also closely collaborate with François-Xavier Joly (University of Stirling) who works on complementary questions to that of the studentship.

**Timeline**

**Year 1:**
- Identification of study sites
- Method development (incl. training in gas flux methods, radiocarbon methodologies and root/mycorrhizal techniques)
- Initiate soil transplant/mycorrhizal in-growth experiment

**Years 2&3:**
- Soil flux measurements
- Soil C-stock profiles at chronosequence sites
- Set-up of lab studies; training in enzyme activity methods
- Drafting of manuscripts/chapters

**Year 4 (6 months only):**
- Finalise field and lab work
- Data evaluation, including soil C modelling
- Publication of results, completion of thesis
Training & Skills

- General science training
- Specific lab methods (C & N analysis, determination of soil organic matter pools and fractions)
- Application of $^{14}$C in experiments, including technical training in AMS use
- Measurements of soil trace gas flux
- R-programming for statistical analysis and modelling
- A range of additional technical, statistical and generic skills (e.g. paper writing, hypothesis testing, presentation skills and science communication) will be available through the university, CEH and the IAPETUS partnership.

References & Further Reading


Further Information

Please contact Jens-Arne Subke (jens-arne.subke@stir.ac.uk) for any further information regarding this project.