

Securing soils in a changing climate: A soil route map for Scotland

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March 2025

DOI: <http://dx.doi.org/10.7488/era/6006>

1. Executive summary

Our soils underpin all nature-based systems and are therefore vital for Scotland's communities and economy. From food security to transport disruption through events such as landslides, the climate resilience value of investing in healthy soils is recognised by the Climate Change Committee as a priority adaptation area for Scotland.

There are many risks threatening Scottish soils across different soil types and land covers. However, unlike air and water, there is no single overarching soil policy providing security and governance for Scottish soils. Soils are spread across multiple policy divisions, which results in a lack of cohesive leadership in tackling threats to soils.

The aim of this route map is to consolidate the challenges of managing soil systems to develop an overarching strategy for delivering improved soil security across Scottish landscapes.

1.1. Key points

There is increasing awareness of the important role soils play for our communities, economy and environment in terms of their ability to contribute to climate regulation, flood resilience, food security, support forestry and assist biodiversity. This is reflected in recent policy updates which have outlined objectives that directly relate to improvements in soil health and/or security, such as:

- [The 3rd Scottish National Adaptation Plan 2024-2029](#)
- [Scotland's National Peatlands Plan](#)
- [National Planning Framework 4](#)
- [UK Forestry Standard 5th Edition](#)
- The Vision for Agriculture and Agricultural Reform Programme ([Agriculture and Rural Communities Act](#))
- [Scottish Biodiversity Strategy to 2045](#)

This route map acknowledges the challenges of addressing soil security in a policy context due to the absence of an overarching soil-specific policy. Currently actions to support soils sit across different policies, which focus on different environmental challenges at different scales. Nevertheless, this route map outlines opportunities to gain value and effectiveness through better coordination of existing activities and policy delivery.

1.2. Next steps

1.2.1. Objectives

This route map recommends six objectives for Scotland to achieve our vision of ‘thriving soils for Scotland’s communities, economy and environment’:

1. Lead – Inspire and collaborate to deliver the vision for Scottish soils
2. Protect – Prevent further damage to soils
3. Restore – Repair damaged soils
4. Enhance – Strengthen soils for the future
5. Evidence – Data, knowledge and wisdom relating to Scottish soils
6. Mobilise – Communicate, engage and participate towards thriving soils in Scotland

1.2.2. Next steps

We recommend that the delivery of the route map is supported by ensuring the following:

1. Scottish Government support the vision and common goals through the allocation of a soil policy group to lead and coordinate the delivery of this route map
2. Baseline Scottish soil status to ascertain a starting point towards ‘thriving’ soils
3. Collaboratively identify specific cross-sectoral actions to protect, restore and enhance Scottish soils
4. Mobilise actions into practice through bespoke implementation plans
5. Monitor progress and review future developments

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2. Glossary

Brownfield	Refers to land that was previously urban/used for industry
Ecosystem services	Ecosystem Services are the direct and indirect contributions ecosystems (known as natural capital) provide for human wellbeing and quality of life. This can be in a practical sense, providing food and water and regulating the climate, as well as cultural aspects such as reducing stress and anxiety. In fact, the vast number of services provided by ecosystems can be categorised into more manageable groups of: provisional; regulating; cultural; and the slightly more ambiguous, supporting services
Eutrophication	The gradual increase in the concentration of nutrients (e.g. nitrogen and phosphorus) in aquatic ecosystem
Flood resilience	Reduce the intensity and/or frequency of flood events and severity
Food security	To have reliable access to a sufficient quantity of affordable and nutritious food
Greenfield	Land that was previously undeveloped
Net zero	A target of completely negating the amount of greenhouse gases produced by human activity, to be achieved by reducing emissions and implementing methods of absorbing carbon dioxide from the atmosphere
Peatlands	Peat is a defined soil type that has at least 50 cm organic horizon. NatureScot use Ramsar Convention's definition of peatland: "Peatlands are ecosystems with a peat deposit that may currently support vegetation that is peat-forming, may not, or may lack vegetation entirely". The Soil Survey for Scotland states that peat should have an organic layer or layers that exceed 50 cm deep from the soil surface and an organic matter content of more than 60%
Peaty soils	Also known as organo-mineral soil. Mineral soils with a peaty topsoil which is less than 50cm thick
Soil acidification	Soil acidification is the lowering of soil pH due to an accumulation of hydrogen ions. Soils with a pH of less than 5.5 is considered 'acidic'
Soil carbon sequestration	Soils are in constant exchange with the atmosphere, they take in carbon (<i>via</i> photosynthesis, root exudates and the addition of organic material) and release carbon (through gas emissions associated with respiration or indirectly via leaching). Where a net gain in carbon exists the soils are considered to be 'sequestering' carbon
Soil carbon stock	The mass of carbon stored in the soil organic matter per area
Soil compaction	Soil compaction is a form of physical degradation in which soil biological activity and soil productivity for agricultural and forest cropping are reduced, resulting in environmental consequences away from the immediate area directly affected
Soil contamination	Soil contamination is when soil is polluted, implying the presence of chemicals and materials in soil that have a significant adverse effect on any organisms or soil functions. Soil pollutants include inorganic and

	organic compounds, some organic wastes and the so-called “chemicals of emerging concern”
Soil degradation	Soil degradation is defined as a change in the soil health status resulting in a diminished capacity of the ecosystem to provide goods and services for its beneficiaries
Soil enhancement	To improve soil health and resilience beyond its current state and the status quo
Soil erosion	The process of soil being gradually damaged and removed by the waves, rain, or wind, or the result of this process
Soil function / functionality	Soil Functions refers to the six key roles that soil plays in an ecosystem, including providing a medium for plant growth, supplying and purifying water, recycling nutrients and organic wastes, serving as a habitat for soil organisms, modifying the atmosphere, and acting as an engineering medium
Soil health	Physical, biological and chemical status of a soil which provide a range of soil functions (e.g. see AHDB Soil health card for Scotland)
Soil management	A collective term describing a range of practices and applications imposed on soils for a range of purposes (e.g. food production, ground preparation, urban developments, conservation etc)
Soil organic matter	Soil organic matter means all living, or once-living, materials within, or added to, the soil. This includes roots developing during the growing season, incorporated crop stubble or added manures and slurries
Soil protection	Refers to activities which contribute to the prevention of degradation of soils
Soil resilience	Soil’s ability to buffer or ‘cope’ with stresses such as extreme weather events and disturbance
Soil restoration	To 'repair' soils which have been degraded in some way (e.g. physical, chemical or biological degradation)
Soil risks/risks to soil	Refers to the threats and pressures on soils which may negatively impact on soil health and/or soil function
Soil salinisation	Soil salinization is a term that indicates the phenomenon or process of accumulation of water-soluble salt in the soil
Soil sealing	The covering of soil (generally with an impermeable material) for the purpose of urban development
Soil security	To defend soils from risks, dangers and threat that jeopardise its existence, health and function
Soil structure	The spatial arrangement of soil particles (called aggregates, crumbs, blocks or peds). Soil structure influences soil functions, for example how water moves through it and susceptibility to degradation such as erosion and compaction.
Water storage capacity / water retention	The ability for soils to hold or maintain water

3. Why we need a “Soil Route Map for Scotland”

We rely on soils for a wide range of primary functions (outlined on [Scotland’s Soil Website](#)) as soils underpin all nature-based systems and are therefore core to Scotland’s communities, environment and economy (Figure 1). However, evidence shows that there are several risks associated with poor soil management which threatens the future security of Scottish soils.

The costs associated with inaction are not only related to environmental impacts as these risks cascade to include socio-economic repercussions. [Baggaley et al \(2024\)](#) estimated that compacted soils in Scotland costs land managers up to £49 million annually in yield losses, up to £26 million per year in additional fertiliser use required to operate with compacted soils and up to £76,000 per household from increased flood risk and insurance claims attributed to soil compaction and soil sealing (Appendix A). From food security to transport disruption (e.g. through landslides) the climate resilience value of investing in healthy soils is recognised by the [Climate Change Committee](#) as a priority adaptation area for Scotland.

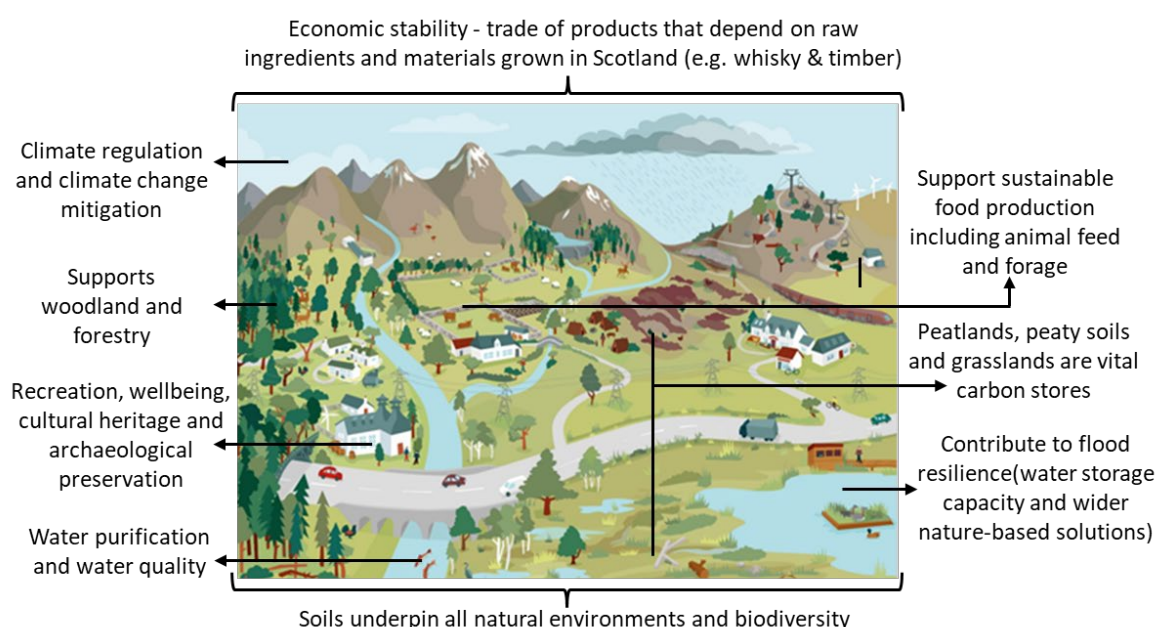


Figure 1. The role of soils in our environment (Figure adapted from the [3rd Scottish National Adaptation Plan](#) and [Adaptation Scotland’s Climate-Ready Places](#))

3.1.1. Risks to soil health

There are many risks to the health and security of our soil systems. Table 1 shows risks outlined in the [Scottish Soil Framework \(2009\)](#) and more recently in the [Environmental Standards Scotland \(ESS\) report \(2024\)](#). This highlights that many of the risks identified in the [Scottish Soil Framework \(2009\)](#) are still prevalent and jeopardising the future security of Scotland’s soils and the many functions they provide (Figure 1).

Table 1. Risks to Scottish soils outlined in the Scottish Soil Framework (2009)

Threats to soils ranked across all soil functions at the national scale (1 being the highest risk) and the Environmental Standards Scotland Report (2024), ranking threats as high, medium or low based on a set of criteria.

	Scottish Soil Framework (2009)	Environmental Standards Scotland Report (2024)
Climate change impacts on soil	1	-
Loss of organic matter and carbon	2	Medium
Soil sealing	3	Low
Acidification and eutrophication	4	-
Loss of soil biodiversity	5	High
Soil contamination	6	Medium
Soil erosion and landslide	7	High
Pesticide application	8	-
Soil compaction	9	High
Salinisation	10	-
Risks from the inconsistent approaches to data collection and monitoring	-	High
Risks from carbon sequestration schemes	-	Medium
Water retention/capacity of soils	-	Medium
Application of waste to land	-	Medium
Landfilling of waste soil	-	Medium
Soilborne diseases and pests	-	Low

In terms of prioritising these risks, the two publications suggest different rankings, with the [Scottish Soil Framework \(2009\)](#) listing the impacts of climate change, the loss of organic matter (and carbon), soil sealing and soil degradation from acidification and eutrophication as the top four threats to Scottish soils. The [ESS report \(2024\)](#) ranked soil erosion and landslides, soil compaction, the loss of biodiversity and risks associated with inconsistent approaches to data collection and monitoring as being of highest priority. Opinions from a recent stakeholder workshop (Appendix B) identified soil disturbance, erosion and organic matter loss to be the highest priorities within agricultural and forestry sectors, with soil sealing ranking highest in the urban/built environment sector. At the landscape scale, the lack of a soil-specific policy was noted as the highest risk to soils in Scotland.

3.1.2. Soil degradation

Soil degradation (i.e. soils with diminished functionality) has wide reaching impacts, not just on soil properties, but also in terms of soil functionality and the broad ecological services

which soils provide, which can also result in wider economic impacts. For example, impacts of soil degradation can include loss of yields, greater fuel use, loss of land, increased greenhouse gas emissions, increased diffuse pollution and degraded water quality, increased flooding events and flooding intensity and loss or damage to cultural and archaeological sites.

Soil degradation is not limited to one soil or land use type; it cuts across landscapes making the protection of soils challenging as there is no single solution. Therefore, due to the broad range of soil and land use types across Scotland (Appendix B), addressing the risks to soils will require a multi-layered, cross-sectoral approach. Despite this, unlike air and water, there is no single overarching soils policy focus with governance of soils being spread across multiple policy divisions. This has resulted in a fragmented approach to tackling the threats to soil resources.

In addition to the wide range of policy objectives which impact on soils, the Scottish Government has a long history of investing in research for future policy development and delivery through the [Environment, Natural Resources and Agriculture Strategic Research Programme \(SRP\)](#) and Centres for Expertise ([ClimateXChange](#), [CREW](#) and [SEFARI](#)). Through the current SRP (2022-2027), approximately [£50 million](#) a year is invested to ensure that ‘Scotland maintains its position at the very cutting edge of advances in agriculture, natural resources and the environment’, with the research of soils being vital across SRP themes (see Appendix D). The protection and enhancement of soils is essential for achieving many of Scottish Government’s policy objectives (e.g. net zero, food security, flood resilience, biodiversity and climate adaptation). However, without an overarching vision for Scottish soils and soil-specific policy, it can be challenging to harness such evidence into impactful implementation to better protect Scottish soils.

3.2. The Route Map

The aim of the route map is to consolidate the challenges of managing soil systems (see Appendix E) across multiple land uses and policy themes and to develop an overarching strategy for delivering improved soil security across Scottish landscapes. The route map is also intended to indicate – and drive forward – positive actions towards the protection, restoration and enhancement of Scottish soils while delivering objectives across the nature-based policies highlighted. Specific aims of the route map for Scotland include:

1. **Review existing soil protection within Scottish policy** – to support the development of a route map, current knowledge and public policy-related research is reviewed to ascertain how Scotland’s policy objectives are underpinned by healthy soils and how available knowledge is used in decision making and policy development.
2. **Develop a framework for the ‘Soil route map for Scotland’** – set a vision to act as a common goal across policy themes and identify objectives which offer an effective pathway for improving soil security in the future.
3. **Implementation considerations of the ‘Soil route map for Scotland’** – explore potential actions that offer opportunities for delivering the route map objectives across existing policy deliverables.

4. Soil protection in existing Scottish policy and legislation

Currently, in Scotland the legislative landscape for soils is fragmented across multiple policy divisions within Scottish Government and largely aims to protect other environmental areas (such as water and biodiversity) from poor management of soils, rather than soil itself. However, soil security and soils are referenced across environmental acts, policies and strategies, as outlined below.

4.1.1. The Scottish Soil Framework (2009)

The [Scottish Soil Framework \(2009\)](#) is the most comprehensive, soil-specific document, to date, bringing together the wide range of risks to soils as well as activities that contribute to overcoming these risks through 13 positive soil outcomes, which are;

1. Soil organic matter stocks protected and enhanced where appropriate.
2. Soil erosion reduced and where possible remediated.
3. Soil structure maintained.
4. Greenhouse gas emission from soils reduced to optimum balance.
5. Soil biodiversity, as well as above ground biodiversity, protected.
6. Soils making a positive contribution to sustainable flood management.
7. Water quality enhanced through improved soil management.
8. Soil's productive capacity to produce food, timber and other biomass maintained and enhanced.
9. Soil contamination reduced.
10. Reduced pressure on soils by using brownfield sites in preference to greenfield.
11. Soils with significant historical and cultural features protected.
12. Knowledge and understanding of soils enhanced, evidence base for policy review and development strengthened.
13. Effective coordination of all stakeholders' roles, responsibilities and actions

A [Scottish Soil Framework Progress Report \(2013\)](#) highlighted developments since the framework's publication, which highlights a range of activities such as the launch of the Centres of Expertise (2011), the publication of [The State of Scotland's Soil report \(2011\)](#) and the development of the '[Scotland's Soil Website](#)'.

4.1.2. Other key policy documents

A review of where soils are included in a Scottish policy context is outlined in Appendix F. Recent developments in Scottish policies include some focused consideration of soils, such as:

- [Scotland's National Peatland Plan](#) and Peatland ACTION has the vision to see peatlands in a healthy state and widely regarded as resilient by 2030 and the rewards of restoration effort undertaken in previous decades should be evident by 2050 and beyond.
- [The National Planning Framework 4 \(NPF4\)](#) – the policy intent of NPF4-Policy 5 is “to protect carbon-rich soils, restore peatlands and minimise disturbance to soils from development with policy outcomes of a) valued soils are protected and restored, b) soils,

including carbon-rich soils, are sequestering and storing carbon, c) soils are healthy and provide essential ecosystem services for nature, people and our economy.”

- Scottish Forestry and [UK Forestry Standard \(UKFS\) 5th edition](#) – chapter 8 provides the ‘UKFS Requirements for Forests and Soil’ and ‘UKFS Guidelines on Forests and Soil’ for soil protection, acidification, contamination, compaction, disturbance, erosion fertility and organic matter (carbon) loss.
- The [Vision for Agriculture](#) and [Agricultural Reform Programme](#) (Agriculture and Rural Communities Act) – this includes compliance via [Good Agricultural and Environmental Conditions \(GAECs\)](#) in terms of maintaining a minimum soil cover (GAEC 4) to protect soil against erosion after harvest, to protect soil against erosion in certain situations (GAEC 5) and maintaining soil organic matter levels (GAEC 6). In addition to compliance, support has been available since 2022 for soil testing and nutrient management (The National Test Programme, [Preparing for Sustainable Farming](#)), which will become a requirement under the [Whole Farm Plan](#) introduced to Tier 1 payment requirements, with additional support associated with the introduction of measures contributing to regenerative agricultural practices (including continuous soil cover as outlined in the [Agricultural Reform list of measures](#)).
- The [3rd Scottish National Adaptation Plan 2024-2029](#) – Outlines the importance of soils and the need for further protection as outlined in ‘Nature Connects objective’ for landscape scale approaches “Landscape scale solutions are implemented for sustainable and collaborative land use, including protecting and enhancing Scotland’s soils.”
- The [Scottish Biodiversity Strategy to 2045](#) provides a range soil specific objectives, (particularly objective 3 for agricultural soils) notably the action to “ensure increased uptake of high diversity, nature-rich, high soil-carbon, low intensity farming methods while sustaining high quality food production”. This includes the action to revise and update Scotland’s Soil Framework and action/implementation plan by 2030; to develop evidence-based Soil Health Indicators (SHIs) that can be considered for inclusion in Whole Farm Plans and forest management plans (and monitoring frameworks to assess change in soil health) as well as improving information and guidance for land managers.

There is a wide range of Scottish policy themes that are linked to soil systems across our landscapes (Appendix F), however the list above demonstrates that the protection of soils is concentrated to only a few policies. It is worth noting that despite soil protection being a key objective in some of these strategies and policies, the degree to which implementation into action occurs is often more difficult to assess. The varied challenges associated with soil management are outlined in Appendix D. The [Scottish Biodiversity Strategy to 2045](#) offers the most recent policy area to set out specific objectives relating to soil protection is which, despite some gaps, has made great strides in collaborative discussion and objective setting in terms of soil health, particularly in the agricultural section. .

Soils are also considered within a range of Scottish regulations as outlined on [Scotland’s Soil](#) website, with their relevance to soils highlighted in Appendix F:

- [The Pollution Prevention and Control \(Scotland\) Regulations \(2012\)](#)
- [Waste Management Licensing \(Scotland\) Regulations \(2011\)](#)
- [The Water Environment \(Controlled Activities\) \(Scotland\) Regulations \(2011\)](#)
- [Action Programme for Nitrate Vulnerable Zones \(Scotland\) Regulations \(2008\)](#)
- [Radioactive Contaminated Land \(Scotland\) \(Amendments\) Regulations \(2007\)](#)

- [The Contaminated Land \(Scotland\) Regulations \(2005\) & Statutory Guidance SE/2006/44](#)
- [Conservation \(Natural Habitats, &c.\) Regulations \(1994\)](#)
- [Sludge \(Use in Agriculture\) Regulations \(1989 and later amendments\)](#)

5. Developing a framework for the “Soil Route Map for Scotland”

The vision for the soil route map is **“Thriving soils for Scotland’s communities, economy and environment”**. This was developed to encompass the 13 outcomes (listed in Section 4) of the [Scottish Soils Framework](#), which is a comprehensive and representative list of essential soil functions and reflects the contribution soils have to Scottish communities and economic stability.

Six objectives to achieve this vision and address the range of soil risks identified (Table 1) are outlined below (see Figure 2). These objectives are considered essential to support a series of proactive actions which offer practical opportunities for positive change towards soil security in Scotland and are further described in Table 2 below. Appendix G provides further description of approaches taken in the route map development.



Figure 2. The six objectives of the Route Map for Scotland

Table 2. Description of the six objectives within the Route Map for Scotland

Objective	Description
LEAD (L)	‘Inspire and collaborate to deliver the vision for Scottish soils’ Provide an overarching vision and evidence-based policy framework to support the various levels of leadership in conducting activities that relate to the protection, restoration and enhancement of Scottish soils, which is mobilised through effective communication, upskilling and engagement.
PROTECT (P)	‘Prevent further damage to soils’ Ensure soils across Scottish landscapes are safeguarded against further decline in soil health or increase in vulnerability to physical loss from risks outlined in Table 1
RESTORE (R)	‘Repair damaged soils’ Provide evidence-based guidance, policies and where appropriate legal pathways to identify and alleviate degraded soils across different land uses in Scotland.
ENHANCE (En)	‘Strengthen soils for the future’ Recognising change and additional measures to soil improvement above and beyond the status quo, which contribute to future proofing via resilient healthy soils and maximising the potential of our soils for generations to come.
MOBILISE (M)	‘Communicate, engage, participate’ The delivery of the route map will rely heavily on engaged participation, collaboration and effective communication of the objectives and best practices to achieve them through strengthening delivery mechanisms and processes that will enable actions whether that be via legal pathways or otherwise. This includes participation across policy makers, regulators, researchers, land managers, practitioners, local councils, community groups and land use partnerships working collaboratively to foster positive changes for the future.
EVIDENCE (Ev)	‘Data-information-knowledge-wisdom’ Utilising data to underpin interdisciplinary and cross-sectoral evidence-led decision making and monitoring progress. Harnessing local and cultural knowledge and wisdom to identify areas of success and potential opportunities for change.

6. Potential implementation of the route map

The six key objectives in the route map (Figure 2 and Table 2) provide a framework to address the range of challenges faced by soils and allow flexibility for specific actions within each objective to be applied across temporal and spatial scales. The aim of the route map is to build upon existing progress, to explore opportunities and develop a cohesive (and inclusive) plan which is effectively communicated to drive the delivery of objectives outlined.

The Scottish policy landscape can appear complex as it represents the diverse environmental landscapes of Scotland which are intertwined with our communities and national economy. Therefore, a vital component of successful implementation will be the active engagement and participation across multiple organisations, agencies and industries spanning a range of sectors that represent the cross-sectoral importance of our soils.

The route map proposes a blended approach of strategic policy-led coordination driven by the identified policies which impact on soils (Appendix F) and a risk-led delivery of actions requiring coordination across multiple stakeholders, outlined across the six objectives.

The risks to soils span different land use types providing cross-cutting themes affecting multiple policy areas. A risk-led approach to identifying actions provides an opportunity for policy teams and wider delivery sectors to come together to collaboratively address soil risks which can then be delivered/implemented within existing policy frameworks. As there are specific, place-based risks and pressures associated with soils, it will be important to engage across the range of stakeholders and sectors with soil-related interests, to share experiences and to exchange knowledge towards a better understanding of good soil management specific to that place.

6.1. Objective 1 – Leadership (L)

Actions to support the implementation of leadership	
L1	Assemble a ‘Soil Policy Team’ within Scottish Government
L2	Update the Scottish Soil Framework
L3	Review the potential of statutory targets to be introduced and potential alignment with EU Soil Monitoring Law and Nature Restoration Law

6.1.1. Action L1: Assemble a ‘Soil Policy Team’ within Scottish Government

This route map highlights that the legislative landscape for soils is particularly fragmented across different policy areas. To better coordinate the delivery of a cross-sectoral route map for Scottish soils, this action proposes the establishment of a soil-focused policy team to lead in the progression of collaboration to effectively implement objectives and achieve the objectives outlined.

6.1.2. Action L2: Update the Scottish Soil Framework.

This route map provides an initial cross-sectoral framework for integrating soil-focused activities across the current suite of environmental protection policies to safeguard Scottish soils (and wider environment) from future challenges. It is recommended that the [Scottish Soil Framework \(2009\)](#) be updated to contribute to policy priorities including those set out in the [3rd Scottish National Adaptation Plan 2024-2029](#), [Scotland's National Peatland Plan](#), [National Planning Framework 4 \(NPF4\)](#), [UK Forestry Standard \(UKFS\) 5th edition](#), the [Vision for Agriculture](#) and [Scottish Biodiversity Strategy to 2045](#) as well as supporting the objectives set out in the recent [Natural Environment \(Scotland\) Bill \(2025\)](#) and [National Flood Resilience Strategy \(2024\)](#) through soils underpinning nature-based systems (Figure 1) and being central to many nature-based solutions. An updated [Scottish Soil Framework](#) will also support progress of the route map objectives and the continuation of the current Soil Policy Working Group (comprising representatives from core Scottish Government policy and analytical services divisions, ClimateXChange, NatureScot, SEPA and Historic Environment Scotland) to allow for regular updates on any developments that influence or impact Scottish soils and to maintain momentum in the delivery of activities relating to soil protection, restoration and enhancement.

6.1.3. Action L3: Review the potential of statutory targets to be introduced and potential alignment with EU Soil Monitoring Law and Nature Restoration Law.

In the [ESS report \(2024\)](#) it was noted that 'Scotland, formerly a world leader with the Soils Framework, is now falling behind international best practice in this area and should consider mirroring developments in Europe and initiate statutory duties to protect and monitor soils'. It is suggested that statutory duties include mandatory targets for the restoration of drained peatland soil, assessment of contaminated land and soil sealing policy as well as legislative proposals that reflect the proposed EU Soil Monitoring Law and Nature Restoration Law.

Currently, there is no EU-wide soil-specific legislation, however as part of the [European Green Deal](#) and [EU Biodiversity Strategy 2030](#) the European Union has developed their [EU Soil Strategy for 2030](#). The [Kunming-Montreal Global Biodiversity Framework \(GBF\)](#) and [International Initiative for the Conservation and Sustainable Use of Soil Biodiversity](#) were adopted at the Convention on Biological Diversity COP 15 meeting in December 2022 to support the restoration, maintenance and enhancement of soil health. Following this, the EU proposed a new [Soil Monitoring Law](#) in July 2023 to protect and restore soils and ensure that they are used sustainably.

Targets can provide common goals to work towards and benchmarks for assessing progress. However, these need to be in tune with the overarching vision and objectives and in relation to specific soil characteristics and varied land cover types we have in Scotland.

Consideration needs to be given to the implications which target-setting can have to avoid unintended consequences. For example, targets for increased soil carbon contents can be set, however managing soil carbon is complex and involves dynamic biogeochemical processes as part of the global carbon cycle (see Appendix H). The simple message of 'increasing soil carbon' may lead to management practices which are conducted in goodwill, but whilst leading to improvements in soil health, may also inadvertently lead to increased greenhouse gas emissions from soils.

A workshop was held to review stakeholder views on soil monitoring in Scotland and the potential of EU alignment (Appendix I). The workshop outputs (Appendix I) outline opportunities for Scotland to produce a more appropriate monitoring platform in relation to Scotland's unique landscape which would better reflect Scotland's communities, economy and environment (reflected in Objective 5, Action Ev3). Therefore, Action L3 proposes a two-stage review.

1. A thorough examination of the principles and objectives of the [EU Soil Strategy for 2030](#) and the proposed [EU Soil Monitoring Law](#).
2. An assessment of how these principles and objectives can be best implemented in Scotland. The assessment should consider both the potential for a tailored, bespoke soil protection plan that reflects Scotland's unique landscape and priorities (as informed by stakeholder engagement) and an evaluation of whether direct alignment with the EU framework would be beneficial and feasible for Scotland. This includes reviewing the range of metrics which may be appropriate to apply as targets within future statutory requirements. Finally, to identify opportunities for Scotland-specific targets offering multiple benefits to soil health with transparency in relation to any trade-offs.

6.2. Objective 2 – Protect, Restore and Enhance (PREn)

Identify actions needed to protect (P), restore (R) and enhance (En) soil - Identifying what needs to be achieved in practical soil management.	
PREn1	Coordinate task groups for shared best practice
PREn2	Place-based evidence reviews to identify actions needed

The route map suggests a collaborative, cross-sectoral approach to mobilise Scottish soil security through evidence-led leadership, soil protection, soil restoration and soil enhancement for the future. To achieve this collaborative approach, Objective 2 suggests the operation of task groups to come together to share knowledge and best practice to protect, restore and enhance soils in relation to risks identified (Section 3).

6.2.1. Action PREn1: Coordinate task groups for shared best practice

Within each 'task group' the aim would be to review what activities currently work well and what else can be done to protect, restore and enhance soils in relation to risks identified (Table 1, Section 3). The groups should be forward-thinking and involve appropriate representatives from across different sectors who work with, or are affected by soils (i.e. landowners, practitioners, local authorities, community groups, policy makers, regulators and researchers etc). It is suggested that the task groups have clear terms of reference to outline core purpose, terms for delivery and effective coordination of all stakeholders' roles, responsibilities and actions. This offers opportunities for co-delivery across various policy objectives to be explored. For example;

Theme 1: Soil sealing and management of soils in construction and urban development

This task group will aim to protect high value soils from sealing and opportunities to reduce, reuse and recycle soil resources. In addition, the task group will share knowledge on soil

'value' across land use, land capability and the provision of ecosystem services (and nature-based solutions). Examples of areas the task group could review;

- Review of tools used to assess soil 'value' to provide further support for informed decision-making in relation to new developments, such as how soils and other assessments (for example, The [Land Capability for Agriculture](#)) are used in Environmental Impact Assessments during the land use planning process. There are opportunities to support soil protection (particularly high carbon soils) and offer further guidance on interpreting soil data/information for improved understanding of soil systems and their value across soil types/land use types and associated wider functions, contributing to more informed decision making.
- Engage with local authorities (e.g. Heads of Planning Scotland) and agencies (e.g. SEPA) to provide support on soil protection, restoration and enhancement (where appropriate) in local development plans and [Strategic Environmental Assessments](#) (as outlined by [SEPA](#))
- Promote and support the reuse of valuable soil during developments as outlined by [SEPA](#) and review good practice codes (E.g. [SEPA Guidance \(2017\)](#) ; [SR/SEPA guidance \(2012\)](#) and [Construction Code of Practice for the Sustainable Use of Soils on Construction Sites, Defra, UK](#) to reduce soil 'waste' and limit the quantity of soil going to landfill.

Theme 2: Erosion, compaction and slope stability (physical integrity of the soil)

Review where current guidance exists for supporting the physical integrity of soils as well as the prevention and restoration of soils affected by, or at risk to soil erosion, compaction or diminished stability. Explore where this guidance can be translated across to other land uses/sectors to enable wider application and support co-delivery across sectors. For example, there is guidance relating to soil structure for agriculture in the '[Valuing your Soils](#)' brochure, which may offer transferrable knowledge. In addition, the Centres of Expertise have guidance which offers an initial evidence base to develop this action further, such as;

- [Assessing the socio-economic impacts of soil degradation on Scotland's water environment](#)
- [Effect of Soil Structure and Field Drainage on Water Quality and Flood Risk](#)
- [Soil Erosion and Diffuse Water Pollution Mitigation](#)

Theme 3: Application of chemicals (nutrient management and soil contamination)

Explore best practice to protect soils from contamination resulting from the application of chemicals (e.g. pesticides), poor nutrient management (e.g. synthetic fertilisers), wastes applied (e.g. sewage sludge) and emerging contaminants (e.g. PFAS, microplastics, pharmaceuticals within or additional to those in wastes applied). Review strategies for alleviating soils already affected by contamination as well as identifying soils at future risk and in need of further protection. For example, the task group could review guidance and legislation which exists to protect soils from poor nutrient management and contamination to identify pathways to improve awareness and implementation through existing policies such as;

- Scottish Nitrogen Balance Sheet to reduce excess nitrogen in soil systems which can lead to leached nitrates (affecting waters) and emitted as nitrous oxides (indirect and indirect greenhouse gas emissions). This will be considered in the nutrient

management plans to come within the Whole Farm Plan of the Agriculture Reform Program, and nitrogen balance sheet of the Climate Change Plan. How can the implementation of improved nitrogen management be applied more widely across sectors?

- Diffuse pollution prevention (CREW) offers soil management guidance to minimise negative effects on local watercourses
- The James Hutton Institute and Fidra have outlined the impacts of unregulated microplastic, organic chemical and pharmaceutical contaminants on soil health (Re-assessment of environmental risks of sewage sludge, 2024), some of which are currently not regulated or included in soil routine soil testing.
- Environmental Standards Scotland has begun investigatory work on the application and effectiveness of Environmental Protection Act Part 2A. Support local authorities to identify and remediate contaminated soils as part of the Environmental Protection Act, Part 2a

Theme 4: Soils in private sector sustainability plans and corporate responsibility

In recent years there has been growing interest in soil health, soil carbon sequestration potential and the role of soils to support biodiversity and other ecosystem services with respect to sustainability reporting within the private sector. This is a rapidly evolving field as businesses look to evaluate how their business may impact climate and nature as well as identifying risks associated with their business being impacted by adverse climate and nature-related events as outlined in TCFD (Taskforce for climate-related financial disclosures) and TNFD (Taskforce for nature-related financial disclosures). There are a range of emerging tools and guidance available for companies to use which offers opportunities for further guidance in relation to soil management in relation to ecosystem services and how this may link to supply chain resilience, nature-related risks and private investment opportunities for nature restoration and carbon sequestration.

Theme 5: Soil monitoring and metrics

To understand the extent to which soils need protecting and restoring requires, to some extent, the need to monitor soil condition. The ESS report (2024) highlighted the lack of a comprehensive monitoring network in Scotland, resulting in, for example, not knowing whether the number of soil erosion incidences (and magnitude of erosion) is increasing or decreasing. There are a range of approaches to monitoring soils and stakeholders agreed (Appendix I) that to formalise a soil monitoring programme for Scotland, an agreed purpose or set of objectives for the programme going forward is required. This will provide clarity in the specific metrics needed to monitor soil health, risk and resilience in Scotland and inform the development of the soil monitoring framework in terms of establishing baselines, whether targets and benchmarks should be incorporated, the degree to which stratification may be required and how the data could contribute to further research and support evidence-led decision making. This also includes scoping opportunities for the soil monitoring programme to contribute to environmental modelling and amalgamated landscape-scale datasets for wider environmental assessment. Therefore, there is scope to review how best to monitor developments in soil protection, restoration and enhancement across the actions proposed (and appropriate metrics required to do so). This may entail exploring the possibility of a Directive on Soil Monitoring and Resilience to be established as

outlined in the ESS report (2024). Initial recommendations in relation to evidencing and monitoring Scottish soils are outlined in Objective 4.

6.2.2. Action PREn2: Place-based evidence reviews to identify actions needed

A core objective of the task groups would be to support the delivery of existing ‘good’ practice and explore potential alignment of these practices across other sectors through place-based, cross-sectoral evidence reviews on appropriate practical measures to protect, restore and enhance soils; as well as exploring mechanisms and pathways to mobilise activities identified. This may include identifying where the underpinning research and practical experiences can be translated to inform task groups on future applications, as well as identifying gaps to explore. For example, there may be gaps or areas for improvement in relation to soil literacy and soil-based skills, which could be addressed so that soils can be better protected, restored and enhanced in the future. Evidence reviews will support mechanisms for decision making and identifying ‘minimum viable product’ that can be deployed to initiate change following the evaluation of impacts (positive and negative) in terms of overall trade-offs.

6.3. Objective 3 – Mobilise (M)

Actions to support the identification of how to mobilise and achieve objectives.

M1	Identify existing legal/regulatory avenues for implementing actions for soil protection, restoration and enhancement via implementation plans
M2	Identify existing and new avenues to implement actions for soil protection, restoration and enhancement via landscape-scale implementation plans

Task groups might be put in place to identify pathways for implementation, which use existing avenues in the first instance. The groups could also give insight into new opportunities for the implementation of actions that protect, restore, and enhance soils.

6.3.1. Action M1: Identify existing legal/regulatory avenues for implementing actions for soil protection, restoration and enhancement via implementation plans

Current codes of practice and guidance exist across most sectors. These can be updated with latest evidence providing a streamlined approach to safeguarding soils across sectors. Common language, metrics and messaging will support landscape-scale problem-solving. Therefore, it would be useful to develop and expand good practice guidance across Scottish land uses, to share knowledge and best practice, develop commonalities and ensure alignment across the different sectors, for example:

- Agricultural codes of practice include [GAECs](#), [Whole Farm Plan](#), [Prevention of environmental pollution from agricultural activity guidance \(PEPFAA\)](#), ['Valuing Your Soils' brochure](#)
 - Explore opportunities to include additional measures to [GAECs](#) or the [Whole Farm Plan](#) such as tests for ‘soil compaction’ and/or ‘soil degradation’ to be performed utilising evidence and guidance that is already available, in order to identify and alleviate soil compaction and wider degradation. This would also enable the development and promotion of clear guidance for practitioners and support the [Scottish Biodiversity Strategy to 2045](#)

recommendation that by 2030 farm and forestry machinery contractors are engaged in ensuring appropriate use of equipment, uptake of decision-making tools and training, to minimise and ultimately avoid compaction damage to soils.

- Review opportunities to harness and better utilise information collated through the Agricultural Reform Programme's [Whole Farm Plan](#), which includes soil testing alongside carbon and biodiversity audits (and will introduce nutrient plans in 2028). This may include the provision of further advice on how to interpret the information collected into sustainable soil management that supports soil health and resilience in terms of aligning to the objectives of soil protection, restoration and enhancement. In addition, there may be opportunities for the knowledge gathered from soil testing to be collated in some way, for the purpose of supporting evidence and monitoring (e.g. national soil health status and a Scottish soil monitoring framework) and research (e.g. for national soil mapping, modelling changes and forecasting, better understanding of the interaction between soils and land management practices).
 - The [Agricultural Reform Programme Tier 4](#) offers opportunities for mobilising soil protection, restoration and enhancement measures as it refers to additional, 'complementary' activities that support good practices, such as developing new skills, knowledge, training and continued professional development, as well as advisory services and business support (advice, knowledge exchange and linkages to wider land management support from Scottish Government officials and/or public partners) and development of measurement tools.
 - '[Valuing Your Soils](#)' brochure was published in 2015 and provided case studies of effective management related to challenges such as managing soil pH, nutrient management, compaction and drainage. The booklet provided peer-to-peer learning in the form of short, clear messages and on-farm examples (case-studies). An update to the '[Valuing your Soils](#)' brochure offers a mechanism for communicating and mobilising recommendations related to the route map's objectives on soil protection, restoration and enhancement in relation to the risks identified and incorporating recent developments across the agricultural reform programme.
- UK Forestry Standards
 - Review whether there is scope to update and widen woodland management guidance and plans (between 2023 and 2030) to reflect greater emphasis on actions that will improve biodiversity including use of elements from 'Site Condition Monitoring' and 'Woodland Ecological Condition' monitoring as recommended in the [Scottish Biodiversity Strategy to 2045](#).
 - There is also scope to include 'soil compaction' or 'soil degradation tests' as outlined above, which will support the development and promotion of clear guidance for practitioners on soil compaction and ensure that by 2030 farm and forestry machinery contractors are engaged in ensuring appropriate use of equipment, uptake of decision-making tools and training, to minimise and

ultimately avoid compaction damage to soils – as recommended in the [Scottish Biodiversity Strategy to 2045](#).

- Peatland Action
 - Review whether there is scope to include some protection or further guidance for ‘peaty soils’ in relation to different land uses (notably planning, agriculture and forestry) to enhance the protection of high carbon soils.
 - Originally proposed in The [Scottish Strategic Framework for Biodiversity](#), the development of the targeting of peatland restoration for cost-effective delivery (i.e. identifying priority restoration projects) including for greater private investment in peatland restoration. It is also noted that there’s a need to “scale delivery of the [Peatland Action programme](#), restoring the condition of peatlands as a key ecosystem in line with net zero targets and supporting the expansion and upskilling of the peatland restoration workforce”.
 - Ensure all peatland restoration projects are completed to the same standards regardless of funding source, including transparency in data collected for defining peatland condition used to calculate baseline emissions.

6.3.2. Action M2: Identify existing and new avenues to implement actions for soil protection, restoration and enhancement via landscape-scale implementation plans

The delivery of actions will need to be coordinated at the landscape-scale and will involve engagement with a range of cross-sectoral stakeholders. To begin this process there are opportunities to engage with existing initiatives, for example Regional Land Use Partnerships, Climate Adaptation Partnerships, Landscape Enterprise Networks and Local Authorities. Developing from M1, action M2 seeks to provide evidence-based opportunities and solutions following the identification of gaps, limitations and barriers to implementation. This will entail reviewing the appropriateness and applicability of solutions across sectors, land cover and soil type (for example where soils are naturally compacted) as well as exploring pathways for effective implementation.

6.4. Objective 4 – Monitor (Ev)

Actions to support current and future baselining, monitoring and evidencing Scottish soils	
Ev1	Baseline soil ‘status’ across land use types of Scotland.
Ev2	Identify evidence gaps and future improvement options across different land uses
Ev3	Scottish soil monitoring framework
Ev4	Evidence-led recommendations for future soil protection, restoration and enhancement.

To effectively manage our landscapes for improved soil protection and future resilience to risks, there is a need to establish a baseline i.e. what is the current status of our soils.

Several attempts have been made to define a set of metrics to monitor soil physical, biological and chemical properties and wider soil functionality (and ecosystem services). A recent [UK workshop](#) on soil monitoring reviewed approaches to soil monitoring across the four nations to evaluate the readiness of soil-assessment-focussed research used within UK policy delivery. The [workshop](#) highlighted that despite the challenges of identifying the most appropriate strategy for monitoring such complex systems, “there is great potential value in working to ensure the data collected has a degree of consistency, to support wider targets and understanding of soil health.” Further research into harmonisation of soil monitoring across the four nations is currently being undertaken to develop this knowledge further.

6.4.1. Action Ev1: Baseline soil ‘status’ across land cover types of Scotland.

The assessment of Scottish soils is currently conducted via a range of mechanisms governed by different policy groups across different land uses (e.g. agriculture, peatland, forestry, planning, construction/development, sport & recreation, protected areas etc). Despite this, there is a general consensus amongst policy makers and academics (Appendix I) that there is a need to progress with the current data and knowledge available to create a baseline of soils in terms of soil health plus its vulnerability to risks and the wider potential impacts on soil function. It is acknowledged that there is already a lot of data available in Scotland and so there is a good base from which to develop baselines and a monitoring framework.

Benchmarking soils are not easy as changes occur at different temporal (and spatial) scales and are so diverse that in turn their value in terms of services they provide, vary significantly across sectors and can be quite subjective. In order to set meaningful targets, and to appropriately benchmark across soil-land use types, a specific soil policy lead (team) should be identified. At present there is no single agreed soil monitoring framework for Scotland and little standardisation or harmonisation of data across different sectors. Therefore, this objective proposes further progression of the Scottish [Soil Monitoring Action Plan \(2012\)](#) which followed the [State of Scotland’s Soil Report \(2011\)](#) as well as developments being made through Scotland’s [Strategic Research Programme 2022 to 2027](#) (Appendix D), Centres for Expertise research (E.g. [Monitoring soil health in Scotland by land use category – a scoping study](#)) and [National Soil Inventory of Scotland](#) (demonstrated on the [Scotland’s Soils](#) website) towards a Scottish Soil Monitoring Framework (which aligns with other UK monitoring schemes where appropriate).

Specifically, this objective calls for some agreement on the most appropriate metrics to baseline soil ‘status’ (an indication of soil health, soil functionality and soil’s vulnerability to risk) and resource a baselining exercise from which changes in soils over time can be assessed.

6.4.2. Action Ev2: Identify evidence gaps and future improvement options across different land uses

This action is to identify evidence gaps with respect to monitoring soil protection, restoration and enhancement across different land uses, as identified by the soil monitoring workshop (Appendix I). For example,

- Review the extent of current soil monitoring and how it may vary across land use types;

- Assess the availability and accessibility of data across sectors and identify where improvements can be made;
- Evaluate methods and metrics used and to study soils and how they may vary across sectors due to the contextual differences in soil functioning and ecosystem services provided. Explore where there are opportunities for some harmonisation to better identify the functions offered by soils at a landscape scale (for example how soils are valued across land uses and better connect land management practices to the potential ecosystem services and nature-based solutions which different soils can provide) and understand the drivers of change in soil management and subsequent soil condition across land uses and sectors;
- Identify priority issues for soil protection, restoration and possible enhancement across landscapes. This includes vulnerable soil types which areas are at most risk of degradation and potential locations for the greatest opportunities for protection, restoration and/or enhancement of soils.
- Establish how are ‘degraded’ soils currently defined across land use/soil types and policy themes and to what extent are Scottish soils degraded;
- Review opportunities to better assess soil health and vulnerability to risks through emerging technologies and novel applications in terms of what they provide/contribute to soil protection, their technical readiness and potential to incorporate/implement into baselining soil protection (e.g. Infra-red, soil acoustics, X-Ray Diffraction, eDNA and microbiome characterisation, LIDAR, AI, etc).

6.4.3. Action Ev3: A Scottish Soil Monitoring Framework

A soil monitoring programme will need clear vision, purpose and objectives to ensure the monitoring programme is transparent, robust, fit for purpose and can be interpreted by wide-ranging audiences. Therefore a ‘task group’ comprising key stakeholders is suggested (see Table 3) to agree objectives and technical content of a monitoring framework as well as terms of reference for the governance and management of a soil monitoring framework. This would develop upon the findings from the ‘Scottish Soil Monitoring Framework’ workshop December 2024 (Appendix I). Other considerations include: deciding on the most appropriate metrics to be included in a monitoring framework, align to policy and reporting needs; encourage data sharing (e.g. personal, research, government and third-party data sources), review what tools/mechanisms/technology are available to assess soils in Scotland and to ensure that any framework is future-proofed. There is also scope to review metrics used across different schemes (e.g. agri-environmental schemes and the measuring, reporting, verification used in carbon schemes) and corporate reporting frameworks (see Table 3) to promote some harmonisation across terminology and approaches used in relation to soils, such as how they are valued and how current soil status and/or soils may change over time are measured and interpreted.

A Scottish soil monitoring framework would directly deliver to the Scottish Biodiversity Strategy objective of “set up monitoring frameworks to assess change in soil health, based on evidence from the Strategic Research Programme (2022-2027)”. The framework will provide evidence to monitor and validate impacts as well as contribute to future evidence-led decision making and inform further research developments.

6.4.4. Action Ev4: Evidence-led recommendations for future soil protection, restoration and enhancement.

Action Ev4 is to review progress towards the objectives set out in the route map. The evaluation of progress should allow for flexibility and adaptability to include future/emerging challenges and pressures which may be environmental (e.g. changing climates and emerging contaminants), industry-related (e.g. market vulnerabilities and/or new environmental reporting requirements) and/or community-based (e.g. workforce needs). Action Ev4 will identify knowledge gaps and opportunities for further information to be collected out with the soil monitoring framework, which would provide valuable insight on the progression to soil security in Scotland. For example, identifying what works and does not work to inform where improvements could be made as well as future research needs across fundamental and applied science. This will enable Scotland to be a leading example in mobilising actions towards thriving soils through effective landscape-scale and cross-sectoral soil protection, restoration and enhancement measures, which support future Scottish communities, the economy and environment.

7. Conclusions

This route map provides an overview of the range of risks threatening Scotland's soils and highlights challenges in tackling these risks across different soil types, site characteristics, land use types and a range of cross-cutting policy themes at the landscape scale.

Without co-ordination from an overarching soil policy, it will be difficult to overcome the existing, and future, challenges in deploying actions to specifically target landscape-scale challenges relating to soil security in Scotland.

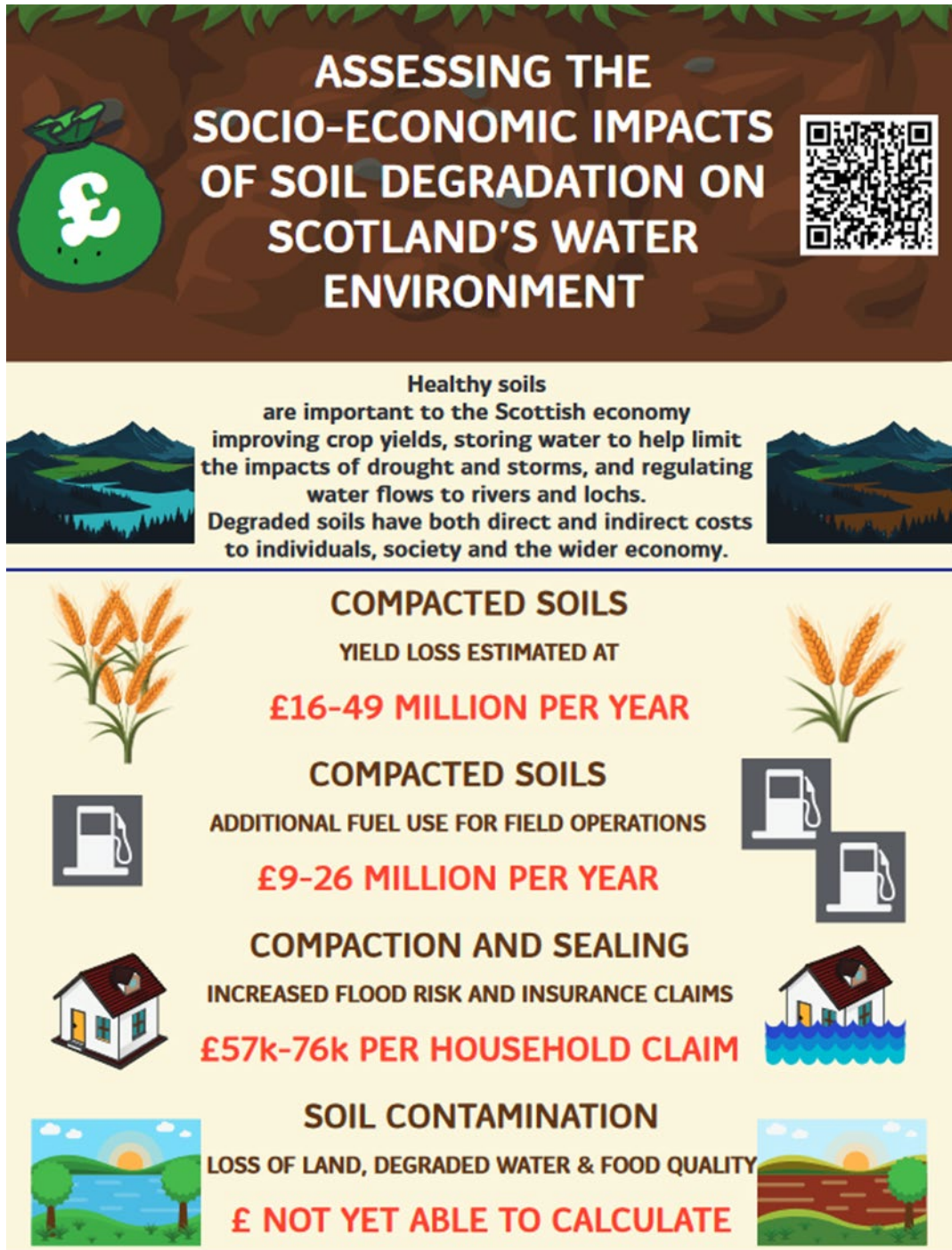
The route map sets out early thinking about the actions which might be put in place to lead, mobilise and gather evidence, in the first instance. The proposed actions that will protect, restore and enhance soils need to be grounded in the latest evidence, requiring development work by interdisciplinary and cross-sectoral task groups to inform evolving overarching policy.

The [3rd Scottish National Adaptation Plan](#) objective NC2 specifically outlines the need to take actions at the landscape scale, in a collaborative way, in order to protect and enhance Scotland's soils, increasing their resilience to the impacts of climate change, and land use challenges. Therefore, this route map provides an opportunity to build on the existing progress and momentum that has been developed in specific policy areas, to ensure soil protection, restoration and enhancement of all of Scottish soils.

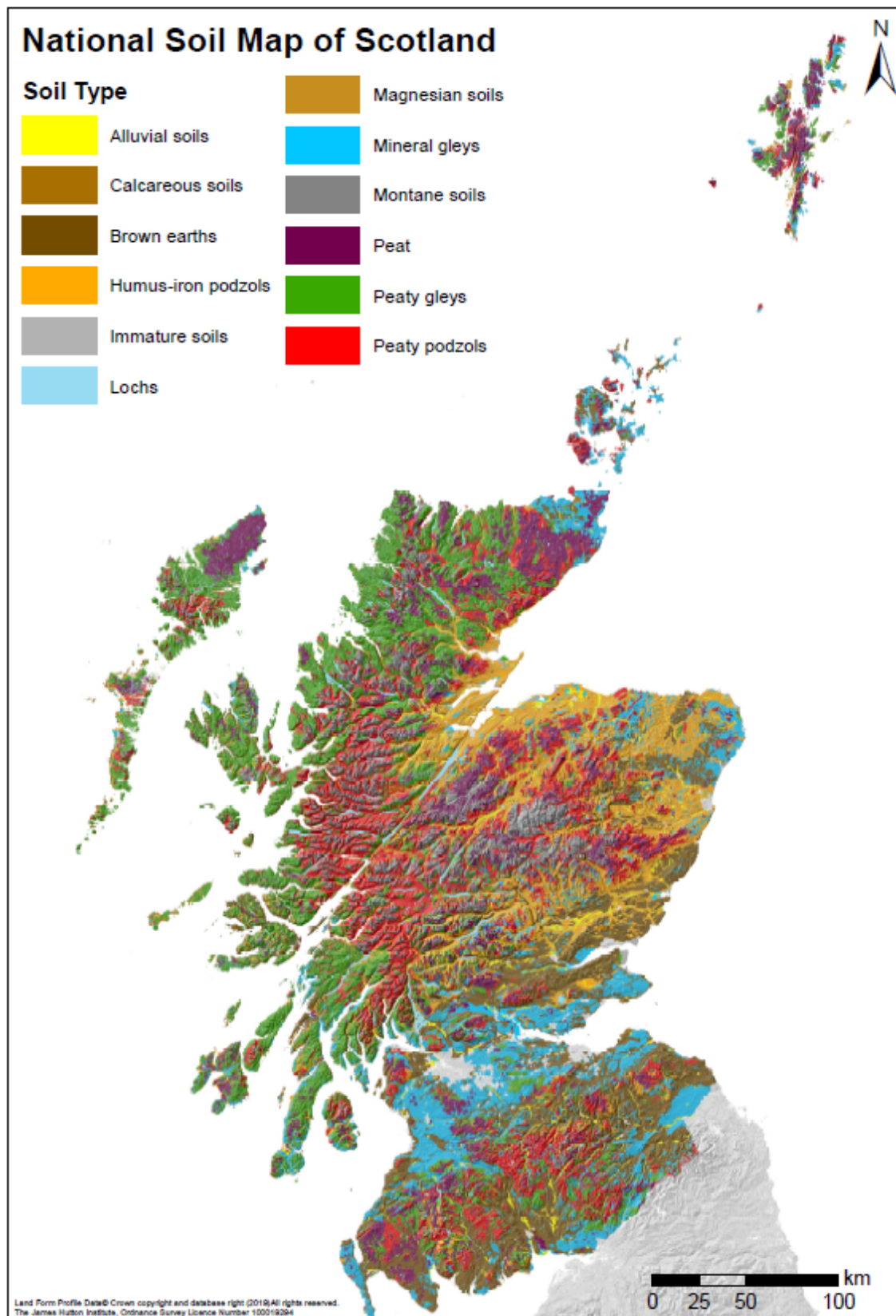
8. Appendices

Appendix A Socio-economic impacts of soil degradation

Infographic on the assessment of socio-economic impacts of soil degradation on Scotland's water environment (Baggaley et al 2024)



Appendix B Soils of Scotland



Soils of Scotland, taken from the Scotland's Soils Web [National soil map of Scotland | Scotland's soils](#)

Appendix C Summary of Workshop 1 outputs - Identifying risks and opportunities for Scottish soils

The workshop aimed to collate stakeholder views and opinions in relation to current issues and opportunities for soil security in Scotland. In particular, to review changes and developments since the publication of the Scottish Soil Framework (2009).

Participants were grouped (where possible ensuring there was a mixture of research & policy representatives and organisation across groups) and asked to engage with two group activities and two individual activities outlined below;

Group Activity 1:

Each group was asked to discuss and note **“What do you think are the key risks/threats for soil security and/or soil health in Scottish”** and **“What do you think are driving these risks?”** relating to the specific land use of the session (Agriculture, Forestry, Urban and Integrated landscapes) and feedback to the wider group.

Individual Activity 1:

Following the group discussion and sharing of key risks, threats to soil and their drivers, participants were given 5 stickers each (black for researchers, red for policy/regulator representatives) to vote on the risk they thought is of most priority. Participants could choose to allocate all of their stickers to one specific risk or to spread them out across a range of risks (providing some indication on the weight of concern across the risks identified). Participants were also encouraged to move around the room and review risk/threats identified by other groups when allocating their stickers.

Group Activity 2:

Each group was asked to discuss and note -

- **What policy/regulation is in place (relating to Agricultural soils)?** Comments noted on pink post-it notes or directly on the list of policies outlined in the SSF (print out provided)
- **What research, evidence, data, guidance is used to support soils in agriculture?** Comments noted on blue post-it notes
- **What do you think are the key gaps, updates and/or opportunities to better protect soil?** Comments noted on yellow post-it notes

Discussions were to be specific to the land use session (Agriculture, Forestry, Urban and Integrated landscapes) with the groups feeding back to the wider group of participants

Individual Activity 2:

Following the group discussion and sharing of key gaps and opportunities to better protect soil within agriculture/forests/urban/landscapes in Scotland - participants were again given 5 stickers each (black for researchers, red for policy/regulators) to vote on the gaps and opportunities they thought is of highest priority. Participants could choose to allocate all stickers to one specific gap/opportunity or spread them out across a range of gaps/opportunities (providing some indication on the weighted priority across gaps/opportunities identified). Participants were also encouraged to move around the room and review gaps/opportunities identified by other groups when allocating their stickers.

Information provided by participants was collected and transcribed.

Summary of workshop outputs:

The top 5 risks and threats to Scottish soils voted for by participants across agriculture, forestry, urban and integrated landscapes.

	Agriculture	Forestry	Urban	Landscape
1	Soil disturbance, erosion & organic matter loss	Soil disturbance, erosion & organic matter loss	Soil sealing & consumption	Lack of soil-specific governance and policy
2	Biodiversity loss	Biodiversity loss	Cumulative effects of climate change	Under valuing soils as an asset/resource
3	Soil contamination & environmental pollution	Climate change (Tree species, pests, weather impacts)	Soil contamination (historic)	Difficulty dealing with spatial heterogeneity
4	Climate change & extreme weather events	Wider impacts (loss of peat)	Soil classification as 'waste' going to landfill, limited reuse	Loss of soil function (via compaction, erosion)
5	Lack of collaborative, catchment scale management	Market pressures & demands (driving specific tree species)	Undervaluing soil as an asset	Data available, sharing, accessibility

The top 5 gaps/opportunities voted for by participants relating to 'securing Scottish soil' across the four land use sessions.

Rank	Agriculture	Forestry	Urban	Landscape
1	Need for soil governance or policy (joint 1st)	Better data availability & accessibility	Review classification of soil as 'waste'	Need for soil governance or policy. Mainstream & update SSF
2	Better data availability & accessibility (joint 1st)	Need for soil governance or policy	Strategic planning for rainwater runoff	Better data availability & accessibility
3	System scale modelling & visualisation tool	Re-design of schemes to better mitigate impacts on soil	Improve enforcement of soil reuse &	Integrate soils focus into place-based approaches

Rank	Agriculture	Forestry	Urban	Landscape
			contamination rules	
4	More peer-to-peer learning	Improve soil literacy, education & training	Assess soil data/information is utilised in planning	Better links across policy areas
5	Improve soils literacy	Include soil assessment in licensing plantations	Biodiversity (above & belowground) in urban soils	Spatial data integration

Appendix D Soil research across Scottish Government's Strategic Research Programme (2022-2027)

Underpinning evidence for informing policy comes from the Scottish government research programme (SRP). Research relevant to soils occurs in all 6 themes in the SRP and Underpinning National Capacity;

- Theme A: Plant and Animal Health
- Theme B: Sustainable Food System and Supply
- Theme C: Human impacts on the Environment
- Theme D: Natural Resources
- Theme E: Rural Futures
- Theme F: BioSS research

It is also a key part of the work within CxC and CREW for example the project on the socio-economic cost of soil degradation funded through CREW and the Soils Fellowship funded through CxC. Soils research highlighted here includes work on understanding how soils function, how changes can be monitored and translation it so it can be used by a range of stakeholders.

The table below gives an outline of how soils underpin SRP themes as well as where there is ongoing direct soil-focused research

Theme	Topic	Link to Scottish soils
A: Plant and Animal Health	A1. Plant Disease	Soil health can influence the prevalence of pests and diseases which may impact plant and animal health. Soils can be a carrier of plant and animal diseases, and soil properties can impact their availability. Soil borne diseases can be a form of soil contamination.
	A2. Animal disease	
	A3. Animal Welfare	
B: Sustainable Food System and Supply	B1. Crop improvement	The combination of land management and climate change influences trajectories of soil properties. Long term trials allow the adaptation and mitigation potential, sustainability and trade-offs associated with management practices to be analysed. This includes an exploration of the interactions between management practices and crop cultivars.
	B2. Livestock improvement	Understanding soils in the context of livestock management is important part of understanding feed availability, carbon footprints and how managing livestock is impacted by climate change.
	B3. Improving agricultural practice	Soils are vital for sustainable productivity and impact food and drink quality and subsequently human nutrition and overall health.
	B4. Food supply and security	

Theme	Topic	Link to Scottish soils
	B5. Food and drink improvements	Soil contamination including contaminants of emerging concern are held in soils and can be transferred to vegetation and water courses. B5:(Contaminants of emerging concern in the food chain) B6:(Antimicrobial Resistance)
	B6. Diet and food safety	Soil contamination including contaminants of emerging concern are held in soils and can be transferred to vegetation and water courses. B5:(Contaminants of emerging concern in the food chain) B6:(Antimicrobial Resistance)
	B7. Human Nutrition	Understanding human nutrition can be linked to the “One Health Concept” but the focus of this work is on human interactions and choices linked to food.
C: Human impacts on the Environment	C2. Agricultural GHGs	Development of options for a monitoring agricultural GHGs within a soil monitoring framework. Interactions between soil health and land management decisions across land covers
	C3. Land Use (inc. mapping)	Soil data and information contributes to wider landscape quality and functioning
	C4. Circular Economy (inc. waste)	Understanding the circular economy can be linked to issues of “waste to land” and “soil as a waste” but there is no specific work on these here.
	C5. Large Scale Modelling	Development of options for a soil monitoring framework and the requirements for the incorporation of monitoring data in large scale modelling across landscapes.
	C6. Use of Outdoors and Greenspace	Understanding the use and value of our outdoors and greenspace is important part of understanding soils in these areas but the focus of this work is on how these areas are used and viewed by people.
Theme D: Natural Resources	D1. Air Quality	Soil is in constant exchange with the atmosphere. Soil impacts air quality through GHGs. Soil health is impacted by air quality
	D2. Water (including flooding)	Nature based solutions - Soil is in constant exchange with the water cycle. Soils can retain water (important for flood resilience), filter and buffer chemicals (important for water quality). Soil leaching and erosion can be problematic for water quality and flood resilience

Theme	Topic	Link to Scottish soils
	D3. Soils	Soil health can be impacted by management decisions. Understanding soil functional relationships across different land covers supports improved land management decisions. It also identifies trade-offs and win-win scenarios. Understanding forestry systems, soil health and ecosystem carbon dynamics is important for landscape scale decision making. New technologies and analysis protocols can lead to the ability to rapidly sample soils and also identify changes providing indications of soil contamination. Farmer led soil assessments and data provide tools for on farm decision making. Exploring the potential for real time monitoring and whether this can help inform management in cultivated systems. Peatlands are a unique habitat and understanding GHG fluxes, being able to monitor the interactions between these fluxes, water balance and biodiversity under restoration in a changing climate is important for understanding their impacts on wider ecosystem services such as water quality.
	D4. Biodiversity	Soil biodiversity underpins and can be an indicator of soil functions in both semi-natural and cultivated ecosystems. It therefore supports plant communities and underpins our wider biodiversity and natural capital. Understanding links between soil biodiversity, which can be more responsive than other indicators of soil health, soil functions and wider ecosystem services is important for understanding the potential impacts of climate change and setting baselines that better represent soil functions.
	D5. Natural Capital	Combining data on climate and soil functions in modelling approaches provides insight into changes in soil vulnerability and risks in a changing climate. Implementation of the LCA in a research platform, enabling it to be updated with new soils and climate data and run with future climate projections to explore consequences on land use.
Theme E: Rural Futures	E1. Rural Economy	Indirect link - soils underpin ecosystem services of rural communities. Healthy soils will contribute to a healthy economy and rural community.
	E2. Rural Communities	
	E3. Land Reform	

Theme	Topic	Link to Scottish soils
Theme F: Vision and Impact : Horizon scanning		Development of statistical methods to analyse diverse soils data and inform the design of a monitoring framework. (BIOSS statistical research)
Underpinning National Capacity	Soils Data and website	Combining and Managing soils data in Scotland's soils database increases its power to do policy relevant research. Translation of soils data and making the data available to a wide range of stakeholders. Including the development of apps.
	Soils Archive	Management of the soil archive allows for the testing of laboratory protocols and the analysis of samples for new indicators

Appendix E Challenges to landscape-scale soil management

To effectively as well as stakeholder feedback (link to Workshop outputs) highlighted a range of challenges associated with managing soils in a changing climate, which are summarised below

Challenge	Description
Lack of soil focused governance	No overarching policy to support accountability and leadership to drive soil protection in Scotland
Climate change	Soils play a vital role in climate change adaptation and mitigation. Soils are impacted by variable weather patterns and more frequent extreme weather events (flooding and droughts), which can have knock on effects to soil protection, fertility and productivity, flood resilience, water quality etc.
Diversity of Scottish soils	Scotland's soils (Appendix B) are diverse, providing a range of specific functions to the wider ecosystem. They include mineral soils which provide fertile land for food production, deep peat storing carbon to depths in excess of 10 meters, soils which are linked to specific land covers and soils where protection is critical to protect wider ecosystem services such as water quality and quantity. However, this variation across soil types, topography, local weather patterns, land capability, land use history and current land use leads to multiple layers of complexity affecting overall soil health and security. This requires the provision of management guidance and a monitoring framework that is fit for purpose across different soil types and land covers.
Multiple demands on Scottish soils	Balancing the multiple demands on soils requires an assessment of the multiple requirements from our land. For example Scottish food security (e.g The production food contributing to Good Food Nation (Scotland) Act (2022)); the production of raw ingredients for wider produce (e.g. whisky production, which requires agricultural soils for barley production but impacts peatlands via peat burning in some malting processes); production of animal feed; soil sealing to support housing developments, infrastructure and urbanisation; platform for achieving forestry targets.
Defining soil 'value' across sectors and land uses.	How soils are 'valued' varies across land uses and soil types. This leads to variable levels of knowledge, evidence and protection across land uses. Soils have a wide range of properties, and not all soils can deliver the same services. There is scope for decision-making and management to be more place-based in relation to specific value and functions provided by different soils.

Challenge	Description
Defining, measuring and monitoring soil health, security & resilience	Clearer guidance is required in terms of defining, understanding and measuring various components of soil systems and well as capturing (and understanding) their dynamic nature, such as soil carbon sequestration potential. There is also a need for keeping abreast of UK and wider EU initiatives on defining and monitoring soil health and the indicators that maybe required to align with these.
Linking soil health to functionality	Soil health indicators are context dependant and are not a one size fits all. It is important to understand how 'soil health' should be defined and quantified across different soil and land use types where what the soil can deliver (soil functionality) and the 'value' of those functions in those areas also vary.
Soil biodiversity	Lack of research relating to the role of soil biodiversity in soil health and protection, particularly in terms of monitoring changes in soil biodiversity, which can often require complex measurements. There is however increasing availability of powerful data analysis techniques that allow more detailed interpretation of this kind of data and along with the availability of archived samples the ability to investigate change.
External (industry) challenges	Markets & supply chains can have direct and indirect influences on our landscapes and soils. With more attention on soil health within corporate nature-related target-setting and reporting, it is important that there are resources available to guide appropriate interpretation and implementation of soil knowledge for future sustainability, environmental net gain, resilient landscapes and carbon management.
Emerging challenges	It is important to consider emerging and future challenges (e.g. new pollutants, increased demands on our soils etc) which may impact soils. For example, ensuring mechanisms exist which support new challenges being identified, monitored and support exists to protect soils from any negative impacts and future degradation.
Soil literacy	As soils support a wide range of ecosystem functions across different sectors, there can be some inconsistencies in relation to how soils are described, understood, valued, evidenced and managed. Improved soil literacy across sectors (e.g. clearer definitions, understanding the dynamic nature of soils, interpreting core soil metrics and potential limitations of soil tests/models) will support informed decision making and land management going forward. It is also important to address any skills gaps that may hinder the delivery of healthy, resilient soils across Scotland.

Appendix F Where soils sit across different policies and legislation

List of policies and their connection to soil protection.

Policy	Are soils mentioned?	Specific action/objective to address soil risks?					
		Physical (soil loss)	Physical / structural (compaction)	Conservation of OM and C	Soil biology / biodiversity	Chemical / contamination	General health & protection
Scottish Soil Framework (2009)	Y	Y	Y	Y	Y	Y	Y
Scotland's National Peatland Plan and Peatland Action;	Y	Y	Y	Y	Y	Y	Y
(5th) edition of the UK Forestry Standard (UKFS) (2023)	Y	Y	Y	Y	Y	Y	Y
Agricultural Reform Programme (List of Measures)	Y	Y	Y	Y	Y	Y	Y
Scottish Biodiversity Strategy and Delivery Plan, 2024	Y	Y	Y	Y	Y	Y	Y
Scotland's National Planning Framework 4	Y	Y	Y	Y	Y	Y	Y
Agricultural Reform Programme (Cross Compliance)	Y	Y	Y	Y			Y
Building standards technical handbook 2020: domestic, 2020	Y		Y			Y	Y
The 3rd Scottish National Adaptation Plan (2024)	Y			Y			Y
Sludge (Use in Agriculture) Regulations, 1989	Y					Y	Y
The Action Programme for Nitrate Vulnerable Zones (Scotland) Regulations, 2008	Y					Y	Y
Environmental Protection Act 1990 - Part IIA Contaminated Land (2006)	Y					Y	Y
The Pollution Prevention and Control (Scotland) Regulations (2012)	Y					Y	Y
Statutory Guidance Waste Management Licensing (Scotland) Regulations (2011)	Y					Y	Y

Policy	Are soils mentioned?	Specific action/objective to address soil risks?					
		Physical (soil loss)	Physical / structural (compaction)	Conservation of OM and C	Soil biology / biodiversity	Chemical / contamination	General health & protection
The Radioactive Contaminated Land (Scotland) (Amendment) Regulations (2007)	Y					Y	Y
The Water Environment (Controlled Activities) (Scotland) Regulations (2011)	Y	Y					Y

The policies below include reference to soil health more generally:

Environmental Assessment (Scotland) Act 2005	Circular Economy and Waste Route Map to 2030	The Public Gas Transporter Pipeline Works (Environmental Impact Assessment) Regulations 1999
Climate Change Plan (2018-2032);	Wildlife Management and Muirburn (Scotland) Act 2024	The Offshore Petroleum Production and Pipelines (Environmental Impact Assessment and other Miscellaneous Provisions) (Amendment) Regulations 2017
Forestry and Land Management (Scotland) Act (2018)	The Electricity Works (Environmental Impact Assessment) (Scotland) Regulations 2017	Fitting Landscapes Policy, 2014. Transport Scotland
Scotland's Forestry Strategy 2019 to 2029	Land Reform (Scotland) Bill, 2024	Town and Country Planning (Scotland) Act 1997
Right Tree in the Right Place (RTRP)	Local Food Strategy, 2024	Local development planning guidance, 2023
Sustainable and Regenerative Farming - next steps: statement (2022)	Bioenergy - draft policy statement: consultation (2024)	Onshore wind: policy statement 2022

Appendix G How the 'Soil Route Map' was developed

The route map was developed across three key phases:

Phase 1: What do we already know?

The initial phase involved reviewing current policies, regulations, frameworks and evidence (research) across different land uses to ascertain current knowledge as well as policy and/or legislative support in relation to soil health and security in Scotland. This included a review of The Scottish Soils Framework (2009) in terms of developments in knowledge and actions since its publication.

Phase 2: What are the key challenges for securing Scottish soils in a changing climate? Consolidating evidence, guidance and opinions. The second phase of the project comprises the collation of key messages derived from a stakeholder workshop. These discussions included researchers, policy makers, regulators, and representatives from charities and other governmental agencies.

Phase 3: Opportunities and pathways to implementing soil security in Scotland for 'The Route map'. The development of the proposed route map comprises an iterative process with phase 3 being the refinement of consolidated evidence from phases 1 and 2, into an easy-to-follow report outlining future opportunities, potential barriers/challenges, research gaps and where additional resources may be required.

8.1.1. Stakeholder Engagement

A key component of the route map development is the input from stakeholders across all areas of land management to contribute to- and provide feedback on- the route map development, which included three sets of workshops:

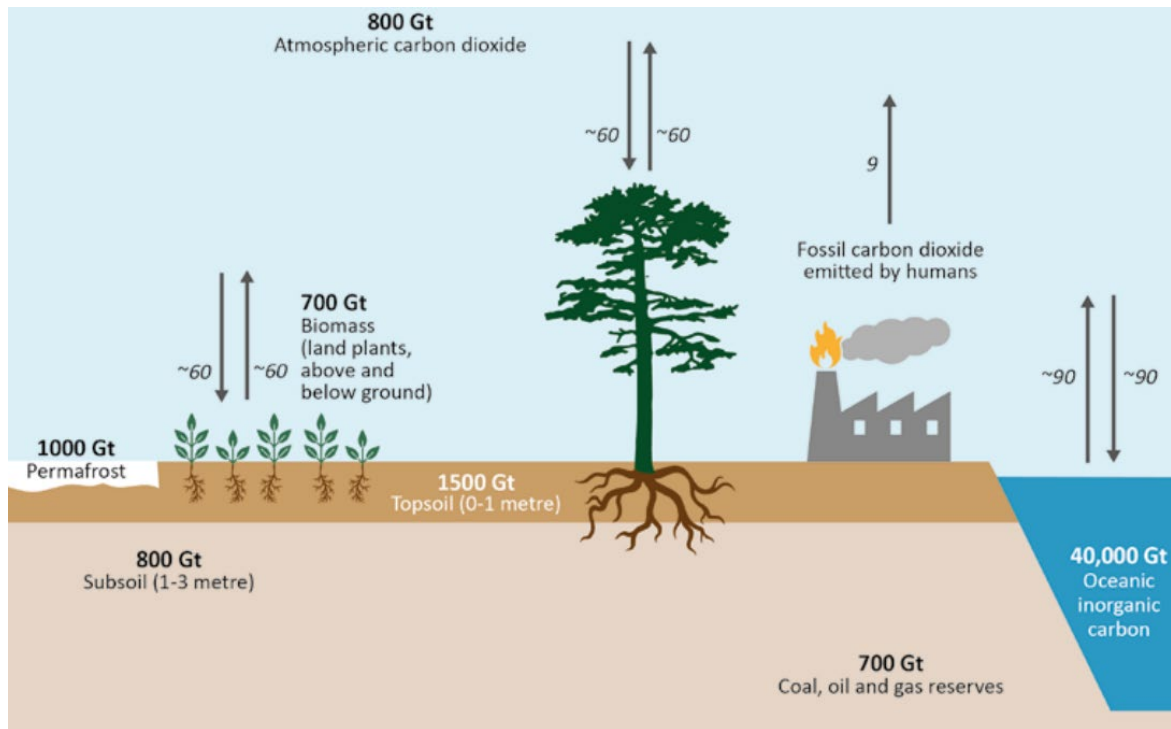
Workshop 1: Identification of the risks and threats to soils across land covers to review the challenges across different land use sectors (August 2024);

Workshop 2: Discuss the development of a soil monitoring framework for Scotland, potential alignment with the EU Soil Monitoring Law and how a monitoring framework could support the objectives within the soil route map (November 2024);

Workshop 3: Refining the vision and objectives of the Scottish soil route map

Within all phases of the route map development, consideration was given to the specific barriers and opportunities outlined in the Scottish National Adaptation Plan 3, particularly the underpinning research and how this is translated into policies and how these can be implemented to protect soils better in the absence of overarching governance relating specifically to soils in a Scottish policy context.

Appendix H The carbon cycle



The carbon cycle from The [British Soil Science Society – Science Note on Soil Carbon](#). Carbon stocks and flows on land and in the oceans (adapted from [Jenkinson, 2010](#)). The numbers in bold are stocks in Gigatonnes (Gt) C: those in italics are flows in Gt C per year. Topsoil and subsoil stocks exclude peatlands.

Appendix I Workshop outputs – A Scottish Soil Monitoring Framework (SSMF)

The workshop comprised 4 group activities (outlined below) to discuss the development of a Scottish soil monitoring framework (SSMF) with attendees from across Scottish research institutes, Scottish Government, NatureScot, SEPA and Historic Environment Scotland.

Activity 1: What do we want to achieve with a SSMF? Objective setting - What should be monitored? For example;

- **Soil health status** - a record of physical, biological, chemical characteristics at a given moment in time and space.
- **Soil vulnerability to risk** – climate and weather resilience, contamination and diffuse pollution risks, soil compaction, rate of sealing, vulnerability to physical loss (erosion) and destabilisation (landslides)
- **Soil functionality** – for example how soils are contributing to biogeochemical cycling and climate change, water storage, water quality and flood management and supporting ecosystem biodiversity etc.
- **Soils across land use** – are the objectives of a SSMF the same across different sectors and land uses? (peatlands, agriculture, forestry, horticulture, urban, recreational and mixed land uses)
- Should a SSMF review **compliance, regulation and licensing**
- How could a SSMF inform the **delivery of policy objectives** and support future decision making?

Activity 2: Reviewing the proposed EU Soil Law and how it relates to Scottish data - Presentation by Dr Allan Lilly followed by a group discussion

Activity 3: Reviewing options for;

- **Baselining Scottish soils** – what for and which metrics would be needed
- **Benchmarking** - e.g. Is it appropriate to set targets or benchmarks for Scottish soils? What are the Pros and cons
- **Stratification of landscapes and data** – how to stratify monitoring needs across different objectives and across different soil types and land cover/uses?

Activity 4: Group discussion on how we move from theory to action? Is there sufficient knowledge/data to initiate a SSMF?

Summary of workshop outputs:

Visions of a soil monitoring framework

- To be a leader across the 4 nations of the UK and internationally
- To have sustainable soils in perpetuity
- Linking monitoring to decision making and ultimately evidence-based policy
- A system to be able to respond rapidly to policy questions

Key overarching messages from stakeholders

- Strengthening Scottish soil monitoring with a bespoke soil monitoring framework (SSMF) could make Scotland a 'global exemplar'

- Reviewing the EU Soil Monitoring Law demonstrates opportunities for Scotland to develop a more advanced monitoring framework that is more appropriate and beneficial for Scottish landscapes and land uses.
- Creating a SSMF that can support and co-deliver across different policy objectives (E.g. Biodiversity strategy, vision for agriculture, flood resilience, SNAP3, NPF4 etc)
- A bespoke SSMF would build a useable resource that supports and informs future evidence-based policy making and delivery (e.g. climate adaptation and mitigation, food security, flood resilience, water quality and air quality) and further utilises historic government funded data/platforms to provide broad scale conclusions and modelling requirements, as well as directing future research and policy needs.
- We are not starting from scratch - Scotland already has a lot of data and knowledge to utilise and build upon. A monitoring framework needs to start with the soil properties and strong conceptual understanding of the soil functions.
- “Let’s get started” - Do what we can with what we have and make improvements over time.

Overall Summary

There was wide support for a soil monitoring framework in Scotland that evidences why and how changes in soils may be occurring, as well as being able to better benchmark progress towards ‘thriving’ soils in Scotland. Stakeholders agreed that there is a significant amount of data already available providing a firm foundation from which to develop a SSMF, but in order to develop this further an overarching objective(s) is needed to inform the design and functionality of a SSMF. Across stakeholders present, there was a strong consistent message that the SSMF needs to be able to answer questions across scales, disciplines, sectors and land uses, as well as not letting financial constraints be a barrier for inaction (particularly when the ultimate costs of soil degradation is taken into account as highlighted by [Baggaley et al., 2024](#)). There was significant discussion regarding the types of data that may be required to inform soil health, functionality and security as well as how data could/should be translated to inform decision making i.e. how a SSMF can be designed to facilitates the translation of data into knowledge, action and wisdom. This discussion raised many questions relating to data requirements in terms of identifying appropriate soil metrics which will inform on the current state of soil resources as well as allowing the monitoring of changes in soils over time.

There were a variety of views on the use of a baseline, benchmarks and stratification. There was a view that a baseline of Scottish soils was needed even if it is imperfect. It was clarified that a baseline was just that and that it was not a “Preferred state”. Again, there was much discussion with respect to identifying which metrics/properties should be recorded in a baseline assessment and what is needed in terms of harmonisation of existing data sets to achieve the best possible baseline with the data available. Stakeholders were confident that potentially sufficient data exists to derive one, particularly through the national soil surveys ([NSIS1](#) and [NSIS2](#)) and monitoring of forest soils (e.g. [Forest soil sustainability](#), [BIOSOIL](#)) but that there is a lack data for soils relating to urban/suburban and recreational soils. However, it was highlighted that NSIS 2 was carried out nearly 20 years ago (2007-2009) and so changes in soil condition may have already occurred.

There was a lot of debate about whether there should be soil targets and benchmarks set. The use of benchmarks to incentivise actions and to better monitor progress was emphasised. Conversely there was concern with respect to identifying suitable benchmarks across different soil types and land uses. This includes the dependency on soil type, land use and management practices and the challenges of what defines a benchmark for multi-functional land uses or how to incorporate potential land use change over time. Stakeholders demonstrated caution with respect to the implementation of benchmarks as it is difficult to predict and manage potential unintended consequences, knock-on effects and trade-offs that target setting could bring. Stakeholders highlighted that there is a risk that benchmarks and targets lead to an oversimplification of soils and therefore the overarching message of holistic soil (and ecosystem) health and resilience may become lost as land managers strive to accomplish specific targets set.

Stakeholders agreed that a SSMF needs to represent all soil and land use types, but that there are challenges relating to how best Scotland's landscapes should be stratified (e.g. based on soil type, land use (or sector) and/or by management) in the SSMF. It was suggested that a tiered or modular approach may be most suitable to reflect the complexity of Scottish landscapes, allowing for simple actions to be identified from collated data/information (and support adaptive learning over time). The challenge of encapsulating changes in land use and land management within a robust statistical SSMF design was identified at the workshop. Therefore, the potential to stratify or interpretation the SSMF based on soil vulnerability was proposed.

An overarching reaction of the workshop relates to the phrase "perfect is the enemy of good" in terms of there being a consensus that a SSMF is needed/wanted by stakeholders but that current data or knowledge gaps shouldn't be barriers preventing the development of a SSMF. There was a sense of optimism that an agreement on SSMF objectives, purpose and design (metrics included) can be made to generate a transparent work-in-progress SSMF with its implementation informing future developmental needs. A key factor in implementing a monitoring framework is the presentation of data derived from it and ensuring that information is appropriately and proportionately translated to support the needs across Scottish Government, agencies, researchers, investors and land managers.

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How to cite this publication:

Buckingham, S., and Baggaley, N. (2025) 'Securing soils in a changing climate: A soil route map for Scotland', ClimateXChange. <http://dx.doi.org/10.7488/era/6006>

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This work was supported by the Rural and Environment Science and Analytical Services Division of the Scottish Government (CoE – CXC).

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