Technical report 61

Proposal for a European soil monitoring and assessment framework

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Executive summary

This report has been prepared in the framework of the EEA annual work programme, as part of the work plan of the former European Topic Centre on Soil. It contains a proposal for the establishment of a comprehensive framework for monitoring, assessing and reporting on soil conditions in Europe.

In particular, the report provides the background for discussion with Eionet partners and Commission services to help reach a common understanding on the purpose and need for a European framework on soil, similar to those already in place for air and water.

The proposal was presented at the Eionet workshop held in Vienna on 13 and 14 October 1999. Country representatives were asked to express their opinion on the proposal and to respond to a short questionnaire. Proceedings of the workshop as well as country responses are presented in a separate EEA publication.

The assessment of soil-related environmental issues is based on the identification of suitable, policy-relevant indicators, using the multi-function/multi-impact approach (MF/MI) and DPSIR assessment framework. Further development of the assessment system concerns the derivation of indicators using monitoring data and validation and comparison of the results achieved with defined reference values. In addition, validation of derived data against measured data is required in order to ensure scientific control of calculated results.

The proposal contains an initial list of policy-relevant indicators on soil to support soil protection policies across the environmental spectrum and, furthermore, outlines a minimum set of soil data that needs to be considered for monitoring at the European level in order to feed these indicators.

The proposed framework should be based as far as possible on existing activities in EEA member countries. Therefore, the report provides an overview of soil monitoring networks and related activities at the international, national and regional levels; it also highlights the differences between existing networks and explores ways in which these activities can be used as a basis for a wider assessment of the condition of soils at EU level. A stratification scheme is used to separate monitoring sites into three classes, to coordinate national monitoring and to enable harmonisation across the many different monitoring activities. This scheme encompasses integration with the developing European network for water and monitoring of special sites with specific soil problems.

A site selection procedure would place different classes of sites over many diverse soil categories within the EU, taking into account the soil region and land use. The different requirements of monitoring systems concerning major soil degradation patterns are considered within this framework. This allows maximum extraction of soil information to assess and quantify effectively the direct/indirect impacts on soils.

Data collected from the European soil monitoring network sites as well as other relevant data will be stored in the future SoilBase. To enable this, a satisfactory data flow from the national monitoring networks to the proposed EuroSoilNet has to be implemented. Hence the development of suitable data exchange formats and a procedure to aggregate national collected ‘raw’ data are necessary. Finally, after assessment of the data and their transformation into information presented in reports, the data and the information should be readily accessible to the users, for example to soil and policy experts in EEA member countries.

SoilBase should contain the data sets which will be collected within the future SoilNet supplemented with non-site data from other databases (e.g. statistical databases). SoilNet should consist of a restricted number of carefully chosen sites within comprehensive monitoring programmes, which would act as reference or control sites for harmonisation and quality control between disparate monitoring networks. Additionally, monitoring programmes on local contamination and soil sealing in all European regions should be included in the future SoilNet.

In the longer term, SoilNet and SoilBase will provide a base that will help to develop models which are more representative for Europe's soils and will be a useful tool in assessing soils in the future, for prediction and comprehensive reporting on the state of Europe's soils.

Finally, a soil information reporting mechanism is proposed, which identifies the users of soil data, the levels of aggregated soil information required and the variety of soil information reporting necessary at the national and European level.

This report, presented at the Eionet workshop held in Vienna in October 1999, has also served as basis for discussion and reference in the development of the EEA work programme on soil in the following years. However, by the time of its publication, a series of events had taken place, modifying the context of the discussion:

- The EEA and JRC agreed on a joint strategy on soil (November 1999). The strategy focuses on the adoption of a common framework for the monitoring and assessment of soil in Europe and on the development of a common soil information system. The JRC will also contribute to the development of the core set of indicators.
- The European Commission presented its proposal for the sixth environmental action programme (6EAP, February 2001). The programme lays down the Community action programme for the period 2001–10 in the field of environment. The programme introduces a new strategy on soil protection for the European Union.
- A new European Topic Centre on Terrestrial Environment (ETC/TE) has been designated (March 2001). The ETC will help the EEA in the implementation of the European soil assessment and monitoring framework. SoilBase will be integrated in Terris, the EEA integrated information system on terrestrial environment.

On a long-term perspective, the implementation of the framework for the assessment and monitoring of soil in Europe presented in this report would certainly contribute to improve the information basis needed to prepare, implement and monitor a sound European policy on soil, in line with the priorities set down in the 6EAP.

1. Introduction

The European Environment Agency (EEA) operates under Council Regulation (EEC) No 933/1999 of 29 April 1999, which amends Regulation (EEC) No 1210/90 on the establishment of the EEA and the European Environmental Information and Observation Network (Eionet). Its overall objective is 'to provide the Community and its Member States with objective, reliable and comparable information at European level enabling them to take the requisite measures to protect the environment, to assess the results of such measures and to ensure that the public is properly informed about the state of the environment'.

The European Topic Centre on Soil (ETC/S) was established by the EEA in 1996 with the objective to provide and develop information and data on soil aspects, covering all EEA member countries, in order to increase the understanding of soil as a natural resource, document soil degradation processes and improve the level of reliable and comparable information on contaminated sites, thus contributing to the development of the EEA work programme.

The EEA's main tasks are:

- to report on the state and trends of the environment;
- to establish, develop and make use of the Eionet;
- to facilitate access to data and information supplied to, maintained and emanating from the EEA and Eionet, together with access to other relevant environmental information developed by other national and international sources.

The role of the EEA, as defined by its mission and mandate, is therefore to provide policy-makers and the public with quality information, and to do so through a range of products and services. The Agency works as a facilitator or bridge between member countries (EU-15 plus Iceland, Liechtenstein and Norway), EU institutions (in particular the Commission, Parliament and Council) and other environmental organisations and programmes to bring together, use, make available and thereby improve the quality of information on the environment relevant at the European level for policy-making and assessment.

This is done through basic activities, including the support to national monitoring, the gathering and storage of existing information and currently accessible and reliable data, the analysis and assessment of data to produce policy-relevant information and indicators, the reporting of results to the policy-makers and the dissemination of information to the general public (Envision model, 'monitoring to reporting' — MDIAR — core activities) (Gentile, 1999).

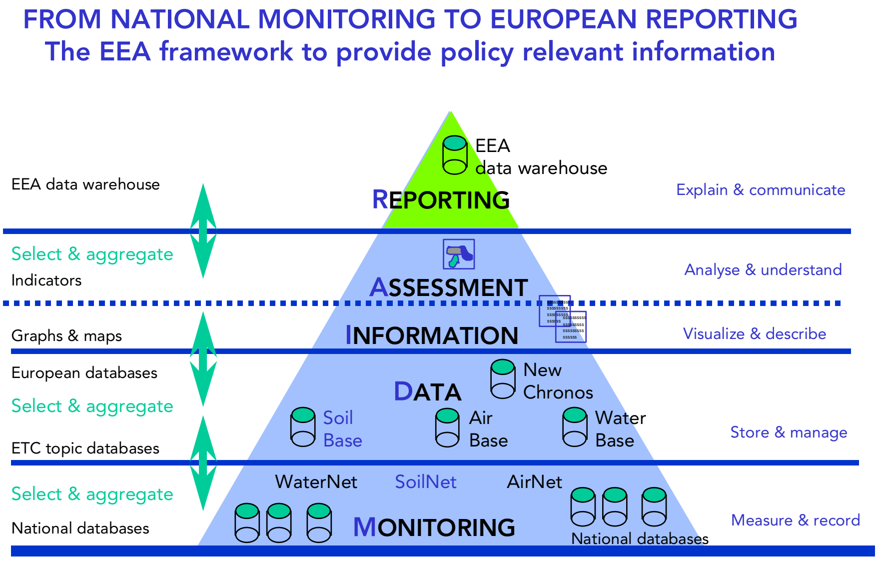
This report has been prepared in the framework of the second EEA multi-annual work programme (MAWP 1999–2003), which contains two specific projects on soil-related issues:

- State and quality — State of soil
- Land and soil degradation

In order to make best use of the available information on soil, as well as on other environmental areas, the EEA is building a framework 'from national monitoring to European reporting' (MDIAR-soil). The purpose of this framework is to provide policy-relevant information on soil, making use of activities and capabilities within member countries, including monitoring, data collection and storage. The framework incorporates the 'indicator concept' which quantifies complex phenomena (e.g. environmental issues) in a way that can be simplified and easily communicated. The indicator approach has the benefit of enabling integration of environmental issues with the dynamics in the economic sectors, with the added advantage of overcoming limited data and resources (Gentile, 1998).

This MDIAR 'monitoring to reporting' chain is a part of the EEA's environmental vision (Envision) model, which integrates all of the EEA's basic activities on monitoring, data and information gathering, assessing and reporting, with the networking and facilities provided by the European Environmental Reference Centre (E2RC) to structure and make this information and knowledge accessible. From these central activities, the processes, products and services of the Agency are derived: periodical reporting, integrated assessment, reporting on topics and developments, building on the databases and information of member countries and beyond (EEA, 1998).

Figure 1.1: From national monitoring to European reporting



The figure above illustrates the EEA's main activities (under the EEA Envision strategy):

- monitoring, to produce harmonised national networks and data relevant at the European level (European networks);
- data management and storage, to produce databases and establish data flows (topic and European databases, EEA warehouse);
- information, to visualise and describe the data in maps, tables and graphs for topic reports;
- assessment, to analyse and understand the information and to produce indicators for topic reports;
- reporting, to produce reports on the state of the environment and the yearly indicators.

Within this context, the ETC/S was requested in 1999 to produce a proposal for a European soil monitoring and assessment framework, which addresses these issues and sets out the first steps for establishing a coherent and comprehensive reporting mechanism for soil.

The main objectives of this task are:
- to develop a comprehensive European monitoring and assessment framework for soil similar to those already in place for air and water;
- to support the development of a coherent policy framework for soil, which takes into account the problems arising from the competition among its concurrent uses (ecological and socioeconomical), and which is aimed at the maintenance of its multiple functions;
- to contribute to the EEA's environmental monitoring, assessment and reporting activities, aimed at providing relevant, comparable and reliable data necessary to assess the state and trends on Europe's soils and the effectiveness of policy measures and to produce policy-relevant information on emerging soil issues;
- to ensure a broader common approach to the EEA's environmental monitoring, assessment and reporting activities, by linking to other relevant the EEA assessment and reporting frameworks and monitoring networks, with particular reference to water (EuroWaterNet) and air (EuroAirNet);
- to lay down the basis for a future European soil monitoring network, SoilNet, by evaluating case, scope and need;
- to prepare a proposal for discussion with Eionet partners.

1.1. Scope of the report

This report contains a proposal for the establishment of a comprehensive framework for the monitoring, assessing and reporting on soil conditions in Europe (MDIAR-soil), as part of the EEA work programme.

The scope of this report is to provide the background for discussion with Eionet partners and Commission services and to help reach a common understanding on the purpose and the needs for a European framework for soil, similar to those already in place for air and water. The proposal contains an initial list of policy-relevant indicators on soil to support soil protection policies across the environmental spectrum. Furthermore, it sets out a basic set of soil properties that should be considered for monitoring at the European level in order to feed these indicators.

The proposed framework should be based as far as possible on existing activities in EEA member countries. Therefore, the report provides an overview of soil monitoring networks and related activities at the international, national and regional level.

To date, EEA work on soil has shown that there is a lack of reliable, comparable data from across Europe and EU countries, which is one of the major problems limiting our ability to analyse the state and prospects for Europe's soils. This in part explains, and is explained by, the limited focus given to soil issues at the European level, compared with air and water, although soil is central to Europe's environment (EEA, 1999a).

There is no Europe-wide monitoring network for soil; rather, statutory soil monitoring is carried out in a number of member countries, but rarely for the purposes of soil protection per se. Since soil plays a central role in Europe's environment, and any changes in its functions have multiple effects and contributions to major environmental problems, monitoring and assessment of soil need to be addressed in an integrated manner (EEA, 1999a).
A proposal for a European monitoring and assessment framework for soil is necessary to meet the needs of the future, to ensure that soils have a high level of protection from degradation and pollution and that problems are identified as they arise.

1.2. Relevant soil issues in Europe

This section summarises the main findings of the chapter on soil degradation in the report 'Environment in the European Union at the turn of the century' (EEA, 1999a).

Many different definitions of soil exist, according to the particular context, purpose, and point of view from which soil issues are approached. This report, which considers soil, with its multiple functions and impacts, as having a fundamental role in Europe's environment, requires a broad definition, including all relevant aspects of land.

Soil is a three-dimensional body performing a wide range of socioeconomic and ecological functions. It is a complex medium, formed by a porous matrix, in which air, water and biota occur, together with the fluxes of substances and fluids between these elements. Alteration of soil processes leads to changes in the functioning of ecosystems and many environmental problems, which become apparent in other media, actually originate from within the soil (EEA, 2000b).

Soil is one of the fundamental systems for agricultural food production, life and the environment, and therefore its functions (see Table 1.1) and quality must be maintained in a sustainable condition. It is particularly pertinent to note that, unlike air and water, soil is relatively static. However, once its quality or functions are impaired, remediation (regeneration) can be extremely difficult and expensive.

Table 1.1: Soil functions

Ecological functions	Production of biomass	Soil produces food and fodder, providing nutrients, air, water. It provides a medium which plants can penetrate with their roots.
	Filtering, buffering and transforming	This function enables soils to deal with harmful substances, mechanically filtering organic, inorganic and radioactive compounds; adsorbing, precipitating or even decomposing and transforming these substances, thus preventing them from reaching the groundwater or the food-chain.
	Gene reserve and protection of flora and fauna	Soil protects numerous organisms and micro-organisms which can live only in soil.
Socio-economic functions	Support to human settlements (housing and infrastructure, recreation) and waste disposal	Soil provides ground for the erection of houses, industries, roads, recreational facilities and waste disposal.
	Source of raw materials, including water	Soil provides resources of numerous raw materials, including water, clay, sand gravel and minerals, as well as fuel (coal and oil).
	Protection and preservation of cultural heritage	Soil, as a geogenic and cultural heritage, forms an essential part of the landscape and is a source of paleontological and archaeological evidence, relevant for the understanding of the evolution of the earth and mankind.

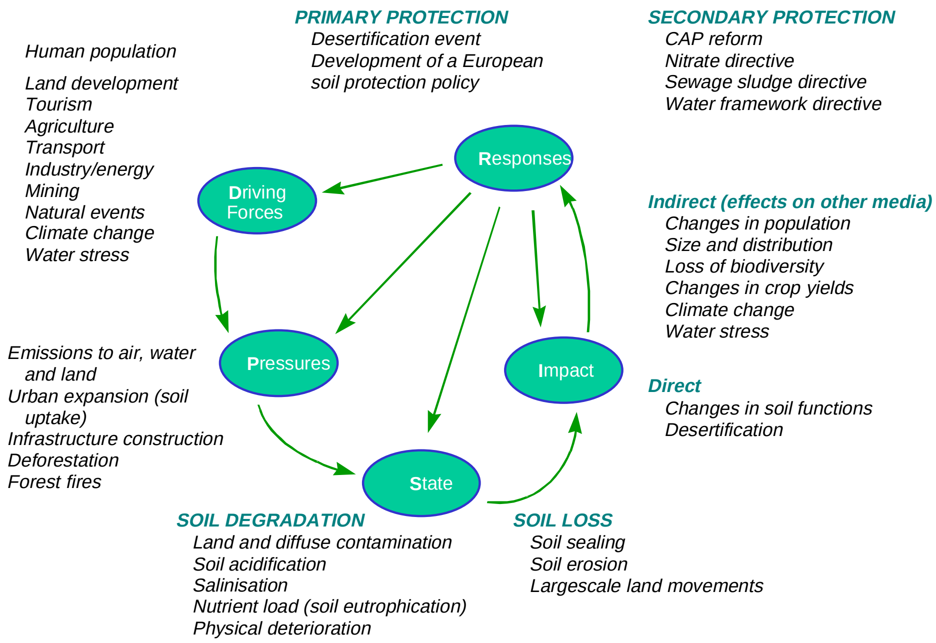
Source*:* Blum, 1990, 1998.

Soil is affected in terms of 'loss' or 'deterioration' of its functions, and several economic sectors play an important part in contributing to soil degradation. Soil losses due to sealing and erosion can be considered in large part as irreversible in relation to the time needed for soil to form or regenerate itself. Soil deterioration due to local and diffuse contamination can be reversed if adequate measures are taken, such as clean-up and remediation plans.
Since the regeneration of soil through chemical and biological weathering of underlying rock requires a long time, soil must be considered as a finite and non-renewable resource.

The concept of multiple soil function and competition is crucial in understanding current soil-protection problems and their multiple impact on the environment. Accordingly, a conceptual assessment framework has been developed applying the DPSIR system adopted by the EEA to soil issues (see Figure 1.2.). This framework requires the development of policy-relevant indicators on soil issues which describe the interconnections between economic activities and society's behaviour affecting environmental quality.

The problems of soil degradation and soil loss are mainly caused by activities such as intensive agriculture or by increases in human population, which lead to pressures on the environment (such as overuse of fertilisers and pesticides, deforestation or increase of built-up areas). As a consequence, these pressures directly affect the state of the environment, for example, in terms of degradation of the soil quality due to emissions of hazardous substances or topsoil loss due to erosion. Hence, information about these pressures on the environment is of great importance. Changes in the state of the soil may lead to impacts (changes in the population size and distribution, changes in crop yields), finally resulting in society's responses, such as the reform of the common agricultural policy or the UN Convention to Combat Desertification. In turn, these responses will again affect each part of the DPSIR assessment framework (Figure 1.2.).

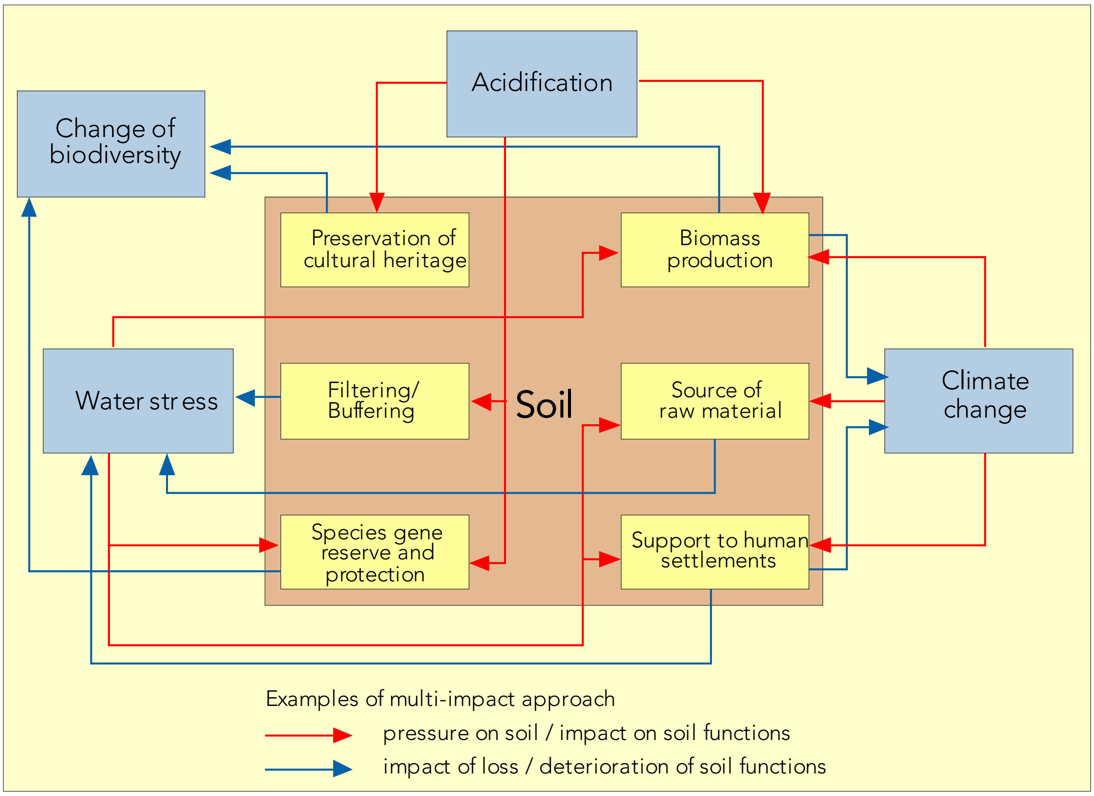
Figure 1.2: DPSIR assessment framework applied to soil



In order to show how degradation of soil affects the environment and has impact on other environmental compartments, the EEA has developed a multi-function/multi-impact (MF/MI) approach (see Figure 1.3.). Soil's central role and importance to the environment is further supported by MF/MI, which identifies other, closely interrelated key environmental issues with soil, such as:

- acidification: particularly affecting sensitive, poorly buffered soils;
- biodiversity: including gene reserves and protection, biomass production, protection of the landscape;
- climate change: leading to soil degradation, but climate change is also influenced by soils and vegetation;
- dispersion of hazardous substances, due to run-off and/or leaching;
- water stress: soil has a filtering/buffering capacity (EEA, 1999a).

Figure 1.3: Multi-function/multi-impact approach



Although soil degradation at the European level is generally recognised as an ever increasing, serious and widespread problem, its quantification, geographical distribution and the total area affected are only roughly known. The most recent assessment of soil conditions in Europe, with almost comprehensive coverage, is an evaluation of the current state of human-induced soil degradation, derived by ISRIC in 1993 from the world map on the status of human-induced soil degradation (Glasod — maps of soil degradation in Europe, prepared by ISRIC, are published in Council of Europe, 1995 and EEA, 1998). There is, however, a need for better and more detailed information.

The main causes of soil loss and deterioration (EEA, 1999a) are:

- **Soil sealing:** Soil losses due to surface sealing through urbanisation and infrastructure within the EU, are particularly high in Belgium, Germany and the Netherlands, and increasing in Greece, Portugal and Spain. Data on the rates of soil sealing are available only for a number of countries and are not consistent. Since countries use different methodologies to assess the extent of surface sealing, the comparability of the data poses a further problem. However, even within this margin of uncertainty, soil loss rates through land development and infrastructure may exceed those due to soil erosion in many European countries.
- **Soil erosion** is mainly due to water and, to a lesser extent, wind. Prolonged erosion causes irreversible soil loss over time, reducing the ecological functions of soil: mainly biomass production, crop yields due to removal of nutrients for plant growth, and reduction in soil filtering capacity due to disturbance of the hydrological cycle (from precipitation to run-off). The major reasons are unsustainable agriculture practices and overgrazing. Soil losses are high in southern Europe, but soil erosion due to water is also becoming an increasing problem in the north.

- **Local contamination** is characteristic of regions where intensive industrial activities, inadequate waste disposal, mining, military activities or accidents pose a special stress on soil. If the natural soil functions of buffering, filtering and transformation are overexploited, a variety of negative environmental impacts arise. The potentially largest and most affected areas are located in north-west Europe, northern Italy, Poland and the Czech Republic as well as areas around all major urban agglomerations in Europe due to the high density of industries, mining and so on.
- **Diffuse contamination** affects the soil functions most in its buffering, filtering and transforming capacity. Currently, the most important problems are soil acidification, mainly due to emissions from vehicles, power stations and other industrial processes; heavy metals, high concentrations of which may occur due to high lithological contents or be due to anthropological influences, causing threats to the food chain; and nutrient surplus, mainly due to over-application of fertilisers, with high phosphorous and nitrogen contents leading to eutrophication of groundwater, waterways or coastal systems through soil erosion or surface run-off.

To make an assessment on the state of soil and its impacts on the wider environment, the following soil degradation patterns should be taken into account:

Table 1.2: Soil degradation patterns (abbreviations: ph = physical, ch = chemical, bio = biological)

SOIL DETERIORATION	SOIL LOSS	
	Soil displacement	Soil 'de-functioning'
Local contamination (ch)	Soil erosion (ph) Wind Water	Soil sealing
Diffuse contamination (ch) Inorganic trace elements (e.g. heavy metals) Organic compounds Acidification Eutrophication	Large-scale land movements (ph)	
Salinisation (ch)	Desertification (ph)	
Compaction deterioration (ph)		
Loss of biodiversity (bio)		

Local and diffuse soil contamination, soil sealing, and soil erosion have been identified as major soil degradation patterns. Therefore, they are given precedence in this proposal for a comprehensive European soil monitoring and assessment framework.

To report on the state of soil, an indicator-based reporting system will be applied. On a **short-term basis** (autumn 1999) preliminary indicators for soil sealing, soil erosion and local soil contamination issues have been defined and calculated based on available data. The results are included in the EEA-UNEP message on soil (EEA, 2000).

On a **long-term basis**, European soil indicators shall be defined for the issues of soil sealing, soil erosion, local soil contamination and diffuse contamination. These indicators shall rely on sound monitoring data. The appropriate systems are currently being developed or planned. Results shall provide the appropriate basis for the EEA 'Environmental signals' reports (EEA, 2000b).

2. Need for a comprehensive monitoring and assessment framework

A monitoring and assessment framework for soil is an 'operational model' that outlines necessary measures to effectively gauge the current state of soils within Europe. The framework is meant to be a guide or reference aiming to provide consistent measuring and assessment at any site, from handling of soil samples to the treatment and storage of data. Accordingly, it takes into account the best utilisation of existing resources on soil activities and how to use them to achieve a more harmonised soil monitoring programme at European scale.
The main soil-related emerging issues emphasising the need for comprehensive soil information for policy-making within Europe are:

- climate change impacts;
- pollution impacts (diffuse and point);
- agricultural impacts;
- development impacts;
- soil degradation: desertification, erosion, salinisation, contamination, acidification;
- overall sustainability;
- background soil condition.

While planning to monitor the impacts of soil issues which are of concern today, there is also a need to be able to identify new problems and trends, which have yet to emerge on soil-related degradation. Over-specialised monitoring design is inflexible, and to avoid this problem SoilNet should be designed flexibly to enable a broad range of basic data to be gathered when considered necessary.

Table 2.1: Matrix of environmental issues and relevant soil/land parameters

Environmental concerns ⇒ **Parameters** ⇓	Climate change impacts	Pollution impacts	Agriculture & development impacts	Degradation	Back-ground condition	Sustainability index	Future concerns
Site characteristics	X	X			X	X	X
Soil type	X			X	X	X	X
Vegetative cover	X		X	X	X	X	X
Fertility			X	X	X	X	X
Organic carbon	X		X	X	X	X	X
Soil chemistry		X	X	X	X	X	X
Soil water characteristics	X		X	X	X	X	X
Soil structure	X		X	X	X	X	X
Soil biology	X	X	X	X	X	X	X
Contamination		X	X	X	X	X	X
Soil management		X	X	X	X	X	X
Contaminated land		X		X	X	X	X
Greenfield development		X	X		X	X	X
Conservation		X	X	X	X	X	X
General land use	X	X	X	X	X	X	X

In the Kyoto Protocol, the need is recognised to consider additional human-induced activities related to changes in greenhouse gas emission by sources and removals by sinks in the categories of agricultural soils, land-use change and forestry. So far, activities related to forestry since 1990 have been regulated. Reliable and transparent methodologies and guidelines on how to take additional sources/sinks into account still need to be developed (UNFCCC, 1998).

Soil acting as a carbon sink also has implications for bio-availability and mobility of metals in soils and has potentially harmful effects on human, plant and animal health. Soil can also act as a carbon source, as well as a source of other greenhouse gases. The direct application of agro-chemicals in the industrial agricultural sector and other related management practices result in increased emissions of nitrous oxides, methane and carbon oxides to the atmosphere, hence contributing to climate change.

Regional climate changes can lead to desertification. Desertification as a gradual and progressive reduction of the capacity of the land to support vegetation and animal communities, agriculture and forestry is threatening some southern parts of Europe (regions of France, Greece, Italy, Portugal and Spain). The affected areas typically have limited freshwater supplies and precipitation that varies greatly spatially and temporally, with frequent and recurrent periods of drought.

Furthermore, the use of land for urban development and transport in European Union countries harms the environment through, for example, loss of high-quality arable land, destruction of biotopes and fragmentation of ecosystems. In some regions, there are increasing spatial conflicts between additional housing requirements, commercial developments, agricultural use and protection of open space. On the other hand, there is about 2 000 km^2 of derelict industrial sites in Europe, which are, however, unevenly distributed. Reclamation costs are estimated at EUR 7 million per hectare of land (ESDP, 1999).

The spatial development of the European territory and the increasing competitiveness between social and economic interests as well as interest in the conservation of natural resources demand precise considerations and decisions at EU level.

It is an underlying objective of the European spatial development perspective to achieve a balanced and sustainable spatial development within the EU, in particular by strengthening economic and social cohesion, also taking into account the endangering of soils by increasing soil degradation and soil loss as well as the reduction of biological diversity and natural areas (ESDP, 1999).

Moreover, there is an agreed need to develop specific principles of soil protection policy, based on the precautionary principle. Ensuring to keep soil degradation and soil losses at sustainable levels, the importance of strengthening administrative structures, in particular encouraging and assisting Member States and applicant countries in developing instruments and procedures for soil protection and sustainable soil management was underlined in the Bonn Memorandum on soil protection policies in Europe of the European Soil Forum (ESF, 1998).

Considering the developments above, an effective protection of soil from harmful substances and the complete loss of its functions can only be achieved with international and worldwide cooperation. A harmonised, Europe-wide monitoring and assessment framework on soil is therefore needed to provide policy-makers with relevant environmental indicators based on reliable and comparable data related to soil and other essential issues in order to agree on effective and useful actions and directives to preserve the natural heritage soil for further generations.

In order to achieve these objectives, this framework will:

- identify priorities of soil issues (through agreement on the set of policy-relevant indicators);

- identify data availability and data gaps;
- provide for integration of relevant information from other environmental compartments and economic influences;
- provide benefits for more comparable measurements of changes and their assessment and evaluation on a larger geographical area (European soil monitoring network);
- produce information through the development of indicators and integrated assessment;
- enable a more comprehensive reporting on the state of soils in Europe.

Information that already exists on soil is patchy, dissimilar and not always easily available among member countries. This reflects the diverse interests countries have for their own particular soil problems. Another reason is that information on issues concerning soil are wide-ranging, from mining and waste disposal to land-use planning, agriculture and biodiversity. The information is therefore often held by a variety of organisations/authorities and the distribution of information within each country may be organised quite differently. This makes collation and evaluation of soil concerns especially difficult at the European level.

Consequently, the proposal covers a mechanism for data flow and information accessibility between providers and users through many data exchange channels within Eionet.

Furthermore, the development of a monitoring and assessment framework for soil is needed to combat limitations and gaps of present programmes, information and data on soil at the European level. There is little EU legislation that directly addresses the problems of soil degradation and loss, unlike for air and water (EEA, 1999a). Several directives are in place (e.g. nitrates, sewage sludge) which protect soil to some degree, but they have been set primarily to protect other environmental compartments (water and the food chain) than soil.

At national level, many member countries have produced legislation, policies or guidelines to ameliorate or prevent soils from further degradation. However, the information on soil obtained at country level indicates widely different types of administration across EEA member countries. Thus, some countries have only one central government responsible for laws, whereas, in others, regional governments also have the power to make binding legislation on soil and environment (see Appendix 5).

The application of a comprehensive monitoring and assessment framework will provide a means of obtaining comparable measurement of changes to soil and their assessment and evaluation on a larger geographical scale (European soil monitoring network, EuroSoilNet) as well as incorporating a guideline for different monitoring requirements, depending on the soil problem and the scale of the problem.

In conclusion, a Europe-wide framework is needed to provide information on soil to support policy development and to bring together the wealth of soil information derived from member countries monitoring programmes relevant at the European level. Furthermore, the framework is an important tool to deal with the incomparability between existing data and to harmonise this information together with new measurements, to produce a reliable and coherent SoilBase.

SoilBase will contain the data sets which will be collected within the future EuroSoilNet supplemented with non-site data from other databases (e.g. statistical databases). This European soil monitoring network should consist of a restricted number of carefully chosen sites within comprehensive monitoring programmes, which would act as reference or control sites for harmonisation and quality control between disparate

SMNs. Additionally, monitoring programmes on local contamination and soil sealing covering all European regions should be included in the future EuroSoilNet.

In the longer term, EuroSoilNet and SoilBase will provide a base that will help to develop models, which are more representative for Europe's soils and will be a useful tool in assessing soil in the future, for prediction and comprehensive reporting on the state of Europe's soils.

3. Assessment of soil conditions

The term 'soil assessment' stands for the analysis and reporting on the state of soil, the changes of soil conditions and their impacts on the wider environment. These activities are based on the derivation of defined indicators gained through the analysis of comparable, targeted and reliable data sets from harmonised soil monitoring networks and other data sources.

As for the assessment of diffuse contamination in particular, it must be ensured that the data is representative of the sites, the soil type and the land use. The assessment has to be done according to the politically relevant concerns on soils based on up-to-date technical knowledge. As a consequence, a concept for the procedure of assessment should be developed. The following points describe the four main steps in the process of soil assessment:

- identification of relevant indicators and priorities;
- calculation of the indicators using the data gathered by regular monitoring or specific investigations;
- validation of the achieved results;
- comparison with target values, threshold values and background values (if they exist).

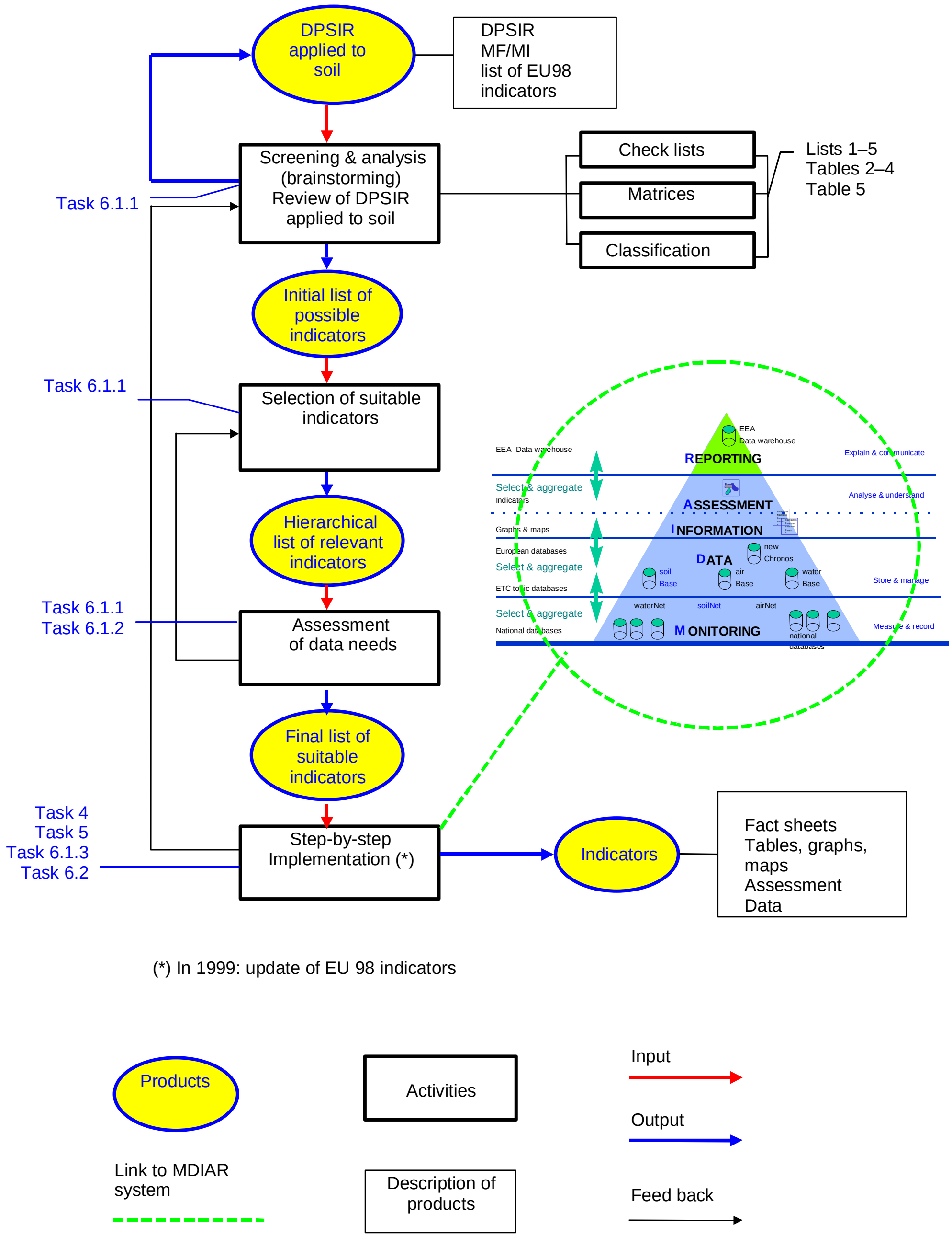
3.1. Identification of policy-relevant indicators

Indicators can either be a single measurement, or an aggregation of several measurements that provide information about a subject. Aggregated indicators have the advantage of simplifying and structuring the final data set, because they will contain fewer, more comprehensive data. However, the individual parameters can be used for detailed analysis and research by special interest groups and the scientific community. It is sometimes necessary to qualify the components of aggregated indicators to allow for the fact that one component indicator might have a greater weighting than some or all of the others involved in the aggregation.

The EEA has developed a procedure for the identification of relevant indicators on soil, based on EEA assessment tools (Figure 3.1.). This procedure is an iterative process which includes feedback (cycles) in different steps of the process. This gives the opportunity to review the DPSIR approach applied to soil and to update the selection of suitable indicators.

The first step refers to the identification of suitable indicators which is based on the considerations of the DPSIR framework applied to soil and the multi-function and multi-impact approach. Screening and analysis of these considerations lead to a development of check lists for soil parameters/indicators, describing the driving forces; the consequent pressures on soil; soil functions and soil degradation patterns (state of soil); direct and indirect impacts as well as the responses with an effect on soil (legislation in force, limits of pressure, standards for soil quality). Relationships between these issues, and, subsequently, with other relevant environmental issues, facilitate the description and classification of indicators according to the DPSIR framework. The first output describes a preliminary list of possible indicators (see Appendix 4) that has to be screened to select the most suitable ones. According to this list, an estimation of data needs is necessary to estimate the data gaps by analysing the available data. This of course gives feedback to the selection of suitable indicators. This iterative process leads to a final list of suitable indicators. Hence, a hierarchical list of relevant indicators can be organised (relating to the agreed priority issues) to execute a step-by-step implementation linked to the MDIAR system. The final result represents defined indicators, which are used for assessments, tables, maps, fact sheets and so on.

Figure 3.1: Iterative process to develop a system of policy-relevant indicators for soil



Source: EEA

This procedure can be used for two different approaches for the development of policy-relevant indicators on soil.

In the short-term approach, a better temporal and geographical coverage for the indicators developed for the ‘Turn of the century’ report has been updated and provided, with specific reference to the management of contaminated sites, soil sealing and soil erosion. The feasibility to develop indicators on heavy metals and content of organic matter in soil was considered, with reference to data collected in 1998 and in collaboration with JRC/Ispra. The results are published in the EEA-UNEP Message on Soil, ‘Down to earth: soil degradation and sustainable development in Europe’, and the

‘Environmental signals’ 2001 report, made available through the EEA web site (http://www.eea.eu.int).

In the long-term approach, a complete list of policy-relevant indicators will be identified, using the DPSIR framework and multi-function/multi-impact approach. Furthermore the assessment of data needs, identification of data availability and data gaps and necessary monitoring and modelling activities for the proposed list of indicators will be set up. The results shall contribute to the future editions of the EEA ‘Environmental signals’ reports, as well as to the further development of the EEA soil monitoring and assessment framework.

3.2. Example of regional assessment: boreal soils

A European framework for assessment and monitoring of soil should take into consideration regional and local conditions and be able to address and provide information on specific regional issues related to soil. As an example, specific questions related to the so-called boreal soils are presented here.
This section summarises the findings of a forthcoming technical report prepared by the ETC/S which draws up the characteristics of soils in the Nordic countries (Denmark, Finland, Iceland, Norway and Sweden) and makes recommendations on further activities.

Soils in northern Europe are relatively young, compared with most other soils in Europe, having developed only after the last glaciation during a period of 12 000 years at most. The majority of them are formed under a rather harsh climate with heavy precipitation and periods with temperatures below freezing.

Low temperatures imply periods of highly reduced or non-existing microbial activity and soil weathering, and very limited soil formation. As a consequence, shallow and acidic soils with a low buffer capacity and organic matter content are common in these countries, resulting in an even higher sensitivity to soil degradation processes than soils in other parts of Europe. Furthermore, boreal soils cover about 35 % of the total area of the EEA member countries, thus these soils deserve special emphasis in this chapter.

With the exception of Iceland, where alkaline volcanic soil types are very common, most boreal soils are acidic by nature. Areas of fertile clay soils are well known only in Denmark and in the southern and central part of Sweden.

Natural soil degradation processes, followed by an overall transport of material from the upper to the deeper soil layers, have been active since the last ice age. Since early human settlements, impacts of human activities on the soil environment have led to an aggravation of the soil degradation processes. Anthropogenic impacts have resulted, for example, in an increasing intensity of soil erosion during the last 1 100 years in Iceland and in the appearance of heathlands in Denmark and southern Sweden.

The natural vegetation in the Nordic region is forest, most often of the boreal type (spruce and pine). Until a few hundred years ago, most of the land was not affected by man and the environment was shaped mainly by natural factors. Nowadays, forests are still very important in Finland, Sweden and Norway, but human exploitation, associated industrial activity and a greatly expanded transport network, have left their marks on the landscape. In Iceland, the original birch and willow woodlands have been reduced from about 25 % at the time when settlement started 1 100 years ago to only 1 %.

Larger agricultural areas occur in Denmark and in southern Sweden. In other parts of the region, the agricultural share is lower and only makes up a few percent of the cultivated land. In the Nordic region, the number of manufacturing industries is increasing and, together with mining, may put local pressure on soils. Further, in built-up areas, soil quality and soil functionality are affected.

Given the specific conditions and high vulnerability of soils in the Nordic region, as illustrated above, it is recommended to carry out the following assessments of the conditions of soil in the Nordic area:

- acidification, acid neutralisation capacities and weathering indexes in natural land and forest land;
- background values of heavy metals in different geological deposits related to soil functionality (including ecological and human toxicological reference values) and mobility of heavy metals;
- pools of soil organic matter due to changes in land use or increasing concentrations of greenhouse gases and global warming; changes in soil organic matter in drained peat land should also be included in the description of the carbon cycle;
- soil erosion due to wind and water, including erosion in volcanic soils; a proper evaluation tool should be chosen for the modelling of frozen soil conditions;
- soil quality related to nitrogen and phosphorus eutrophication, pesticide pollution and changes in biodiversity;
- soil sealing and soil loss due to the development of industrial areas, built-up areas and infrastructures.

Suitable soil parameters covering the above-mentioned soil issues should be included in the future European soil monitoring network. Only data for an assessment of erosion are available at present. The description of other soil degradation processes needs additional data collection.

3.3. Further processes of soil assessment

Another part of the soil assessment concerns the calculation of values for the indicators using selected and aggregated national data sets, as identified during the analysis of data requirements. A very important part within the whole 'assessment process' is the validation of these values.

To enable soil assessment, the establishment of certain reference values for specific soils are required. Qualitative and quantitative descriptions and normal ranges within each of the properties should be available to facilitate the identification of anomalies in soil conditions. For this purpose, the comparison with target values, threshold values and background values, which describe the natural content, is mainly used.

Currently, few countries in Europe employ quantitative criteria or standards values to assess and control soil conditions. The variety of criteria and standard values that are applied is considerable and the terminology used is far from uniform. However, there is ample evidence that proper criteria/standards need to be flexible to accommodate a range of site-specific characteristics, such as soil properties, type of degradation, socioeconomic issues and additional environmental factors.

Scientific control of calculated results and used models should be mentioned as well as validation by the data provider (national experts) because of their special knowledge on regional soil conditions and the national political acceptance. For the correct interpretation of the data obtained, information on accepted relevant target values, critical values and background values is necessary.

Indicators are either derived from direct observations or derived from so-called 'pedo-transfer functions' or models. The results from derived indicators should be compared with direct measurements on the representative sites. The indicator values may be measured against threshold values, giving rise to performance or type ‘B’ indicators (see below).

Soil qualities are inherent attributes of soils that are inferred from soil characteristics or indirect observations such as compactness, erosion and fertility (SSSA, 1987). Key soil properties can serve as indicators of soil quality. Soil quality assessments provide a means to evaluate the sustainability of soil management systems (Doran and Parkin, 1994).

To be of practical use, soil indicators need to fulfil three basic requirements. They must be:

- sensitive to management and able to respond to changes in a relatively short time;
- accessible, i.e. measurement methodologies or data sets must be easily available;
- if not directly measurable, it must be possible to define them using pedo-transfer functions or models (Larson and Pierce, 1991).

These requirements are in good agreement with the three basic criteria for indicator development designed by the OECD (1993):

- policy relevance and utility for users (indicators must provide a representative picture, be simple and easy to interpret, be comparable, etc.);
- analytical soundness (indicators must be scientifically and technically well-founded);
- measurability (indicators must be based on data readily available, well documented and updated at regular intervals).

In addition to the above criteria, the EEA selects indicators having in mind the target audience, together with the most suitable level of aggregation and the availability of data needed to compile them.

The target audience influences the level of aggregation. Policy-makers or the general public need an overview of the situation, which is provided by indicators with a high level of aggregation, for example the so-called ‘headline indicators’. On the other hand, more detailed indicators are needed to better understand, for example, underlying trends and existing links between policy measures and their effects. Therefore, an appropriate balance between simplification and completeness must be found.

For the identification of policy-relevant indicators on soil issues, the EEA has defined a typology of environmental indicators (Table 3.1) as a further extension of the DPSIR framework.

Table 3.1: EEA typology of environmental indicators

Type A:	'What is happening?' — For example vehicle kilometres driven, emissions to soil, soil losses, environmental expenditures for air pollution abatement ('descriptive indicators').
Type B:	'Does it matter?'— Indicators linked with some kind of reference value, like the critical load or carrying capacity concept, health standards, or policy targets ('performance indicators').
Type C:	'Are we improving?' — The eco-efficiency of production and consumption processes, e.g. energy use per unit of GDP, use of fertilisers/agriculture production ('efficiency indicators').
Type D:	'Are we on the whole better off?' — Environmental sustainability, e.g. Green GDP, etc. ('total welfare indicators').

Descriptive indicators (type A) give information on what is happening to the environment, provoking the question 'Does it matter?'. This leads to the second type, performance indicators (type B), hence it matters if the value of these indicators are near to or above some kind of reference value. If performance indicators show that there is a problem (or in the absence of a standard reference value or a policy target value, a type A indicator shows that there could be a problem), the improvement is characterised by the efficiency indicators (type C), which measure the eco-efficiency of production and consumption processes. They can often be compiled merging two type A indicators. Finally, the indicators on total welfare (type D) answer the question 'Are we on the whole better off?'. The latter indicator type is not currently included in the EEA work programme (Gentile, 1998; EEA, 1999b).

Table 3.2 below shows a first tentative list, intended to describe high-priority indicators related to major soil problems. The different shades in the table correspond to a simple classification of the proposed indicators by degradation pattern. The whole list of the suggested policy-relevant indicators on soil can be found in Appendix 4.

The list is based on indicators and topics already included in the 'Turn of the century' report.
The next steps are:

- analysis of data needs and selection of indicators according to relevance and practicability;
- assessment of data needs and identification of data sources;
- elaboration of an Eionet data exchange module or questionnaire with the objective of receiving data from national databases.

Table 3.2: Preliminary list of priority indicators for soil

Issue/question	Indicator	Dimen-sion	DPSIR	Indicator type	Soil degradati-on pattern	Short-term core indicator
Contaminated sites management	Progress in identification of contaminated sites: (a) potentially contaminated sites — already identified sites versus estimated total (b) Number of sites which pose a significant risk to human health and the environment and where remediation action is urgently needed — already identified sites versus estimated total	%	R	B	Local soil cont.	Yes
Intensity of Agriculture: (1)			D	A	(Not applicable)	Yes
What is the extend of total soil loss by soil erosion (water erosion)?	Short-term: rough estimations:(3) estimation of the total gross erosion of defined areas based on the sediment delivery ratio of selected rivers (in dependence of the watershed area)	t	S	A	Soil erosion	Yes
What is the impact of soil erosion by water on other media?	Annual suspended sediment yields in selected rivers (cp. state indicator)	$t/m^3/a$	I	A	Soil erosion	Yes
What is being done to remove off-site damages by soil erosion?	Expenditures for removals of sediment deposits in built-up areas (traffic routes, houses)	Euro	I/R	A/B	Soil erosion	Yes
Urban expansion (2)			P	A	Soil Sealing	Yes
What is the state of urban expansion?	(Increase of) area covered by human settlements and traffic routes	%	P/S(?)	A	Soil sealing	(Yes)
	Estimated sealed area (by area covered by human settlements and traffic routes) per inhabitant	ha/pers on	P/S	A/B	Soil sealing	(Yes)
To what extend are soils of high quality/environmentally important soils affected by soil sealing (3)?	Portion of high-quality and/or environmentally important soil sealed	%	S	A	Soil sealing	Yes
Development of infrastructure, traffic and transport.	Emissions due to traffic issues	g/day	P	A	Diffuse contamin.	Yes
To which extent are industry and waste management contributing to air pollution?	Emission records due to industrial and waste burning activities	g/day	P	A	Diffuse contamin.	Yes

(1) Complex indicator: the intensification of agriculture of cost-effective but unsustainable land-use practices, the use of machinery for the cultivation of enlarged fields, the overgrazing and other instruments of intensive land-use practices could be seen as the main driving forces and corresponding pressures on soil that cause erosion in regions with potential and actual soil erosion risks. Average field sizes (and increase of field sizes), combined with average farm size per region as well as the consumption of fertilisers and the number of grazing animals, gives an indication of the intensification of agriculture. The main message is: the higher the degree of intensity of agricultural land use, the higher the risk of soil loss by water and wind erosion in potentially high erosion risk areas.

(2) Urban expansion could be described by the total area covered by human settlements and traffic routes per Member State, perhaps related to the total amount of inhabitants of the Member State. If detailed information is available, classified regional settlement structures may be good indicators for the state of urban expansion:

Class and description
Areas with large conurbation: regions with a regional centre of at least 300 000 inhabitants and/or a population density exceeding 300 people/km^2. Areas where conurbation is beginning to develop: population density on average above 150 people/km^2 and as a general rule a regional centre of at least 100 000 inhabitants.
Rural areas: districts and autonomous cities with a joint population density of less than 150 people/km^2.

(3) May not be feasible in a short-term approach, but should be taken into account for a long-term approach.

Although indicators are often used in connection with thresholds, it is very difficult to identify suitable threshold values for a Europe-wide analysis of soil degradation. For example, in the EEA STAR database, an inventory of international and national sustainability reference values and policy target values, there are very few thresholds and reference values for soils. The subject should certainly be considered again at a later date, and it may be possible to identify some thresholds which could be used on a region-specific basis. At present, it would probably be more convenient to identify the direction of trends in the indicators.

3.4. Data needs and gaps

An overall framework for monitoring, assessing and reporting on soil issues in Europe has not been implemented, despite the multi-functional aspects of soil and the multi-impacts on this limited resource from human activities and the environment. An adequate assessment of the current state or potential risk of soil degradation in Europe is still missing, as well as comparable data on the loss of the soil resource through erosion and sealing. Basic data, such as detailed European soil maps, is still unavailable for assessment and there has been no progress in the quality and comparability of data available at the European level (EEA, 1999a).

There is no Europe-wide monitoring network for soil (SMN), although some progress has been made in some areas, such as the monitoring of forest soils. Statutory soil monitoring is carried out in a number of EEA member countries, but rarely for the purposes of soil protection per se. Consequently, there is a large diversity in the design of soil monitoring schemes, the frequency of sampling, the range of parameters determined and the methods of analysis used. A further, also increasing, problem is the ownership and transfer of data. As a result of this diversity, there is a lack of harmonisation of the data derived from soil monitoring, and there is no pan-European quality control of the existing soil monitoring networks. A European inventory of contaminated sites is still lacking but requirements are being developed. Nevertheless, the importance of the soil medium and the need for European comparable data are being recognised (EEA, 1999a).

Bearing this in mind, soils are much more space-related than any other environmental media. Accordingly, the spatial dimension needs to be fully integrated in the assessment of the conditions of European soils. A new approach which takes into account the multi-functionality of soil requires more integration with issues such as spatial planning, critical loads and ecosystem analysis. The tools of spatial analysis, as well as geo-referenced data such as soil maps and high-resolution data from digital elevation models should be used. Furthermore, the utility of remotely sensed data needs to be explored. Remote-sensing technology could prove to be useful, for example, in assessing the actual state of land degradation or the amount of sealed surface at a suitable territorial level — information which is still missing and difficult to obtain with traditional monitoring techniques. Additionally, a multi-purpose integrated inventory of emission sources, to cover a variety of uses would be of great benefit (EEA, 1999a).

In addition, data needs can also be met through analysis of measurements such as the area of land protected by conservation agreements or the amount of land that has been lost through greenfield (previously undeveloped) site development, that are not appropriate for measurement at single SMN sites. Such non-site-specific data will nevertheless be an important element in assessing the state of European soils. This information can usually be obtained through national or area statistics held by national environment authorities, derived from census or remote sensing data. In addition, regional data held centrally by the EU may be useful. The EU has defined a nomenclature of administrative units, referred to as nomenclature of territorial units (NUTs). It may be useful to structure the SMN around these statistical units for ease of reference to data held in Eurostat. For soil monitoring and assessment, level 3 of the NUTs is seen as the most suitable reference to tackle the main soil degradation processes. Data at this level give the opportunity to link it to soil regions or catchments, focus on specific regions and aggregate them to different levels (e.g. country level).

4. Reporting of the results

4.1. Need for a reporting mechanism for soil

The objective of MDIAR-soil is to contribute to the environmental monitoring, assessment and reporting activities of the EEA (see Section 1). The EEA uses harmonised data collected at the national level, analyses, assesses, transforms and aggregates these data into relevant and useful information/indicators for reporting to its main clients and the public on the state and the changes of soil conditions at the European level.

Soil data feed into many policy areas and are required at different aggregation levels. It is extremely important that data be supplied to the user at the right aggregation level. Below is a description of these levels and examples of why soil data at that level might be needed:
- local (data useful to feed into local Agenda 21/environmentally friendly strategies and assess how effective these strategies are);
- regional (assessment of soils environment at the regional scale and effectiveness of regional policies);
- national (inter-regional comparison for national reporting and assessment of effectiveness of national policies);
- European (inter-country comparison for European reporting and assessment of effectiveness of European policies).

Those requiring reports at the European or national aggregation level on soils are:
- policy-makers, national and European level;
- government departments (transport, environment, land-use planning, etc.);
- scientific research centres, experts and consultants;
- NGOs and environmental/pressure/conservation organisations;
- educational establishments (e.g. universities);
- the general public.

Those below national scale requiring reports are:
- policy-makers at the regional scale;
- NGOs;
- industrial development;
- construction/building industry (possibly);
- insurance companies;
- environmental/pressure/conservation organisations;
- the general public (more at a local level than regional).

The aims of a soil-reporting mechanism are therefore to meet the diverse constituency of needs for soil data and information and enable the assessment of the condition of Europe's soils with respect to its many concerns at both the national and European scales.

One objective for policy-makers is to assess the impacts of anthropogenic activities on the environment, the consequences of these activities and, where possible, develop suitable responses to ameliorate/stabilise any negative impact on that environment. Furthermore, continual environmental monitoring will enable assessment of whether developed responses are working and adjustments of measures if and when needed.

Consequently, there now is a continuing move towards treating the environment as an integrated system and incorporating environmental considerations into the various economic sectors both at a national and EU level (EEA, 1996). So, to develop adequate responses to protect the soil environment, there is a demand for making policy-relevant associations with other environmental compartments (air, water) and economic issues (e.g. land development, agriculture, transport). The basis for that has already been set through the EEA's DPSIR and MF/MI tools (EEA, 1999a) (see Section 1).

Table 4.1: Policy-relevant tools for connecting soil issues, environmental issues and economic issues together (from a soil perspective)

• **The Indicator tool** is central in linking soil issues to economic issues (identified by DPSIR), other environmental issues existing in different environmental compartments (identified by the MF/MI or DPSIR) or issues not included by these approaches. Indicators are listed either as broad brush pointers for soil issues (i.e. soil erosion, indicator*:* loss of soil kg/ha) or as explicit pointers, for example by linking soil issues and soil functions (i.e. soil acidification, indicator: pH of soil, directly related to the filtering/buffering soil function). • **DPSIR tool:** links driving forces and pressures (derived from economic activities/pressures from other environmental compartments) — i.e. 'the causes' — to changes in soil quality and the consequent impacts (indirect and direct impacts assessed through the change/loss of soil functions). For example, industrial gas/metal emissions produce diffuse/local soil contamination. Indicators should cover the whole DPSIR chain. • **MF/MI tool**: links interrelated key environmental issues to soil functions (indicator tool can also be applied): for example acid deposition (indicator*:* pH of rain falling on soil) can be linked to the soil filtering/buffering function (indicator: pH of soil). This is basically a tool to identify impacts on soil or other media lead by the change/loss of soil functions and helps in selecting the appropriate indicators. DPSIR and MF/MI can be used together to link changes originating in other environmental compartments to their effects on the soil compartment. For example, industrial emissions affect air quality, resulting in acid depositions and soil acidification; acidification impacts on soil functions which in turn affects soil (and water) compartment and/or economic activities.

4.2. From data to reporting

4.2.1. Data analysis

It is important that, before any reporting can be done, there is sufficient analysis of the data obtained from the EuroSoilNet and national networks beforehand, to make often complex data understandable and comparable. Hence, in order to alter data into information relevant for reporting to all tiers, the following activities may be helpful:

- Redistribution of data to different reporting units according to their usefulness (e.g. geo-referenced information at sites will have to be aggregated to larger dimensions or divided according to land use, soil type or key sectors).
- Contrasting data (this will need to have supporting data).
- Streamlining data with emphasis on analysis.
- Performing detailed statistical analysis to obtain a range of errors in measurement and confidence limits for interpretation.
- Manipulate data using best techniques (e.g. empirical and dynamic modelling) for forecasting, prediction and scenario analysis.
- Integrate soil data with data sets obtained from other environmental monitoring networks (e.g. Earth observation data, to produce a sound database in order to derive information and indicators). This can occur at a variety of spatial scales, for example in the case of the EEA information strategy triangle (Figure 1.1.), data in the second tier (European level) from different databases (soil, air, water) can be integrated/overlaid to provide information at environmental compartment

boundaries. Use of the data in this way can provide policy-makers with better ideas of how to develop integrated environmental protection policies, as well as give better indications of pollution sources.
- Utilise spatial analytical tools for assessing data, for example by producing maps for comparisons between countries or regions or as an aid to identifying 'hot-spot' areas.

4.2.2. Nature and format of soil reporting

Once the data have been altered into information, the form of reporting may be quite different depending on the 'user' group. It is also important to ensure that any reporting is regular and consistent at both the national and EEA levels. Possible types of reporting are described below.

- **Easily deliverable reporting.** Information that can be processed quickly.
  Reporting can be achieved at the first tier (national) and second tier (European). The most likely way of reporting this information is on the Internet to the general public/environmental organisation users via the EEA web site, the Eionet telematic network and/or through a linked information system (EuroSoilBase).

- **Three-dimensional reporting.** Assessing the current state of soils in its spatial patterns (where the third dimension is the depth).
  The first tier (national level) reporting could be an annual event. Individual countries will be able to:
  1. Summarise and update their soil monitoring activities e.g. number of sites set up, quality assurance and control results.
  2. Analyse and calculate indicators based on their soil data to report on the current state of soils within their boundaries.
  3. Produce an annual national report that is only possible if the framework is implemented fully and that measured data is recorded, treated and analysed on a regular basis. The annual reports can be summaries outlining main conclusions from soil data analysis and updating monitoring activities as a means of informing those outside of the SoilNet. The reports could be aimed largely at other environmental networks for information on soil data gathering; or as a first port of call for those networks or other organisations requiring soils data for addressing policy issues, modelling, future prediction at national and EEA scale.
  4. Enhance internal discussion between different sites of the SoilNet. A variety of forums could be set up either web-based or in newsletter format, to report on many subjects associated with the soil monitoring network such as technicalities, contact changes, in-house research, modelling exercises, development of predictive soils tools and so on.

  The second tier (European level) reporting relates to supporting the many EEA activities, such as reporting on the state and outlook of the environment (SOE) at the European scale. Soil data from the harmonised EuroSoilBase will be fed into this periodic (five-yearly) SOE report, allowing detailed assessment of the current state of soils at the European dimension.

  'Raw' comparable data supplied by national data keepers will be used to feed into the EEA indicator-based reporting system to derive indicators at the European level for presentation of these results through the EEA periodic indicator-based reports. Principally, indicators for the main soil degradation patterns, soil sealing, soil erosion, local and diffuse contamination will be developed.

- **Four-dimensional reporting.** In many ways this is linked with three-dimensional reporting on soils spatially, but also includes changes in soil over time. The inclusion of time is an important distinction, because the monitoring of soils' many parameters occurs on time-scales usually greater (approx. 3–20 years) than for air and water (daily/weekly/monthly/yearly). Hence, the appraisal of 'changes in soil conditions' through time is not so quick to obtain because there is a large gap between each data point on a soil time series line. Also due to heterogeneity of soils data collected by member countries, time series-based data sets are incomplete or not available at all.

At the first tier, reporting on time-based data will be very much dependent on the member country and the amount of time-based soils data obtainable.

At the second tier, assessing changes with time and production of indicators (derived from soil monitoring) will only be possible with the establishment and continual soil monitoring at the EEA scale for some years to come.

- **Filling in areas of the reporting 'time gap' at the European and national scale.** It is also possible to utilise data/information gathered outside of a European/national soil monitoring network, to assist with filling in time series-based data gaps. A variety of soil data already held in databases such as FAO, SOTER and the European soil map database would be extremely useful to use in this way.

- **Sector reporting**. Reporting on various economic sectors (e.g. tourism, agriculture) and displaying relevant data that illustrate how these sectors are affecting the state of the soil environment — i.e. improvements or deterioration in the soil as a result of changing sectoral activity — and providing information on the 'eco-efficiency' of the sectors with respect to soil. Examples are the feeding of soil data at the European level for the EEA contribution to the review of the EC fifth environmental action programme (EEA, 1996) and a future soil-reporting mechanism which could be based on the model developed for the transport environment reporting mechanism (TERM; EEA, 2000c) and touch all sectors relevant to soil (e.g. transport, agriculture, industry, tourism, etc.).

5. Conclusions and further developments

5.1. Conclusions

The proposed European soil monitoring and assessment framework (MDIAR-soil) will provide the backbone of the EEA system for policy-relevant indicators on soil. Outputs include:

- an agreed list of policy-relevant indicators on soil;
- improved data flow between the national and the European level;
- more comparable data and information on conditions of Europe's soils — validation of measured data;
- a suitable assessment procedure;
- a European soil monitoring network (SoilNet) to enable the assessment of the state of European soils and effects of anthropogenic activities, and whether the soils are deteriorating, as well as changes in soil quality;
- a standard set of measured parameters and additional parameters where necessary for more specific soil issues;
- a European soil database (SoilBase) containing aggregated and harmonised raw data;
- an agreed reporting mechanism on soil.

The development of SoilNet is necessary to provide the EEA with information about soil trends and enable the assessment of anthropogenic impacts to the soil environment, so that future European and national policies can protect soil from degradation and pollution and new needs and conditions are identified as they arise.

Soil assessment comprises the reporting on state of soil and changes of soil conditions, based on the derivation of defined indicators gained through comparable, targeted and reliable data sets from harmonised soil monitoring networks and other data sources. Developing trends should be attainable by the comparison of harmonised data with earlier inventories, considering a special time reference and other reference values.

The assessment has to be done according to the politically relevant concerns on soil based on up-to-date technical knowledge. The main parts of the process of soil assessment are:

- identification of relevant indicators and priorities;
- data collection;
- calculation of the chosen indicators using the data gathered through monitoring or specific investigations, or collected from existing sources;
- validation of the achieved results;
- comparison with target values, threshold values and background values (if they exist).

The EEA has developed a procedure for the identification of relevant indicators on soil, based on EEA assessment tools (DPSIR assessment framework, multi-function/multi-impact approach). This procedure is an iterative process which includes feedback (cycles) in different steps of the process. This gives the opportunity to review the DPSIR approach applied to soil, to update the selection of suitable indicators and to proceed step-by-step in the implementation. According to the indicators chosen, data needs and gaps can be identified considering the data available from existing soil-monitoring networks and soil databases. The design and structure of SoilNet should be developed according to the results of these identification and analysis processes.

SoilNet should be based on current soil-monitoring activities within member countries, utilising existing sites within these networks or gathering relevant data for assessing non-site specific soil issues. As the nature of the networks differs between countries in concepts, objectives, content, size, scale, accuracy and technical procedures, it is obvious that harmonisation and coordination between national systems is necessary.

Integrating, where possible, soil sites with existing sites from other monitoring networks — for example the EuroWaterNet (EWN) — will minimise costs, increase information exchange, enable extrapolation to unmonitored areas and give useful information on compartmental boundaries.

Stratifying soil according to soil regions and land use means that the sites selected for the monitoring network will be as representative as possible of the many soil categories found in Europe. This will make it easier to identify changes particular to a certain group of soils and will provide a simple way of filtering soil data for particular users. In addition, a site stratification system similar to the system developed by the ETC/IW provides a rapid way of integrating soil sites with EWN sites. Using key sites as a reference for national networks is a useful method to enhance comparability between countries. The degree of site coverage will be a matter of national decision.

The design should neither limit the number of parameters monitored nor neglect the effort in establishing a sampling design allowing reliable statistical analyses and comparisons between benchmark sites. A standard set of parameters and indicators is defined which allows the detection of changes, even within short periods of time, with additional parameters tailored to specific soil problems included with the minimum set when needed (see Part II — Appendix 2 for more details on site design and stratification of the SoilNet).

It is proposed that, in order to develop further the concept of a pan-European SMN, the following areas will require elaboration:

1. A report on harmonisation protocols

Protocols will need to be drawn up describing standard procedures to be followed in:
- site selection, design and management;
- description of sampling methods, timing of sampling, transport and storage of samples, sample preparation and analysis;
- site and data recording in terms of a data dictionary, which will also define parameter codes, formats, units and acceptable range of variables;
- database requirements, especially in terms of accessibility and compatibility;
- validation of the collected data to ensure that each site can be compared (quality control).

Using standard procedures and coordinating national efforts with key sites will produce comparable harmonised data at the national level, this will then be in a format to be supplied at the European level.

2. The setting up of demonstration sites

The harmonisation protocols report could be used to select and design the layout of three pilot sites, which will have dual roles:
- to allow practical problems to be identified and the relevant protocols to be tested and refined;
- to act as demonstration sites for scientists who will be responsible for running national networks in the final SMN.

3. A method for costing the operation of a SMN site

SMN sites will be the financial responsibility of member countries. It is proposed to develop a spreadsheet which will allow the calculation of the costs of establishment and operation of a SMN reference site. Inputs will be specified in terms of staff effort and equipment, to which costs can be attached at local rates.

Data collected from the SMN sites will be stored in the future SoilBase. To enable this, a satisfactory data flow from the national monitoring networks to the SoilNet has to be implemented. Hence, the development of suitable data exchange formats and a procedure to aggregate national collected 'raw' data is necessary. Finally, after assessment of the data and transformation to information presented in reports, the data should be accessible in streamlined form to the users, for example to the member countries.
SoilBase will contain the data sets which will be collected within the future SoilNet amended with non-site data from other databases (e.g. statistical databases). This European soil monitoring network should consist of a restricted number of carefully chosen sites within comprehensive monitoring programmes, which would act as reference or control sites for harmonisation and quality control between disparate SMNs. Additionally, monitoring programmes on local contamination and soil sealing covering all European regions should be included in the future SoilNet. In the longer term, it is a base that will help to develop models, which are more representative of Europe's soils and will be a useful tool in assessing soils in the future, for prediction and comprehensive reporting on the state of Europe's soils.

EuroSoilBase should be seen as a part of the European soil information system being developed jointly by the EEA and JRC. It is the result of a pan-European effort. Even though some effort is needed to improve the data, many issues may already be addressed with this basic information (e.g. European soil map). Several tasks are in progress in order to improve this database, however the database cannot be applied to all demands and so, in view of this situation, it is clear that harmonisation of other existing data collections and coordination of data access are necessary.

Reporting on soil issues at each spatial level (i.e. regional, national, European) can be achieved by several means. The soil reporting mechanism described here is one where users of the data receive soil data at the aggregation level relevant to them and incorporate results in a number of reports for national and European reporting. Sub-national level reporting is very much dependent on individual countries and their specific requirements for soil reporting.

5.2. Follow-up of the work

This report was prepared as a background document for the Eionet workshop held in Vienna on 13 and 14 October 1999. Since then, it has also served as a basis for discussion and reference in the development of the EEA work programme on soil. By the time of its publication, a series of events had happened which have modified the context of the discussion. The major developments are presented below.

The European Topic Centre on Terrestrial Environment

The follow-up on the implementation of the European soil assessment and monitoring framework will be undertaken by the new European Topic Centre on Terrestrial Environment (ETC/TE).

The choice to integrate soil and land-related issues in one ETC reflects the more comprehensive approach to soil and the environment adopted by the EEA and presented earlier in the report.

In this context, the main task of the ETC/TE will be to gradually develop a monitoring and assessment framework for terrestrial environment, extending the framework for soil (to be used as a basis for further developments) to all relevant aspects of terrestrial environment.

In particular, the ETC/TE will develop and maintain a core set of indicators (focusing on sustainable land use, soil protection and integrated assessment of coastal areas) in collaboration with Eionet partners, relevant networks and the Commission services. The indicators will reflect pressures from sectors (transport, agriculture, tourism), land cover changes, soil degradation (sealing, local and diffuse contamination) and impacts on land such as habitat fragmentation.

The initial list of policy-relevant indicators included in this report, further extended to all relevant aspects, will be used as a basis for prioritisation.

The ETC/TE will also contribute to the multi-purpose and integrated European environmental information system with the design, development and implementation of Terris, the EEA integrated information system on terrestrial environment. SoilBase will be an integral part of this system.

Collaboration with the Joint Research Centre

In late 1999, the EEA and JRC agreed on a joint strategy on soil. The strategy focuses on the adoption of a common framework for the monitoring and assessment of soil in Europe and on the development of a common soil information system.

The common information system will integrate the relevant parts of Terris (SoilBase) and the European soil information system (EUSIS), developed by the JRC/European Soil Bureau. JRC will also contribute to the development of the core set of indicators.

A future common strategy for soil protection

The sixth environmental action programme (6EAP) introduces a new strategy on soil protection for the European Union. The programme, presented by the European Commission at the beginning of 2001 and to be approved by the European Parliament and the Council, lays down the Community action programme for the period 2000–10 in the field of environment.

The draft 6EAP recognises that '… little attention has so far been given to soils in terms of data collection and research. Yet, the growing concerns on soil erosion and loss to development as well as soil pollution illustrate the need for a systematic approach to soil protection...'

Moreover, '… given the complex nature of the pressures weighing on soils and the need to build a soil policy on a sound basis of data and assessment, a thematic strategy for soil protection is proposed...' (European Commission, 2001)

In a long-term perspective, the implementation of the framework for the assessment and monitoring of soil in Europe presented in this report would certainly contribute to improve the information basis needed to prepare, implement and monitor a sound European policy on soil, in line with the priorities set down in the 6EAP.

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Appendix

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Appendix 1: Existing soil monitoring networks and databases

Soil protection requires an integrated approach. There is a need to work towards the establishment of certain standards for all relevant types of soil degradation, based on a uniform general methodology. An appropriate degree of coordination at the EU level would be necessary to obtain some level of homogeneity between countries in the development of criteria and methodology for the production of relevant data on soil conditions and avoid duplication (EEA, 1999a).

To this end, it is necessary to consider existing monitoring and related activities on soil within member countries, and to make use of them in order to monitor soil conditions across the environmental spectrum.

Here, environmental monitoring applied to soil means to repeatedly observe and measure, often at predefined time intervals, the spatial dimension of the (soil) environment, by examining certain variables that are markers for changes within the soil compartment, or are pointers of changes to adjacent compartments. Assessment of the relative state of the soil environment through compliance with associated directives/targets/threshold values and objectives defined through legislation or policy and for general environmental control should be considered.

To point out and clarify the main distinctions between soil monitoring and soil survey, the following table includes the most important differences.

Table 1.1: Main differences between soil monitoring and soil survey

Issue	Soil monitoring	Soil survey
Site selection	Based on a representative distribution due to characteristic landscape units, different pollution exposure, land use and soil types (for example)	Based on a regular grid-system
Number of sites	Few	Many
Investigation	Intensive investigation, comprising comprehensive environmental measurements	Commonly a very limited number of measured parameters
Interval of measurements	Mainly yearly measurements, in some cases shorter intervals	Not required in general, usually time-interval of several years

Although official frameworks for comprehensive soil monitoring exist in most countries, uniformity in methodology and coverage is far from common even among national systems. The purpose, now, is not to harmonise existing networks as such, but to harmonise certain activities associated with these networks that are of interest to EuroSoilNet.

Employing harmonising techniques in this way would utilise soil information and data already obtained, saving the expenses of introducing a monitoring network at the European level from scratch. Considering the need to produce comparable and consistent results between countries, it is important that the differences between national networks are highlighted and ways of overcoming these differences are implemented.

1.1. National and regional soil monitoring networks

This section summarises the main results of a questionnaire regarding national soil monitoring activities across Europe distributed to the 18 EEA member countries and Switzerland in the beginning of 1997. Overall results indicate that a large amount of soil information is available, and that soil monitoring networks have been established in a number of European countries for regular recording of soil changes (Table 4.1). (NB: the following table is meant to give an indication of the breadth and scope of activities on soil at the national level, it is not an exhaustive list).

Table 1.2: Summary of soil monitoring activities within EEA countries based on responses from returned questionnaires

	EU monitoring activities	National soil monitoring activities								
EEA countries	Monitoring as part of ICP forests/ICP-IM network?	National soil monitoring network present?	general soil properties (e.g. org C, pH)	soil nutrients (P, Mg, K) & nitrate	soil (and/or water) chemistry	microbiology & soil fauna	deposition of air pollutants	radionuclides	heavy metals/ trace elements	organo chemicals/ pesticides
Austria	•	•	•	•	•	•	•	•	•	•
Belgium	•									
Denmark	•	•	•	•			•		•	
Finland	•	•	•	•			•		•	
France	•	•	•	•		•		•		
Germany	•	•	•	•	•	•	•	•	•	•
Greece	•									
Iceland	No Response									
Ireland	•	• 22% of country	•	•					•	
Italy	•									
Luxembourg	•									
Liechtenstein		• %?	•	•		•			•	•
Netherlands	•	•	•						•	•
Norway	•	•	•	•					•	•
Portugal	•									
Spain	•	•	•		•					
Sweden	•	•	•	•	•	•	•	•	•	•
UK	•	•	•	•					•	
Non EEA										
Switzerland	•	•	•	•					•	

Two soil monitoring programmes exist at the European level, the international cooperative programme on assessment and monitoring of air pollution effects on forests (ICP Forests) and the international cooperative programme on integrated monitoring (ICP-IM), measuring effects of long-range transboundary air pollution on forests and an integrated assessment of effects on ecosystems and catchments respectively. Programmes cover 31 European countries, including EU-15 and Norway (EC-UN/ECE-MFC, 1997).

A further European monitoring programme including soils, called Foregs (forum of European geological surveys) geo-chemical baseline programme, is currently running as a European contribution to the IUGS (International Union of Geosciences) Working Group on Global Geo-chemical Baselines. The aim of this programme for the period 1997–2000 is to collect, store and analyse several sampling materials (stream water, stream sediment, floodplain sediment, overbank sediment, residual soils and humus) from the global terrestrial network (GTN). These reference materials taken from the European cells (160 x 160 km) will be analysed and used to combine national geo-chemical mapping results into a Europe-wide or even global geo-chemical atlas, which will be available in 2001.

Based on EEA–ETC/S questionnaire returns, 12 EEA member countries as well as Switzerland have an established national SMN; with complete coverage. Two other countries have SMNs in place: Ireland, where the SMN coverage is approx. 22 % of the country and Liechtenstein, where the extent of the SMN is unknown.

1.1.1. Content

National and regional networks are much denser in northern and eastern parts of Europe than in southern parts. This is also the case of the density of ICP-IM sites, whereas the ICP forest network displays a more regular site scattering. Some existing networks are comprehensive at the national level, whereas others are limited to just a few sites. This heterogeneity in SMN coverage results primarily from the fact that issues such as soil acidification and the effects of air pollution on soil seem to be more addressed in northern and eastern countries than in other parts of Europe.

The measurement of human impacts on soil, soil biological degradation and other soil issues, according to priorities defined by individual countries, have been the main objectives in the design of existing national soil monitoring networks. Often, the impact is assessed by comparing the value of a soil property to a threshold or guideline value. A number of EU Member states, for example — which have adopted the EC directive on sewage sludge application, setting the limits on heavy metal concentrations permitted in agricultural soils — have often employed more stringent guideline values than those set out in the EC directive.

National soil monitoring programmes across the EEA have common monitoring objectives. Primarily, general properties, total contents of heavy metals or macro-nutrient elements are monitored, whereas less emphasis is placed on recording organic compounds or biological properties. Usually, there is a minimum set of parameters which are systematically measured at least once or monitored with different frequencies. This minimum set and the analytical methodologies employed by one country can differ considerably from the methods adopted by of another country; sometimes there are differences in methods adopted within the same country. Soil samples are obtained at a variety of spatial scales and depth. A broad range of time intervals is observed, depending on parameters and networks. Because of these differences in measurements, it would be difficult to undertake inter-country comparisons at the European scale.

In some member countries, measuring deposition of heavy metals and acidifying compounds to soils is the responsibility of the national air monitoring networks. Microbiology, soil flora and fauna are some of the least monitored parameters at national level. The cost of analysis and the presence of other soil issues with greater priority in the national agenda (e.g. acidification) mean that soil 'as a support for life' cannot be assessed easily. Soil information in this area is important for identifying changes in the soil medium as a protector for numerous organisms and micro-organisms.

Responses to emerging soil problems are heterogeneous among member countries. For example, since the Chernobyl disaster, some member countries have customised their soil monitoring networks to look at radio-nuclides, whilst other countries have not yet done so.

The locations of SMN sites are usually selected using different criteria: grid-based site selection or representativeness (based on landform, soil types, land use, specific site-related conditions). Major land use types covered are: cultivated land, forest, natural areas and urban areas where soil contamination is highly probable. Approximately half of the EU countries cover most landscape types, the majority focusing mainly on forest soils and agricultural soils.

1.1.2. Methods

In measuring soil properties, sampling results in removal of soil and disturbance of the sampling site. Hence, repetitive sampling is not possible at exactly the same place. Due to the heterogeneity of soil and in order to reduce spatial variability with regard to temporal variations, national SMNs often have sites on relatively homogeneous soil under constant land use.

Numerous soil mapping and sampling methodologies have been developed to maximise representativeness of samples. In most cases, the sampling design is based upon a systematic grid (most often squared or rectangular, in some cases circular or hexagonal). The grid is used to locate samples at its nodes or to delineate cells in which clusters are sampled. This is the easiest way to ensure a wide coverage of large areas. Some sampling designs pay attention to spatial variability and to scale, others ignore short-range variability or only use composite samples. The size of the monitored area varies also, but nearly all sites have areas ranging from 100 m^2 to a few ha and are homogeneous with regard to soil characteristics. Watersheds are monitored for erosion processes in most cases and sampling is based upon several sub-samples (from 6 to 100) taken in the catchment area. The exact location of these cores should be known in order to avoid these locations in a later re-sampling to ensure sampling of undisturbed cores.

In the case of core sampling, fixed depth increments are most often used. This method of soil sampling ensures standardisation between sites and it is the most relevant to characterise anthropogenic impacts and strong gradients near the surface. Samples from pedogenic horizons are often collected in soil pits, near but outside the monitoring area. This method is relevant for parameters such as particle size, water retention properties and mineralogy.

Time intervals of repetitive site observations cover a broad range from several times a year to every 20 years, depending on parameters and networks. However, for most of the relatively stable properties of soils, time steps ranging from 1 to 10 years are commonly used.

In the majority of the questionnaire responses, the analytical procedures applied were not given in detail. However, in SMNs for which this information was available, the analytical methods showed numerous differences, indicating that the use of international standards is far from common among the national systems. Moreover, as numerous international standards for soil analysis are still lacking, standardisation will be one of the main issues in setting up a SMN at the European level.

Most SMNs use inter-laboratory quality control. Long-term storage of samples is not always recommended. However, this storage seems to be necessary in order to make possible use of new analytical techniques which could appear in the future and in order to be able to re-analyse samples when a new problem is encountered.

1.1.3. Databases

All countries have a computerised form of recording data obtained from monitoring activities. The type of recording varies from one country to another. Some national SMNs use GIS techniques or relational databases to hold spatial soil information and process monitoring data. Most data retrieval systems are able to deliver their data in various formats without major technical problems.

Actual access to basic data is not always possible. In numerous cases access to data is limited, although in most cases a meta-database describes the nature and the origin of the information. Most national soil monitoring networks have not yet defined clear rules for data availability.

In order to be able to use information from national networks, it is important to know the representativeness of SMN data at the regional level. In other words, it is important to know how the data obtained from soil monitoring sites adequately reflect the surrounding area of interest, in terms of describing relevant soil types, land use, specific soil problems, etc. A representativeness study could be undertaken by superimposing the existing networks on the soil map of Europe at 1:1 000 000 scale. Answering this question on representativeness requires enough information to be collected from SMNs and this has not yet been possible. Hence, more information will have to be gathered on soil monitoring sites: e.g. pedology, geo-reference of sites, list of collected parameters. Clearly, the feasibility of this activity depends on data availability.

1.1.4. Conclusions

Reviewing soil monitoring programmes in EEA member countries and available soils information and data, it is clear that, within existing soil monitoring activities, there are three main gaps, as described below.

First of all, although many national SMNs share similar monitoring programmes (heavy metals, nutrients, etc.), measurement techniques vary considerably. As there is no integration between the various approaches adopted by each country, inter-country comparison would be difficult at this stage.

Secondly, because of the way existing monitoring networks have been designed, there is a lack of predictive analysis. For example, there is no Europe-wide database of heavy metal concentrations in soil and very few databases at the country level, making it impossible to assess future risk for heavy metals in Europe. There are still major data gaps in quantifying emissions from industrial processes depositing on the soil surface either through wet or dry deposition. There is also insufficient knowledge about the prolonged effects of toxic substances on different soil ecosystems or the bearing capacity of different soils on accumulating heavy metals, organic chemicals and other pollutants.

Finally, there is no mechanism in place that allows for easy transfer of soil monitoring data between users (decision-makers, environmentalists, scientists, etc.).

1.2. Data needs and gaps of existing SMNs

Data needs are derived from specific user needs according to identified priorities (agreement on set of policy-relevant indicators). In order to develop those indicators, an analysis of data needs should be carried out. In particular, a list of parameters to be provided by EuroSoilNet should be defined, together with frequency and methods of measurements. This will enable the identification of data gaps within existing soil monitoring networks and databases, in relation to long-term and short-term indicators.

A parameter may be a direct measurement or it may be derived from a pedo-transfer rule (e.g. for predicting catchment hydrological characteristics, usable water quantity) or a model (e.g. simulation model for soil acidification) which must be based on site data.

Clearly, there is a very large number of parameters which are monitored at various SMNs. A choice has to be made so as to arrive at a set of parameters leading to indicators which reflect our ability to show whether the quality of Europe's soils is improving or declining especially in relation to factors which could influence sustainability and human health. Parameters to be measured are already grouped in many existing SMNs, although not all parameters are measured at all sites.

The site characterisation of SMNs generally includes a list of mandatory general site parameters (coordinates, landform, slope, elevation, meteorological data, soil type, land use, vegetation and management practices). In some cases, soil mapping must be conducted according to standard procedures. Soil classification, profile description and soil texture are nearly always mandatory, but the guidelines for classification and description, as well as the threshold for texture classes may differ among the countries.

Related to the preliminary indicators chosen for diffuse contamination (see Appendix 3) some derived parameters are nearly always investigated in existing SMNs, comprising the pH value, chemicals parameters such as CEC and major nutrients (total and available), the total organic carbon and the particle size distribution.

Sometimes, more information about soil physical properties (aggregate size and stability, bulk density, soil structure, porosity, etc.), electrical conductivity, heavy metal concentration and some radio-nuclides is required.

Parameters, which are almost never measured at existing SMNs concern some radio-nuclides and soil solution chemistry, such as nitrates, dissolved organic carbon or chemicals. Particularly under-represented are measurements relating to early changes in organic matter and biological and microbiological attributes, such as light fraction organic carbon, particular organic carbon, microbial biomass, soil respiration or soil enzymes. This poses problems for the integration of existing sites into the network, as these are emerging areas of interest to the scientific community. As many biological indicators methods are still at an early stage of development, standard procedures cannot be recommended yet.

The lack of solute chemistry may be partially addressed by a successful integration of SMN sites with EuroWaterNet monitoring sites (see Appendix 2).

Appendix 2: Europe-wide soil monitoring network

2.1. Requirements of a Europe-wide soil monitoring network

Work carried out by the ETC/S to review existing legislation on soil shows that relatively few initiatives and policies directly related to soil have been implemented (see Appendix 5). However, recognition of the interconnections between water, air and soil concerns means that soil is being increasingly taken into account when environmental recommendations are made. This is relevant when considering a European SMN (EuroSoilNet), because the existence of policy imperatives, and statutory water, air and soil monitoring will to some extent determine its design and objectives.

Data comparability and harmonisation

One of the stated objectives of the EEA is to ensure that environmental data within the Community are both representative and comparable. When considering a European SMN, the first questions one should ask are — what do you measure and where? The second point raises a number of questions, not all of which relate to analytical methodology:

- geo-referencing — standard resolution (± 10 m?) according to national and/or UTM coordinates;
- site layout — agreed protocol;
- site and soil description — standard system, e.g. FAO;
- language — national with certified translations;
- sampling protocols (including parameter-dependent sampling frequency);
- sample treatment and storage — protocols such as ISO/TC190 (are the samples to form an international archive of reference material? If so, who keeps them, who pays for this, who has access to them and under what conditions?);
- analytical methods — ISO/TC190;
- analytical QA — national and/or international validation programmes; limited number of laboratories; ring tests, etc.;
- reporting and storage of data;
- who 'owns' the data, who has access to it, and by what mechanism;
- who 'owns' the intellectual property inherent in derived data.

One way to enhance comparability is to develop EuroSoilNet (SoilNet) acting as a reference for national networks. The need for protocols, which member countries would agree to apply to all reference sites is central to the operation of SoilNet, as proposed here. Part of the protocol system would be a system of analytical quality control to ensure that the data produced from the reference sites is indeed comparable. It is not, in our view, acceptable to rely entirely on in-house or other internal systems. International valid analytical measurement is of growing concern and importance, and SoilNet should take appropriate note of this. Such a programme would also allow the assessment of the data produced from the national networks, as the reference sites we propose would act as control centres for these networks as well.

It is important to note that such a SMN would lose much of its value if the structure and protocols are not robust. It must be designed to withstand changes of staff and management, with as few operating procedures left to subjective judgment as possible. The information gathered will increase in value with the length of the monitoring period, and we believe that firm commitments will be needed to maintain the climate in which the SMN will develop into a meaningful tool.

According to the many different analytical methods, it seems useful to fix some of the most common ones that have to be carried out on the reference sites by every member country. In this way, it would be possible to create transformation functions, depending on the most important soil parameters (pH-value, Corg, etc.) and to ensure the comparability of the different soil data, as until now no universally valid method has been established.

The question remains, what should be the general framework for an harmonised sampling design? The choice should be optimal with respect to both to the objectives and to technical and financial considerations. But it should also depend on the degree of homogeneity and on the spatial structure of soil attributes. However, the variability of soil properties is usually unknown and its estimation may often be one of the main objectives of a study. Moreover, if the spatial structure is to be studied, this may lead to a very great number of determinations for estimating the variograms at short lags. It is striking that intra-site geostatistical data processing is almost never undertaken. One reason is that the number of subsamples is often too small to allow geostatistical comparisons. As many soil parameters are spatially correlated, a preliminary geostatistical assessment of some key soil parameters (e.g. particle size distribution, CEC, pH, soil organic carbon) could result in an improvement of the sampling design to detect actual changes within the soil as opposed to spatial variation, and therefore to make monitoring more sensitive to early changes.

Data flow and management

From the technical and administrative point of view, a satisfactory data flow between data producer, the EEA and main clients has to be developed. In the case of soil data, these should flow from the national monitoring networks to SoilNet, the future soil monitoring network for Europe (if an agreement is reached). Eionet plays a central role in this data transfer. From this network, aggregated data will be stored in the future SoilBase. After assessment of the data and transformation to information presented in reports, the data will be distributed in streamlined form to the users, for example to the member countries. To enlarge the utility of gathered soil information and save resources this concept will consider parallels with other EEA topic databases for practical data management.

In the process of coordination of the data flow the following activities need to be organised:

- making the connection to national monitoring and soil survey data collection;
- developing appropriate data exchange modules including definitions of specific terms;
- organising the data coming from countries and international organisations (Eurostat, OECD, etc.) and store them in databases like SoilBase;
- making the assessment and producing information;
- making the achieved information accessible to the users in a suitable way (e.g. through reports, web applications, etc.).

In general, for all data transfers, related items like data protection, data access, useful tools (Eionet Telematics, Circle documentation) and data exchange formats, clear and precise rules and guidelines should be developed.

2.2. Description of the EuroSoilNet — design and structure

The purpose of a soil monitoring network is to provide reliable data in order to report on the state and the changes of environmental issues relating to soil. Depending on the major soil degradation patterns (diffuse contamination, local contamination, sealing and erosion) different parameters, methodologies and monitoring designs are required to enable a targeted and mostly effective data-information. The Tables 2.1 and 2.2 give a short overview from these different requirements on soil monitoring networks incorporated in SoilNet.

Table 2.1: Monitoring approaches for the major soil issues

	Diffuse contamination	**Local contamination**	**Soil sealing**	**Soil erosion**
Monitoring units	• Selected monitoring site • 'Classic monitoring'	All European regions	All European regions	Selected monitoring sites in representative European regions
Monitoring methodology	Point based monitoring (100 to 10 000 m²) representative selection of monitoring sites	Based on: • regional summary reports • modelling of data gaps	Based on: regional summary reports (to be specified)	• Geographical databases (soil erosion risk maps) • Modelling of topographic, climatic, soil, land use and other data • Measurements: sediment transports and climatic data
Data requirements	Obligatory set of analytical data	Aggregated data on contaminated sites	Aggregated data from European regions	Model results, erosion measurements
Time intervals	On average 5 years for obligatory data set	1–2 years	2–5 years	1 year

Table 2.2: EuroSoilNet monitoring tools

	Diffuse contamination	Local contamination	Soil sealing	Soil erosion
Development of indicators	Long-term approach	Short-term and long-term approach	Short-term and long-term approach	Short-term and long-term approach
Implementation of indicators	2000	1999 (short-term) 2000 (long-term)	1999 (short-term) 2000 (long-term)	1999 (short-term) 2000 (long-term)
test monitoring	Data collection from European reference sites	Data collection and assessment of selected European test regions	Data collection and assessment of European regions	Data collection from European reference sites
Implementation of test monitoring	2001/2002	1999	1999/2000	1999/2000
Up-scaling: from test monitoring to European monitoring	(1) Development of methods to make available national data comparable (2) Definition of a reporting format and mechanism (3) Development of models for data gaps	(1) Development of methods to make available national data comparable (2) Definition of a reporting format (3) Development of models for data gaps	(1) Development of methods to make available national data comparable (2) Definition of a reporting format (3) Development of models for data gaps	(1) Development of methods to make available national data comparable (2) Definition of a reporting format (3) Development of models for data gaps
Output	(4) Data basis for the calculation of soil indicators for the state of diffuse soil contamination	(4) Data basis for the calculation of contaminated sites indicators for the state of local soil contamination	(4) Data basis for the estimation of soil sealing indicators	(4) Data basis for the validation of soil erosion maps and prognoses models

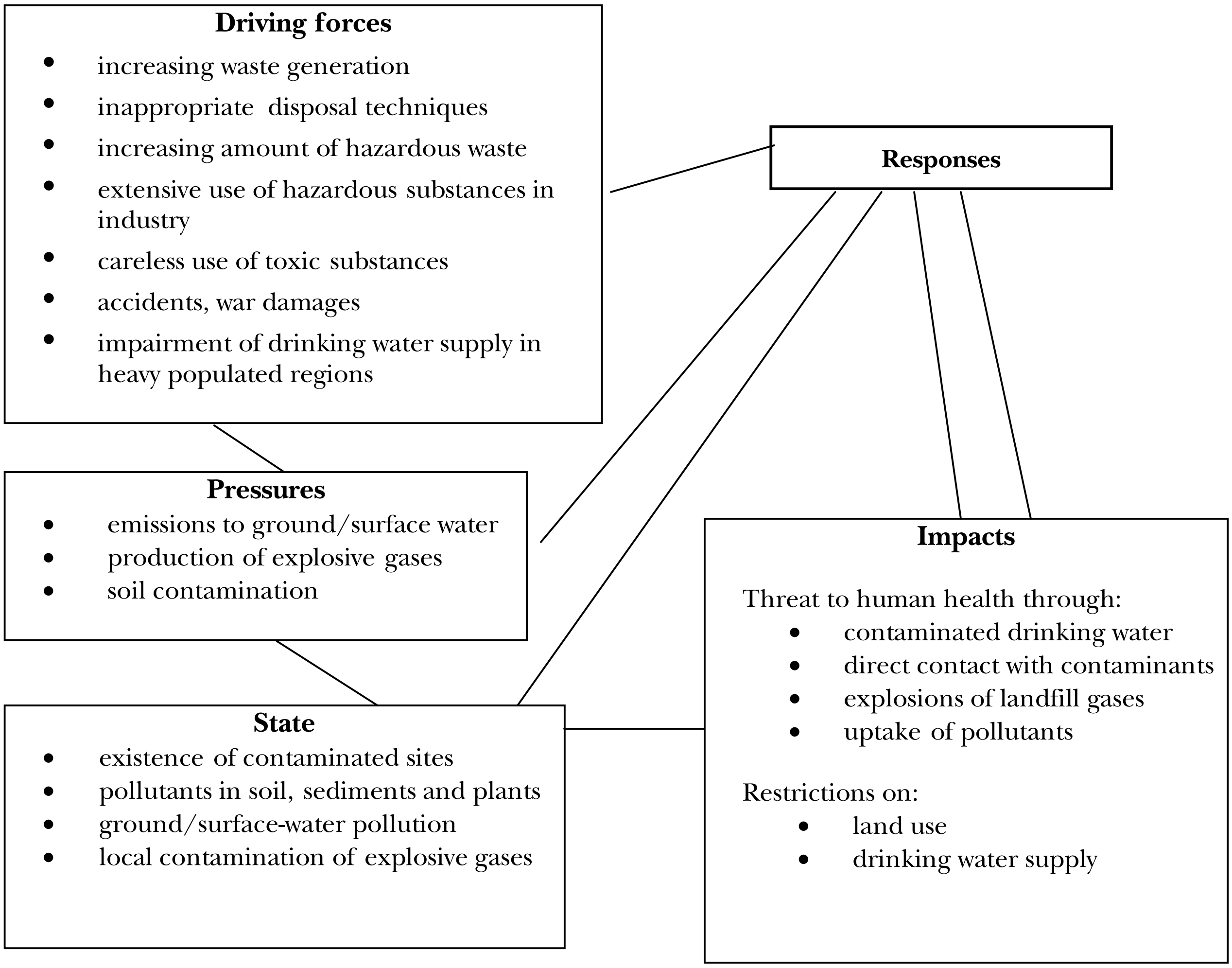
The following section of this chapter mainly focuses on diffuse contamination patterns, as the common, 'classic' soil monitoring is usually due to the description of the soil quality. A first attempt has also been undertaken to design a European monitoring and assessment approach for local soil contamination issues. Approaches to the other issues are still as yet undeveloped.

Recognising soil degradation in general as an ever increasing, serious and widespread problem, local contamination is one specific component in the soil degradation pattern which needs to be considered specifically.

It is one of the characteristics of local contamination that a great deal of damage was caused in the past. Activities concerning local contamination are focusing on remediation of damages or risks occurred in the past. Compared with other soil degradation patterns, slight differences in the components and content of the monitoring and assessment framework for local contamination have to be stated.

In order to illustrate cause–effect relationships for local soil contamination and to show impacts of soil degradation on humans, the DPSIR approach was chosen. Based on the DPSIR assessment framework applied to soil the figure below shows the specific application for local contamination.

Figure 2.1: DPSIR approach applied to local soil contamination



For each of the DPSIR elements, draft indicators to characterise local contamination management were described (see Appendix 4). For the moment, the draft indicators are rather comprehensive and need to be revised in order to focus on a small amount of selected data. Data needs to calculate the selected indicators create the basis for the monitoring and assessment framework.

The monitoring and assessment framework for local contamination will cover all European regions; the monitoring method will be based on available and reliable data provided by regional reports, the planned reporting period is 1–2 years. Data gaps will be filled by modelling and using estimations in case of lack of hard data.

In order to define data needs and the outline of the monitoring and assessment framework for local contamination, a data collection and analysis in 10 voluntary test areas across the EEA countries was started in spring 1999. Results of the data analysis of the test areas provide an important input for the further development of the monitoring framework. A draft implementation was discussed at the second contaminated sites workshop of the ETC/S in Dublin, November 1999.

2.2.1. Background considerations for 'classic' soil monitoring

The data of a 'classic' soil monitoring network may be used to establish definitions of soil quality and will demonstrate whether any changes have occurred in given soil properties over time. The presence or absence of such change (whether it is an increase or decrease in a property) may be used to demonstrate or predict a change in soil quality. It is also possible that the data may be used to derive, model or predict a property that is difficult to measure directly. The establishment of a SMN implies that choices have to be made about:

- **The soils themselves**. As there is a very large number of 'soil types' within Europe, their complexity can for example be differentiated at the levels of spatial extent, frequency of occurrence, soils representing environments under some kind of stress and soils which might be expected to respond rapidly to a change in (specific) environmental conditions.

- **Soil-land use combinations.** These could be confined to major systems, e.g. urban vs non-urban soils; soils representative of intensive agriculture, long-term grassland, and forest. There are several 'types' within each of these categories which may need to be addressed in more detail. A more difficult question is whether monitoring sites should be representative of normal land use practice, or whether sites should be 'preserved' under one particular system of land use. The latter may be acceptable for forestry, which has a long land-use cycle, but might rapidly become atypical, for example land under arable cultivation.

- Soils exhibit wide spatial variability. However, temporal fluctuations in soils are difficult to detect and are sometimes masked by background 'noise'. It is important therefore to choose sites that are homogeneous and can be treated statistically, so that spatial and temporal variations can be separated.

- **The density of observations**. A SMN should be robust, meaning that the data collected for particular sites should be demonstrably representative of the system that each site represents. This has implications for the number of sites also considering the different requirements on the monitoring designs related to the major soil issues.

- **Reducing costs** and minimising the intensity of sampling and site numbers can still be achieved through the use of geostatistical analysis.

- **The methods for selecting sites**. The most widely considered are a regular net such as a grid, a geostatistical approach, an expert judgement, a combined method of the first two approaches or a co-location with other monitoring networks.

Most existing SMNs fall within two categories: many sites monitoring few parameters, or fewer sites monitoring more parameters. An early decision was that the SMN should be designed to consist of a restricted number of carefully chosen sites (as opposed to a large number of sites with relatively basic monitoring programmes). The potential which lies in a system of relatively few benchmarks sites with comprehensive monitoring programmes adopted to the actual and emerging environmental soil-related issues should be considered further. Thus, SoilNet could best be set up by establishing reference sites in each country, which would act as control sites in linking national networks across member countries and, where possible, be co-located with or adapted from existing soil monitoring sites, and benefit from historical records and local expertise. These reference sites would be run to harmonised protocols common to all member countries, and would act as the validation sites for future SMNs within member countries. They would further save costs by integration with other networks, enabling monitoring at soil and at boundaries of other environmental compartments.

2.2.2. Integration with other relevant environmental issues

Work developed by other ETCs, with specific reference to monitoring activities, has been reviewed, with the objective of identifying those with the most compatible approach and subject area for future cooperation and integration. This will enable maximum exchange of relevant information and provide a mechanism for extrapolating data to unmonitored areas.

Inland waters*:* Freshwater monitoring, developed by the ETC/IW, is based on existing national and international networks as far as possible, with new sites being established if necessary. EuroWaterNet (EWN) discriminates between statutory and surveillance monitoring, with most statutory monitoring carried out as specified by particular national or international policies, and controlled by individual countries. Surveillance monitoring distinguishes between five types of sites:

- Reference sites: undisturbed water (rivers/lakes/groundwater).
- Baseline or benchmark sites: general characterisation of region or system, to generate data suitable for extrapolation to similar unmonitored systems.

- Representative or Index sites: subset of sites used to provide summary estimates of regional or national pictures. Most are selected from long-term monitoring projects, to have maximum historical data.
- Impact sites: record and characterise particular aspects of human impacts.
- Flux sites: sites where rivers cross international boundaries or merge with another water body (lake, sea, aquifer).

The EWN appears to be one of the most comprehensive monitoring systems using a stratified random sampling approach, and is one of the most relevant to soil issues. There may be considerable benefits to be gained from integration of the soil and water monitoring systems. The concept of different types of sites could be adapted for soil (with the exception of flux sites). Similar or nearby locations could be used as reference and impact sites, although additional locations will probably be needed for soil issues which are not covered in the water network. Soil monitoring sites can be linked to catchments (watersheds) according to the water framework directive since they are geo-referenced (geographical catchments are available). The link with EWN sites provides synergism by gathering information on the total and suspended solid loads in rivers on the one hand and contents of mobile elements in the soil. If these catchments may be chosen according to specific human activities — the ETC/W collects data on pressures at the catchment area level — this will aid to explore pressure/state/impact relationships.

Land cover and remote sensing (RS) data: The Corine land cover database, developed and maintained by the ETC/LC, constitutes a useful source of basic information, especially in consideration of the current lack of geo-referenced data on actual land use and the extension of urban areas. However, the low resolution of the database (25 ha) — which do not allow, for example, the identification of the portion of land covered by infrastructures, the period of time since the data have been collected (around a decade) and the lack of time series — makes this database less suitable as a source of major soil information. On the other hand, RS data holds a big potential for relevant data on soil, which still needs to be explored (e.g. the employment of RS data and techniques to assess actual soil erosion, desertification, the effects of climate change on soil and vegetation, etc.).

Air quality: The data from national networks is exchanged under an EC agreement and held in the Airbase, maintained by the ETC/AQ. In addition, the ETC/AQ is setting up EuroAirNet, which will select urban and background sites from the existing national networks. There are 35 parameters in the Airbase system. Additional parameters on measuring stations and networks are also included. This is a comprehensive monitoring system that will be able to provide a useful source of data to compare with deposition patterns in specific regions.

Air emissions*:* Air emissions are monitored using an inventory-based system. No monitoring stations are being established to estimate soil emissions (N_2O, CH_3, CO_2, NO_x, etc.). Emissions will be available at NUTS 3 level, an EEA project on integrated emissions inventories that has started, but does not contain emission to soil at this stage. Nevertheless, the information on monitored air emission data will provide a useful source to estimate a rough calculation on deposition rates affecting soil properties.

Nature conservation: The monitoring system is in the process of being drawn up, and few details are available. The scheme will be based on habitat classifications in Natura 2000, with sites chosen from existing monitoring stations. No links with the work on soil have been established so far, although this would be necessary in relation to inter-linked relevant issues such as changes in biodiversity (including soil biodiversity) and landscapes.

Marine and coastal environment: Information and data relevant for the assessment of the status and trend of the marine and coastal environment comprise a very large range of parameters in different fields. The ETC/MCE promotes the compilation of a quality-assured set of marine and coastal data on water, sediments and biological quality. A wide set of environmental parameters (chemical, biological and physical) to be used for the production of Europe-wide maps for eutrophication, oil spills and harmful substances have been collected under the 1998/99 subventions of the ETC. These data could be linked with soil data from monitoring sites and local contaminated sites near the coast line for assessment of pollution processes.

Waste: Data on hazardous waste will be collected by the ETC/W from the member countries, while data on municipal waste are based on already collected data from Eurostat/OECD. These data will be included in WasteBase which is currently under development. Furthermore, data and information on waste-management facilities, waste minimisation and so on will be gathered. For soil issues, in particular contaminated sites, basic entities like waste sources, quantities or treatment facilities are of interest.

2.2.3. Site stratification

In view of the likely financial restraints on site numbers and the correspondingly increased importance of selecting representative sites to monitor, we propose that a grid system will not be used to locate sites for SoilNet, but selection should be based on the concept of soil regions, which integrates soil type, geology and climate. This hierarchical system further breaks down soil regions into soil scapes and soil bodies. Soils can be categorised under many diverse land uses throughout the EU (e.g. agricultural soils, forest soils, contaminated sites, etc.). Furthermore, soil regions can be combined with watersheds (e.g. big river basins) according to the EuroWaterNet, depending on their homogeneity of soil types and land use.

EuroWaterNet seems the most appropriate for integration. Nevertheless, links with other ETC work should still be developed and maintained, and the status of each soil site within other ETC classification systems should be identified.

Consequently, a site stratification system for the future EuroSoilNet was designed to establish a clear site hierarchy, and to maximise the potential for integration with EuroWaterNet.

Three site categories were identified:

- **Key national sites:** reference sites in each country to coordinate national monitoring.
- **Benchmark sites:** general monitoring, divided into groups and sub-groups for stratified sampling (e.g. according to land-use, soil type).
- **Specialist sites:** additional sites to monitor particular local or regional issues as required.

Key sites will be the national reference sites within each country. Benchmark sites will be set up gradually, following or adapting to the model of the key sites. Additional specialist sites will be identified on an ad hoc basis, as they become necessary.
This will enable maximum exchange of relevant information and provide a mechanism for extrapolating data to unmonitored areas.

It is then a relatively simple matter to identify which EuroWaterNet sites fall within which soil region, and could thus be candidates for co-location of ESN sites with groundwater monitoring sites in particular, depending on overlapping of the used site selection strategies. Although it is recommended that key sites be co-located with or adapted from existing national SMN sites, the belief is that such existing co-location is likely to be rare, because of the variability of the density of existing networks.

This is compounded by the relative paucity of such networks in many member countries. Thus, we believe that, in most member countries, key sites (as an absolute minimum) will have to be set up from scratch.

This approach will ensure that a representative proportion of European soils is sampled, and creates a route for extrapolation of trends to unmonitored areas. The stratification will help to analyse monitoring results in a meaningful way; cutting down on total variation by dividing the soil population into (relatively) comparable groups and sub-groups. This is the simplest way of making the results easy and accessible to the main end users (European, international and national institutions).

2.2.4. Site design

Most SMNs use discrete areas rather than catchments, and sample soils based on depth increments or pedogenic horizons (or both). Time steps range between 3 and 20 years. Sampling is generally carried out using paired stratified samples, with varying use of composite or individual spatial sample points, the most common system being a grid of sampling points.

In order to minimise the inevitable effects of soil heterogeneity, SMN sites will need to be discrete areas, the spatial variability of which will have to be determined by an acceptable statistical process. This is essential in order to ensure that apparent changes in properties are not simply due to inherent site variation. We recommend that sampling is based on both fixed depth increments, and on pedogenic horizons.

To ascertain the current status and properties of soils as well as future changes, the aim of a SMN is to monitor each parameter over a period of time (not necessarily defined) in order to measure changes and identify trends. However, the parameters can be expected to change at different rates, some of which may be almost imperceptible. Some soil problems are static and accumulative (e.g. build up of metals in soil) others mobile (soil erosion). It will therefore be necessary to design a schedule according to different levels of monitoring like the two levels on forest soil conditions defined in the ICP forest programme (see below).

Level I: As a large-scale survey of primary parameters (minimum parameters), which have to be measured on every site repeatedly, like pH, organic carbon or total nitrogen.

Level lI: Intensive monitoring of permanent plots, which have to be representative for their special region. Additional to the parameters measured under level I, there are several more, like CEC, exchangeable cations or exchangeable acidity.

The establishment of a third level is under discussion, implementing forest ecosystem analysis with special regards to the impacts of air pollution.

As a result of these considerations three basic sets of parameters to be used within the ESN have been established (a description of parameter sets are in Appendix 2)

- **Minimum data set (MDS)**: parameters to be monitored at all sites (possible exception of some specialist sites). At key national sites, additional analytical methods on the minimum parameters have to be carried out simultaneously to ensure the comparability of the measured data set.
- **Regional data set**: parameters to be monitored at some sites in addition to MDS, according to local or regional concerns (specialist sites, some benchmark sites).
- **Non-site parameters**: information to be collected from non-site sources, e.g. centrally held census data, remote sensing data (if necessary).

Comparing the sets presented here with existing SMNs reveals that although most SMNs include a common set of basic parameters (particle size analysis, total organic carbon, pH, chemical parameters such as CEC and exchangeable cations, and major nutrients), many of the detailed parameters are only measured in a smaller proportion of sites, if at all. Areas which are particularly under-represented include measurements relating to biological and microbiological attributes, soil organic matter dynamics, and soil solution chemistry. This poses problems for the integration of existing sites into the network, as these are emerging areas of increasing interest to the scientific community. The lack of solute chemistry may be partially addressed by a successful integration of SMN sites with ETC/inland waters monitoring sites.

Appendix 3: Sets of parameters to be measured by EuroSoilNet

Table 3.1: EuroSoilNet minimum data set parameters

Family	Parameters
Site characteristics	• Elevation • Slope • Meteorological data
Soil type	• Classification • Soil profile
Nutrients	Macro-nutrients (total and available)
Organic carbon	Total
Soil chemistry	• PH • CEC, exchangeable cations
Soil structure	Bulk density
Soil biology	Key species (earthworms)
Contamination	Selected heavy metals, e.g. Pb

Table 3.2. EuroSoilNet regional data set parameters

Family	Parameters
Desertification	• Rain aggressiveness • Evapotranspiration • Vegetation cover & biomass • Specific key species
Acidification	• Acid deposition (wet and dry) • Mobile Al • PH • Soil water chemistry • Specific key species
Salinisation	• Irrigation • Evapotranspiration • Saline and sodic development • Water retention • Conductivity
Eutrophication	• N deposition (wet and dry) • Available soil N • Soil water chemistry • Specific key species

Table 3.3: EuroSoilNet non-site indicators

Non-site indicators	
Indicator	Parameters
Contaminated land	Total area of contaminated sites
Greenfield development	• Total area of new greenfield development • Ratio of greenfield: brownfield development
Conservation	Total area protected under conservation agreements
General land use	Total areas under arable, grassland, forestry amenity, unmanaged, residential and industrial use

Appendix 4: List of relevant indicators on soil

The following table shows a first tentative list of soil indicators.

Issue/question	Indicator	Dimension	DPSIR	Indicator type	Soil degradation pattern	Short-term core indicators
Contributors to local soil contamination	Contribution of industrial sectors to local soil contamination	%	D	A	Local soil cont.	No
Contaminated sites management	Progress in identification of contaminated sites (a) potentially contaminated sites — already identified sites versus estimated total (b) Number of sites which pose a significant risk to human health and the environment and where remediation action is urgently needed — already identified sites versus estimated total	%	R	B	Local soil cont.	Yes
Implemented measures against local soil contamination	clean-up to multifunctional land and gw use clean-up to limited/restricted land and gw use	(Number)	R	A?	Local soil cont.	No
Supporting measures to remediation of local soil contamination	Overview of clean-up funding tools		R	A?	Local soil cont.	No
How much is spent on the remediation of local soil contamination?	Environmental expenditures at the national level on — site investigation — risk assessment — remediation measures	Euro	R	A?	Local soil cont.	No
Intensity of agriculture: ([1])			D	A	Not applicable	Yes
What is the degree of agricultural land use? To what extent does agricultural land use intensify during a specified time within a given country?[1]	Consumption of fertilisers per defined region (e.g. Member State) (and its increase)	t/ha	P	A	Soil erosion	No
	Average farm size per defined region (e.g. Member State) (and its increase)	ha	D/P	A	Soil erosion	No
	Average field sizes (and its increase)	ha	D/P	A	Soil erosion	No
	Average crop yield per area (and its increase)	t/ha	D/P	A	Soil erosion	No
	Average net profit per area	Eur/ha, yr	D	A	Soil erosion	No
	Number of grazing animals	no./ha	P	A	Soil erosion	No
To what extent is the **area** of member countries affected by soil erosion (both wind and water erosion)?	Short term: rough estimations by the countries ([2]): percentage of area affected to soil erosion per defined region (e.g. Member State)	%	S	A	Soil erosion	No
To what extent is the total **area** of Europe affected by soil erosion (both wind and water erosion)?	Depending on the progress of validation of the ISRIC Map	km^2	S	A	Soil erosion	No
What is the extent of **total soil loss** by soil erosion (water erosion)?	Short term: rough estimations ([3]) estimation of the total gross erosion of defined areas based on the sediment delivery ratio of selected rivers (in dependence of	t	S	A	Soil erosion	Yes

Issue/question	Indicator	Dimen-sion	DPSIR	Indicator type	Soil degradation pattern	Short-term core indicators
	the watershed area)					
What is the impact of soil erosion by water on other media?	Annual suspended sediment yields in selected rivers (cp state indicator)	$t/m^3/a$	I	A	Soil erosion	Yes
What is being done to remove off site damages by soil erosion?	Expenditures for removals of sediment deposits in built-up areas (traffic routes, houses)	Euro	I/R	A/B	Soil erosion	Yes
How much is spent on sustainable farming?	Local agricultural programmes to enforce sustainable farming management systems (incl. terminated set-aside of arable land)	Euro	R	A	Soil erosion/ diffuse contamin.	No
How much is spent on erosion prevention?	Expenditures for special soil erosion prevention programmes, forest fire protection	Euro	R	A	Soil erosion	No
What instruments are used within the countries to avoid soil erosion?	Development and implementation of action plans (advisory activities, incentives, participatory activities, awareness)		R	A	Soil erosion	No
To what extent is the erosion risk area of member countries protected from soil erosion (both wind and water erosion)?	Portion of actual erosion risk area under erosion control management (set-aside arable land, strip cropping, contour ploughing, crop changing, balanced grazing, reforested), on total area of actual erosion risk	%	R	A/B	Soil erosion	No
Development of human population ([4]):			D	A	Not applicable	No
What is the extent of human population (during a specified time within a given country)?	Total amount of human population	no.	D	A	Soil sealing	No
	Population growth rate	%	D	A	Soil sealing	No
	(Increase of) number of households	no.	D	A	Soil sealing	No
Urban expansion ([5])			P	A	Soil sealing	Yes
What is the state of urban expansion?	(Increase of) area covered by human settlements and traffic routes	%	P/S	A	Soil sealing	(Yes)
	Estimated sealed area (by area covered by human settlements and traffic routes) per inhabitant	ha/perso n	P/S	A/B	Soil sealing	(Yes)
	Classified regional settlement structures (presentation as circle diagrams): 1. areas with large conurbation 2. areas where conurbation is beginning to develop 3. rural areas	%	D	A	Soil sealing	No
What is the total amount of consumption of build-up material per Member State?	Total consumption of build-up material	t	P	A	Soil sealing	No
To what extent are soils of high quality/environmentally important soils affected by soil sealing? ([6])	Portion of high-quality and /or environmentally important soil sealed	%	S	A	Soil sealing	Yes
What are the effects of soil sealing on the environment? ([7])	Number of serious floods /landslides in recent years	(number)	I	A/B	Soil sealing/ Mass erosion	No
Does legal bases for the prevention of soil sealing exist?	Existing directives to minimise soil sealing		R	A	Soil sealing	No
To which extent shall soil sealing continue in the future?	Local activities in defining targets for future soil sealing rates (increase of area covered by human settlements and traffic routes)	%	R	A/B	Soil sealing	No
How much sealed soil could be repaired? (Incl. changing the sealing material to	Local assessments of de-sealing potentials (portion of de-seable and	%	R	A	Soil sealing	No

Issue/question	Indicator	Dimen-sion	DPSIR	Indicator type	Soil degradation pattern	Short-term core indicators
permeable materials)	changeable surface areas (increase of permeability) on the total area covered by human settlements and traffic routes)					
Tourism ([8])						
What is the extent of tourism in environmental sensitive areas	Overnight lodgings in selected areas (highly attractive for tourism)	No	D/P	A	Not applicable	No
Development of infrastructure in areas highly attractive for tourism	Area covered by human settlements and traffic routes in selected areas (highly attractive for tourism)	No	P	A	Soil sealing	No
Development of infrastructure, traffic and transport	Length of traffic infrastructure	Km	D	A	Diffuse contamin.	No
	Motor vehicle licences	No	D	A	Diffuse contamin.	No
	Consumption of fuels	L	D	A	Diffuse contamin.	No
	Traffic frequency	No/day	D	A	Diffuse contamin.	No
	Emissions due to traffic issues	g/day	P	A	Diffuse contamin.	Yes
Influences on housing to the environment?	Sales on fuel oil and -gas for domestic use	l/year	D	A	Diffuse contamin.	No
To which extent are industry and waste management contributing to air pollution?	Emission records due to industrial, and waste burning activities	g/day	P	A	Diffuse contamin.	Yes
Intensive agriculture	Livestock	No	P	A	Diffuse contamin.	No
How much and in which quality is sewage sludge used in agriculture?	Consumption of sewage sludge in the different qualities	T	P	A	Diffuse contamin.	No
Amounts of pesticides used in agriculture?	Amount of pesticide applications	Kg	P	A	Diffuse contamin.	No
Estimating the buffering capacity of the soils per defined region (e.g. member countries)	Base saturation	%	S	A	Diffuse contamin.	No
To which extent does soil acidification occur?	pH CaCl2 distribution < 3 3–5 5–7 > 7	%	S	A	Diffuse contamin.	No
To which extent does soil eutrophication occur?	C/N and C/P relationship	—	S	A	Diffuse contamin.	No
How many sites show trace element contents over nationally used thresholds? (Geogenic or anthropological enrichment)	Exceedance of thresholds of heavy metal contents in soils (e.g. Pb)	No	S	A	Diffuse contamin.	No
Changes in nutrient supply	Makro- and micronutrients in plants, soils and soil water	mg/kg	S	A	Diffuse contamin.	No
Changes in biodiversity	Changes in occurrence of specific key species in soils	%	I	A	Diffuse contamin.	No
Changes in forest health	Assessment of crown conditions	%	I	A	Diffuse contamin.	No
What is done to reduce emissions?	Statutory regulations on emission standards		R	B	Diffuse contamin	No
How much on support is spent for ‘organic farming”	Environmental expenditures on national level	Euro	R	A	Diffuse contamin	No

Notes:

(1) Complex indicator: The intensification of agriculture of cost-effective but unsustainable land-use practices, the use of machinery for the cultivation of enlarged fields, the overgrazing and other instruments of intensive land use practices could be seen as the main driving forces and corresponding pressures on soil that cause erosion in regions with potential and actual soil erosion risks. Average field sizes (and increase of field sizes), combined with average farm size per region as well as the consumption of fertilisers and the number of grazing animals, gives an indication of the intensification of agriculture. The main message is: the higher the degree of intensity of agricultural land use the higher the risk of soil loss by water and wind erosion in potentially high-erosion risk areas.

(2) Soil erosion state indicators should be able to provide a picture of the extent and the severity of the potential soil erosion risk (taking into account climatic topographic and soil conditions) and of the actual soil erosion risk (taking into account also the vegetation cover respectively the actual land use). They should also provide information on the rate of the actual soil loss (under the existing soil management and erosion control practices) and on the rate of soil loss tolerance.
The comparison of the potential with actual soil erosion risk could be considered as an indicator for risks in land use changes. The comparison of the rates of soil erosion with the soil loss tolerance would provide estimates of the impacts and the required response.
The assessments of the state of soil erosion should be scientifically sound and provide quantitative (if possible, otherwise qualitative) regionalised georeferenced estimates of soil erosion risks of both potential and actual erosion risk, based on the methodology of the 'universal soil loss equation' (USLE) or preferably on recent regional quantitative models, where available and applicable.
On a medium time scale (approximately two years) soil erosion maps could be prepared on the basis of the 'Soil Geographical database of Europe' (soil data), the 'Soil regions of Europe' map (topographic data), land cover data (Corine) or better recent remote sensing images and climatic data.
The State Indicators should be presented as 'circle diagrams' for each considered region (e.g. Member State).

(3) In order to get some short-term estimates about the soil erosion problem, the gross erosion in defined watersheds of selected rivers could be estimated from the 'sediment delivery ratio', if needed data (watershed size and sediment concentrations respectively annual suspended sediment yields (t/m^3/a) are available.

(4) Complex indicator: The major causes for soil sealing could be seen in urban expansion driven mainly by increasing human population. The main message is: the higher the development of human population the higher the pressures from urban expansion.

(5) Urban expansion could be described by the total area covered by human settlements and traffic routes per Member State, perhaps related to the total amount of inhabitants of the Member State. If detailed information is available, classified regional settlement structures may be good indicators for the state of urban expansion:
Class description
Areas with large conurbation: regions with a regional centre of at least 300 000 inhabitants and/or a population density exceeding 300 people/km^2.
Areas where conurbations are beginning to develop: population density on average above 150 people/km^2 and as a general rule a regional centre of at least 100 000 inhabitants.
Rural areas: districts and autonomous cities with a joint population density of less than 150 people/km^2.

(6) May not be feasible in a short-term approach, but should be taken into account for a long-term approach.

(7) Soil sealing has effects on other media, e.g. natural hazards and the environment in general. For the short-term approach, it might be feasible to evaluate the number of serious floods in recent years. For longer term estimations of losses in biomass, the increase of surface run-off, changes in albedo and in land–atmosphere interactions and changes in microclimate should be taken into account.

(8) The 'tourism' sector could be seen as a further important driving force causing pressures on soil resources. Tourism has direct impacts in both soil sealing and soil erosion. Indicators should be included into the short-term approach, if feasible. (Examples for soil erosion: pressure: outdoor sport activities (winter sports as well as summer sports activities); state: soil loss by soil erosion; impact: increase of land vulnerability against natural events; response: any activities in directing tourism to 'soften' (= environment friendly) tourism).

Appendix 5: European policy, legislation and agreements on soil

One of the early tasks of the ETC/S was to undertake a review of national and EU policy, legislation and agreements on soil quality and pollution, involving a compilation and review of all relevant national and EU legislation relation to soil quality, degradation and pollution covering the EEA 18 members countries and Switzerland. The present report includes information on EU legislation and policy from the various DGs of the European Commission and JRC as well as data from EEA member countries and published reports. Comparable information at a national level was based on questionnaires that were distributed to national reference centres. Fifteen countries completed and returned the questionnaires, two others sent relevant published material.

The information on soil obtained at country level indicates widely different types of administration across the EEA member countries. Thus, Ireland, for example, has one central government responsible for all laws. In Germany, on the other hand, the federal government has law-making powers and, below, this there is a second tier of 16 *Länder*, each with the power to make binding legislation on soils and the environment. Other countries have widely varying systems, some have variants of the above. Also, the soil aspects included can be very different, e.g. monitoring of dangerous substances such as heavy metals and PCPs is important in some countries while in others, erosion is monitored as a major soil problem.

The information collected in the present study covers large variations in density and content, but the overall picture indicates that not much of the legislation is related to the soil medium directly; in many cases, it relates directly to air or water (surface and ground water) and only indirectly to soil. Some of the legislation relates to other media or to health aspects and considers soil properties indirectly via ecological functions or human activity-related functions of the soils, e.g. biomass production, filtering water and as a source of raw material. This is also reflected in the content of this report.

Policy, legislation, and agreements included at the European level which relate directly or indirectly to soil are also discussed in the report. These include the nitrate directive which restricts the concentration of nitrate in groundwater and places a limit on the amount of organic and inorganic nitrogen fertilisers that can be applied to soil. The sewage sludge directive sets out to regulate the use of sewage sludge in agriculture in such a way as to prevent harmful effects on soil, vegetation, animals and man. The habitats directive, the fifth environmental action programme, the groundwater directive, the dangerous substances directive, and the waste directive includes some soil aspects.

On the basis of the questionnaires answered by the national experts of the EEA and Switzerland, the major conclusions at a national level are summarised in the following and in Table 5.1.:

- Many States use soil-monitoring networks to record the soil condition, particularly with regard to heavy metals and organic matter. Special national aspects may be reflected in the choice of other monitored parameters. Half of the systems reviewed were statutory.

- In all countries, the soil is protected indirectly by application of the nitrate directive and directly through the sewage sludge directive which controls the spreading of dangerous substances in all EEA countries. Both of these are examples of the land conservation acts. Many countries also make recommendations for biocide levels in soils.
- In most countries, the industrial discharge to air and water is rigidly controlled by statutes and these indirectly relate to the soil medium. Only in Finland, Ireland, and United Kingdom is the handling of industrial discharge included in the planning process.
- In most countries, the planning process controls non-agricultural uses of land. The control may be part of the regional planning, conservation of nature, infrastructure demands, or other regulations. Except the Netherlands, and to some extent also Sweden, the statutory control of uses of land are common in all countries.
- Many countries encourage organic farming by financial incentives through policy measures.
- Greater use of economic instruments such as environmental taxes has been recommended and have been increasingly implemented at country level, particularly in Scandinavia, Austria, Belgium, France, Germany, the Netherlands and UK.
- All countries have water acts to protect groundwater and to institute monitoring programmes for control purposes. This is clearly set out in the nitrate directive which applies to all countries as mentioned above.
- Some countries have restrictions on land use for protection against erosion and subsidence. Erosion may be encouraged by the planting of trees and grass (e.g. Austria, France and Iceland) whereas subsidence is restricted, for example, to mining areas (France).

On the basis of the information obtained at EU and country levels, it is obvious that only few initiatives directly related to soil have been implemented at present. However, the soil media seems increasingly kept in focus when environmental recommendations are given. National monitoring programmes, already implemented in some countries are under consideration in many more countries. In many cases, the monitoring systems were designed to suit different research programmes or for soil management purposes. However, with some redesign, statutory soil monitoring systems may in future become the basic structure for a environmental monitoring and control programme.

Table 5.1: Summary of the form of legislation for different categories in each country

Country	Statutory soil monitoring	Land conservation acts	Spreading of dangerous substances	Industrial discharges and protection of soil	Control of non agricultural land use	Legislative encouragement for organic farming	Protection of soils by environmental taxation schemes	Soil monitoring for groundwater protection	Restriction of land use for protection against erosion and subsidence	Restrictions on land drainage
Austria	Not statutory	Direct	Direct	Direct	Statutory	Comprehensive	Tax incentive	Direct	Direct	Regional
Belgium	Setting up	Direct	Direct	Direct	Statutory	Encouraged	Tax incentive	Direct	Direct	No
Denmark	Statutory	Direct	Direct	Direct	Statutory	Encouraged	Minimal	Direct		Direct
Finland		Direct	Direct	Indirect	Statutory	Comprehensive	Minimal	Direct	Direct	Direct
France		Indirect	Indirect	Direct	Statutory	Encouraged	Tax Incentive	Direct	Direct	Regional/local
Germany	Not statutory	Direct	Direct	Direct	Statutory	Encouraged	Tax Incentive	Direct	Indirect	
Greece										
Iceland		Direct	Direct	Direct	Statutory	Encouraged	Quotas	Direct	Direct	
Ireland		Direct	Direct	Indirect	Statutory	Encouraged	Minimal	Direct		
Italy		Indirect	Direct	Indirect	Statutory	Encouraged	Minimal	Direct		No
Liechtenstein	Statutory	Direct	Direct	Direct	Statutory	Encouraged	Minimal	Direct	Direct	
Luxembourg		Direct	Direct	Direct	Statutory	Encouraged	Minimal	Direct	Direct	Direct
Netherlands		Direct	Direct	Direct	Minimal	Encouraged	Tax Incentive	Direct		Local/Municipal
Norway		Direct	Direct	Direct	Statutory	Comprehensive	Tax Incentive	Direct	Direct	Indirect
Portugal										
Spain	Statutory	Indirect	Direct	Indirect	Statutory	Encouraged	Tax Relief	Direct	Indirect	Direct
Sweden		Direct	Direct	Direct	Statutory	Encouraged	Tax Incentive	Direct		Direct
Switzerland	Statutory	Direct	Direct	Direct	Statutory	Encouraged	Minimal	Direct		
UK			Direct	Indirect	Local	Encouraged	Tax Incentive	Direct	Indirect	