

Soil Information: Uses and Needs in Europe

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Introduction

There is now abundant evidence of the need for soil surveys, monitoring and information systems to meet the demands for information at all scales. In the early years the use of the information was mainly national and regional but in recent years this has expanded to be increasingly continental (Europe-wide) and global. Information about the soil resources of Europe and its contribution to such issues as food production for an ever-growing population, biodiversity, urban and rural infrastructures, are now required at all of the following levels:



Global Requirements

There has been an exponential increase in the need for soil information at a global level. Much of this can be attributed to the creation of the World Commission on Environment and Development in 1983, at the request of the United Nations. This was followed by the publication of *Our Common Future* (Bruntland, 1987) and the the United Nations Conference on Environment and Development, known as the Earth Summit. Important outcomes of these initiatives were Agenda 21, the Climate Change Convention and the Biodiversity Convention.

The need to make changes on a global scale and to develop long-term environmental strategies for sustainable development by the year 2000 has been added to the agenda of most nations.

As a result most of the EU and EFTA countries have prepared strategies for sustainable development that have included soils. Governments that have signed up to the UN protocols have been expected to take more account of soils because of concerns expressed by the Earth Summit.

Subsequently, a number of initiatives at a global scale have been undertaken with the United Nations as the driving force. These include:

1. Earth Summit and Agenda 21;
2. World Soil Charter;
3. FAO-UNESCO Soil Map of the World at 1:5,000,000 scale, already prepared by the time of the Earth Summit;
4. Global Assessment of Soil Degradation (GLASOD);
5. UN Convention to Combat Desertification (UNCCD);
6. UN Framework Convention on Climate Change (UNFCCC);
7. UN Framework on Biodiversity.

All of these initiatives require soil information. The UNFCCC is an interesting example of a global scale project involving the need for information about soil properties on a national basis and requiring such information rapidly. Countries signing up to the Convention are obliged to prepare budgets of greenhouse gas emissions, including those involving soils, and to estimate the principal sources and sinks of terrestrial carbon.

It is known that soils are a significant source of carbon, and hold three times as much as the above-ground vegetation. This is an important statistic because this carbon can contribute to greenhouse gases depending on land use. In the UK, for example, the area of land emitting carbon is far larger than that being afforested.

Globally, as part of the need to estimate the terrestrial sources and sinks, it is important to know what is happening to the reserves of soil

organic carbon. Some countries were able to obtain this information from their Soil Information Systems (Cannell *et al.*, 1999) in responding to UNCCD.

Because several EU and EFTA countries lack national soil databases, they are unable to meet fully the requirements of the Convention. Only those countries with a spatial soil database at 1:250,000 scale or larger, supported by a good quality soil profile and analytical data, are able to respond adequately.

Global, continental and national requirements for soil information are increasing because of the interest in sustainable development, food security, retention of biodiversity and preservation of an environment that is not being degraded.

European Needs

Part of the role of the European Union is to protect its natural resources by bringing in *directives* to ensure sustainable development. Unlike the global scene in which there is no single body able to set policies, the European Union does have a mandate to protect its natural resources.

Protection of the Environment

In 1991, the environment ministers of all the European countries created a new theme *Environment for Europe* aimed at promoting and coordinating policies for environmental protection throughout Europe. An Environmental Programme for Europe was formally adopted in 1995. As a result of these initiatives, a pan-European State of the Environment (Dobris Report) was published (EEA, 1995) and this was followed by a second report (EEA, 1998), which assessed the changes that have taken place with respect to 12 prominent European environmental problems. Now with the European Environment Agency (EEA) operational, supported by a burgeoning interest in protection of the environment, the need for soil information to support its mandate is clearly established.

Directives Relating to Soils

During the last decade in parallel with these developments, the European Commission has produced a number of Directives aimed at protecting the European environment. These include:

1. EC Nitrate Directive (91/676/EEC);
2. Directive on Environmental Assessment (85/337/EEC);

3. Sewage Sludge in Agriculture Directive (86/278/EEC);
4. Habitats and Species Directive (92/43/EEC);
5. Directive on Integrated Pollution Prevention and Control (96/61/EC);
6. Framework Directive on Waste (75/442/EEC; Amended 91/156/EEC).

Implementation of all these requires detailed information about the soil. A good example is nitrate leaching to surface and ground waters on which the EU moved quickly to issue a Directive after swift recognition of a widespread problem.

The aim of the Nitrate Directive is to reduce 'water pollution caused by nitrates from agricultural sources' through the designation of Nitrate Vulnerable Zones (NVZs). The delimitation of the NVZs depended greatly on detailed spatial information about soil properties such as texture, organic matter content, structure, porosity and depth.

Using the appropriate soil data combined with simple models it has been possible to delineate Nitrate Vulnerable soils on maps of Belgium (Dudal and Deckers, 1999), Denmark (Greve and Madsen, 1999), Ireland (Lee and Coulter, 1999), Germany (Eckelmann and Hartwich, 1996) and the UK (Bullock, 1991).

Soil Protection Policy

There have been a number of other developments that point to the need to ensure an ongoing, improving Europe-wide database for soils. In 1992, the Committee of Ministers of the Council of Europe recommended that Member States develop a Soil Protection Policy that included the following:

1. Framing of the Policy
2. Survey of the current state of degradation
3. Inclusion of soils in environmental assessments

Associated with this there have been two major initiatives:

1. The Tutzing Project, *Preserving Soils For Life*. This is a proposal for a Convention on the Sustainable Use of Soils brought about by the fact that there are considerable efforts world-wide to protect air, water and biota but none specifically on soil, and soil is inadequately addressed by these other measures.
2. The Bonn Memorandum on Soil Protection Policies in Europe (1998), the objective of which is to establish a Soil Forum to review the current status of soil protection policies in

Europe and the challenges of implementation in the EU.

Trans-boundary Initiatives

Since the phenomenon of acid rain became headline news in the 1970s, increasing attention has been paid to the trans-boundary effects of pollution. Initially, interest focussed on Western and Northern Europe with, in particular, Sweden seeking to establish the intra-country and extra-country origins and effects of acid rain.

These initiatives led to major research programmes being established focussing on the soil as a receptor of acid rain and a medium capable of both being affected by it and also modifying its impact. It led to monitoring programmes being established to determine the impacts of trans-boundary pollution on soil and its ability to support a particular land use.

The scale of interest in trans-boundary movement of pollutants has extended to most of Europe and beyond, leading to the UNECE Convention on Long-Range Trans-Boundary Air Pollution. There are now major concerns not only for this but also for a range of potential pollutants resulting from over-fertilisation of ecological habitats. There are now several research and monitoring programmes Europe-wide aimed at understanding the scale and implications of such migrations. These in turn depend on a well developed understanding of soil properties and processes.

There was intense interest in trans-boundary migrations of pollutants following the Chernobyl Nuclear Accident in 1986. This resulted in deposition of varying amounts of caesium-137 across large areas of Europe. Some soil types, particularly those with large organic matter contents, eg. peaty soils, absorbed the caesium-137 and have released it slowly into the food-chain every year following the actual deposition. Soil type has been shown to be an important factor and soil maps have proved invaluable in predicting where the risk of contamination of the food supply is most likely to occur.

Currently, there are also trans-boundary initiatives being established which are strategic rather than responsive to existing problems. An example of this is the trans-frontier Algarve-Andalucia project which was part of the CORINE programme. One of the major benefits of EU research projects, such as those of Frameworks IV and V, is the liaison they create between research workers in the countries of the European Union and as such encourage cross-boundary collaborative research. It is unfortunate that soil does not feature overtly

as a key topic in the recent EU Framework V Research Programme.

Information at European Level

All these initiatives depend for their success to a greater or lesser extent on the availability of soil information. Since its inception, the European Soil Bureau has seen the demand for harmonised soil information escalate across Europe. The necessity to deal with such issues as soil protection, crop suitability, land management, waste disposal, pollutant transfer, soil degradation, geotechnical issues and environmental disasters in the future will place increasing demands on the European Soil Bureau to provide Europe-wide soil information.

Therefore, it is of paramount importance for member countries of the EU to strengthen the Bureau as well as augment their soil databases to deal with these issues and support the Europe-wide initiatives of the Bureau, the European Environment Agency and the various Directorates General of the European Commission.

The EU and EFTA countries will need to assess whether they have an adequate information base on soil resources to support effective soil protection policies and strategies to reverse undesirable trends in the environment in general. The evidence presented here reveals that there are very few countries with adequate detailed data to address these issues.

There was a good response from all over Europe to the requests for help in producing the 1:1,000,000 scale soil map and database. However, the minimum in a spatial terms for supporting present and future requirements would be a 1:250,000 scale georeferenced soil database for the whole of the EU and neighbouring countries. The European Soil Bureau is already actively involved with experts from the Member States in creating a framework for such a database (ESB 1998). It now needs the full support of the European Commission to undertake the guiding role in this demanding project.

National Needs

The fact that the environment is now such a topical issue, and one that has captured the public interest, has put pressure on national governments to respond to soil-related matters. Over the last few decades, Soil Survey organisations, through mapping and management of soil information, have responded in the best way possible to a wide range of demands.

The following sections summarise many of the issues that have been tackled.

Land Degradation

It is generally accepted that land degradation is one of the major threats to sustainable development. In the recent European Environment Agency Report *'Europe's Environment: The Second Assessment'* (EEA, 1998), land degradation was identified as one of the key problems in the environment in Europe and one for which there has been continuing decline in the last five years. It can take several forms including:

1. Soil erosion and desertification;
2. Salinisation/alkalisation;
3. Contamination;
4. Loss of biodiversity;
5. Loss of land to urbanisation.

Soil Erosion and Desertification.

The problems of soil erosion and desertification have been known for decades, if not centuries, and although attempts to remedy the problem have been made, significant improvements have only been on a local scale and the overall problem has increased rather than decreased. In 1987 a motion for a resolution was put to the European Parliament on erosion of agricultural soils (European Parliament, 1987). Estimates for erosion given then included '5 million hectares of land subject to erosion in France, 600,000 hectares in Belgium and 37% of agricultural land in the UK'.

The situation in the Mediterranean region is much more severe with, according to CORINE programme (1992), about two-thirds of the rural area having a moderate to high potential risk of erosion. Most European countries are affected; water erosion in Europe is estimated to affect 115 million ha or 12% of the total European land area, and wind erosion 42 million ha or 4% of the land (Oldeman *et al.*, 1991; EEA, 1998).

Most of the national Soil Surveys have been involved in erosion monitoring, prediction and control. Iceland has an ongoing erosion survey in which the extent and severity of soil erosion has been mapped at 1:100,000 scale. Here the problem is large, with >50% of the country having considerable to severe erosion (Arnalds, 1999). The most severely affected areas are now being mapped at a scale of 1:5,000 to 1:25,000.

In the Nordic countries erosion is generally less severe but is increasing mainly as a result of unsustainable agricultural and forestry practices. In Norway the Universal Soil Loss Equation (USLE)

has been modified for Norwegian conditions and soil erosion risk maps prepared (Arnoldussen, 1999). These identify target areas in which agricultural practice needs to change.

In Western and Central Europe the increase in erosion is also attributable to unsustainable agricultural practices. Both France and Germany have mapping programmes to identify soil erosion probability. Generally the scale of erosion in the Nordic countries, western and central Europe is localised and the situation retrievable given a level of intent, which is lacking at present. The same cannot be said of Iceland and certainly not of the Mediterranean countries where the situation is already severe and difficult to rectify.

Erosion is a major problem in Mediterranean countries and already large areas have been so severely damaged that they are no longer capable of supporting arable agriculture. This is leading to depopulation of the land. Much of the Mediterranean zone of Europe is now threatened by desertification, as defined by the United Nations Convention on Combatting Desertification (UNCCD, 1997). All of the Mediterranean countries of the European Union have assembled information about the scale of soil erosion and desertification within their national territories and much is now known about the causes.

The information assembled by soil survey and other research organisations and that obtained through the CORINE and MEDALUS programmes, sponsored by the European Union, form an important base from which to build a strategy to deal with the problem.

The UNCCD has an important role in seeking improvements in the situation. The recent formation of a Soil Erosion Risk Working Group by the European Soil Bureau also should lead to a much needed coordination of effort in risk assessment and provide a methodology for a Pan-European approach. However, at the present time the problem remains, intensifies and as the European Environment Agency has advised, is becoming ever more serious.

Contamination.

Like soil erosion and desertification, contamination of soils has also been identified by the European Environment Agency as an area where improvements to the problem are slow (EEA, 1998). It has proved to be a difficult aspect of land degradation to remedy. Much of the contamination is to be found in western and central Europe, where it is often a residue of the industrial era of the 1800s and 1900s.

There is no detailed map of the locations of all contaminated sites but it is estimated that there are over 300,000 contaminated sites in western Europe alone (EEA, 1998). The problem is a serious one in view of the real risk to human health, ecosystems and water resources.

There are several types of contamination that need to be considered. The most common and the most difficult to deal with is that associated with present and former industrial sites, many of which may date back over 100 years, and military sites that are more recent and where access is often restricted.

There is a problem not only identifying the sites but also their region of influence. Here, the soil is again important, acting both as a source and sink for contaminants but also as the medium through which much of the migration of contaminants can take place when the conditions favour migration. The other method of contamination and pollution, now increasingly under scrutiny, is that of aerial migration both in wet and dry forms and deposition of the contaminants up to several hundreds of kilometres from the source.

Most soil surveys and monitoring organisations are contributing significantly to identification of contaminated and polluted sites. There have been a number of national monitoring programmes, such as those in Austria, Denmark, France, Finland, Germany, Ireland, Netherlands, Sweden and the UK, which have helped to identify contaminated sites and the nature of the contaminants. Several of the countries of the European Union are also undertaking periodic monitoring to establish trends in soil contaminants.

The main problems that remain include:

1. Identifying the spatial distribution of contaminated sites;
2. Identifying the source and nature of the contamination;
3. Understanding the source-sink properties of soils containing contaminants and how these change with time;
4. Deciding, given the above information, whether/how to decontaminate the soils to an acceptably safe level;
5. Finding a suitable method of decontamination.

Salinisation/Alkalisiation.

Concern about salinisation/alkalisiation of land has been voiced over several decades. Within the EU this form of degradation is mainly associated with the Mediterranean countries. Some 4 million hectares of land in the Mediterranean and Eastern

Europe are affected by salinisation (EEA, 1998). The increase in amounts of saline soils is due mainly to irrigation and a disregard for the principles of soil drainage. Other contributors to the problem are intrusions of sea water and evapotranspiration of saline soil moisture. Once the level of salinity is high, it is difficult and costly to remediate although in Greece land has been reclaimed on the basis of soil physical and chemical data provided from soil studies.

Loss of Biodiversity

At a time when there is a strong focus on biodiversity nationally and internationally, it is unfortunate that soil biodiversity is one of the most neglected areas of soil science. Despite the estimate that there are many thousands of organisms in a small teaspoon full of soil very little is known about the species present, the true numbers, the role that they play and the interactions between them and with the vegetation that the soil supports. Only broad, rather crude information exists about soil biodiversity despite the soil being such an important habitat for flora and fauna. In the view of André *et al.* (1994) soil biota are one of the last biotic frontiers.

There is evidence to suggest that land use can have large effects on the soil biota, but these effects are not clearly understood (Usher, 1996). There is also evidence that soil biodiversity is affected by human influences, for example through changing land use, atmospheric pollution, additions of certain heavy metals and by climate change. Another key area of interest is the influence that invasive or genetically modified organisms can have on the soil ecosystem.

Compared to many other areas of soil science, knowledge of soil biota and biodiversity is embryonic. The French and Dutch reports identify this as one of the most important areas for future research and one that is fundamental to the sustainable development of soil resources.

Urbanisation

The continuing development of urbanisation in most countries of the EU and EFTA poses a major threat to soils. Once covered by buildings, roads or other structures of the modern industrial state, the soil is incapable in most cases of being returned to agricultural use. Rates of loss of land in this way given in a recent EU Report (Montanarella, 1999) are: Netherlands 36 ha. per day, Germany 120 ha per day, Austria 35 ha per day and Switzerland 10 ha per day. In the UK over a ten year period about 1% of the land area is taken for urban development

(Best, 1981) and in France some 40,000 hectares are lost each year, equivalent to one French Department every 10 years (King *et al.*, 1999).

Clearly, difficult decisions have to be made about the use of land particularly when it is used for buildings, since in effect this can ultimately rob a nation of its ability to produce food and timber. At a minimum, good quality agricultural land, important potential areas for forestry production and important nature reserves should be safeguarded. The use of land capability classifications and land evaluations based on a sound knowledge of the quality of the soils should be an essential stage in reaching decisions about whether or not to take land out of these uses. Such information should be part of every country's land use strategy.

Soil Quality and Sustainability

The EEA Report 'Europe's Environment: The Second Assessment' (EEA, 1998), in-line with national reports on sustainable development, makes it clear that some current land use practices are unsustainable and, as a result, land degradation continues to increase.

Van Lynden (1994) identifies two principal approaches to controlling soil degradation:

1. identify the source of the problem and take steps to change the source so as to diminish or remove the problem;
2. aim to treat the adverse effects where they occur with a view to reducing the extent of the problem.

Some progress has been made towards addressing the problem through the DPSIR framework:

1. *D-Drivers*: the human impacts causing the problems and impacts;
2. *P-Pressures*: the level and source of the pressure;
3. *S-State*: the extent of the current problems, i.e. amount of soil erosion, contamination, etc.;
4. *I-Impacts*: the effect of the problem on creating further problems, eg. climate change;
5. *R-Responses*: policies that can be implemented to deal with the problem.

There is currently much attention being given to the identification of indicators also. These are a suite of key components that can be measured and act as indicators of change to the environment. Given the cost of regular measurement of an indicator, attempts have been made to keep the list a short one. Indicators for soils that are being

proposed include: acidity, organic matter content and heavy metals. There is interest in having at least one soil biological indicator also and attempts are being made to derive a simple measurement to represent the extremely important biological components in soils.

The main soil quality problems facing the countries of the European Union and former EFTA are declining organic matter levels under intensive agriculture, increasing soil erosion in all countries, acidification, particularly in northern, western and central Europe, nutrient overload with implications for air and water quality, salinisation, contamination with airborne pollutants, soil compaction and loss of soil biodiversity.

Soil Survey organisations and the information they have assembled have a vital role to play in combating these problems. All of the Country reports (see Section 2) refer to studies that have been undertaken to promote improved soil management in the quest for sustainable development. These range from analysis of the *impact of agrochemicals* on soil and water quality (most countries), influence of *acidity* on forests (several of the countries as part of the Forest Site Monitoring scheme; Sweden, in particular, has a large monitoring programme for acidity), *loss of organic matter* (mainly western and central European countries in which intensive agriculture has led to a decline in organic matter levels), *suitability of land for irrigation* (Greece, Portugal, Spain and Italy), *soil erosion* (all countries), *pollutants* and *contaminants* (most countries), and *tillage practices and compaction* (Germany, Switzerland and Italy).

Water Resources and Management

Soils have long been recognised as having an important hydrological function. They store enormous amounts of water, they mediate the flow of water from surface to depth and they have the capacity to change (ameliorate or pollute) the quality of water entering and leaving the soil. The way in which soils are classified takes into account factors such as drainage, depth to watertable, and thus soil maps can be used to establish some of the hydrological characteristics of soils locally and regionally.

The problem of soil salinity and salinisation is closely linked with soil properties, particularly salt content, drainage, and leaching versus capillary rise. In the past too little attention has been paid to recognising the importance of these properties leading to the extension of salinisation, which now

is a major problem in southern Europe. It is a good example of practices such as irrigation being applied without adequate knowledge of the regional soils and geology.

Much attention has been given in the last decade to the soil as a medium for the transfer of would be pollutants, be they excess nutrients, heavy metals or organic contaminants. The soil has come to be recognised as a key zone between the land surface and surface- and groundwater and as a conductor of would-be pollutants out of the soil system into water bodies. Much research has been undertaken to develop models to understand better this link and to identify the hydrological and chemical properties of soils that can influence the change in quality of migrating waters.

The Netherlands has taken the lead in linking the information obtained in soil surveys about soil drainage and depth to watertable with that of actual monitoring of surface and ground water. From the beginning Dutch soil maps included information about groundwater depth classes. This, and long-term monitoring of groundwater, represent an extensive information base by which the Dutch government has been able to identify areas where surface application of manure is not permitted.

Soil and groundwater table maps, together with physical and chemical soil data and pedotransfer functions, have been used in the development of N, P and H₂O fate models which form the basis for the Dutch present and future manure policy. These developments are a good example of the way in which soil survey information can be used to strengthen the basis for policy requirements.

The fact that this can be done effectively is due in large measure to the fact that the Netherlands has one of the most comprehensive soil information bases of any country in the European Union.

Waste Disposal to Land

Waste disposal to land has been a feature of the environment for many decades. During the industrialisation period in many countries, waste-containing contaminants and pollutants were added to the land particularly around urban areas. Sewage sludge and agricultural wastes, including manures, have been applied for decades, for example 'night soiling' on land around the principal cities and sewage sludge applied to areas of farmland.

Particularly in the years before treatment of the waste was deemed necessary, this was a source of

soil contamination and pollution. In recent years the application of waste to land has become more regulated but with the EU ban on disposal of sewage sludge to sea in 1998, the soil is now again seen as one of the major routes for disposal.

Increasing amounts of waste are being produced throughout Europe. Already the national Soil Survey organisations have been involved in predicting the suitability of soil for disposal of sewage sludge but the problem will grow and so will the pressures on the land to receive the waste. A detailed knowledge of the soils, their properties and the major processes occurring in them, will be essential in selecting the most appropriate soils for disposal of waste products.

Food Safety and Human Health

Food safety is, like that of the environment, becoming a major issue in EU and EFTA countries. Because the soil has a number of functions, including adsorption, filtering, leaching, flow control, storage and amelioration, it can act as a sink for contaminants and pollutants and at other times release them into the food chain or into groundwater. The operation of any of the particular soil functions depends on the state of the soil at the time.

Depending on pH conditions, contaminants can be 'locked up' in the soil matrix, where they can only affect the soil ecosystem, or they may become mobile and enter the food chain or find their way into watercourses. One example of this is aluminium (Al), which at pH 4.5 or above tends to be held in the soil, but which becomes mobile at pH below 4.5. At low pH (<4.5), Al can be taken up by various plants and passed directly into the human food chain (Blake *et al.*, 1994) or it can go into solution and end up in rivers and lakes.

This is one of the reasons acid rain, which can lead to increasing acidification of the soil, is a matter of major concern. A knowledge of the properties of soils, the processes operating in them, and their distribution in the landscape, is essential for the management of contaminants and would-be pollutants in the soil system with respect to food safety.

The soil can also act as a source and sink for germs and other microorganisms that carry a health risk. Pathogens in the soil can lead to tetanus and hookworm infestation. Deficiencies or toxic amounts of elements in the soil can also lead to ill health. Radon emissions from soils have been linked with some forms of cancer. The soil-health

area of research is still its infancy but there is evidence of growing interest (Oliver, 1997). In Section 2, the reports for France and the Netherlands list food safety as an important use for soil information.

Land Classification and Land Evaluation

One of the traditional uses of soil maps and associated databases has been to classify land according to its potential use and to evaluate the this potential for agriculture, forestry, ecological habitats, recreation and other non-industrial purposes. It facilitates decision making on the most appropriate use of land, be it a field, forest, region or national territory.

For many users, soil maps and related information are too complicated and the terminology too technical to be readily understood by the layman. But given the basic soil property information, it is relatively easy for a soil scientist/pedologist to convert the material into a capability class or evaluation that can be readily understood by non-specialists.

Initially, many of the EU and EFTA countries produced general purpose land capability classification (Klingebiel and Montgomery, 1961) maps. Thus the maps did not indicate capability for one specific use, they merely indicated the overall quality of land. These general-purpose maps were often used to protect the better quality of land for future agricultural production.

With improvements in soil databases, and their links to other data and the development of modelling, it became possible to evaluate the suitability of land for specific kinds of use. These may be the major kinds of land use such as wheat, grass production, coniferous forests or can be more specific in nature, eg. relating to the introduction of new crops, specific species of trees, different ecological habitats.

It is possible to produce land evaluations for a given region provided there is an adequate soil and climatic database, a knowledge of the particular requirements of land use and land management, simple or, if available, more complex models, and a land information system capable of integrating the different types of information and providing spatial distributions. Up to now, land suitability assessments have been the most common uses of soil information in strategic and advisory roles.

In both Ireland and the Netherlands, soil surveys have been used in regional planning and

development. The Netherlands is in a particularly strong position with respect to its database because it has a full cover of soil mapping at both 1:50,000 and 1: 250,000 scales. As van der Pouw and Finke (1999) state, 'there is hardly an environmental, nature conservation or rural planning project in the Netherlands beyond the point scale that does not use soil data in some way'.

Portugal has also used its soil maps and derived land capability maps in the enactment of a law to protect the best agricultural soils, creating the so-called National Agricultural Reserve (Reserva Agricola Nacional – RAN), and the important ecological reserves, soils being included as part of the National Ecological Reserve (Reserva Ecologica Nacional – REN) (Bessa, 1991).

In Germany, Ireland and Italy soil maps and associated information have been used to identify marginal land and less favoured areas, both of which require special dispensations (often with supporting subsidies) if they are to be used for agricultural production. In Austria, land has also been evaluated specifically for taxation purposes. The quality and natural productivity of Austrian soils have been assessed for every parcel of agricultural land. This useful database of soil information is also being used for other purposes such as soil reform, compensation needs and regional land use planning.

Agricultural Uses of Soil Surveys

Many countries in Europe saw the need to increase agricultural production, particularly after World War II, and this led to many of the Soil Survey organisations being established in the 1950s and 1960s. Indeed, it is not surprising that agriculture has always been a principal user of soil survey and associated information. Land suitability maps and models to increase agricultural output or to assess the potential for new crops to be grown, have been a vital support for the agricultural industry in most of EU and EFTA countries.

However, steps to increase agricultural production in the last few decades have not been without their problems. In seeking to take in new land for crop production, decision makers have made many mistakes as a result of either being unaware of the soil information available or choosing to ignore it.

There have been situations where land has been brought into cultivation without an adequate knowledge of soil properties and the result has been damage beyond repair.

One of the most striking examples of this is the use of potential acid sulphate soils. When kept under permanent grassland with a naturally high groundwater table, these soils cause no real problems. However, in a number of countries, e.g. Denmark, Finland and the UK, attempts were made to drain these soils in order to grow arable and horticultural crops. These measures quickly changed the soils from potential to actual acid sulphate soils. The pH of some soil layers fell below 3.5 rendering them of little value for arable and horticultural purposes and in addition under the acid conditions produced, significant quantities of iron were released into the drainage waters causing land drains to block up with iron ochre. The restoration of such soils would now be a major, costly undertaking so many of them remain in a degraded condition.

In some places, nutrient-rich organic soils are being used for arable and horticultural crops. Again, as in the case of acid sulphate soils, the drainage of such soils makes them vulnerable to structural damage. Losses of soil material through erosion and shrinkage can amount to 1 cm thickness of soil per year. For example, since drainage of the Fenlands in Eastern England, in the late 1700s, and their subsequent reclamation for growing arable crops, more than 85 per cent of the area of these fertile organic soils have been lost. After drainage the organic matter has merely oxidised and disappeared completely.

In future there may be a need to change to other forms of land use. The examples of the acid sulphate soils and the degradation of the Fenlands indicate how important it is to have a sound knowledge of soils and their properties, particularly when changing to new land uses. For ensuring sustainable development it is surely essential.

Intensification of agriculture has also come to be associated with a decline in water quality. In part this has been attributed to the huge increases in the use of artificial fertilisers and pesticides used to generate increased yields. Reference has already been made to the problems associated with the use of large amounts of nitrogenous fertiliser; more recently emphasis has moved towards identifying the fate and behaviour of phosphorus in the soil because of a suggested link with eutrophication in lakes and rivers.

The potentially excessive use of fertiliser and pesticides is now under intense scrutiny. The concerns about the link between agricultural production and the decline in water quality have

led to much research into the fate and behaviour of nutrients and pesticides in soils and, in particular, the properties of soils that affect the retention of pollutants and the pathways by which excess amounts can leave the soil system.

A number of models have been developed in an attempt to understand their fate, behaviour and translocation within fields and catchments (Plentinger and Penning de Vries, 1996). The hydrological characteristics of different soils are particularly important inputs into these models.

Virtually all the countries contributing to this Report have been involved in this area of research. Soil surveys have been important in establishing the principles of catchment management in the landscape. Soil maps are now used to select fertiliser recommendation practice (as in Finland, Greece and Portugal), best pesticide practice (as in Belgium, Ireland, Netherlands and the UK), and overall nutrient management both on-farm and in catchments (in most countries).

The other important consideration to emerge in agricultural production in the last few decades is the need for appropriate soil tillage and sustainable methods of cultivation. Soils of Western and Central Europe are particularly prone to compaction with consequences for crop production, run-off and erosion. Soil maps, for example those in Germany, have been used to identify those areas most at risk. The problem of subsoil compaction is now the subject of an EU-funded Concerted Action (Van den Akker, 1999).

Forestry

Forestry is a major industry in some of the countries of the EU and EFTA and many have undertaken soil mapping and monitoring to support sustainable practices. Sweden and Austria stand out in having conducted such programmes over many years and are now in a good position to detect changes that are taking place in forest soils.

For the last three decades, there has been concern over transboundary migrations of pollutants and the impact of these, particularly on forest soils. Several of the countries reporting here are signatories to the UNECE Convention on Long Range Trans-Boundary Air Pollution and some belong to the Europe-wide ECE/ICP Levels I and II forest soil monitoring network. Perhaps more so than under any other land use forest soils are now being closely monitored.

Ecological Habitats

Soil information has been made most use of in agriculture and forestry. Other ecological habitats, under natural or semi-natural vegetation, have received much less attention, partly because there have been relatively poor links between ecologists and soil scientists in many countries. This has probably arisen from a long period when ecologists have concentrated on the 'above-ground' vegetation rather than the 'below-ground' influences on that vegetation.

Fortunately this situation is beginning to change as concerns about the impact of changing soil conditions under the various driving forces on precious ecological habitats increase. Examples of these driving forces include the United Nations Climate Change Convention and the UNECE Convention on Long Range Transboundary Air Pollution. Climate change will have a major effect on soils and change a number of their properties, thus affecting the ability of habitats to survive in their present state.

The deposition of acidifying nitrogen compounds on the soil on the one hand, and the eutrophication that can take place when nitrogen enters a system on the other hand, may change ecological habitats significantly. The major development in identifying critical loads on soils, and the policy approach to reducing the emission of potentially harmful substances that contribute to these loads, is an important step forward and needs to be supported with the best possible soil information. Most national soil databases are linked into supporting these initiatives in some way or other.

Much attention has been given to using soil survey information to conserve and manage ecological habitats, for example in Austria, Portugal and Switzerland. In Belgium decision support systems using soil information have been built to support nature conservation and in several countries, the soil properties of endangered habitats have been identified.

Archaeological Preservation

Over centuries many buildings and other remains of different cultures have fallen into disrepair and become buried by the soil. The soil today can be a key to a better understanding of past cultures and of the basic principles of land use which were followed in the past. With the help of remote sensing it is possible to discover the infrastructure of past human activity in the soil. Soils that are neutral or only slightly acid are able to preserve

features better than acidic ones, the acidity tending to lead to more rapid decay.

It is possible by studying the present morphology of soils on an archaeological site and comparing it with the morphology of undisturbed adjacent soils to obtain information about past events and civilisations. The most common disturbances, reflected in archaeological investigations, are caused by erosion, ploughing, excavation, infilling and deposition, sometimes by flooding (Yassoglou and Nobeli, 1972). A knowledge of soil can be used to distinguish between man-made features and geomorphological features.

Soil survey methodology is being used increasingly by archaeologists in their attempts to unravel past cultures. Soil inventories become ever more related to the wishes and expectations of the users. As van der Pouw and Finke (1999) have noted in their report on the Netherlands, soil surveys can be 'tailor-made' to identify archaeological sites and to help in the reconstruction of prehistoric landscapes.

In Greece, soil maps and associated data have been used to identify the positions of buried settlements and structures, former land use patterns and past population densities. There is now more interest than ever before in preserving archaeological sites and understanding their cultural history. Soil maps and associated data have an important part to play in this process

Environmental Impact Assessment

Environmental Impact Assessments (EIA) have become a feature of most countries. The likely impact on soil resources of a particular development is an important consideration and needs to be part of the assessment. Most soil survey organisations have contributed information for EIAs, though countries differ in their approach and in identifying the need for soil to be taken into account.

Environmental Economics

Some countries have adopted or are considering adopting 'a polluter pays' principle in an attempt to make those who cause pollution more accountable for the consequences. For various reasons little explicit legal protection is given to soils and most legislation that does exist is focussed on human health rather than on the soil *per se*. Along with increasing interest in protection of the environment, there is increasing interest in *environmental economics* and in placing a

valuation on the world's ecosystems and natural capital (Costanza *et al.*, 1997). In both France and the Netherlands, this is identified as a topical area of interest (King *et al.*, 1999; van der Pouw and Finke, 1999).

Overall Conclusion

This summary catalogues many of the uses to which soil information is being put globally, at the continental level (in Europe) and nationally. Already there are several major issues emerging which require expertise on soils as well as from related disciplines. These include:

1. food safety and security;
2. loss of biodiversity;
3. climate change impacts;
4. sustainability of land use systems in southern Europe, particularly in the Mediterranean zone;
5. sustainable development of soil resources;
6. management of the water resources

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- To meet these and other challenges that will arise, in the future, there needs to be an integrated strategy for soil that:
1. identifies the current state of soil, its capability, vulnerability, sensitivity and resilience to potential misuse;
 2. develops sustainable land use and management systems;
 3. establishes environmental quality standards for soil *per se*;
 4. designates vulnerable and sensitive soil zones.
- As the contributions published in this volume testify, an important body of information on the soil resources of Europe is being built up to help meet current and future demands. However, it is also clear that such are the pressures on land resources in this densely populated continent that not enough is being done. The onus is now on the citizens of Europe to take immediate steps to protect and sustain their precious soil resources to ensure a healthy and safe environment for future generations.
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