

Agroforestry, soil health and delivery of public goods

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Agroforestry is the practice of deliberately growing trees in combination with arable crops and/or pasture on the same piece of land (Figure 1). Agroforestry is seen as a sustainable land management practice, where trees and agriculture co-exist to provide multiple benefits. Therefore growth and innovation in agroforestry has the potential to improve farmland productivity, resilience and diversity while maintaining and/or improving the provision of other ecosystem services, via improving soil health (Dollinger & Jose, 2018;), sequestering carbon (De Stefano & Jacobson, 2018; Lorenz & Lal, 2014) and slowing water runoff (Marshall et al., 2009). While long-established in sub-tropical and tropical climates, uptake of agroforestry in temperate agricultural systems has been slow, particularly in the UK (Woodlands Trust, 2018). In order to realize this potential, there is urgent need for greater understanding of how planting trees in temperate agricultural systems impacts upon soil health indicators and thus helps to reduce flooding and mitigate climate change.



Figure 1 (a) Silvopastoral system in which trees are mixed with grazing animals and (b) Silvoarable system in which trees are planted in rows with an arable crop in the alleys between.

While literature reviews have shown that agroforestry can increase the amount of carbon stored in the soil (De Stefano & Jacobson, 2018; Lorenz & Lal, 2014) and thus help to mitigate climate change, the majority of studies (~80%) were located in tropical and sub-tropical climates, with less than 20% in temperate climates. Oelbermann et al. (2014) found that in temperate zones agroforestry had to be established for greater than 10 years in order to see an increase in soil carbon due to lower turnover rates than in the tropics. In addition, it is unclear whether planting trees in pastures has the same benefit for soil organic carbon content as planting trees in arable fields (Upton et al., 2016). Recent studies in the UK have shown that planting trees on farmland can increase soil infiltration rates (e.g. Marshall et al., 2009). However, these studies were carried out at one site. In addition, it is not clear if similar impacts would be observed in lowland

agricultural systems; highlighting the need for further research. Given the long time required to study the development of agroforestry and the complex interactions between crops, animals and trees, calibrated and validated simulation models can significantly contribute to the understanding and quantification of environmental benefits and to forecast the resilience of the systems to the predicted climate change (Cardinael et al., 2018).

The major aim of this project is therefore to determine the impact of agroforestry on soil health, in particular its impact on soil carbon storage, soil structure and hydrological properties.

Objectives:

In this project, you will work with scientists at the University of Leeds to quantify the impact of different agroforestry systems on key soil health indicators (e.g. carbon, bulk density, permeability, water storage) in temperate climates to understand how agroforestry impacts upon wider ecosystem services such as climate change mitigation and flood control. This will be achieved through fieldwork at a newly established silvopastoral site in the Vale of York, an older silvoarable site established at the University of Leeds farm in the 1980s, and other agroforestry sites across the UK, France, Spain, Italy and Germany. In particular, according to your particular research interests, the studentship could address a combination of the following objectives:

1. Determine short-term and longer-term impacts of agroforestry on soil health indicators.
2. Evaluate the impact of different agroforestry types (silvoarable, silvopasture, shelter belts, and hedges) on soil health indicators.
3. Investigate the effects of distance and depth on soil health indicators in a range of different aged agroforestry plots soil types .
4. Quantify the impact of climate change on carbon cycling in agroforestry systems via process-based modelling of soil processes.

Fit to NERC Science

This project is aligned to the NERC 'Terrestrial and freshwater environments' research area. Specifically the project aligns to the following NERC research areas: (1) **Biogeochemical cycles** – by considering the fluxes and cycling of matter within and between the biosphere and the physical environment (2) **Land - atmosphere interactions** – through quantification of the fluxes and transformations of material between the land (including the biosphere) and the atmosphere (3) **Soil science** – by quantifying the impact of land use change on physical, chemical and biological properties of soil, and (4) **Ecosystem scale processes** – in particular the interaction between land use and the delivery of wider ecosystem services.

Potential for high impact outcome

The project will enable significant, timely advancements to be made in understanding the impact of agroforestry on soil health in temperate ecosystems and wider ecosystem services such as flood

control and climate change mitigation. On-farm tree planting could be included in the new Environment Land Management (ELM) scheme, rewarding farmers for public goods delivered by agroforestry. In order for this to occur considerably more research is needed to quantify these public goods benefits and this project could deliver this. Agroforestry could contribute to the UK's afforestation targets, carbon budgets for agriculture, and ambitions for healthy soil by 2030.

The project will produce several outputs, including (i) 3–4 academic publications, at least one of which we anticipate being suitable for submission to a high-impact journal and (ii) policy briefing notes to inform Defra on how different types of agroforestry in the UK result in the delivery of public goods.

Training

The student will work under the supervision of Professor Pippa Chapman, Professor Joseph Holden and Dr Marcelo Galdos within the Faculty of Environment, University of Leeds. The successful candidate will develop a range of research skills, including experimental design, field sampling, chemical analysis, statistical analysis and data interpretation, academic writing skills and giving presentations. Training will be provided in field/laboratory health and safety procedures and the use of field and analytical equipment. In addition the candidate will develop their understanding of (i) soil properties used to quantify soil health, (ii) soil processes and fluxes related to the cycling and storage of carbon in the soil, (iii) soil hydrology.

The student will be supported throughout the studentship by a comprehensive PGR skills training programme that follows the VITAE Research Development Framework and focuses on knowledge and intellectual abilities; personal effectiveness; research governance and organisation; and engagement, influence and impact. Training needs will be assessed at the beginning of the project and at key stages throughout the project and the student will be encouraged to participate in the numerous training and development courses that are run within the NERC DTP and the University of Leeds to support PGR students, including statistics training (e.g. R, SPSS), academic writing skills, grant writing etc (<http://www.emeskillstraining.leeds.ac.uk/>). Supervision will involve regular meetings between all supervisors and further support of a research support group. The student will also be part of water@leeds – a major interdisciplinary water research centre at the University of Leeds - where there are over 180 PhD students studying water-related topics. That network will broaden the student experience and enhance the network of contacts.

Student profile:

The student should have a keen interest in soil processes and environmental issues with a strong background in one or more of physical geography, earth sciences, soil science, environmental sciences or related discipline. Strong analytical/statistical/fieldwork skills are desirable but not essential, as full training will be provided during the PhD.

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