Scratching the surface - let's love our soils

Acknowledging the importance of soils and threats to their quality are vital in land-use policy for food production, flood protection, water quality, nature conservation and carbon storage. This article promotes a greater understanding of soils in the conservation sector and looks at some key examples of wise soil management.

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In *ECOS* 34 3/4 (pages 38-45), Saunders and Brenman identify "the conservation of soil biology and structure, and the building and securing of organic matter rather than depleting it" as components of 'good agriculture', and highlight "the lack of acknowledgment of the soil as a conservation issue" as a blind spot affecting some parts of British conservation.

A strategy developed by Defra[1] for the protection of England's soils, contains the following vision statement: "By 2030, all England's soils will be managed sustainably and degradation threats tackled successfully. This will improve the quality of England's soils and safeguard their ability to provide essential services for future generations".

What are these things called soils?

A teaspoonful of soil contains more organisms than there are people on earth. At the simplest level, soil forms by weathering processes breaking down mineral material, together with additions of organic matter from dead plants and animals. The eventual soil type depends also on landform, climate and time – some soils are evidently much older than others – together with the impacts of land use and management. Soil provides a home for living things (and is frequently termed *living soil*) and supports the growth of both natural vegetation and specific crops, while delivering many other ecosystem services. Most are called mineral soils because they are derived predominantly from the broken-down remains of rock with surface additions in some places of wind-blown dust (loess). Organic matter in the soil derives from the remains of plants and animals; organic soils are mostly developed in deposits of peat, formed under wet conditions. For those who wish to delve deeper into the subject, a comprehensive introduction to soil science is given by White.[2]

How do soils form?

Soil-forming processes begin to take place as soon as suitable materials become available on the surface of the earth. The rate and degree of development depend on the properties of that substrate and environmental conditions, including temperature, moisture and consequent biological activity, landform and vegetation. The annual rate of soil formation in Europe is probably in the range 0.03-1.4 tonnes per hectare. Compare this with losses from erosion, and one immediately sees the serious need for soil protection.

Peat soils form in organic material accumulated where the rate of decomposition is slower than that of accumulation. Where conditions remain permanently waterlogged, decomposition is largely precluded by anoxic conditions limiting the activity of organisms responsible for decay. Peat can accumulate at varying rates: Walker[3] gives a range of 21-60 cm per 1,000 years for the British Isles. On the other hand, peat loss or wastage can be much more rapid: measurements at Holme Fen, Cambridgeshire in the period 1850 to 1860 recorded an average annual loss of 18 cm.[4]

How are soils described and classified?

In the field, soils can be described *in-situ* in a section or a purpose-dug pit, or from samples taken using a spade, hand auger or mechanized corer. A vertical section through a soil is called the profile, comprising individual layers, broadly referred to as topsoil, subsoil and substrate, and which can be coded by a system of letters and numbers. Manuals are available to guide the description of key properties.[5] Important soil characteristics are:

Texture: the relative proportions of sand, silt and clay giving the particle-size class, eg sandy loam, silty clay; loam is a general term for soil material of mixed particle sizes.

Colour: Standard soil colour charts are used to describe the matrix and subsidiary colours including mottles, mineral deposits, infilling of pores and channels.

Stoniness: in particular the content, size, shape and rock type of stones

Structure: the shape and size of units of aggregation (peds) and the degree to which they have developed. Soil structure forms from the action of weather (wetting and drying, shrinking and swelling) and of soil biota (roots, earthworm activity, microbes).

Organic matter: this plays an important role in nutrient cycling and fertility, and in the development of soil structure.

Two of the most important soil classification schemes, used on a global basis, are those developed by the FAO (Food and Agriculture Organisation of the United Nations) and in the USA.[6,7] The FAO system subdivides 30 Groups successively down to over 200 Sub-units, while the US Soil Taxonomy has 10 Orders and over 10,000 Series. Small countries have proportionately fewer categories; for example in England and Wales, 10 Major Groups subdivide down into 1,080 Soil Series.[8]

Among many classification systems, and certainly within the UK there are a number of commonly used general terms to describe important types: *rankers* are thin soils with bedrock at shallow depth; *brown earths* are well drained loams, brownish or reddish in colour; *podzols* are acid soils in which materials have been leached

Compaction at harvesting can cause standing water even on sandy soils.

Photo: David Hogan

from upper layers and re-deposited deeper down, giving profiles a characteristically striking banded appearance; *gleys* are frequently wet, or artificially-drained mineral soils, greyish in colour often with ochreous or rusty mottles; *organic* soils are predominantly peaty.

Finding out more about soils

In England and Wales, soil and related environmental information is available through the Land Information System (LandIS), hosted at Cranfield University.[9,10] Of particular interest here is the *Soilscapes* application, a map depiction of soil landscapes for non-specialists, based on a simplified soils dataset derived from the 1:250,000 National Soil Map. The map units shown explain variations among soil types at specific locations by providing information on soil characteristics such as texture, drainage and fertility, together with associated habitats and land cover. For more detailed soil information, the application *Soils Guide* is provided, while educational materials are available from *Soil-Net*. In Scotland, a new soils website is now available.[11] The British Society of Soil Science is for those who are interested in the study and profession of soil science. Its local soils discussion groups organize meetings on a wide range of soil-related topics.[12]

What soils occur where and why

The 1980s saw the completion of a series of national soil maps at 1:250,000 (quarter inch to the mile) scale. At this time, a little less than 25% of the land in England and Wales had been surveyed in more detail at scales suitable for individual site management, mainly at 1:63,360 (one inch to the mile) or 1:25,000 (two and a half inches to the mile). Soils of most of the arable land of Scotland have now been mapped at 1:63,360 scale. In Northern Ireland, soil mapping did not begin until 1988, but since then complete coverage of the province at 1:50,000 scale has been achieved from which a map at 1:250,000 has been derived to ensure that the whole of the UK now has soil information mapped at that scale. The results of these soil investigations in Northern Ireland have been reported in Cruickshank.[13] *The Soil Atlas of Europe* was produced to raise public awareness of the importance and role of soils for many human activities and for the survival of ecosystems.[14] The Atlas provides not only soil maps for the whole of Europe at a scale of 1: 1,000,000, but a comprehensive introduction to soils for non-specialists, attractively illustrated with photographs and charts.

Soils and catchment management

In the past, the main issues relating to soils were concerned with their capabilities for agricultural cropping and requirements for maximizing fertility and yields. These included land drainage to extend the period suitable for land work or grazing, optimizing fertility, and maintaining organic matter levels. Soil testing for agricultural purposes has long been available for farmers to optimize crop yields, while advice on farm management and developing appropriate plans addresses issues such as waste management and reduction of pollution risk to water courses and groundwater, for example in Nitrate Vulnerable Areas.

More recently key issues of soil erosion, compaction and consequent runoff generation have been recognized more widely in flood risk management. The silver bullet of dredging in the Somerset Levels has missed a number of important factors including persistently large amounts of rainfall and run-off from the wider catchment. Soils in the headwaters of the River Parrett are known to be unstable and prone to capping, and susceptible to generating runoff and erosion under only modest amounts of rainfall. A timely recent paper summarises studies of soil compaction carried out in 31 catchments (including the Tone and Parrett, mentioned by the Prime Minister) in South West England over the period 2002-2011.[15] Results indicated that 38% of sites (55% of cultivated sites) had high or severe levels of structural degradation where enhanced surface runoff occurred across whole fields. A further 50% of fields showed moderate degradation with patchy enhanced runoff. Enhanced runoff also leads to loss of nutrients from farmland and pollution of watercourses. In South West England, an example of joined-up thinking here is funding support from the Environment Agency to enable Devon Wildlife Trust to provide soil aeration machinery to grassland farmers to alleviate compaction problems in the Northern Devon Nature Improvement Area.

Soil ecosystem services

The framework for ecosystem services, derived under the Millenium Ecosystem Assessment, indicates the wide range of benefits available for human well-being from natural ecosystems.[16] Soils are a key component in the functioning of these systems. Key soil functions include:

- providing food, fuel and fibre
- storing carbon and controlling climate change interactions
- buffering pollution
- regulating water storage and flows, and reducing flood risk
- supporting biodiversity
- protecting buried cultural heritage from damage and depletion
- providing foundations for buildings and infrastructure

Soils and nature conservation

When concerns were being expressed in the 1970s at the degree and extent to which habitat and consequent species loss were taking place, the role was identified which soil survey information might play in the creation of wildlife habitats within intensively managed agricultural land.[17] The debate has since moved on but the principles remain, in particular is the key role played by soil type in defining the habitats in which specific communities develop. Having good quality soil information is vital to the successful restoration of degraded habitats and the creation, extension and management of nature reserves.

Bradley and others review soil-related issues in habitat restoration and the kinds of soil data required to be collected.[18] The time scale can be extremely important as too-rapid changes can bring about undesirable consequences. While some soil properties are reversible, such as re-wetting land previously drained, the question of high topsoil fertility, especially phosphorus, a legacy of previous intensive agricultural management, can be difficult to deal with. Stripping of the topsoil to remove nutrients reduces carbon stocks and can increase the risks of erosion and off-site water quality issues. Once a decision has been made about the target habitat, the current nutrient status of the soil should be determined (see case study). If the available-P content is within twice that appropriate for the target habitat, harvesting biomass should be the first option to reduce fertility. If P-content is higher, then topsoil stripping becomes an option, or deep inversion ploughing by which topsoils are buried up to 1 meter depth. Other soil-related factors in habitat restoration include structural degradation, organic matter levels, water regime, microtopography, microbial communities, soil fauna and seed banks.

Case study: Dunsdon National Nature Reserve, Devon

The 57 hectare Dunsdon National Nature Reserve, owned by Devon Wildlife Trust, contains some of the best examples of Culm grassland, or Rhôs pasture. Dunsdon is also a demonstration farm for educational purposes. Culm grassland comprises marshy grassland and heathy vegetation developed on poorly drained impermeable soils over shales and sandstone of the Culm Measures, the Carboniferous rock outcrop of mid and north-west Devon and north Cornwall. Surviving remnants of

Culm grassland are being linked by restoration of adjoining fields of predominantly reseeded pasture.

Dunsdon is part of the Culm Restoration Project, with early stages of habitat restoration which include taking soil factors into account. Identifying the suitability of sites for re-creation of Culm grassland from rye-grass monoculture has included a measurement of residual soil fertility indicated by the content of phosphate in the topsoil. There are many examples, both locally on the Culm, and more widely in the country, where phosphate level is low in agriculturally improved fields, and where reversion to semi-natural vegetation of higher wildlife value has been achieved with appropriate management such as avoiding drainage and fertilizer use, and employing an appropriate grazing regime. Where moderate or high levels of phosphate exist, other techniques of soil management need to be considered.

In March 2009, soils were sampled from candidate fields with low wildlife value to determine phosphate levels at the surface and at 15 and 30 cm depth, followed by plant surveys undertaken in April. No unusual or interesting assemblages of plants were found. Soils here are two distinctly different type in equal proportion[19]: one is a seasonally wet poorly drained surface-water gley soil of low permeability with a topsoil of heavy loam (clay loam or silty clay loam) over a heavier subsoil (clay, silty clay or clay loam); the other is a better drained brown earth comprising more permeable heavy loam, susceptible to only slight season waterlogging. Phosphate content was found to vary from *low* to *very high*. In principle, where *moderate* phosphate levels were found, the soils were shallow ploughed to around 25 cm depth. Where phosphate levels were *high* or *very high*, the soil was deep-ploughed to a depth of 50-70 cm in order to bury the topsoil and bring subsoil material of lower fertility to the surface. Some shallow soil stripping has taken place including in one area to provide material for the construction of a hedge bank. Ground works were started in spring 2009. In July 2009 ploughed and scraped areas were rolled and power-harrowed prior to reseeding with a meadow mixture of 22 species; parts were also hand-sown with 'green hay' obtained from adjoining areas of Culm grassland. Details of the site and work of the Culm Restoration project, including ecological survey results are given in Dunsdon annual reports on the Devon Wildlife Trust website. (www.devonwildlifetrust.org).

It is fortunate that the area of Dunsdon is covered by a detailed published soil map.[19] But it is not clear whether this was used in the selection of locations for habitat restoration nor design of the work programme. Comments in site reports suggest that some soil compaction had probably been caused during operations, and in fact this was noted by the author on a site visit for another purpose in 2010. This highlights how beneficial it would have been to have undertaken an assessment of soil structural condition during the first winter following ground works in order for soil loosening and aeration to take place the following spring or summer to aid habitat restoration. A linking of the vegetation survey with the soil map could also help to explain details of plant recolonisation, including relations to the kinds of material brought to the surface by deep ploughing.

Culm grassland at Dunsdon NNR, Devon

Photo: Peter Burgess/Devon Wildlife Trust

Protecting future soil quality

In 1996, The Royal Commission's report on *The Sustainable Use of Soil* highlighted the need for a soil protection policy.[20] Among its key recommendations were implementing such a policy for the UK, giving greater weight to appropriate use of soils in the planning policies, and establishing a national monitoring scheme for soil quality. Work is on-going to develop indicators of soil quality and a monitoring network.[21]

In September 2006, the European Commission adopted a Thematic Strategy for Soil Protection, which included proposals for a Soil Framework Directive, agreement about which has not been reached among member states, some of which feel the issues are better addressed at a national level. The proposed Directive targeted seven key threats to European soils: erosion, organic matter decline, compaction, salinisation, landslides, contamination and soil sealing. The FAO (Food and Agriculture Organisation of the United Nations) has designated 2015 as *International Year of Soils*, which will provide the opportunity for a global raising of awareness about soils.

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