Soils

Scotland's soils are diverse and rich in carbon; they are vital for Scotland's health, prosperity and environment.

Summary

Scotland's soils provide many environmental, economic and social benefits, including the supply of food, wood, clean water and habitat, as well as storing carbon.

The key pressures that soils face are climate change and changes in land use and land management; these can have environmental and socio-economic impacts.

Sustainable soil management should be recognised as part of the solution to a number of key issues that the world faces. We need better policy integration, better trend data on the state of soils and good practical soil management solutions to achieve this.

Introduction

Scotland may be a small country but our soils are amongst the most varied in Europe. Our soils are a result of the interactions between our rocks, topography, climate and vegetation over time. Scotland's iconic landscapes are developed on different soils; soil is a key factor in the quality of streams, rivers and lochs, and it also influences air quality.

Through management over thousands of years, humans have greatly influenced soils. The pattern of human settlement we see now is, in part, due to soil quality.

Scotland's soils tend to be acidic, carbon rich and nutrient poor: there is more carbon in our soils than in all the vegetation in Europe.

The amount of carbon stored in our soils is estimated to be equivalent to around 180 years worth of Scotland's current greenhouse gas emissions. Over half of this carbon is stored in peat soils, arguably our most iconic soil, and one which supports habitats of global importance. More information can be found in the Joint Nature Conservation Committee report 445.

Soils carry out a number of functions and provide a range of benefits:

- providing the basis for food, timber and sources of renewable energy production;
- regulating water flow and quality;
- storing carbon and maintaining the balance of gases in the air;
- providing valued habitats and sustaining biodiversity;
- preserving cultural and archaeological heritage;
- providing raw materials;
- providing a platform for buildings and roads.

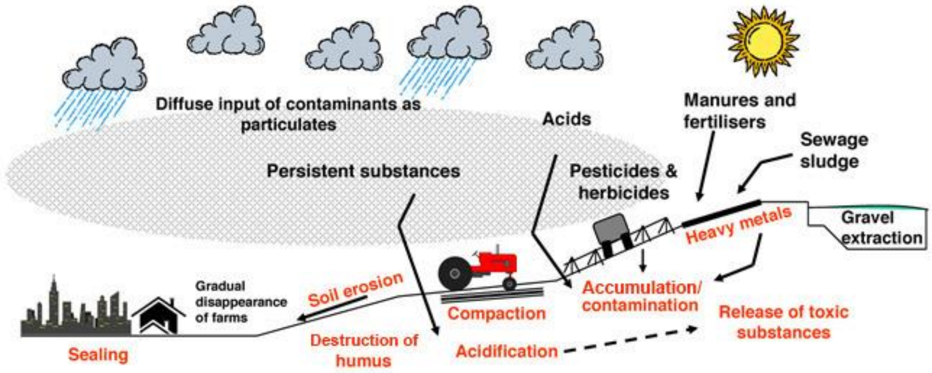
Soil quality is defined as the ability of soil to carry out these functions. Soils can carry out more than one function at the same time and thus provide multiple benefits. For example, a soil used for growing barley—its intended main function—also filters rainwater, stores carbon and is home to a number of different species.

Soil quality is at risk from a number of threats which can result in soil being damaged to such an extent that it can no longer carry out its essential functions, or soil being irretrievably lost. For example, Figure 1 shows the main threats to, and resulting impacts on, agricultural soils.

The main threats to soil quality are:

- a reduction in the total amount of soil organic matter;
- permanent covering with an impermeable material (soil sealing), for example tarmac;
- the addition of substances resulting in contamination, for example heavy metals from pig manure;
- a change in soil biodiversity (i.e. the variety of all life in soil);
- erosion (movement of soil particles by water or wind at a rate exceeding 'natural' levels) and landslides (mass movement of material down a slope);
- compaction (soil becoming denser because of increased pressure on the surface).

Figure 1: Impact of human activities on soil, causing risk of soil degradation



Source: Reproduced from JRC Scientific and Technical Report '[threats to soil quality in Europe]'.

More detail on the main threats to soil quality can be found in the [state of Scotland's soil report].

Description of soils

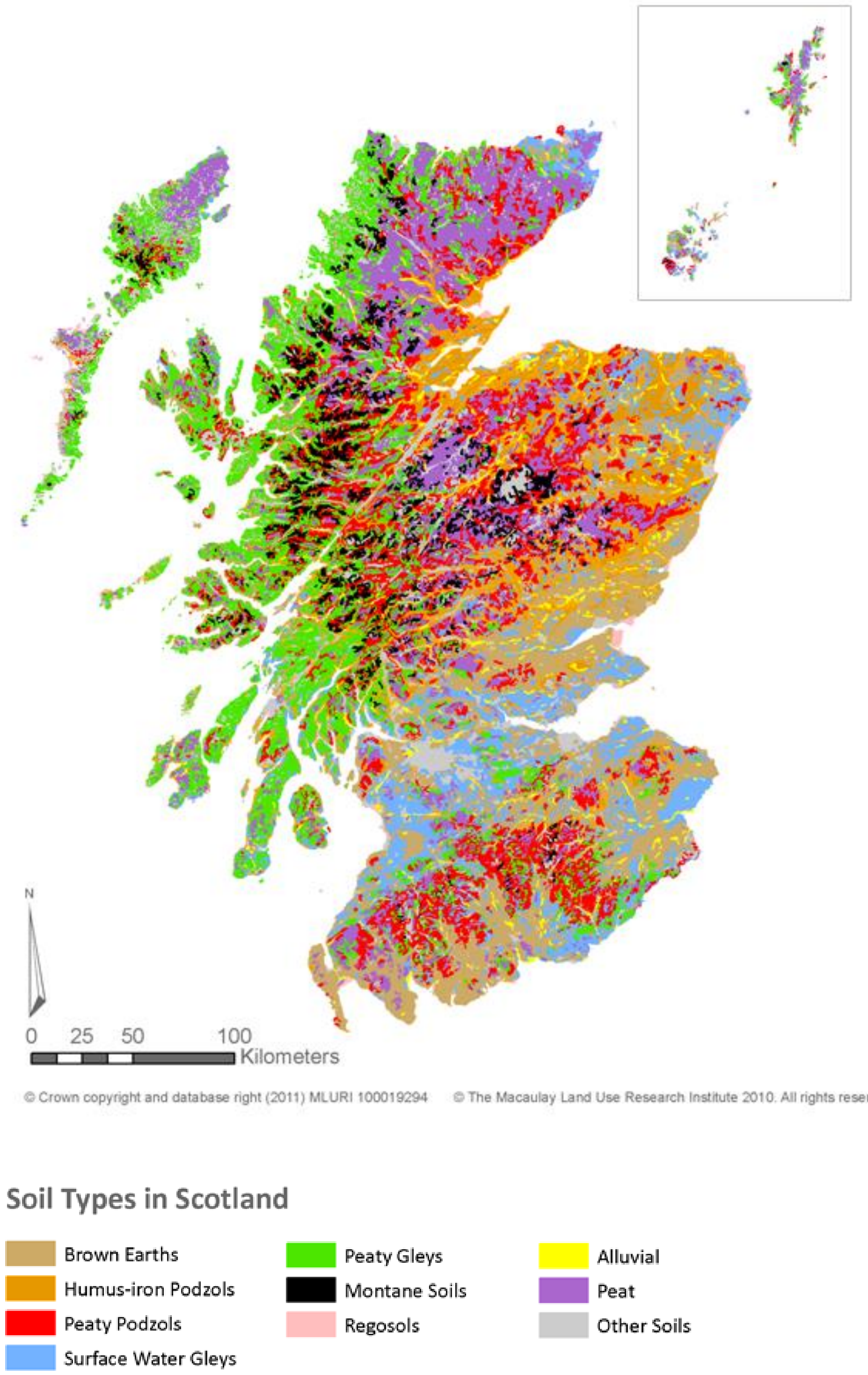
It is difficult to evaluate the condition of soils and whether they are in 'good' condition because one soil can provide a number of different benefits at the same time.

Any consideration of 'soil quality' or 'state' must be related to the intended use and benefits that we want from different soils. Soils in a good state to provide one benefit may not be in a good state to provide another.

The performance of different soils directly depends on their properties. For example, an intensively managed, slightly acidic brown earth may be ideal for growing barley but, if poorly managed, it can also release greenhouse gases into the atmosphere. On the other hand, an acidic peat soil can only grow a limited range of plants but can be a huge carbon store and is part of an internationally recognised, and valuable, ecosystem. Figure 2 shows the location of the main soil types in Scotland.

Generally, there is a lack of trend data from which evidence of change in, and damage to, Scottish soils can be assessed.

Figure 2: Main soil types in Scotland



A more detailed soil map and further information on the distribution and properties of soils in Scotland can be found on Scotland's Soils Website. The state of soil in relation to the main threats to soil quality is described in detail in the state of Scotland's soil report and outlined below.

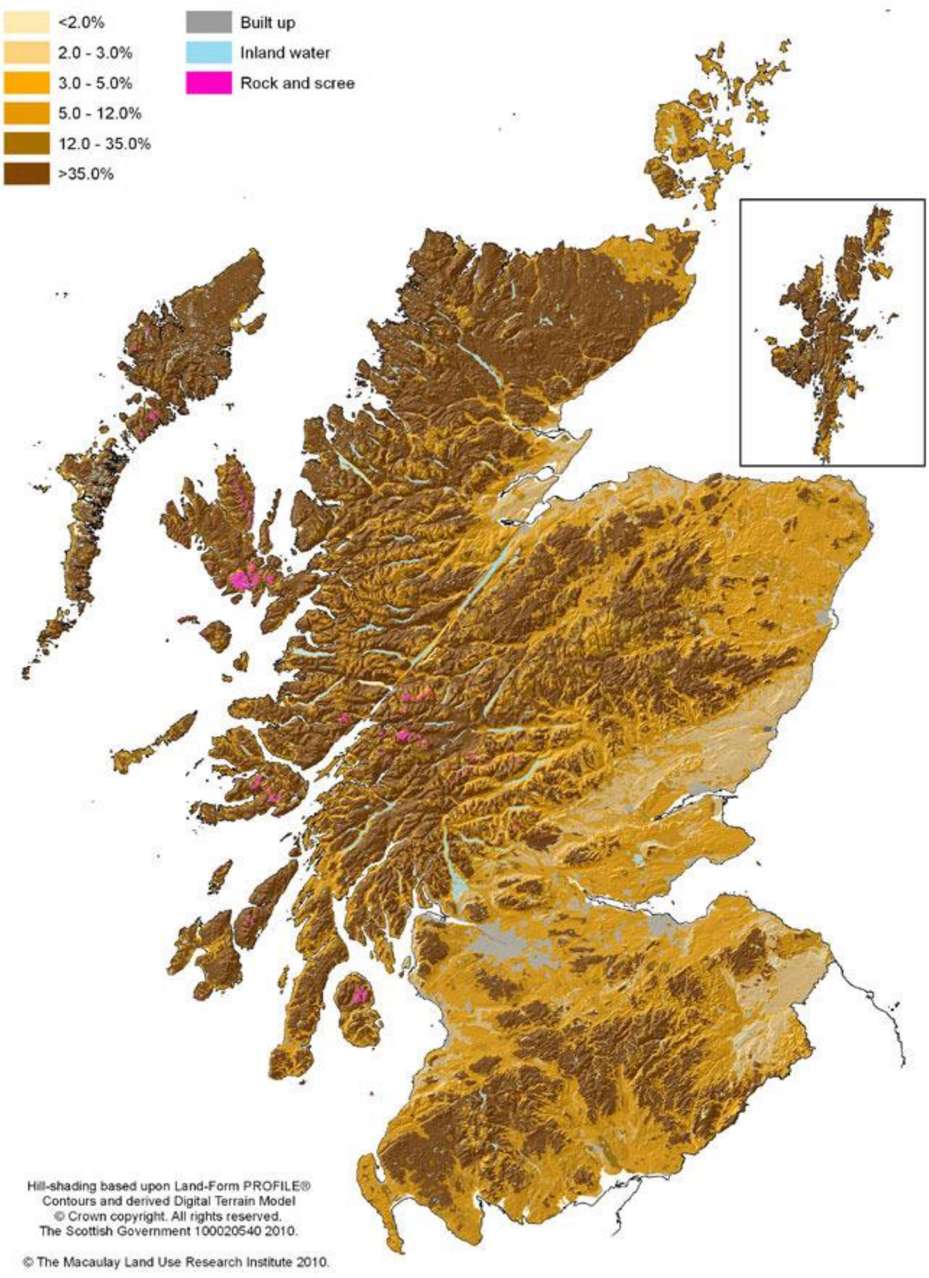
Soil organic matter

Despite only covering around a third of UK land, Scottish soils contain more than half of the UK's soil carbon and 30 times as much carbon as all the vegetation in the UK.

Soil organic matter is a universal constituent of soils and plays a vital role in contributing to a range of soil functions. It is formed from the breakdown and incorporation of plant and animal matter in soil. Organic carbon is the largest component of soil organic matter (around 50%), so management of soil has important wider consequences in the context of greenhouse gas emissions and climate change.

The location of soils rich in organic matter in Scotland is well known thanks to national scale soil mapping (Figure 3, also see Scotland's Soils website).

Figure 3: Soil organic carbon concentration in uppermost soil horizon



It is estimated that Scottish soils contain approximately 3200 million tonnes of carbon. However, there is still some uncertainty about the exact amount, as most earlier studies have not considered the entire depth of soil. More detail can be found in the state of Scotland's soil report.

In 2008, Scotland's greenhouse gas emissions were equivalent to 15.3 million tonnes of carbon, which is only 0.5% of the carbon stored in its soils. So, if just 0.5% of the carbon contained in soil was lost in a year, it would be enough to double Scotland's annual greenhouse gas emissions.

The little evidence available suggests that there is no—or relatively low rates of—change in the concentration of organic matter in Scottish soils, particularly in cultivated soils. For further details see the state of Scotland's soils report.

Scottish Natural Heritage's News and Information Notice identification of carbon-rich soil mapping units provides information on a reproducible method for categorising the carbon richness of soil mapping units produced by the Soil Survey of Scotland. The Soil Carbon Richness map can be found on Scotland's Soils website.

Sealing

There is no systematic collection of data capturing the extent and quality of land being sealed. A possible indication of sealing is the area covered by 'urban land'. Around 2.5% of Scotland is classified as 'urban', but not all 'urban' land is recognised as being sealed.

Based on best estimates, about 1200 ha of land is sealed every year (approximately 0.02% of Scotland). This is equivalent to a town the size of Dunfermline.

Contamination

A wide range of substances can contaminate soil, for example acids and nutrients, metals, organic chemicals, pathogens and man-made radioactive substances.

Soil acidity and nutrients

In large areas of Scotland, the level of acidity and nitrogen already in the soil is such that soil is unable to absorb any more. Soils in these areas may not be able to deliver certain benefits, potentially resulting in poorer water quality or damage to habitats, for example.

A reduction in acid deposition from the atmosphere over the last 30 years because of international agreements on emission reductions is reflected in a decline in soil acidity. In contrast, nitrogen deposition has not declined enough to prevent continuing damage to vulnerable habitats.

In Scotland, the amount of phosphorus available for plant crop growth in agricultural soils is generally satisfactory. In some fields, however, very low, or excessively high, levels are found. Occasionally, there can be much more than the plants need, which can lead to the surplus finding its way into watercourses, causing problems for the plants and animals in the water environment.

Phosphorus concentrations in agricultural soils have remained relatively stable in the last 10 years. However, there is some concern that the nutrient status of agricultural soils is declining and that they are becoming more acidic because of a change in agricultural practices. Further monitoring is needed to confirm this trend.

Metals

A wide range of metal concentrations are found in soils, reflecting the diversity of rock types and materials from which soils are formed.

In some areas, naturally high soil metal concentrations can damage crops, for example high nickel concentrations can be found in soils formed from volcanic rocks.

Metal deficiency can also be a problem in some soils leading to plant and animal health problems.

Increased applications of materials containing metals to land, for example sewage sludge, animal wastes or composts, are likely to result in gradual increases in soil metal concentrations. Activities are regulated and monitored to ensure there is no risk to human health.

Man-made radioactive substances

Concentrations in soils across Scotland are generally low and trends are difficult to determine. More information can be found in radioactivity in food and the environment 2009.

Contaminated land

Land is defined as 'contaminated' if contaminant concentrations could pose a threat to human health, ecosystems or water bodies.

Approximately 67,000 sites covering an area of 82,000 ha have had some form of previous land use, which could potentially result in the land being affected by contaminants, for example industrial activity. This is approximately twice the area covered by the Greater Glasgow urban area and comprises 1% of land in Scotland. However, it is important to put this figure in context. In reality, as local authorities continue to inspect such land, only a small proportion is likely to meet the statutory definition of contaminated land.

It is difficult to determine trends, or the severity of contaminated land in an area, as methods for recording data have not been historically consistent across the country. More information can be found in dealing with contaminated land in Scotland.

Changes in soil biodiversity

Although the amount of available data and knowledge on soil biodiversity in Scotland has increased considerably in recent years, it is still not yet possible to comment on the 'state' and impossible to comment on historical trends.

Losses of soil biodiversity may have already occurred as a result of historical pressures such as habitat losses or contamination.

Erosion and landslides

There is no systematic assessment of soil erosion at a national scale in Scotland. Measurements of erosion are generally site-specific and often in response to a severe erosion event.

Soil erosion and deposition is a natural process. It is suggested that current annual erosion rates are acceptable for the majority of Scotland, except for the arable areas of eastern Scotland, where it is estimated that erosion rates are more than 2 tonnes per hectare per year – greater than the European tolerable soil loss of 0.3–1.4 tonnes per hectare per year.

In upland areas, it is estimated that around 35% of Scotland's peatlands show signs of erosion.

Suspended sediment in rivers can give an indication of trends in soil erosion but the national picture is unclear. For instance, catchments draining into the Moray Firth show an increase in suspended sediment levels, whilst catchments in the central belt show a decrease.

It is estimated that approximately 3% of Scotland is highly susceptible to debris flows (a type of landslide). However, it is not known how much material is lost in each debris flow. There have been several roads blocked by these events in recent years.

Predictions of more frequent and intense rainfall events in the future suggest that we may see greater levels of erosion, more frequent landslides and peat slides as a result of slope failure.

Compaction

Heavier farm machinery is likely to increase soil compaction in Scotland. A number of small-scale studies have found local increases, but there has been no systematic study of the national extent, or severity of, soil compaction. Therefore, it is not possible to provide a quantitative assessment of the current state or trend.

Pressures affecting soils

There are a number of high level, and often global, drivers that create a number of pressures on our soils, including:

- increasing food supply demand;
- increasing food security demands;
- population changes;
- climate change;
- renewable energy demand;
- recreational use of land.

These can create situations that are incompatible, for example the demand for more food at the same time as the need for biofuels from the same piece of land—which should be prioritised?

The key pressures can be grouped under two main headings:

1. climate change;
2. changes in land use and land management practices.

In turn, these can contribute to the range of threats — i.e. soil degradation processes, as well as a direct loss of soil, which determine how well soils can provide their various benefits.

Climate change

Potentially, climate change is the greatest pressure on our soils as it could have a range of impacts on soil processes because of changes in soil wetness, temperature and rainfall patterns.

It may lead to:

- a gradual or catastrophic loss of soil organic matter;
- changes in soil biodiversity;
- increased rates of soil erosion and landslides;
- increased soil compaction.

Changes in land use and land management practices

These can be divided into a number of different pressures:

- development/transport (e.g. road building);
- cultivation of soils for agriculture or forestry;
- application of chemicals in agriculture or forestry (e.g. fertilisers, pesticides);
- expansion of agriculture or forestry;
- changes in grazing pressure (i.e. increased animal numbers on farms).

While these pressures act on a number of different soil functions, there are other pressures which only act on one function. These have less of an overall impact, for example fossil fuel combustion leading to land contamination. More details can be found in the state of Scotland's soil report.

It should be acknowledged that some pressures can bring about benefits to soil as well as threats, for example increasing temperatures may result in greater plant growth.

Consequences of a change in soils

Soil degradation (i.e. threat to soil quality) can have damaging environmental and socio-economic impacts.

The state of Scotland's soil report developed a method allowing a theoretical comparison of the environmental impacts of each threat. Using this, loss of soil organic matter appears to be the greatest threat to soil function, meaning that soils would not be able to provide many of the benefits we expect. This is unsurprising, as soil organic matter underpins many soil functions.

Changes in soil biodiversity could also have a high environmental impact, as the organisms in soil control many of the processes in soil, for example the recycling of nutrients or earthworms helping to create good soil structure.

Effectively, soil sealing results in the loss of all functions and, although the effects are local in scale, it has a high impact.

The main environmental consequences of soil degradation are often caused by a combination of the threats and include:

- poor conditions for plant growth (leading to loss of yield or contamination of crops, including timber) caused by all of the threats and due to a range of factors including:
  - damage to soil structure;
  - reduction in water-holding capacity;
  - lowering of nutrient levels;
  - increasing contaminant levels.
- increased run-off and erosion leading to poorer water quality by increasing nutrients and other potential pollutants in the water;
- increased frequency and magnitude of flooding caused mainly by loss of organic matter, sealing, erosion and compaction;

- increased greenhouse gas concentrations in the atmosphere caused by loss of soil organic matter, soil contamination (excess nitrogen) and compaction;
- damage to valuable above-ground habitats, as well as habitat for soil micro-organisms, leading to further soil degradation;
- impaired archaeological or cultural heritage sites affected by loss of organic matter, erosion, compaction and contamination;
- *'contaminated land'* caused by the input of contaminants above a level considered safe for a specific land use, taking into account the risk to human health.

As well as the obvious environmental impacts, soil degradation also has important socio-economic impacts. For example, loss of crop yield has economic implications for farmers, while increased erosion and run-off to watercourses may mean that the water has to be treated before it is safe to drink. Once a site is designated as contaminated land then it may have to be cleaned up before it can be developed to ensure there is no risk to human health.

A recent study tried to identify the socio-economic impacts of the threats to soil in Scotland. Using this as a basis, the state of Scotland's soil report developed a method allowing comparison of the socio-economic impacts of each of the threats. It concluded that the threat with the greatest socio-economic impact was erosion and landslides, followed by changes in soil biodiversity and the loss of organic matter. More data are required to confirm these judgements.

By combining the environmental and socio-economic impacts, the threats with the greatest potential impact are:

- loss of soil organic matter;
- changes in soil biodiversity;
- soil erosion and landslides;
- soil sealing.

Response by society

Ensuring that soils are in a good condition to provide their services and benefits to society is vital for the sustainability of the environment.

Why are soils important?

There is growing recognition amongst policy makers and land owners/users alike of the benefits gained from healthy and productive soils. Soils are essentially a non-renewable resource whose role in supporting sustainable use and management of the environment needs to be better understood and protected. Soil management is a key part of the solution to the wider issues of climate change, food security, water quality and flood risk mitigation.

Are our soils protected?

In Scotland, and the wider European Union (EU), soil has not been given the same level of protection as the water and air environments. This is partly because there is currently no single Directive specifically to protect soils, although many EU and UK policies protect some aspects of soil.

The importance of soil as a non-renewable resource essential to a sustainable environment needs to be more fully recognised. This is being addressed by overarching soil protection measures, such as the European Commission's thematic strategy for soil protection and proposed soil framework directive, and the Scottish Government's Scottish soil framework.

Policy recommendations have been made in the state of Scotland's soil report, covering a number of policy areas, including climate change, organic wastes, diffuse pollution and planning.

In the land use strategy, published as part of the Climate Change (Scotland) Act 2009, the management and protection of carbon-rich soils is seen as a key element of Scotland's climate change mitigation strategy.

What has to be done?

The challenges are to understand and deal with a number of issues including:

- tackling the lack of systematic Scottish soil data: understanding what is already available, identifying gaps and making recommendations for future monitoring in order to obtain a better evidence base to determine any change in the state of soil. A robust co-ordinated monitoring scheme should address both current issues and have flexibility to accommodate any future issues;
- understanding the wider impacts of soil management and providing recommendations for management options to address the key threats to soil.

Who should do it?

Ultimately, the responsibility for the future of Scotland's soil rests with all of Scotland's people. However, organisations and research bodies that have direct involvement with, and responsibility for, soil have a duty to ensure that the wider public are continually informed of its state and value.

In 1937 the President of the United States of America, Franklin Roosevelt, eloquently summarised the importance of soil: "A Nation who destroys its soil destroys itself".