Managing soils for ecosystem services

Sustainable management options for farming systems…

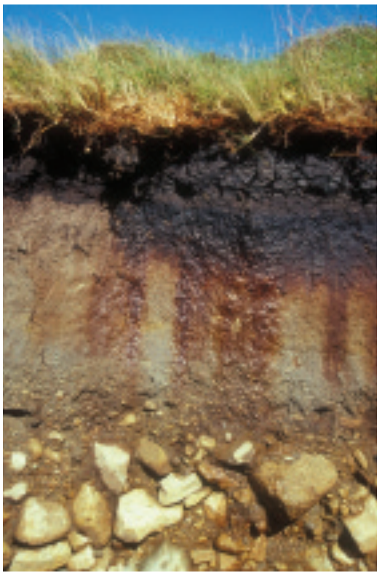
For much of history, few things have mattered more to humans than their relationship with soil. Not only does soil sustain the production of crops for human consumption, but it also plays a primary role in all global biogeochemical cycles and is key to the provision of ecosystem services, such as nutrient cycling and carbon sequestration.

Soil is also highly susceptible to degradation, and degraded soils now cover 15-17% of the Earth's surface. As a result, one of the most important challenges facing agriculture is the need to develop sustainable farming systems that restore and enhance the ability of soils to deliver ecosystem services, such as carbon sequestration and efficient nutrient cycling, whilst also maintaining viable food production for the burgeoning world population.

Our research in the Lancaster Environment Centre (LEC), Lancaster University, is aimed at this challenge. Not only do we seek to advance understanding of the mechanisms involved in the delivery of ecosystem services from soil, but we also aim to use this knowledge to develop sustainable management options for farming systems. Here we describe three projects at Lancaster that are tackling these goals.

The first project focuses on grasslands, which cover a large proportion of the UK and European land surface and form the backbone of the livestock industry. Moreover, grasslands hold 32.4% of the UK soil carbon stock, amounting to 0.55 Pg carbon or 2.2 Pg carbon dioxide equivalents (Countryside Survey 2007). A major goal of this research is to investigate the potential for grasslands to meet multiple objectives of soil carbon sequestration and biodiversity conservation, the latter being a key aim of European agri-environmental policy.

We are gaining evidence that high diversity grasslands could have the potential to increase soil carbon sequestration from a number of studies. First, as part of a national survey of 180 grasslands, funded by Defra, we found that the carbon concentration of surface soil was significantly greater in traditionally managed, species-rich grassland



than in intensively managed, species-poor counterparts. Second, studies of experimental grasslands, funded by the BBSRC, showed that the uptake (ie. photosynthesis) and allocation of carbon below ground to roots and soil fungi increased with increasing species-richness, which was primarily due to the presence of certain plant species, especially legumes, in high diversity grasslands. Third, in a long-term field experiment in the Yorkshire Dales, we have found that when management treatments that best increased plant species diversity (namely, the cessation of fertiliser use and addition of a seed mix) were combined with a small enhancement of the legume red clover by seeding, there was a rapid increase in soil carbon sequestration.

While these studies suggest that managing grassland for plant biodiversity could be a win-win strategy, increasing both habitat value and soil carbon storage, much remains to be learned. For example, we know very little about the mechanisms involved, especially with regard to the way

that changes in plant diversity and abundance of different plant species caused by agricultural management influence carbon in soil. Moreover, we know very little about the distribution of carbon in grassland soils, in terms of how it varies across different grassland types and with soil depth, and how agricultural management and climate change affect it.

The influence of climate change on soil carbon storage remains a major area of uncertainty, the prime concern being that warming will increase the decomposition of soil organic matter and hence the liberation of carbon dioxide to the atmosphere, thereby creating a positive feedback on climate change. Our current research is trying to resolve these issues, and, ultimately, we aim to develop an improved mechanistic basis for the management of carbon storage in soil, thereby providing policy relevant tools for managing soil carbon and offsetting carbon emissions, with potential benefits for other ecosystem services.

Another important ecosystem service delivered by soil is the retention of nutrients, such as nitrogen and phosphorus. Not only does the efficient recycling of these nutrients sustain plant growth, but also their loss from soil in drainage waters or through soil erosion can cause major problems for water quality. Our studies, which form part of a large EU funded project called SOILSERVICE, are exploring how agricultural management can affect nitrogen retention in the soil. We have shown that soil losses of nitrogen through leaching are lower from traditionally managed, species-rich grasslands compared to more intensively managed plant species-poor grasslands. The reason for this could be that the soil food web of plant species-rich grasslands is richer in fungi, which immobilise and recycle nitrogen more efficiently than do bacteria that dominate intensively managed species-poor grasslands.

To examine the mechanisms involved, we are now carrying out experiments where we add isotopically labelled nitrogen (15N) to soil of different grasslands. This allows us to trace whether the added nitrogen is leached from the soil or taken up by microbes and plants, and test how this differs across grasslands. We are also examining how drought affects the soil food web and the delivery of ecosystem services under different land uses. Preliminary results show that soil food webs of extensively managed systems might be more resistant to drought, which has implications for the delivery of ecosystem services under climate change.

Finally, studies at Lancaster are also focusing on soil erosion. Recent research carried out at Lancaster and Leuven (Belgium) has estimated that for every person on the planet an average of five tonnes of soil is eroded every year by rain, water, wind and tillage. That's around 35,000 million tonnes of soil in total each year.

In addition, our work shows that erosion has a double impact on the planet: it washes away vital nutrients from the soil, and, surprisingly, helps lock carbon into the soil preventing it from reaching the Earth's atmosphere. A recent paper on this topic, published in Nature Geoscience, 'The impact of agricultural soil erosion on biogeochemical cycling' (Quinton et al, 2010) argues that if we are to produce accurate climate change models, we need to start thinking about agricultural landscapes as dynamic, mobile systems, which can cause 'major modifications' to carbon, nitrogen and phosphorus cycles.

In fact, the amount of nitrogen and phosphorus lost through soil erosion is about equal to the amount of fertilisers being added to agricultural soils every year. Research at Lancaster is focusing on the impact of soil erosion on landscape-scale transfers of nutrients and carbon, and on developing sustainable management strategies for erosion prevention.

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