Soils

Scotland's soils are diverse and rich in carbon; they are a vital natural resource providing a range of essential benefits and need to be protected. We have good information about some soil properties in some parts of the country. However, there is a lack of trend data.

Summary

Key messages

- Scotland has a diverse range of soils, formed from a number of different rock types under a variety of environmental conditions.
- Soils are a vital natural resource. They provide a range of benefits, which include growing food and trees, filtering impurities from water and storing carbon.
- It is difficult to assess if, and how, soil is changing because of a lack of comparable data, especially trend data, from which evidence of change can be found.
- The main pressures on soils are the impacts of climate change and changes in land use and land management; these can damage soil, which can lead to wider environmental and socio-economic harm.

State and trend

State: Good - medium agreement, low evidence

Trend: Insufficient data to determine trend

There is an explanation of the diagram and further information on how we carried out the assessments on the summary pages.

- The wide diversity of soil types and their broad range of properties mean that soils can provide a number of different benefits. Some soils can provide a variety of benefits while others may only be able to provide one or two. Therefore it can be difficult to make an overall assessment of the state of soil.
- Soil can be in a whole range of conditions, from excellent to very poor, depending on what benefit we expect it to provide. For example a soil that is accumulating peat and in a good state for storing carbon is unlikely to be in a good state for growing crops. Here we make an assessment of the "average" condition.
- We have several sets of soil data in Scotland which can give us some information on some aspects of the state of soil, however these datasets are not always comparable.
- It is difficult to assess whether, and if so, how, Scotland's soils are changing, because there is hardly any trend data.

Overview

Soil develops on the earth's surface as the climate (temperature and moisture), plants, and animals (from tiny bacteria to people) break down the underlying rocks over time. The way soil develops is also influenced by topography – the slope of the land, which direction the land faces and how high it is. The rocks from which soils form are known as the 'parent materials'.

Scotland has a complex geology (rocks and landforms), so it has a wide range of parent materials and soils. In fact, for a country of its size, Scotland's soils are amongst the most varied in Europe.

Soil is made up of mineral and rock fragments, water, gases and living and dead organic material from plants and animals. The relative amounts of these materials in soil and what they are made of determines the properties of the soil. Soil changes slowly all the time as materials are added and removed. Figure 1 shows the main factors that shape soil properties.

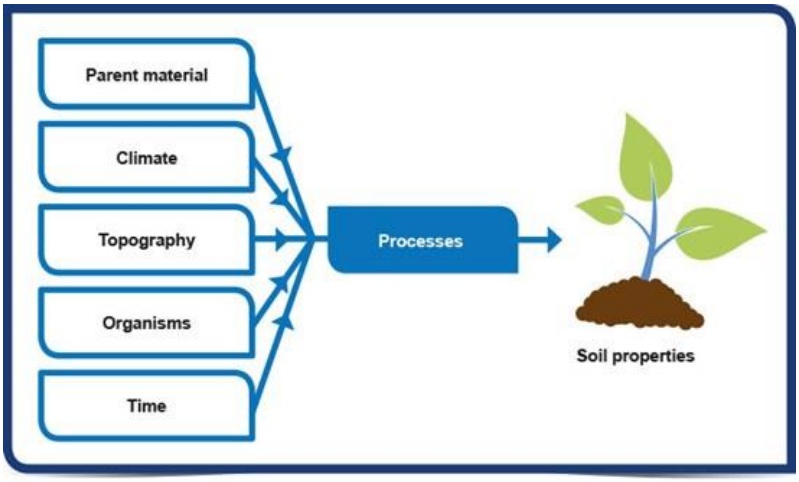

Figure 1: Factors influencing soil formation.

It takes hundreds of years to create a few centimetres of soil. Most of Scotland's soils have formed since the end of the last ice age, so they are relatively young compared with soils in other parts of the world.

The combination of geology and climate means that Scotland's soils tend to be acidic, carbon rich and nutrient poor. For example, Scotland has large amounts of peat soil, which is formed by plant material decomposing in cold, wet conditions.

People have greatly influenced soils by the range of land use and management practices carried out over time; for example, by creating artificially thickened (plaggen) soils. People have also damaged some soils by continuously cultivating them, depleting them of organic matter.

Figure 2 shows the distribution of the main soil types in Scotland.

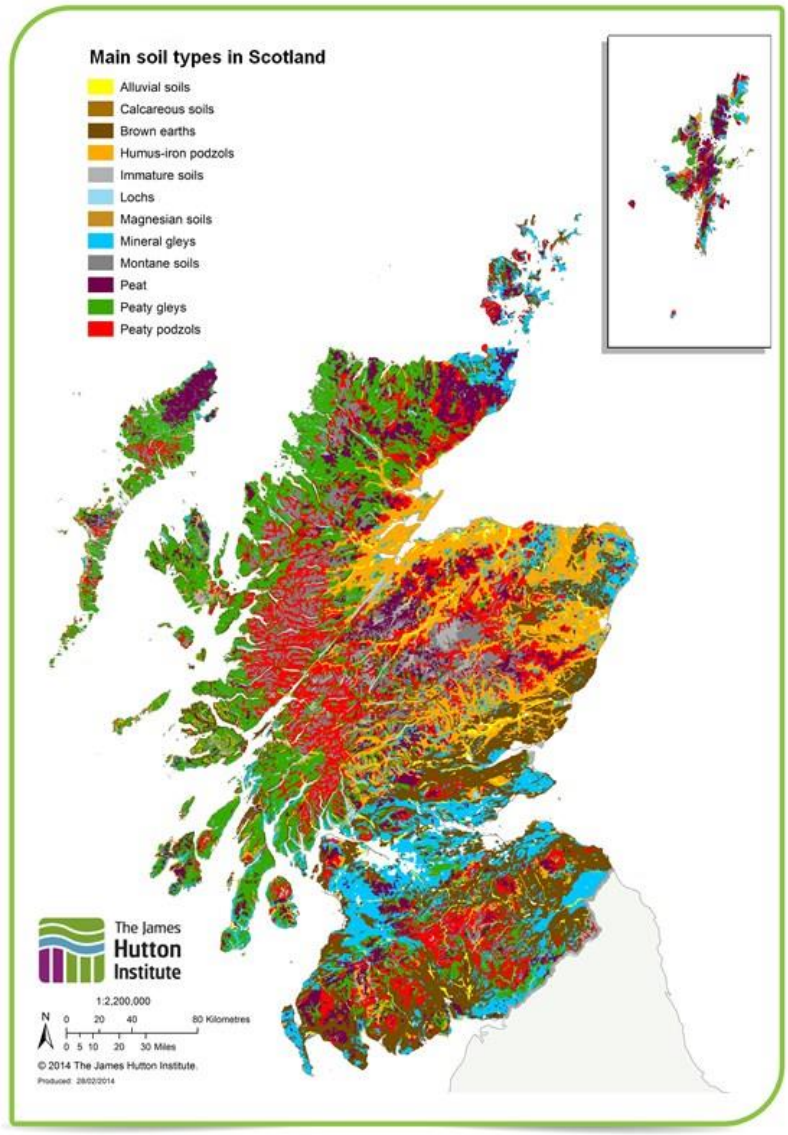

Figure 2: Main soil types in Scotland.

The key characteristics and functions of the main soil types found in Scotland are presented in Table 1. More detailed information about Scotland's soil types can be found on the Scotland's soils website.

Table 1: Key characteristics and principal benefits of the main soil types found in Scotland.

Soil type	Main characteristics	Principal benefits
Brown earth	Brown in colour. Well or reasonably well drained.	Provides good-quality agricultural land, used for growing crops in the east and for grazing and forestry in the hills and uplands.
Humus-iron podzol	A thin, dark organic surface layer, overlying a grey layer, overlying a brown subsoil. Sharp boundaries between layers. Well or reasonably well drained.	Used for mixed agriculture or supporting semi-natural habitats and species, such as pinewoods and heather.
Peaty podzol	Dark, organic surface layer, up to 50cm thick, overlying a grey layer, overlying a brown subsoil. Sharp boundaries between layers. Well or reasonably well drained.	An important carbon store. Supports heather and much of the grouse population.
Surface-water gley	Drab, greyish colour Poorly drained.	Supports improved grassland managed for livestock grazing (meat and milk production). Also supports wetland habitat and species.
Peaty gley	Drab, greyish colour with a dark, organic surface layer up to 50cm thick. Poorly drained.	Supports large areas of coniferous woodland and wet heath habitat. Extensively used for deer management. Important carbon store.
Montane soil	Similar to podzols, but is very loose because of intermittent freezing and thawing.	Supports rare mountain habitat and species.
Regosols	Sandy soils with only weak (if any) layering.	Supports sand-dune habitat and species, including machair.
Alluvial soils	Found along rivers. Weak (if any) layer structure.	Some are very productive, others support our valuable wetland habitats.
Peat	An organic soil with an organic surface layer more than 50cm deep. Can often be much deeper.	Valuable carbon store. Supports internationally important blanket bog habitat and rare bird species, such as hen harriers, merlins and golden plovers.

Importance of soil

The main benefits that soils provide include:

- growing food and trees;
- controlling water flow and quality;
- storing carbon and maintaining the balance of gases in the air;

- supporting valuable habitats, plants and animals;
- preserving cultural and archaeological heritage;
- providing raw materials;
- providing a platform for building on.

Soils can carry out more than one function at a time, providing a range of benefits in the same place. Soil quality is defined in terms of its ability to provide these benefits.

Soil degradation

Soil quality can be improved or damaged by a range of natural and human processes. The main degradation processes that damage soils are:

- loss of soil organic matter;
- covering soil with an impermeable material, e.g. tarmac (soil sealing);
- the addition of contaminants or loss of essential nutrients;
- erosion;
- compaction;
- a change in soil biodiversity.

These degradation processes are caused by a range of pressures.

Soil degradation can affect the wider environment. For example, the loss of organic matter in soils can increase the amount of greenhouse gases (GHGs) in the atmosphere, contributing to climate change. We have so much carbon in our soils that the loss of just 0.5% of our soil carbon in one year could double Scotland's annual GHG emissions.

The relative impacts of soil-degradation processes

The State of Scotland's Soil report developed methods to compare the environmental and socio-economic impacts of soil-degradation processes. The report combined these and concluded that the degradation processes with the greatest potential impact are:

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

Figure 3 shows the main human activities that damage soil quality.

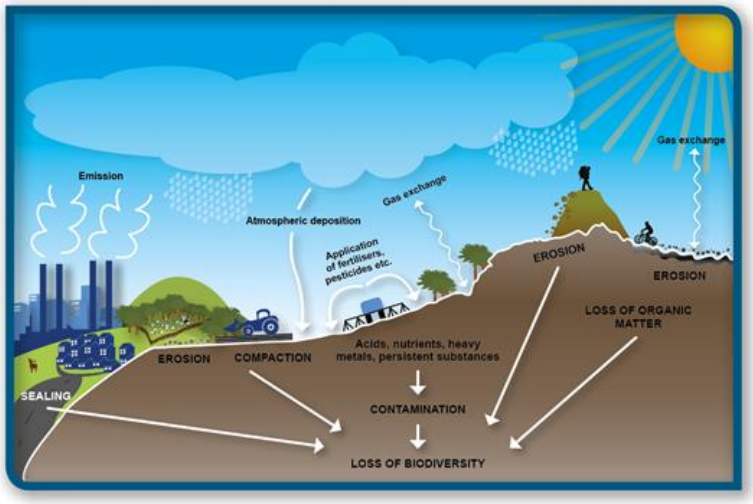

Figure 3: Human activities causing soil degradation.

State

The state of soil – that is, soil quality – is measured by the soil's ability to provide a range of benefits. Here we discuss the main soil properties that affect the state of soil.

We have several sets of soil data in Scotland. These can give us some information about the state of the soil, but it is not always possible to compare the data because they have been collected in different ways for different reasons. It is also difficult to assess whether, and if so, how, Scotland's soils are changing, because there is hardly any trend data available.

You can find more details on the range of soil data and information available in the State of Scotland's Soil Report and on the Scotland's soils website.

The main pressures on soil are caused by the impacts of climate change and changes in land use and land use management.

Soil organic matter

Soil organic matter is found in nearly all soils. It is formed from broken down plant and animal matter that is incorporated into the soil. Organic carbon is the largest component of soil organic matter (around 50%). This is the material that gives soils their dark colour.

Scotland's soils contain approximately 3200 million tonnes of carbon. The location of soils rich in organic matter is shown in Figure 4. You can find more information on the carbon richness of soils in Scottish Natural Heritage's Identification of carbon-rich soil mapping units and on the Scotland's soils website.

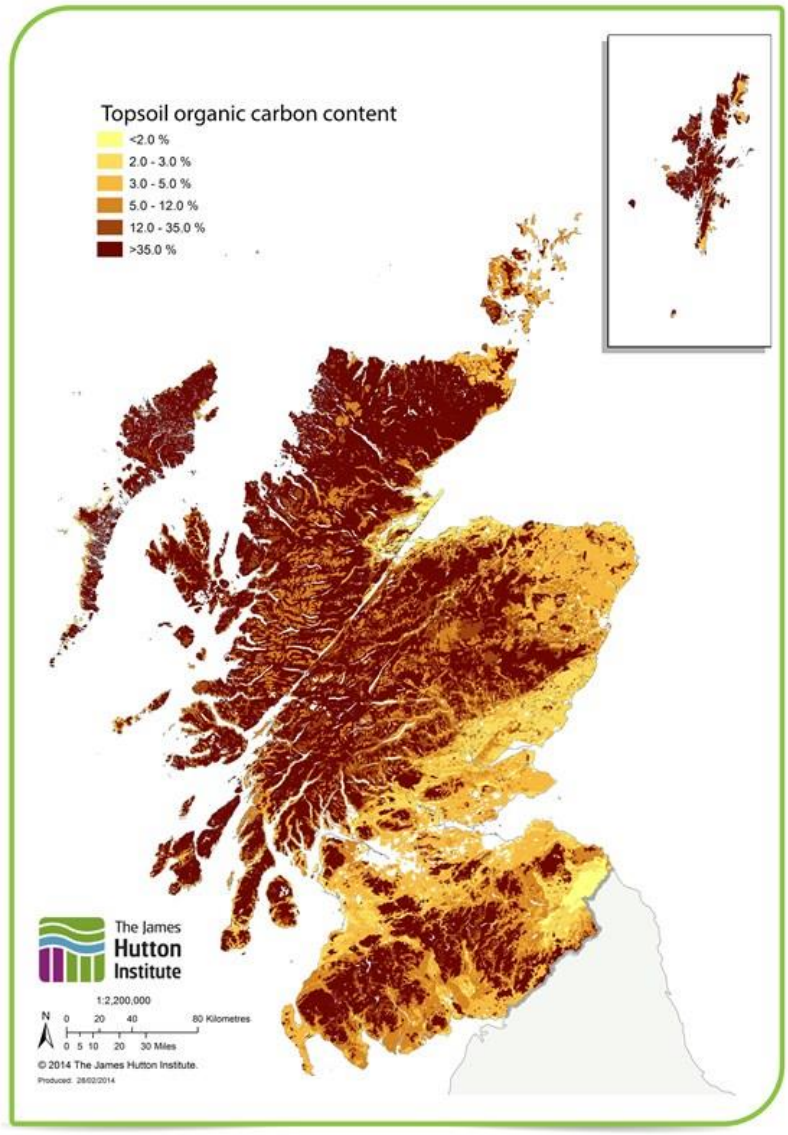

Figure 4: Soil organic carbon concentration in the surface layer of soil.

A partial resurvey of the National Soils Inventory of Scotland (NSIS) has shown that the amount of carbon stored in the top metre of soil within different habitats in Scotland has not changed significantly in the last 25 years, except for in woodland soils. However, this does not tell us anything about the effects of changes in land use on overall losses (or gains) of soil carbon.

This is consistent with Countryside Survey data for Scotland, which shows no overall change in carbon concentration in the top 15 cm of soil between 1978 and 2007.

Soil chemistry

The chemical make-up of the soil affects a range of properties and processes. The pH value (a measure of acidity) and concentrations of nutrients and trace elements (e.g. metals) in a particular soil partly determine what functions that soil is most suited to. For example, whether it is most suited to growing crops, supporting rare habitats or preventing water pollution. Adding, or removing, elements outwith the optimum range can result in losing some or all of the soil function.

Soil acidity and nutrients

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

International agreements to reduce industrial emissions has led to a reduction in acid deposited from the atmosphere onto land over the last 30 years, which is reflected in a decline in the extent of habitats affected by acidification. In contrast, nitrogen deposition has not declined to the same extent, resulting in continuing damage to vulnerable habitats.

Results from the Countryside Survey show that the top 15 cm of soils in Scotland across all habitats became less acidic between 1998 and 2007, continuing a trend observed between 1978 and 1998.

Countryside Survey data also show that while in some habitats there were no significant changes in soil nitrogen concentration in the top 15 cm, in others significant decreases were found.

However, the resampling of the National Soils Inventory of Scotland has shown no overall change in the last 25 years or so in the pH or nutrient nitrogen levels of soil across the country as a whole.

The differences in results between the National Soils Inventory of Scotland and the Countryside Survey show that it is difficult to compare data for soils sampled for different reasons and sampled, analysed and reported in different ways: while the results averaged across the country (in the National Soils Inventory of Scotland) show no significant change, results within specific habitats (in the Countryside Survey) do show change. This illustrates that the variability between different types of soil can be greater, and thus mask, any change within specific soils or habitats.

The amount of phosphorus in agricultural soils available for plant growth has remained relatively stable in the last 10 years, and is generally satisfactory. In some fields, however, very low, or excessively high, levels are found. If there is more phosphorus available than plants require, it can find its way into watercourses and lead to environmental harm.

Metal concentrations in soils

A wide range of metal concentrations are found in soils, reflecting the diversity of rock types and materials from which soils have been formed. While some metals in soils are beneficial in trace amounts, if there is too much then they can become toxic to plants, soil organisms and, ultimately, to humans via the food chain.

Metal concentrations in Scottish soils are generally low. However, in some areas, naturally high concentrations exist and can damage crops. For example, high nickel concentrations can be found in soils formed from volcanic rocks (Figure 5).

In contrast, metal deficiency (e.g. copper) can also be a problem in some soils, leading to health problems for plants and animals (Figure 6).

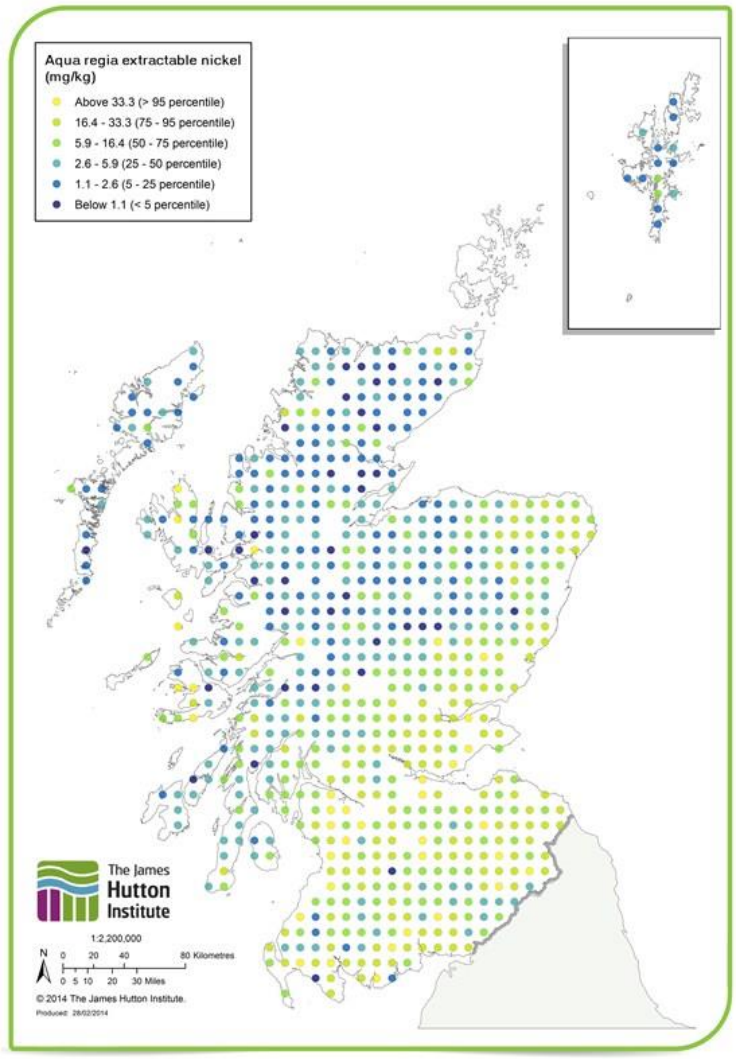

Figure 5: Nickel concentrations in soils across Scotland, as determined from the James Hutton Institute (JHI) National Soil Inventory of Scotland dataset (NSIS_1). Maps supplied by JHI.

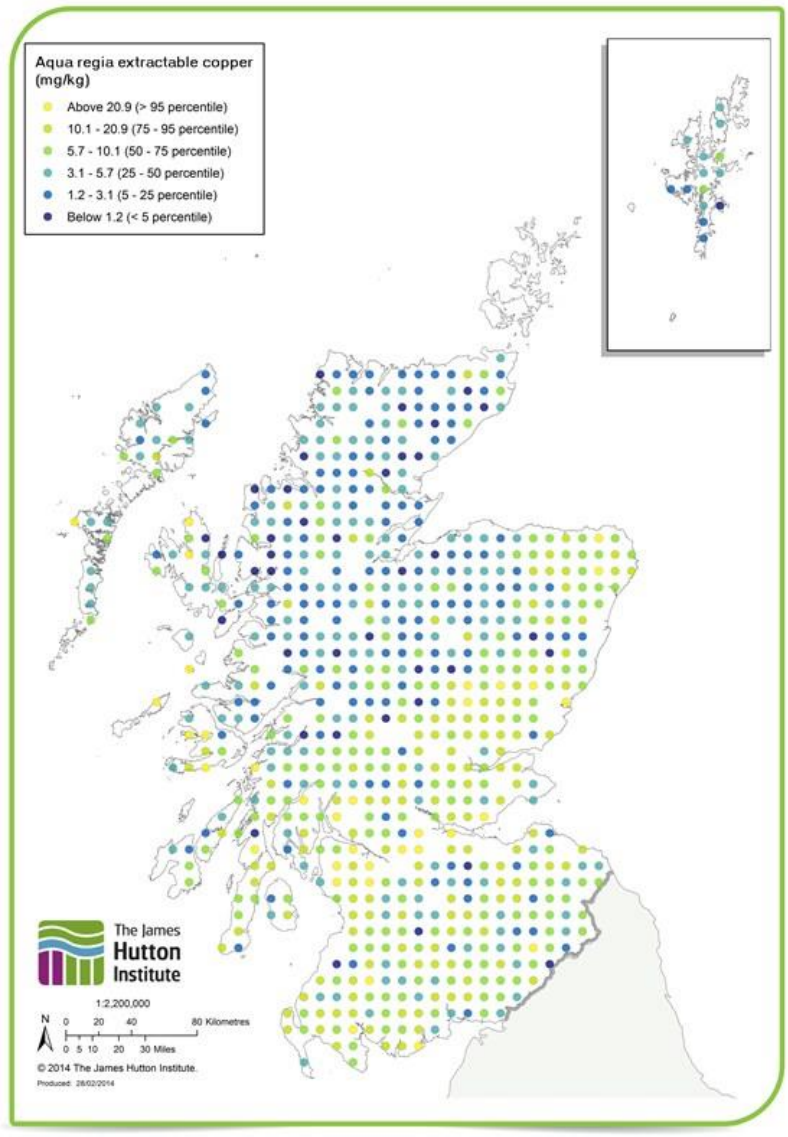

Figure 6: Copper concentrations in soils across Scotland, as determined from the James Hutton Institute (JHI) National Soil Inventory of Scotland dataset (NSIS_1). Maps supplied by JHI.

Increasingly applying organic materials (e.g. sewage sludge, animal wastes or compost) to land in order to recycle nutrients may result in gradual increases in soil metal concentrations if these materials contain metals. However, these activities are monitored to protect human health and the environment.

Organic chemicals

A wide range of organic chemicals is found in the environment. However, their concentrations in soils are not routinely measured.

The use of many long-lasting organic chemicals has declined. Results from the UK Soil and Herbage Pollutant Survey show that concentrations of polychlorinated biphenyls (PCB) in soils have declined by 800% in the last 30 years – restrictions on their production were introduced in the mid-1970s. The concentrations of dioxins in soils have also dropped by around 70% in the last 30 years. However, there are many other organic compounds used that are not being measured.

Man-made radioactive substances

Concentrations of man-made radioactive substances in soils across Scotland are generally low and trends are difficult to determine. More information can be found in the Radioactivity in Food and the Environment report.

Contaminated land

Land is defined as 'contaminated' if hazardous substances are present in concentrations that could pose a threat to human health, ecosystems or water bodies. What level is considered acceptable depends on the land use and soil type. More information can be found in the Dealing with land contamination in Scotland report.

Soil biodiversity

Soil biodiversity is the variety of all living organisms found within soil.

Although the amount of data and knowledge on soil biodiversity in Scotland has increased considerably in recent years, it is still not yet possible to assess the current 'state', and it is impossible to comment on historical trends. The resurvey of the National Soils Inventory of Scotland indicates that microbial diversity varies significantly with different soil types and land uses. You can find more information about soil biodiversity in the State of Scotland's Soil report and on Scotland's soils website.

Erosion and landslides

Soil erosion by water or wind is a natural process that can be made worse by poor land management. The consequences of soil erosion, such as the loss of fertile topsoil from fields, can damage a range of soil functions. There is no systematic assessment of soil erosion on a national scale in Scotland, so we do not know how much soil is being lost from our fields or uplands or whether it is a widespread problem or not.

It is estimated that in some arable areas of eastern Scotland, erosion rates caused by water are double natural rates.

Although less frequent and widespread, wind erosion can occasionally have severe consequences; for example, in Moray in spring 2013, when roads became blocked by wind-blown soil and had to be cleared using snowploughs.

In upland areas, it is estimated that around 35% of Scotland's peatlands show signs of erosion. This has important implications for loss of soil carbon, as well as for soil biodiversity.

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. Several roads have been blocked by these events in recent years, causing considerable disruption and expense. The most frequently blocked road has been the A83 at the Rest and Be Thankful – which was closed four times in 2012.

Predictions of more frequent and intense rainfall in the future suggest that we may see higher levels of erosion and more frequent landslides.

Compaction

Soil compaction occurs when soil is squeezed by something heavy (e.g. a tractor or a herd of cows), causing the particles that make up the soil to move closer together. This means that there is less space in the soil for water and air to move through, making it harder for plant roots to grow and find nutrients. Heavier farm machinery is likely to increase soil compaction in Scotland.

A number of small-scale studies elsewhere in the UK have found local increases, but there has been no systematic study of the national extent or severity of soil compaction in Scotland. Therefore, it is not possible to provide figures showing the current state or trend.

Sealed soils

The land surface is said to be sealed when it is covered by an impermeable material, such as tarmac.

There is no systematic collection of data on 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 land, but not all 'urban' land is sealed – we still have greenspace, such as gardens and parks, in our urban areas.

Based on best estimates, about 1,200 hectares of land is sealed every year (approximately 0.02% of Scotland).

Pressures affecting soils

Soils are damaged by a variety of processes caused by a range of pressures. These pressures result from a number of global drivers which include:

- more demand for food;
- the need to ensure the availability and supply of food;
- population change;
- climate change.

Pressures on our soils can be grouped into two key areas.

1. Those caused by climate change.
2. Those caused by changes in land use and land-management practices.

Pressures caused by climate change

Climate change is potentially the greatest pressure on our soils, as the climate is one of the main factors affecting soil formation. The climate also affects a range of processes occurring in soils because it influences how wet the soil is, how warm the soil is and rainfall patterns. Therefore, a significant change in Scotland's climate could have a major effect on the benefits our soils provide.

A change in climate may lead to:

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

Pressures caused by changes in land use and land-management practices

These pressures include:

- development (e.g. building new houses and roads);
- 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 (i.e. more animals on farms).

These pressures can directly influence the state of our soil by changing its properties. For example, urban expansion leads to more soil being sealed, meaning rain cannot drain away slowly through the soil and instead may flow over land directly into rivers, potentially leading to more flooding and water pollution.

It is important to remember that because soils can carry out more than one function at a time, some of the pressures, while damaging one soil function, could at the same time improve another soil function. For example, applying fertiliser to soil can increase GHG emissions and pollute watercourses; however, it will almost certainly result in increased plant growth and greater crop yields.

What is being done

There is increasing recognition that soils require protection in the same way that air and water do, and policy developments are beginning to reflect this. There are a number of practical soil-management options that, if implemented, will not only protect our soils but also protect the wider environment.

Policy and legislation

Soil protection

In Scotland and the wider European Union, soil has not been given the same level of protection as the water and air. In 2006, the European Commission published a Thematic Strategy for Soil Protection and proposed a Soil Framework Directive, similar to the Water Framework Directive. However, it has not been possible to reach agreement on this and in April 2014 the Commission decided to withdraw the proposal. The Commission remains committed to protecting soil and will look at the best ways to do this.

Scotland, however, has gone ahead and published two main policies/strategies with soil protection at their core. The first of these is the Scottish Soil Framework, which was published in 2009 to co-ordinate existing policies that relate to soils. A number of actions to help protect soils and encourage sustainable soil management were also agreed. Progress made under the Scottish Soil Framework up to December 2013 has included publication of the State of Scotland's Soil report, the Scotland's soils website and the soil monitoring action plan (Soil MAP). These initiatives provide the best evidence of the state of Scotland's soils, increasing access to the data that this evidence is based on, increasing soil awareness and starting to meet the requirement for new data.

The second main response is the land use strategy, published in 2011 as part of the Climate Change (Scotland) Act 2009. The management and protection of carbon-rich soils to reduce the effects of climate change is a key element of the land use strategy. These are some of the proposals in the strategy that can help protect soils.

- **Identifying which land is best for woodland planting.** Planting trees on peat soil may result in more carbon being lost from the soils than the amount of carbon likely to be stored in the trees and vegetation. Therefore, proposals for new woodland creation are not approved by Forestry Commission Scotland if they include the planting of trees on deep peat (more than 50 cm in depth).
- **Improve understanding of the benefits that may be obtained from peatland restoration.** In October 2012 the Scottish Government launched the Green Stimulus Peatland Restoration Project. This sets out to reduce the amount of carbon released into the atmosphere by helping to restore degraded peatlands. As well as preventing more carbon from being released, and increasing the amount of carbon taken out of the atmosphere by peatland vegetation, restoring peatlands can help to increase biodiversity, improve water quality and reduce the impact of flooding.

There are a number of other policies that relate to soil protection from a range of different sectors – agriculture, waste management and planning, for example. These are listed in full in the Scottish Soil Framework.

Environmental protection

There are a number of practical management options that land managers can adopt to help protect the environment, and indeed they are increasingly obliged to do so. The Farming for a Better Climate initiative provides practical support to farmers and land managers to help reduce GHG emissions and adapt to a changing climate. Most of our nitrous oxide emissions (an important GHG) come from fertilised agricultural soils. The Farming for a Better Climate initiative aims to help farmers reduce GHG emissions by using nitrogen fertiliser more efficiently. As well as reducing GHG emissions, this can help prevent nitrogen pollution of watercourses.

The Farm Soils Plan recognises the role that soils play in day-to-day farm management and the key problems that can damage soils. It provides practical advice about how to repair damaged soil and how to avoid damage in the first place. The PEPFAA (Prevention of Environmental Pollution From Agricultural Activity) Code has a section on soil protection and sustainability, which offers similar advice.

SEPA has produced a number of guidance documents for sustainable soil management; for example, about how to reduce the risk of diffuse pollution. These are often linked directly to specific parts of the legislation, and practical steps are offered to help farmers adhere to them. Scottish Natural Heritage has also produced a range of guidance documents, with an emphasis on upland semi-natural soils. The Forestry Commission has produced guidelines on forests and soil that support the UK Forestry Standard.