# Chapter 6:
# Soil

# Soil

## 1. Introduction

While we might not immediately think of soils when we think of nature, soils are the Earth's largest habitat. They are essential for life: they support terrestrial plant life used as food by humans and animals. Soil health is vital to biodiversity, plant growth and food production, climate control and water quality regulation. The value of soils is not limited to supporting plant growth: they also provide a wide range of essential services (Baer and Birgé, 2018; Smith *et al.*, 2021). Maintaining soil health is essential to enable soils to continue to supply the important services they provide (Figure 6.1).

> "Too few know that the thin layer that lies below our feet holds our future. Soil and the multitude of organisms that live in it provide us with food, biomass and fibres, raw materials, regulate the water, carbon and nutrient cycles and make life on land possible. It takes thousands of years to produce a few centimetres of this magic carpet."
>
> **EU Soil Strategy for 2030 (EC, 2021a)**

**Figure 6.1** Soil services

**Climate and air quality regulation**
Soils hold the largest terrestrial carbon stocks and are an important carbon sink. Carbon storage as soil organic carbon is important as a carbon sink. Soils can be a source of greenhouse gases (GHGs) such as carbon dioxide, methane and nitrous oxide.

**Regulation of water flow and quality**
Healthy soil can help regulate the water cycle (Keesstra et al, 2021). "Green" water is the water that is available in soil for plants. "Blue" water is the water available in groundwater and in surface water bodies like rivers and lakes. This water is replenished by infiltration through soils. If plant cover is low, or the soil structure is insufficiently able to cope with rainfall, then water can run off leading to flooding, loss of soil nutrients (which can impact water quality) and soil erosion (Keesstra et al, 2021). Healthy soils can play an important role in regulating floods and droughts (Saco et al, 2021).

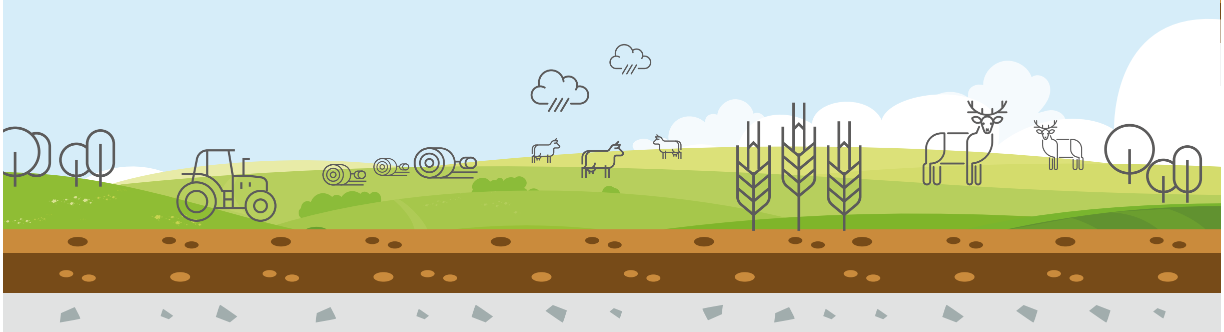
**Soils & human health**
There is evidence that exposure to soil micro-organisms can lessen the prevalence of allergies and atopic health conditions like asthma (Thiele-Bruhn, 2021). Micro-organisms in soil can be used to produce antibiotics (Waksman, 2010).

**Support for terrestrial ecosystems**
As well as providing a habitat for life below ground, soils impact on habitats above ground by influencing the diversity of plants that grow and the fauna that depend on the plant life. Soil life has a complex interaction with plant life, which in turn drives the formation of soil in the long term (De Deyn Gerlinde and Kooistra, 2021).

**Supply of food, fuel and material**
Soil is essential for plant growth, which is essential for food and raw materials (Baer & Birge, 2018).

**Nutrient cycling**
Nitrogen (N) and Phosphorus (P) are two of the main sources of water pollution in Ireland (EPA, 2023a). Soil biota can remove N from the ecosystem. Levels of P in rivers can be abated by the strategic use of wetlands (Baer & Birge, 2018).

**Soil as a habitat**
Soils are the largest habitat, being home to the majority of all living species on Earth (Thiele-Bruhn, 2021). Soil contains an abundance of bacteria, fungi, insects, isopods, earthworms, spiders, centipedes, millipedes and other invertebrates. While soil is an ecosystem in its own right, this ecosystem is vital to plant health and agricultural production (Baer & Birge, 2018).



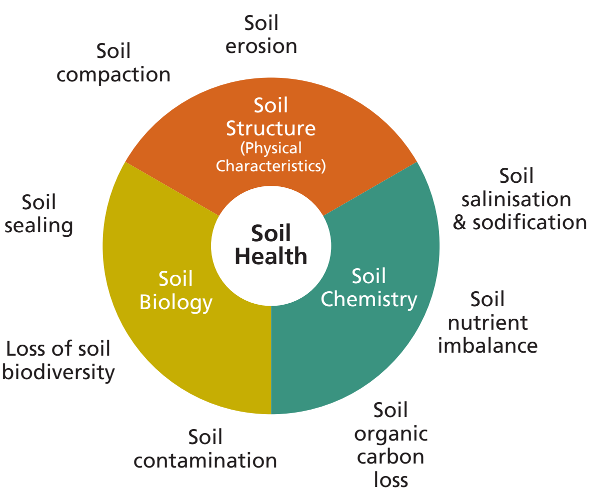
## 2. Soil health and global threats to soil health

Soil health is defined as the continued capacity of soil to function as a vital living ecosystem that sustains plants, animals and humans (Lehman *et al.*, 2020). A healthy soil has good biological, chemical and physical (structural) properties. Healthy soils are better able to support the functions and services outlined in Figure 6.1. They take many years to form, so protecting their health is of vital importance to ecosystems and food systems. Soil health is protected by ensuring that soil chemistry is in the right balance, maintaining soil structure and integrity, and safeguarding the soil biome.

Healthy soils support climate action. Soil can act as a carbon sink to mitigate climate change, and healthy soils have better water retention capacity for withstanding droughts or helping with flood management during extreme rainfall and flooding events.

Soils are essential for food security: 95% of our food is directly or indirectly produced on soils. Healthy soils are essential for supporting high yields of nutritious food. The European Commission estimates that soil degradation is costing the European Union (EU) tens of billions of euros every year. A United Nations' (UN) assessment identified global threats to soil health (UNCCD, 2017) (Figure 6.2).

**Figure 6.2** Soil health and threats to soil health



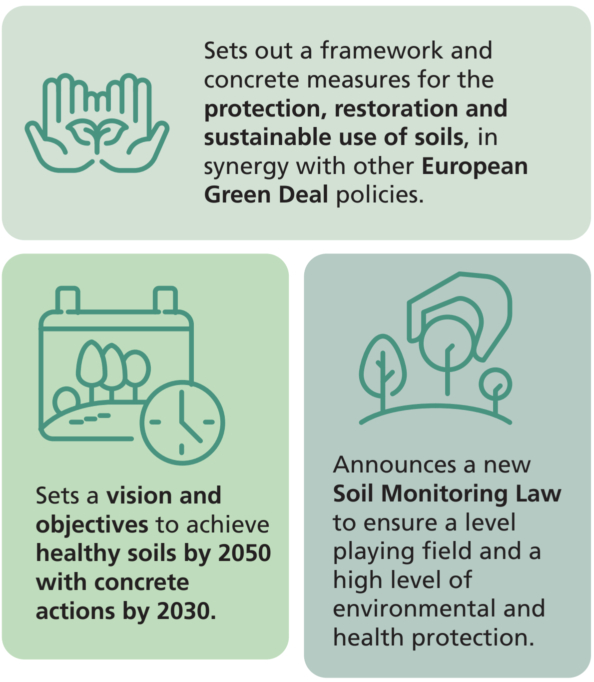

Source: Adapted from UNCCD, 2017

## 3. EU Soil Strategy

Research on the links between soil health, plant diversity, terrestrial ecosystems and carbon sequestration shows that protecting soil health delivers benefits to the whole ecosystem, to food security and to climate action.

The EU Soil Strategy for 2030 (EC, 2021a) sets out a vision to achieve healthy soils by 2050. The strategy follows a European Environment Agency (EEA) conclusion in 2019 that the lack of a comprehensive policy framework to protect land and soil would limit European environmental and sustainability objectives. A review identified that, while soil-relevant EU policy spans many themes, it does not include specific overarching soil legislation (EI, 2017). Adopted in 2021, the EU Soil Strategy seeks to address the lack of a legal framework for the protection of soils and to provide soils with legal protection similar to that of water, air and the marine environment (Figure 6.3). A pillar of the EU Soil Strategy is to provide a legal framework through the development of a soil monitoring law. A proposal for an EU soil monitoring law was published in 2023 and is being reviewed by the European Parliament in 2024.

**Figure 6.3** What the EU Soil Strategy sets out




Source: Adapted from EC, 2021b

Achieving all the goals and objectives of the EU Soil Strategy depends on full implementation of other related EU initiatives, as outlined in Table 6.1.

**Table 6.1** EU Soil Strategy objectives

| MEDIUM-TERM OBJECTIVES (2030) | RELATED EU INITIATIVE |
|---|---|
| Restore significant areas of degraded and carbon-rich ecosystems, including soils | EU Biodiversity Strategy for 2030[a] |
| Make significant progress in the remediation of contaminated sites | EU Biodiversity Strategy for 2030[a] |
| Achieve an EU net greenhouse gas removal of 310 million tonnes of carbon dioxide equivalent per year for the land use, land use change and forestry (LULUCF) sector | Proposal for a revision of the LULUCF Regulation[b] |
| Reach good ecological and chemical status in surface waters and good chemical and quantitative status in groundwater by 2027 | Water Framework Directive[c] |
| Reduce nutrient losses by at least 50%, the overall use and risk of chemical pesticides by 50%, and the use of more hazardous pesticides by 50% by 2030 | EU Farm to Fork Strategy[d] |

| LONG-TERM OBJECTIVES (2050) | RELATED EU INITIATIVE |
|---|---|
| Reach no net land take | Roadmap to a Resource Efficient Europe[e] and the Eighth Environment Action Programme[f] |
| Soil pollution should be reduced to levels no longer considered harmful to human health and natural ecosystems and should be within the boundaries our planet can cope with, thus creating a non-toxic environment | Pathway to a Healthy Planet for All, EU Action Plan: 'Towards Zero Pollution for Air, Water and Soil'[g] |
| Achieve a climate-neutral Europe and, as the first step, aim to achieve land-based climate neutrality in the EU by 2035 | European Climate Law Regulation[h] and Proposal for a revision of the LULUCF Regulation |
| Achieve a climate-resilient society for the EU, fully adapted to the unavoidable impacts of climate change by 2050 | EU Adaptation Strategy[i] |

Source: Adapted from EC, 2021a

a EU Biodiversity Strategy for 2030 (COM(2020) 380).

b Proposal for a revision of the LULUCF Regulation (COM(2021) 554).

c Water Framework Directive (2000/60/EC).

d EU Farm to Fork Strategy (COM(2020) 381).

e Roadmap to a Resource Efficient Europe (COM(2011) 571).

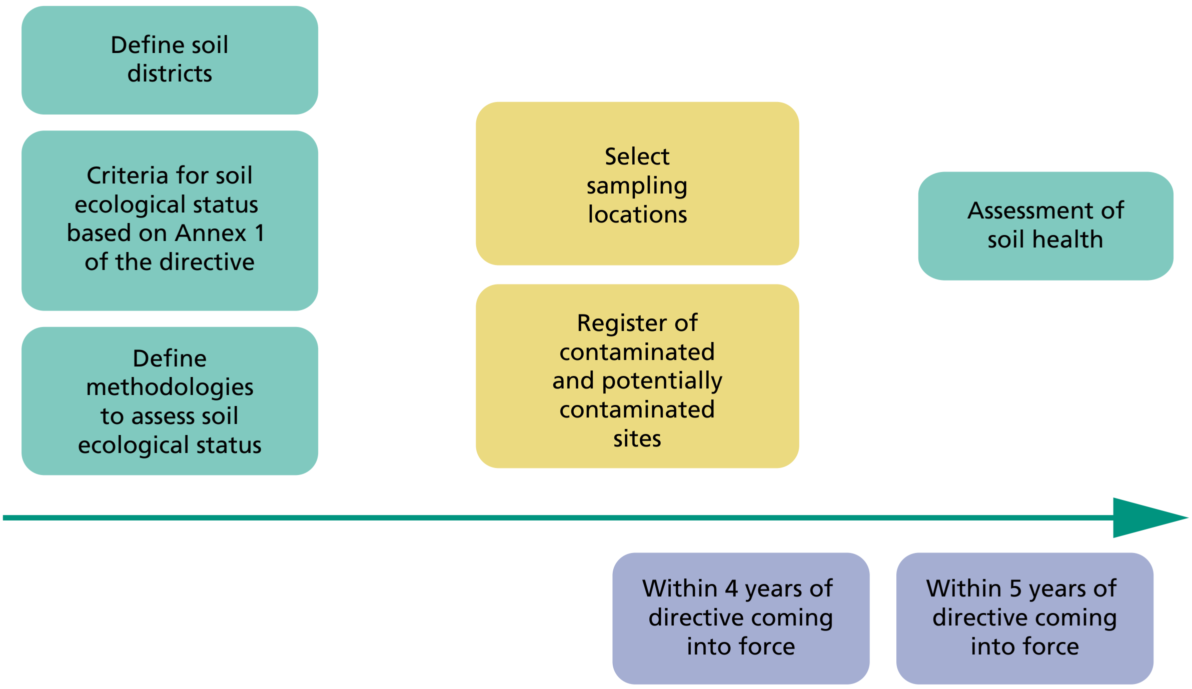
f Eighth Environment Action Programme (Decision No 1386/2013/EU).

g EU Action Plan: Towards Zero Pollution for Air, Water and Soil (COM(2021) 400).

h European Climate Law Regulation ((EU) 2021/1119).

i EU Adaptation Strategy (COM(2021) 82).

**Figure 6.4** Proposed soil monitoring law




Source: Adapted from EC, 2023a

The current proposal for an EU soil monitoring law (EC, 2023a) is a response to scientific evidence that 60-70% of EU soils are in an unhealthy state and that pressure on land and soil is increasing soil sealing.[1] The proposal will require EU Member States to establish a framework for monitoring soil health (Figure 6.4).

Under the proposed soil monitoring law (EC, 2023b), Member States will be required to identify soil districts and define criteria for soil ecological status and the methodologies to assess them. The annexes of the proposed directive set out the soil health criteria that can be taken into consideration. Member States will be required to assess soil health at selected sampling locations within 5 years of the directive coming into force, and then every 5 years after that. Soil will be considered healthy if it achieves good or high ecological status.

To work towards an aspirational goal of achieving no net land take by 2050, soil sealing and soil destruction are to be managed as the first and most impactful step. A register of contaminated and potentially contaminated sites must be created.

An obligation to include soil restoration in the proposed soil monitoring law was considered but not included. The European Commission will analyse the requirements to restore unhealthy soils by 2050. This assessment will take place 6 years after the proposed law comes into force and will be informed by the information collected by Member States in their implementation of the law.

## 4. Status of soils in Ireland

Ireland's soil types are variable. They are influenced by Ireland's geology and terrain (slope), rainfall, drainage, vegetation types, land use and climate, which includes the influence of past glaciation. Gley and peat soils are characterised as having poor drainage. Podzols and brown podzolic soils are found where there is moderate drainage and the soil forms distinct horizons (layers) created by minerals and nutrients leaching at different rates. Brown earth soils (Figure 6.5) are relatively young soils formed where dense vegetation has resulted in decaying leaves (humus), which is mixed with soil organisms, giving the soil a brown colour and less distinctive horizons.

1 Soil sealing is the process whereby ground is covered with impermeable materials (such as asphalt and concrete) for residential or commercial buildings or infrastructure such as roads, rail and piers, rendering it impervious to water.

**Figure 6.5** Brown earth soil type

Source: Teagasc Irish Soil Information System

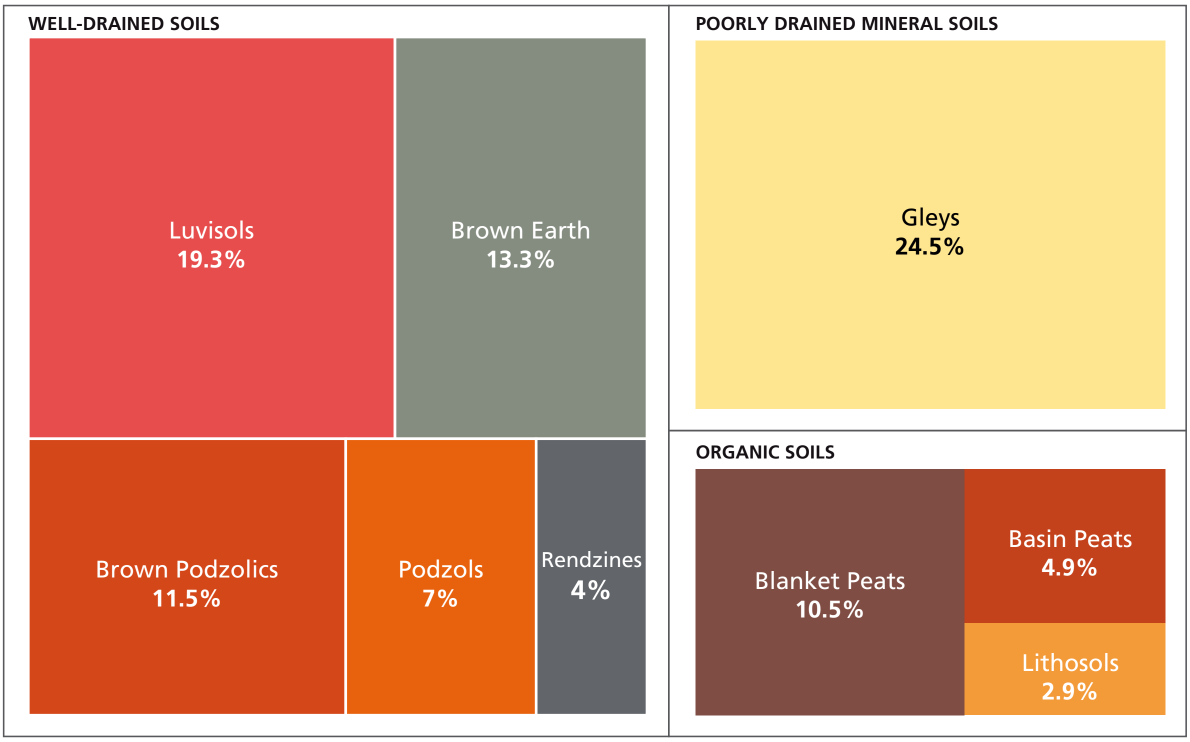
Ireland's Soil Information System classifies soils using a hierarchical grouping. Figure 6.6 shows Ireland's great soil groups. Well- and moderately drained soils (podzolics, brown earths, podzols and rendzinas) make up 55% of Ireland's soils. Poorly drained mineral soils (gleys) make up 24.5% and organic soils (peats and lithosols) make up 18%. Urban areas and water make up the rest of Ireland's soil area but are not included in Figure 6.6.

A review of Irish soil research and data from 2013 to 2021 identified major gaps in our knowledge of Ireland's soils (McNamara *et al.*, 2022). It found that current research was biased towards the collection of data on soil pH and nitrogen content and that agricultural soils were studied more than urban or contaminated soils. It concluded that soil knowledge in Ireland is not well aligned to EU or national priorities.

## Irish soils and the proposed EU soil monitoring law

Annex 1 of the proposed EU soil monitoring law (EC, 2023b) sets out soil health descriptors and criteria for healthy soil condition under specified aspects of soil degradation (summarised in Table 6.2).

**Figure 6.6** Ireland's soil groups, graphed by total area




Source: Adapted from Teagasc, 2020a

Table 6.2 Soil health descriptors in Annex 1 of the proposed EU soil monitoring law

| |
|---|
| **Part A: Soil descriptors with criteria for healthy soil condition established at the EU level** |
| Salinisation |
| Soil Erosion |
| Loss of organic soil carbon |
| Subsoil compaction |
| **Part B: Soil descriptors with criteria for healthy soil condition established at the Member State level** |
| Excess nutrient content in soil |
| Soil contamination |
| Reduction of soil capacity to retain water |
| **Part C: Soil descriptors without criteria** |
| Excess nutrient content in soil (nitrates) |
| Acidification (soil acidity in pH) |
| Topsoil compaction |
| Loss of soil biodiversity |
| **Part D: Land take and soil sealing indicators** |
| Land take and soil sealing<br>The indicators (in $km^2$ and as a percentage of the Member State's land surface area) are:<br>▪ total artificial land<br>▪ soil sealing<br>▪ land take, reverse land take and net land take[a]<br>▪ additional optional indicators such as land fragmentation, land recycling rate, land taken for commercial, logistics and energy use, and the consequences of land take, such as effects on ecosystems or flooding intensity |

Source: EC, 2023b

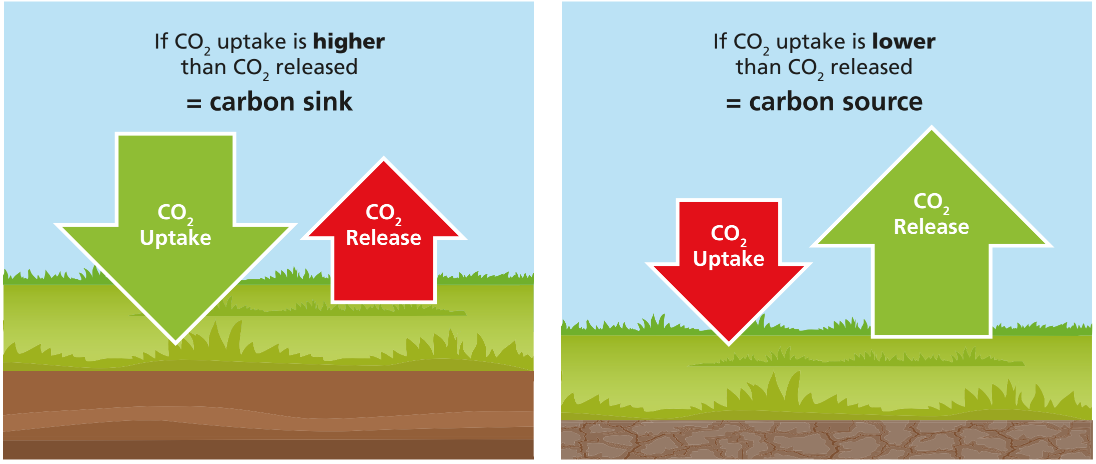
[a] where 'reverse land take' means the conversion of artificial land into natural or semi-natural land and 'net land take' means the result of land take minus reverse land take.

The four parts of Annex 1 are discussed in the following section, based on data from Irish studies or indicative (modelled) data from the EU Soil Observatory (EUSO, 2023). The criteria are presented only for general guidance to indicate whether the soil condition is likely to be of concern. They are not based on detailed, local assessments, which will be a requirement under the proposed soil monitoring law.

## Part A indicators: criteria set at EU level

***Salinisation.*** This is the accumulation of soluble salts such as sodium, magnesium and copper at a level that affects soil health. Salinisation is not a prevalent issue in Ireland. It affects southern European soils in the Iberian Peninsula and Mediterranean coastal areas (EC, 2008).

**Figure 6.7** Schematic of carbon sources and sinks




Source: Adapted from Teagasc, 2020b

***Soil erosion.*** The EU Soil Observatory identifies four drivers of soil erosion: water, wind, harvest and tillage. Of these four, tillage erosion and water erosion are the two most prevalent in Ireland, based on the EU Soil Observatory model, with wind erosion confined to small coastal areas. Harvest erosion occurs when soil that adheres to crops or rock fragments is removed during harvesting; it is more prevalent during the harvesting of root and tuber crops than other crops. Harvest erosion is lower in Ireland than in other EU Member States, as our land use for crops is relatively low (Ireland's agricultural land use is predominantly grassland).

Tillage erosion occurs in the east, south-east and south where tillage activity is more widespread. The EU Soil Observatory model has identified greater potential for water erosion in areas of higher altitude (including uplands in Wicklow, Cork, Kerry, Galway and Donegal). Soil loss by water erosion in Europe is expected to increase as climatic conditions change. An assessment of different land use and climate change scenarios predicts an increase in soil erosion but at relatively lower rates in northern European countries such as Ireland than in southern Europe (Panagos *et al.*, 2021).

***Loss of soil organic carbon.*** Soil organic carbon improves soil productivity and water retention and acts as an important carbon sink. Teagasc research shows that clay soils have a higher carbon sequestration capacity; however, ploughing can increase carbon loss and, in a dry year, soils can switch from being carbon sinks to sources of carbon emissions (Figure 6.7). Soil organic carbon is affected by soil management regimes, fertilisation and animal stocking rates (Teagasc, 2020).

Grasslands on mineral soil can be a carbon sink and grasslands on drained peat soils are a substantial carbon source (Teagasc, 2020).

Soil organic carbon stocks are influenced by short-term changes between cropland and grassland and by soil disturbances. The Environmental Protection Agency (EPA)-funded Soil Organic Carbon and Land Use Management (SOLUM) project examined methods for accurately measuring soil organic carbon in Ireland (Saunders *et al.*, 2022). The EU Soil Observatory has identified peatlands in Europe that are within a fixed radius of croplands to ascertain the risk of peatland degradation. This model identified 62% of Ireland's peatlands at risk of degradation. Corine (Coordination of Information on the Environment) Land Cover data, while coarser in resolution, offers longer term trend information and indicates that Ireland's peatlands decreased by 22% between 1990 and 2018. This figure does not account for peatlands lost before 1990, or since the establishment of the Bog Commission in the early 1800s. Further research, the RePeat project,[2] is mapping the extent of peatlands using Bog Commission maps and advanced geospatial and Earth observation techniques.

Peatlands are unique ecosystems and can sequester large amounts of carbon dioxide, so they are an important element of Ireland's climate mitigation efforts (Figure 6.8). Peatland degradation is a result of peat extraction for energy and horticultural use and of drainage for agricultural, forestry or settlement use.

2 sites.google.com/view/project-repeat/home

**Figure 6.8** Irish peat bog

Credit: Mark McCorry, Bord na Móna

## Part B indicators: criteria set at Member State level

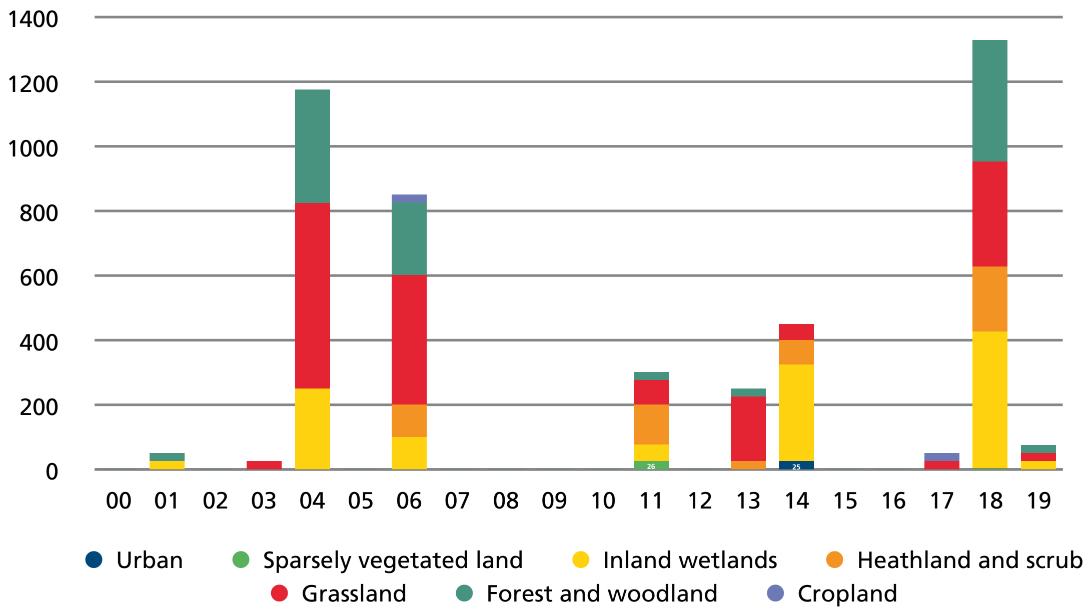
***Excess nutrient content in soil.*** Phosphorus is essential for plant health. Excess phosphorus in soils affects water quality (see Chapter 8) and contributes to biodiversity decline and human health risks. The EU Soil Observatory model maps lands where the phosphorus surplus exceeds the threshold used by many European countries to define phosphorus excess (50 mg/kg). Teagasc sampling programmes have identified that 63% of Ireland's soil is deficient in soil phosphorus (O'Donnell *et al.*, 2021). This results in a high dependency on fertiliser application in Ireland.

Between 12% and 20% of the country's soils have sufficient or excess phosphorus (O'Donnell *et al.*, 2021); this is consistent with the modelled values for phosphorus excess from the EU Soil Observatory. Excess phosphorus is a greater issue in agricultural soils with poor drainage and is detrimental to the ecological health of rivers and lakes (EPA, 2022).

***Soil contamination.*** The proposed soil monitoring law will require Member States to create a register of contaminated and potentially contaminated sites. While there is no register of contaminated soils or sites in Ireland, data sources exist that could be used to inform such a register. For example, historical mine sites were assessed in 2009 by Geological Survey Ireland and the EPA. The EPA also maintains a register of data from local authorities on closed, unregulated landfills (sites that operated in a local authority area without a waste licence between July 1977 and March 1997). The EPA also reports to the European Chemicals Agency on the implementation of the Persistent Organic Pollutants (POPs) Regulation (S.I. No. 146/2020); this includes sites contaminated with POPs.[3] Furthermore, the EU Soil Observatory used data from the Land Use and Coverage Area Frame Survey (LUCAS) to model potential soil pollution from copper, mercury and zinc and has identified areas that are above their proposed safe thresholds for mercury and/or zinc.

3 echa.europa.eu/documents/10162/16596982/report_pops_ie_en.pdf/f31f7f36-fa84-d599-6cd6-7f65b9aaf9cd?t=1667378478475

**Figure 6.9** Area of soil moisture deficit by year (km²), per tier 1 land cover in Ireland




Source: EEA, 2021b

***Reduction of soil capacity to retain water.*** The ability of soil to retain adequate water is essential for plant growth. The EEA's Copernicus service tracks soil moisture over time to detect and monitor agricultural droughts (EEA, 2021a). For the 2000-2019 period, Europe had a long-term soil moisture deficit. During that period, Ireland's overall soil moisture profile showed a slight surplus rather than a deficit in soil moisture (Figure 6.9). The data for Ireland indicate the close relationship between drought and soil moisture deficit; the years that Ireland experienced drought conditions (such as 2004, 2006 and 2018) are clearly identifiable in their effects on soil moisture deficit (DAFM and DECC, 2023). Soil water retention is important in lessening the impact of flooding, particularly where it is because of extreme rainfall.

## Part C indicators: descriptors without criteria

***Excess nutrient content in soil (nitrates).*** While nitrogen is essential for plant growth, excessive nitrates in soil cause water pollution (see Chapter 8), have negative implications for human health and contribute to greenhouse gas emissions.

The EU Soil Observatory used agricultural data and a European biogeochemical model framework to identify agricultural land areas where nitrogen surplus exceeds 50 kg/ha per year. Ireland has the third highest value in Europe (at 80%) of agricultural land above the 50 kg/ha per year threshold. Nitrates can leach from soil into water; this is a greater issue in free-draining soils in the south-east where it causes a problem for water quality in estuaries along the southern seaboard (EPA, 2022). Soil acidification can be accelerated by the application of ammonium-based fertilisers.

***Topsoil compaction.*** Compaction is a decrease in soil porosity or volume due to stress from machinery or animal traffic, which compromises the capacity of soil to hold air or water. It represents one of main soils threats in Ireland. The Teagasc Soil Quality Assessment Research Project (SQUARE) examined soil health indicators (physical, chemical and biological) for Irish grassland soils (Bondi *et al.*, 2019). Among the array of physical indicators measured, soil structure emerges as a pivotal factor supporting all other soil functions. The deterioration in soil structural quality, leading to soil degradation and compaction, is frequently the outcome of intensive management practices (Bondi *et al.*, 2021). This can result in water's diminished ability to permeate and drain through the soil, hampering water storage and purification in the landscape.

Bondi *et al.* (2019) found that Irish grassland soils were generally healthy but that some soils were better at delivering soil functions than others. Well- and moderately drained soils such as brown earth and podzolic soils could support agricultural production but do not have the same capacity as poorly drained soils to store carbon or contribute to water purification. Poorly drained soils, such as gleys, are not as productive as well-drained soils. While poorly drained soils can store more carbon and support a more active soil microbiome, they are more susceptible to structural degradation in the form of compaction.

For Irish soils, Bondi *et al.* (2021) developed a soil trafficking intensity index that considers the effect of geo-climatic variability or differences in drainage classes on soil compaction risk.[4] In general, poorly drained sites were more vulnerable to machinery trafficking than grazing trafficking pressure, being more prone to damage. At a national scale, this index can be used to identify soils at risk of compaction and to underpin targeted management advice for supporting sustainable grassland production.

***Acidification (soil acidity in pH).*** Chemical indicators yield substantial information on nutrient cycling, primary production and carbon sequestration functions in soils. Notably, soil pH and soil organic matter have been recognised as key elements in regulating nutrient availability in soils and influencing various soil functions, including carbon sequestration and nutrient cycling.

***Loss of soil biodiversity.*** Soil biology is often referred to as the 'engine of the soil', with soil biodiversity and the soil microbiome positioned at the core of soil functioning. Biological indicators provide insights into the impact of past and current management practices on soil health. For instance, the abundance and presence of earthworms serve as practical and easily recognisable soil health indicators (Figure 6.10). Nevertheless, a considerable portion of soil biology necessitates more advanced analysis, which may not always be feasible for routine in-field soil health assessments.

**Figure 6.10** Photo of soil biodiversity (earthworm)

Credit: Olaf Schmidt, UCD

The soil biome is an ecosystem and provides essential services to support soil formation, soil structure and plant growth. The EU Soil Observatory modelled a set of 13 factors, such as habitat fragmentation, land use change, soil pollution and soil sealing, that negatively affect soil biological functions. The model differentiates between soils that have a higher than moderate risk of loss of soil biological functions. The assessment identified that 36.73% of the EU's soil area has potential threats to its biological functions that are moderate or worse than moderate. Two-thirds of Ireland's soil area falls within these categories (62.98%). The EU Soil Observatory assessment is based on modelled data. A national assessment to understand the status of Ireland's soil biome would be important to validate this assessment.

Intensive exploitation and soil organic matter decline are the highest potential threats to soil biodiversity in the EU (Orgiazzi *et al.*, 2016). Agricultural practices with high levels of mechanisation and use of pesticides strongly affect soil biodiversity. To counteract such threats, Orgiazzi *et al.* (2016) recommend that agri-environmental schemes include measures to protect and enhance soil biodiversity. The EU Soil Observatory assessment also identifies soil areas under threat within protected area boundaries; Orgiazzi *et al.* (2016) recommend considering soil biodiversity as a criterion for protected area designation and planning.

Further research highlights the links between farming practices, soil biodiversity health and terrestrial ecosystem health. The research suggests a strong link between pesticide and fertiliser use and declines in bird populations across Europe (Rigal *et al.*, 2023). This is attributed in part to the known impact of pesticide use on invertebrates, a crucial food source for many birds.

Such assessment of soil organisms is an important part of measuring soil health, but these data are currently sparse in both the EU (Orgiazzi *et al.*, 2016) and Ireland (Bondi *et al.*, 2019). Given the importance of the soil biome, and the impact of soil biological functions on plant growth and terrestrial ecosystems, measures to collect data and to protect soil biodiversity functions against potential threats should be prioritised (Orgiazzi *et al.*, 2016).

The ability of soils to absorb and sequester carbon has a relationship with plant diversity. Studies of agriculturally degraded and abandoned lands found that the carbon sequestration rate was greatly enhanced when the plant diversity of these lands was restored (Yang *et al.*, 2019).

4 The index can detect changes in direct indicators of soil structural quality, such as bulk density, total porosity, water holding capacity, water conductivity and visual soil appearance, but also indirect indicators, such as soil carbon content, earthworm abundance and microbial biomass.

### Part D indicators: land take and soil sealing

Soil sealing is the result of creating impervious surfaces for residential and commercial buildings and for infrastructure such as roads, rail and piers. The new national landcover map of Ireland indicates that 4% of Ireland's soil is sealed. Longer term data from Corine Land Cover, although less detailed, show that soil sealing has doubled since 1990.

In Ireland, the creation of sealed soils has occurred at the expense of agricultural land cover loss. Sealed soil is impervious to water, leading to run-off and a poor ability to help mitigate flooding. Soil sealing removes the ability of the soil biome to function, but it also impacts terrestrial biodiversity through the fragmentation of terrestrial habitats. The creation of hard surfaces, such as roads, can break habitats into smaller, unconnected parts, a process called fragmentation. This has a negative impact on access to food and on the genetic diversity of animal populations. The national biodiversity indicators rate habitat fragmentation in Ireland as 'amber' on a red-amber-green scale (NDBC, 2021).

## 5. Emerging aspects of soil health

Microplastics in soil have been identified as an emerging threat to the world's soils (FAO, 2021). They come from a variety of sources. Waste water and biosolids from waste water treatment plants are major sources (O'Kelly *et al.*, 2021; Nash *et al.*, 2023). Other sources include agricultural plastics, landfills, beach littering and urban run-off. These plastics can degrade into smaller microplastics that transfer into surface waters where the particles are absorbed by small aquatic animals and fish and their predators (Nash *et al.*, 2023).

Research has examined the impact of microplastics on soil, soil fauna and plant growth. They have been found to affect soil chemistry, as they are carriers of heavy metals (O'Kelly *et al.*, 2021). Microplastics also have an impact on soil structure, which can change water dynamics (de Souza Machado *et al.*, 2018) and the enzyme activities of soil microbes (Yang *et al.*, 2021) and soil invertebrates (Huerta Lwanga *et al.*, 2016). Earthworms exposed to different concentrations of microplastics show lower growth rates and higher mortality rates in higher concentrations of microplastics (Huerta Lwanga *et al.*, 2016). This has implications for soil, as earthworms have a beneficial impact on its structure and aeration. Research into the effects of microplastics on soil ecosystems discovered reduced shoot height, changes in root structure, alterations in leaf composition and other impacts on plant growth, including lower seed germination rates, (Boots *et al.*, 2019; de Souza Machado *et al.*, 2019). The effects on plant growth were due to chemicals in the microplastics and their impact on soil structure and chemistry.

## 6. Conclusions

Given the many vital services that we depend on our soils to deliver, from supporting food production and water purification to supporting ecosystems and production of raw materials, we have everything to gain from safeguarding the health of Ireland's soils. Soil health is complex: it depends on the physical, chemical and biological attributes of soil.

Unlike air and water, soil does not have specific overarching legislation to protect it. To address this, the EU soil monitoring law, proposed in July 2023, sets out indicators for soil health that Member States can use to assess soils and identify areas of poor soil health.

Ireland's primary source of soil information is the Irish Soil Information System. This identifies Ireland's main soil classes. To implement the proposed soil monitoring law, Ireland will need to undertake an assessment of its soil health, using a soil sampling programme across defined soil districts. Achieving this assessment will fill evidence gaps. The kind of modelling capability illustrated by the EU Soil Observatory shows the opportunities offered by soil mapping and modelling to help us understand soil health. Ireland should take a cross-public sector approach to the advancement of soil mapping and modelling to rapidly improve our knowledge of soil health at a national level. The proposed EU law will also require the creation of a national contaminated sites register, which will be a welcome development in identifying potential hazards to human health.

Addressing the threats to Ireland's soil will have a positive impact on water quality, biodiversity and climate action as well as improving soil health. Different soil types offer different types of service and this diversity is enormously important in addressing different needs. Well-drained soils support agricultural production, whereas less productive soils can often store more carbon or support a more active soil biome. Detailed knowledge of Ireland's soils would enable the appropriate use of different soil types according to the services they are best placed to provide.

Research has improved knowledge of the factors that influence the capacity of soil to store carbon. Knowing which soils can act as carbon stores and how to manage them to maximise their organic carbon is important for climate change mitigation. Peatlands have a very high carbon storage potential, which it is crucially important to protect (Figure 6.11).

**Figure 6.11** Peat soil over lake alluvium


Source: Teagasc Irish Soil Information System

Protecting soil's ability to regulate water flow has benefits for both climate change adaptation and water quality. Limiting soil sealing means that soil's natural ability to help regulate flow in times of flood is conserved, which is vitally important in areas subject to flood risk. Ireland's soils have not generally shown a moisture content deficit, but this can change locally in times of extreme drought. Compaction has been identified as a threat to Ireland's soil health and its ability to regulate and purify water; measures to address compaction are important in protecting or restoring soil health.

Soil can help to regulate the nutrients that are available to plants and the amount of nutrients that leach into Ireland's waterways. The levels of nitrates and phosphorus in Ireland's surface waters indicate that there are excess nitrates leaching from soil and some areas where there is excess phosphorus.

The status of Ireland's soil biome is not easy to measure directly, but modelled information from the EU Soil Observatory suggests that Ireland is not unique in Europe in having many factors that threaten soil biodiversity. Given the importance of the soil biome to good soil health and to healthy terrestrial ecosystems, a national assessment to understand Ireland's soil biome is important to confirm the potential extent to which Ireland's soil biome may be under threat.

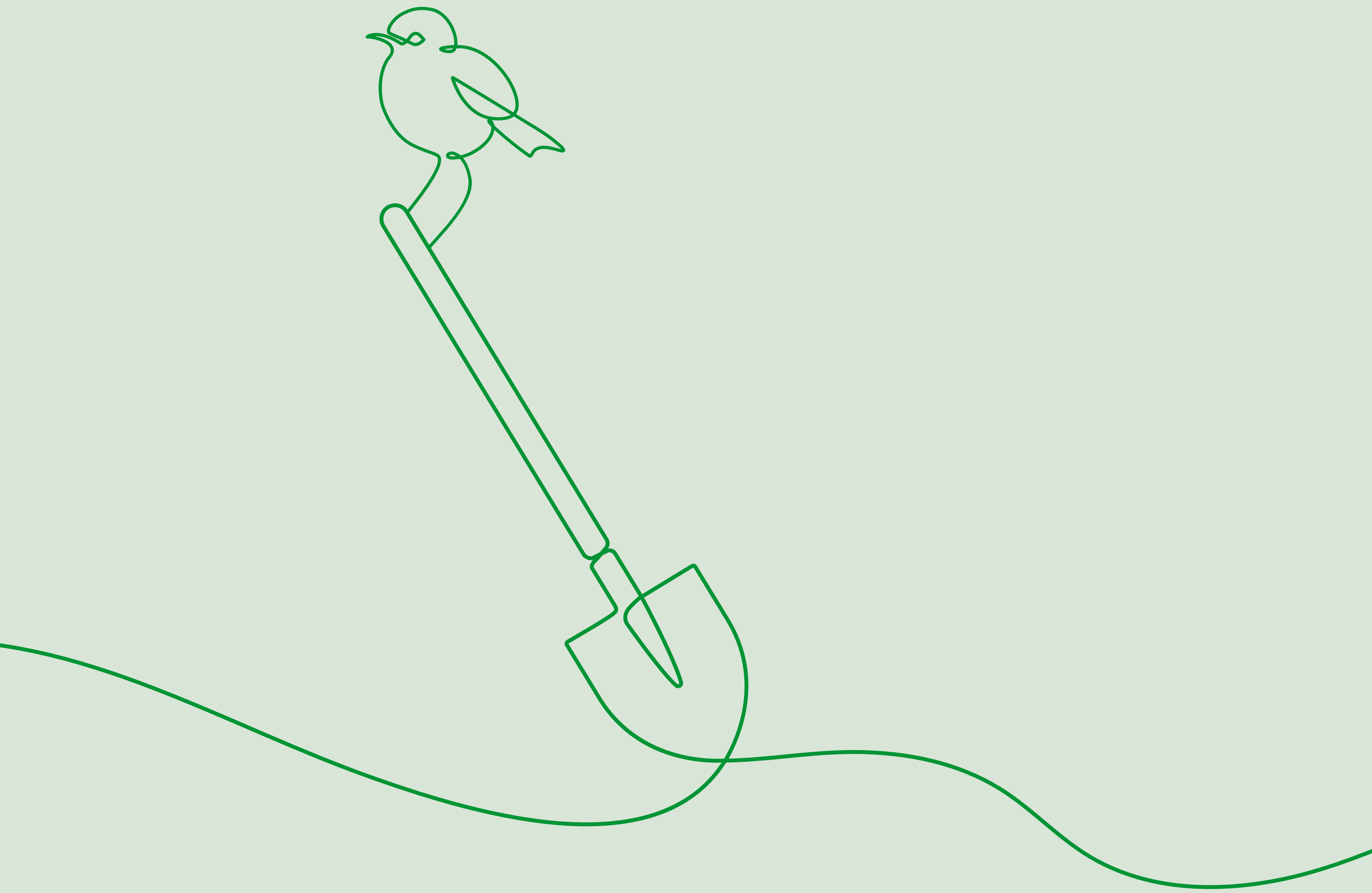
The advent of a proposed soil monitoring law and the existing EU Soil Strategy indicate that the vital importance of soil to human life and a healthy, well-functioning environment is being recognised. However, the proposed law does not include any obligations to restore unhealthy soils to full health. Given the vital impact of soil health on Ireland's agriculture and its important role in climate action, we should be ambitious in going beyond the requirements of the soil monitoring law and enact soil health restoration plans. This is an opportunity for Ireland to show leadership in soil restoration practices for the benefit of food security, ecosystems, climate action and water quality that would underscore our green credentials as a truly sustainable food producer.

## Key chapter messages

**1.** Ireland's soils play important roles in storing carbon, in regulating both water flow and water quality and in growing food and raw materials. Soils are under threat from excess nutrients, compaction, soil sealing and loss of soil biodiversity, in Ireland and across the EU. Soil health must be prioritised to ensure food security, protect the soil biome, and safeguard the important environmental services that soil provides.

**2.** The protection of soils lacked a legal and policy framework until recently and the publication of the EU Soil Strategy in 2021 and the proposed soil monitoring law in 2023 are significant. Ireland faces challenges in achieving the objectives of the EU Soil Strategy and in implementing the proposed soil monitoring law. However, getting this right would significantly advance the protection of Ireland's soil health.

**3.** To support the proposed soil monitoring law and soil health assessment, Ireland should advance soil mapping and modelling, through a cross-public sector approach, which would rapidly improve our knowledge of soil health at a national level.



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