Soil Monitoring Action Plan

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1. Introduction

Historically, environmental monitoring in Scotland has been developed in an iterative and often sporadic manner by a range of organisations in response to statutory drivers and environmental issues of concern. The 2011 Scottish Environmental Monitoring Strategy[1] developed by the Coordinated Agenda for Marine, Environment and Rural Affairs Science (CAMERAS) partnership provides a framework for monitoring which will encourage practical steps to improve the co-ordination of environmental monitoring programmes in Scotland and therefore improve the cost-effectiveness of monitoring activities. The implementation of the strategy is being taken forward as part of the CAMERAS programme of work, with individual Monitoring Action Plans (MAPs) to be produced for key environmental issues by 2013. Phase 1 of MAP development activities covers soil, air quality, freshwater and marine topics.

The underlying rationale for a soil MAP also reflects and supports the aim of the Scottish Soil Framework (Scottish Government, 2009) to promote the sustainable management and protection of soils consistent with the economic, social and environmental needs of Scotland. The development of a soil monitoring programme fulfils a number of actions in the Scottish Soil Framework including for the Scottish Government to help develop a soil monitoring network and various actions relating to knowledge exchange and awareness raising.

It has become increasingly recognised that land provides multiple benefits to the Scottish people, environment and economy[2], and that healthy soils are fundamental to delivering these. An objective of soil monitoring should be to maintain and identify the opportunities to enhance the supply of these benefits. The State of Scotland's Soil Report 2011[3] found that while there is a considerable amount of existing soil data, there is still only a limited amount of systematic data to allow a comprehensive assessment to be made on the state of Scotland's soil resources for multiple purposes and whether/how these resources are changing as a result of management, land use changes or other drivers such as climate or pollution sources.

The purpose of the Scottish soil MAP is to support the development of efficient and co-ordinated soil monitoring across Scotland. This builds on previous research activities in the UK and elsewhere in Europe to determine suitable soil quality indicators and on the design and implementation of national and European soil monitoring networks (e.g. UK Soil Indicators Consortium). This is particularly timely given the recent publication of a report by the European Commission on the implementation of the Soil Thematic Strategy and on-going activities[4,5], including the on-going development of a proposed EU Soil Framework Directive. In addition, the wider recognition of the cross-cutting nature of soils and the need for integration across different policy areas presents new end-user needs for soil information.

[1] CAMERAS Scottish Environmental Monitoring Strategy www.scotland.gov.uk/Publications/2011/12/05085553/0

[2] The Land Use Strategy / Scottish Government, 2011 www.scotland.gov.uk/Publications/2011/03/17091927/0

[3] The State of Scotland's Soil Report / Dobbie et al., 2011 www.sepa.org.uk/land/soil.aspx

[4] European Soil Thematic Strategy, 2006. http://ec.europa.eu/environment/soil/three_en.htm

[5] Report on the implementation of the Soil Thematic Strategy and ongoing activities (COM(2012) 46). http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2012:0046:FIN:EN:PDF

The soil MAP has been developed by a subgroup of the Soil Focus Group as a linked activity to the Scottish Soil Framework[6] (**Figure 1**). Initial development was carried out using expert knowledge. This was followed by consultation of key stakeholders, through a questionnaire, to assess user needs and their awareness of available soil information.

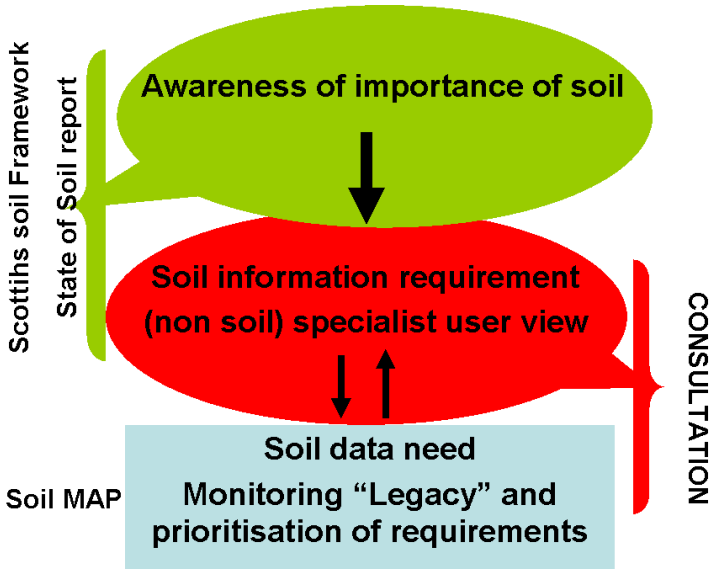

Figure 1 Background of the soil MAP development project and consultation

The questionnaire responses (SFG 2012 unpublished report) have been user to progress the development of the soil MAP.

Box 1- Soils in Scotland – what do we need to know?
[Extract from State of Scotland's Soil Report 2011]

- In what circumstances are Scotland's soils a source or sink of carbon? How much are soil carbon stocks changing?
- Are greenhouse gas emissions from soils reducing or increasing? By how much?
- What are the effects of soil management practices on mitigating climate change, diffuse pollution and flood-risk?
- Which soils are being used as a platform for development and what is the ecosystem impact?
- How do we maintain or improve the ability of soils to produce high yields of good quality produce sustainably?
- How do we maintain healthy soil biodiversity able to support ecosystem services?
- How do we maintain a good soil structure and also control soil erosion and landslides?
- What harm is being caused through contamination of land and how is this best controlled?
- How do we incentivise land managers to carry out good soil management practices?
- Are all of the above contributing to the sustainable use of soil and its protection for future generations?

[6] The Scottish soil Framework / Scottish Government, 2009 www.scotland.gov.uk/Publications/2009/05/20145602/13

2. The framework for monitoring

2.1. Scope

The soil MAP assesses what data and information is required on Scottish soils and who needs it, reviews the current evidence on the status of soils in Scotland, brings together disparate information sources, and identifies overlaps, efficiencies and gaps. The soil MAP determines whether current policy, regulation and land manager needs for soil information can be met from existing soil monitoring efforts and, where relevant, links or brings together distinct survey and monitoring efforts to optimise the delivery and utility of soils data and information for Scotland.

A soil monitoring network is a means to provide progressive information on the extent and condition of Scotland's soil resources, including data on differences and trends between places and over time. The monitoring should assess risks from existing threats and ideally be able to pick up future as yet unreported threats.

The soil MAP therefore considers the whole soil environment; how it is changing, what causes the changes and what impact these changes in soil quality have on soil functions, the wider environment, society and the economy. This will provide information which will be used to integrate monitoring activities across the wider environment.

Soil is a non-renewable resource which underpins a range of functions vital for our environmental, social and economic systems. The EU Soil Thematic Strategy recognises the pivotal role that soil plays in:

- providing the basis for food, wood and biomass production;
- controlling and regulating environmental interactions: regulating water flow and quality;
- storing carbon and maintaining the balance of gases in the air;
- providing valued habitats and sustaining biodiversity;
- preserving cultural and archaeological heritage;
- providing raw materials;
- providing a platform for buildings and roads.

The soil MAP focuses on these functions as well as considering:

- sustainability of soil resources;
- human and animal health.

The soil MAP recognises that there are different requirements for soil information including for statutory, policy and guidance purposes which should meet the needs of a wide range of end users in the public, private and voluntary sectors. **Table 1** provides a range of examples of the services soils are expected to provide and link those to eight main functions of soils as described in the state of Soil report. These will be further developed to provide specific details on information needs and soil data requirements.

Table 1 Examples of the services soils provide and the functions underpinning them.

what are the services associated with soils?	The main function of soils								
	Food and fibre crop production	Controlling and regulating environmental interactions	Storing carbon & exchanging GHG with atmosphere	Sustain valued habitats and biodiversity	Preserve cultural & archaeological heritage	Provide raw materials	Platform for building and roads	Human and animal health	Sustainability of soil resources
to provide good quality, healthy food	X							X	
for sustainable timber and biomass production	X							X	
to support other commercial plant production	X								
to support above ground biodiversity				X					
to achieve good status (species and habitats) both within designated sites and in the broader countryside				X					
to provide appropriate conditions to sustain / enhance soil biodiversity				X				X	X
to protect water quality		X							X
to regulate water quantity and flow (i.e. mitigate and control the impact and frequency of flooding events)		X							
to maintain and if possible enhance soil carbon stocks		X	X						X
to reduce GHG emissions from soils and reduce GHG concentrations in the atmosphere		X	X						X
To contribute to sustainable rates of erosion		X	X						X
to protect buried archaeological and cultural artefacts					X				
to protect imprints and evidence of past human land use and historical / archaeological environmental change					X				
to protect man-made features associated with specific soil					X				
to protect record of palaeo-climate and palaeo-environment					X				
provide soil systems that are resilient to loss of the soil resource resulting from the extraction of raw materials for construction industry (e.g. borrow pits), commercial exploitation and traditional crofting practices						X			
provide soil systems that allow for restoration of soil functions post extraction						X	X		
provide soil systems that are resilient to structural damage resulting from soil handling operations during construction							X		X
soils under planning systems to be "uncontaminated" or be in a state that can be sufficiently remediated for development to take place							X		X
soils able to maintain system capacity to mitigate and control point source pollution events							X		X

2.2. Objectives

The overall objective of the soil MAP is to devise a systematic, co-ordinated approach to soil monitoring in Scotland to provide the data and information required to ensure Scotland's soils are managed sustainably and protected from harm. In addition, it is essential to have the evidence to support the mitigation of any wider environmental, societal or economic damage caused by soil degradation.

The soil MAP will therefore:

- identify who needs soil data / information;
- assess what data / information is required;
- determine what data / information exists and who collected/ collects it?
- establish any gaps / overlaps in data and data coverage?
- suggest how the gaps could be filled and how any overlaps could be rationalised;
- identify and prioritise monitoring needs;
- consider who might be best placed to undertake any new monitoring required;
- outline a timetable for implementation.

Much work has already been carried out to determine suitable soil quality indicators and on the design and implementation of national monitoring schemes alongside UK wide reporting (e.g. UK Soils Indicator Consortium – UK SIC activities)[7,8]. The 2009 Design of a UK Soil Monitoring Programme report outlines the main elements for a UK scheme. The design of soil monitoring in Scotland should take account of this work, along with outputs from the 2006–2011 Scottish Government funded research programme[9], with respect to the most appropriate field sampling methods, analytical techniques and indicators, and the targeting of specific areas for identified threats. Expert knowledge and Scottish stakeholder consultation provided additional material to refine our understanding of current and future soil data and information requirements in Scotland.

2.3. Who requires monitoring and why?

There are a variety of individuals and organisations which use or could use soil information. The cross cutting nature of soils means that a wide range of policy initiatives and their delivery mechanisms require information on soil properties and trends to assess the effectiveness of measures implemented to mitigate harm to soils and the wider environment, society and the economy. In addition, many land use and land management decisions are informed by soil data and information. Soil information is also used by the general public (e.g. for gardens and allotments), in our education system (e.g. curriculum for excellence) and by the wider academic community for varied research purposes.

The questionnaire asked the users what their organisation currently uses soil information for and what they would / could use soil information for in future if existing soil information became more accessible or if new information became available.

[7] National Soil Monitoring Network: Review and Assessment Study (LQ09), SNIFFER 2006
http://nora.nerc.ac.uk/3317/

[8] Design and operation of a UK soil monitoring network 2009 Environment Agency Science Report SC060073
publications.environment-agency.gov.uk/pdf/SCHO0908BOMX-e-e.pdf

[9] RERAD work programme 2005-2010 Work package 3.2 and 3.3
www.scotland.gov.uk/Topics/Research/About/EBAR/StrategicResearch/research-strategy/programmes/land-use

Table 2 Example of policies, legislation and guidance which may require soil information as part of their development and implementation

European Directives

- Integrated Pollution Prevention and Control Directive (2008)
- Floods Directive (2007)
- Groundwater Daughter Directive (2006)
- National Emissions Ceiling Directive (2001)
- Strategic Environmental Assessment (2001)
- Water Framework Directive (2000)
- Landfill Directive (1999)
- Habitats Directive (1992)
- Urban Waste Water Treatment Directive (1991)
- Sludge Directive (1986)

EU policy / guidance

- EU Biodiversity Strategy (2011)
- Common Agricultural Policy (2007) / Cross Compliance / GAEC)
- Thematic Strategy for Soil Protection (2006)

UK legislation

- Environmental Protection Act – Part IIA: Contaminated Land (1990)
- The control of pesticides (Amendment) Regs (1997)

UK policy / guidance

- UK Forestry Standard (including forests and soil guidelines) (2011)
- Woodland Carbon Code (2011)
- Code of Practice for the agricultural use of sewage sludge (2001)
- BS 10175 Code of Practice for the Investigation of Potentially Contaminated Sites

International commitment

- IPCC LULUCF
- UN Framework Convention on Climate change - Aichi Targets
- Global Soil Partnership

Scottish legislation

- Wildlife and Natural Environment (Scotland) Act (2011)
- The Water Environment (Controlled Activities) (Scotland) Regs (2011)
- Habitats Regs (2010)
- The Environmental Liability Regs (Scotland) (2009)
- Climate Change Act (2009)
- Flood Risk Management (Scotland) Act (2009)
- Action Programme for Nitrate Vulnerable Zones (Scotland) Regs (2008)
- Radioactive Contaminated Land (Scotland) (Amendments) Regs (2007)
- Planning etc (Scotland) Act (2006)
- The Contaminated Land (Scotland) Regs (2005) & Statutory Guidance SE/2006/44
- Environmental Assessment (Scotland) Act (2005)
- Nature conservation Scotland (Act) (2004)
- Water Environment and Water Services (Scotland) Act (2003)
- Landfill (Scotland) Regulations (2003)
- Pollution Prevention and Control (Scotland) Regs (2000) (and later amendments)
- Waste Management Licensing (Scotland) Regs 2011
- Conservation (Natural Habitats, &c.) Regs (1994)
- Radioactive Substances Act (1993)
- Sludge (Use in Agriculture) Regs (1989 and later amendments)

Scottish policy / guidance

- Agri-renewables strategy (in development)
- 2020 Route map – Renewables
- Land Use Strategy (2011) and action plans
- Scottish Government's discussion paper on the management of carbon rich soils (2010)
- Scottish Planning Policy (2010)
- Scotland's Zero Waste Plan (2010)
- National Planning Framework 2 (2009)
- Planning Advice Note 33 (Development of Contaminated land)
- Scottish Soil Framework (2009)
- Scottish Rural Development Programme 2007 - 2013
- Cross Compliance – Good Agricultural and Environmental Conditions (GAEC) (2007)
- Scottish Forestry Strategy (and implementation Plan) (2006)
- Scotland's Biodiversity Strategy (2012)
- River Basin Management Plans
- Flood Risk Management Plans
- Scottish Historic Environment Policy
- Scottish Peatland Plan (due 2013)

Industry / business requirement

- Code of good practices and Guidance e.g..Peat depth survey , windfarm decommissioning
- Code of practice for the use of sludge, compost and other organic materials for land reclamation (2010)
- Farm Soils Plan – Protecting soils and income in Scotland (Voluntary code of practice) (2005)
- Prevention of Environmental Pollution from Agricultural Activity (PEPFAA) Code (Voluntary code of practice) (2005)
- Windfarm carbon calculator
- Carbon accounting
- Environmental Impact Assessment
- Strategic Environmental Assessment (SEA)

Partnership engagement

- IUCN peatland programme – restoration
- Scottish Geodiversity Charter (2012)
- **Woodland Expansion Advisory Group** (WEAG) (2012)

There was a good response from government and agency bodies but a poor response from the land based industries and local authorities. At this stage the wider academic community and other industries were not consulted. This means that there was a strong focus on legislative and policy needs for soil data. A wider consultation is required to better understand non-legislative needs.

Table 2 provides a range of examples of policies, legislation and guidance which may require soil information while **Table 3** provides a list of the main types of organisations who may need data or information on Scottish soils.

Table 3 Examples of organisations who may require or provide Scottish soil information.

Type of organisations	Example of organisation
International bodies	IUCN, FAO, UNEP
European Institutions	EU, research Councils, JRC
UK Government (Non devolved) including UK level operating agencies	DECC, JNCC, BGS, Forest Research
Scottish Government (devolved) including Scottish government agencies	SEPA, SNH, FCS, Historic Scotland
Local administration	Scottish Local authorities, National Park Authorities
Scottish research and development partnership	CAMERAS, SAGES, RESAS
Land based business	Crofting commission, NFUS, Scottish land and Business, private forestry sector
Industry	Water and energy providers, Waste and recycling industries Developers and/or contaminated land consultancy sector, renewable on-shore industry, planners
NGO	Conservation, voluntary sectors/ environmental sectors / LNCS
Tourism	Golf course, access tracks
Scientific communities	UK research councils
Education	Higher and further education, schools, professional bodies (e.g. BSSS, SESEF)
Public engagement / citizen science	The Conservation Volunteers, NGO

The high level of response from the SG and associated agencies expressed a clear and strong need for soil information across a range of issues and policy needs. Table 4 presents examples of what users currently use soil information for and what they could use it for in future.

Discussion with the Soil Focus Group on the consultation responses suggests that the low level of responses from land based businesses and local authorities could reflect a lack of awareness of the fact that soil data underpins their business practises. The soils data are “hidden” in integrated information sources e.g. Land Capability for Agriculture or SuDS. It may also reflect the diverse range of needs within a single organisation which are not easily assessed by a single consultation at a high level. This lack of awareness is a significant impediment in identifying the soil information needs of these user groups.

Table 4 Example of users requirements – general view

	Current user requirements	Expected user requirements
FCS	Ecological site classification – site / species suitability	Better determine GHG sequestration levels of different land uses, better scenario planning techniques for climate change
SEPA	Compliance with regulations (risk assessment e.g. diffuse pollution, flooding, contaminated land). State of Environment reporting	Fill data gaps for risk assessments
SNH	Statutory consultees EIA / SEA. Soil Biodiversity, Carbon rich soil mapping for planning advice	Ecosystem Services indices / land capability
FSA Scotland	to inform nutrition policy	
Historic Scotland	Need for site specific data.	historical "carrying capacity" of larger area
RSPB	Site projects / ecological monitoring	more of the same
GCC	to inform whether land is suitable for development / anthropogenic soil	
RESAD	Follow the latest issues? Currently Carbon – Climate change - Ecosystem approach – Food security	Follow the latest issues?

2.4. Identify and prioritise the monitoring requirements

The questionnaire responses and subsequent discussion with stakeholders showed that there was a strong demand for soil information, however the respondees were not always sure what exactly they needed and in some cases were not aware that the information they needed was derived from soil data. The responses very much focussed on the need for information rather than raw data.

The responses received from Government and agencies allowed links to be made between their key information needs and specific soil data requirements. However, a wider consultation is required to understand non-legislative needs. A full assessment of Scotland's soil data requirements will require further, more detailed, communication with a wider range of stakeholders using different methods of engagement. The Soil Focus Group will need to consider this needs gap when reviewing the activities of the Scottish Soil Framework later in 2012.

Table 5 provides a list of soil information and data which have been identified as relevant to inform or to enable an assessment to be made on the ability of soil to carry out specific functions and to response to users specific needs.

However, it also transpires that even when users identify a need for specific soil data there is limited awareness of what existing activities may provide this and whether it is fit for the intended user's purpose. This requires further investigation and may need one to one discussion with respondees to better understand the suitability of existing data and their sources.

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Table 5 List of measureable soil characteristics, properties and processes

Category	Soil properties / quality / processes
Soil chemistry status / stock / flux / capacity	pH / acidity level nutrient / micronutrient status pollution status / soil chemistry buffering, filtering and degradation capacities nutrient cycling rates oxalate extractable Fe, Al and P*
Soil water & gas – status / stock / flux / capacity	soil water / moisture content (availability / storage) anaerobic/ aerobic conditions drainage (is it there, is it working)* permeability* water level & fluctuation of water levels* soil hydrology & hydrogeology* soil hydraulic conductivity*
Soil carbon – status / stock / flux / capacity	soil organic matter / soil carbon levels carbon stocks GHG fluxes soil respiration (microbial)*
Soil biodiversity – status / stock / flux / capacity	pests and diseases beneficial organisms soil biological activity invasive non native species*
Soil physical properties	soil structural integrity - compaction soil depth extent of soil types / resources soil temperature regulation soil formation rates extent of soil loss and erosion* porosity* texture & clay content* soil compaction* soil profile and horizon visual description*
Others	soil resilience / resistance / adaptive capacity

* additional needs identify by the consultation

Based on the questionnaire responses, it is possible to say that there is an overall good level of awareness of the existence of current monitoring activities / schemes although few respondents indicated that they are actively using data from these and even fewer are manipulating data. The barriers to use of information are unclear and may included lack of awareness of availability of data, licensing arrangements or apathy to change established routine procedures.

Value could be added to existing soil data / information by promoting better access to data from sources and, in particular, interpreted information. This requires exploring links with Scotland's Soil Database and Website project and Scotland's Environment Web.

Table 6 provides a more detailed analysis of the responses received. By linking the user information requirements with specific drivers and soil related information needs (**table 2**) we are able to assess the nature of soil data and information used.

Table 6 Example of user requirements derived from Scottish Government agency needs

Users requirement	drivers - legislative and policy drivers	theme	Users	Information requirement, as identified by user (soil related only)	Soil data needed, as identified by user or by soil MAP group based on information provided by users
To assess impact of atmospheric deposition and effectiveness of regulations. - current practices for appropriate assessments of impact of atmospheric deposition from regulated industrial activities.	IPPC Directive (2008) -> PPC Scotland Regs (2000) Habitats Directive (1992) -> Conservation Regs (1994)	Air	SEPA - Local authority	Dry and wet deposition of potential pollutant -> need to know how site has been impacted currently looking at vegetation impacts	Could used nutrient / micronutrient status pH / acidity level nutrient cycling rates pollution status / soil chemistry soil organic matter / soil carbon levels carbon stocks soil biological activity soil structural integrity
To assess risk of entry of hazardous or non hazardous pollutant into groundwater	WFD and Groundwater Daughter Directive 2006	conta minate d land	SEPA Local authority - SNH	soil information used in risk assessment modelling to establish contaminant fate and transport to environmental receptors	pH / acidity level nutrient / micronutrient status pollution status / soil chemistry buffering, filtering and degradation nutrient cycling rates soil water / moisture content (availability / storage) soil hydraulic conductivity, porosity, permeability soil hydrology & hydrogeology soil organic matter / soil carbon levels Carbon stocks soil structural integrity soil biological activity texture & clay content soil depth extent of soil types / resources capacities Anaerobic/ aerobic conditions soil temperature regulation soil resilience / resistance / adaptive capacity
assessing eligibility of activties under Woodland carbon code	Woodland Carbon Code (2011)	foresty	FCS / FR / forest manager	soil type as expressed in locational guidance maps	soil organic matter / soil carbon levels soil depth
to develop wetland environmental standards for classification	WFD classification -> Water Environment and Water Services (Scotland) Act (2003)	Wetla nd	SEPA	soil distribution soil type (peat) drainage?	soil hydrology & hydrogeology soil organic matter / soil carbon levels soil depth extent of soil types / resources

2.4.1. What is changing in the soil environment?

There is a perception that Scotland's soils are generally in good health. However there is evidence that soil degradation is occurring. In many instances, degradation of soil quality and the capacity of soils to function effectively have become evident in other environmental problems e.g. flooding, diffuse water pollution, greenhouse gas emissions, health risks. Soil monitoring is necessary to identify the soil-based cause of these problems and establish the effectiveness of the various policy and guidance interventions put in place to address them.

The following paragraphs summarise the known and possible changes to Scottish soils from available data, expert knowledge and studies from elsewhere with a comparable environment to Scotland. Further details are available in the State of Scotland's Soil Report 2011. To date, most information is available for individual soil properties with, as yet, little assessment of changes to the functions of soil. The soil MAP recognises the need to move towards a more functional assessment of soil quality which would integrate information on individual properties and processes.

Soil chemical properties and processes including soil carbon

- Soil organic matter (SOM). There is no evidence of significant changes in SOM concentration since the 1980s within agricultural and semi-natural habitats[10,11]. However, the levels of SOM in Scotland's agricultural soils are typically far lower than in semi-natural soils while arable soils generally have lower SOM levels than grassland soils. In contrast, a proportion of cropped soils with particular cultural significance (e.g. machair, plaggen soils) have become enriched in SOM relative to surrounding semi-natural areas. Future SOM levels may be expected to increase in habitats undergoing restoration.

- Soil carbon stocks. Again there is no evidence of significant changes to soil carbon stocks over recent decades[12]. However the degraded state of many Scottish peatlands indicates that the below-ground stock of carbon in these habitats will have declined and likely to continue to decreasing into the future without restoration actions[13]. Soil carbon stocks may be expected to increase in future under peatland restoration.

- Greenhouse gas emissions. Emissions of nitrous oxide are typically greatest from fertilised agricultural soils while methane emissions are generally greatest from peatland systems. In both instances, empirical evidence of change is lacking but modelling suggests that GHG emissions from agricultural systems soils have increased significantly during the 20th Century[14,15].

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[10] Lilly, A & Baggaley, N.J.. In press. The potential for Scottish cultivated topsoils to lose or gain soil organic carbon. Soil Use and Management.

[11] Chapman et al Submitted – Comparison of soil carbon stocks in Scottish soils between 1978 and 2009. European Journal of Soil Science

[12] Smith, P et al. 2010 Consequences of feasible future agricultural land-use change on soil organic carbon stocks and greenhouse gas emissions in Great Britain. Soil Use and Management,26,4, 381-398

[13] Artz, R., Chapman., S., Donnelly, D. and Mathews R. 2012 *Potential Abatement from Peatland Restoration.* Research Summary. Climate Exchange.

[14] Smith, J, U et al 2010 Estimating changes in Scottish soil carbon stocks using ECOSSE. I. Model description and uncertainties. Climate Research, 45 (Special 24: Climate change and the British Uplands). 179-192.

[15] Smith, J, U et al 2010 Estimating changes in Scottish soil carbon stocks using ECOSSE. II. Application. Climate Research, 45 (Special 24: Climate change and the British Uplands). 193-205.

- Soil pH. Data and modelling suggest there was a decrease in soil pH (increase in acidity) in the early 20th Century in most soil types and most habitats. In general, agricultural soils are managed to maintain soil pH within the optimal agronomic range. Since the late 1990s, soil pH has increased across most soil types. Increases may continue but there is uncertainty to future trends linked to future changes in atmospheric pollution.

- Metals. Localised urban and industrial areas of Scotland have atypical elevated levels of metal contaminants in soils as a legacy of industrial contamination but these levels may decrease through remediation. In contrast metal levels in agricultural soils are predicted to increase because of fertiliser use and increased use of organic amendments (e.g. slurry and composts) that contain metals.

- Organic pollutants. Persistent organic pollutant levels have increased in soils in the 20th century with distribution and concentrations linked to urban, industrial and certain agricultural locations. The levels of some of these pollutants are predicted to increase in managed soils with continued use of certain agrochemicals while some will decline as a result of regulation. Meanwhile, levels in urban and industrial areas may decline through remediation and regulation.

- Radioactive materials. There have been localised increases in radionuclides in soils with these expected to continue to decline with no major changes to wider levels of radioactive materials under current circumstances.

- Nutrients (e.g. nitrogen, phosphorus) and micronutrients (e.g. selenium). There is evidence of elevated soil nutrient levels in managed and unmanaged soils across Scotland as demonstrated by critical loads and agricultural fertility assessments. There are sparse data on changes to micronutrients though certain soils are known to be deficient in important nutrients.. Trends in nutrients within semi-natural habitats are expected to decline in general although localised increases may occur due to specific activities.

Soil physical properties and processes including water

- Soil compaction. There is anecdotal information to suggest that soils in Scotland are showing signs of compaction in managed systems but there is insufficient evidence to demonstrate whether this is an increasing issue. Changes to agricultural machinery and management will have implications for compaction.

- Soil erosion: wind, water. Model results demonstrate that the risk of soil erosion varies across Scotland. There are however no systematic assessments of actual soil erosion by wind or water.

- Landslides. Susceptibility to landslides has been assessed indicating regional differences but again no systematic data are available on changes in susceptibility or actual occurrence over time.

- Soil structure. Historical differences in soil texture in the same soils under different land uses indicate agricultural land use will change soil texture and soil bulk density, and therefore soil structure, relative to surrounding soils. There is little evidence of structural changes within land uses over recent

decades. Anecdotal evidence on compaction does however link to potential changes in soil structure.

- Soil moisture characteristics. Assessments of potential soil moisture deficit suggest that soil moisture has changed in recent decades with trends corresponding to regional conditions[16]

Soil biological properties and processes

- Pathogens. There is insufficient data to comment on pathogens though they are predicted to increase in future.

- Soil biodiversity. There are significant differences in soil biodiversity (species, communities and activities) with respect to land use suggesting that soil biodiversity has declined in agricultural soils over decades if not centuries. Declines in certain species (e.g. fungi, ants) have also been recorded within semi-natural habitats and managed grasslands. Following recent results, trends in soil biodiversity are likely so show both increases and decreases.

Spatial extent and composition of soil types

- There is evidence that extent of the most productive soils, as identified by prime agricultural land, has been and will continue to be reduced (through continued land development).
- The extent of undisturbed organic soils, in particular peat soils, has been reduced in the last century.
- Recent analyses of the Land capability for agriculture suggest that the relative proportions of different Agricultural Land Capability Classes may change as a result of changes in soil conditions due to climate change[17,18].

2.4.2. Why is it changing?

This section explains what factor(s) are responsible for the changes outlined above.

- Historical changes to agricultural land use and management practices along with atmospheric deposition of pollutants have been linked to changes in SOM, carbon, nutrients, pH, structure, etc. and to the reduced capacity of soils to retain organic matter, carbon, nutrients, water and particles. Local activities, e.g. septic tanks, are also linked to increased nutrient levels. On-going changes to these pressures will have corresponding effects in soils.

- The acidity of soils in Scotland, reflecting the soils capacity to buffer against pollution, has changed as a consequence of agricultural land use (liming), atmospheric deposition of sulphur and now increasingly atmospheric nitrogen deposition.

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[16] Brown et al. 2011 Climate change, drought risk and land capability for agriculture: implications for land-use in *Scotland.,* Regional Environmental Change, 11, 503-518.

[17] Brown et al. 2008 Influence of climate change on agricultural land-use potential: Adapting and updating the land capability system for Scotland. Climate Research, 37(1), 43-57.

[18] Brown et al**.** 2011 Land capability classification to plan for a changing climate*.,* In: Land Quality and Land Use Information - in the European Union (eds. G. Toth and T. Nemeth). EUR - Scientific and Technical Research Series.

- Greenhouse gas emissions. Agricultural intensification over 100s of years has led to an increase in greenhouse gas emissions from, and a reduction in carbon in, agricultural soils compared to natural and semi-natural soils.

- Metals and persistent organic pollutants: The application of wastes and other materials to land has long been known to affect soil quality through the addition of metals and other potentially toxic compounds. Localised areas of contaminants are associated with historical industrial activity.

- Elevated levels of radioactive materials reflect transfer from nuclear incidents (e.g. Chernobyl) and weapons testing while declining trends reflect natural decay processes alongside remediation.

- It has been suggested from evidence elsewhere that increasing use of heavy agricultural machinery may be resulting in increased soil compaction while reduced tillage may be reduce compaction in the short-term.

- Soil erosion and landslides. Inappropriate management of agricultural land (including grazing), land use change and construction activities have been cited as causes of increased erosion and landslides alongside changing weather patterns.

- Recent climate change alongside land use and management impacts on soil structure and soil organic matter will have influenced soil moisture characteristics although there is little direct evidence of the impacts to date.

- The presence of pathogens in wastes and organic materials utilised on agricultural land have been linked to the presence of pathogens in soils. Land use change is perceived to have been the biggest driver of changes in soil biodiversity with management and pollution resulting in additional changes.

- Construction, in particular the expansion of urban and industrial areas and of transport routes, is a significant threat to the most productive soils in Scotland. Historically many urban areas were developed in regions with fertile soils for benefits of food provision and labour force, for example.

- Changes in land use and land management practices, along with pollution, have resulted in the degradation of Scottish peat soils.

Table 7 lists the main pressures on soils and shows which functions they impact on and which threats they contribute to.

Table 7 Pressures impacting on functions / leading to soil degradation (threats) (adapted from State of Soil report 2011)

The main soil functions						Pressures	Threat to soil (degradation process)					
Food and biomass production	Controlling and regulating environmental interactions	storing carbon and exchanging GHG with atmosphere	providing habitats and sustaining biodiversity	preserving heritage	providing raw materials / providing a platform for building		loss of organic matter	sealing	contamination	change in biodiversity	erosion / landslides	compaction
x	x	x	x	x		**Climate Change**	x			x	x	x
x	x	x	x	x		**Land Use Change**	x	x	x	x	x	x
						e.g. expansion of agriculture	x	x	x	x	x	x
						e.g. expansion of forestry	x	x	x	x	x	x
x	x	x	x	x	x	**Land Management Practices**	x	x	x	x	x	x
						e.g. cultivation	x			x	x	x
						e.g. application of fertilisers / pesticides			x	x		x
						e.g. burning	x			x	x	
x	x	x	x	x	x	**Development / infrastructure**	x	x		x	x	
x	x		x			**Transport**			x	x		
x	x		x		x	**Industry**	x	x	x	x	x	x
						e.g. gas emissions			x	x		
						e.g. quarrying / mining	x		x	x		
		x	x	x	x	**Peat exploitation**	x					
						Recreational use of land	x			x	x	

2.4.3. What are the consequences of change?

This section discusses what the consequences of changes in the soil environment have on the wider environment, society and the economy.

Depletion of the capacity of soils to retain nutrients, water and particles have resulted in various consequences for the wider environment including impacts on water quality, climate change, flooding and habitat condition as well as soil quality itself. In many case, policy and guidance have been put in place to improve this situation.

Water quality has suffered as nutrients (e.g. nitrogen and phosphorus) have been transferred and continue to be transferred from soils to the water environment. The EU Water Framework Directive recognises the importance of soils in maintaining and achieving good water quality with accordant land management and land use changes such as buffer strips and alternative nutrient inputs. In addition, Nitrate Vulnerable Zones have been implemented to reduce the transfer of N through regulated management of agricultural inputs of N to soils with a high susceptibility to leaching. Changes in soil management, in particular the drainage of upland organic soils, have been linked to the increased frequency and intensity of flooding downstream which has consequences for human health and welfare. Again this relationship is recognised in the Floods Directive.

Elevated levels of pollutants in soils have obvious implications for human and animal health, as well as habitat condition, water and air quality. Regulation and guidance have been developed in some cases to identify, mitigate and remediate such risks. Consistent monitoring and guidance assist in maintaining acceptable levels. Progressive remediation of brownfield sites may continues to reduce this issue while monitoring can help to prevent future problems developing from on-going industrial activities.

Soils have an important role in regulating the global climate since soils are the largest terrestrial store of carbon and also exchange greenhouse gases with the atmosphere. Scotland has significant soil carbon stores in organic soils while agricultural soils are significant sources of greenhouse gases. The Land Use Strategy recognises the need to quantify, maintain and ideally restore peatlands, and associated organic soils, for climate change and wider benefits e.g. biodiversity conservation, tourist value, etc.

In recent years, urban expansion has posed a significant threat to some of the most productive soils in Scotland and thus on the ability to produce food. Historically many urban areas have developed in regions with fertile soils for benefits of food provision and labour force, resulting in the loss of prime agricultural land which is a non-renewable resource. This may be increasingly important as we enter a phase of unprecedented environmental change.

As identified above, changes to soil quality can influence a wide range of issues from water quality, food security to climate change. The State of Scotland's Soils report 2011 provides a comprehensive summary of the implications of soil changes on the environment and, for the first time, highlights the potential economic impacts of soil degradation as a consequence of the main threats. These impacts are illustrated in **Figure 2**.

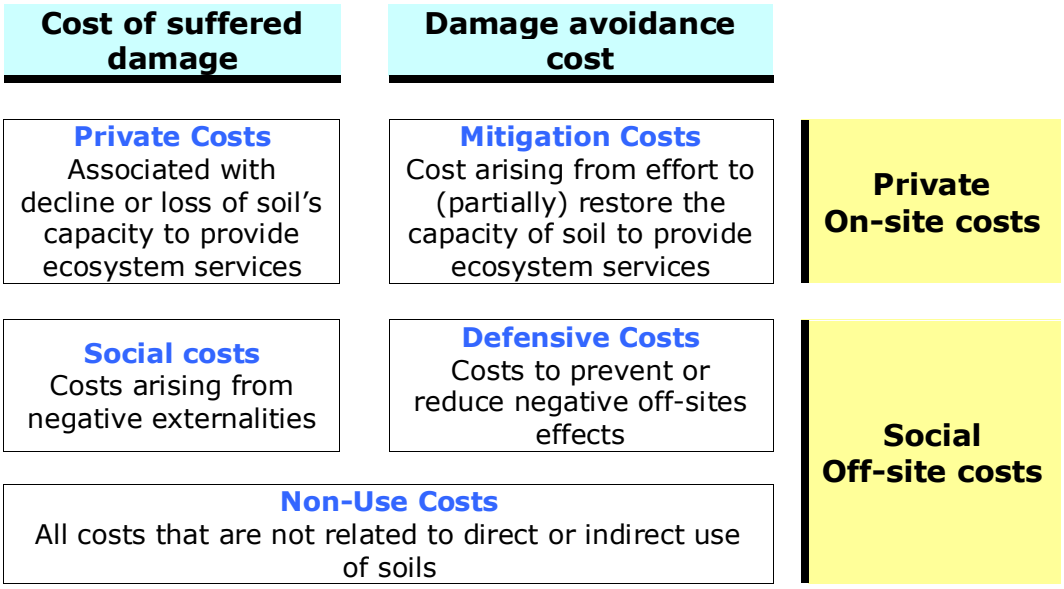

Figure 2 Overview of 5 type of costs associated with the soil degradation (adapted from the State of Scotland's Soil Report 2011).

The report developed a scoring system to assess the impact of seven degradation processes. It showed that the principal threat to soil functions in terms of socioeconomic impact is erosion and landslides which reflects the disruption to society caused by such events, and the fact that the individual soil functions facing the biggest impacts from erosion and landslides are those on which direct economic benefit is highly dependent upon (e.g. provision of food and provision of a stable platform for buildings and transport infrastructure).

Changes in soil biodiversity, loss of soil organic matter, soil sealing and contamination (contaminated land) all have similar and relatively high socioeconomic scores reflecting their linkages to a wide range of soil functions. In all cases, high levels of uncertainty associated with the socioeconomic impacts reflect the lack of quantitative data. In particular, there are very high levels of uncertainty associated with changes in soil biodiversity, soil sealing and contamination as a result of atmospheric deposition. Monitoring would be one route to obtaining the data required to support quantitative economic assessments.

2.4.4. What do we need to monitor to assess change in soil environment?

The above discussion has outlined what is changing in the soil environment, why it is changing and what the consequences of these changes are on the environment, the economy and society.

In this section we consider what can be measured to identify what is changing in the soil environment to identify whether soil degradation is occurring or whether soil quality is improving

It remains to define what specific soil qualities are required to ensure that soil can provide the wide range of services expected of it and what parameters / indicators can be measured / monitored to inform whether if, and if so how, soil quality is changing.

A range of potential sources of soil information can be considered including:

- information taken directly from soil surveys;
- information collected as part of other environmental surveys;
- information collected from remote sensing surveys;
- information derived from environmental and ecological models.

The work undertaken by UK SIC and others for the development of suitable SQIs for the development of a national soil monitoring network is being used as a starting point for this analysis. UK SIC undertook an assessment of the practical use of SQIs as a quantitative tool to measure and assesses soil quality in relation to specific soil functions in a range of contexts and at a wide variety of scales[19]. Similar work in Scotland, undertaken for the then Scottish Executive[20] also carried out a detailed assessment of SQIs suggesting those essential or desirable for the main soil functions. Soil quality indicators in this context covered the major physical, chemical and biological properties of soils, soil processes and other contextual information relevant to the soil ecosystem.

The soil properties and processes for which we require information to enable an assessment to be made on the ability of soils to carry out specific functions (**Table 5**) are also important for monitoring other aspects of the natural environment.

For example, atmospheric deposition may change soil pH as well as nutrient, metal and / or organic chemical concentrations, thus measuring these parameters in the soil may tell you something about air quality. Similarly, monitoring air quality may tell us something about potential sources of pollution arising from soil as a result of re-suspension of soil particles.

Similarly, there is a close relationship between soil and water quality. Run off and leaching of water over and through soil into rivers, lochs and groundwater can seriously harm water quality if there is transfer of potential pollutants such as nutrients, metals, organic chemicals and pathogens either in solution or through erosion of soil particles. This is determined by the concentration of any potential pollutants in the soil and how strongly they are bound to soil particles – thus measuring the soil chemistry may provide useful information on the potential for water pollution and vice versa.

Monitoring of biodiversity, recording of status of species and habitats and the ecosystem they support are closely linked to the status and interaction with soil biodiversity and the characteristics of soil as a growing medium for plants and a habitat to many species.

These interacting pathways should be developed further by integrating the various environmental MAPs now being developed through CAMERAS and thus help prioritise monitoring requirements across the whole environment.

[19] The development and use of soil quality indicators for assessing the role of soil in environmental interactions. Environment Agency, 2006. http://publications.environment-agency.gov.uk/PDF/SCHO0306BKIQ-E-E.pdf

[20] Development of a Soil Monitoring Scheme for Scotland. Hough et al. 2007 Final report to Scottish Government (ENV/2006/2.4.5 unpublished)

2.5. Identify existing monitoring

2.5.1. What are the main elements of current monitoring and where?

Previous work under the remit of UK SIC and follow up activities on the development of a national soil monitoring scheme reviewed the range of existing activities recording soil information. Of the 29 Schemes identified in the National Soil Monitoring Network: Review and Assessment Study in 2006 (LQ09), 18 operate in Scotland. All schemes are described in full in a soil monitoring catalogue available on-line[21]. The State of Scotland's Soil Report 2011 identified a further 13 relevant schemes and provides a summary description of these with links to further information.

The main activities identified that gather soil information in Scotland are:

a. national / regional scale field surveys of a wide range of soil information;
b. targeted sampling relating to specific soil issues at national and regional scales;
c. site specific sampling;
d. remote sensing of soils;
e. research at a range of scales to support the development of soil monitoring activities and understanding of soils;
f. other environmental monitoring schemes which may include soil sampling or gathering of surrogate soil information.

In addition, projects such as the 2006-08 EU funded ENVASSO[22] programme have assessed harmonisation issues across Europe in relation to any future EU soil monitoring actions, but only offer limited information on the intra-country comparability of any existing national schemes and have limited information for Scotland. It is therefore important to review all known soil monitoring activities to assess how they individually, or in combination, address the purpose and scope of the soil MAP.

Table 8 lists the existing monitoring activities in Scotland which collect some form of soil information. It also includes schemes which may have the potential to provide information on soil functions.

Analysis of the data / information available in those schemes has been part of earlier UK SIC studies towards the development of SQIs. For historical reasons (e.g. interest in improving soil fertility) most past and current soil monitoring activities record soil chemistry data. Soil physical data has only occasionally been recorded while soil biological properties are rarely included as routine measurements.

[21] Insert link to LQ09 catalogue (the web link to the sniffer report is still not working ☹)
[22] htt://eusoils.jrc.ec.europa.eu/projects/envasso/

Table 8 Scottish soil "monitoring" activities (updated from SNIFFER 2006, and State of Soil Report 2011) - Review of organisational responsibilities

	Primary data holder
National / Regional scale field surveys of a wide range of soil information	
National Soil Inventory of Scotland (NSIS)	James Hutton Institute
Representative soil profiles of Scotland (RSPS)	James Hutton Institute
Countryside Survey (CS)	Centre for Ecology and Hydrology
Forum of European Geological Surveys European Geochemical survey (FOREGS)	Association of the Geological Surveys of The European Union (the EuroGeoSurveys
EU Land use/cover area frame survey (LUCAS)	EU – JRC
Targeted sampling of specific soil issues at national and regional scales	
Environmental Change Network (ECN)	Centre for Ecology and Hydrology
Trends in Pollution of Scottish Soil (TIPSS)	James Hutton Institute & SEPA
Biosoil	Forest Research
Level I Forest Condition Survey (Level1Forest)	Forest Research
Geochemical Survey of Urban Environments (G-BASE_urban)	British Geological Survey
Geochemical Baseline Survey of the Environment (G-BASE)	British Geological Survey
Scottish Earthworm Survey	James Hutton Institute
Site Condition Monitoring (Natura sites and SSSI) (SCM)	Scottish Natural Heritage
Soil and Herbage Survey (UKHerbage)	Environment Agency
Site specific sampling	
Level II Intensive Monitoring of Forest ecosystem (Level2Forest)	Forestry Commission
Soil fertility / agronomic sampling	Scottish Agricultural College
Peat survey part of EIA	Industry / Local Authorities
Soil sampling in support of the Sludge Regs and Waste Management Licensing Regs	Scottish Water and other sludge producers / waste operators / Scottish Environment Protection Agency
Soil compliance monitoring	Scottish Environment Protection Agency
Soil sampling in support of Contaminated Land Regs / Development Regime and Planning Advice Note 33	Local Authorities
Site investigation reports	Local Authorities
Scottish Pesticide Surveys (SCOPES) database	Science and Advice for Scottish Agricultural (SASA)
Radionuclide monitoring in vicinity of licensed sites and radiological habitat survey	Scottish Environment Protection Agency
UKBAP	NBN gateway
Research	
Long term field experiments • JHI Dundee experimental plots • SG Micronet • NERC Soil Biodiversity programme • Moorland colonisation (MOORCO) studies • CEH Whim moss • others	Universities and other research institutes
Effects of sewage sludge applications to agricultural soils on soil microbial activity and the implications for agricultural productivity and long term soil fertility.	ADAS
RESAS research Programme and underpinning capacity	SG Main research providers
Remote sensing	
Government Information From The Space Sector (GIFTSS) erosion study	SG / BNSC
LIDAR coastal survey	SNH

Other possible sources of information include:
Animal / plant research institutes (Soil biodiversity sites study)
The National Soil Archive (held by James Hutton Institute)
Air quality monitoring network
UKREATE - Defra Terrestrial Umbrella for atmospheric pollution
SEPA harmonised monitoring (water quality)
Water companies – DOC and sediment loading in rivers and reservoirs
Coastal surveys (e.g. SCAPE / Shorewatch SNH / saltmarsh surveys)
John Muir Trust Wild land biodiversity surveys
National Parks Authorities
Invasive species (Food and Environment Research Agency (FERA))
Scottish Soil Biodiversity species list (State of Scotland's Soil report 2011)
Wetland inventory - Various (SNH/SEPA/UKBAP/LA)

Table 9 presents a breakdown of the data available from specific soil monitoring schemes. It highlights how these data could be used to inform a national soil monitoring scheme and the scale of data coverage. It highlights that many schemes include some measurement of soil pH, nutrient status and carbon or organic matter content. However, it is not always possible to compare between schemes because different methods of sampling and analysis are used. In addition, many of these activities are one-off sampling and are rarely repeated thus trend data is scarce.

It is important to note that these activities were never set up to provide a country-wide catch all soil monitoring programme for current issues and so are not expected to provide that level of information.

Table 9 Information provided by existing soil monitoring activities in Scotland which could be used by a national scale soil monitoring scheme. (Schemes shown in plain text have up to 10 sampling locations, those in *italics* have between 10 and 50 locations, those in **bold** have between 50 and 100 locations while those in ***bold italics*** have more than 100 locations)

Soil information potentially available in Scotland	National /regional	Targeted	Site specific	Remote sensing	Re search
nutrient / micronutrient status	***NSIS*** ***RSPS*** ***CS***[1] ***LUCAS***[1,2] FOREG	**Level1** **Forest**[1,3] UKherbage	ECN Level2 Forest[3] ***SEPA Soil compliance Regs sampling***		*
pH / acidity level	***NSIS*** ***RSPS*** ***CS***[1] ***LUCAS***[1,2] FOREG	**Biosoil**[3] **Level1** **Forest**[1,3] UKherbage **GBase_urban**[4]	ECN Level2 Forest[3] ***SEPA Soil compliance Regs sampling***[1]		*
soil organic matter / soil carbon levels	***NSIS*** ***RSPS*** ***CS***[1] ***LUCAS***[1,2] FOREG	**Biosoil**[3] **Level1** **Forest**[1,3] UKherbage **GBase_urban**[4]	ECN Level2 Forest[3] ***SEPA Soil compliance Regs sampling***	LIDAR studies	*
pollution status / soil chemistry	***NSIS*** ***CS***[1]	**Biosoil**[3] **Level1**	ECN Level2 Forest[3]		*

Soil information potentially available in Scotland	National /regional	Targeted	Site specific	Remote sensing	Re search
	LUCAS[1,2] FOREG	**Forest**[1,3] UKherbage **GBase_urban**[4] ***SCOPE***[5]	***SEPA Soil compliance*** ***Regs sampling***[1] *Radiological habitat survey*		
pests and diseases			***NBN gateway*** ***FERA***		*
beneficial organisms	***CS***[1]	***SCM***	ECN ***SEPA Soil compliance*** ***Regs sampling***[1] ***NBN gateway***		*
soil structural integrity	***NSIS*** *RSPS* ***LUCAS***[1,2]	**Biosoil**[3] **Level1** **Forest**[1,3] UKherbage	ECN Level2 Forest[3]	GIFTSS	*
soil water / moisture content (availability / storage)	***NSIS*** *RSPS* FOREG	**Biosoil**[3] **Level1** **Forest**[1,3]	ECN Level2 Forest[3]	LIDAR studies	*
soil depth	***NSIS*** *RSPS*	**Biosoil**[3]	ECN Level2 Forest[3] Peat survey EIA		*
extent of soil types / resources	***NSIS*** *RSPS*		Peat survey EIA		*
buffering, filtering and degradation capacities	***NSIS***		Level2 Forest[3]		*
soil gaseous fluxes		Various academic studies	Various academic studies		*
Carbon balance (GHGs versus C stocks)	***NSIS***		Peat survey EIA		*
soil temperature regulation					*
soil biological activity	***NSIS***	CS	***SEPA Soil compliance*** ***Regs sampling***[1]		*
nutrient cycling rates					*
soil formation rates				LIDAR studies	*
soil resilience / resistance / adaptive capacity	***NSIS***	CS	ECN Level2 Forest[3]		*

1 – sample depth fixed – top soil analysis only / 2 - mainly lowland coverage
3 – only for forest soil / 4 – only urban soil (Glasgow)
5 - pesticides application level only / * - wide range of projects

2.5.2. Strengths, weaknesses and accessibility of monitoring data

Accessibility of existing data

The responses to the questionnaire show that there was a high level of awareness of current soil monitoring activities (Table 10). However, only a limited number of users were accessing the data and fewer were using and manipulating the data provided.

Most users indicated that their need was for information rather than data, and that fitness of information to suit their own need and age of the data were factors restricting their current use of information.

Table 10 Users awareness and use of soil information

		Total number of response			
	Number of scheme	User aware	User access	use	manipulate
national / regional scale field surveys collecting a wide range of soil data / information;	5	32	14	10	6
targeted sampling relating to specific soil issues at national and regional scales;	8	45	24	15	6
site specific sampling;	9	40	17	13	5
remote sensing of soils;	2	34	14	11	8
research at a range of scales to support the development of soil monitoring activities and understanding of soils;	unknown	32	14	10	6

In future, the Scottish Soil Database and Website project and its links with Scotland's Environment Web should address some of these issues by making soil data and information more widely available. However it has to be stressed that unless data is interpreted and information products developed for specific user needs then it is unlikely to be of use for an audience outside the immediate soil science community.

Strengths and weaknesses of existing data

Past demand for soil information in Scotland concentrated on supporting agriculture / forestry business needs and dealing with environmental impacts associated with soil contamination. As a consequence, soil information requirements were primarily focused on soil chemistry and many schemes include some measurement of soil pH, nutrient status and carbon or organic matter content. Therefore, most of the existing soil data relates to soil chemical properties and related processes.

There are limited national scale data for measured soil physical properties (including soil hydrology) and even less soil biodiversity data. However, recent method developments for both soil physical and biological measurements now mean that these are more feasible within monitoring schemes, as explored in NSIS2.

However, even where specific data on soil properties and processes (e.g. soil carbon content, pH, nutrient concentrations) are available across Scotland, it is often impossible to establish direct comparison between schemes. This has been explained in detail in UK SIC work (LQ09) and reflects differences in sampling networks and sampling and analytical methods. The age of some data is also a constraint for extrapolation to the present day as is the lack of repeat sampling meaning that it is not possible to assess trends.

Demand for soil information in many cases for decision making at the land manager / users level is often at a scale which was not anticipated by earlier national soil monitoring activities.

Data from many existing site specific surveys (e.g. contaminated land, environmental impact assessments, soil fertility measurements) are not necessarily publically available. If commercial and confidential restrictions on use of information collected could be overcome this could prove a valuable source of data to assess current change in key soil properties.

Most users need information for their specific purpose rather than pure data and at a scale that is suitable for their purpose. In some cases this requirement is for site specific information (e.g. Local Authority, Historic Scotland) rather than a broad scale distribution.

Although the above strengths and weaknesses have been assessed, there has been no consideration of the fitness for purpose of the available data. This will require more detailed communication with users.

3. Interpretation of gaps and overlaps

The analysis illustrated in Table 9, combined with the responses from the questionnaire, have allowed gaps and overlaps in existing monitoring activities to be identified. However, the information gathered from the consultation is incomplete and strongly biased by the responses from statutory and regulatory bodies. Despite providing only a partial view on the current Scottish user needs a strong message has emerged from the available information.

As discussed earlier, the National Soil Inventory for Scotland, the Scottish Soils Information Database, BioSoil and Countryside Survey have provided a wealth of information for large-scale and policy planning purposes, although there are issues over the age of some data since extensive coverage is now >30years old. A consistent message has been the availability of soil information or data at other spatial scales for end-users needs.

There is a gap in the availability of data at relatively high resolution e.g. from field, habitat to catchment. Furthermore, end-users are looking increasingly for information on how soils are changing, or their likelihood of changing under planned changes to management or other drivers. The use of soil carbon modelling to predict changes to soil carbon stocks and GHG emissions is a good example here. The Scottish Government has a key interest in the amount of carbon stored in Scotland's soils and the GHG fluxes from these soils for international reporting and increasingly for national and local carbon accounting purposes. Much of the information of changes to soil carbon and GHGs are derived from soil models which rely on the availability of adequate and sufficient input data. NSIS and NSIS2 have been used to support the development of these models but further information is required to support on-going development of these models.

There is a need to have similar tools or information for other soil functions. Linked to this is the issue of data age and whether soils data that is over 30 years old is the most suitable for contemporary purposes.

The most common soil data and information required by the respondees was related to soil chemistry, specifically soil pH, soil organic matter / soil carbon concentration, soil nutrient concentration and the concentration of other potential pollutants such as metals and organic compounds. Most of this information is already available in some forms from existing sources with the exception of organic compounds where only limited data is currently available.

There is also a clear demand for soil physical data, with specific needs for interpreted information using these data. This includes information on the movement of water through soil to support flooding and pollution issues. There is a gap in current routine and comprehensive assessments of key soil physical properties and processes e.g. porosity, permeability.

There is a growing interest for information on soil biology–in terms of soil biodiversity assessments and soil biological processes. These are key factors in controlling GHG emissions and other soil functions e.g. plant growth, water flows, carbon stocks since many soil processes are biologically mediated e.g. decomposition of organic matter, nutrient cycling. Recent research developments have produced suitable methods and approaches for monitoring soil biodiversity and soil biological processes however there has been no comprehensive or systematic monitoring to date.

Practical soil biological approaches were trialled in NSIS2. There is a key knowledge gap in what to expect where and why. There are on-going research activities in the RESAS programme and elsewhere, which can be used to further inform the inclusion of soil biological measures in monitoring.

While there are data available for many rural soils, there is much less data available for urban soils, especially at the scale required by local authorities to enable them to make planning decisions. Urban soils data is a gap.

Information on soils associated with particular habitats and geographical locations e.g. peatlands / wetlands/ montane and coastal habitats, have also been identified as areas for improvement as they have been under-represented in some national surveys. Similarly information on soil biodiversity species is sparse in national datasets.

A consistent gap is sufficient coverage of different soil types under different land uses in particular organic and organo-mineral soils especially in relation to forestry practices on peat soils. In the latter instance, there is an opportunity to address coverage by linking forestry soil monitoring (e.g. BioSoil) with the national inventory.

Overlaps

With reference to overlap in monitoring, this is not a major issue since most schemes providing data are historical, not currently active or spatially distinct. However, due to difficulties in direct comparison between schemes, there is also an issue of integrating data from different sources to gain added-value or to increase the extent of data coverage. This has been explained in detail in UK SIC work (LQ09) and reflects differences in sampling networks and sampling and analytical methods. There is a lack of non-expert user-friendly information on whether and how different data sources could be integrated for different purposes.

A key issue for future development is the integration of approaches to obtain sufficient spatial coverage and sufficient detail of particular issues e.g. land uses, management practices.

This can be addressed by various means including standardisation and complementarity of sampling approaches, analytical procedures and statistical analyses and reporting. These approaches have been reviewed at some length by UKSIC with universal procedures proposed.

The soil MAP should ensure that these sampling and analytical procedures are implemented across schemes in Scotland, while still including flexibility to monitor their individual key issues.

We also need further detail on the spatial and temporal scales of soil information required by different end-users, in particular for the groups currently under represented in the consultation since many of these users require data at relatively high resolution spatial scales.

Finally, it is vital to address the fact that most end-users require interpreted soil information and not raw data (e.g. maps for soil erosion risk, flood risk, land capability). A key gap is in understanding what these specific interpretation needs are and how they could best be met using within a monitoring programme.

Fitness for purpose of the existing data

For existing data sources, it is not possible to determine whether these are entirely fit-for-purpose or simply being used because they are the only sources of information available to users. Not all data currently available is suitable for use in answering today's questions. For example, while soil nutrient data exists, it is not always fit for purpose due to differences in analytical methodology, commercial sensitivity, spatial coverage or age of data.

Comprehensive data from NSIS is at least 30 years old – which leads to questions over its suitability for contemporary use. The limited re-sampling in the NSIS2 gives some indication of major national trends in certain properties e.g. carbon, pH, nutrients but cannot be used to explore higher resolution issues as it stands. In addition there have been major developments in analytical approaches which now enables the measurement of new or more appropriate soil properties e.g. soil carbon fractions or available nutrients. Existing data are therefore not necessarily fit for purpose.

4. Next steps – prioritisation

Given the information obtained from the consultation, general conclusions can be drawn with acknowledgement that further detail is needed from particular users to develop a comprehensive programme of soil MAP activities.

Interpretation of the questionnaire suggests that currently Government departments and agencies are using information obtained by the national scale schemes (NSIS, CS, BioSoil) where available. This group has identified (either directly or indirectly) requirements for a wide range of soil chemical, physical and biological data.

- The user needs for soil chemistry data are better met in those schemes than the soil physical and biological data needs, although is considerable room for improvement. The current needs for soil chemical data could be improved using new analytical approaches while there is a need to produce sufficient contemporary data, including extending spatial coverage and further information on trends.

- Some data for soil physical and biological properties exist but these are limited and insufficient for current needs.

- Soil monitoring for this group of end-users now needs to address the need to update soil information with building on historical schemes the most sensible approach to extend current coverage, address particular issues, generate information on trends and aid the development of integrated products.

Some specific needs of Government departments and agencies are being met by targeted monitoring. There is a need to establish continuity between these and the national schemes through standardisation and complementarity of approaches.

The needs of other users groups require further investigation. However it is clear that there is a need to generate soil data that can be used to develop integrated information products. The issue of information at higher spatial scales for decision-making is likely to remain a primary need and should be built into monitoring. This will need closer investigation of whether expansion of existing / historical schemes would be appropriate for producing this information or whether new schemes are required.

R&D requirements / additional work required to support the implementation of the soil MAP

The following areas of work need to be addressed;

- Engage more effectively with stakeholders with low response to date (e.g. land based industries, local authorities) and those not yet consulted (e.g. academic community) to identify user needs for soil information. Especially those who are to a large extent unaware of the use of soil data in their business, as the data are “hidden” in already integrated information sources e.g. Land Capability for Agriculture.

- Evaluate the requirements for repeated sampling and new types of soils data to provide better information on status and trends for government and agency activities.

Based on the above users requirements, prioritise the need for information. Consider the cost/ benefit of undertaking partial responses to specific user soil information needs by building on existing data rather than collecting new data (e.g. risk mapping)

- Evaluate the options for integrating data between schemes operating across scales.

- Work out the practicalities of establishing the individual components of an integrated programme that would adequately cover the spatial scales and trends information required by different users. Including: who / where / what / how / and how much.

Potential contributors

As outlined in the main text, there is a range of organisations that have been involved in obtaining, analysing and interpreting soil data, each with its own specialist knowledge and capabilities (see table 8).

These organisations should all be asked to engage in developing the monitoring programme to make best use of existing experience and resources.

A key requirement will be the establishment of cross-programme comparability of soil data and agreeing which organisations would be best placed to deliver specific data for specific needs. In the first instance, we need to seek CAMERAS guidance on how this could be taken forward and how it could be funded.

Implementation of the soil MAP.

At present we have identified the following steps required to implement the soil MAP. However this is at an early stage and it is not yet possible to identify specific roles / responsibilities.

- identify soil data / information requirements of the wider stakeholder groups (by March 2013 depending on funding)

Possible delivery mechanisms -> proposal for an audit of stakeholder requirements for soil information in Scotland to address the weakness identified in the consultation

- Using output of the consultation identify the needs for new information products that require soil data and identify any R&D required to fill the gaps.

Possible deliver mechanisms -> some soil information needs expressed by users may be fulfilled by further interpretation / reanalysis of existing data (e.g. risk map development) -> This is primarily a research outcome which could be delivered by MRPs and not necessarily a soil MAP development activity per se. This will require separate support and funding.

- Building on both the consultation and new evidence obtained from the wider stakeholder audit, prioritise data / information requirements

- Address the practicalities for new monitoring work including
    - Audit existing data to assess fitness for purpose & select suitable monitoring scheme(s) for acquisition of new data
    - To secure relevant organisations engagement and buy-in with the implementation processes. identify (and agree) who should do what (as soon as possible)

In the meantime, other related activities are:

- To assess how best to provide access to soil data. This is part of the current SSDW project. This project should cover issues such as communication of soil information to a wider audience and will address some of IPR issues relating to data access, and,

- To discuss the overlap with other MAPS and how joint working might be progressed.

It is expected that the final soil MAP will be integrated with the other topic MAPs under development for the CAMERAS environmental monitoring strategy. In addition, it is expected that any outputs from future soil monitoring activities will be made available through Scotland's Environment Website and any future soil daughter website (SSDW).