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# Soil Status and Protection

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Comhshaol, Pobal agus Rialtas Áitiúil
Environment, Community and Local Government

SOIL STATUS IRELAND

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**ENVIRONMENTAL PROTECTION AGENCY**

The Environmental Protection Agency (EPA) is responsible for protecting and improving the environment as a valuable asset for the people of Ireland. We are committed to protecting people and the environment from the harmful effects of radiation and pollution.

## The work of the EPA can be divided into three main areas:

Regulation: *We implement effective regulation and environmental compliance systems to deliver good environmental outcomes and target those who don't comply.*

Knowledge: *We provide high quality, targeted and timely environmental data, information and assessment to inform decision making at all levels.*

Advocacy: *We work with others to advocate for a clean, productive and well protected environment and for sustainable environmental behaviour.*

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- waste facilities *(e.g. landfills, incinerators, waste transfer stations)*;
- large scale industrial activities *(e.g. pharmaceutical, cement manufacturing, power plants)*;
- intensive agriculture *(e.g. pigs, poultry)*;
- the contained use and controlled release of Genetically Modified Organisms *(GMOs)*;
- sources of ionising radiation *(e.g. x-ray and radiotherapy equipment, industrial sources);*
- large petrol storage facilities;
- waste water discharges;
- dumping at sea activities.

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- Supervising the supply of drinking water by public water suppliers.
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- Monitoring and reporting on Bathing Water Quality.

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The EPA is managed by a full time Board, consisting of a Director General and five Directors. The work is carried out across five Offices:

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- Office of Environmental Enforcement
- Office of Evidence and Assessment
- Office of Radiological Protection
- Office of Communications and Corporate Services

The EPA is assisted by an Advisory Committee of twelve members who meet regularly to discuss issues of concern and provide advice to the Board.

**EPA Research Programme 2014–2020**

# Soil Status and Protection

# (2013-SL-DS-2)

# EPA Research Report

Prepared for the Environmental Protection Agency

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Teagasc

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# Executive Summary


The 68th United Nations General Assembly declared 2015 the International Year of Soils (IYS) and accordingly gave the Food and Agriculture Organization (FAO) responsibility to implement the IYS 2015 objectives. Soil protection and sustainable soil management are at the core of the objectives of the IYS. Sustainable land management is a necessity to protect soil resources and to guarantee associated ecosystem goods and services into the future. A key element is identifying and reducing degradation processes in soil, many of which are caused by humans. The withdrawal of the European Union's proposed Soil Framework Directive in May 2014 highlights a great need to think differently about soils and their role in securing sustainable development and food production. At the European Union level, the European Commission, acknowledging the Rio + 20 goal of 'Zero net land degradation by 2030', remains committed to the objective of soil protection through policies such as the Seventh Environment Action Programme and the Resource Efficiency Roadmap. At the international scale, the United Nations Sustainable Development Goals highlight four actions that explicitly deal with soils. The Environmental Protection Agency document *Towards Setting Environmental Quality Objectives for Soil. Developing a Soil Protection Strategy for Ireland* stated in 2002 that Ireland lacked a centralised collection of information on soils, soil quality and soil fertility.

The Soil Status and Protection project evaluated the state of the art for data on soil quality and protection in Ireland, and identified future research needs for soil science and related research. An online meta-data catalogue was developed that synthesises information with a focus on soil. This catalogue, Secure Archive For Environmental Research Data (SAFER)-SOIL, provides an overview of what data are available, methods applied and how this information could be used to inform current and future policy drivers and research in Ireland. The SAFER-SOIL database can be found at http://erc.epa.ie/soils/projects/soilstatus/index.php

The project looked at potential soil-monitoring network (SMN) strategies and scenario analyses to respond to data requirements at national and European levels on soil protection and status.

In March 2015, a final workshop was held: Soil Status – Stakeholder Workshop, and the project outputs were presented there. Scenario analyses and key priorities for soil protection and research in Ireland were discussed and future research recommendations were identified. These included four key areas.

**Policy**

The project provided an overview of the range of policies/legislation and initiatives that address soil protection in Ireland. These relate to the national, European and international scales. At the national scale, no legislation currently exists that explicitly deals with the protection of soil as a resource. The European Union developed a proposal for a Soil Framework Directive in 2006, but this was never ratified by all Member States and it was withdrawn in 2014. Therefore, this report addresses other policies and indirect legislation that considers soil.

**Soils Research Meta-data Catalogue**

A SAFER-SOIL meta-data catalogue was much needed to provide an overview of existing soils research in Ireland. The catalogue should be supported as a multi-agency tool, whereby all funded soil projects are asked to provide meta-data for the online catalogue. This will provide an online summary of all soil-related data availability and provide a resource for both policymakers and funders of research in terms of future policy and research requirements.

**Soil Monitoring**

A lot of soils data are currently available; however, they are disjointed in terms of spatial extent and methods applied. This project recommends developing an SMN of sampling sites, from which future research projects can add value. This desk study examined the various options for an SMN and recommended a 16 $km^2$ stratified grid based on soil drainage class and land use. An SMN should allow comparison of those soil properties that remain the same and those that change over time, to report on changes in soil conditions, but also be used to guide and respond to policy drivers.

**Research Requirements**

There is an increased need for knowledge transfer in terms of highlighting the role that soils play in primary productivity and the need for sustainable management practices to get the best from the soil. Soils information should also be included in monitoring of other environmental compartments such as climate, hydrology and above-ground habitats.

There has been considerable research on peat-scapes in Ireland, as these are a unique resource. However, there is little link-up between projects, so there is still not much of an inventory on the classification and management of the different types of peat bogs in Ireland.

Knowledge of soil biology and biodiversity is essential for understanding many of the mechanisms that drive biochemical processes in soils, such as nutrient mineralisation and carbon sequestration. Therefore, this report recommends future development of biological indicators and understanding of biochemical processes for nutrient mineralisation.

Further work is required on understanding the role that soils play in supporting society across a range of landscapes. While a lot of research exists on agricultural landscapes, further work is needed on urban, forestry, mountain and peat landscapes. This is needed to develop the knowledge required for the National Landscape Strategy.

# 1 Introduction

## 1.1 Background

The 68th United Nations (UN) General Assembly declared 2015 the International Year of Soils (IYS) and accordingly gave the Food and Agriculture Organization (FAO) responsibility to implement the IYS 2015 objectives. Soil protection and sustainable soil management are at the core of the objectives of the IYS. Specifically in relation to soil protection, the UN calls for effective policies and actions for sustainable management and protection of soil resources. It also advocates the rapid enhancement of capacity to collect and monitor soil information at all levels (global, regional and national) (United Nations, 2015a). Despite the growing recognition that soil is an important non-renewable resource that delivers multiple benefits to society, it lacks legal protection. Soil quality (its ability to provide ecosystem services and goods) and protection are vital to ensure soil resources and sustainable development into the future.

At the national scale, the Environmental Protection Agency (EPA) published a document entitled *Towards Setting Environmental Quality Objectives for Soil. Developing a Soil Protection Strategy for Ireland* (EPA, 2002). In this document, the EPA stated that "Ireland's soils are considered to be in good condition, but also extremely vulnerable to land use changes, particularly in the case of peat areas." However, information on the status and protection of soils has been limited to date. Although many Irish projects collect data on the various aspects of soil, there is little harmonisation across projects. This means that it has not been possible to undertake a robust gap analysis on specific soil-quality issues or assess areas under external pressure, in order to support policy development into the future.

At the European scale, a policy document relating to the protection and quality of soils dates back to 2006, when the Thematic Strategy for Soil Protection (COM (2006)231 final) was published (EC, 2006a). It introduced the concept of *soil functions* and *soil threats*, which *The Implementation of the Soil Thematic Strategy and On-Going Activities* (COM (2012)46 final) reiterated (EC, 2006b, 2012a). Soil is broadly recognised as being under increasing environmental pressure across the EU, and these threats are often driven by human activity (Chesworth, 2008), such as land management practices, industrial activities, tourism, urban and industrial sprawl, and construction works (EC, 2006b, 2012b). Soil degradation refers to the incapacity of soils to produce economic goods and to perform soil functions (Bridges and Oldeman, 1999; Seybold *et al.*, 1999). The eight main threats to which soils in the European Union (EU) are vulnerable are:

1. erosion;
2. decline in organic matter;
3. local and diffuse contamination;
4. soil sealing;
5. compaction;
6. decline in biodiversity;
7. salinisation;
8. floods and landslides.

The Thematic Strategy for Soil Protection was followed up by a proposal for a Soil Framework Directive (SFD) (COM (2006)232 final) (EC, 2006b), which would provide the legislative basis for soil protection and preservation across Europe. Creamer *et al*. (2010) published a review of current threats to soil quality, based primarily on the agricultural management cycle in north Atlantic Europe. Creamer *et al*. (2010) concluded that the main threats to soil quality were loss of soil organic matter, erosion, compaction and contamination. They identified that some existing legislation was aimed at reducing these threats. However, in many cases the legislation required only the voluntary adoption of best practice guidelines, such as the Good Agricultural and Environmental Conditions (GAEC). Creamer *et al*. (2010) also recognised "loss of soil biodiversity" as a potential threat. The Directive did not list it as a key threat because it was difficult to quantify changes in biodiversity status at the European or even national scale. Overall, they summarised that ratifying the SFD would unify all soil protection measures under one directive and provide Member States (MSs) with a common approach and level playing field for soil protection. However, the SFD was never ratified by all EU MSs and was withdrawn from discussion in May 2014. This

shows how important it is to change how we consider our soils.

In the last 10 years, research on soil protection funded at EU level has tended to focus on the negative aspects, the threats to soil described above, while overlooking the multi-functional capacity of soils. There is a great need to think differently about soils and to understand what they can provide to society through a range of ecosystem services/soil functions. The status of a soil is defined in terms of soil quality, which supports and sustains its multiple properties and functions. Soil quality is "the capacity of a specific kind of soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation" (Karlen *et al*., 1997; see also Creamer *et al.*, 2010). For the human community, soil quality services (soil functions) could be regarded as the ability of soil to protect the environment, produce food, perform waste disposal, and provide foundations for infrastructures, biodiversity and human health (Karlen *et al.*, 1997; Chesworth, 2008). Soil quality is vital to secure sustainable development, energy, raw materials and food production into the future.

The Thematic Strategy for Soil Protection (EC, 2006a) and the proposal for an SFD (EC, 2006b) both recognise that soils perform a number of essential functions (ecosystem services) from which humans benefit (Karlen *et al.*, 1997; Chesworth, 2008; EC, 2012a; Schulte *et al.*, 2014, 2015a,b):

- provide food, biomass, raw materials and habitat for organisms;
- act as reservoir, storing, redistributing, regulating, filtering and transforming resources, including water, solar energy, nutrients and carbon;
- are a gene and biodiversity pool;
- provide a platform for human and socio-economic activities;
- store geological and archaeological heritage;
- sustain biological activity, diversity, and productivity; and
- undertake filtering, buffering, degrading, immobilising and detoxifying of organic and inorganic materials, including industrial and municipal by-products and atmospheric deposition.

Following the withdrawal of the SFD legislative proposal (EC, 2006b) in 2014, there has been a new focus on the benefits and services provided by soils. This approach looks at how we can enhance and maintain the functional capacity of soils by using land management options that are fit for purpose and based on the physical, chemical and biological make-up of a soil. In Ireland, this concept has been developed further by Schulte *et al.* (2014), who coined the term *functional land management*, which deals with these aspects.

## 1.2 Soil Status and Protection Project

The Soil Status and Protection desk study project was carried out from April 2014 to May 2015. The main objectives were to:

- review the current EU and Irish legislation, policies and available data that assess or encompass soil protection issues for Ireland (Chapter 2);
- collect and review existing data from soil-based projects funded to date in Ireland and incorporate them into a meta-data catalogue (Chapter 3);
- review potential options for future soil monitoring, based on existing soil data described in the meta-data catalogue (Chapter 4);
- identify knowledge transfer (KT) requirements across different sectors of stakeholders (Chapter 5);
- review current research strategies (Chapter 6);
- identify future research requirements (Chapter 7).

## 1.3 Project Website

The Teagasc Environment programme website hosts the Soil Status and Protection web page: http://www.teagasc.ie/soil/soil_status/ (Figure 1.1). The homepage describes the project's objectives and work packages; events, for example the Stakeholder Workshop; the project team; contacts; funders; and Steering Committee members. All the resources generated by this project will also be made available via the EPA Secure Archive For Environmental Research (SAFER) Data portal: http://erc.epa.ie/safer. The pattern colouring the letters in the logo comes from the Third Edition Soil Map of Ireland derived from the Irish Soil Information System project (EPA, 2014), which was launched jointly by Teagasc and the EPA, in September 2014.

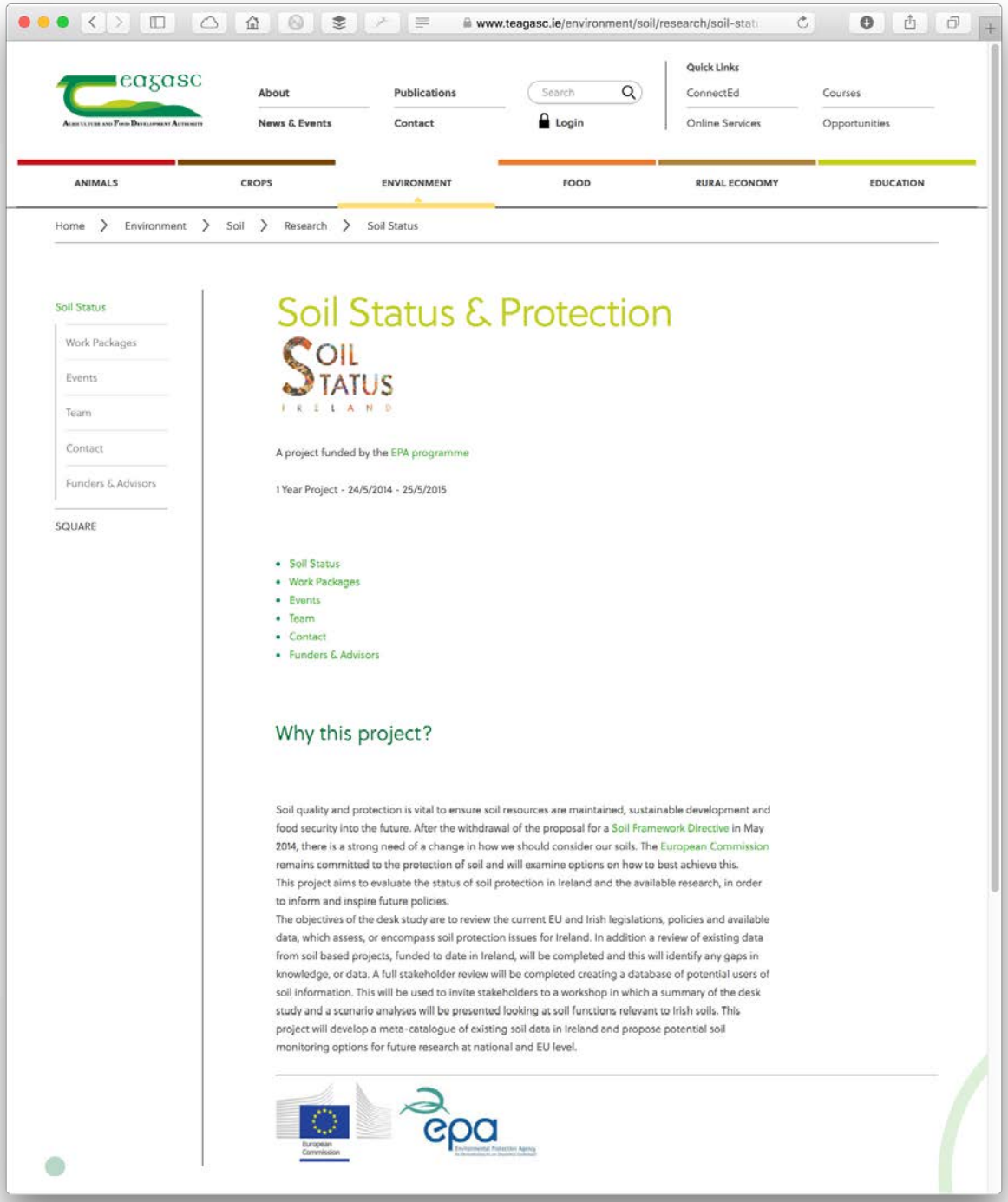


**Figure 1.1. Snapshot of the Soil Status and Protection homepage: https://www.teagasc.ie/environment/soil/research/soil-status/**

# 2 Review of Soil Legislation and Policy

This chapter provides an overview of current legislation and policy at national (section 2.1), European (sections 2.2, 2.3 and 2.4) and international (section 2.5) levels. Chronological order has been followed within each section to try to explain the development of policies and legislation over time, starting with the development of the Soil Thematic Strategy for soil protection published in 2006, through to recent measures in greening of the Common Agricultural Policy (CAP) and Areas of Natural Constraint (ANCs).

## 2.1 National Policies, Legislation and Initiatives Addressing Soils

The National Landscape Strategy Steering Group was established by the Department of Arts, Heritage and the Gaeltacht (DAHG) in 2011 to develop a National Landscape Strategy with the aim of sustainably managing change that could affect the landscape. This strategy does not deal with the issue of soil protection as part of the landscape. It does, however, highlight the need to develop a data framework for collection of spatial data in relation to soil.

Food Harvest 2020 (DAFF, 2010) was an industry-led initiative, supported by the government. It identified opportunities, obstacles and actions required to expand the dairy industry following the phase-out of the EU milk quota in 2015. Headline figures included a 50% increase in the volume of milk production and a 20–40% increase in the value of total beef output, along with similar value targets for other sectors. The strategy explains that this expansion would be based on a process of knowledge intensification, resulting in more efficient farming systems with extended-grazing systems of ruminant production. Food Harvest 2020 acknowledged the need to mitigate the increased pressures on the environment that would result from this increased agricultural activity. It specifically mentions soil management as a necessary action for environmental sustainability (DAFF, 2010).

In 2015, Food Harvest 2020 was superseded by Food Wise 2025 (DAFF, 2015), which provides direction to the agricultural industry for the period 2015–2025. Food Wise 2025 differs from Food Harvest 2020 in two aspects. First, whereas Food Harvest 2020 was developed with the idea that sustainability would drive growth, the environmental analysis was conducted retrospectively. This process has been reversed in the development of the new Food Wise 2025 strategy: it was actively informed by the environmental analysis, which was conducted concurrently. As a result, page 4 of the Food Wise 2025 document states: “A guiding principle that Food Wise 2025 will seek to embed at all levels of the agri-food industry is that environmental protection and economic competitiveness are equal and complementary: one will not be achieved at the expense of the other.” Second, key to achieving this “parity of esteem” between environment and economics is sustainable intensification, which “leverages the strengths of the sector by improving productivity while using natural resources in a manner which protects them into the future”.

In practice, this means that, under the Food Wise 2025 strategy, any further increases in productivity must be achieved through “sustainable intensification”. Measures are put in place for the ongoing monitoring and reporting of indicators of agricultural sustainability, with a view to implementing a correcting action should these metrics show deviations from the sustainable intensification pathway.

For this reason, Food Wise 2025 envisages that further growth of the industry will be underpinned primarily by increasing the value of products and exports. Specific value targets include:

- increasing the value of agri-food exports by 85% to €19 billion;
- increasing value added in the agri-food, fisheries and wood products sector by 70% to in excess of €13 billion;
- increasing the value of primary production by 65% to almost €10 billion;
- the creation of an additional 23,000 direct jobs in the agri-food sector all along the supply chain from primary production to high value-added product development.

Food Wise 2025 ascribes a significant role to “soil health” as a pillar of environmental sustainability,

emphasising soil fertility and soil carbon sequestration as key attributes that must be the focus of further research and KT activities.

Other national policies and regulations in which soil protection measures may be considered relevant can be found in Table 2.1.

At present, there is no single authority in charge of monitoring the status and protection of soils in Ireland. While the EPA undertakes a range of activities, mostly on soil protection, other agencies and government bodies have different roles and responsibilities relating to soils. For example, the Department of Agriculture, Food and the Marine (DAFM) is responsible for the implementation of the Green, Low-Carbon, Agri-Environment Scheme (GLAS) and, therefore, assessment of GAEC.

## 2.2 European Policies Directly Addressing the Status and Protection of Soils

At the European level, addressing soil protection is dealt with in two ways: (1) directly, through legislation or policies that relate directly to the status and protection of soils (section 2.2); and (2) indirectly, where soil protection is not directly considered but rather embedded within a wider primary objective such as protection of a water body or a habitat protected area (section 2.3).

There are currently no legislation or policies directly relating to soil quality and protection in Europe since the withdrawal of the SFD proposal (EC, 2006b) in May 2014. However, a number of policy statements exist.

**Table 2.1. National policies and regulations in respect of potential soil protection measures**

| National policies and regulations | Department responsible | Implementing authorities |
|---|---|---|
| Rural Environment Protection Scheme (REPS) | DAFM | DAFM |
| Protection of the Environment Act (2003) | DECLG | EPA, local authorities |
| Green, Low-Carbon, Agri-Environment Scheme (GLAS) | DAFM | DAFM |
| Environmental Liability Regulations 2015 [S.I. No. 293 of 2015] | DECLG | EPA |
| Act & Associated Regulations on Waste Management and on Use of Sewage Sludge in Agriculture (148/1998) | DECLG | EPA, local authorities |
| Local Government Water Pollution Acts (1977–1990) | DECLG | EPA, local authorities, Irish Water |
| Environmental Objectives Groundwater Regulations (9/2010) | DECLG | EPA, local authorities |
| Good Agricultural Practice for Protection of Waters Regulations (9/2009) | DECLG | Local authorities, EPA, DAFM |
| Planning & Development Strategic Infrastructure Act (2006) | DECLG | Local authorities, An Bord Pleanála, regional authorities |
| Environmental Assessment of Certain Plans & Programmes Regulations (45/2004) | DECLG | Relevant competent authorities (responsible for the preparation of a plan or programme), relevant public authorities (as prescribed) |
| Chemicals Act (2008) | DJEI | Relevant competent authorities (as prescribed for various responsibilities – including EPA, Health Service Executive and Revenue) |
| European Communities (Birds and Natural Habitats) Regulations | DAHG | NPWS, relevant public authorities (as prescribed) |
| Derelict Site Act (1990) | DECLG | Local authorities |
| Energy (Miscellaneous Provisions) Bill (2006) | DCENR | |
| Climate Action and Low Carbon Development Bill (2015) | DECLG | Prescribed bodies, public bodies |
| Second National Biodiversity Plan (2011) | DAHG | NPWS |
| Arterial Drainage Acts (1945 & 1995) | | OPW, local authorities |
| The Forestry Act (2014) | DAFM | DAFM |

**DAFM, Department of Agriculture, Food and the Marine; DECLG, Department of the Environment, Community and Local Government; DJEI, Department of Jobs, Enterprise and Innovation; NPWS, National Parks & Wildlife Service; OPW, Office of Public Works.**

### 2.2.1 Soil Thematic Strategy (COM (2006)231)

The Thematic Strategy for Soil Protection was initially developed in 2006, after the Environment Directorate-General of the European Commission (DG Environment) had consulted on soil quality and protection. In 2012, the initial focus of the Soil Thematic Strategy was reiterated in the document *The Implementation of the Soil Thematic Strategy and On-going Activities* (EC, 2012a). The SFD proposal (EC, 2006b) was withdrawn in May 2014, but the Soil Thematic Strategy is still accepted and the Commission remains committed to the objective of protecting soil (EC, 2012a). The purpose and contents of these legislative documents are described in section 1.1.

### 2.2.2 Resource Efficiency Roadmap (COM (2011)571)

The Europe 2020 Strategy has a Resource Efficiency Roadmap that contains a framework for actions. It includes many policy areas such as climate change, energy, transport, industry, raw materials, agriculture, fisheries, biodiversity and regional development. The roadmap aims to develop a framework that will design and implement future actions oriented to resource efficiency.

The roadmap includes soil- and land-related milestones: "By 2020, EU policies should take into account their direct and indirect impact on land use in the EU and globally, and the rate of land take is on track with an aim to achieve no net land take by 2050; soil erosion should be reduced and soil organic matter increased, with remedial work on contaminated sites well underway" (EC, 2011a). The roadmap is an example of EU policies relating to the objectives of the Seventh Environment Action Programme on protecting, conserving and enhancing the Union's natural capital.

### 2.2.3 Seventh Environment Action Programme (EAP)

The Seventh Environment Action Programme, guiding EU environmental policy until 2020, recognises soil degradation as a serious challenge and addresses soil quality issues by using a targeted and proportionate risk-based approach within a binding legal framework (EU, 2013a). The thematic objectives listed by the programme are:

- protecting, conserving and enhancing the Union's natural capital;
- turning the Union into a resource-efficient, green and competitive low-carbon economy; and
- safeguarding the Union's citizens from environment-related pressures and risks to health and well-being.

### 2.2.4 The Future Communication on Land as a Resource (EC)

To respond to the Rio+20 UN conference political mandates, the Commission is working on a Communication on "Land as a Resource" to ensure sustainable EU land management.

The European Commission organised a conference entitled "Land as a Resource" in June 2014. This was declared to be part of the preparatory work to develop a communication on land as a resource. As of July 2015, this communication has not been released and no further documents have been produced.

A policy review was completed in 2014 and the article can be found in the Teagasc journal *TResearch* (Bampa *et al.*, 2014). The article was written in co-operation with the Joint Research Centre (JRC) of the EC and can be found in Appendix 1. In parallel, several papers have recently been published in peer-reviewed journals to review/discuss the range of issues related to European soil policies/political recommendations (Bone *et al.*, 2010; Creamer *et al.*, 2010; Arrouays *et al.*, 2012; Kibblewhite *et al.*, 2012; Bouma and McBratney, 2013; Gardi *et al.*, 2013; Tóth *et al.*, 2013b; Bone *et al.*, 2014; Brus, 2014; Glæsner *et al.*, 2014; Schulte *et al.*, 2014).

## 2.3 European Policies and Legislation Indirectly Addressing the Status and Protection of Soils

In the absence of SFD, there are other EU policies that address soil and its protection as a secondary objective or indirectly, such as the policies on agriculture, environment, chemicals, industrial pollution, nature protection, pesticides, waste and water.

The Common Agricultural Policy (CAP) contributes to protecting soil from erosion and maintaining soil organic matter and soil structure. *The CAP towards 2020* explores options for future agricultural policy on how farming practices could limit soil depletion,

water shortages, pollution, carbon sequestration and loss of biodiversity (EC, 2010). The Agri-Environment Measures offer opportunities to favour the build-up of soil organic matter, the enhancement of soil biodiversity, and the reduction of soil erosion, contamination and compaction. In addition, cross-compliance requires a mechanism that encourages farmers to comply with common rules and standards for respecting the environment, as well as public, animal and plant health and animal welfare. This mechanism can play an important role for soil protection. The obligation to keep agricultural land in Good Agricultural and Environmental Condition (GAEC) (EC, 1999a,b, 2009a) constitutes a common policy framework for certain aspects of agricultural soil protection, and land and landscape maintenance. It is up to each MS to define the minimum soil protection requirements for soil, in accordance with the recommendations for minimum soil cover, minimum land management to limit erosion and for maintaining soil organic matter content. With regard to the Rural Development Policy 2007–2013, soil is listed under point 4 of the Union's priorities for rural development (Regulation (EU) No. 1305/2013) (EU, 2013b), which names preventing soil erosion and improving soil management as two of its focus areas. The European/government aid schemes to farmers in ANCs (previously known as less favoured areas, LFAs) have been in place since 1975 as a mechanism for maintaining the countryside in areas where agricultural production or activity is more difficult because of natural handicaps (e.g. difficult climatic conditions, steep slopes in mountain areas or inherently unproductive soil). To enhance the effectiveness of the aid, in its Communication on "Towards a better targeting of the aid to farmers in areas with natural handicaps" (EC, 2009b), the EC identified a new classification of agricultural areas with natural handicaps based on eight soil and climate criteria. MSs have been asked to provide simulations using national data to show how the criteria might work. For Ireland, the ANC Scheme is managed under the new Rural Development Programme 2014–2020. It is co-funded by the European Agricultural Fund for Rural Development (EAFRD) and will continue until 2018. Through the scheme, farmers receive payments to help them farm in ANCs such as mountain areas or lowland that is severely handicapped. The physical characteristics relevant to Ireland are soil moisture balance (trafficability), soil drainage, slopes, soil rooting and depth, soil texture and organic matter.

The EU remains committed to the international climate change negotiations. The EU 2020 Climate Change and Renewable Energy Package includes a set of binding legislation, which aims to ensure that the EU meets its ambitious climate and energy targets for 2020. The land use sector is currently not part of the EU's Emissions Trading System (ETS) and is not considered towards national climate targets under the European Effort Sharing Decision. However, the EC's conclusion of October 2014 states that a policy to include land use, land use change and forestry (LULUCF) in the 2030 greenhouse gas (GHG) mitigation framework will be established before 2020.

In 2013, the Council and the European Parliament adopted a decision (EU, 2013c) to harmonise accounting rules for GHG emissions and removals from soils and forests across the EU. Integrating the LULUCF accounting systems would help to strengthen the capacity of forests and agricultural soils to maintain and capture carbon in a sustainable manner (recognition of practices aimed at management of carbon stored in forests and soils). The EU decision sets out accounting rules applicable to the reporting and accounting of emissions and removals of GHGs resulting from LULUCF activities covered under Articles 3.3 and 3.4 of the Kyoto Protocol, as a first step towards including those activities in the Union's emission-reduction commitment. By this decision, from 2021 onwards it will be mandatory to account annually for GHG emissions and removals arising from management of grazing land and cropland in the MSs. Currently, this decision does not set a target for emission reductions in the LULUCF sector. It has not yet been decided how to integrate the land use sector into the climate change mitigation framework.

The EU is considering the possibility of including mitigation options within LULUCF activities as part of the Energy and Climate Package. Three options are on the table, only one of which involves transactions with the ETS. The ETS was initiated in 2005 and operates on a "cap and trade" basis. The EU MS governments are required to set an emissions cap for each installation in the scheme. The number of allowances allocated to each installation must be set down in the National Allocation Plan (NAP) for the period in question, which must be approved by the EC. There are various other European directives that in some way relate to soil protection or status. Table 2.2 is taken from the paper by Glæsner *et al*. (2014). At a national level, Ireland has

already elected to account for emissions and removal from grazing land management and cropland management during the second commitment period of the Kyoto Protocol, from 2013 to 2020.

The Environmental Impact Assessment (EIA) Directive (85/337/EEC amended by 97/11/EC and 2003/35/EC) and the Strategic Environmental Assessment (SEA) Directive (2001/42/EC) have had legal status in Ireland since 2004 in terms of land use planning. The EIA Directive should be applied over a 3-year period to reflect changes in EU legislation. In July 2009, the Commission published a report on the application and effectiveness of the EIA Directive and, on 26 October 2012, the Commission adopted a proposal for a new directive that would amend the current directive. The report refers to the Soil Thematic Strategy and the Roadmap to a Resource Efficient Europe as highlighting the importance of sustainable use of soil and the need to tackle land take. In line with this proposal, "Public and private projects should therefore consider and limit their impact on land, particularly land take, and soil, including on organic matter, erosion, compaction and sealing. This should be facilitated through appropriate land use plans and policies at national, regional and local levels" (EC, 2012b).

**Table 2.2. Policies related to soil from Glæsner *et al.* (2014)**

| Policy | Number | Title |
|---|---|---|
| **CAP** | 1305/2013 | European Agricultural Fund for Rural Development (EAFRD) |
| | 1306/2013 | European financing, management and monitoring of the Common Agricultural Policy |
| | 1307/2013 | Common rules for direct support schemas |
| | 1308/2013 | European common organisation of the markets in agricultural products |
| **Plant Protection Products Directive** | 91/414/EEC | Concerning the placing of plant protection products on the market |
| **Nitrates Directive** | 91/676/EEC | Concerning the protection of waters against pollution caused by nitrates from agricultural sources |
| **GMO Directive** | 2001/18/EC | Deliberate release into the environment of genetically-modified organisms |
| **Pesticide Use Directive** | 2009/28/EC | Action to achieve the sustainable use of pesticides |
| **Industrial Emissions Directive** | 2010/75/EU | Industrial emissions (integrated pollution prevention and control) |
| **Landfill Directive** | 1999/31/EC | Landfill of waste |
| **Mining Waste Directive** | 2006/21/EC | Management of waste from extractive industries |
| **Biocidal Products Regulation** | (EU) 528/2012 | Concerning making available on the market and use of biocidal products |
| **Waste Directive** | 2008/98/EC | Waste |
| **Sewage Sludge Directive** | 86/278/EEC | Protection of the environment and, in particular, of the soil, when sewage sludge is used in agriculture |
| **Urban Waste Water Directive** | 91/271/EEC | Concerning urban waste water treatment |
| **Carbon Storage Directive** | 2009/31/EC | Geological storage of carbon dioxide |
| **Renewable Energy Directive** | 2009/28/EC | Promotion of the use of energy from renewable sources |
| **Habitat Directive** | 92/43/EEC | Conservation of natural habitats and of wild fauna and flora |
| **Water Framework Directive** | 2000/60/EC | Establishing a framework for community action in the field of water policy |
| **Air Quality Framework Directive** | 2004/107/EC | Relating to arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons in ambient air |
| **Environmental Liability Directive** | 2004/35/CE | Environmental liability with regard to the prevention and remedying of environmental damage |
| **Floods Directive** | 2007/60/EC | Assessment and management of flood risks |
| **Resource Efficiency Roadmap** | COM/2011/571 | Roadmap to a Resource Efficient Europe |
| **7 EAP** | | Seventh Environment Action Programme to 2020, "Living Well, within the Limits of Our Planet" |

**Source: Glæsner *et al.* (2014). Reproduced with permission of the authors.**

Soil provides a habitat for at least one-quarter to one-third of all living organisms on the planet and yet only around 1% of soil microorganisms have been identified, compared with 80% of plants (Jeffery *et al*., 2010). It is, therefore, essential that we understand more about our soil biodiversity. In terms of biodiversity protection, the EU Biodiversity Strategy to 2020 aims at halting the loss of biodiversity (EC, 2011b) and describes the Natura 2000 network. There is no specific legislation that deals with the loss of biodiversity in soils, but there is both political and research momentum on this topic, with the development of the Global Soil Biodiversity Initiative (https://globalsoilbiodiversity.org/). Soil supports a diversity of living organisms, such as microorganisms, mesofauna and macrofauna. Soil organisms contribute a wide range of essential services to the sustainable function of all ecosystems. They cycle nutrients, regulate the dynamics of soil carbon, modify soil structure and water cycling, increase the amount and efficiency of nutrient absorption by vegetation and can promote plant health. These services not only are essential to the functioning of natural ecosystems but constitute an important resource for the sustainable management of ecosystems (Jeffery *et al*., 2010).

For forest protection, there is the Forest Focus Regulation (http://ec.europa.eu/environment/archives/forests/ffocus.htm) concerning monitoring of forests and environmental interactions in the Community (EC, 2003) and the ICP Forest International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (http://icp-forests.net/) operating under the UN. One of the aims of the regulations is to monitor biodiversity, climate change, carbon sequestration and soils (e.g. the Biosoil project in forests: https://ec.europa.eu/jrc/sites/default/files/jrc_20101018_forest_biosoil.pdf). Another policy worthy of mention is the European Landscape Convention (http://www.coe.int/en/web/landscape), adopted in 2000, which seeks the right balance between management planning and protection of a landscape. The convention recognises the importance of holistic, territorial approaches to protecting landscapes through joined-up working by regional and local authorities to prevent landscape degradation.

The regional policies that could be considered in terms of soil protection are the Structural Funds and Cohesion Fund (http://eustructuralfunds.gov.ie/background/eu-cohesion-fund/) and the European Territorial Cooperation, better known as Interreg IV (2014–2020) (http://ec.europa.eu/regional_policy/en/policy/cooperation/european-territorial/). Many Interreg reference projects aim to protect soil. On the other hand, the EU Cohesion Policy provides ample opportunity for MSs to encourage soil protection in cropland, forests and grazing land through environmental goals (e.g. soil, biodiversity and water resource protection).

## 2.4 Key Reports Addressing Soil Issues for the EU

### *2.4.1 State of the Environment Report (SOER 2015. The European Environment: State and Outlook 2015)*

The synthesis report from the European Environment Agency (EEA, 2015) provides an environmental outlook from 2015 to 2020. It includes a reflection on land use changes and intensification, which may potentially threaten soil ecosystem services and drive biodiversity loss. The only explicit objectives that SOER 2015 identifies are non-binding: “no net land take by 2050” and restoring at least 15% of degraded ecosystems by 2020 (EEA, 2015). Looking forward, the SOER highlights that, while a reduction in pollution has seen a significant improvement in the quality of Europe’s air and water resources, there are still major concerns about loss of soil functions, land degradation and climate change.

### *2.4.2 Overview of Best Practices for Limiting Soil Sealing or Mitigating Its Effects in EU-27 – EC DG ENV (SWD(2012) 101 final/2)*

The EC assigned the Austrian Environment Agency to develop the report *Overview of Best Practices for Limiting Soil Sealing or Mitigating Its Effects in EU-27* (EC DG ENV (SWD (2012) 101 final/2) (http://ec.europa.eu/environment/soil/sealing.htm), completed in April 2011. The report deals with the best-practice strategies to limit, mitigate or compensate soil sealing in the EU. The report reviews the state of land take and sealing in the EU and gives an overview of existing MS policies to reduce and mitigate soil sealing. It presents the technical measures taken to mitigate the effects of sealing, as well as the compensation systems introduced. These are supplemented by information on soil quality criteria and existing networks that are relevant to reducing sealing. The report highlighted that, between 1990 and 2000, at least 275 hectares of soil were lost per day in

the EU, amounting to 1000 km² per year, with half of this soil being sealed by layers of concrete and asphalt. This trend in general has been cut back in recent years, as a lot of large infrastructure programmes, in particular road networks, had been completed by 2000. Between 2000 and 2006, the average increase in artificial areas in the EU was 3%; figures exceeded 7.5% in only Cyprus, Ireland and Spain.

### *2.4.3 Review of Existing Information on the Interrelations between Soil and Climate Change (CLIMSOIL)*

The CLIMSOIL Final Report (http://ec.europa.eu/environment/archives/soil/pdf/climsoil_report_dec_2008.pdf) is a follow-up of a high-level conference held in 2008 on soil and climate change. On that occasion, the EC asked a group of European scientists to assess the contribution that soils can make to climate change mitigation, and the effect of climate change on soil productivity and organic matter depletion. The objective of the CLIMSOIL study was to provide a more complete understanding of the link between soil under different land uses and climate change through a comprehensive literature review and expert contributions. The report identifies a range of currently available soil management strategies that would be feasible to implement within all land use categories: cropland, grassland, forest lands, and cultivated peat soils and lightly managed or unmanaged heathlands and peatlands. According to the CLIMSOIL report, the current area of peat occurrence (referring to peat and organic soils) in the EU MSs and candidate countries is over 318,000 km$^2$. More than 50% of this surface is in just a few northern European countries (Norway, Finland, Sweden and the United Kingdom); the remainder is in Ireland, Poland and the Baltic states. The report states that these soils are the largest emitters of $CO_2$ resulting from land use change and drainage.

### *2.4.4 Soil Biodiversity: Functions, Threats and Tools for Policymakers*

In 2010, the EC published a JRC reference report to celebrate the International Year of Biodiversity: *European Atlas of Soil Biodiversity* (Jeffery *et al*., 2010; http://ec.europa.eu/environment/archives/soil/pdf/biodiversity_report.pdf). The report emphasises the importance of soils remaining healthy and capable of supporting human activities, sustainably. It reviews the status of soil biodiversity across Europe and presents an overview of monitoring frameworks and indicators. It highlights the CréBeo project as a valuable resource for monitoring soil biodiversity in Ireland. CréBeo was funded by the EPA Science, Research, Technology and Innovation for the Environment (STRIVE) Programme and co-ordinated by University College Dublin (UCD) in conjunction with the University of Limerick (UL), the National University of Ireland (NUI) Maynooth and Teagasc.

### *2.4.5 The State of Soil in Europe: A Contribution from the Soil Action Team in JRC to the European Environment Agency's Environment State and Outlook Report – SOER 2010*

The previous 2010 synthesis report from EEA, SOER 2010 (EEA, 2010; https://ec.europa.eu/jrc/sites/default/files/lbna25186enn.pdf?search and http://www.eea.europa.eu/soer/what-is/what-is-soer-2010), presents a pan-European overview of the knowledge and understanding of the state of soil in Europe. It is based upon data available at the EU level about the key processes that affect soil resources. In a review of soil organic carbon (SOC) in topsoils across Europe, Ireland showed high levels of SOC compared with other EU countries (Jones *et al*., 2012), due in part to its richness in peatlands.

### *2.4.6 Progress in the Management of Contaminated Sites in Europe*

The JRC reference report *Progress in the Management of Contaminated Sites in Europe* (van Liedekerke *et al*., 2014; http://www.eea.europa.eu/data-and-maps/indicators/progress-in-management-of-contaminated-sites-3) describes data on contaminated sites collated by the European Environment Information and Observation Network (EIONET). Data were obtained in 2011–2012 and related to the period from 1998 to 2011. The report is based on data that were collected from the designated national reference centres for soil in 39 countries belonging to EIONET co-ordinated by the JRC European Soil Data Centre (ESDAC). For the whole of Europe, this report estimated 2.5 million "potentially contaminated sites", of which about 14% are expected to be significantly contaminated and likely to require remediation. Within Ireland, 2371 "potentially contaminated sites" and 30 "contaminated

sites" were identified. Most of the contamination (55%) comes from oil spills from transport operations; the next-biggest source is industrial and commercial activities.

#### 2.4.7 Biosoil Project

The Biosoil project on forest biodiversity and soil monitoring is a demonstration project (http://eusoils.jrc.ec.europa.eu/ESDB_Archive/eusoils_docs/other/EUR24729.pdf). It is co-financed under the Forest Focus Regulation No. 2152/2003, which is on the monitoring of forests and environmental interactions. Biosoil had two modules: one on biodiversity and one on soil. The biodiversity module was aimed at getting above-ground data and information on forest biodiversity. The soil module provides basic information on the chemical and physical soil status to demonstrate the feasibility of systematic forest soil monitoring at the European scale. Thirty-seven plots in Ireland were identified and assessed for biodiversity, soil parameters, crown condition and foliage.

#### 2.4.8 The New Assessment of Soil Loss by Water Erosion in Europe

Panagos *et al*. (2015) produced the paper "The new assessment of soil loss by water erosion in Europe", focusing on the threat of soil erosion by water and its negative impact on ecosystem services, crop production, drinking water and carbon stocks. A modified version of the Revised Universal Soil Loss Equation (RUSLE) model (RUSLE2015: http://esdac.jrc.ec.europa.eu/themes/rusle2015) has been applied to estimate soil loss in Europe for the reference year 2010. The input factors (rainfall erosivity, soil erodibility, cover-management, topography, support practices) were modelled with the most recently available pan-European datasets. The study estimated an annual mean soil loss rate in the EU of 2.46 t/ha, with a specific loss of > 5 t/ha annually from European arable lands (12.7%). Ireland was calculated to have a loss rate of 0.96 t/ha/year for all lands, including arable lands, which accounted for only 0.55% of the total loss of soil by water erosion in the EU. The application of GAEC over the past decade has reduced the soil loss rate in Europe by 9.5% on average, and by 20% for arable lands (Panagos *et al*., 2015).

### 2.5 International Policies Addressing the Status and Protection of Soils

There are a variety of commitments on land use and soil at an international level. The Climate Change Policy and the post-Kyoto debate provide a discussion, which includes the role of soils in carbon sequestration (http://www.un.org/climatechange/towards-a-climate-agreement/). In Article 3.4 of the Kyoto Protocol (http://www.un.org/climatechange/towards-a-climate-agreement/), the United Nations Framework Convention on Climate Change (UNFCCC) recognises the capacity of soils – in the agricultural, land use change and forestry categories – to store carbon, and their mitigation potential, in terms of both increasing the carbon sink and reducing $CO_2$ emissions. At the UN Conference on Sustainable Development in 2012, "Rio+20", world leaders gathered together to agree on a sustainable goal for land (https://sustainabledevelopment.un.org/rio20/). The proposed Sustainable Development Goal of a "zero net land and soil degradation world" paves the way towards a renewed global effort on land, soil protection and restoration activities, to support food security and poverty eradication (http://www.unccd.int/Lists/SiteDocumentLibrary/Rio+20/UNCCD_PolicyBrief_ZeroNetLandDegradation.pdf). The goal needs to be achieved by 2030 and will require the commitment of both public and private sectors (Ashton, 2012).

#### 2.5.1 UNFCCC

Climate change negotiations have been focusing mainly on the reduction of GHG emissions, especially from industrial activities, but also from deforestation and forest degradation (IPCC, 2003; and see http://www.unece.org/env/treaties/welcome.html). The recent shift to a more holistic approach towards accounting for LULUCF has brought the issue of SOC and its possible role in the negotiation process to the attention of policymakers. In December 2015, the Conference of the Parties (COP21) was held in Paris (http://www.cop21paris.org/). It is an annual meeting organised by the UN where policymakers from around the world search for global approaches to combating climate change. Discussions are informed by facts and figures provided by the Intergovernmental Panel on Climate Change (IPCC). The Paris Agreement is more ambitious than its predecessor (the Kyoto Protocol), in that it now seeks to keep the global temperature rise "well below 2

degrees Celsius" and "ideally below 1.5 degrees" (UN, 2015c).

The FAO of the UN is particularly active in this debate, as food and agriculture are directly affected by climate change. Climate-smart agriculture and agro-ecology, for example, are emerging as ways to increase food production while adapting to climate change, and reducing and removing GHG emissions. At the root of these concepts are sustainable grassland management practices, such as the reduction of grazing intensity and the improvement of pastures to protect the soil, but also practices aiming to increase grassland biodiversity and the capacity of soils to hold water and lock in more carbon. With regard to cropland, it is important to improve soil management practices, such as no-till farming, crop diversification and the use of natural nitrogen fixation methods, thus diminishing the need for fertilisers (José Graziano da Silva, Director General, FAO, 23 April 2015, online communication).

### *2.5.2 The Global Soil Biodiversity Initiative*

Many areas of the world host a richer biodiversity below ground than above, in terms of abundance, numbers of species and functions of organisms. The dynamic equilibrium of SOC under unchanged land use is driven by the active soil biodiversity pool. For this reason, any disturbance of organic matter levels immediately affects soil biota. Given that many soil organisms remain unknown or unclassified, there is a possibility that a large unknown part of the soil biodiversity has already been irreversibly lost worldwide due to rapid soil depletion. Soil biota perform a wide variety of processes and functions. It is therefore of fundamental importance to complete the full assessment of global soil biodiversity resources as well as to implement an effective strategy for protecting endangered soil species. The Global Soil Biodiversity Initiative (GSBI) (https://globalsoilbiodiversity.org) was launched in September 2011, representing a consortium of political, research and industry representatives with the aim of developing a platform for promoting soil biodiversity into environmental policy and sustainable land management for the protection and enhancement of ecosystem services. A key output of this group will be the publication of the *Global Soil Biodiversity Atlas*, managed by the Land Resource Management Unit at EU-JRC, published in 2016 (http://esdac.jrc.ec.europa.eu/Atlas).

### *2.5.3 United Nations Convention to Combat Desertification (UNCCD)*

The United Nations Convention to Combat Desertification (UNCCD) (http://www.unccd.int/en/Pages/default.aspx) was originally negotiated, in 1994, to address land degradation in drylands (arid, semi-arid and dry sub-humid areas), especially in sub-Saharan Africa, one of the most vulnerable ecosystems (FAO, 2004). However, in recent years, the convention has been realigning its strategy towards addressing land degradation in other parts of the world too (10-Year Strategy of the UNCCD, 2008–2018). The transition from a regional towards a global focus was clearly reflected by the fact that nearly all countries in the world ratified it with the aim of reversing global land degradation trends. Nowadays, the convention aims to combat desertification and mitigate the effects of drought through national action programmes that incorporate long-term strategies supported by international co-operation and partnership arrangements. In this context the Soil Leadership Academy has been launched in partnership with the private sector and aims to support and strengthen international policy frameworks for soil conservation and sustainable land management ensuring effective on-ground implementation (http://www.unccd.int/en/Stakeholders/private_sector/Pages/Soil-Leadership-Academy.aspx). In 2015 the UNCCD joined forces with the Conventions of Biological Diversity (CBD) and Wetlands Convention (RAMSAR) to highlight the risk of peatland degradation as a result of drainage. The three initiatives have called for the development of an online global peat atlas (http://www.unccd.int/Lists/SiteDocumentLibrary/Publications/2015Nov_Land_matters_For_Climate_ENG.pdf).

### *2.5.4 Food Security and Soil*

The Global Soil Partnership (GSP) (http://www.fao.org/globalsoilpartnership/en/) was established by the FAO, in collaboration with the EC, as a voluntary partnership in September 2011. The partnership includes soil stakeholders such as governmental bodies, FAO Member Nations, universities, research organisations, civil society organisations, industry and private companies. The aim is to provide a platform for active engagement in sustainable soil management and soil protection at all scales: local, national, regional and global. Ireland is not currently represented on the political membership of the GSP.

### *2.5.5 United Nations Sustainable Development Goals*

In September 2015, at the UN Sustainable Development Summit, the post-2015 development agenda was adopted as an action plan to be implemented by all countries. It includes 17 Sustainable Development Goals (SDGs) (https://sustainabledevelopment.un.org/sdgs) and 169 targets that seek to build on the progress achieved in the forerunning Millennium Development Goals (MDGs) (UN, 2015a). The agenda includes four targets that specifically cite soil: 2.4, “land and soil quality”; 3.9, “soil pollution and contamination”; 12.4, “management of chemicals and all wastes ... and significantly reduce their release to air, water and soil”; and 15.3, “By 2030, combat desertification, restore degraded land and soil” (United Nations, 2015b). Then, there are also other targets that focus on land and soil functions, such as primary productivity or water ecosystem protection (United Nations, 2015b). By 2030, these targets seek to progressively improve soil quality, reduce soil pollution and contamination and restore degraded soils (United Nations, 2015b).

# 3 Soils Research Projects Meta-data Catalogue

The purpose of the meta-data catalogue is to offer a tool able to bring soils research together.

*Meta-data are data that describe other data.*

"Meta" is a prefix that in most information technology usages means "an underlying definition or description". Meta-data, as defined by the American National Standards Institute, summarise basic information about data, which can make finding and working with particular instances of data easier.

Meta-data describe who owns or created the resource, why the resource was created and why it is important, the geographical location of the resource study area, when the project represented by the resource was operating or was actively collecting or analysing information, and what the key outputs and deliverables are.

## 3.1 SAFER: an Archive for Project Resources

The EPA SAFER (http://erc.epa.ie/safer/) is a public web-based interface for the EPA's Environmental Research Data Archive. Information is presented on SAFER as a "resource" and contains a general description and any related datasets that are publicly available for download. On SAFER a resource can be thought of as a composite object: it is the combination of meta-data (simple text-based information about a project or dataset) and the actual datasets and/or other information. Put simply, meta-data + digital data or digital information = a resource. As its basic definition, a resource contains only text-based descriptive meta-data. Consequently, datasets and other digital information objects may be added to this resource at a later stage.

In the SAFER interface the following meta-data details are available:

- abstract;
- contact information;
- data, files, information objects;
- access information (URL, keywords, project code, resource availability, limitation on the use file attached, etc.);
- geographical and spatial information;
- supplementary information.

## 3.2 Collation of Data Sources

The first step undertaken in order to build the soils meta-data catalogue was the review of all available Irish data from soil-based projects funded to date (from available records of 2000 onwards). The broad review assessed (1) meta-data already present in the general SAFER meta-data catalogue (http://erc.epa.ie/safer/) (2) existing soil projects in Ireland recorded on databases of various organisations (e.g. DAFM Research Stimulus Fund (RSF), Science Foundation Ireland (SFI), Geological Survey Ireland (GSI), DG Research CORDIS Framework programme (FP6, FP7), Teagasc, academia); and (3) expert knowledge.

## 3.3 SAFER-SOIL Meta-data Catalogue Development

An initial review was carried out with a range of academic stakeholders from a range of universities and research institutes to assess what kind of meta-data is sought in terms of future uses of the database.

On the basis of the existing information collected (Figure 3.1), especially data types, coverage and methods, an assessment on the best way to develop the soil meta-data catalogue has been done with a freeware mind-mapping application (https://coggle.it/) (Figure 3.2).

The new meta-data catalogue SAFER-SOIL (Figure 3.1) contains more structured details specifically related to soil inventories and mapping (e.g. scale, climate, management, archive, ancillary data). Users will be able to filter searches by soil sub-themes, for example (1) soil functions, (2) soil threats, (3) soil attributes and (4) policy drivers.

The Directive of the European Parliament and of the Council establishing an Infrastructure for Spatial Information in the European Community (INSPIRE) (COM (2004)516) represents the most significant piece of European legislation of relevance to the entire spatial

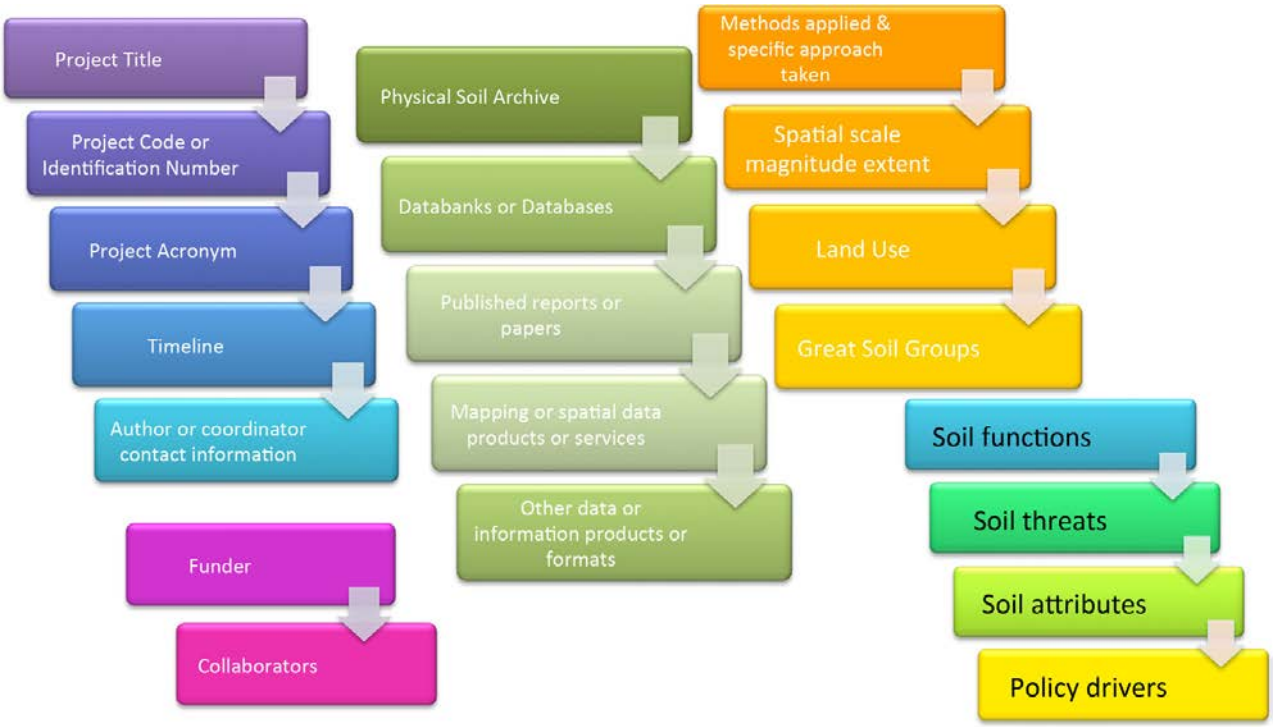


**Figure 3.1. Diagram of the soil meta-data selected.**

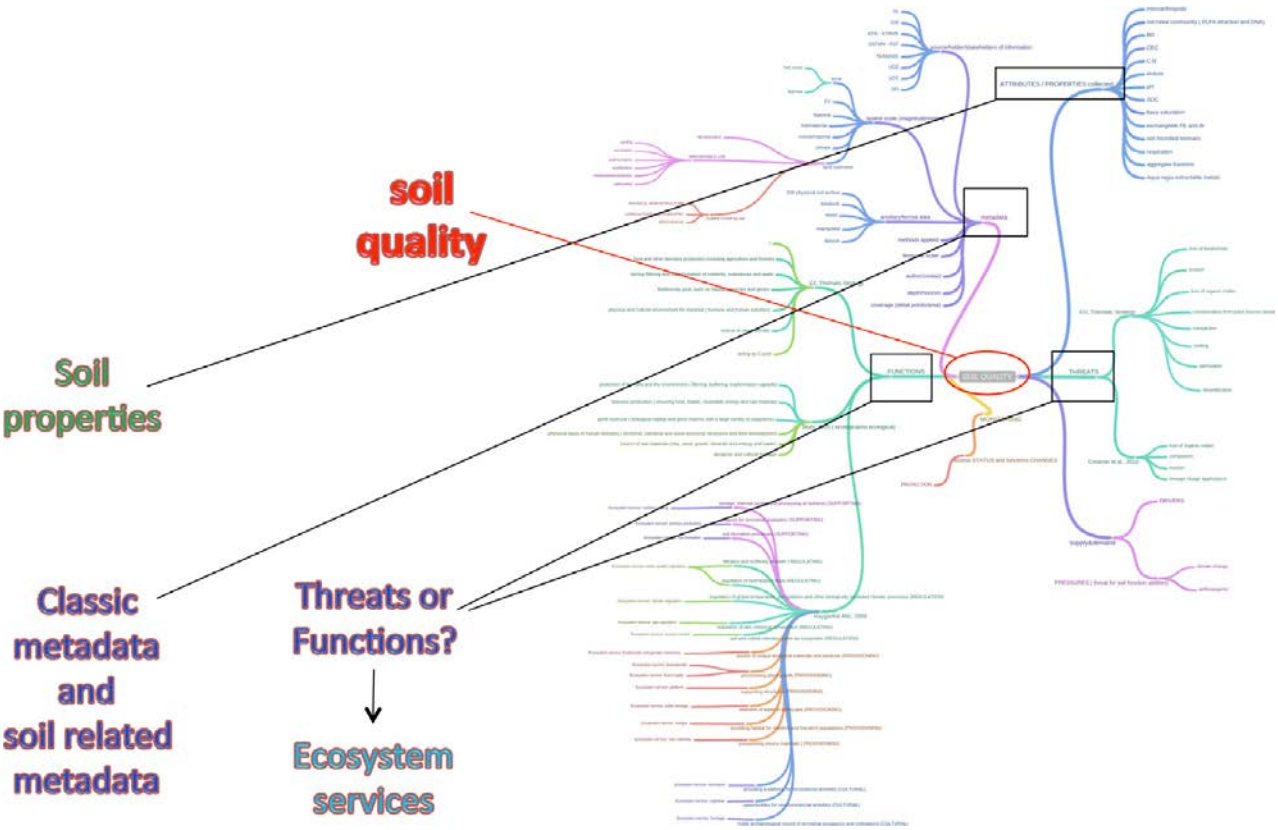


**Figure 3.2. Snapshot of the Coggle mind map of the Soil Status and Protection meta-data catalogue structure. The structure takes into account both soil threats and soil functions and their related ecosystem services. The concepts of soil quality and soil properties are also captured and it reflects on the classic meta-data plus more specific soil-related meta-data such as data types, coverage and methods.**

data community, including both users and producers. Following INSPIRE, data should:

- be collected once;
- combine seamlessly;
- be easily shared between different levels;
- have extensive use;
- be easy to discover (catalogued);
- be properly documented (meta-data).

More detailed information can be found at: http://inspire.ec.europa.eu/documents/Data_Specifications/INSPIRE_DataSpecification_SO_v3.0rc3.pdf

The INSPIRE Directive requirements essentially deal with meta-data collection for individual data points or samples. This project only performed a review of projects. Therefore, while it has followed the general guidelines from INSPIRE, it is not possible to implement at a project summary level the detail that is required. In general, this EU directive will have a significant effect on the distribution of soils data in Ireland and the development of information systems in the future to facilitate such distribution.

## 3.4 SAFER-SOIL Online Interface

SAFER-SOIL (http://erc.epa.ie/soils/projects/soilstatus/index.php) is a web-based interface that facilitates the querying of research projects meta-data in many ways including assessment by soil functions, soil threats and European policies. For guidance on how to use the online meta-data catalogue, please see Appendix 2. There are currently 109 research projects listed, which took place between 2000 and 2015 and included soil in their remit. See Table 4.4 for some examples of a number of projects on soil-related research between 2000 and 2015.

The following are examples of large-scale projects that have collected soil data at a range of spatial, and temporal scales, as well as a range of soil depths/horizons:

### *3.4.1 Irish Soil Information System (SIS) (EPA funded, Teagasc lead)*

(http://erc.epa.ie/safer/iso19115/displayISO19115.jsp?isoID=3068)

This project, completed in 2014, is the largest of the datasets that incorporate data on pedological and property attributes for the classification of soils. This database includes historic data for soils described in the 14 county monographs and an additional 228 new soil profiles for the country, surveyed to a depth of 80 cm, where appropriate. This database provides information on a range of soil attributes including soil texture, pH, SOC, carbon to nitrogen ratio, cation exchange capacity (CEC), base saturation, exchangeable Fe and Al content, and bulk density.

### *3.4.2 NEtwork monitoring Rewetted/restored peatlands and Organic Soils for climate and biodiversity benefits (NEROS) (EPA funded, UCD lead)*

The NEROS project (www.ucd.ie/neros/) was funded to set up a monitoring network of re-wetted/restored peatlands and organic soils in order to appraise their climate and biodiversity benefits. The project was funded between 2013 and 2015 to establish a network of both degraded and re-wetted and restored peatlands throughout Ireland where GHG fluxes and biodiversity components will be monitored. The ultimate aim was to provide high-quality information to guide policy decisions that recognise the climate change–biodiversity nexus and its benefits in facilitating Ireland's commitment to a more sustainable environment through the reduction of GHG emissions and conservation and sustainable use of a natural resource.

### *3.4.3 National Soils Database (NSDB) (EPA funded, Teagasc lead)*

(http://erc.epa.ie/safer/iso19115/displayISO19115.jsp?isoID=7)

This national-scale project has measured 40 chemical analytes in samples taken on a 10 $km^2$ basis to a depth of 10 cm. From 1995 to 2006, a countrywide geochemical survey was conducted sampling 1310 sites on a national grid (two samples per 10 $km^2$). Samples were analysed for SOC, pH and a suite of 40 chemical elements. The result has been the production of soil geochemical maps (an atlas) and a freely accessible database. This study also applied large-scale microbiological analysis of soils for the first time in Ireland and investigated microbial community structure in a range of soil types.

#### 3.4.4 CréBeo (EPA funded, UCD lead)

(http://erc.epa.ie/safer/iso19115/displayISO19115.jsp?isoID=239)

This project used approximately 60 of the NSDB sites, where it measured a range of soil biological properties. The analysis provides baseline data on the distribution and diversity of key soil micro- and macro-organisms: soil bacteria, mycorrhizal fungi, nematodes, ants and earthworms.

#### 3.4.5 Soil C (EPA funded, University College Cork (UCC) lead)

(http://erc.epa.ie/safer/iso19115/displayISO19115.jsp?isoID=107)

This project used approximately 60 of the NSDB sites, where it measured a range of soil carbon properties. The Soil C project provides a quantitative baseline understanding of SOC concentrations and soil carbon stocks in Ireland to a depth of 50 cm.

#### 3.4.6 TELLUS (EU Interreg IVA-funded regional mapping project, GSI and British Geological Survey (BGS) leads)

This project (http://www.tellus.ie/) collected soils and water data for the border counties (Donegal, Sligo, Leitrim, Cavan, Monaghan and Louth) to complement an Aerial Remote Sensing Survey. Geochemical topsoil (5–20 cm) data were collected on a scale of 1 sample per 3.5 $km^2$ and measured for approximately 50 chemical analytes.

#### 3.4.7 Agricultural Catchments Programme (DAFM funded, Teagasc lead)

The Agricultural Catchments Programme (http://www.teagasc.ie/environment/water-quality/agricultural-catchments/) is studying the source-to-water pathway for nutrients in agricultural systems, based on a number of catchments located around the country. Soils data are collected, but are not the focus of the research, as it is based around the Water Framework Directive and Nitrates Directive.

#### 3.4.8 Pathways (EPA funded, Queen's University Belfast lead)

(http://erc.epa.ie/safer/iso19115/displayISO19115.jsp?isoID=3082)

This project studied the source-to-water pathway for nutrients in agricultural systems, based on a number of catchments based around the country. Soils data were collected as part of this project, but are not the focus of the research, as it is based around the Water Framework Directive and Nitrates Directive.

#### 3.4.9 Demonstrating Best Practice in Raised Bog Restoration in Ireland (EU-LIFE-funded, Coillte lead)

(http://www.npws.ie/sites/default/files/general/Project%20Brochure%20for%20LIFE09%20222.pdf)

As part of the EU-LIFE funding mechanism, this nature conservation project is jointly funded by DG Environment, the DAHG and Coillte (The Irish Forestry Board) under the EU-LIFE Nature Programme. The project is being managed by Coillte and focuses on the restoration of 636 ha of raised bog habitat on 17 Coillte-owned sites within the Natura 2000 Network and in natural heritage areas. This project implements best-practice restoration techniques developed in Coillte's previous Raised Bog Restoration Project.

### 3.5 Final Stakeholder Workshop: Meta-data Workshop

*Peter Mooney, Einar Eberhardt and Francesca Bampa*

To follow up on the usefulness and application of such a meta-data catalogue, a special session was organised at the final stakeholder workshop in March 2014. The focus of the workshop was the use and application of meta-data in soils research. A summary of the discussions is provided below.

During the workshops, Dr Einar Eberhardt and Dr Peter Mooney delivered two presentations on:

- the INSPIRE SOIL implementation on meta-data;
- the general SAFER and SAFER-SOIL meta-data catalogue structure, implementation and use, created within the Soil Status and Protection project.

### *3.5.1 Key findings and take-home message*

- Meta-data have different meanings to different users and stakeholders. There seems to be general confusion or misunderstanding about different types of meta-data, which leads people to think that they are reporting information twice.
- Meta-data for resources, such as research projects, papers or reports, is an understandable concept for most scientists. However, meta-data for describing observational and modelled data can be an abstract concept, when the scientist is not involved in generating or managing this meta-data. They may be involved only in the field or laboratory data collection. Nonetheless, these data can be underpinned with dataset meta-data via 'Observations and Measurements', although this connection needs to be made more obvious by providing a logical schema for INSPIRE soils data.
- Despite all of the advances made in data- and information-handling software and technologies, there is still limited software tool support for meta-data, such as INSPIRE meta-data or ISO 19115 for Spatial Data. Where software tool support exists it is usually most efficiently and effectively used for new data collection or modelling projects. Data that have been collected in the past using different data formats, databases or structures remain documented using older or non-supported meta-data standards. It can be difficult for most researchers and scientists to understand why so many meta-data are required when adhering to standards such as INSPIRE meta-data or ISO 19115 for Spatial Data because in the past the requirements for meta-data were far fewer and less stringent.
- Becoming an expert user or practitioner of meta-data takes many years of training and experience. However, good support from software tools can help environmental scientists and researchers without this experience understand meta-data better. In some cases in soil science, researchers have resorted to building their own software tools in an effort to support the complex meta-data schemas of, for example, INSPIRE and ISO 1915. However, in general this is not the case and if good proprietary off-the-shelf software tool support is not available then there will always be a lack of uptake of meta-data in environmental science.
- Some users, depending on the application, may consider meta-data their primary data.
- Meta-data can contain thematic and attribute data about the data objects they are modelling, which can be used for other applications. Consequently, this adds to the value meta-data can provide, once the necessary steps are taken to ensure the meta-data are correct.
- In the soils field the monitoring setup can be very complex and there might not yet be adequate meta-data support from INSPIRE. Now and in the future, soil projects (and indeed any project with an INSPIRE thematic area) cannot simply separate the processes of environmental data collection and modelling and the more IT- or ICT-specific areas of data modelling, data structures and data management technologies. Meta-data should be one of the first things considered by any project and not the last as is currently the case in the majority of situations.
- *Take-home message*: There is an urgent need to provide better educational and software support for understanding the meta-data schema for the INSPIRE soils data. INSPIRE is a complex meta-data schema for most soil researchers and scientists. Indeed, INSPIRE is probably better understood by computer scientists and data scientists. It was clear in the workshop that participants found it difficult to differentiate the concepts of meta-data about data (e.g. what units a soil measurement should be recorded in or the use of general code-lists from which to pick names of scientific procedures, to minimise spelling errors) and general meta-data (the abstract for a project, project title, etc.). This needs to be addressed by providing educational and training support for environmental scientists to ensure that meta-data are not something that is left to IT people. Better support of INSPIRE meta-data in popular software tools such as GIS software is also necessary.

# 4 Soil-Monitoring Network Scheme

## 4.1 Development of Soil-Monitoring Concepts

In Ireland, the development of a consistent national-level SMN is still lacking. Evidence of the impact of external pressures on soil functions can be acquired only by making repeated observations and measurements of the soil (Arrouays, *et al*., 2012; Marchant and Arrouays, 2014). Soil monitoring is the systematic determination of soil properties over spatial areas and time to detect and record any changes. While an SMN can be defined as the set of sites/areas where the periodic assessment is carried out (Morvan *et al*., 2008), monitoring must be done at predefined time intervals and a strict spatial sampling system applied in order to compare samples over time and space to allow replication of the measurement. Soil properties can be defined as static or dynamic. Increasingly, an integrated approach is required that looks at the total soil system, not only assessing temporal and spatial patterning of soil processes, but also including variables in adjacent compartments to the soil, as well as external pressures that affect soil functions, including climate and management (EEA, 2001).

The design of an SMN must consider the geographical coverage and scale, within-site sampling and the variables to measure. The key characteristics of an SMN would include representativeness, a standard set of parameters and standardised methodologies for measurement. The designers of a monitoring scheme need to decide the spatial pattern (e.g. random selection or defined design, such as a regular grid, etc.) and the monitoring frequency. There are a number of challenges and difficult choices associated with the implementation of an SMN, including which soil indicators should be measured and the analytical methods that should be used. Marchant and Arrouays (2014) state that it is imperative that these indicators relate directly to the functions of the soil in question, and care should be taken when using historical data that measurements made many years apart are comparable. The application of spatial and temporal soil data for a range of soil properties/attributes to monitor and measure change in soil functions is further complicated by changes in the dynamic behaviour of soils based on climate and management.

An SMN needs to have a clear mandate, which can facilitate additional measures over time. It is necessary at the start to define the criteria for monitoring and assess the time scales necessary to measure change. For example, monitoring of soil organic matter should not be carried out annually, but rather should be assessed over a 5- to 10-year cycle, whereas soil biological measures would benefit from seasonal to yearly estimates. However, given the costs of the field component of any monitoring system, it would be impractical to measure all parameters at an ideal frequency. An intermediate solution would be to select a time frame that covers most properties sufficiently, while simultaneously addressing the issue of the sampling costs. Alternatively, a two-tier system could be applied, as proposed in the UK (Black *et al*., 2008).

Figure 4.1 provides a conceptual diagram that should be considered in assessing what to monitor, why and when. ‘Routine observation’ refers to routine monitoring of a comprehensive suite of soil properties that are representative of soil quality in an Irish context, at robust spatial and temporal scales, capturing change for reliable decision making. This can be coupled with a parallel but complementary investigative or evaluation-based approach on a smaller number of sites, representative of the main monitoring network, but monitoring dynamic soil properties at a higher temporal resolution.

There is a growing need to use existing soil data to inform research and policy and to increase awareness of soils and their associated functions. When possible, existing datasets should be utilised. Morvan *et al*. (2008) state that accurate global positioning system (GPS) location data must exist and that one or more measuring campaigns must already have been conducted or future measuring campaigns be planned. To facilitate the current review carried out by this project on soil monitoring requirements in Ireland, Table 2.2 provides a list of the current policy drivers both nationally and at a European scale, which may require reporting in the future.

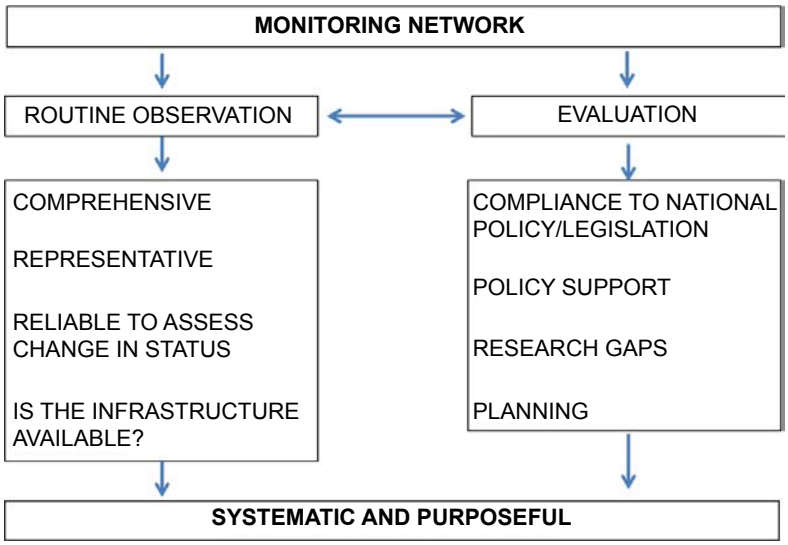


**Figure 4.1. Overview of requirements of a soil-monitoring network.**

An initial appraisal of the soil projects using the SAFER-SOIL meta-data catalogue highlighted a lack of continuity in the measurements of soil property data both spatially and temporally (e.g. grid-based versus random sampling design, different density of sampling across projects, depth of samples taken, sampling frequency – most sites have only been sampled once). We are not now in a position to use current datasets from the large-scale national and regional projects, to infer soil quality changes, trends or scenarios in Ireland over time, for the major soil properties (e.g. SOC stock). Therefore, this project recommends that a systematic monitoring framework be developed that builds upon existing data where possible, but is not biased as a result of it (by sampling design or methodology).

In summary, the following key points should be considered in designing a monitoring scheme:

1. What is the purpose behind a monitoring network? Should a monitoring scheme be a *routine observation* of standard soil properties over time or an *evaluation* of change of a particular property/set of properties to support policy requirements?
2. When developing a monitoring scheme, do we design a new monitoring programme or utilise existing legacy sites? These may include sites used in previous research projects.
3. Finally, should a monitoring network be systematic and/or purposeful? A systematic sampling approach would imply a grid-type sampling design, while a purposeful one would suggest a stratified random approach, where site selection is first based on a stratification of either land use or soil type, or a combination of the two, followed by random selection of replicate sites within the stratified category.

## 4.2 Soil Monitoring Networks Elsewhere in Europe

To develop a monitoring system, it is important to consider existing monitoring and related activities on soil within EU MSs and at EU level and to make use of them in order to find a suitable strategy for Ireland (see Table 4.1). Both grid and stratified sampling approaches have previously been applied in existing monitoring systems (Rutgers *et al*., 2009; Saby *et al*., 2009; Chapman *et al*., 2013); therefore, both options would seem applicable to an Irish application. The size of the grid varies considerably between countries; for example the French Réseau de Mesures de la Qualité des Sols (RMQS) monitoring system applies a 16 km grid, while the National Soil Inventory (NSI) in England and Wales is implemented using a 5 km grid. Sampling frequency is often dependent upon external drivers (such as available budget or political support), rather than a specific decision on sampling interval at the start of the programme of work. The French RMQS was originally sampled in 2004 and will be repeated in 2016, when 200 sites will be randomly selected from the total dataset and re-sampled each year for a 12-year period (Nicolas Saby, INRA,

**Table 4.1. Soil monitoring systems in Europe**

| Territory | Sampling programme | Sampling design | Sampling frequency | Number of sites | Source |
|---|---|---|---|---|---|
| **France** | RMQS | 16 km grid | 12 years | 2200 | Saby *et al.*, 2009 |
| **Great Britain** | Countryside Survey | Stratified on land use classes | 1978, 1998, 2007 | 591 | Black *et al.*, 2003 |
| **England and Wales** | NSI | 5 km grid | 1983, 1995 | 6127 with 1800 re-sampled in 1990s | Bellamy *et al.*, 2005 |
| **Scotland** | NSIS | 10 km grid | 1978–1988, 2007–2010 | 721 soil profiles, 195 revisited | Chapman *et al.*, 2013 |
| **Netherlands** | Biological Indicators for Soil Quality (BISQ) | Stratified random sampling based on land use × soil types | 1999 | 300, 60 sites revisited per year | Rutgers *et al.*, 2009 |
| **Germany** | Permanent Soil Monitoring Sites | Stratified approach to cover a variety of specific site conditions | Every 10 years from 1986 | 829 | Barth *et al.*, 2001 |
| **Europe** | Land use/Cover Area Frame Statistical survey (LUCAS Soil) | 2 km grid sampled by land use data across 23 MSs | 2009, 2014 | 20,000 | Tóth *et al.*, 2013a |
| **Europe** | Geochemical Mapping of Agricultural and Grazing Land Soil in Europe (GEMAS) | One site per 2500 $km^2$, from each of 33 European countries | 2009 | 2108 sites on arable land (0–20 cm) and 2023 sites on grassland (0–10 cm) | Reimann *et al.*, 2014 |

November, 2015, personal communication). The NSI for Scotland (NSIS) was originally sampled between 1978 and 1988, with a re-sample of a subset of sites taking place between 2007 and 2010.

## 4.3 Current Situation in Ireland

Three large-scale national/regional soil projects have been used as the basis for assessing future monitoring options (Figure 4.2). In their paper, O'Sullivan *et al.* (submitted) investigate options for an SMN for Ireland and consider the following existing datasets as baseline options.

### *4.3.1 Existing national datasets*

*National Soils Database (NSDB)*

The NSDB includes a soil geochemistry dataset including 1310 soil samples, of which 1015 were collected between 2003 and 2015 on a national grid, two samples per 100 $km^2$ (Fay and Zhang, 2007). These samples were added to existing data surveyed by Teagasc between 1995 and 1996 (McGrath and McCormack, 1999). The NSDB also includes a subset of 60 sites that are measured for biological parameters captured within the CréBeo Soil Biodiversity (Schmidt, 2015) and Soil-C (Kiely *et al.*, 2009) projects. Sample data from this project are freely available at http://erc.epa.ie/safer/iso19115/displayISO19115.jsp?isoID=7 (Fay and Zhang, 2016).

*Irish Soil Information System*

A total of 228 reference pits were dug in a field campaign between 2012 and 2013. Horizon-level data were analysed for a suite of chemical properties, soil textural analysis, physical properties, including bulk density, and biological properties. Methods included multiple substrate-induced respiration (MSIR) and phospholipid fatty acids (PLFAs). Soil samples were also collected for carbon fractionation analysis at a subset of sites. Sample data from this project are freely available at http://erc.epa.ie/safer/iso19115/displayISO19115.jsp?isoID=3074 (Creamer, 2016).

*Tellus project data*

Completed in 2013, the Tellus Border was an EU Interreg IVA-funded regional mapping project, collecting geo-environmental data on soils, water and rocks in the six border counties of Ireland (Tellus, 2015). Tellus is a geoscience mapping programme both on the ground and airborne, and maps a suite of geochemical and geophysical properties. Tellus data are made freely available online to download: http://spatial.dcenr.

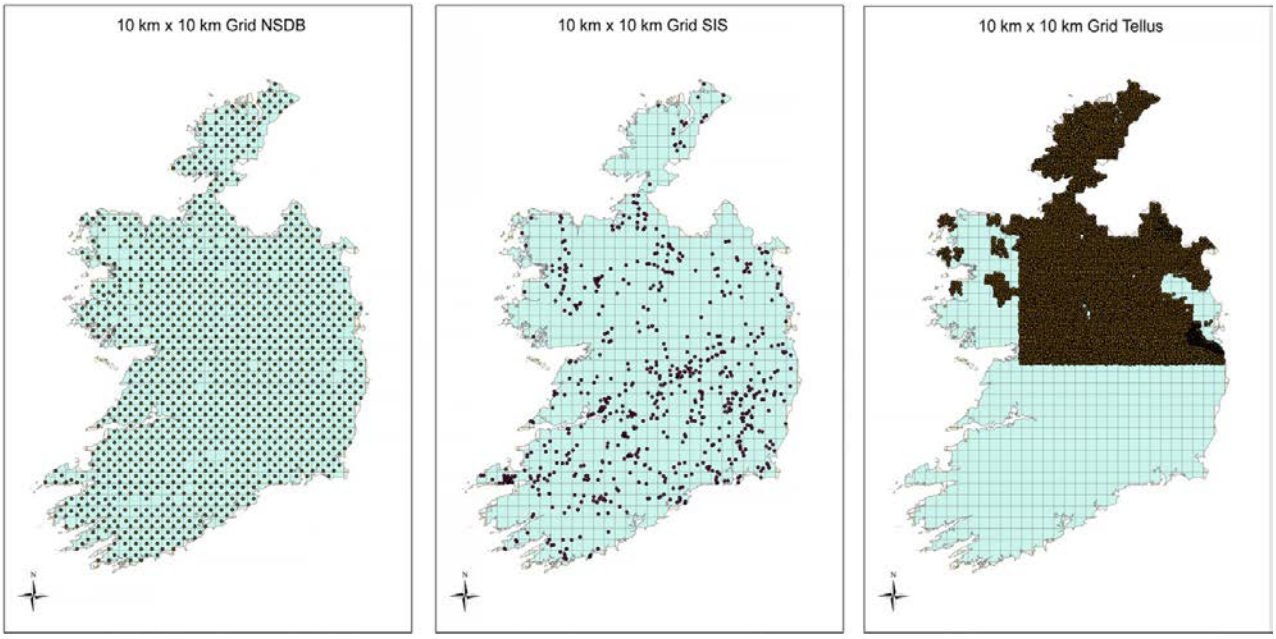


**Figure 4.2. Spatial distribution of three national-/regional-scale soil projects.**

gov.ie/GeologicalSurvey/TellusBorder/index.html (see Scanlon and McGinn, 2013 for terms).

### *4.3.2 Geographical coverage of existing datasets and representativeness analysis*

O'Sullivan *et al*. (submitted) find that the NSDB dataset represents the best geographical coverage, while Tellus sites are concentrated in the northern half of the country (Figure 4.2). Like the NSDB, the Irish SIS sites are spread across the country, albeit not as uniformly as the NSDB. Tellus sites are geographically concentrated, but have the highest point density in the locations where they occur.

Because of a growing demand for interoperability of SMNs between EU MSs, the representativeness analysis considered different soil-monitoring approaches as utilised elsewhere, including:

- Geochemical Mapping of Agricultural and Grazing Land Soil (GEMAS) (50 km × 50 km) over agricultural soil (0–20 cm) and grazing land (0–10 cm) across 33 European countries;
- French National Soil Quality Monitoring Network (RMQS) (16 km × 16 km);
- National Soil Inventory for Scotland (NSIS) (10 km × 10 km);
- National Soil Inventory for England and Wales (NSI) (5 km × 5 km);
- Biological Indicators for Soil Quality (BISQ) – approximately 300 locations in the Netherlands across multiple land use types have been investigated and analysed for soil biological characteristics (Rutgers *et al*., 2009);
- Land use/Cover Area Frame Statistical Survey (LUCAS) (2 km × 2 km) collecting information from EU MSs on land cover and land use.

The application of different grid sizes resulted in a wide range in the number of (internal) grids, from 49 for 50 km to 18,858 for 2 km (Table 4.2). The application of a known spatial coverage threshold is necessary to allow a known extent for any geostatistical analysis or applications to be carried out. Because of the limitation of utilising only full grids, an arbitrary 40% minimum coverage threshold was applied. The grid sizes reflect an inverse relationship between grid spatial extent and percentage geographical coverage; the smallest grid size, unsurprisingly, facilitates the highest geographical capture (93.8%). A grid size of 50 km is likely to capture changes in soil quality insufficiently for a country of Ireland's size. Conversely, the 2 km and 5 km grids are likely to quickly become cost-prohibitive and too intensive from the perspective of repeatability or monitoring frequency. Of the varying spatial grid sizes, either 16 km or 10 km achieves the highest geographical coverage and the highest grid capture. This is comparable to the NSIS (10 km), which surveyed 721

**Table 4.2. Sites and grid representativeness**

| Grid extent (total number) | 40% minimum (geographic coverage) | Data source | Intersecting points | Grid capture (%)* | Minimum points (per grid) | Maximum points (per grid) |
|---|---|---|---|---|---|---|
| 50 km × 50 km (49) | 63.27% (*n* = 31) | NSDB | 1183 | 100 | 18 | 50 |
| | | SIS | 727 | 100 | 1 | 63 |
| | | Tellus | 6858 | 64.52 | 12 | 692 |
| 25 km × 25 km (161) | 72.67% (*n* = 117) | NSDB | 1244 | 100 | 3 | 13 |
| | | SIS | 762 | 88.03 | 1 | 41 |
| | | Tellus | 7170 | 51.3 | 1 | 280 |
| 16 km × 16 km (359) | 79.11% (*n* = 284) | NSDB | 1263 | 100 | 1 | 8 |
| | | SIS | 761 | 72.54 | 1 | 22 |
| | | Tellus | 7270 | 47.18 | 1 | 141 |
| 10 km × 10 km (860) | 83.14% (*n* = 726) | NSDB | 1283 | 98.48 | 1 | 3 |
| | | SIS | 778 | 46.28 | 1 | 21 |
| | | Tellus | 7551 | 46.28 | 1 | 69 |
| 5 km × 5 km (3215) | 88.71% (*n* = 2852) | NSDB | 1296 | 45.44 | 1 | 1 |
| | | SIS | 781 | 17.99 | 1 | 12 |
| | | Tellus | 7625 | 42.36 | 1 | 27 |
| 2 km × 2 km (18,858) | 93.79% (*n* = 17,687) | NSDB | 1302 | 7.36 | 1 | 1 |
| | | SIS | 796 | 4.5 | 1 | 1 |
| | | Tellus | 7627 | 43.12 | 1 | 1 |

***Of minimum 40% geographic coverage, proportion of grids intersected at varying spatial extents by data source.**

sites across Scotland from 1978 to 1998 and re-sampled 195 sites between 2007 and 2010 (Chapman *et al*., 2013).

An SMN must also consider pressures that affect soil quality. In Ireland, the natural soil drainage class, land use and management are considered key drivers of soil quality. O'Sullivan *et al*. (submitted) conclude that requirements for an SMN for Ireland could be satisfied using either a 10 km or a 16 km stratified network based upon land use and soil drainage class. Although the results of the 10 km grid yielded a slightly better result than the 16 km grid, this would be offset by the increased costs associated with smaller grid size.

A final issue to take into consideration is the heterogeneous nature of many soil measurements and properties, which can be described as static (samples that require one-off measurements, such as soil texture) or dynamic (properties that may vary over short periods of time because of local management/environmental conditions, such as soil phosphorus). A two-tier approach would facilitate this problem, by measuring static and slow-turnover soil properties (SOC, bulk density, etc.) on a 5- to 10-year cycle, whereas more temporally sensitive measures (e.g. soil respiration) could be measured at a subset of sites on a more regular basis, or as part of integrated research projects into the framework. In Ireland, the Irish SIS dataset contains the most comprehensive data in relation to static properties such as texture, which has been measured to a depth of 1 m or bedrock. Certain parameters, such as soil biodiversity, are likely to be better captured by the CréBeo Soil Biodiversity project, which is a subset of the NSDB.

Along with the spatial heterogeneity of soil types and/or land use categories dominant across Ireland, the monitoring framework must be able to adapt to changes including future measurements and policy developments over time (Tables 4.3 and 4.4). Table 4.3 presents a list of the current policy drivers relevant at national or EU level that are linked to soil monitoring.

Table 4.4 highlights the main soil properties measured to respond to current policy requirements. O'Sullivan *et al*. (submitted), deploying a similar approach, infer a baseline of soil properties that would be required as a minimum dataset within an SMN, which aligns with Table 4.4 presented here.

**Table 4.3. List of policy drivers linked to soil monitoring**

| Policy drivers | Scale |
|---|---|
| CAP Pillar 1 (greening measures, cross-compliance) | EU |
| Agri-Environment Schemes (REPS, Agricultural Environment and Options Scheme (AEOS), GLAS, etc.) | EU/national |
| Food Harvest 2020 and 2025 | National |
| Nitrates Directive | National |
| Water Framework Directive | EU |
| UNFCCC/2020 Climate and Energy Package/2030 Framework For Climate and Energy Policies | International |
| Climate Action and Low Carbon Development Bill 2015 | National |
| Habitat Directive/National Biodiversity Strategy | National |
| Sewage Sludge Directive | National |
| Environmental Impact Assessment (EIA) and Strategic Environmental Assessment (SEA) Directives | National |
| Sustainable Use of Pesticides Directive | National |
| Forestry Sector Action Plan 2014–2020/EU Forestry Strategy | National/EU |
| ANCs/LFA/Disadvantaged Areas | EU |
| Floods Directive | EU |
| Environmental Liability Directive | EU |
| Other (former EU proposal for a Soil Thematic Strategy, future Communication on land as a resource, Bird Directive, etc.) | EU/national |

## 4.4 Future Needs

The research by O'Sullivan *et al*. (submitted) provides a starting point for the development of an SMN for Ireland. However, they also emphasise the following as implicit requirements that must be considered within an SMN:

- Standardised methodologies must be defined and deployed at field and laboratory level.
- Thresholds or trigger points for action in relation to changes in soil properties must be established.
- A clear mandate for action must be defined where changes in soil quality are found.
- A harmonisation function to allow an Irish SMN to be interoperable with those of other EU MSs must be developed. Further work to align final SMN strategy to incorporate sites from LUCAS and GEMAS systems would be recommended.

## 4.5 Final Stakeholder Workshop: Soil Monitoring

*Rachel Creamer, Reece Hill and Lilian O'Sullivan*

### *4.5.1 Objective*

The objective of this workshop (March 2015) was to conceptualise a national soil-monitoring system for Ireland to assess changes to soil quality over time. The workshop adopted a participatory approach whereby participants were placed into five teams to develop, propose and present their strategy for a soil-monitoring system for Ireland. The workshop, led by Dr Rachel Creamer, included 26 participants representing the EPA, DAFM, researchers and students from GSI, Teagasc, UCC, UCD, UL and Institute of Technology Sligo. The opening keynote address, delivered by Dr Reece Hill, described the evolution of the soil quality monitoring programme in the Waikato Region in New Zealand. Areas of focus included soil mapping, soil-landscape interpretation, soil description, sampling strategy and soil and land monitoring.

### *4.5.2 Toolkit*

To facilitate teams in the development of their soil quality monitoring strategy, groups were provided with a toolkit. This included a summary sheet of all direct/indirect policy drivers that currently drive soil quality in Ireland. Other materials included a national soils map, a land use map and an indicative drainage map. Transparent grid sheets at scales of 2 km × 2 km, 10 km × 10 km and 16 km × 16 km were also provided. Posters on other soil-monitoring schemes in Europe (as described in Table 4.1) were provided to inform the stakeholders of the various options for monitoring in place across Europe.

**Table 4.4. Soil-Monitoring Network Framework based on soil policy drivers**

| Policy driver | Soil property | Projects with related information |
|---|---|---|
| **Productivity-related drivers** | | |
| CAP Pillar I (greening measures, cross-compliance) | SOC (arable land); GAEC (erosion, organic matter) | Soil Quality Assessment Research (SQUARE) Project |
| ANCs/LFA/Disadvantaged areas 2014–2020 | Trafficability, stoniness, drainage, depth, soil texture | Irish SIS |
| AGRI-ENV (GLAS priority for entry I, II, III, REPS, AEOS, etc.) | pH, P, K, drainage | Irish SIS (indicative soil drainage map); Soil H |
| Food Harvest 2020 and Food Wise 2025 | pH, P, K, drainage, SOC, Mehlich-3 P + Al + Ca + Fe, etc. | NSDB; Irish SIS; TELLUS Border; Pathways; Quantification of Phosphorus Loss from Soil to Water; Soil H; LUCAS-SOIL; Agricultural Catchments Programme |
| GMO | | AMIGA |
| **Directives** | | |
| Nitrates | P Morgan, [a]total P, [a]pH, loss of ignition, organic matter [%]; Mehlich-3 P + Al + Ca + Fe, etc. | NSDB; Irish SIS; TELLUS Border; Pathways; Quantification of Phosphorus Loss from Soil to Water; Quantification of Erosion and Phosphorus Release from a Peat Soil Forest Catchment; LUCAS-SOIL |
| Water Framework | Hydrology/pathways, thickness, porosity, hydraulic conductivity and absorptive properties of the deposits and soils, carbon, clay content to calculate erosion potential | Irish SIS (indicative soil drainage map); Soil H |
| Floods | | Irish Flood Warning System; www.floodmaps.ie |
| Sewage sludge | Heavy metals; soil health/soil biodiversity[a]; soil pathogens | LUCAS-SOIL; *The Geochemical Atlas of Europe* |
| Pesticides | PCBs; pesticides | |
| Habitats | pH; soil biodiversity[a] | EcoFINDERS; CréBeo; Irish SIS |
| **Climate change** | | |
| Climate Action and Low Carbon Development Bill 2015 | Carbon (SOC content/stock/ sequestration potential); drainage; land use; aggregate fractions/carbonate associate | Irish SIS; Soil C; Soil H; Mapping the Extent of Peat in Ireland; BOGLAND; NSDB; CARBiFOR (I and II); FORESTSOILC; FORSITE CForRep; National Forest Inventory; LUCAS-SOIL; Identification, Mapping, Assessment and Quantification of the Effects of Disturbance on the Peat Soil Carbon Stock in Ireland; Acquisition of Essential Data for Assessments of Carbon Sequestration by Soils; Quantification of Erosion and Phosphorus Release from a Peat Soil Forest Catchment |
| Forestry Sector Action Plan | Sediments; pH; dissolved organic carbon and dissolved organic nitrogen; P, SOC content, SOC stocks; bulk density | CARBiFOR (I and II); FORESTSOILC; National Forest Inventory; Quantification of Erosion and Phosphorus Release from a Peat Soil Forest Catchment |
| **Environmental assessment** | | |
| Environmental Liability Directive | Heavy metals; soil health/soil biodiversity[a]; PCBs; pesticides | |
| EIA and SEA | Drainage operation; SOC[a]; [a]soil biodiversity | Irish SIS |

**[a]Potential attribute.**

**PCB, polychlorinated biphenyl.**

### *4.5.3 Key findings and take-home messages*

- There was a high level of consensus across groups, with the exception of one group, which indicated a need for better research information to target specific questions, for greater spatial resolution geographically on soil types and for more knowledge of the changes at depth first.
- Generally, all groups agreed that any scheme should build upon existing data from national projects, where possible.
- Although they differed on the logistics of delivering a monitoring strategy (Appendix 3), the need to track temporal changes was a high priority for all groups.
- Dissemination must be a natural extension to the monitoring system at both farm and policy levels.
- The majority of groups cited a range of physical and chemical indicators as important indicators to be monitored (Appendix 3). In general, all agreed that a suite of chemical and physical indicators should be included and, where possible, build on the existing data.
- Overall, based on the workshop discussion, biodiversity was reflected as a lower priority.
- The development of an archive was considered essential for unknown future requirements.

# 5 Knowledge Transfer

The main KT and dissemination activities in this project have been applied in two specific ways: (1) multi-stakeholder workshops and (2) educational materials and engagement. A strong science–policy interface that can foster collaboration and knowledge exchange is essential for finding solutions to complex environmental challenges. Meeting the challenge of sustainability relies, in part, on researchers communicating scientific findings to policymakers, educators and land managers in an understandable way that will help them develop policies, education and land management decisions aimed at sustainable solutions to agri-environmental land and soil management. This project targeted a broad range of national stakeholders dealing with soil from different perspectives to participate in two participatory catchment model workshops to design-optimise the delivery of a suite of *soil functions* at two farms in a modal catchment. The cross-cutting activities involved policymakers and legislators, primary, secondary and tertiary educationalists (e.g. teachers, university researchers), farmer representatives and governmental institutes.

National and international soil experts were also invited to a final project workshop in March 2015, to capture the stakeholders' opinions on the major findings of the project.

## 5.1 Multi-stakeholder Workshops

Following the concept of functional land management developed by Schulte *et al*. (2014), two workshops were carried out, focusing on the multi-functionality aspect of soils and on the concept that all soils, in principle, have the capacity to perform all functions to some extent, simultaneously (Haygarth and Ritz, 2009). The five soil functions taken into account (Schulte *et al*., 2014) were:

1. primary productivity [production of food, fibre and (bio)fuel, which traditionally is the soil function that provides a livelihood to farmers and associated sectors in the rural environment];
2. water purification;
3. carbon sequestration;
4. habitat for biodiversity;
5. recycling of (external) nutrients/agro-chemicals.

However, soils differ in their relative capacity to perform each of these functions. The capacity depends on soil type, and land use and management, with some land use/management types incentivising specific functions. The two workshops engaged different stakeholder groups. Workshop 1 engaged policymakers, focusing on the assessment and maximisation of policy tools to achieve multi-functionality of soils in a hypothetical catchment, while in workshop 2 land managers/advisors were invited to assess the variability in decision making at the land management level.

While both workshops prioritised soil functions in a similar fashion, with primary productivity ranked first, there were differences in the order of priority of the other functions. A key recognition by the project team following the two workshops was the importance of tailoring the language used to the audience, when presenting and discussing soils with different stakeholder groups. The policymaker audience used policy tools to discuss and inform decision making in the catchment, while this was not suitable for the land managers, who discussed more detailed land management strategies, such as ploughing depth and drainage type. Both stakeholder groups underlined the need for more education and KT in this area and praised the approach of a catchment-scale model to discuss the issues of soil and land quality.

## 5.2 Final Stakeholder Workshop

The final stakeholder workshop took place in the EPA, Johnstown Castle Estate, County Wexford, on the 24 March 2015. The focus of the workshop was a review of soil knowledge and research to date in Ireland and discussion of research priorities for Irish soil. The target audience for this meeting was identified by a review of soil stakeholders in Ireland. Attendees included policymakers, government representatives, researchers, education officers, members of local authorities, parks and wildlife specialists, farmers, gardeners, etc. The workshop was opened with a talk by Dr Arwyn Jones of the Land Resource Management Unit, EC JRC, followed

by an overview of the Soil Status and Protection project, by Dr Francesca Bampa.

The final part of the morning session was a roundtable discussion with 12 stakeholders chaired by Dr Rogier Schulte, on the issue of 'Moving forward: what are the key priorities for soils in Ireland?' The stakeholders provided a range of different perspectives and backgrounds (Appendix 4).

An article regarding the final stakeholder workshop can be found in the Teagasc journal *TResearch*, Autumn 2015. This article was written in co-operation with all the invited speakers and can be found in Appendix 6.

### *5.2.1 Key findings and take-home message*

Take-home message: information and data on soil protection in Ireland are available but lack continuity in collection (harmonisation), monitoring and a common framework. As a summary of the panel discussion (see Table 5.1), all the attendees agreed on the following keywords as representative of the previously discussed knowledge gaps for better managing our land:

- harmonised;
- holistic;
- monitoring;
- interpretation;
- knowledge transfer.

> The challenge is to get our own education and knowledge and to become our own scientist.
>
> From the Soil Status Final Stakeholder workshop discussion, Johnstown Castle, Wexford, Ireland March 2015

## 5.3 Development of a Communication Strategy for Soils Information

### *5.3.1 2015 International Year of Soils*

In December 2012, the FAO approved the Terms of Reference of the GSP and recommended its immediate implementation. The mandate of the GSP is to improve governance of the limited soil resources of the planet in order to guarantee healthy and productive soils for a food-secure world, as well as supporting other essential ecosystem services, in accordance with the sovereign right of each State over its natural resources. In addition, the Intergovernmental Technical Panel on Soils (ITPS) was launched in June 2013. The International Year of Soils 2015 serves as a platform for raising awareness on the importance of sustainable soil management as the basis for food systems, fuel and fibre production, essential ecosystem functions and better adaptation to climate change for present and future generations. The FAO GSP has supported the Soil Status and Protection project, as one of the awareness-raising projects taking place in 2015, as part of the IYS 2015 campaign.

### *5.3.2 Soil Science Society of Ireland: Working Group on Education and Awareness*

On 14 October 2014, Teagasc colleagues and representatives of the Soil Science Society of Ireland (SSSI) and other education institutes established a working group on soil education and awareness. This was in response to the agenda for the IYS 2015 campaign promoted by the GSP. The working group met to discuss with primary, secondary and tertiary teachers/lecturers

**Table 5.1. Summary of discussion from stakeholder workshop, March 2015**

| Soil meta-data | Soil monitoring | Soil education |
|---|---|---|
| Meta-data has a different **meaning** to different users and stakeholders<br>Meta-data for **objects** (e.g. research projects, research papers, reports) versus meta-data for **data** - as in the **INSPIRE Data Specification Soil**. Urgent need to provide better support for understanding<br>Limited **software tool support** for meta-data<br>Meta-data are data in their own **right** | **Forthcoming monitoring network designs** should build upon existing data and systems in place<br>Able and responsive to **track temporal changes** over time<br>Should include as many parameters as possible, as major cost is visiting the sites<br>Flexible to include further **parameters** to support future policies at national and EU level (e.g. microbial activity)<br>**Archive development**<br>**Timelines, costs and sampling scales** raised discussions and did not reach a common agreement | **Stakeholders** interested in raising soil awareness and soil education were teachers from primary and secondary levels, farmers, scientific policy officers from national governmental bodies, researchers, Irish charities, non-governmental organisations, private consultancies, environmental journalists and soil supporters<br>An **educational soil package** of learning tools to teach about soil functions at different education levels (primary, secondary and tertiary) and in different audience languages (public and policymakers)<br>Posters<br>Soil investigations |

to determine how soils could be further incorporated into the national/local curricula. A consensus of the group was that the current inclusion of soils in the secondary education syllabi was outdated and uninspiring, both for teachers and for students. The goal is to get soil into the school programmes at different levels: primary level with simple concepts and activities, and secondary level with low-tech experiments inserted in the different curricula. It is recognised that soils can currently be taught within the agricultural science and geography subjects at secondary level, but that there are many other subjects that could include soils as a tool for teaching, for example biology, with the inclusion of soil biota and utilising microscopes to visualise soil biota. The final outcome of this kick-off meeting was the development of some simple materials for teachers to use. A PowerPoint slideshow on the soils of Ireland will be made available on the SSSI website, and posters on soil functions will be further refined in line with comments from teachers, to provide some visual examples of the functions that soils provide. Since the finalisation of this project, secondary teaching materials have been developed by Teagasc in conjunction with AG Education Services, which provides these materials to all secondary schools in the country.

#### *5.3.3 EPA SOER: Soils Chapter*

A detailed review was completed of the 2012 SOER. To complete this task, the report was sent to a large number of the research stakeholders affiliated to this project, at Teagasc, UCD and UL. The main findings of this review are detailed below:

- This report is focused on the issue of soil threats, as proposed by the SFD proposal. Since the withdrawal of the SFD proposal, research has focused on the positive message of soil functions and this should be the focus of the 2016 SOER.
- Since the publication of the 2012 SOER there have been considerable developments in soil science research in Ireland. Therefore, the 2016 SOER should highlight some of the projects that have been completed in the last 4 years, such as Soil H and the Irish SIS project.
- There is very little information relating to agricultural landscapes in the 2012 SOER. This should be significantly increased, as agricultural land management accounts for approximately 64% of the land area in Ireland.
- Soil-related policies and legislation have changed significantly in the last 4 years. This needs to be updated in the 2016 SOER. We recommend using the policy review in Chapter 2 of this report to provide the basis for updating this information.
- Sections on the functions provided by soils would provide a useful overview of the services provided by soils. This should include primary productivity, nutrient cycling, water purification and regulation, habitat for biodiversity and carbon sequestration.

### 5.4 Final Stakeholder Workshop: Soil Education

*Francesca Bampa and William Considine*

One of the parallel workshops run in the afternoon of the final stakeholder workshop focused on the work done on a communication strategy: soil education and awareness. During the workshop, the attendees developed activities and educational materials to promote soil awareness at different educational levels (primary, secondary and tertiary). The number of participants was 20 and included representation from Teagasc, the EPA, the GSI, primary, secondary and tertiary teachers, researchers and students from tertiary institutions.

The core purpose of the workshop was to highlight the strong need to think differently about soils and their functionality. It produced some concrete outputs. From this workshop, the project team and the attendees produced a number of recommendations for teaching soil functions at different levels (see Appendix 5).

#### *5.4.1 Key findings and take-home message*

Take-home message: one system of communication and dissemination does not fit all stakeholders. For this reason, different structures and systems need to be developed for a number of different stakeholder frameworks. Suitable frameworks need to inform policymakers, farmers (the major stakeholder in soils), education (primary, secondary and tertiary) and the general public.

# 6 Soils Research Needs

The Soil Status and Protection project has completed an evaluation of existing projects, current policy and legislation requirements in relation to soil and stakeholder opinions. As a result of this full review, the project will put forward a number of requirements for future research calls on the basis of:

- policy requirements and how these can be benefited by future research;
- gap analysis of existing data;
- providing a framework for future soil monitoring and highlighting the main requirements of such a monitoring network;
- highlighting stakeholder requirements and how these can be facilitated by research and KT projects in the future.

The online meta-data catalogue provides summary information on existing and completed soil research projects, with details on scale, climate, functions, threats, policy drivers, etc., where provided in the project reports.

## 6.1 Review of Soils Research Strategies (EU/National)

Funding for research into soil quality and related topics is supported in Ireland by EPA, DAFM, DECLG, the GSI, Teagasc, SFI and universities. At a European level, funding is available through a range of mechanisms including Horizon 2020, Framework Projects (FP7, FP6, etc.), LIFE projects, Cooperation in Science and Technology (COST) Actions, Marie Skłodowska-Curie Actions, ERC grants and joint programming initiatives (JPIs). Of these, the major funding streams supporting soils research in Ireland are detailed in the sections that follow.

### *6.1.1 EPA Soils and Land use/Land Cover Research*

(http://www.epa.ie/pubs/reports/research/eparesearch-strategy2014-2020/workshopsdiscussiondocuments/soilsandlanduseresearchworkshops/Soils_&Landuse_Landcover_Res_Priorities_2014_2016.pdf)

The EPA Research Programme 2014–2020 in the Soils and Land use/Land Cover areas will support the development of sustainable soils and land use policies. This includes research to ensure a sustainable use of soil and better appreciation of the role of soil functions in providing a range of ecosystem services. In addition, the EPA has highlighted in its 2014–2020 programme that activities in this period will also focus on sustainable urban and land use policies.

### *6.1.2 DAFM SHARP research agenda*

The DAFM SHARP research agenda (https://www.agriculture.gov.ie/research/) focuses on the vision for the Agri-Food and Bioeconomy sector, by operating three competitive agri-food research-funding programmes: the Food Institutional Research Measure (FIRM), the RSF, and the programme of Competitive Forestry Research for Development (COFORD). Each of these provides a framework for agricultural-based research. FIRM is based on research funding for the food research sector. RSF funding focuses on agri-environment: biodiversity, nutrients and gaseous emissions, animal bioscience, plant bioscience, non-food uses of agricultural land/produce, plant health, forestry, agri-economy and associated policy areas. COFORD funding is aimed at forest research and development.

### *6.1.3 Department of the Environment, Community and Local Government statement of strategy for 2011–2014*

(http://www.environ.ie/sites/default/files/migrated-files/en/Publications/StatisticsandRegularPublications/StrategyStatements/FileDownLoad,29675,en.pdf)

This statement of strategy does not highlight the issue of soil protection and status; however, one of the mission goals is to achieve a high-quality environment with effective environmental protection, and this may incorporate the protection of soil, although it is not explicitly stated in the document.

## 6.2 Methodology Used to Identify Research Needs

A thorough review of soil projects that have been funded in the last 15 years was completed as part of the Soil

Status and Protection project. This review identified the main funding mechanisms for soil-related research and the key topics that have been supported. Figures 6.1 and 6.2 provide an overview of the commonly applied words written in the project meta-data abstracts, describing the various projects funded by the EPA and DAFM, respectively. EPA-funded research has a focus on nutrient transport, water quality and carbon and biodiversity management, with a large focus on peatlands, while the DAFM-funded projects are soil management and production orientated, also with a focus on soil carbon.

Future research needs have been identified through the mechanisms described above in this chapter: assessing policy requirements, gap analysis of research to date, monitoring requirements for the future and KT requirements identified by stakeholders. A review of existing projects in Ireland supported by a range of funding agencies was completed (Chapter 3). In total, 109 projects were analysed and incorporated into an online meta-data catalogue. As a result of this review a number of research recommendations are detailed in section 7.5.

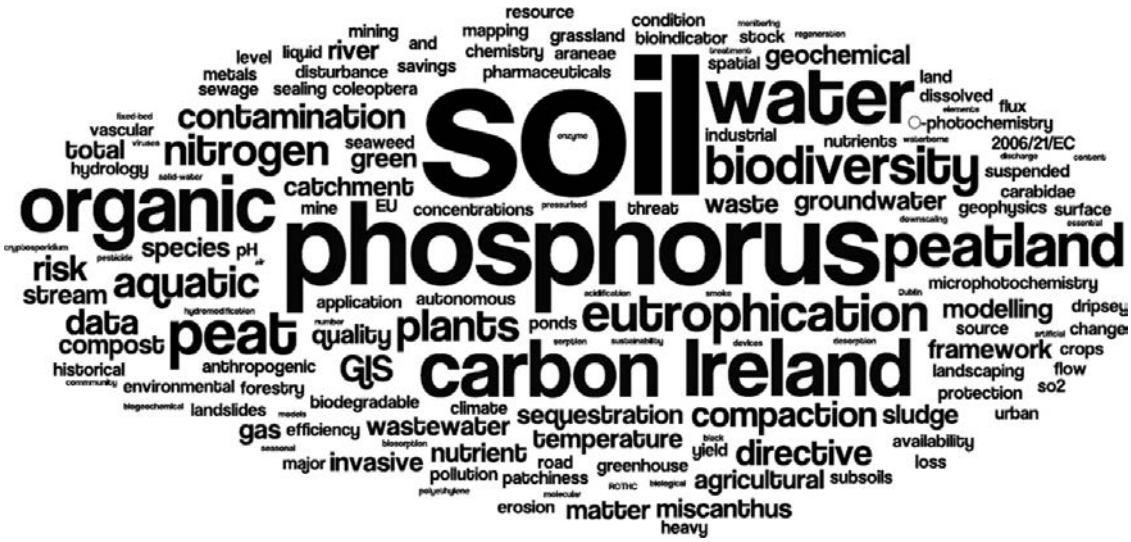


**Figure 6.1. EPA-funded research: project abstracts word cloud generated using Wordle.**


**Figure 6.2. DAFM-funded research: project abstracts word cloud generated using Wordle.**

# 7 Recommendations

## 7.1 Recommendations Following a Soil Policy Review

The Soil Status and Protection project has provided an overview of the policy and legislative drivers currently dealing with soil protection, at both the European and the national scale (Chapter 2). With the withdrawal of the SFD proposal in 2014, there is no overarching legislation concerning soil protection or preservation. However, there are a number of other policies at the European level that address the role that soil plays in the wider environment. At the national level there is very little information or legislation that directly deals with soil protection. However, there are several policy statements that refer to the importance of soils and the need to preserve and protect soil resources from further degradation. While no policy exists to facilitate this, a number of initiatives are developing globally to which Ireland should sign up. These include GSP and the Global Soil Biodiversity Initiative. This project also supports current initiatives by DG Environment in the development of a new land policy that will focus on the delivery of ecosystem services by soils.

## 7.2 Recommendations for the SAFER-SOIL Meta-data Catalogue

The project reviewed soils research to date in Ireland, particularly focusing on projects completed within the last 15 years, as very little summary information existed in public databases until now. A major finding of this work was the lack of publicly available meta-data on soils-related projects from the last 15 years. Another was that meta-data/summary information for funded projects rests with either the funder or the principal researcher who conducted the work, with the exception of the EPA and FP7 meta-data platforms. Thus, it is quite difficult to obtain comparable meta-data for the various projects, as each funding organisation has a different approach to final reports and papers, and principal researchers often do not disseminate the findings of research projects, other than in scientific papers.

SAFER-SOIL is an online meta-data catalogue of soils research projects that has been created by the Soil Status and Protection project to provide freely accessible meta-data to researchers/funders to utilise for data repository and data mining for further research gap analyses for future funding calls. The catalogue has been designed to facilitate data mining in relation to spatial coverage of research, soil functions or soil threats described and relevant current policies that could be related to the research carried out. As it currently stands, the SAFER-SOIL meta-data catalogue can be queried to obtain summary information on all soils research projects carried out in the last 15 years.

This project recommends that SAFER-SOIL should be supported in the long term to facilitate the ongoing data input into this catalogue. This should be an online multi-funder tool (which will need online support from a lead agency such as the EPA). All funding agencies should be asked to encourage or mandate all soils research projects to complete the required meta-data fields to keep the catalogue up to date. Currently, the online catalogue is available to all and will need further development by the EPA to allow access for funders, researchers and an administrator. New projects can currently be uploaded; details are available in Appendix 2. An existing example of a multi-funder online research catalogue is the DROPLET catalogue for water research hosted by the EPA (http://erc.epa.ie/droplet/). This would require support by the range of funders of soils research, as well as the support of the scientific community, to continue to manage this resource.

## 7.3 Recommendations for a Monitoring Network

This project has evaluated the need for a soil-monitoring framework, based upon a review of existing data and policy driver requirements for the foreseeable future. There have been several large-scale research projects looking at soil chemistry; these include the NSDB, the Tellus project and the Irish SIS project. These large-scale projects have tried to assess the chemical behaviour of soils from a regional or national perspective; however, there is very little continuity between projects, making any comparison of data between them particularly difficult. All three projects have a lot of information on soil/soil chemistry in Ireland, but they are currently

stand-alone pieces of research. Therefore, based on the assessment of these existing large-scale datasets, the Soil Status and Protection project proposes that using a stratified 16 km grid (based on soil drainage class and land use) would facilitate acceptable replication of the major soil drainage × land use categories (similar to the findings of Arrouays *et al*., 2012) to allow meaningful representation of the major changes in soil quality and associated soil properties over time. The dynamic nature of soil properties would need to be taken into consideration and a further assessment of the sampling frequency would need to be completed before any such monitoring framework is put into place, with a dedicated financial support system in place to allow the monitoring system to be effective.

In addition, the Soil Status and Protection project proposes the following:

- The SMN design should also be flexible enough to include further parameters to support future policies at national and EU levels.
- A framework should be developed that facilitates the co-ordination of future national research projects to utilise the network of sites, to provide added value to the overall monitoring framework. This framework would need careful management and would require a co-ordinated approach from all funders that support soils research, and agreement with land owners to facilitate open access to data and locations for the research.
- Further development of soil property/indicator measurement would need to be refined and sampling frequency considered in line with a target budget for implementing such a monitoring framework. This would require close collaboration between funders and researchers to reach agreement.
- This project also recommends that soil physical and biological attributes be considered in any monitoring plan. For details see Table 4.4.

## 7.4 Recommendations for Knowledge Transfer

This project reviewed the educational support for soil science and related topics, and this work found that within the primary and secondary education sectors there is a lack of materials available to teachers to promote soils within the curriculum. Further KT on soil management and soil nutrient management is desired by the stakeholder community. KT to the wider community about soils is still lacking. There have been small initiatives to increase awareness of soils and, particularly in 2015 IYS, many activities have been promoting the importance of our soil resource. However, a longer-term systematic approach is required that integrates better KT on soils:

- Our schools and colleges (primary, secondary and tertiary) need lesson plans and support materials.
- Key KT resources are needed for soils advice to the agricultural sector through advisors to promote the importance of good soil management on farms (this should be further supported by DAFM and Teagasc). Key issues in relation to agricultural management highlighted by the KT stakeholder workshop included:
  - increased capacity for KT about soil management;
  - recognition of the diversity of soils – current regulations/policies do not account for differences in soil types;
  - a wider understanding of the role of soil in delivering multiple functions/ecosystem services;
  - further understanding of the role of soil biodiversity in understanding the delivery of many soil processes;
  - remaining knowledge gaps on soil's fertility status at catchment level.

## 7.5 Recommendations for Future Research Needs

There is very little research on soil biology. The CréBeo project tried to assess the range and diversity of soil biota at 60 sites, in conjunction with the NSDB project. In addition, some microbial biological measures have been incorporated into the Irish SIS project. The recommendations of the CréBeo project were to develop a soil biological monitoring plan for Ireland, which would include a wider range of land use classes than were applied in the original project. It also recommended that the monitoring scheme should have a two-tiered system that allowed the measurement of core measurements, but facilitated some additional measures on a larger timescale. Monitoring should provide information on the role of soil biota in delivering soil functions and the pressures they are placed under. These recommendations are supported from the Irish SIS project and this project recommends that such a monitoring system should be considered in conjunction with the SMN described in this report.

There has been considerable research on peat-scapes in Ireland, as this is a unique resource. However, there is little link-up between projects, so there is still a poor inventory on the extent and spatial occurrence of the different types of peat bogs in Ireland and how they respond to various managements. The Irish SIS project did not assess the coverage and depth of peat bogs within Ireland; therefore, the SOC map that has been produced cannot account for peat stocks in the overall carbon stock inventory. The Irish SIS project recommends that peat depths of the varying main peat types (fen, blanket bog and raised bog) be evaluated to allow the peat-scapes to be included in a soil carbon stock inventory.

Further research is needed in understanding the functional role of soil at landscape level. The National Landscape Strategy (DAHG, 2015) highlights the importance of soils and geology in forming landscapes, but little consideration is given to the functional role played by soils in supporting society across different landscapes. There are currently no projects listed in the meta-data catalogue that support this area of research.

The EPA Soils and Land use/Land Cover Research strategy highlights the need for further work on the urban soil environment. A number of projects have been completed on soils in urban areas including the Dublin Soil Urban Geochemistry (SURGE) Project, the Urban Environment Project and the Teagasc–EPA Soils and Subsoils mapping project. However, there is a real scope for research on the functional capacities of soils in urban environments.

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# Glossary

| | |
|---|---|
| **Food security** | Physical and economic access for all people at all times to adequate quantities of nutritious, safe and culturally appropriate foods |
| **Functional land management** | A framework for assessing the supply of and demand for soil-based ecosystem services for the sustainable intensification of agriculture and other land use |
| **INSPIRE** | Directive of the European Parliament and of the Council establishing an Infrastructure for Spatial Information in the European Community (INSPIRE) |
| **Meta-data** | Data that describe other data |
| **Multi-functionality of soil** | The capacity of the soil to deliver multiple functions simultaneously |
| **SAFER** | A fully web-based interface for the EPA's Environmental Research Data Archive. Information is presented on SAFER as a "resource" and contains a general description and any related datasets that are publicly available for download |
| **SAFER-SOIL** | A meta-data catalogue that contains more structured details specifically related to soil inventories and mapping |
| **Soil degradation** | The reduced capacity of soils to produce economic goods and to perform soil functions |
| **Soil functions** | The ecosystem services and goods provided by the soil |
| **Soil monitoring** | The systematic determination of soil properties over spatial areas and time to detect and record any changes by making repeated observations and measurements of the soil |
| **Soil-monitoring network** | A set of sites/areas where a periodic assessment is carried out to allow the changes in soil characteristics and properties to be identified and recorded at predefined time intervals utilising a standardised strict spatial sampling system to compare samples over time and space |
| **Soil threats** | The challenges that (potentially) compromise or increase the vulnerability of the soil resource and its quality |
| **Wordle** | A tool for generating "word clouds" from text that you provide. The clouds give greater prominence to words that appear more frequently in the source text |

# Abbreviations

| | |
|---|---|
| **ANC** | Area of Natural Constraint |
| **BISQ** | Biological Indicators for Soil Quality |
| **CAP** | Common Agricultural Policy |
| **CEC** | Cation exchange capacity |
| **DAFM** | Department of Agriculture, Food and the Marine |
| **DAHG** | Department of Arts, Heritage and the Gaeltacht |
| **DCENR** | Department of Communications, Energy and Natural Resources |
| **DECLG** | Department of the Environment, Community and Local Government |
| **DG** | Directorate-General |
| **DJEI** | Department of Jobs, Enterprise and Innovation |
| **EAFRD** | European Agricultural Fund for Rural Development |
| **EAP** | Environmental Action Programme |
| **EC** | European Commission |
| **EEA** | European Environment Agency |
| **EIA** | Environmental Impact Assessment |
| **EIONET** | European Environment Information and Observation Network |
| **EPA** | Environmental Protection Agency |
| **ESDAC** | European Soil Data Centre |
| **ETS** | Emissions Trading System |
| **EU** | European Union |
| **FAO** | Food and Agriculture Organization of the United Nations |
| **GAEC** | Good Agricultural and Environmental Conditions |
| **GEMAS** | Geochemical Mapping of Agricultural and Grazing Land Soil in Europe |
| **GHG** | Greenhouse gas |
| **GLAS** | Green, Low-Carbon, Agri-Environment Scheme |
| **GPS** | Global positioning system |
| **GSBI** | Global Soil Biodiversity Initiative |
| **GSI** | Geological Survey Ireland |
| **GSP** | Global Soil Partnership |
| **INSPIRE** | Infrastructure for Spatial Information in the European Community |
| **IPCC** | Intergovernmental Panel on Climate Change |
| **ITPS** | Intergovernmental Technical Panel on Soils |
| **IYS** | International Year of Soils |
| **JRC** | Joint Research Centre |
| **KT** | Knowledge transfer |
| **LFA** | Less favoured area |
| **LUCAS** | Land use/Cover Area Frame Statistical Survey |
| **LULUCF** | Land use, land use change and forestry |
| **MS** | Member State |
| **MSIR** | Multiple substrate-induced respiration |
| **NPWS** | National Parks & Wildlife Service |
| **NSDB** | National Soils Database |
| **NSI** | National Soil Inventory |
| **NSIS** | National Soil Inventory for Scotland |
| **OPW** | Office of Public Works |
| **PLFA** | Phospholipid fatty acid |
| **REPS** | Rural Environment Protection Scheme |
| **RMQS** | Réseau de Mesures de la Qualité des Sols |
| **RSF** | Research Stimulus Fund |
| **RUSLE** | Revised Universal Soil Loss Equation |
| **SEA** | Strategic Environmental Assessment |
| **SFD** | Soil Framework Directive |
| **SFI** | Science Foundation Ireland |
| **SIS** | Soil Information System |
| **SMN** | Soil-monitoring network |
| **SOC** | Soil organic carbon |
| **SSSI** | Soil Science Society of Ireland |
| **UCC** | University College Cork |
| **UCD** | University College Dublin |
| **UL** | University of Limerick |
| **UN** | United Nations |
| **UNCCD** | United Nations Convention to Combat Desertification |
| **UNFCCC** | United Nations Framework Convention on Climate Change |

# Appendices

Available for download at: http://erc.epa.ie/safer/[1]

**Appendix 1 The Soil Framework Directive is history: so what is the future? *TResearch*, Autumn 2014, Teagasc**

**Appendix 2 SAFER-SOIL Online Meta-data Catalogue User Guide**

**Appendix 3 Monitoring Workshop Results**

**Appendix 4 Stakeholder Roundtable Discussion**

**Appendix 5 Educational Materials**

**Appendix 6 Soil Status and Protection Project *TResearch*, Autumn 2015, Teagasc**

1 Full URL: http://erc.epa.ie/safer/iso19115/displayISO19115.jsp?isoID=3121

**AN GHNÍOMHAIREACHT UM CHAOMHNÚ COMHSHAOIL**

Tá an Ghníomhaireacht um Chaomhnú Comhshaoil (GCC) freagrach as an gcomhshaol a chaomhnú agus a fheabhsú mar shócmhainn luachmhar do mhuintir na hÉireann. Táimid tiomanta do dhaoine agus don chomhshaol a chosaint ó éifeachtaí díobhálacha na radaíochta agus an truaillithe.

## Is féidir obair na Gníomhaireachta a roinnt ina trí phríomhréimse:

Rialú: *Déanaimid córais éifeachtacha rialaithe agus comhlíonta comhshaoil a chur i bhfeidhm chun torthaí maithe comhshaoil a sholáthar agus chun díriú orthu siúd nach gcloíonn leis na córais sin.*

Eolas: *Soláthraímid sonraí, faisnéis agus measúnú comhshaoil atá ar ardchaighdeán, spriocdhírithe agus tráthúil chun bonn eolais a chur faoin gcinnteoireacht ar gach leibhéal.*

Tacaíocht: *Bímid ag saothrú i gcomhar le grúpaí eile chun tacú le comhshaol atá glan, táirgiúil agus cosanta go maith, agus le hiompar a chuirfidh le comhshaol inbhuanaithe.*

## Ár bhFreagrachtaí

### Ceadúnú

Déanaimid na gníomhaíochtaí seo a leanas a rialú ionas nach ndéanann siad dochar do shláinte an phobail ná don chomhshaol:

- saoráidí dramhaíola *(m.sh. láithreáin líonta talún, loisceoirí, stáisiúin aistrithe dramhaíola)*;
- gníomhaíochtaí tionsclaíocha ar scála mór *(m.sh. déantúsaíocht cógaisíochta, déantúsaíocht stroighne, stáisiúin chumhachta)*;
- an diantalmhaíocht *(m.sh. muca, éanlaith)*;
- úsáid shrianta agus scaoileadh rialaithe Orgánach Géinmhodhnaithe *(OGM)*;
- foinsí radaíochta ianúcháin *(m.sh. trealamh x-gha agus radaiteiripe, foinsí tionsclaíocha);*
- áiseanna móra stórála peitril;
- scardadh dramhuisce;
- gníomhaíochtaí dumpála ar farraige.

### Forfheidhmiú Náisiúnta i leith Cúrsaí Comhshaoil

- Clár náisiúnta iniúchtaí agus cigireachtaí a dhéanamh gach bliain ar shaoráidí a bhfuil ceadúnas ón nGníomhaireacht acu.
- Maoirseacht a dhéanamh ar fhreagrachtaí cosanta comhshaoil na n-údarás áitiúil.
- Caighdeán an uisce óil, arna sholáthar ag soláthraithe uisce phoiblí, a mhaoirsiú.
  - Obair le húdaráis áitiúla agus le gníomhaireachtaí eile chun dul i ngleic le coireanna comhshaoil trí chomhordú a dhéanamh ar líonra forfheidhmiúcháin náisiúnta, trí dhíriú ar chiontóirí, agus trí mhaoirsiú a dhéanamh ar leasúchán.
- Cur i bhfeidhm rialachán ar nós na Rialachán um Dhramhthrealamh Leictreach agus Leictreonach (DTLL), um Shrian ar Shubstaintí Guaiseacha agus na Rialachán um rialú ar shubstaintí a ídíonn an ciseal ózóin.
- An dlí a chur orthu siúd a bhriseann dlí an chomhshaoil agus a dhéanann dochar don chomhshaol.

### Bainistíocht Uisce

- Monatóireacht agus tuairisciú a dhéanamh ar cháilíocht aibhneacha, lochanna, uiscí idirchriosacha agus cósta na hÉireann, agus screamhuiscí; leibhéil uisce agus sruthanna aibhneacha a thomhas.
- Comhordú náisiúnta agus maoirsiú a dhéanamh ar an gCreat-Treoir Uisce.
- Monatóireacht agus tuairisciú a dhéanamh ar Cháilíocht an Uisce Snámha.

### Monatóireacht, Anailís agus Tuairisciú ar an gComhshaol

- Monatóireacht a dhéanamh ar cháilíocht an aeir agus Treoir an AE maidir le hAer Glan don Eoraip (CAFÉ) a chur chun feidhme.
- Tuairisciú neamhspleách le cabhrú le cinnteoireacht an rialtais náisiúnta agus na n-údarás áitiúil *(m.sh. tuairisciú tréimhsiúil ar staid Chomhshaol na hÉireann agus Tuarascálacha ar Thascairí)*.

### Rialú Astaíochtaí na nGás Ceaptha Teasa in Éirinn

- Fardail agus réamh-mheastacháin na hÉireann maidir le gáis cheaptha teasa a ullmhú.
- An Treoir maidir le Trádáil Astaíochtaí a chur chun feidhme i gcomhair breis agus 100 de na táirgeoirí dé-ocsaíde carbóin is mó in Éirinn.

### Taighde agus Forbairt Comhshaoil

- Taighde comhshaoil a chistiú chun brúnna a shainaithint, bonn eolais a chur faoi bheartais, agus réitigh a sholáthar i réimsí na haeráide, an uisce agus na hinbhuanaitheachta.

### Measúnacht Straitéiseach Timpeallachta

- Measúnacht a dhéanamh ar thionchar pleananna agus clár beartaithe ar an gcomhshaol in Éirinn *(m.sh. mórphleananna forbartha)*.

### Cosaint Raideolaíoch

- Monatóireacht a dhéanamh ar leibhéil radaíochta, measúnacht a dhéanamh ar nochtadh mhuintir na hÉireann don radaíocht ianúcháin.
- Cabhrú le pleananna náisiúnta a fhorbairt le haghaidh éigeandálaí ag eascairt as taismí núicléacha.
- Monatóireacht a dhéanamh ar fhorbairtí thar lear a bhaineann le saoráidí núicléacha agus leis an tsábháilteacht raideolaíochta.
- Sainseirbhísí cosanta ar an radaíocht a sholáthar, nó maoirsiú a dhéanamh ar sholáthar na seirbhísí sin.

### Treoir, Faisnéis Inrochtana agus Oideachas

- Comhairle agus treoir a chur ar fáil d'earnáil na tionsclaíochta agus don phobal maidir le hábhair a bhaineann le caomhnú an chomhshaoil agus leis an gcosaint raideolaíoch.
- Faisnéis thráthúil ar an gcomhshaol ar a bhfuil fáil éasca a chur ar fáil chun rannpháirtíocht an phobail a spreagadh sa chinnteoireacht i ndáil leis an gcomhshaol (*m.sh. Timpeall an Tí, léarscáileanna radóin).*
- Comhairle a chur ar fáil don Rialtas maidir le hábhair a bhaineann leis an tsábháilteacht raideolaíoch agus le cúrsaí práinnfhreagartha.
- Plean Náisiúnta Bainistíochta Dramhaíola Guaisí a fhorbairt chun dramhaíl ghuaiseach a chosc agus a bhainistiú.

### Múscailt Feasachta agus Athrú Iompraíochta

- Feasacht chomhshaoil níos fearr a ghiniúint agus dul i bhfeidhm ar athrú iompraíochta dearfach trí thacú le gnóthais, le pobail agus le teaghlaigh a bheith níos éifeachtúla ar acmhainní.
- Tástáil le haghaidh radóin a chur chun cinn i dtithe agus in ionaid oibre, agus gníomhartha leasúcháin a spreagadh nuair is gá.

### Bainistíocht agus struchtúr na Gníomhaireachta um Chaomhnú Comhshaoil

Tá an ghníomhaíocht á bainistiú ag Bord lánaimseartha, ar a bhfuil Ard-Stiúrthóir agus cúigear Stiúrthóirí. Déantar an obair ar fud cúig cinn d'Oifigí:

- An Oifig um Inmharthanacht Comhshaoil
- An Oifig Forfheidhmithe i leith cúrsaí Comhshaoil
- An Oifig um Fianaise is Measúnú
- An Oifig um Cosaint Raideolaíoch
- An Oifig Cumarsáide agus Seirbhísí Corparáideacha

Tá Coiste Comhairleach ag an nGníomhaireacht le cabhrú léi. Tá dáréag comhaltaí air agus tagann siad le chéile go rialta le plé a dhéanamh ar ábhair imní agus le comhairle a chur ar an mBord.

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# Soil Status and Protection

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## Informing Policy

At EU level, the European Commission (EC), acknowledging the Rio+20 goal on 'Zero Net land degradation by 2030', remains committed to the objective of soil protection through policies such as the 7th Environment Action Programme, the Resource Efficiency Roadmap. At International scale, the UN Sustainable Development Goals highlight four actions which explicitly deal with soils. Therefore at a national level there needs to be increased recognition of the role that soils play in supporting sustainable land management, and this needs to be incorporated into national policy development in the future. The Soils Status & Protection Project has provided an overview of the policy and legislative drivers currently dealing with soil protection, both at a European and a national scale. The research team has highlighted a number of initiatives are developing globally which Ireland should sign up to. These include Global Soil Partnership and the Global Soil Biodiversity Initiative.

## Developing Solutions

Soil information on the status and protection of soil has been limited to date, preventing any robust gap analysis on specific soil quality issues or assessments of areas under external pressure, in order to support policy development into the future. While many Irish research projects exist which collect data on the various aspects of soil, there is little harmonisation across projects. The Soils Status & Protection Project identified that meta-data/summary information for funded projects rests either with the funder or the principle researcher who conducted the work, with the exception of the EPA and FP7 meta-data platforms. The Soils Status & Protection Project evaluated the state of the art on data for soil quality and protection in Ireland and identified future research needs for soil science and related research. An online meta-data catalogue was developed which synthesises information with a focus on soil. This catalogue SAFER-SOIL (http://erc.epa.ie/soils/projects/soilstatus/index.php) provides an overview of what data are available, methods applied and how this information could be used to inform current and future policy drivers and research in Ireland.

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