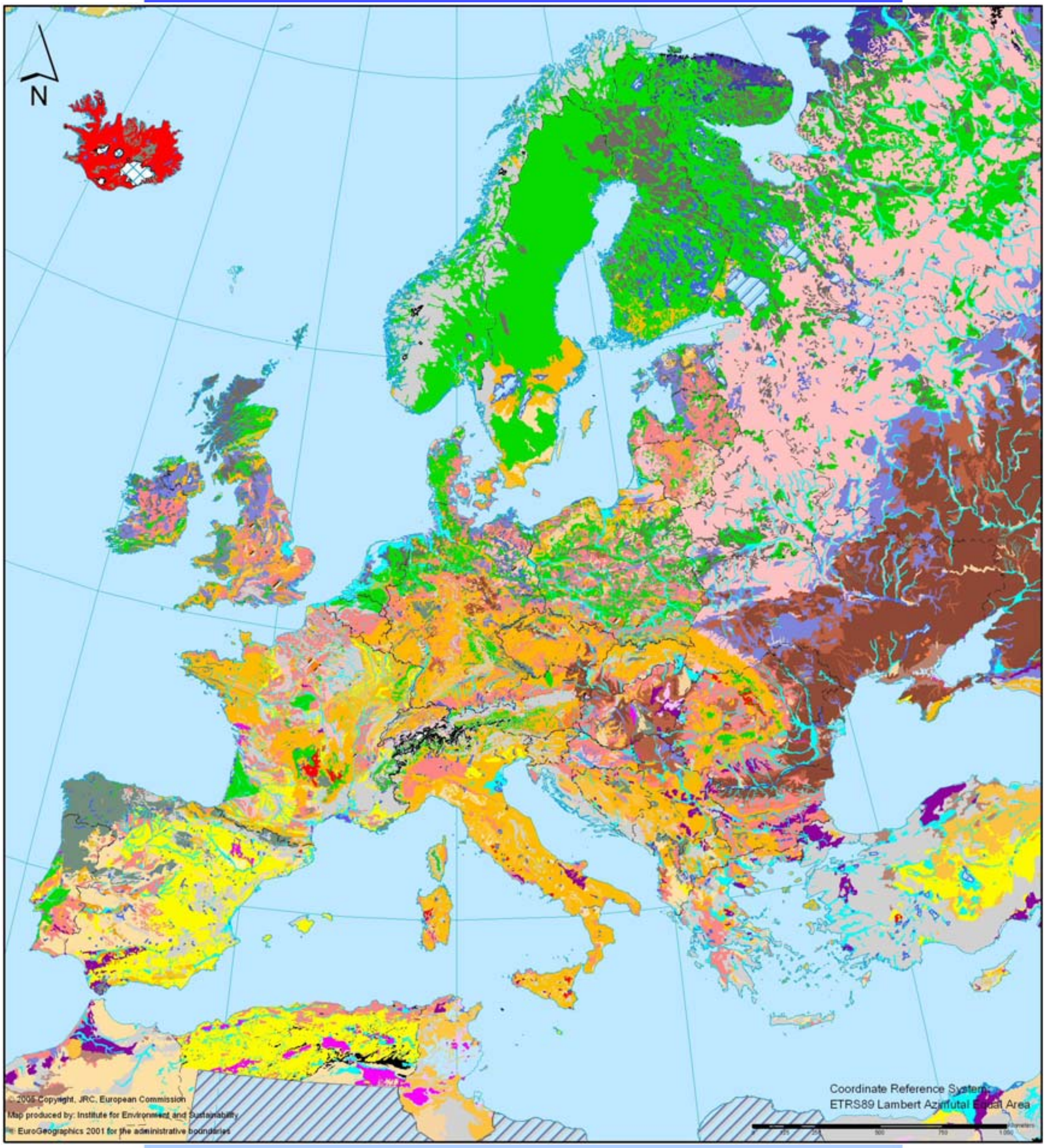
Soil Resources of Europe

second edition

Robert J A Jones, Beata Houšková,
Peter Bullock & Luca Montanarella

European Soil Bureau
Institute for Environment & Sustainability
JRC Ispra



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by

R.J.A. Jones, B. Houšková, P. Bullock & L. Montanarella
(eds.)

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Cover map:
The European Soil Reference Groups according to
the World Reference Base for Soil Resources (WRB, 1998)

Preface

The last five years have seen major new developments with respect to interest in, and managing of, the soil resources of the countries of the European Commission.

Firstly, the Commission has welcomed in ten more Member States: Cyprus, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovenia and Slovakia. In addition there are three Candidate Countries due to enter in the next five years, Bulgaria, Croatia and Romania, as well as Neighbouring (Bordering) Countries including Albania, Bosnia and Herzegovina, FYROM (Macedonia), Serbia & Montenegro, and Turkey. Many of these countries have a long history of mapping their soil resources, some of which link through to the father of pedology, V.V.Dokuchaev, who was influential in bringing the importance of soils to the attention of the European people in the mid and late 19th century. These new countries, and the countries awaiting entry into the European Union, have generally a longer history of soil science than those of western Europe (EU-15), and in some cases a more comprehensive soil information base.

Secondly, there has been a realisation within the European Commission that soil is one of its major natural resources, alongside air and water, and that all the natural resources need protection in the light of increasing pressures in Europe and neighbouring states. The European Environment Agency has issued a number of reviews of 'the State of the European Environment' and these have highlighted several areas needing urgent attention. This has been one of the factors leading to the European Commission establishing a Thematic Strategy for Soil Protection. In the launch of the first communication on this thematic strategy in April 2002, the Environment Commissioner said 'We are now placing soil protection on a level with cleaning up our water and air. For too long we have taken soil for granted. However, soil erosion, the decline in soil quality and the sealing of soil are major problems across the EU. This is a sustainability issue given that these trends are largely irreversible and that soil is vital for our livelihood'.

Thirdly, the European Soil Bureau, established in 1996 to support the EU in soil related matters, and to provide a link through to national soil organisations, has gone from strength to strength. It has masterminded the Georeferenced Soil Database for Europe at 1:1million scale and the Soil Profile Analytical Database for Europe and is currently driving the mission for a Georeferenced Soil Database for Europe at 1:250,000 scale. In addition it has promoted several important research projects on themes important for Europe. It continues to be an important link with national soil organisations.

Soil surveys have been responsible for collecting information about the soils of Europe over many years. Initially, the surveys produced paper maps at various scales identifying the spatial distribution of the different types of soils and supporting these with analyses defining the main properties of the soils. More recently there have been major advances in the construction of digital databases of soil types and their properties to which have been added information on climate, geology, topography, hydrology and land use. The resulting land information systems provide data on soils and their interaction with other facets of the environment for use in dealing with problems of pollutant transfer, soil degradation such as soil erosion, land contamination, climate change and sustainable land use. In some countries there is now on-line access to these databases. Major monitoring programmes are also being developed as a vital means of detecting changes in soil quality with time and use.

Each country of the European Union, and many of the Neighbouring Countries, have supported soil surveys to a greater or lesser extent depending on resources available. However, the methods used have varied between countries and over time. While it is matter of great satisfaction that many of the new countries have extensive information, there will be much work needed to harmonise this information and to move forward with uniform methodology for mapping, analysis, databases, inventories and monitoring. The increasing demand for information about the soils of Europe suggests that is a laudable aim. It is hoped that this review of the current state of mapping and documenting the soil resources of the new enlarged European Union and the Neighbouring Countries will help to raise public awareness and focus attention on some of the main issues that need to be addressed.

Peter Bullock,
March 2005

EDITORS' NOTE

The editors would like to thank all the contributors for their hard work, ready responses to queries and their acceptance of our editing. Their friendly co-operation was a great help to us in preparing this text and we appreciate their patience during the final production of this second edition of the Soil Resources of Europe.

The scientific and technical content of the individual chapters represents the collective professional views of the authors and does not reflect the official position of the European Commission or of the Commission's Directorate General Joint Research Centre. The authors and editors have compiled this second edition of the Soil Resources of Europe without prejudice to and without intent for personal or professional gain.

The editors would also like to thank colleagues in the National Soil Resources Institute, Cranfield University, Silsoe, and in the Soil & Waste Unit of the Institute for Environment & Sustainability, JRC, Ispra, for their support and encouragement throughout. To Maria Grazia Giaretta, Publications Service, Ispra Site Directorate, we offer our sincere thanks for her support and patience during the production of this book, and the many previous European Soil Bureau Reports which she has guided so expertly through to publication.

Bob Jones – Beata Houšková – Peter Bullock – Luca Montanarella

Ispra March 2005

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Section 1: European Perspectives

The European Soil Bureau Network

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Summary

The European Soil Bureau Network (ESBN), located at the Joint Research Centre (JRC), Ispra (I), was created in 1996 as a network of national soil science institutions. Its main tasks are to collect, harmonise, organise and distribute soil information for Europe. This paper describes the history, background and current work programme of the network.

The ESBN is experiencing a surge in the demand for soil information in Europe, for addressing a number of environmental problems and questions. These include: leaching of agrochemicals, deposition of heavy metals, disposal of waste (agricultural, domestic and industrial), degradation of soil structure (through loss of organic matter, salinisation and subsoil compaction), risk of erosion (by water and wind), immobilisation of radionuclides, supply of water at catchment level, assessing the suitability (and sustainability) for traditional and alternative crops, and estimation of soil stability. This report is an update on that published in the first edition (Bullock *et al.*, 1999).

Introduction

The European Soil Bureau Network (ESBN) was created in 1996, as a network of national soil science institutions, managed through a permanent Secretariat located at the Joint Research Centre (JRC), Ispra, Italy. It is part of the Soil and Waste Unit (SWU) of the Institute for Environment and Sustainability (IES), one of three institutes at the JRC's Ispra site (Meyer-Roux and Montanarella, 1998).

The ESBN's aim is to carry out scientific and technical work programmes in order to collect, harmonise organise and distribute soil information relevant to Community policies, to a number of Directorates General (DG's), to the European Environment Agency (EEA) and to individual Institutions of the EU Member States.

The origins of the ESB go back to the 1980s and are inextricably linked to the compilation of a European Soil Map and associated attribute databases. An EC Soil Map was produced at 1:1,000,000 scale in the 1970s by a loose network of academic soil scientists. The most important contributors to the map are listed below.

Belgium: *J. Ameryckx, A. Louis, R. Maréchal, R. Tavernier*; Denmark: *K. Rasmussen;* France: *J. Dupuis, M. Jamagne, A. Mori, E. Servat;* Germany: *E. Mückenhausen;* Greece: *A. Koutalos, N. Yassoglou;* Irish Republic: *M. Gardiner, J. Lee;* Italy: *F. Mancini, R. Salandin;* Luxembourg: *A. Puraye, J. Wagener;* Netherlands: *H. De Bakker, J. Pons, J. Schelling, R. Van der Schans;* Portugal: *J. Carvalho Cardoso;* Spain: *A. Guerra, F. Monturiol;* United Kingdom: *B. Avery, R. Glentworth, R. Grant;* FAO: *R. Dudal;* CEC: *A. Cole, J. Gillot, A. Prendergast;* Advisors: *K. Beek, S. Lunt, G. Smith, C. Sys,;* Computerisation: *H.B. Madsen, A.M. Norr, S.W. Platou*

The 'digital age' for European soil information effectively began in 1982 when a 'Computerisation of Land Data Group' (CLDG) was established by DGVI, comprising representatives of the main centres of expertise within the EC at that time. The work of the CLDG was executed under the guidance of the Land and Water Use Steering Committee of DGVI, now DG AGRI (Agriculture).

The first meeting of the group was in Ispra in 1982. Draft proposals for the compilation of a Land Data Catalogue for the whole of the EC were presented at the second CLDG meeting in Montpellier (1983).

In 1985, the EC Soil Map and legend (FAO-UNESCO, 1974) was finally published in 7 sheets and covered the EC-12 countries (CEC, 1985). It was printed on a base map provided by the UK Military Authorities with a topographical component compiled from the ONC-map series (Operational Navigational Chart Series).

The base map comprised the geodetic constants of a Lambert conformal conical projection. A manual, describing the soil map units and their contents, was also published with the maps. This task was completed in parallel with the work of the CLDG but provided a key foundation for the future of digital European Soil Data.

The group continued to meet annually until 1988 and it was responsible for a number of initiatives with respect to European soil and land data:

- Digitisation of the EC Soil Map (Platou et al. 1989)
- Compilation of an EC Land Data Catalogue (Nørr, 1986)
- Proceedings of the Bonn (1986) and Pisa (1987) meetings (Jones and Biagi, 1989)
- Proceedings of the Wageningen meeting (1988) on applications of the digital EC Soil Map and climate data (van Lanen and Bregt, 1989)

In 1989, DGVI ceased funding the activities of the Computerisation of Land Data Group and a period of dormancy followed. However, there was still a need for such activities at a European level. The Directorate General for Agriculture (DG VI) MARS (Monitoring Agriculture with Remote Sensing) Project at JRC needed information on the water holding capacities of European soils for input to the crop growth monitoring system (CGMS) that was under development for forecasting the yields of the main agricultural crops throughout the continent (Vossen and Meyer-Roux, 1995).

This lead in 1990 to the setting up of a Soil and GIS Support Group funded by the MARS Project (JRC). In the previous year (1989), a meeting of Heads of European Soil Surveys was held at Silsoe (UK) to review the activities connected with soil survey and data collection throughout Europe (Hodgson, 1991).

In addition to providing MARS with data on the water holding capacities of soils in Europe, the Soil and GIS Support Group began work on a number of fundamental database projects:

1. A major update of the EC Soil Geographical Database (the digital version of the published EC Soil Map) described by King *et al*. (1995b);
2. The compilation of a soil profile analytical database (Madsen, 1991, Madsen and Jones, 1995);
3. Development of a pedotransfer rules database (King *et al.*, 1994; van Ranst *et al.*, 1995).

As a result of its expanding activities, the Soil and GIS Support Group was renamed, in 1992, the Soils Information Focal Point (SIFP) with a work programme devised by a Soil Information System Development (SISD) Committee, under the chairmanship of Dr. D. King (INRA, Orleans, Fr.). The Heads of Soil Surveys met again in December 1994, in Orleans. At this meeting (Le Bas and Jamagne, 1996), it became clear that the amount of soil survey and soil monitoring activity, being undertaken in the member states of the EU, had reduced significantly compared to 1989 (Hodgson, 1991).

In an effort to revive soil monitoring as an important research activity, a network of centres of excellence in soil hydrology was set up (in 1994) under the EU Human Capital and Mobility Programme. This began to produce data for computing pedotransfer functions for estimating the hydraulic properties of European soils (Bruand *et al.*, 1997).

At the Athens meeting of the SIFP in 1996, the European Soil Bureau Network (ESBN) came into existence and the SISD evolved into the ESBN Scientific Committee. Table 1 charts the meetings of the ESBN and its predecessor organisations that have been associated with the computerisation of soil and land data in Europe. Much of the work undertaken by the Soil and GIS Support Group, the SIFP/SISD and the ESBN (in its first year) is described in King *et al*. (1995a) and Heineke *et al*. (1998).

European Soil Bureau Network

The activities of the ESBN are, and have always been, driven essentially by the demands for soil information by the EU Member States and the European Commission. The services most heavily involved in soil related policies are DG AGRI (Agriculture) and DG ENV (Environment), though recently a surge of interest in soil information has been observed coming from other Commission services. These are most notably DG REGIO (Regional policy) in relation to the European Spatial Planning Perspective (ESDP), and DG RELEX and DG DEV (Development) in relation to soil information in non-EU countries.

The extension of the European soil databases to non-EU countries has indeed been stimulated by the needs of these Directorates General. Specifically in the framework of the United Nations Convention to Combat Desertification (UNCCD), there is the need for adequate soil information systems in the affected regions.

Table 1 Meetings on the computerisation of soil and land data in Europe

Date	Location	Organiser
1982	JRC Ispra, Italy	
1983	INRA, Montpellier, France	Jean-Paul Legros
1984	Bureau of Land Data (ADK), Vejle-Copenhagen, Denmark	Henrik Madsen
1985	Royal Institute of Chartered Surveyors and the Ministry of Agriculture, Fisheries and Food, London, UK	Doug Fitch
1986	Ministry of Agriculture, Bonn, West Germany	E. C. Lapple
1987	CNR Instituto Elaborazione Informazione, Pisa, Italy	Benedetto Biagi
1988	Stiboka, Wageningen, The Netherlands	Johan Bouma
1989	No meeting held	
1990	IRSA, JRC, Ispra, Italy	Paul Vossen
1991	University of Ghent, Ghent, Belgium	E. Van Ranst
1992	Madrid, Spain	Juan Jose Ibanez
1993	Geographical Institute, University of Copenhagen, Copenhagen, Denmark	Henrik Madsen
1994	BGR Hannover, Germany	Wolf Eckelmann
1995	FAO, Roma, Italy	Freddy Nachtergaele
1996	University of Athens, Athens, Greece	Nicholas Yassoglou
1997	Regione Emilia Romagna, Bologna, Italy	Nicola Filippi, Luca Montanarella
1998	No meeting held	
1999	Umweltbundesamt, Vienna, Austria	Gundula Prokop, Luca Montanarella

Therefore significant extension of the current coverage of the soil databases, available from the ESBN, is foreseen in the future.

The European Soil Information System (EUSIS)

The core of this system is currently the European Soil Database, based on the 1:1,000,000 scale 'Soil Geographical Database of Europe' (Jamagne *et al.*, 2001) that is currently covering Europe.

The database has been recently extended to cover countries in the Mediterranean basin, the Russian Federation, Ukraine, Belorus and Moldova, formerly part of the Soviet Union (Montanarella, 2001; Stolbovoi *et al.*, 2001).

This new coverage also forms part of the joint Circumpolar Soil Database under development in collaboration with Canada (Agriculture Canada) and the United States of America (USDA-NRCS). This extension will serve as a tool for the more accurate estimation of soil organic carbon pools in the boreal areas and for estimates of potential changes in GHG emission in relation to changes of soil temperature regimes in these areas. A first version of this common Euro-Asian Soil Database is available (Figure 1).

EUSIS is developing into a multi-scale spatial system integrating data at different levels of detail into a single Geographic Information System (GIS) (King, *et al.*, 1998; Montanarella, 1999).

It forms an essential link in the chain from global scale systems with the 1:5,000,000 scale World Soil and Terrain database (SOTER) (UNEP/ISSS/ISRIC/FAO, 1995) to detailed national, regional and local soil information systems, at scales 1:250,000 to 1:5,000, within the European Union, ensuring a coherent approach from the local to the global scale (Figure 2).

The system incorporates also a number of pedotransfer rules (Van Ranst *et al.*, 1995) that allow the preparation of derived products, such as soil erosion risk maps, soil organic carbon estimates, susceptibility to subsoil compaction, water holding capacity and many others. More complex models (CGMS) use EUSIS for the early forecast of crop production in MARS, risk of desertification, groundwater vulnerability to agrochemicals, etc. Future developments will improve the links to other environmental databases – land cover/use, elevation, climate, geology and hydrology. Although there is considerable scope for improving the resolution and quality of the data currently incorporated, EUSIS remains the only soil information system covering the entire European continent. The main elements of are described in the sections below.

Soil Geographical Database of Europe at scale 1:1.000.000

Version 1 of this database (SGDBE) was digitised by Platou *et al.* (1989) for inclusion in the CORINE project (Co-ordination of Information on the Environment). To answer the needs of the, MARS Project (see above), the database was enriched in 1990-1991 from the archive documents of the original EC Soil Map and the resulting database became version 2. The work of the Soil and GIS Support Group of the MARS Project lead to version 3 of the database. A slightly updated version (3.2.8) of the Soil Geographical Database at scale 1:1,000,000, covering central and eastern European and Scandinavian countries (Jamagne *et al.*, 1995), forms the core of version 1.0 of the European Soil Database.

The aim of the database is to provide a harmonised set of soil parameters, covering Europe (the enlarged EU) and bordering Mediterranean countries, to be used in agro-meteorological and environmental modelling at regional, national, and/or continental levels.

Recently the Soil Geographical Database of Europe (SGDBE) has been extended in version 4.0, to cover Albania, Austria, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, FYROM (Former Yugoslav Republic of Macedonia), Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Malta, The Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland and the United Kingdom.

The most recent extension covers Iceland and the New Independent States (NIS) of Belarus, Moldova, the Russian Federation and Ukraine. Work is ongoing to incorporate soil data for other Mediterranean countries: Algeria, Egypt, Jordan, Lebanon, Morocco, Palestine, Syria, Tunisia and Turkey.

In addition to these geographical extensions, the database has also experienced important changes during its lifetime. The latest major changes include the introduction of a new extended list of parent materials, and, for coding major soil types, the use of the new World Reference Base (WRB) for Soil Resources (FAO, 1998). The database is currently managed using the ArcGIS® Geographical Information System (GIS) software system and associated relational databases.

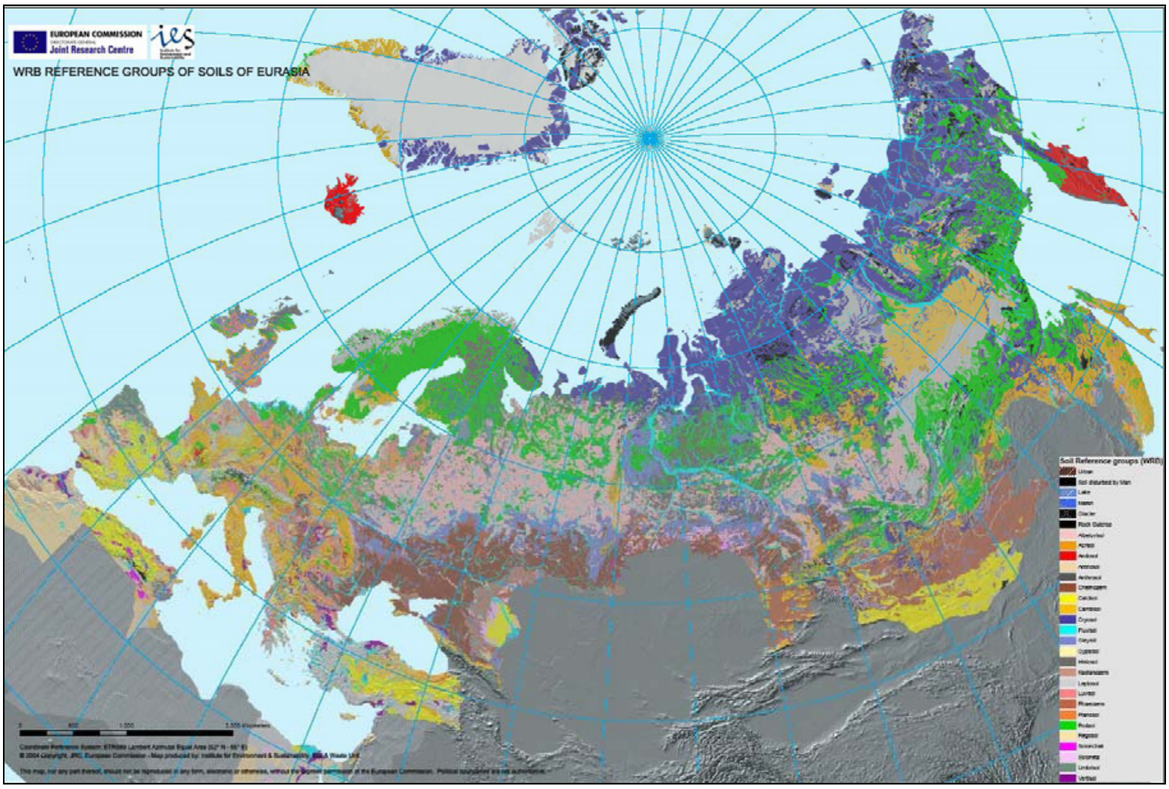


Figure 1: Provisional map extracted from the Soil Geographical Database of Eurasia at Scale 1:1,000,000 (SGDBE).

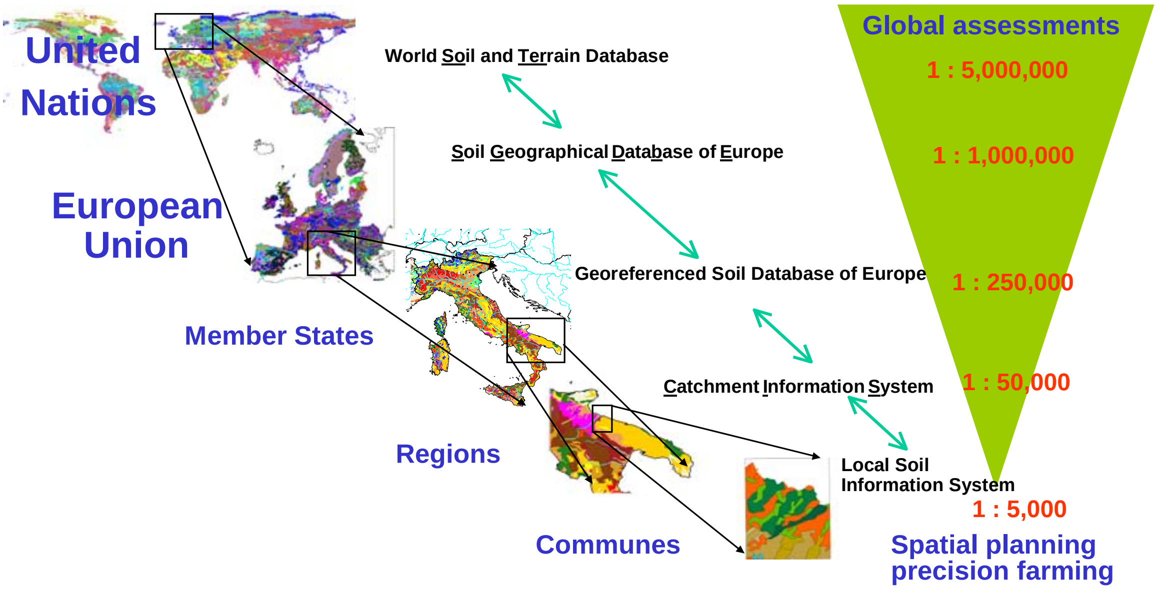


Figure 2: EUSIS responding to users (in blue) needs at different scales (in red)

The database contains a list of Soil Typological Units (STU), characterizing distinct soil types that have been identified and described. The STU are described by attributes (variables) specifying the nature and properties of the soils, for example the texture, the moisture regime, the stoniness, etc. It is not appropriate to delineate each STU separately thus STUs are grouped into Soil Mapping Units (SMU) to form soil associations. The criteria for soil associations and SMU delineation have taken into account the functioning of pedological relationships within the landscape. A detailed instruction manual for the compilation of data for the Soil Geographical Database of Europe version 4.0 has been published by Lambert *et al.* (2003).

Georeferenced Soil Database for Europe at scale 1:250,000

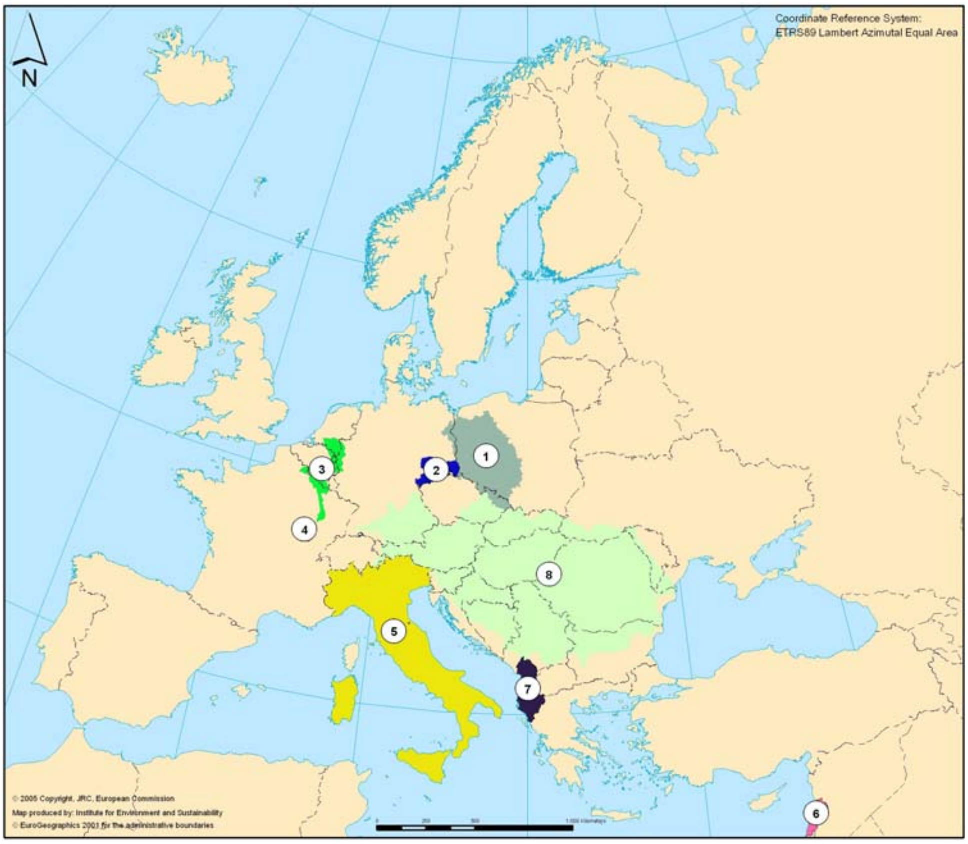
The scale and the precision of the 1:1,000,000 database is no longer sufficient to ensure the harmonisation in methodology between the various soil survey organisations and to meet the needs for users of soil information. The Task Force of the European Environment Agency and DG XI (now Environment) of the European Commission initiated a study on the feasibility of the creation of a soil inventory of Europe at scale 1:250,000 (Dudal *et al.*, 1993). The study concluded that the preparation of such a map was feasible and desirable. Meetings of the heads of soil surveys of the European Union, (Hodgson, 1991; Le Bas and Jamagne, 1996) recommended and endorsed the preparation of a georeferenced soil database for Europe at scale 1:250,000. The implementation of these recommendations was ensured by the (SISD) and subsequently entrusted to the European Soils Bureau (Montanarella, 1996).

A specific working group elaborated the basic concepts underlying the creation of this new database. A Manual of Procedures was therefore published (ESB, 1998), outlining the basic structure and procedures of this new soil inventory. The Manual has subsequently been translated into French (ESB, 2001), Italian (ESB, 1999a) and Spanish (1999b, and a version in German is in preparation.

In five selected areas of Europe (Figure 3) detailed pilot studies were implemented, leading to the creation of the first elements of a complete coverage of Europe in the future. During 2003 a new pilot area covering the complete Danube river basin was initiated and preliminary results are now available for Austria, Slovakia and the Czech Republic.

Soil Profile Analytical Database of Europe

In order to enhance information about soils in the SGDBE, a Soil Profile Analytical Database was complied in 1993-94 (Madsen and Jones, 1995). This database, called SPADE 1 contains soil profile characterisations with physical and chemical analyses. The initial objective was to compile data for the dominant STU in each SMU, from representative soil profile data selected by the experts in each contributing country.



1. Oder basin
2. Test area of Chemnitz (Germany)
3. International pilot project of the Meuse basin (France, Belgium, Germany, Netherlands)
4. Test area of Côte d'Or (Dijon)
5. National Program of Italy
6. National Program of Lebanon
7. Interreg II Italy – Albania
8. *Danube basin*

Figure 3: Pilot areas at 1:250,000 scale completed or on-going by 2005.

Initially difficulties arose because compilation of the data had begun prior to finalisation of the SMUs for the whole of Europe (some geographical coverage was added in 1995-97 after the SPADE 1 project had finished). There were other problems of data harmonisation across country boundaries and some countries, bound by confidentiality, were unable to release georeferenced data. To overcome the latter problem, the decision was made to define two different kinds of profiles, for each STU and record estimated and/or measured soil profile data depending on availability (Madsen and Jones, 1995).

The estimated soil profile data were based on expert judgement that these data are representative of the modal concept of an STU rather than a georeferenced profile. As such the estimated data are, based on the average of various observations and expert knowledge, which are essentially more appropriate. The measured soil profile data are derived directly from georeferenced soil profiles that have been described and sampled in the field, and analysed in the laboratory.

For estimated profiles the analytical methods are defined to facilitate trans-national comparisons. For measured profiles, the analytical methods were coded and missing values identified.

Because of the inherent spatial variability of soil, estimated soil profile data should provide the data that best describe each STU. Lambert *et al.* (2003) describe revised procedures for compiling soil profile data, based on the knowledge gained after completion of version 3.2.8 of the Soil Geographical Database of Europe. However, recently work (in 2001-4) has concentrated on SPADE 2, a revised version of the Soil Profile Analytical Database, containing estimated profile data for the dominant and sub-dominant land uses for the country SMUs. A beta version of SPADE 2 is almost complete (Hollis, pers comm., 2005) but there are still gaps in the geographical coverage. However being land use specific, the data will be much more useful for thematic studies than SPADE 1 data.

Table 1: List of selected output attributes from pedotransfer rules with their required inputs parameters.

Output attributes	Input attributes		Output classes
BIOLOGICAL ATTRIBUTES			
Topsoil organic carbon content (OC_TOP) (0 - 25cm)	SN TEXT USE ATC	- FAO soil name - Topsoil textural class - Regrouped land use class - Accumulated mean temp.	H(igh): > 6.0% M(edium): 2.1-6.0% L(ow): 1.1-2.0% V(ery) L(ow): < 1.0%
Presence of a raw peaty topsoil horizon (PEAT)	SN	- FAO soil name	Y(es) N(o)
CHEMICAL ATTRIBUTES			
Soil profile differentiation (DIFF)	SN	- FAO soil name	H(igh) differentiation L(ow) differentiation O: No differentiation
Profile Mineralogy (MIN)	SN	- FAO soil name	(C)hemical or Geochemical (M)echanical or Physical MC: Chemical and Mechanical ND: No Differentiation
Topsoil Mineralogy (MIN_TOP)	PM MIN	- Parental material - Profile Mineralogy	KQ: 1/1 minerals + quartz KX: 1/1 minerals + oxides & Hy. MK: 2/1 and 1/1 minerals M: 2/1 and 2/1/1 non swelling m. MS: Swelling and non s. 2/1 m. S: Swelling 2/1 minerals TV: Vitric materials TO: Andic materials
Subsoil Mineralogy (MIN_SUB)	PM MIN	- Parental material - Profile Mineralogy	
Topsoil Cation Exchange Capacity (CEC_TOP)	DIFF MIN OC_TOP TEXT	- Soil profile differentiation - Profile Mineralogy - Topsoil organic carbon content - Topsoil textural class	L(ow): < 15cmol(+)kg^{-1} soil M(edium): 15-40 H(igh): > 40
Subsoil Cation Exchange Capacity (CEC_SUB)	MIN_SUB TD	- Subsoil mineralogy - Subsoil textural class	
Topsoil Base saturation (BS_TOP)	SN USE	- FAO soil name - Regrouped land use class	L(ow): < 50% M(edium): 50-75% H(igh): > 75%
Subsoil Base saturation (BS_SUB)	SN MIN_SUB	- FAO soil name - Subsoil mineralogy	L(ow): < 50% H(igh): > 50%
MECHANICAL ATTRIBUTES			
Depth to rock (DR)	SN PM PHASE	- FAO soil name - Parent material - Phase	S(hallow): 0-40cm M(oderate): 40-80cm D(eep): 80-120cm V(ery) D(eep): > 120cm
Volume of stones (VS)	PHASE PM	- Phase - Parent material	0% stones - 10% stones 15% stones – 20% stones
Subsoil textural class (TD)	SN TEXT DR	- FAO soil name - Topsoil textural class - Depth to rock	1 Coarse 2 Medium 3 Medium fine 4 Fine 5 Very Fine
Topsoil structure (STR_TOP)	USE SN	- Regrouped land use class - FAO soil name	G(ood) N(ormal) P(oor) H(umic) or Peaty soil O : Peaty subsoil
Subsoil structure (STR_SUB)	SN	- FAO soil name	
Topsoil Packing Density (PD_TOP)	STR_TOP TEXT USE	- Topsoil structure class - Topsoil textural class - Regrouped land use class	L(ow): < 1.4g/cm^3 M(edium): 1.4 – 1.75g/cm^3 H(igh): > 1.75g/cm^3
Subsoil Packing Density (PD_SUB)	STR_SUB TD SN	- Subsoil structure class - Subsoil textural class - FAO soil name	

Table 1: continued

Output attributes	Input attributes		Output classes
	HYDROLOGICAL ATTRIBUTES		
Parent material hydrogeological type (PMH)	PM	- Parent material	R, C, S, L, H, M (INRA *et al.*, 1993)
Depth to a gleyed horizon (DGH)	SN	- FAO soil name	S(hallow): 0-40cm M(oderate): 40-80cm D(eep): 80-120cm V(ery deep): > 120cm
Depth to impermeable layer (DIMP)	TEXT PD_SUB SN	- Topsoil textural class - Subsoil packing density - FAO soil name	S(hallow): < 80cm D(eep): > 80cm
Hydrological class (HG)	ATC PMH SN ALT DIMP	- Accumulated mean temp. - Parent material hydrogeological type - FAO soil name - Elevation - Depth to impermeable layer	HG1: soil with permeable substratum, remote from groundwater: seldom wet HG2: lowland soil affected by groundwater, seasonally or permanently wet, or artificially drained HG3: soil with impermeable layers within 80cm depth, seasonally or permanently wet HG4: soils of the uplands and mountains
Topsoil Available Water Capacity (AWC_TOP)	TEXT PD_TOP	- Topsoil textural class - Topsoil packing density	V(ery) H(igh): > 190mm H(igh) : 140-189mm M(edium) : 100-139mm L(ow): < 99mm
Topsoil Easily Available Water Capacity (EAWC_TOP)	TEXT PD_TOP	- Topsoil textural class - Topsoil packing density	
Subsoil Available Water Capacity (AWC_SUB)	TD PD_SUB DR	- Subsoil textural class - Subsoil packing density - Depth to rock	
Subsoil Easily Available Water Capacity (EAWC_SUB)	TD PD_SUB DR	- Subsoil textural class - Subsoil packing density - Depth to rock	

Pedotransfer rules

The fourth component of the European Soil Database is a series of pedotransfer rules (PTR) allowing to derive a number of additional properties for practical purposes. These are based on expert judgement, mainly qualitative, and assume that a due weight is given to the confidence level of individual inferred attributes.

A set of tools was conceived within Arc/Info to manage and use a rules database for the inference of new information from that available within an Info database. These tools may be considered as a prototype of an expert system shell and were used in the above context. Several hundred rules were defined by Van Ranst *et al.*, (1995) in the form of IF <condition> AND <condition> ... THEN <inferred value>. At this stage, although rules are applied to spatial objects (soil units) and the system does not take spatial relationships between objects into consideration.

Output attributes were selected on the basis of the environmental parameters needed for the problems faced, e.g., hydrology of soil types for predicting catchment response to rainfall and standard percentage of run-off; location and sensitivity of wetlands; soil buffering capacity for predicting soil susceptibility; ecosystem and surface water deposition; vulnerability of ground -and surface-water to pollution by agrochemicals and farm waste; soil erosion potential, etc.

Table 1 summarises the PTRs defined by Van Ranst *et al.* (1995), listing input and output parameters,. There four groups that respectively correspond to attributes of biological, chemical, mechanical and hydrological nature. Some of them can be derived directly from the European Soil Database, others need attributes derived previously by other PTRs as input.

The output attributes are class values in view of the low level of precision of some input attributes. The thresholds selected for class intervals were chosen as a compromise between currently established values used in Soil Science, and the level of precision at the scale of input data (in this case 1:1,000,000). As a result, the adopted values may not always correspond to the thresholds necessary for environmental problems.

The pedotransfer rules DB remains one of the fundamental tools for deriving useful information from existing soil databases. However it is important to appreciate that most of the PTRs were developed using a knowledge base for Western Europe (EU-12) only (King *et al.*, 1994; Van Ranst *et al.*, 1995) and it would be inappropriate to apply them to the extended Euro-Asian Soil Geographical Database (v4.0).

Recent implementation of complex pedotransfer rule based evaluations of soil erosion (Kirkby *et al.*, 2004) and topsoil organic carbon content (Jones *et al.*, 2004) have demonstrated the great potential of such 'expert-based' approaches compared to more deterministic modelling exercises. The current lack of reliable, comparable and compatible input data for sophisticated deterministic models leaves the pedotransfer approach as the only realistic means to derive policy-relevant information from the SGDBE.

Future perspectives

Within its 6th Environmental Action Programme, the European Commission has established the objective of protecting soils against a number of major threats – erosion, pollution, decline of organic matter content, loss of biodiversity, sealing by infrastructure, salinization and desertification. In order to achieve this objective it has proposed the introduction of a specific thematic strategy for soil protection. The way forward towards this proposed strategy has been outlined in the Communication COM 179 (EC, 2002) 'Towards a Thematic Strategy for Soil Protection'.

The Communication recognizes several distinctive features of soils that make the development of a soil protection policy somewhat different from the protection of air and water. One of these features is the very high degree of spatial variability of soils across Europe. The great diversity of European soils reflects the differences in climate, geology, vegetation, land use and historical development that are characteristic of Europe.

Recognizing soil diversity implies to take into account the strong local connotation of any soil protection policy. Different soils require different management and protection measures.

It seems therefore a mandatory pre-condition to the development of any future soil protection strategy is the compilation of a detailed and up-dated inventory of the current status of European soils.

The future development of a European Spatial Data Infrastructure (ESDI) within the INSPIRE (http://inspire.jrc.it) initiative of the European Commission will generate a fully streamlined flow of soil data and information from the local scale up to the European scale. Such a nested soil information system (King *et al.*, 1998) will allow to access to soil information at the appropriate scale for each of the required applications (global, European, national, regional, local) by the different stakeholders.

The development of a coherent approach to soil protection within the EU will take time. In the long term, a 'soil framework directive' may be the appropriate instrument to achieve fully the goals outlined in the soil protection strategy. Nevertheless, some initial steps are already possible within the existing legislative framework.

One of the major existing instruments for improving soil protection in the EU is the Common Agricultural Policy (CAP). The mid-term review of this policy and the resulting new Council Regulation No. 1782/2003 of 29th of September 2003 explicitly specifies under article 5 obligations for Member States to ensure good agricultural practices and environmental condition of land. Annex IV of the regulation specifies in detail what practices should be implemented and according to which minimum standards. Among these practices there are measures to reduce soil erosion, increase soil organic matter content and improve soil structure. Already implementing these new measures will result in a substantial step forward towards soil protection in Europe.

Other important policy areas where immediate action could be implemented are the Nitrates Directive, the Water Framework Directive, the Air Quality Directives, the Landfill Directive, the Habitats Directive and other, more general environmental legislation, making a significant contribution to the prevention of contamination and the protection of biodiversity.

Pre-condition to the successful implementation of any of such measures will be the development of a coherent European Soil Information System involving stakeholders at all levels: from the local to the global scale.

In this sense, the European Soil Bureau Network will continue in future to be the main European soil data and information provider for the implementation and monitoring of the future thematic strategy for soil protection.

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Soil Resources of Europe: An Overview

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Introduction

Many of the soil survey organisations in Europe were initiated post–World War II in response to the perceived need to expand agricultural output at least to the point of self sufficiency. Most of the early surveys were either general purpose in nature (Table 1) or related to agricultural production in some form, e.g. maps showing the suitability of land for agriculture or for particular crops. Early on, Land Capability Classification (Klingebiel and Montgomery, 1961) was developed and in the UK, Germany and other countries land classification maps for Land Use Planning were also produced in recognition of the need to protect the best agricultural land for the future.

The period 1950-90 was the most productive period for soil survey and the collection of information about the nature, distribution and properties of soils. This period also saw development of an understanding of the main soil processes, information that is now proving so important in helping to find answers to current environmental problems.

In the mid- to late-1980s, a number of EU countries became self-sufficient in staple agricultural products and the EU as a whole built up large surpluses of cereals, wine, olive oil and certain fruit crops. There was a sharp decline in support for soil science because the discipline was inextricably linked to productive agriculture and further research was perceived to lead to even larger surpluses in the future. The importance of soil in the broader environmental debate, that was to follow, had not yet been appreciated.

Funding for soil surveys declined and many soil survey programmes were curtailed or stopped completely. The result was that only one country in the EU-15, namely Belgium, had completed its detailed national soil mapping programme by the end of the 1980s.

Yet, within a very short time, the Bruntland Report, *Our Common Future*, was published (Bruntland, 1987) and the United Nations General Assembly called for a global meeting to discuss and devise strategies to halt and reverse the effects of environmental degradation, leading to the adoption of Agenda 21.

The consequence of these developments was a burgeoning interest in the environment. Concern was expressed about land degradation, pollution and unsustainable land use practices. There was a sudden increase in demand for information about the soil resources of the EU and Neighbouring Countries at a time when most of the soil survey and soil research organisations were in decline, with reduced staff numbers and programmes that were generally incomplete or that had barely even started.

The soil science community has responded to these new demands by organising the information that exists in a form that can readily be used and interrogated. Most countries in the enlarged EU (as from 01 May 2004), and those which border the EU (Candidate and Neighbouring Countries), began to develop soil and/or land information systems, comprising digital databases containing available soil maps in graphical formats, soil analytical data, and related ecological, climatic, geological, land use and cadastral information. Increasingly these systems provided the capability to process the different kinds of environmental information.

An era had arrived in which interest in the environment was very strong and there was a clear need for a wide range of environmentally related information to support policy formulation and legislation, yet most countries of the European Union lacked the basic information about their soil resource that would enable them to address the many emerging land use and management problems.

The papers in this book are an update to those in the first edition of the Soil Resources of Europe (Bullock *et al.* 1999) and have been expanded to include New Member States of the EU and Candidate Countries. These reports provide as complete account as possible of the current status of soil mapping, soil monitoring and associated database development in Europe as a whole.

Concept of Soil Mapping

The general aim of soil mapping is to provide a spatial representation of the soils of continents, countries, regions, farms, or in fact any area of land of interest. It involves identifying the different types of soils that occur, collecting data on their nature, properties and potential use, and recording this information on maps and in supporting documents. The following sections offer a simple description of soil mapping.

Soils can be mapped at a *range of scales* from very detailed at 1:1,250 to 1:5,000, showing soil patterns within individual fields or parcels of land, to broad exploratory or reconnaissance surveys at 1:500,000 to 1:5,000,000 providing only a very generalised picture of the soils of a country or continent (Table 1).

In establishing a soil mapping programme, decisions need to be made on whether surveys are to be general purpose or special purpose. *General purpose surveys* are expected to provide the basis for interpretations for many different uses, some of which may not yet be known. General purpose surveys lead to the production of soil maps in which the units are primarily separated on the basis of the morphology of the soil supported by analytical data.

By contrast, *special purpose maps* are prepared for specific uses and the relevant soil characteristics are emphasised in the separation of the different map units. Examples of special purpose maps include those for planning irrigation or sewage sludge disposal, combating salinity or erosion, and identifying contaminated soils. The drawback of special purpose mapping is that when the information base obtained for map is needed for another application it may be incomplete or unsuitable for it.

Most national surveys of soils involving detailed mapping have been general purpose in nature with the expectation that they will provide a broad information base from which to respond to a wide range of demands.

Table 1: Scales of soil survey and their objectives
(after Dent and Young, 1981 and Avery, 1987)

Description	Scale	Ideal inspection density	Kind of map unit	Typical objectives
Large scale	1:2,500	64 per ha.	Simple	Special purpose and
(Detailed)	1:10,000	4 per ha.	Simple	Detailed general purpose
	1:25,000	64 per km^2	Mainly simple	Surveys. Project planning
Medium scale	1:50,000	16 per km^2	Mainly	Regional land use
(Semi-detailed)	1:100,000	4 per km^2	Simple	Planning. Project
				Feasibility studies
Small scale	1:200,000	1 per km^2	Compound	Regional or national
(Reconnaissance				Resource inventories.
	1:250,000	<1 per km^2	Compound	National land use
	1:500,000	<1 per km^2		Planning
Exploratory	1:1,000,000 or smaller	<< 1 per km^2	Compound	Display. National atlases

In order to identify and map different soil types, it is necessary to classify the soils. A number of classification schemes have evolved and many of the countries in Europe have produced their own systems suited to local conditions of soil formation and distribution. There are also two main International systems of classification, the WRB system (1998) and the US Soil Taxonomy (Soil Survey Staff, 1975, 1994). Most of these systems are hierarchical in structure with a number of divisions representing different degrees of refinement and definition.

The *soil series*, defined as collections of soil profiles showing the same or similar succession of layers in lithologically similar parent materials (Hollis and Avery, 1997) is often the lowest order in a classification and is the one chiefly used to identify map units at scales of 1:65,000 or larger. It is conceived as a grouping of soils, which are alike in their characteristics and behaviour in the landscape.

The basic unit of soil sampling and classification is the *soil profile*, a column excavated from the surface through the soil layers or horizons to the rock or other parent material below.

Soils are classified according to selected *profile characteristics* that can be measured or observed such as particle size distribution of different layers, abundance of organic matter in the topsoil, colours representing aerobic or anaerobic conditions, etc.

Soil mapping involves the use of an auger at intervals throughout the landscape to examine the nature of the soil at a point. The intervals between inspections can be according to a pre-determined grid (grid survey) or more commonly are irregularly spaced and chosen to test and refine conceptual models of soil distribution in the landscape.

Auger boreholes are supplemented by excavated profile pits chosen as representative of a particular soil series, and sampled for analysis to provide more details about the nature of the different soil horizons. Profiles are commonly sampled and the samples analysed for their *chemical and physical properties*, and less commonly for their *biological properties.*

Soil Mapping, databases and Monitoring in Europe

Soil maps in Europe have been prepared at a range of scales and there is little consistency between countries in the scale used or in whether the emphasis is on small or large scale mapping. It is generally accepted that as an absolute minimum each country should have a national map at a scale of 1:250,000. Any scale smaller than this is regarded of little value for in-country management of soil resources. The following sections summarise the progress of soil mapping in the countries of the enlarged European Union and Neighbouring Countries (such as former EFTA states). For more detailed information about soil mapping in these Countries, the reader is referred to the individual Country chapters that follow this Chapter.

Albania

Soil mapping: The whole country has been mapped at scale 1:200,000. More detailed soil surveys, leading to soil maps at scale 1:10,000 to 1:50,000 were produced for each agricultural cooperative, state farm and district, mainly in the period 1971-1991. These maps covered arable soils together with pastureland and forest soils. Since the political changes of the 1990s, soil surveying has been reduced drastically, though in the mid-1990s USAID sponsored a national assessment of soil resources.

Soil and Land Information Systems: In 1998, information about Albanian soils was introduced into the European Soil Database at 1:1,000,000 scale under the sponsorship of the European Commission’s Joint Research Centre. Cooperation and sponsorship from EC, under the guidance of the European Soil Bureau, and that of the Italian Government, has led to the creation of national soil databases and maps at 1:250,000 and 1:50,000 scales.

Monitoring: There is no organised national system of soil monitoring in Albania. There is a need for such a system as a basis for implementing sustainable land use and management practises.

Austria

Soil mapping: Much of the country has been mapped in detail as a result of the efforts of a number of organisations representing agriculture, forestry, environment and taxation. There is likely to be disparity between the requirements of each of these groups so the information collected often has a different emphasis. To date, some 98% of agricultural land and 10% of forestland have been mapped in detail and there is a complete cover of soil maps for the taxable land. In all, it amounts to an impressive accumulation of information and organisation.
Soil and Land Information Systems: Considerable progress has been made in the development of a soil information system, BORIS. The system is seen as essential for providing basic information on general soil conditions, contamination and the sensitivity of soils to detrimental impacts, and for

effective soil conservation. BORIS integrates soil maps, data from environmental surveys, the results of soil monitoring, and cadastral information. The basic aim of BORIS is the capture and combination of existing and future soil data for Austria.

Monitoring: The Forest Soil Monitoring System, which exists at state as well as federal province level, consists of 514 basic plots and the database comprises about 5,000 forest soil profiles. The Environmental Soil Survey, with about 6,000 sites, provides information about the variability of soils all over Austria. Fewer, but more intensively monitored sites, are being established, representing soil landscapes, main agricultural production areas, forestry, different exposures to pollution and types of land use.

Belgium

Soil mapping: The whole country has been surveyed at 1:10,000 scale and the maps published at 1:20,000 scale. Belgium was the first EU country to achieve a complete cover of detailed soil maps. It is thus extremely well placed when needing to respond to a whole range of questions relating to soil resources. Using this detailed survey, a synthesis of soil distribution has been prepared at a scale of 1:500,000. However, Belgium is a small country that does not have great pedological diversity and making a comprehensive detailed soil survey of the country has been an easier task than in the larger EU countries such as France, Germany, Italy, Spain or the UK.

Soil and Land Information Systems: The soil survey of Belgium produced 441 map sheets at a scale of 1:20,000 and details of 15,000 soil profiles, This information is stored in a number of well structured relational databases and has been used to compute pedotransfer functions for moisture retention and hydraulic conductivity, enabling the system to respond to increasing demands for data to support land management decisions.

Monitoring: To date, extensive use has been made of soil survey data in connection with environmental and other land use issues but there is no major programme involving regular soil monitoring.

Bosnia and Herzegovina

Soil Mapping: A detailed soil map at scale 1:50,000 was completed 1966 and 1986. Since then, the country has endured a major military conflict during which the research programme on soils was largely abandoned.

Soil and Land Information Systems: It is important that these are established to enable BIH to move forward in the post-war period as quickly and efficiently as possible.

Monitoring: A monitoring programme needs to be established both to assess the war-created damage and to be able to link with other European countries in monitoring schemes for the protection of European soils.

Bulgaria

Soil Mapping: Survey activities began in 1911, leading to the publication a soil map at scale 1:500,000. Almost (90%) the whole country has now been covered by 1:10,000 scale soil maps. All the arable land and 65% of total area is covered by maps at 1:25,000. A map at scale 1:50,000 was created according to geographical regions and another at 1:100,000 scale for administrative districts. Medium to small scale maps (in range 1:200,000 till 1:600,000) cover the whole country.

Soil and Land Information Systems: This large body of information about the soils of Bulgaria is now summarised and systematised in the Geographic Soil Information System (GSIS). Digitisation of maps at the largest scale has been an important step in building up the GSIS

Monitoring: Soil resources have been monitored for some time, based on 146 SOTER units. The aim of the monitoring is to maintain current information on the degree of vulnerability of Bulgarian soils to degradation processes. Monitoring sites provide information on background values of soil components and records modifications due to different anthropogenic impacts.

Croatia

Soil mapping: Several small scale national maps have been produced, including that of 1:1,000,000 scale in 1992, the first produced after independence of the country. The national soil map of Croatia at 1:50,000 scale was made in the period 1964-1985. This 1:50,000 scale map includes data on soil physical, chemical and biological properties. Larger scale maps (1:5,000 and 1:10,000) were prepared for soil reclamation purposes as case studies.

Soil and Land Information Systems: During preparation of the General Soil Map of Croatia at 1:50,000 scale a large amount of soil data was collected. Information about soils in Croatia can be found in the on-line journal of the Faculty of Agriculture, Zagreb.

Monitoring: Croatia has participated in the development of an organised and integrated soil protection approach within the Alps, Alps-Adria and Danube river regions. In general, soils in Croatia are not strongly damaged, so there is no systematic monitoring of soil properties and soil degradation. In the future there will be needs to have systematic soil monitoring to ensure the sustainable use of soil resources.

Cyprus

Soil mapping: The General Soil Map of Cyprus has been prepared at a scale of 1:200,000 using the FAO classification system. In 2002, a 1:250,000 scale soil map, using the WRB soil classification system, was also printed. This map was created using information of parent material from Geological map of Cyprus at the same scale. A 1:1,000,000 scale soil map has also been prepared for inclusion in the European Soil Database. Soil maps at scale 1:25,000 also exist; these were created by different soil scientists using different classification systems and relate mainly to agricultural land.

Soil and Land Information Systems: Apart from the soil maps at different scales and a land suitability map, there are no national soil or land information systems.

Monitoring: Cyprus, as an EU Member State, follows the EC Nitrate Directive and monitoring is focused on establishing nitrate vulnerable zones.

Czech Republic

Soil mapping: Soil survey and soil mapping have a long tradition in the Czech Republic. The whole country is covered by soil surveys at large scales notably at 1:25,000; 1:10,000 and 1:5,000. Soil maps at scales 1:200,000, 1:500,000 and 1:1,000,000 also exist. Thus the Czech Republic has a strong mapping base from which to plan sustainable use of its soil resources.

Soil and Land Information Systems Soil information systems are generated in three complementary ways:

- Soil GIS for practical uses, mainly taxation and land tenure appraisal of agricultural lands and separately for forests;
- Databases of soil monitoring;
- Soil GIS (PUGIS) for development of concepts and international cooperation on different projects.

PUGIS consists of: polygons of digitised soil maps; thematic layers of geomorphology, climate, geology, vegetation; attributes of soil associations and soil regions; and a database of pedon characteristics of 2,500 selected profiles with a standardised set of characteristics and 250 profiles with additional data from agriculturally used soils.

Monitoring: Trace element monitoring for the whole country has been implemented in two separate monitoring systems: one, monitoring agricultural land at 200 observation plots accompanied by the observation of atmospheric emissions and the second, monitoring forest soils, part of which is performed within the framework of the International Cooperative Programme (ICP) for forest monitoring.

Denmark

Soil mapping: A set of maps for the whole agricultural area in Denmark was published at a scale of 1:50,000 in 1980. Soil types were not differentiated on forested or urban land. About 90% of the country is covered by maps of surface geology, which include some soil attributes. Subsequently there have been improvements to the soil maps by incorporating further soil data, particularly information on soil texture, and combining existing topographic, geological and landscape maps to delineate geographical units having similar soil types. A pedological soil map at 1:1,000,000 has also been derived.

Soil and Land Information Systems: Between 1975 and 1979, 36,000 sites were sampled (1 per 0.7km^2). The descriptions of these sites and data from the analyses are stored in the Danish Soil Profile Database, making it possible to combine the results of profile investigations with soil maps and physical and chemical properties associated with mapping units. This information provides a basis for responding to needs for soil information relating to agricultural and environmental problems and planning.

Monitoring: Test plots have been established, in which the content of inorganic nitrogen has been determined twice a year at four depths. In the beginning of the 1990s, 393 sites were selected to represent Danish soils in the Danish heavy metal monitoring programme. In 1998 funding was granted for the project: 'Monitoring the environmental impact of modern agriculture with respect to phosphorus, copper, zinc and pesticides in relation to management'.

Estonia

Soil mapping: Soil mapping in Estonia was originally based on the use of geological maps. The first comprehensive soil map was at scale 1:800,000 (1923). A 1:400,000 scale soil map was later generalised into 1:1,500,000. In the late 1940s, more detailed soil mapping started (at scale 1:50,000 and 1:10,000) and also special purpose soil mapping e.g. soil acidity map for liming purposes. Today the whole territory of Estonia is mapped at 1:10,000 scale. Estonia is also covered at medium (1:100,000; 1:200,000) and small scales (1:1,000,000, 1:1,500,000 and 1:2,500,000-SOVEUR.

Soil and Land Information Systems: Many of the soils maps including the maps at 1:10,000 scale have been digitised and contribute to the Estonian Soil Database, along with profile data.

Monitoring: In Estonia there has been monitoring of soils for different purposes. First studies concerning temporal and spatial changes of soil properties were carried out in the 1960s as a part of International Biological Programme for both agricultural and forest soils. The monitoring was repeated after 20-35 years, in the period 1986-2000. Geochemical monitoring of soils has been carried out in two series: in 19 and 25 study areas. Forest soils monitoring has been carried out on 91 plots representative of the most important tree species. Monitoring of arable soils was initiated in 1983 and comprised 79 study plots with 3,160 sites. After 1993 this large scale monitoring was stopped.

Finland

Soil mapping: About one-third of the country, including about half of the cultivated land, has been mapped at scales of 1:20,000 to 1:50,000. Initially the mapping was undertaken by the Geological Survey, which produced maps at a scale of 1:100,000, 1:400,000 with an emphasis on the nature of the geological deposits. The Agricultural Research Centre later became involved, producing maps at 1:20,000 scale (southern Finland) and 1:50,000 scale (northern Finland).

Soil and Land Information Systems: A database of soil texture and organic matter properties of Finnish soils is currently being created. The dataset contains the results of texture determinations on some 28,000 samples.

Monitoring: More systematic monitoring of agricultural soils started in 1974 and comprises a collection of 2,000 soil samples. A database of the results of the soil monitoring programme already exists. Computerised data handling and advanced techniques are now available for data storage but more data need to be collected to make a database adequate for national requirements.

France

Soil mapping: The 'Pedological Map of France' programme, in being for 25 years, has led to about 20% of the French territory being mapped at 1:100,000 scale. This has now been supplemented by a programme of mapping at 1:250,000 scale by which about 40% of the country has been mapped. The latter programme is expected to lead to France having a complete mapping cover at 1:250,000 scale. Several regional and national mapping organisations are making maps at larger scales, e.g. 1:25,000 and 1:50,000.

Soil and Land Information Systems: A national soil GIS database, DONESOL, has been under development since 1990. It includes: point data from measurements and observations; descriptive data of soil mapping units; and metadata indicating bibliographic references to important studies. DONESOL contains most of the data from the main national programmes including IGCS and OQS. Other databases have been prepared in conjunction with or in parallel to DONESOL, including ASPITET (reference data on trace elements); SOLHYDRO (analytical database of hydraulic properties); and BNAT (analyses carried out by private companies).

Monitoring: For forest areas, ICP Forest monitoring was created 15 years ago. At level I 540 representative plots are investigated, for level II there exists long term monitoring RENECOFOR on 102 representative plots selected from level I. In 2001, the Soil Quality Monitoring Network (RMQS) was established in order to increase representativeness of results at reasonable cost. Similar to ICP monitoring, it is based on a network (16km x 16km) for 2,150 sites from non-forest areas. A research programme GESSOL started in 2004 with the aim to promote good agricultural practice in respect of soil and water quality.

Germany

Soil mapping: In the past, much of the soil mapping has been carried out by the sixteen state geological surveys and this has varied greatly between states in terms of scale and coverage. Approximately half of the country has been mapped by these state organisations at scales ranging from 1:25,000 to 1:200,000. Also 1:10,000 and 1:5,000 scale maps have been produced but mostly as case studies. Now the national soil survey (BGR) is collaborating with the state surveys to produce a 1:200,000 scale map for the whole of Germany. By the end of 2004, 17 of the 59 sheets were published, 7 draft sheets were under preparation at federal state level and one was prepared at national level by BGR. Small scale maps at 1:1,000,000, 1:2,000,000 and 1:5,000,000 scale show German soils at European and Global levels.

Soil and Land Information Systems: The systematic development of soil information systems in the Federal Republic of Germany began in 1979. The State Geological Surveys and the Federal Institute for Geosciences and Resources manage the project. The soil information system, FISBo BGR, consists of three main components: the spatial database containing all small-scale maps for nationwide needs, the laboratory and soil profile database, including physical and chemical properties and contaminants, and the methods database. It is part of a geoinformation network, which includes and connects geoinformation systems, e.g. geology, soils, hydrology, so the information obtained from this network can be very complex.

Monitoring: Based on information from about 5000 profiles, background analytical values for topsoils, subsoils and bedrocks are being made available. This information is coupled with models to identify risk to soils.

Greece

Soil mapping: Several organisations have contributed to mapping the soils of Greece and over the years there has been some disparity in approach. Semi-detailed and reconnaissance maps have been made for about 31% of the country. About 30% of the high quality agricultural land (4.6% of the country) has been mapped in detail (1:5,000 and 1:10,000 scale maps). Land mapping by the Forestry Service, which includes some soil properties but not sufficient to clearly delimit soil types in the pedological sense, covers about 75% of the country. A soil association map at 1:500,000 has been collated for the whole of Greece and a 1:1,000,000 scale map was incorporated in the European Soil Database.

Soil and Land Information Systems: Soil databases containing a range of soil profile data exist in a number of institutions in Greece. It has now been proposed that all available data be gathered and stored at one institute that would become a reference point for all soil information for the country.

Monitoring: For fertilisation purposes and the application of site-specific fertilisation, the soils at about 3,000 sites have been investigated according to soil typological units. However, little systematic nationwide monitoring exists in Greece at present.

Hungary

Soil mapping: Soil science and soil mapping have a long tradition in Hungary. Maps at different scales have been created during the last seventy years: national level (1:500,000), regional (1:100,000), farm (1:10,000-1:25,000) and field level (1:5,000-1:10,000). Thematic soil maps are available for the whole country at the scale of 1:25,000 and for 70% of the agricultural area at the scale of 1:10,000. Medium scale maps have been used for the assessment of the agro-ecological potential of Hungary. Small scale maps (1:1,000,000 to 1:5,000,000) serve for various international programmes (1:5,000,000 FAO/UNESCO World Soil Map; 1:5,000,000 GLASOD Map; 1:5,000,000 World Map of Salt-affected Soils; 1:1,000,000 Soil Map of Europe).

Soil and Land Information Systems: (HunSIS=TIR) contains point data of soil profiles together with topographic information, (1:25,000 scale thematic maps) and validated models on pedotransfer functions and soil-plant-environment relationships. The Agrotopographical database (AGROTOPO) is a collection of digitised agro topographical maps at scale 1:100,000. The Soil Information and Monitoring System (TIM, since 1992) is an independent part of the Integrated Environmental Information and Monitoring System (KIM), which is under development. It comprises information from 1,200 observation points in both: agricultural (800 points) as well as forest (200 points) environments. Another 200 points are used for ‘hotspots’ studies.

Monitoring: In Hungary, many soil monitoring systems exist for different purposes. The soil fertility monitoring system (AIIR) was established to provide a soil and agronomy database for rational soil management and plant nutrition. It covers about 77% of agricultural area and is realised in 3-year cycles. There is also a Microelement Survey on about 77% of agricultural area, comprising 6,000 soil profiles with 20 elements determined.

Iceland

Soil mapping: Iceland completed a soil map at scale 1:750,000 in 1959. Although soils have been mapped also later in a few localised areas, resources so far have not been put into a systematic detailed soil mapping programme. A preliminary version of the 1:500,000 scale soil map of Iceland is published in the Iceland section in this book. This is a significant development for soil survey in Iceland. A 1:1,000,000 scale soil map was created in 2001 for incorporation into the European Soil Database.

Soil and Land Information Systems: Currently there is no central database for soils but it is planned to establish one. The national erosion and vegetation surveys, as well as the new 1:500,000 scale soil map, have a large amount of associated data, which could become important components of the proposed information system. Iceland has a national Soil Erosion database (ARI-SCS), which is created from about 18,000 polygons.

Monitoring: For the future there are plans to establish systematic monitoring of soil fertility and quality.

Ireland

Soil mapping: Historically, most effort has been put into the production of semi-detailed/reconnaissance soil maps. Detailed, large scale maps (scale 1:2,500) are produced for the experimental stations to underpin various soil research programmes. To date, some 44% of the country has been surveyed using field maps at 1:10,560 scale for soil map publication at scale 1:126,570. The programme of semi-detailed soil mapping was discontinued in 1988. The first small scale map of the soils of Ireland was published in 1969 and a revised and improved version was published at a scale of 1:575,000 in 1980.

Soil and Land Information Systems: There are plans to establish a national land information system containing soil, climate, land use and agronomic data. A considerable amount of data already exists and needs to be brought together in a common information system using modern techniques.

Monitoring: A geochemical survey based on 295 soil monitoring points, covering 22 percent of the land surface, has been started, and soil samples collected and archived. In 1997 a National Report on the concentrations of major and trace elements in Irish soils was produced.

Italy

Soil mapping: Soil mapping activities have increased significantly in Italy over the last few years. It is estimated that 9.5% of the territory has been mapped in detail, *i.e.* at a scale of 1:25,000 or larger. Over 30% has been mapped at scales between 1:30,000 and 1:100,000 and about the same proportion at a scale of 1:150,000. Soil maps mainly at scale 1:50,000 have been produced by many Regional Administrations as a result of systematic soil survey programmes for agricultural purposes. The Ecopedological Map of Italy at scale 1:250,000 was completed in 2001 and published in 2003. This map covers the whole country and has been used to make thematic maps to aid soil management and land use planning.

Soil and Land Information Systems: A first version of the 1:250,000 soil database has been completed for the whole of the country.

Monitoring: There is currently no national soil monitoring system but there is interest in developing one. The Italian National Topic Centre (NTC) on Soil and Terrestrial Environment, promoted by the Italian Environmental Protection Agency, together with some Regional EPA, has enhanced demand for a national soil monitoring network (SMN).

Latvia

Soil mapping: The first generalised soil maps of Latvia were published at a scale of 1:400,000 in 1945 and 1958. After the Second World War, all family farms were nationalised, becoming State or Collective Farms. For each farm, detailed soil maps at scale 1:10,000 were made, showing soil types, texture, land use and soil water conditions. Extensive land reclamation (1972-1976) led to a second soil mapping cycle. Medium scale maps from 1:75,000 to 1:500,000 scale have been created at regional or country level. The most recent is a 1:1,000,000 scale soil map elaborated for incorporation in the European Soil Database.

Soil and Land Information Systems: The main soil archive, involving data from 1959 until now, is at the State Land Service. The Agrochemical Research Centre maintains the computerised Soil Fertility database of Latvian agricultural land - *AGRO*. The Soil Profile Database of Latvia is under development in Latvia University of Agriculture where Latvia's Reference Soil Profile descriptions will be stored.

Monitoring: In the post-war period five cycles of soil fertility testing have been performed. After 1991 systematic soil mapping and fertility testing was stopped at state level. It is now realised on customer basis for selected farms. The Regional Programme for forest monitoring and the Integrated Monitoring Programme also includes soil information. The Agricultural Land Monitoring Programme (1992-2001) is the most complex soil monitoring, which includes 3 levels of observations: long-term observations, agricultural land monitoring in about 190 pilot farms (8,911ha) and land use monitoring at rural level. Geochemical surveys of soils were performed 1996-2000, at 2,547 soil points. In 2002, a new Monitoring Programme of Latvia started after approval from government. It takes into consideration the whole environment and follows national needs and EU directives.

Lithuania

Soil mapping: Soil maps of Lithuania are based mainly on the results of large-scale field surveying. Detailed large-scale (1:10,000 and 1:5,000) maps exist at farm level. At regional level, maps are at the scale of 1:50,000 and at country level at a scale of 1:300,000. Nowadays the land reform programme is ongoing which has necessitated soil mapping at various scales.

Soil and Land Information Systems: Currently, the main problem is the lack of a computerised system for storage and manipulation of the data, and the information is stored mainly as maps in paper form and as manuscripts in archives. A Land Resources Information System of Lithuania (LTlrIS) has been started with FAO support. Simultaneously, a Soil Database of Lithuania (LTdDB) is under construction.

Monitoring: Soils have been investigated at many points and serve as an important source of soil data. Lithuania has soil profile descriptions for about 7,000 points that cover an area of 4 million hectares for both agricultural as well as forest soils. In addition, there are data of the yield from 2,000 experimental sites with different applications of fertilisers on the most representative soils for Lithuania. Soil pollution was also monitored on 2,700 soil samples in the period 1994-1997.

Macedonia, Republic of

Soil mapping: Soil survey and soil mapping originates from the time Macedonia was a former republic of Yugoslavia, thereafter called Former Yugoslav Republic of Macedonia - FYROM. Future plans for the Republic Macedonia are to prepare and digitise a pedological map at a scale of 1:50,000 as well as more detailed soil maps for hot spot locations where soil degradation is present.

Soil and Land Information Systems: There are plans to develop a Soil Information System.

Monitoring: At present, there is no national soil monitoring scheme because of insufficient financial support, so future prospects need to fill this gap.

Malta

Soil mapping: Until recently, Malta did not have a tradition of soil survey, soil mapping and soil monitoring. Nowadays, the newly established National Soil Unit provides systematic soil survey for both the needs of domestic issues and needs coming from the Acquis Communitaire In former soil surveys, Kubiena's classification and soil series concept were used in the process of creating the soil map of the Maltese Islands at scale 1:31,680 (1960). Later reconnaissance survey was performed to identify major soil landscapes according to needs of the European Soil Database at 1:1,000,000.

Soil and Land Information Systems: Significant progress in environment protection and sustainable management of land resources becomes very important from national as well as from a European point of view. The needs for data are oriented towards spatial information on soil physical and chemical properties and compatibility of soil information. In June 2002, the first stage of the Soil Information System for the Maltese Islands: MALSIS LIFE 00 TCY/M/036 was initiated. MALSIS is co-funded jointly by Third countries programme and the Maltese Ministry for Rural Affairs. The first stage comprises 280 sites (1km x 1km grid) in Malta, Gozo and Comino. The aim is national inventory of soil resources according to FAO Guidelines for Soil Description. The second stage (320 sites) is to characterise the small-scale variability of chosen soil properties within landscapes coming out from first stage of soil survey.

M*onitoring:* To date, there exists no comprehensive soil monitoring programme for the Maltese Islands. Areas are currently being selected as primary sites in need of monitoring.

Netherlands

Soil mapping: The Netherlands has a complete cover of detailed soil maps, at a scale of 1:50,000. This particular programme was completed in 1995. In addition, there is a soil map of the whole country at a scale of 1:250,000 and a generalised soil map at a scale of 1:1,000,000. The Netherlands is thus one of the very few countries in Western Europe (EU-15) with soil maps of sufficient detail to respond to enquiries about its soil resources.
Soil and Land Information Systems: All the 1:50,000 soil maps are stored in digital form as is the 1:250,000 scale map. The Dutch soil profile database BIS contains soil data of three different kinds: data from representative soil profiles of the different map units; analytical soil data; and soil

profiles sampled as part of the national stratified random soil sampling programme. With the strong support of GIS technology and extensive development of simulation models this comprehensive soil resource information base can be used to provide inputs to a large number of areas of interest such as pesticide leaching, erosion, soil and groundwater hydrology, acid deposition and crop production.

Monitoring: The National Institute for Public Health and Environmental Protection (RIVM) carries out the National Soil Monitoring and National Groundwater Quality Monitoring Networks. According to purposes the first mentioned comprises information concerning actual quality of soils and its trends and the second performs water quality checks in about 400 localities. Long-term Monitoring of Forest Health is performed every 5 years. The actions in soil data upgrading at national soil information level involve revision of groundwater depth classes, probability sampling according to mapping units (1:50,000) and collection of new data.

Norway

Soil mapping: A programme to map land use at a scale of 1:5,000 was started in the 1960s and a number of soil properties were included, e.g. wetness, depth, stoniness and organic content. Soil maps are also used to evaluate the possible use of sewage waste on agricultural land. Some soil mapping was undertaken at this time but it was mainly geological in nature. Soil mapping *per se* of agricultural land only began in the 1980s and to date about one-third of the arable area has been mapped.

Soil and Land Information Systems: Work began on the Norwegian Soil Information System in the early 1980s. It contains digital maps linked to a soil type database containing soil and terrain properties and a profile database containing analytical data. It has already been used by the Norwegian government to determine ways of reducing soil erosion on arable land. Maps are digitised and data from the monitoring programmes stored in a GIS at the Centre for Soil and Environmental Research.

Monitoring: Norway is part of European Forest Monitoring programme with annual data collection using a 9km x 9km grid. Particular emphasis is given to monitoring changes in the contents of nitrogen, sulphur and heavy metals. There is also a monitoring system based on sampling of the plough layer in agricultural soils.

Poland

Soil Mapping: Soil science in Poland has a tradition dating back to the 19th century. The first complex soil map of Poland, at 1:500,000 scale, was created in 1906. Poland has large scale maps (1:25,000) at district level and maps of agricultural soils at cadastre level (1:5,000). These cadastral maps, so called Classification maps, are updated every five years. The medium scale soil maps include: 1:100,000; 1:300,000 and 1:500,000 scales. Small scale maps have been created according to the needs of many international projects: 1:1,000,000 scale for European Soil Database and SOTER and also for presentation in geographical atlases (scales 1:3,000,000 to 1:1,500,000).

Soil and Land Information Systems: The BIGLEB system was the first complex soil database and its developments started in the 1970s together with soil monitoring. Nowadays the most important soil database is the Geographic Soil Database at 1:1M scale, which is also part of European Soil Database. In 1999, work started on a similar, more detailed database based on data appropriate at the scale 1:500,000, using the same methodology as 1:1M database. Many other soil databases have been created according to different purposes and needs, including flood prediction, soil productivity evaluation, marginal soils, and marsh characteristics.

Monitoring: This is divided into two parts: forest soils and properties of arable soils. Forest soils monitoring is based on 2,000 measuring points and is part of State Environmental Monitoring. Monitoring of arable soils started in 1995 and comprises 216 soil profiles of representative soils. Samples are taken every 5 years.

Portugal

Soil mapping: Systematic soil mapping at 1:25,000 scale, with publication at 1:50,000, began in 1958. The mapping of southern Portugal was completed in 1965 but the completion of northern Portugal has been delayed. Most of the area has been surveyed, but, until now, maps of 55% of Portugal territory have been published and digitised. Maps at 1:25,000 scale are available for about 35% of territory but only as draft versions. Some of these maps have already been digitised. Once the mapping of the north is complete, there will be a good basis for producing a more generalised map at 1:200,000 or 1:250,000. Maps at scale 1:100,000 have been produced for northeast Portugal. The first approximation of the soil map of Portugal at a 1:1,000,000 scale was published in 1949 and the revised version, produced in 1973, has been incorporated into the European Soil Database. A Soil Map at a scale of 1:5,000,000 was published in the 'World Soil Map' in 1990 with FAO soil legend from 1988.

Soil and Land Information Systems: Over the past few years the National Service of Geographic Information (SNIG) has been digitising the CNROA soil maps at a scale of 1:50,000. SNIG has the responsibility for the central soil information system. The data have also been included in the HYPRES database. In the future, a geo-referenced soil database containing both soil descriptions and analyses, linked to a GIS, needs to be developed so that potential users can have easy access to a wide range of information about the country's soil resources.

Monitoring: Soil monitoring is oriented mainly towards soil erosion studies and has a long-term tradition.

Romania

Soil mapping: The first soil map of Romania was published at scale 1:2,500,000 in 1911 and was followed by a map at scale 1:1,500,000 with the new borders of the country after World War I. Soil maps were created for three main purposes: general soil resource inventory, soil mapping of agricultural lands and forest soil mapping. For general purposes, maps at scale 1:50,000; 1:100,000; 1:200,000; 1:500,000; 1:1,000,000 and 1:1,500,000 were created. The most commonly used scale is 1:50,000 and 1:100,000 and these maps cover about 80% of the territory. Mapping soils on agricultural land uses larger scales: (1:10,000 and 1:5,000). Very detailed maps are created at commune or farm level Forest soil mapping is focused mainly on ecological aspects.
Soil and Land Information Systems: Romania has several soil databases, the most important of which are: PROFISOL (Database of soil profiles), Database of the National Integrated Soil Monitoring System and the Pedogeochemical database (1,200 profiles). Nowadays it is important to integrate all soil-connected data into a unique national geographic soil information system for better correlation among different monitoring systems. The plan is to develop an operational and integrated GSIS to cover both districts and communes.

Monitoring: Soil monitoring in Romania started in 1977 and focused on soil quality. It was an integral part of the National System of Environment Quality Monitoring. Since 1992, the new integrated system of soil quality monitoring started for both forest and agricultural soils, following rules of Convention on Long Range Transboundary Pollution. Sampling points, 942 sites, are spread on a 16km x 16km grid. For national level purposes, monitoring on a more detailed grid is necessary, at 4km x 4km for agricultural and 8km x 8km for forestland.

Serbia and Montenegro

Soil mapping: Soil survey in Serbia has followed a national methodology and classification. At municipal level, maps at 1:25,000 scale exist. Medium scale maps are represented by the 1:50,000 map which was created for west and north-west Serbia, Kosovo, Mehotja and the whole area of Monte Negro. In future, the existing research and survey material should be updated and the classification and cartographic units should be identified based on the accepted methodologies and standards coming out from FAO and WRB criteria especially in the construction of medium and small scale maps.

Soil and Land Information Systems: The Information System has been created to store, analyse and present information on agricultural land. Among its functions include uses for agricultural land protection, regulation and utilisation, mainly at municipal level, but it can be used as well as at farm level. This is very important for proper soil use because more than 90% of the territory of Serbia is now in private hands. The data include soil, water, air, geology, geomorphology and climate information together with cadastral information at community and parcel level.

Monitoring: Monitoring of soil fertility, heavy metals and the other harmful substances in soils started in 1992. About 869,000ha were assessed. Later the project was stopped but restarted in 2002 with monitoring of 500 localities (500,000ha). In total this monitoring will cover 2.6M ha.

Slovakia

Soil mapping: The first complex soil map was published in 1973 at a scale of 1:500,000 using the FAO classification system. The second edition of this soil map was printed in 1993 at scale 1:400,000. The WRB classification was used and the map digitised. Large scale soil maps have been created for agricultural land evaluation. The maps at scale 1:5,000 give information concerning soil-ecological units (7 digit code of soil properties) as well as soil regions. Maps at 1:5,000 and 1:10,000 scales cover all the agricultural land, which is 48% of the country. Maps created as special studies are mainly at 1:500,000 scale and include: actual soil erosion, risk of water erosion, risk of wind erosion, compaction and agricultural soil productivity.

Soil and Land Information Systems: The Complex Soil Survey (KPP), undertaken 1960-70, resulted in the creation of a soil profile database containing about 15,000 soil profile descriptions, together with georeferenced, analytical and geological data as well as land management information. AISOP is the computerised version of the database. In 1973, mapping of soil-ecological units began and this led to the creation of the Soil Evaluation Information System, which is permanently updated. It contains soil and ecological information presented in the form of soil ecological units (SEU) as codes of chosen environmental and soil properties. This database for 1:5,000 scale is now in digital form.

Monitoring: Environmental monitoring of Slovakia started in 1993. Soils, both agricultural as well as forestry, represent a part of this monitoring as the Soil Monitoring System. The sampling network consists of 424 georeferenced monitoring sites, of which 313 are on agricultural land and 111 under forest. Sampling frequency is at 5 yearly intervals. There are also Key Monitoring Sites (21) with annual frequency of sampling, which are used for specified research purposes. Monitoring of the influence of the Gabčíkovo hydropower structure on soils and agriculture started in 1989 and has been an important undertaking.

Slovenia

Soil mapping: Systematic soil mapping started in Slovenia in the 1960s at scale 1:50,000, later at 1:25,000. For land use evaluation, a 1:100,000 scale vector map was created. Maps at 1:25,000 scale, now covering the whole country, were digitised and published as DSM25 version. The work was finished in 1999. Several different soil and soil/land related digital maps have been completed with the help of DSM25. These include soil maps with national coverage at scale 1:400,000 and the 1:1,000,000 scale soil map for inclusion in the European Soil Database

Soil and Land Information Systems: Soil data in digital form together with geographical information are stored in the Soil Information System (SIS) of Slovenia. The database was created at 1:25,000 scale (DSM25). SIS includes Soil Profile data (about 1,700 profiles) and Soil Pollution Monitoring data.
Monitoring: The soil pollution monitoring collects the point data of concentrations of several organic and inorganic pollutants in soils. Soil samples are taken at different depths at the density of 2km x 2km for agricultural land and 4km x 4km under forest. In 1998, a project was set up to monitor soil pollution over all Slovenia.

Spain

Soil mapping: Mapping has been undertaken at various scales depending on the perceived needs of the different autonomous regions and communities. These regions have been responsible for much of the mapping in recent years. There has been no central government control. Only a relatively small part of Spain (*ca.*10-15%) has detailed soil maps at a scale of 1:50,000 or larger. Between 20 and 30% of the country has been mapped at scales of 1:75,000 to 1:125,000 and about 50% at scales of 1:200,000 to 1:250,000. The only maps for the whole of Spain are at scales of 1:1,000,000 or smaller. Soil Information at 1:1,000,000 scale has been included in the European Soil Database.

Soil and Land Information Systems: Up to now there has been no central database for the soil resources of the whole of Spain. Different methodologies and soil classifications are used in different regions. Several databases have been developed for various projects, e.g. SEISNET, a first georeferenced soil database elaborated in cooperation with FAO-ISRIC-CSIC, CIEMAT, a Soil Database for critical loads studies. There have also been several regional initiatives e.g. SINAMBA for Andalucia. A further database is the CCMA Digitised Map Library, which contains information about mapping units and soil forming factors.

Monitoring: RESEL, the Experimental Erosion Monitoring and Evaluation Network, is the keystone of the recently approved Spanish Desertification Programme. It is a major erosion-monitoring programme, involving 21 research centres and 41 experimental stations. It coordinates the network of test basins and plots, standardises instrumentation for measurement, in addition to other integrating roles. Soil erosion is also monitored and investigated in the National Inventory of Soil Erosion (INES) using USLE methodology and comprising 20,000 sampling points for whole country. MIMAN is an inventory of all potentially contaminating activities and contaminated sites throughout all the territory of Spain. Soil samples taken from both arable land and pastures in a 8km x 8km grid are analysed for organic matter, heavy metals and other soil components. Soil protection is now one of the most important targets in Spain.

Sweden

Soil mapping: There have been a number of approaches to mapping the soils of Sweden. Agrogeological maps of arable areas at a scale of 1:20,000 have so far been prepared for 3% of the arable land. Geological maps, which include a few soil properties, have been published at a scale of 1:50,000 for about 20% of the country. Quaternary and petrological maps at 1:100,000 and 1:400,000 have been created for the whole country. They reflect also soil properties. Nationwide surveys of forest soils, undertaken since the 1960s, involve surveying and sampling a set of national plots at periodic intervals. A soil geochemical map based on analysis of some 30 major and trace elements has been prepared at a scale of 1:250,000 for 30% of the land. A medium scale map (1:500,000 scale) and small scale maps at 1:1,000,000 and 1:2,000,000 have been prepared at the regional or national level, using ordinary kriging. They reflect many soil properties.

Soil and Land Information Systems: A number of important datasets have been collected in the form of maps, soil analyses and monitoring of both forest and arable soils. Some of these datasets are available on the World Wide Web. Currently environmental surveys are carried out by different organisations and the effectiveness of data collection and data organisation could benefit from a greater degree of coordination.

Monitoring: Systematic soil monitoring in Sweden is provided at national level by several institutions for both agricultural and forest land. The most important are: the Swedish National Survey of Forest Soils and Vegetation at the Department of Forest Soils, SLU (about 76,800 plots), Integrated Monitoring (IM) provided by the Department of Environmental Assessment, SLU, Intensive Monitoring Plots (ICP Forest, Level 2,223 plots) at the National Board of Forestry and Monitoring of Arable Land (3,100 plough layer plots and 1,700 subsoil plots), carried out by the Department of Soil Science, SLU. Currently there is only limited linkage between different datasets because of different methods used, e.g. in agricultural and forest monitoring and these linkages need to be extended and improved.

Switzerland

Soil mapping: Surveys at various scales have been undertaken of agricultural and forest soils since the early 1960s. A plan was formulated in 1977 to map the whole of the national territory with emphasis on the agricultural midlands. This is now an ongoing programme. A national map of Soil Capacity was published at a scale of 1:300,000 in 1973 and 1:200,000 in 1980. A generalised soil map at 1:500,000 was published in 1984. All these maps, as well as 1:1,000,000 scale soil map of Switzerland, represent 85% of total area (100% of land). A medium scale map (1:50,000) of soil capacity was published in 1976 for 6,1% of the total area. Large scale maps at 1:25,000 scale have been produced since 1981 and at present these cover 6,6% of the total area.

Soil and Land Information Systems: Soil resource data are held at FAP and other institutions. A computerised database is planned for improving the organisation and availability of the data. Until now, there is no national office dealing with soil studies at national level.

Monitoring: A control network for monitoring the diffusion of pollutants in the soils of Switzerland (NABO) was set up in 1986 and has been coordinated centrally.

Turkey

Soil mapping: In early 1960s, detailed soil survey and soil mapping restarted. Topographical maps at scale 1:25,000 have been used as base maps and the survey resulted in a 1:100,000 scale map of soil resources at provincial level and a 1:200,000 scale map at river basin level for whole country. About 36% of the total area is cultivated. Suitability for irrigation of the large basins is also included in 1:25,000 scale maps. Soil surveys have been conducted by several Universities, and have included mapping of the Cukurova region of southern Turkey, soils of Thrace and also detailed maps of the State farms.

Soil and Land Information Systems: Detailed soil maps at scale 1:25,000 for the whole cultivated area are now available in digitised form, and these form part of the national database. Nowadays soil studies are oriented to soil protection activities, to soil and water management, to soil fertility monitoring, EIA studies and national soil database creation. NIC, the National Information Centre of Soil and Water Resources, was established to follow these new trends. Digitisation of available soil maps is now complete so thematic maps, e.g. land use, erosion, etc. are now available.

Monitoring: There is currently no national monitoring programme for soils.

United Kingdom

Soil mapping: A formal detailed soil mapping programme began in England and Wales in 1939. Maps have been published at 1:63,360 scale (1939-1966), at 1:25,000 (1966-1988) and 1:50,000 (1988-1994). About 25% of England and Wales is covered by such maps. In Scotland most arable areas have published soil maps at 1:63,360 scale. The detailed mapping programmes for England, Scotland and Wales were effectively terminated in 1987. In Northern Ireland, soil mapping did not begin until 1987, but it is now complete and maps have been published at 1:50,000 scale for the whole area. Consequently, there are now soil maps at 1:250,000 scale for the whole of the United Kingdom.

Soil and Land Information Systems: The Land Information System for England and Wales (LandIS) is a comprehensive database containing soil, climatic and agroclimatic, land use and cadastral information. The soil data sets are comprehensive and include the digitised 1:250,000 National Soil Map, the National Soil Inventory, the National Catalogue of Soils with detailed information on each of the 720 national soil series, benchmark soil profiles, auger borehole and analytical data. Digital forms of the soil maps for both Scotland and Northern Ireland exist together with supporting soil attribute databases.

Monitoring: The National Soil Inventory (NSI) is a programme of sampling and describing the soils of England and Wales on a regular 5km x 5km grid across the two countries. It was undertaken during the National Soil Map programme (1979-1984). Subsequently 900 arable and ley grass sites and 750 permanent grassland sites have been revisited (1995-1996) and samples analysed for pH, organic carbon, P, K, Mg and heavy metals to discover if changes have occurred since the first inventory of 1979-84. In 2002-3 a subset (580) of the non-agricultural sites were re-sampled to complete the exercise. A similar Inventory exists for Scotland but with sampling on a 10km grid. The Soil Survey of Northern Ireland was supported by a soil geochemical survey.

Status of soil mapping in Europe

From this survey of soil mapping, it is clear that relatively few countries have soil maps at detailed scales of 1:50,000 or larger for the whole of their national territories (see Figure 1 & Table 2).

Most of these are small countries that have recently become a part of the enlarged EU. Countries with this complete cover include Belgium, Bosnia-Herzegovina, Bulgaria, Croatia, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Luxembourg, The Netherlands, Romania, Serbia and Slovenia. These countries, mostly small (9 are <70,000km^2, all have areas < 110,000km^2), are in a very strong position with which to address current and future requests for soil information. Austria has mapped 98% of agricultural land at 1:25,000 scale but it is not clear the extent of total national coverage at this scale and 1:50,000scale.

However, some of the mapping dates back thirty or more years, since which time systems of classification have changed. Some updating of this mapping will need to take place in some cases.

Bulgaria, Cyprus, Estonia, Latvia Lithuania, The Netherlands, Romania, Switzerland and the UK are the only countries to have a 1:200,000 or 1:250,000 scale maps of the whole of their national territories though a few others could readily achieve this given their complete detailed mapping cover (Figure 2).

Virtually all of the countries, whose soil mapping is described in this book, have prepared national maps at scales of 1:500,000 or 1:1,000,000, mainly in response to the requirement to develop the 1:1,000,000 European Soil Database. Nearly all countries have conducted soil surveys of small areas at 1:10,000 or larger scales for special purposes.

The Country Reports in the chapters that follow provide a unique overview of the state of soil mapping in each of the countries of the enlarged EU and neighbouring countries. Two important facts emerge:

- Only about 20% of the enlarged EU and bordering countries have a complete cover of detailed soil maps at scales of 1:50,000 or larger.
- Only about 30% these countries have a complete cover of soil maps at 1:250,000 scale.

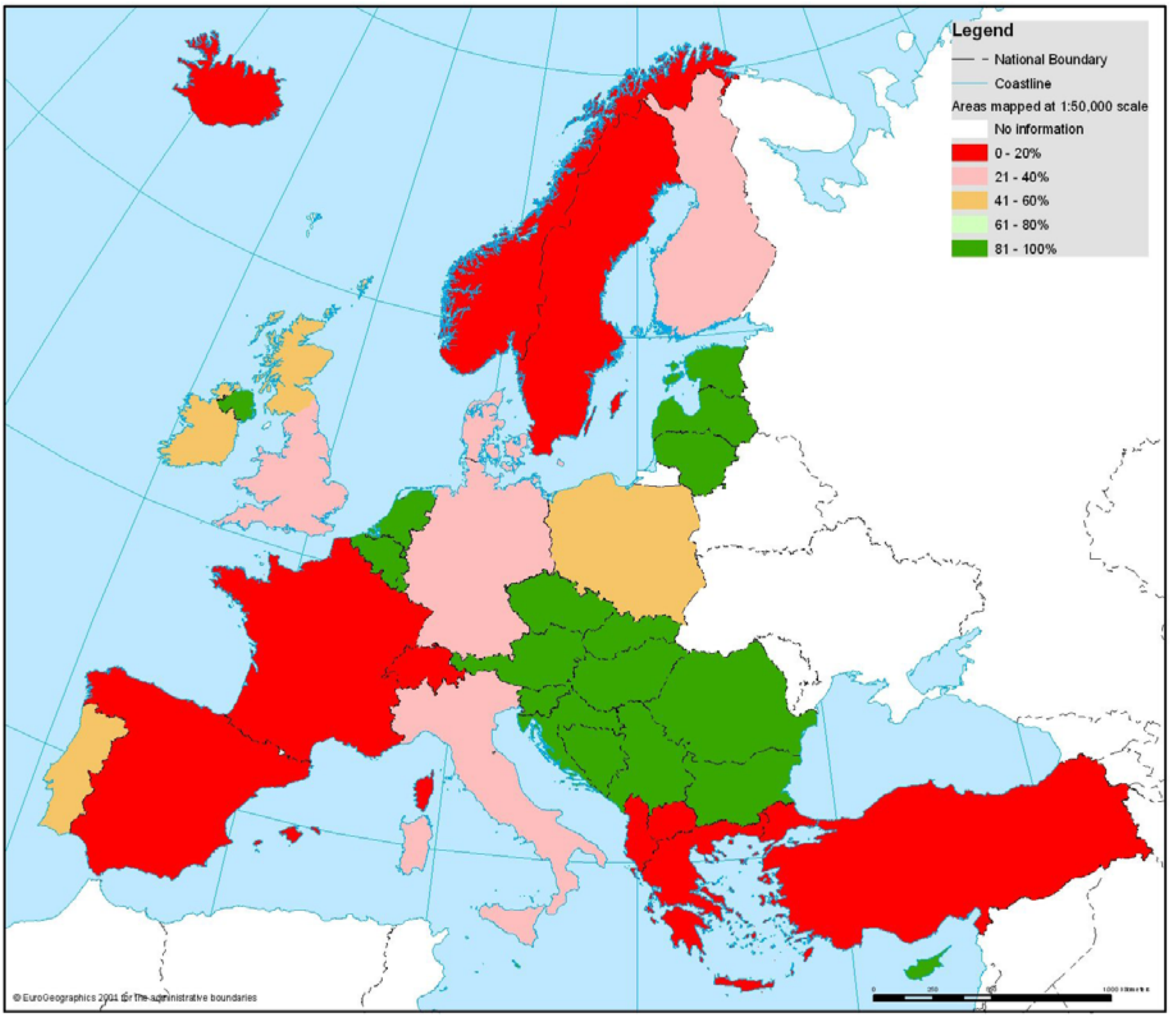
In addition to major reductions in funding by central Governments, one of the major problems in organising national soil mapping programmes has been the transfer of responsibility from central soil survey and research organisations to regional groups and/or private sector organisations. This introduces a number of difficulties, particularly a lack of uniformity in approach and methodology used, proliferation of different soil classifications, a lack of availability of the information after surveys have been completed and difficulties in harmonising the information at national and continental levels.

Although several of the EU and bordering countries have made some progress with mapping soil resources since the last report (Bullock, 1999), many countries still lack a coverage that could adequately support the wide range of demands for soil information that will undoubtedly emerge in the current century.

Table 2 Details of national soil mapping programmes and inventory or monitoring systems

Country	1:250,000	1:50,000 to 1:25,000	1:10,000	Number of Sampling (Inventory or Monitoring) sites
Albania	100%		28% (farms) at 1:5K	
Austria		63-98%	10% F, 63% A 20% 1:5K	514 F plots (grid 8.7 x 8.7km), 5,000 F soil profiles, 26,000 analyses BORIS; 432 agri monitoring points; soil assessments data – 32% Environ. Soil survey 5,000 F + 2,500 A
Belgium	100%	100%	100%	15,000 soil profiles =+ analyses
Bosnia Herz		100%		
Bulgaria	100%	100%	90%	50,000 main soil profiles
Croatia		100%		6,000 soil profiles
Cyprus	100%	100%		Nitrate monitoring (1:250,000)
Czech Republic	100%	100%	100% 100%, at 1:5K,	30,000 soil profiles 200 permanent monitoring plots, 500 forest monitoring
Denmark	100%	A	In prep	8,000 soil profiles, 7km x 7km grid survey; 393 HM monitoring
Estonia	100%	100%	100%	10,000 soil profiles; various monitoring programmes
Finland	In prep.	30%		28,000 texture, 80,000-100,000 samples (for farmers) 2,000 monitoring sites (pH, C, Ca, Mg, K, HM)
France	30%	Incomplete	case studies	ICP Ft (16x16 km, 540 plots); some monitoring
Germany	30% (1:200K)	Incomplete	case studies	
Greece			case studies	3,000 sites for fertiliser monitoring
Hungary	100%	100%	70%	1,200 points (800A + 200F + 200 hot spots)
Iceland				75% vegetation maps at 1:40,000 & 1:25,000, soil erosion databases for 1:100,000
Ireland	100%	44% at 1:126K		295 soil points (22% of country)
Italy	100%		case studies	
Latvia	100%		100% of farms	2,547 points (5km x 5km); various monitoring projects
Lithuania	100%		farm level	7,000 profiles (analytical data A + F); various monitoring projects
Luxembourg	100%	100%		
Macedonia				
Malta		100%		MALSIS: 280 points (1kmx1km) 1st stage; 240 Malta+60 Gozo 2nd stage 350 profile data, 800 soil samples data
Netherlands	100%	100%	55% groundwater table	various monitoring projects
Norway				9km x 9km grid F
Poland		district level		2,000F, 5,700A, 1,000 mineral soil samples 216 arable soil profiles
Portugal	100%	35%	case studies (irrigation)	800 soil profiles described 100 soil profiles analysed 80 soil profiles for hydraulic properties; soil erosion monitoring
Romania	100%	80% A	20% A	soil survey (A) at scales 1:10,000 & 1:5,000) forest survey at 1:50,000; database of land units soil quality A & F – grid 16x16km (942 profiles=670A + 272F) PROFISOL 4,200 soil profiles (16kmx16km) 1,200 profiles for pedo-geochemical database,
Serbia	100%		Case studies	Agriculture and water research-42,000 sq km; some monitoring
Slovakia	100%		100% 100% at 1:5K,	18,000 soil profiles + analyses 330 monitoring points (A) 280 monitoring points ((F)
Slovenia	100%	100%	1:5K for urban soils & on GIS	1,700 soil profiles+analyses; pollution monitoring (2kmx2km A.; 4kmx4km F), 1kmx1km in polluted areas
Spain	50%	15%		453 soil profiles; 2,000 data (critical loads studies) erosion studies 20,000 points; contamination: 1,200 samples from pastures; +2,600 samples from arable land
Sweden		1% A		ICP Forest soil monitoring (no. of sites not known)
Switzerland		7%		Some monitoring
Turkey		A (for irrigation)		
United Kingdom	100%	30%	case studies	6000 soil profiles + analyses; 9,000 national soil inventory points (5km x 5km); 6,500 analyses; 2,200 monitoring sites

A – agricultural; F – forest ; HM – Heavy Metals; 1:5K – 1:5,000



(includes soil surveys at scales 1:65,000 to 1:20,000 map production by Jean Dusart

Figure 1: Availability of detailed soil surveys at 1:50,000 or 1:25,000 scale in the EU and bordering countries

Development of Soil and Land Information Systems

In the past two decades there has been increasing acceptance of the need to organise the soil resource information of a country into a Soil/Land Information System so that it can be more readily available. Most countries have accepted this need but, as with soil maps, there is a large contrast in terms of development of such systems across Europe.

A European Soil Information System

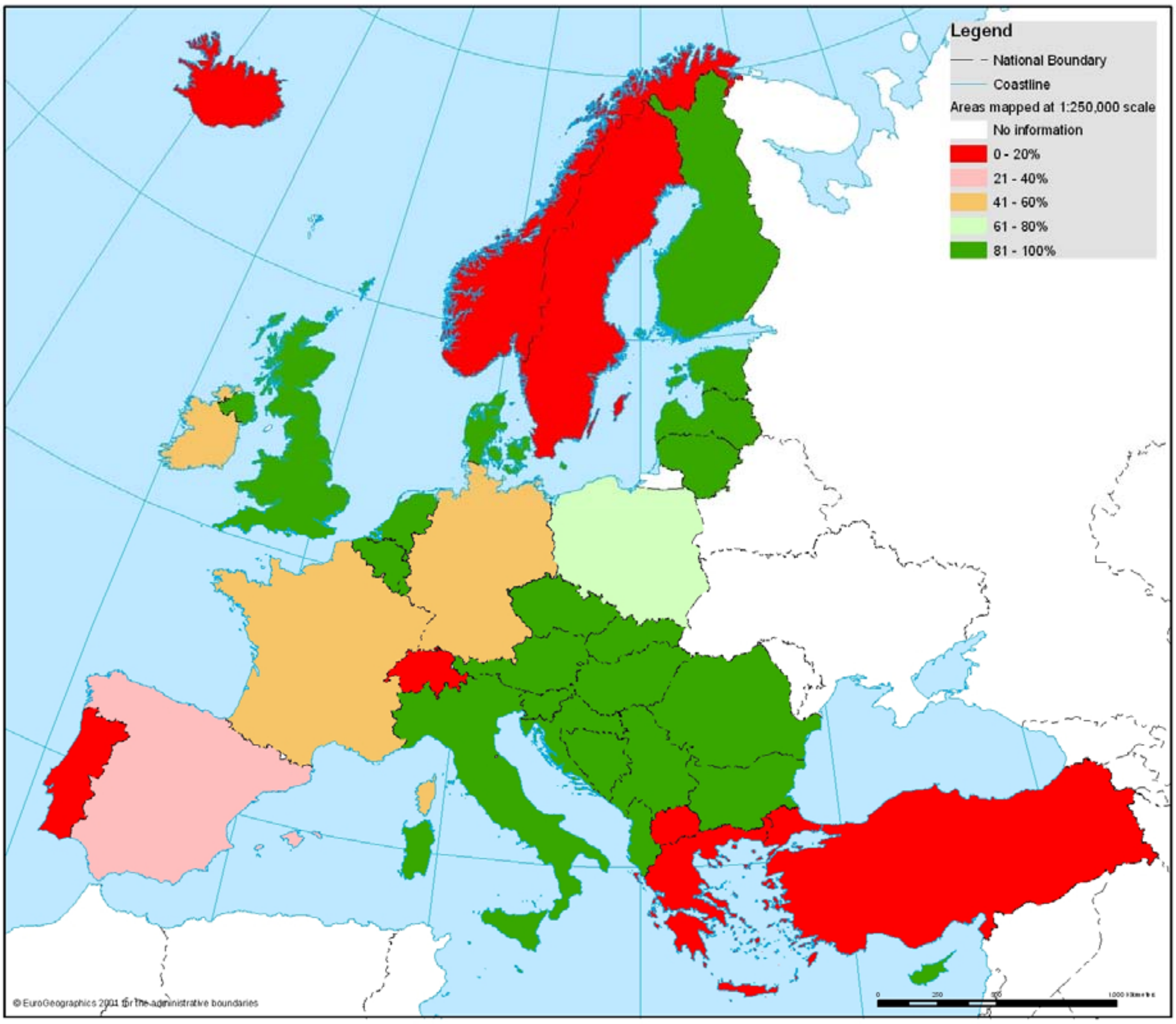
Soil and land information systems vary across the European countries. They range from essentially simple databases containing soil profile and analytical data to well developed integrated computerised systems containing climatic, land use and cadastral information as well as soil data. The capabilities of these systems range from purely storage and retrieval of data to integrated dynamic modelling using GIS technology for evaluating current and future policy requirements at national and regional scale.

The most advanced systems within Europe seem to be those of Austria, Bulgaria, the Czech Republic, France, Hungary Germany, Netherlands and the UK The Austrian system is a good example of one built from the outset to take in a large variety of data from many different sources.

The Dutch system, having the benefit of a digitised set of detailed soil maps for the whole country and associated descriptive and analytical data, is

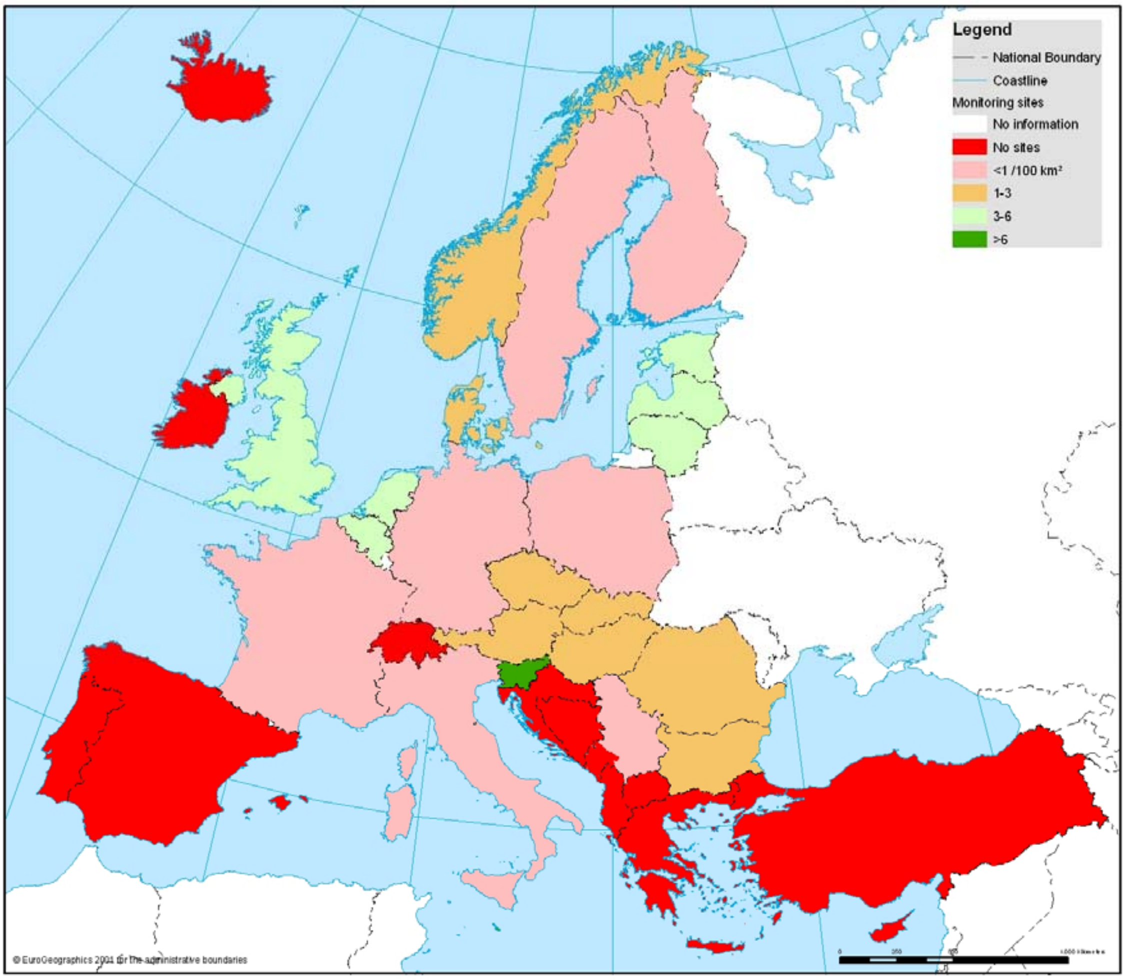
strongly linked with GIS technology and a range of simulation models so as to be able to respond readily to a whole range of topical issues. Slovenia has a similarly based system developed more recently. The UK (England and Wales) system is a good example of one that from its inception had a very flexible design based on relational database technology and at an early stage in its development combined climatic, land use and topographic data.
Many of the countries that have recently entered the EU have large amounts of data about soils but until now have lacked the funding and technology with which to develop such systems. Since 1999, when there was a review of databases in the then countries of the EU, progress has been made in the development of soil and land information systems. The European Soil Bureau has provided an important stimulus in this development.

Computerised information systems are now capable of producing sophisticated graphical output but it is important to appreciate that the outputs are only as good as the input data, and for at a number of the European countries this is inadequate for decision making because less than 50% of the area has sufficiently detailed soil maps.



(includes soil surveys at 1:200,000 and 1:300,000 scale; map production by Jean Dusart)

Figure 2: Availability of 1:250,000 scale soil surveys in the EU and bordering countries



(map production by Jean Dusart)

Figure 3: Soil monitoring sites in the EU and bordering countries calculated in the basis of total land area, excluding water

Monitoring Changes in Soil Quality

Monitoring is now a vital component, alongside soil maps and databases, in the quest for information about the soils of a particular region or country. The monitoring activities reported here are summarised on a country basis (Table 2) and the numbers of sites per $100km^2$, calculated on the basis of total land area excluding water bodies, are shown in Figure 3. From the information given in the country reports, it is not possible to draw a clear difference between inventory sites, e.g. grid surveys, and true monitoring sites that are visited and sampled periodically. The results presented here will undoubtedly have included some grid-based inventory sampling, but with georeferencing, virtually all these sites could potentially be used for monitoring soils in future.

The importance of a monitoring programme is that, if well constructed, it can provide information about how soils are changing with time and can be used to answer questions about whether the quality of a soil is improving, deteriorating or staying about the same under a particular use and management practice.

It is also the chief means of identifying the nature of contaminated land, effects of trans-boundary migration of pollutants and the extent and form of land degradation.

Within European countries, monitoring is usually carried out by a number of different organisations, not just those responsible for soil survey. This is because the reasons for establishing monitoring programmes can be very varied, e.g. forest health, land contamination, fertility of agricultural land, environmental risk assessment, effects of acid rain, land degradation.

However, in most cases soil survey organisations are involved in helping to establish monitoring programmes, relating the monitored components to soil type. The latter is particularly important for distinguishing between natural and man-made effects. It is also essential that monitoring programmes are linked to the national land/soil information systems so that the results can be progressively incorporated into these systems.

This will also allow the results of the monitoring programme to be interactive with other data about the soils of the monitored area and also to benefit from being able to interact with ecological, land use, climatic, cadastral and demographic databases in the Information System. It is particularly important that information collected is not isolated from all the other information about soils, their use and management.

The national reports presented here confirm that many countries in Europe have established monitoring programmes for soil (Figure 3). Some of these programmes, such as the ECE/ICP Levels I and II Forest Health monitoring scheme, are Europe–wide (Vanmechelen *et al.*, 1997; van Ranst, *et al.*, 1998) but most are national and some are regional. Often regional schemes are carried out without reference or linkage to others in the same country. In some countries such as Austria, the Czech Republic, France, Finland, Hungary, Latvia, Lithuania, Netherlands, Romania, Slovakia, Slovenia, Sweden and the UK monitoring schemes are both extensive and intensive.

Most of the countries of the European Union and the Neighbouring Countries have made soil geochemical surveys. Monitoring of soil erosion is undertaken also in a number of other countries e.g. Spain and Portugal. Slovakia has undertaken major environmental impact assessment by monitoring of the effect on soil of hydropower installations. The Netherlands conducts a National Groundwater Quality monitoring programme. Most countries have one or more monitoring programmes directed to specific issues. Further information about monitoring programmes and their results are published from time to time by the European Environment Agency (EEA) (see, for example, EEA, 1995; 1998).

Together these monitoring programmes represent a considerable body of information about European soils. Given this and the considerable costs involved, it is essential that the information obtained be as widely available as possible. In Sweden, for example, information from monitoring programmes is available on the Internet.

The main problem at present is the lack of harmony in the soil monitoring programmes as noted by the European Environment Agency (EEA, 1998). The EEA quite sensibly calls for harmonised soil monitoring programmes to be established, 'similar to those for air and water, and geared to assessments of the state of the soil over large areas, covering a number of parameters'. The EEA also concludes that monitoring systems have so far been designed mainly for specific research purposes or specific objectives such as heavy metal and sewage sludge control or agricultural nutrition programmes, and are rarely well integrated with other survey activities.

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Section 2: Country Reports

Section 2: Country Reports **35**

Soil Survey in Albania

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Introduction

The history of soil survey investigations in Albania dates back to the late 1930s when the first book on the soils of the country was published (Zavalani, 1938), but it was only after the Second World War that soil surveys really began. During the centralised economic and political system that lasted until the early 1990s, soil surveys were conducted regularly throughout the country. Initially, it was the Soil Science Department at the Agricultural University of Tirana that carried out these activities and then the Soil Science Institute (SSI) of Tirana, founded in 1971, took the lead. The latter is under the Ministry of Agriculture and Food (MAF) and is the only Institute in the country specialised in soil science.

Until the early 1990s, the Soil Science Institute was very well organised, operating throughout the country, and conducting pedological surveys and fertility tests all over the agricultural land. Other activities included soil fertility and plant nutrition, drainage and irrigation research, soil microbiology studies, erosion control, and topographic surveys. There were 26 districts at this time in the country, each of them having its own soil laboratory and a small specialised staff, among them one general soil scientist and one soil chemist. The Institute provided scientific and technical guidelines for the 'district soil offices', even though their management was handled by local administration.

With the dawn of political changes and privatisation of the economy, commencing at the beginning of the last 1990s, the scientific institutions of the country went through drastic changes and setbacks. Compared with the year 1990 the Soil Science Institute had experienced almost 70% reduction of its staff. The district soil offices were non-existent and few soil analyses were being made for the arable land. To overcome this situation an effort was made to rehabilitate the National Soil Laboratory at the SSI offices in Tirana. This was fully supported by a grant of the United States Agency for International Development (USAID) in 1998. At present this Laboratory is fully operational and can provide soil, water, plant and fertiliser analyses for major properties.

Soil Mapping

The first national soil map at scale 1:200,000 was compiled in 1958 (Veshi and Spaho, 1988). This was followed by intensive soil surveys, especially during the period 1971-1991, when detailed soil maps from 1:10,000 to 1:50,000 scale, along with soil reports, were prepared for each former agriculture co-operative, state farm and district. In addition to the arable land, soil surveys covered also natural pastures and forests, though the intensity of soil sampling was less detailed than the arable land. This indicates that soils have long been considered to be an important part of agricultural development.

After the political change, soil survey and mapping was reduced drastically. Except for minimal surveys made by the Soil Science Institute, no other mapping was made until the mid 1990s when the USAID sponsored a national assessment of soil resources (Zdruli, 1997a). Another achievement was reported in 1998 when for the first time an Albanian soil data were introduced into the Soil Geographic Database of Europe at scale 1:1,000,000, sponsored by the European Soil Bureau (ESB) at DG-JRC Ispra.

This was followed in 2001 by a more detailed soil survey, under the INTERREG II Programme sponsored by the European Commission and the Italian Government, aiming at the creation of a national soil database at 1:250,000 scale (Figure 1) and another much more detailed soil database for the coastal areas of the country at scale 1:50,000 (Zdruli *et al.*, 2003). The ESB was the technical coordinator of this project and the Mediterranean Agronomic Institute of Bari the implementing institution.

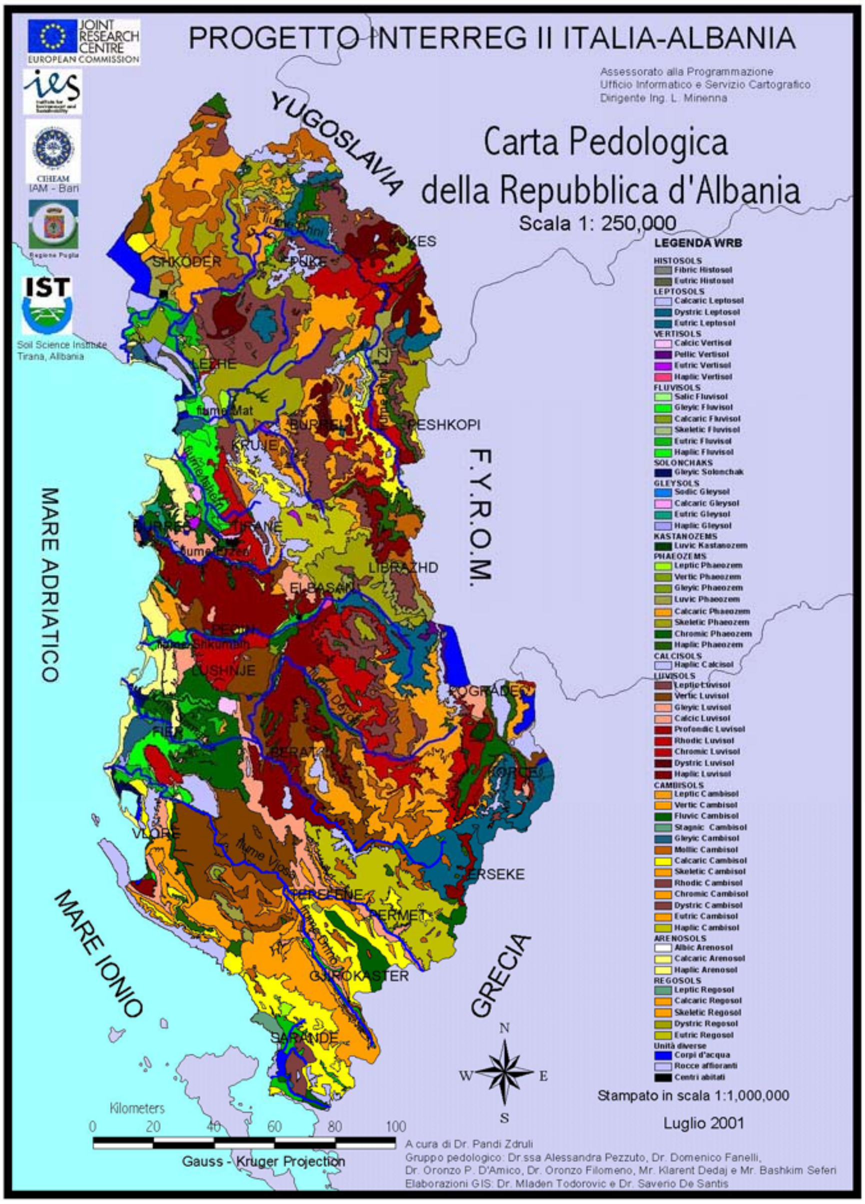

Figure 1: Soil map of Albania at scale 1:250,000 according to WRB

This greatly advanced soil surveys in Albania and put the country at a high European standard, being the only one in Europe at that moment to have completed a national soil database according to the ‘Georeferenced Soil Database for Europe’ Manual of Procedures-Version 1.1. (ESB, 1998, 2000) prepared by the Scientific Committee of the ESB.

Soil Classification

The national soil classification system and methods of soil resource inventory in Albania were developed locally with minimal inputs from the outside world. The system itself was a surrogate of the Russian system of soil classification. Due to the size of the country and particularly, to the extent of arable land, the Albanian system served its purpose. It provided the first assessment of land resources and helped to make decisions on fertiliser use and land reclamation projects. However, modern soil science concepts were not used and the translation to other systems, such as the FAO Legend (FAO-UNESCO, 1974), World Reference Base for Soil Resources – WRB – (FAO, ISRIC and ISSS. 1998), and USDA Soil Taxonomy (Soil Survey Staff, 1998) proved difficult.

The first attempt to convert the national system of soil classification into other well-known systems was undertaken between 1994 and 1997. Zdruli

(1997a) provides the following soil orders of Soil The second major study (Zdruli *et al.*, 2003) conducted in 2001 revealed the distribution of soils according to the WRB (Figure 2). The Albanian pedological landscape is very diverse and complex. The lower coastal area of the western part of the country was mainly formed during the Quaternary period by the fluvial activity of several rivers flowing to the Adriatic and Ionian Seas. The dominant soils are Cambisols, Luvisols, Fluvisols, and Phaeozems, associated with Vertisols, Solonchaks, Gleysols, Arenosols, Histosols and Calcisols.

Taxonomy for Albania (Table 1).

On the eastern side of the coastal flatlands extends the hilly area covered by Mediterranean shrubs, typically Macchia Mediterranea with cultivation of olive groves, vineyards, and fruit trees. Soils are moderately deep, but highly eroded and mismanaged, particularly by overgrazing. Luvisols, Cambisols, and Calcisols are the most extensive. Mountains are spread throughout Albania from the Alps in the north to the central and southern areas. At lower altitudes, pine, beech, and oak forests predominate whereas the highest elevations are mainly just bare rock. Above 2,000m a.s.l. alpine meadows occur.

Table 1. Classification of the soils of Albania according to USDA Soil Taxonomy

Soil Taxonomy orders	ha	%
Histosols	3,978	0.5
Vertisols	58,542	2.0
Mollisols	208,402	7.0
Alfisols	498,670	17.0
Inceptisols	1,015,951	35.0
Entisols	164,613	6.0
Miscellaneous	924,640	32.5
Total land and water area	2,874,796	100

(photo: P. Zdruli, 2000)

Photo 1: Typical landscape of the interior valleys in Central Albania.
In the foreground the deep alluvial/colluvial soils formed by fluvial and erosion activity are seen. In the background, hills and mountains with shallow eroded soils occur. The upper elevations are almost bare of any vegetation.

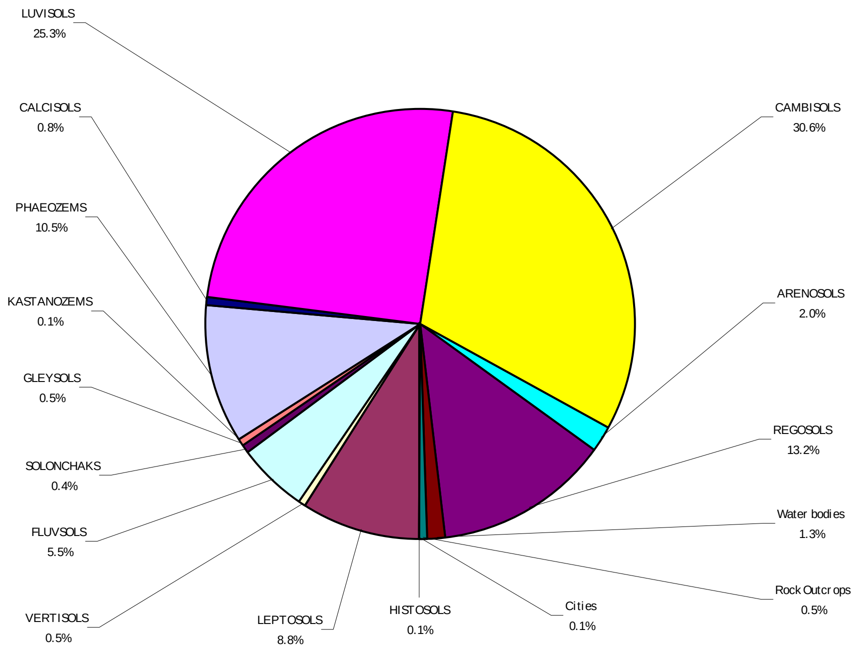

Figure 2: Distribution of soils according to the WRB

Use of Existing Soil Data

Land evaluation of agricultural potentials

Based upon the soil data accumulated during the period 1970-1988, the Soil Science Institute in Tirana began in 1988 a Physical Land Evaluation Study for all the agricultural land of the country. The main soil characteristics used for this land evaluation exercise were soil depth, thickness of the humus horizon, organic matter content at 50cm depth, available phosphorus, texture, and available moisture content of the topsoil. Soil acidity, alkalinity, salinity and the presence of stones are main soil constraints in Albania. Relief is a determining factor for agriculture; therefore slope threshold values were an important part of the evaluation process. Finally, climate determined the ultimate value of the land. Socio-economic factors were not considered in this study.

At the end of the study all the agricultural land was divided into ten classes. Land class 1 is the best for agriculture crops while class 10 is the worst. Integral parts of this study were the preparation of several land evaluation maps, which show the classes of land for each farm, district and the entire country. The western coastal field areas, occupying about 250,000ha, have been identified with the best land classes, which have good potential for intensive agriculture. Classes 1 to 4 occupy nearly 75% of this area. Factors of soil formation, physical landscape and generally similar climatic conditions are the main factors influencing the high land values. Hilly areas occupy roughly 220,000ha. These areas, along with the interior valleys, belong to a variety of land classes, though classes 4, 5 and 6 are dominant. The main reason for the decreasing land values in the hilly zone is slope. Mountain areas covering about 80,000ha include the lowest ranking land classes due to steep slopes and severe climatic conditions (Kaleshi *et al.*, 1992).

The most important soil constraints, such as salinity (about 10,000ha), textural class, soil depth, alkalinity (about 60,000ha) in the western coastal area, and acidity in about 70,000ha mostly in the north-eastern part of the country, were also identified. Possible interventions to mitigate the negative effects of these constraints may increase the land values by one or two classes.

Land use assessment

A first attempt to prepare maps for actual land use and potential land use planning was done by Zdruli (1997b). This was followed by two EU sponsored projects in 1997 and one in 2003. The latter is still in progress and the results are still to be reported.

Zdruli (1997b) reports the distribution of arable crops mainly in the coastal area and the interior valleys; fruit trees, olive groves and vineyards in the hills; and pastures along with forest at the higher elevations.

Under the current conditions, because agricultural land in Albania is high fragmented, the implementation of large-scale projects on land management is almost impossible. One approach to the issue of land consolidation, and sustainable land use planning, is the development of land use policies for single or similar groups of crops to be cultivated in suitable agro-ecological regions. These methods, in a sense, will overcome the obstacle of small land holdings because it will be one or few crops to unify large areas and thousands of farmers. This depends though, on investments and particularly on local and regional markets.

Fertiliser use

The history of fertiliser use in Albania began in the early 1970's with the construction of two factories, one for nitrogen and another for phosphate fertilisers. The impact on agricultural production was immediate and was reflected in the doubling of the yields of major crops over a short period.

The main fertilisers used were ammonium nitrate, urea, single super phosphate and potassium chloride and sulphate. Fertiliser use was rather stable during the period 1985-1990 but declined notably in 1991 to about 33% (Thompson and Xia, 1992) of the average consumption during the previous six years. These declines resulted from the break-up of agricultural cooperatives and state farms, disruption of fertiliser distribution, lack of credit for fertiliser purchases, and relatively slow land reform.

The US-based non-profit International Centre for Soil Fertility and Agricultural Development (IFDC) is assisting Albania in restructuring its fertiliser production and input markets through the support for local dealers that replaced the governmental controlled enterprises of agricultural inputs operating during the old regime. Since 1995 fertiliser imports along with other inputs have increased greatly and continue to provide the greatest stimulus to the increase of agricultural production. It is important to emphasize that the efficiency of fertiliser use has improved significantly since the collapse of the centrally planned economic system. In addition, soil data play a crucial role when establishing the nutrient balance of soils, crop yields and the need for fertilisers.

Natural resources conservation and management

It is estimated that in Albania, in only one year, erosion washes away 1.2 million tons of organic carbon, 100,000 tons of nitrate salts, 60,000 tons of phosphates, and 16,000 tons of potassium salts (Laze and Kovaçi, 1996), while the total amount of fertilisers imported or produced by local industry is far less. Other studies (Qilimi, 1996) show that soil fertility is decreasing mainly because of reductions in organic matter content, nitrogen, and potassium compared to 20 years ago, resulting in nutrient mining of the soils.

Zdruli and Lushaj (2000) report accelerated soil erosion, deforestation, overgrazing, soil pollution, re-salinisation, acidification, water logging, flooding, urbanisation and soil sealing, nutrient mining, and loss of soil fertility as perhaps the most alarming environmental problems in Albania. The basis for making these assessments remain the old and recent soil data supported by the use of a Geographic Information System (GIS) and fieldwork.

While the legal status and institutional strengthening for the conservation of natural resources is making progress, the most constraining problem remains law implementation and enforcement. Deterioration of the forests and natural pastures is the most visible example of such effects. The agricultural land in Albania is a finite resource and there are no areas remaining where the cropland could expand. Many mistakes were made in the past by converting natural pastures and forests to cropland and the negative results of such actions are well known throughout the country. (Zdruli *et al.*, 1997b; 1998).

Future Perspectives

The most striking process that happened in Albanian agriculture after the political upheaval was the change in land ownership. There were about 550 agricultural co-operatives and state farms until 1990 managing all the agricultural land (about 700,000ha) of the country. The picture in 2001 shows the agricultural land being distributed among about 450,000 farm families averaging 1,3 hectares per farm or 0,25ha per person distributed in 1.8 million parcels, often far from each other (Civici, 2001).

This is the greatest 'revolution' in the modern times of Albania with respect to private land ownership. The process has gone on (and is still going on) with controversies on the way in which this privatisation was implemented.

From the soils' prospective, the change in land ownership has brought to difficult times in keeping the link between the thousands of newly created farmers and the corresponding governmental institutions. Even though many farmers recognise for instance, the importance of soil fertility and land conservation, few of them would consider paying for a soil survey investigation on their land.

Consequently, the opinion of the governmental structures remains that public funds or international donors should sponsor soil survey programmes. This becomes a priority especially with the pace of increase in land degradation and environmental damage of Albania's natural resources.

In many areas, Albania is blessed with fertile soils, but the total amount of arable land is finite and may not be able to support the increase in population expected in the coming years. At present, the country relies heavily on agricultural imports, which could make it vulnerable to local or regional crises, putting food security at risk. To reduce the misuse of land and enhance sustainable land use and management in Albania, a soil protection policy should be developed and implemented, addressing the following:

1. Detailed land resource assessments;
2. Monitoring of land and water quality;
3. Awareness among land users regarding environmental protection;
4. Support (extension) services to assist land owners and users;
5. Implementation of sustainable land use and management practices;
6. Drafting a national natural resource management and land use policy.

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Soil Survey and Soil Data in Austria

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Introduction

There are three principal systems of soil survey in Austria: on forested land the Forest Soil Survey, on agricultural land, the Soil Taxation Survey and the Soil Management Survey. In addition, there is an Environmental Soil Survey, a Soil Monitoring System and a Soil Information System (BORIS). Each of these is described below.

Forest Soil Survey

Forest Site Mapping

Major efforts to map forest sites started in the late 1950s and early 1960s, carried out mainly by the University of Agricultural Sciences in Vienna, the administration of the government-owned forests (Österreichische Bundesforste) and the Federal Office and Research Centre for Forest (BFW).

Today, the main emphasis is concentrated on site classification, with site mapping limited to local projects. These local projects are carried out by various organisations of governmental and private forest administration. BFW acts as service unit for harmonisation, quality control and training.

Methods and Output

Forest site mapping in Austria uses the 'combined method' developed in Baden-Württemberg (Kirschner and Schlenker 1955) with some minor variations. The method takes into account climate, soil (geology) and vegetation characteristics in site classification. The goal of mapping is to delineate ecologically-based site units that are locally valid and fit into a hierarchical framework (groups of sites, growth districts, altitudinal zones and growth regions).

Vegetation type, growth data, and soil characteristics, supplemented by chemical analyses (pH value, C_{org}, N_{tot}, nutrients, CEC, base saturation), are identified on plots selected to be representative of the entire range of the sites in the area to be mapped. The plots, which may be arranged in a grid, a transect covering important gradients or distributed randomly in pre-stratified areas, are used to define the site units of the proposed mapping area. Based on these investigations the site units are classified and from this classification is developed the key for mapping the units. Mapping of soil indicators is carried out using a 1m soil auger (1-4 samples per hectare).

Recently a working group of all involved organisations has completed a guide for forest site mapping in Austria, considering new developments and modern techniques e.g. GIS, use of databases, IR-aerial pictures and multivariate statistical analysis (Englisch and Kilian, 1998). Currently, a database (‘METAMAP’) containing meta-information on methods, area mapped, data availability etc. is being set up. Up to now, about 400,000ha, i.e. approximately 10% of forest land has been mapped, predominantly at scales of 1:10,000 and 1:25,000.

Mapping has been focussed on state-owned forest land (mainly the federal provinces of Salzburg, Upper Austria (southern part) and Styria, the floodplain forests of the Danube, the Vienna Woods and North-Eastern Styria. Additionally, the BFW has carried out site classifications in most of the 21 forest growth regions in order to provide a basis for local mapping projects.

Application of results

Forest site maps have been instrumental in the selection of tree species and are thus part of the forest management. In addition, they serve in understanding ecological changes (e.g. to identify changes of the water regime of sites after construction of power stations), as a basis for local forest amelioration and can be used for scientific purposes (e.g. selection of trial plots).

Recently, site classification and mapping has been used for environmental planning, as a basis for the assessment of biodiversity, for nature conservation, and for wildlife management, amongst other uses.

Forest Soil Monitoring

In Austria, there are two schemes for forest soil monitoring. In the late 1980s the *Forest Soil Monitoring System* (FSMS) was started by the BFW as part of the *Forest Damage Monitoring System* in order to obtain information on the causes and effects of forest die-back. The FSMS consists of 514 plots arranged in a grid of 8.7km x 8.7km. At each plot, growth measurements and vegetation relevés, site and soil description, chemical analyses of soil and foliar samples are carried out and crown defoliation class is assessed.

Soil and site descriptions and soil analyses (pH-value, C_{org}, N_{tot}, nutrients (‘total’ contents in aqua regia, cations in $BaCl_2$-solution), carbonate content, CEC, base saturation, heavy metals, texture analysis) were carried out between 1987 and 1990. Soil samples, including soil organic (ectorganic) horizons, were taken at predefined soil depths (0-10cm, 10-20cm, 20-30cm, 30-50cm). About 140 plots are included in the European-wide level I ECE/ICP forest soil monitoring network. Repetition of soil sampling is planned.

Additional forest soil monitoring networks were established in several Federal Provinces (Länder), including Lower Austria, Salzburg, Tyrol and Vorarlberg. All plots of the *FSMS* and of the regional networks were included in the combined report on soil conditions in the countries of ARGE Alp and ARGE Alpen-Adria (Huber and Englisch 1997).
The main results of these projects indicate moderate regional forest soil acidification, wide-spread heavy metal pollution (Pb, Cd), which peaks at the northern fringe of the Alps and varies with increasing altitude, and accumulation of nitrogen.

Another 20 plots are part of the level II /ECE/ICP intensive soil monitoring network, which was established in 1994. Intensive soil sampling (5 samples as a mixed sample of 8 subsamples in the upper soil horizon, 4 samples as a mixed sample from 4 subsamples in the lower soil horizon) is carried out in soil organic (ectorganic) horizons and mineral soil horizons at predefined depth intervals of 0-5cm, 5-10cm, 10-20cm, 20-40cm, 40-80cm. The same methods of soil analyses as in level I are used. The aim of the intensive monitoring is to assess soil changes with time.

Forest Soil Database

The largest forest soil database (GEA) in Austria is managed by BFW. It includes descriptions of about 5,000 forest soil profiles and about 26,000 analyses of individual soil horizons (standard suite of analysis: compare FSMS). It is planned to enlarge this database to become a general forest-site information system.

Applications of Forest Soil Data

Forest soil data are principally used for site mapping, for the protection of forest soils and forest ecosystems (mainly in relation to heavy metal pollution, acidification, nitrogen input), ground water protection and environmental planning, for forest amelioration and fertilisation, and for scientific purposes.

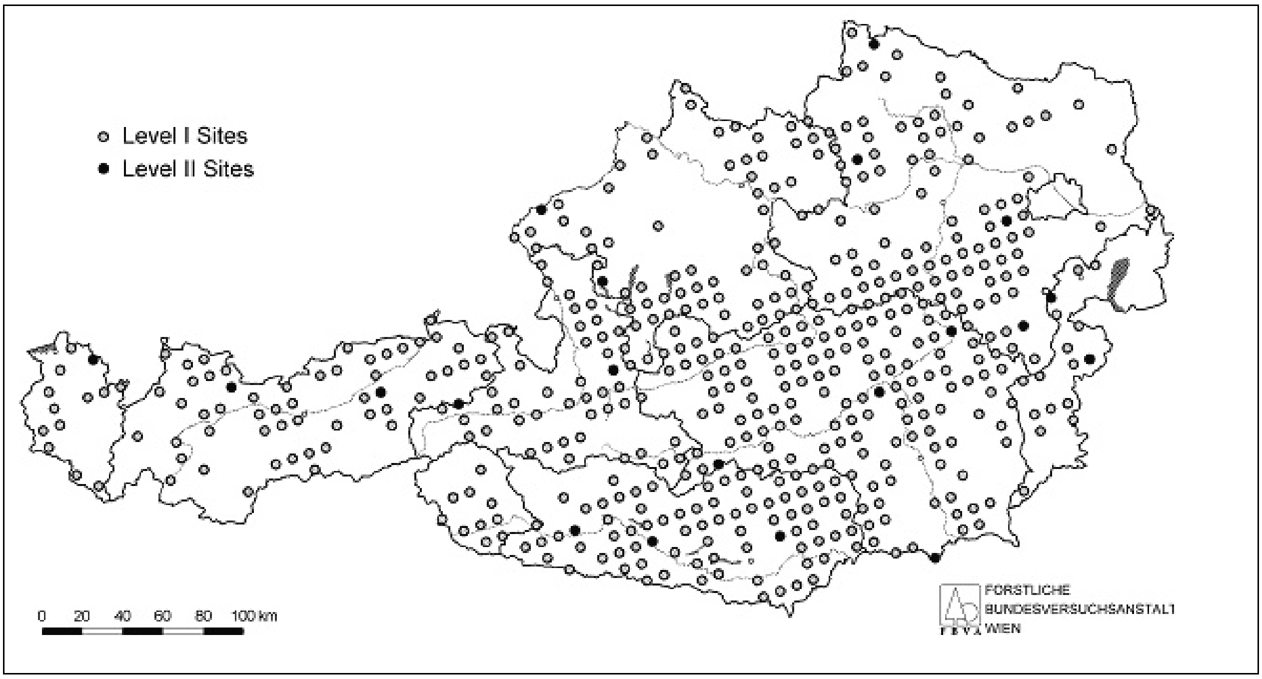

Figure 1: Forest Soil Monitoring System

Outlook

Recently introduced methods for intensive soil monitoring mainly focus on soil biological parameters. The most widely applied microbial parameters are microbial biomass (measured as substrate induced respiration) (Beck *et al.*, 1996) and nitrogen mineralisation potential (Kandeler, 1996). These have been used in soil surveys in Upper Austria and in monitoring programmes (e.g. Salzburg) as indicators of soil fertility. These methods can reveal local soil pollution (Tscherko and Kandeler, 1997).

Soil fauna can also be used as an indicator of soil quality. Earthworms (*lumbricidae*), potworms (*enchytraeidae*), and springtails (*collembola*) have proved to be successful indicators in the intensive monitoring programmes. Because of the constant development of new biological methods and increasing experience in this field, it can be expected that, in the future, these methods will be used increasingly as an obligatory part of intensive soil monitoring programmes.

Agricultural Soil Survey

Soil Taxation Survey

Since 1947 the taxation of agricultural land has been carried out by the financial administration in co-operation with the Federal Surveying Office. The first taxation, mainly based on the German Soil Taxation Act of 1934, was completed in 1973. The Austrian Soil Taxation Act of 1970 provided a new legal basis, regulating the continuity and updating of soil taxation data as well as their integration into the Austrian cadastre.

The main task of the soil assessment is to maintain up-to-date data on agricultural properties. Since 1974 the data have been updated through revision and reassessment to take into account changes in important environmental factors.

Methods and Output

Field methods are used to estimate the quality and natural productivity of soils for taxation purposes. Soil is described to a depth of 1 metre at intervals of 40 metres in general across the agricultural land using a soil auger. Parent material, texture, organic matter, horizons and structure are investigated. Units with comparable conditions of soil, relief, water regime and climate are defined and included in the Cadastre Map. Such maps are at a scale of 1:2,000 or 1:2,880 (scale of the old cadastre).

For comparison purposes, a system of values between 1 and 100 is used to assess soil conditions, relief, climate and water regime. The best possible value is 100, attributed to the soil with the highest yield potential. In typical Austrian regions, 432 standard sites guarantee a harmonised assessment. There is a close relationship between a given soil taxation and these standard sites.

The results of the soil assessment are documented in the Soil Taxation Register, the 'Schätzungsbuch', and in soil taxation maps. These data exist for every parcel of agricultural land in Austria. For each parcel the value mentioned above is multiplied by the size of the parcel and this new value forms the basis for agricultural taxation.

Soil assessment data exist in analogue form for approximately 2.7 million hectares of agricultural land, corresponding to 32% of the total area of Austria.

Application of Results

As the soil taxation data have been investigated with a high degree of continuity and comparability for decades and are characterised by very precise geometric positioning, they can be combined with other data of the Cadastre for every parcel. Therefore, soil assessment data are not only used for taxation of agricultural property. They also include basic ecological information about soils and are used for various purposes, including:

1. Soil reform;
2. Compensation;
3. Land use planning;
4. Use of sewage sludge;
5. Proceedings of the Water Act;
6. Measures within the Austrian Programme for the Promotion of Environmentally Friendly and Extensive Agriculture that Protects Natural Habitats (ÖPUL);
7. Basis for site adapted soil management;
8. Scientific projects.

Outlook

Currently about 20% of the soil taxation data are available in digital form. The continuation of the digitisation in co-operation with the Federal Surveying Office is planned.

Soil Management Survey

The origins of agricultural soil mapping - a cartographic representation of soil conditions at a scale as large as possible - go back to the 19th century. One of the oldest 'agro-geological'soil maps was drawn in 1858, in the Austro-Hungarian Empire, at a scale of 1:500,000 (Szabolcs, 1997). In Austria, soil mapping has been carried out since the 1920s. Experimental soil mapping was carried out after the Second World War. Since 1958, systematic mapping has been conducted by the Federal Institute of Soil Survey and Soil Management. At that time it was decided to survey agricultural land only, and involved the collection of field data and production of maps.

By 1969, 20% of the arable land in Austria had been surveyed at a scale of 1:2,880 (Cadastre scale) and maps produced at a scale of 1:5,000. Since 1970 the survey has been made at a scale of 1:10,000 and published at a scale of 1:25,000, to accelerate the procedure. The latter scale is exact enough to meet several needs and related questions.

Methods and Results

Soil mapping, which includes an assessment of geological, geomorphological and climatic conditions, is carried out from an agricultural and pedological point of view. The sampling density varies with soil heterogeneity but on average one bore per hectare is made. This approach is used to identify Soil Units, which are defined as areas with the same soil type and similar site characteristics.

For each Soil Unit at least one profile is described (to approximately 120cm depth) and samples of the individual horizons are subjected to laboratory analysis, including texture (percentage of clay, silt and sand), organic matter, carbonate, pH-value, electric conductivity, exchangeable cations, nutrients and heavy metals. Until 1995, the 1:25,000 soil maps, as well as the supporting explanatory texts, were produced by offset printing. A digitised soil databank is currently being established. Maps of some 144 mapping regions (mostly judicial districts), representing an area of approximately 22,000km^2 or 63% of agricultural land have been published.

Manuscript soil maps (1:25,000 scale) exist for another 10% of agricultural land. In total, about 98% of the agricultural land has been surveyed and the results are available to interested persons or institutions. Since 2002, the soil survey group has been part of the Austrian Federal Office and Research Centre for Forests, whereas the analytical staff belongs to the Austrian Agency for Health and Food Safety.

The composition of the digital soil map consists essentially of the results of the Austrian Soil Survey, i.e. all information of printed soil maps including the information of printed manuals. Furthermore soil analysis data as well as the extensive data of the soil quality network programme will be integrated in the database. Additional data, like digital topographic maps, digital terrain-models, aerial photographs, satellite images and various other external data enlarge the application area of the digital soil-information system (Figure 2).

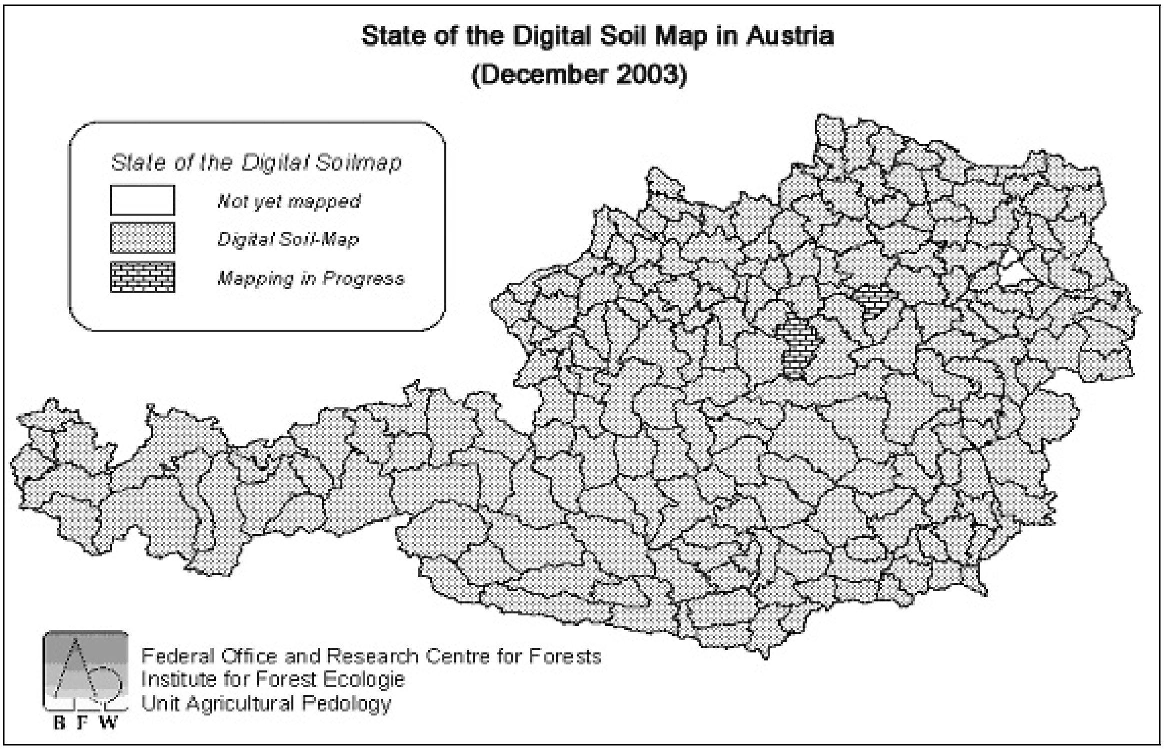

Figure 2: State of Soil Management Survey

Application of Results

Examples of the practical applications of the 1:25,000 scale soil maps include:

1. Sustainable fertilisation and cultivation practice of soil in an environmentally friendly way;
2. Selection of experimental sites;
3. Modelling (e.g. Crop suitability);
4. Regional, Provincial and Integrated Land Use Planning and River Basin Management;
5. Evaluation of the preservation of ecologically sensible sites;
6. Survey of the Potential of Natural Habitats;
7. Use in research projects.

Based on the 1:25,000 soil map, a number of special maps have been generated, concerning:

1. Water regimes;
2. Sensitivity to erosion;
3. Possible use of sewage sludge;
4. Sensitivity to nitrate leaching.

These special soil maps allow early detection of negative impacts on soil, such as wind erosion, water erosion, decline of soil structure, and contamination and drought, enabling relevant measures to be taken.

Outlook

Thirty hectares of agricultural land are lost to non-agricultural purposes every day. This is likely to lead to a greater pressure on soils suitable for agriculture in the future, especially if the planned extensification of crop production takes place. By this time a well-organised digital soil information system will be indispensable. Areal and point data for Austrian soils are essential to protect and conserve the soil and to sustain soil fertility.

Environmental Soil Survey

The decision to establish an intensive environmental soil survey programme was taken by provincial governments, which have the main responsibility for soil management and soil protection of agricultural land. In 1986, Vorarlberg, the most western province of Austria, started an environmental soil survey although, at the time, no special guidelines were available.

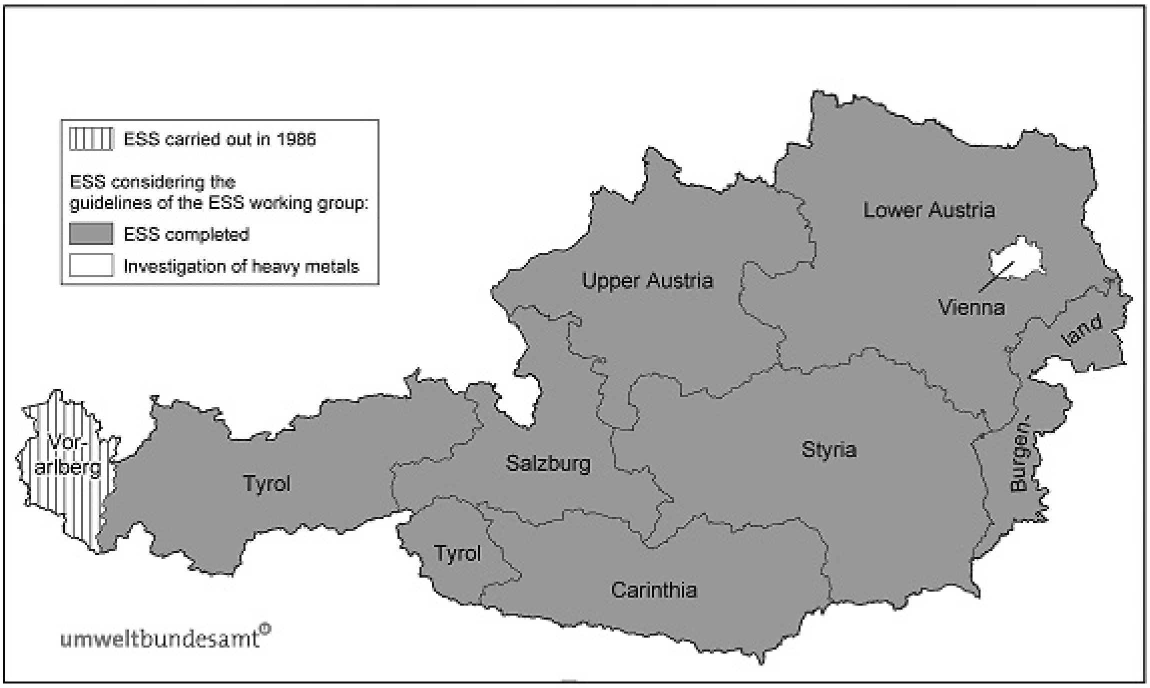

Figure 3: State of Environmental Soil Surveys in Austria

A recommendation for carrying out an environmental soil survey was prepared by the working group 'Environmental Soil Survey' of the ASSS (Austrian Society of Soil Science) (Blum *et al.*, 1989) to create a basis for comparable soil data all over Austria. According to this guideline the investigations of all the other Federal Provinces (between 1989 and 1998) are to a large extent comparable in soil sampling design and analytical methods (Figure 3).

Methods and Output

The sites are situated in a basic grid of about 4km x 4km. In some regions the grid was narrowed to 2.75km x 2.75km. For the Forest Soil Monitoring System (FSMS) a grid of 8.7km x 8.7km was used. Each sampling site is marked and coded.

Sites and soil profiles are described and composite soil samples are taken at predetermined depths (mixed from several parallel samples) using a soil auger. The number of subsamples in each composite sample varied between the Environmental Soil Surveys in the different Federal Provinces. Soil analyses include pH, carbonate concentration, nutrients, heavy metals, humus content, particle size distribution. Special programmes also included organic pollutants, biological and physical soil parameters.

In Table 1 the number of investigated sites according to land use is given. Most of the sites of the environmental soil surveys are situated on agricultural land.

In Tyrol a replicate sampling was made in 1996, eight years after the first investigation. 107 of the original 658 sites were investigated in the second sampling. In Vienna - the capital of Austria - a special programme focusing only on heavy metals was launched in 1992. Since then replications have been carried out at regular intervals (1994, 1997, 2000, 2003). The last investigation includes also analysis of some organic compounds (PAH).

The Forest Soil Monitoring System (FSMS) of the Federal Office and Research Centre for Forest (BFW) is included in Table 1, although the FSMS is a Federal nationwide investigation (*cf.* Forest Soil Monitoring Section above).

An evaluation of all the data (of more than 5,000 sites), investigated with comparable methods, is currently in progress at the Federal Environment Agency in order to derive soil background values according to different land use and the geological conditions for Austria.

Furthermore an overview of the state of agriculturally used land in Tyrol (153 sites), Salzburg (197 sites), Lower Austria (1,449 sites), Upper Austria (453 sites), Burgenland (174 sites) and part of Styria (84 sites) has been made by the Federal Office and Research Centre of Agriculture in 1997 (Danneberg *et al.*, 1997), based on the upper 20cm of arable and grassland soils, with data from approximately 2,500 sites.

Table 1: Number of Environmental Soil Survey (ESS) sites in Austria according to land use (1998).

Land use	Tyrol	(Tyrol [1])	S	UA	LA	St	Vbg+	B	Car	Vie [2]	FSMS	TOTAL
forest	263	(15)	177		90	17	150				514	1,211
agricult. land	47	(33)	14	439*	1,151	193	40	164	140			2,188
grassland	139	(59)		441*	298	256	243	10	250			1,637
extensively used			137									137
intensively used			134									134
alpine pasture	209					61			91			361
others						21	2			286		309
total	658	(107)	462	880	1,539	548	435	174	481	286	514	5,977

[1] ....*replicate sampling*

[2] ....*regular investigations of heavy metals (1992, 1994, 1997, 2000, 2003 additionally some organic compounds): *agricultural and horticultural land*

** ....*grassland incl.alpine pastures, pastures and others*

+..........*As the ESS in Vorarlberg was completed in 1986 before the ESS-guidelines (Blum et al.,1989) were published, the data cannot be compared to the other ESS, due to different methodology.*

S Salzburg, UA Upper Austria, LA Lower Austria, St Styria, Vbg Vorarlberg, B Burgenland, Car Carinthia, Vie Vienna, FSMS Forest Soil Monitoring System

Bundesamt und Forschungszentrum für Landwirtschaft (1996), Amt der Kärntner Landesregierung (1999), Bundesanstalt für Bodenwirtschaft (1994), Bundesanstalt für Agrarbiologie (1993), Amt der Salzburger Landesregierung (1993), Amt der Steiermärkischen Landesregierung (1991-1996), Amt der Tiroler Landesregierung (1988, 1996), Husz (1986), MA 22 (1993, 1995, 1998, 2000), FBVA (1992)

Acidification and pH Value

Acidification is a minor problem on agricultural land compared with land under forest, since acidic inputs are smaller. Moreover, they are neutralised by regular fertilisation and by liming. Problems occur only in extensively used areas.

Alkaline sites, with a pH value of more than 7.2, occupy more than 40% of the areas in the east of the country, in Lower Austria and in Burgenland, whereas the percentage in Tyrol, Salzburg and Upper Austria is less than 4%. Strongly acidic sites with a pH-value below 4.5 are found in Styria (14%), Tyrol (35%) and Salzburg (38%).

Low cation exchange capacity, which indicates sensitivity to acidification, occurs in soils on siliceous parent materials (e.g. granites) in the Wald- and Mühlviertel area, Semmering, Wechsel, Central Alps and the foothills of the Alps.

Organic Matter Depletion

The content of organic matter is determined by the amount of organic litter produced by plants and by the intensity of turnover processes. This is why the humus content in grassland is higher than in crop land and therefore is higher in the cool and humid west of Austria than in the warm and dry east.

For example, in Salzburg 40% of the soils have more than 8% organic matter in the topsoil whereas in Lower Austria about 40% have less than 2%. In the areas used for agriculture in the east of Austria the organic matter content may have diminished by 0.5%, probably due to an intensification of soil tillage and former straw burning or a dilution of organic matter caused by increasing the plough depth.

Heavy Metal Contamination

In general, contamination with heavy metals is not very extensive. The standard values ÖNORM L 1075 (Austrian standard L 1075) for most heavy metals are only exceeded in less than 3% of the sites. Arsenic, lead and cadmium pollution occurs in more than 3% of the sites.

Arsenic contents are especially high in some regions of Salzburg, Styria and Lower Austria. This may be due to geogenic or anthropogenic sources.

The standard value for lead (100 mg/kg) is exceeded in Tyrol at 9.2% of the investigated sites, and in Salzburg at 3.6% of the sites. This could be due to local emissions, impacts of mining or long range transport of pollutants. The latter is seen as accounting for contamination north of the main alpine ridge. Due to high transit traffic, the valley of the Inn river is the most polluted region in Tyrol. Furthermore, local lead emissions (e.g. metal processing) result in point pollution.

High cadmium contents can partly be explained by long-range pollution and subsequent deposition on exposed slopes. On the other hand, the Northern Calcareous Alps seem to have a naturally elevated content of cadmium.

Application of Results

Some Federal Provinces (e.g. Styria, the Tyrol) have taken measures at those sites where the content of heavy metals exceeded the threshold values. More detailed investigations have been carried out, including analyses of plants. In heavily polluted areas a risk assessment programme has been carried out which is used to derive land use recommendations.

As mentioned above, the question of widespread higher contents of arsenic will be answered by detailed studies.

Outlook

One of the Federal Provinces, Styria, is carrying out a replicate Environmental Soil Survey, which forms a transition to an extensive form of Soil Monitoring. Furthermore a replication of the FSMS is planned.

Soil Monitoring

The Environmental Soil Survey, with approximately 6,000 sites, provides information about the variability of soils all over Austria. A repeat of these surveys was originally planned in order to monitor the changes with time. However, the results of replicate sampling in Tyrol showed that the sampling design at each site was not precise enough to distinguish between changes over time and the variability within the sampling site.

Another reason for changing the plan of carrying out environmental soil surveys at regular time intervals is the great expense. Therefore, for technical and financial reasons and with regard to previous results, fewer but intensively investigated soil monitoring areas are being established. A methodological handbook has been prepared by the Institute of Soil Science at the University of Agricultural Sciences, Vienna, on behalf of the Federal Environment Agency and in co-operation with the Austrian Soil Science Society (Blum *et al.*, 1996).

Appropriate nationwide co-ordination of the sites will result in a reduction of costs for the benefit of the individual provinces. There will be a representative distribution of sites according to characteristic landscape units of Austria (soil landscapes, main agricultural production areas, silvicultural growth areas, etc.), different exposures to pollution (background, close to emission sources, etc.) and types of use (forest, cropland, grassland, etc.).

The Institute of Soil Science has elaborated a proposal for possible sites, which is presented in Figure 4 (Blum *et al.*, 1996). Full points in the Figure refer to already established soil monitoring areas. These are found mainly in Salzburg, which was the first province to set up soil monitoring areas (Juritsch, 1994). Further Soil Monitoring Sites are established in Tyrol and Vorarlberg (Figure 4), others are planned in Upper and Lower Austria in the near future. In Upper Austria, the Federal Environment Agency is running a long-term ecosystem monitoring site (UN-ECE Integrated Monitoring) in the Reichraminger Hintergebirge.

As part of the ECE/ICP-Forest Programme, the Federal Office and Research Centre for Forest, Vienna has established 20 forest monitoring areas (see Forest Soil Monitoring Section above). Further sites identified in Figure 4 are non-obligatory proposals. It is expected that between four and ten areas, will be established in each province.

Following the establishment of the soil monitoring sites, the data collected will provide information on changes in soil properties as well as on the state of soil pollution. Optimum selection of areas and standardised methods of investigation will allow relevant policy statements to be made on environmental impacts on certain regions and the whole of Austria (UMWELTBUNDESAMT, 1998 and 2002).

The subject 'soil monitoring' is already being considered by the ARGE Alpen-Adria working group in Bavaria and in Switzerland (Blum *et al.*, 1994). The directives of ARGE Alpen-Adria, which are also binding for Austria, provide a framework, which has been enlarged to contain additional parameters to those in the above mentioned Austrian methodological handbook and more precise investigation methods.

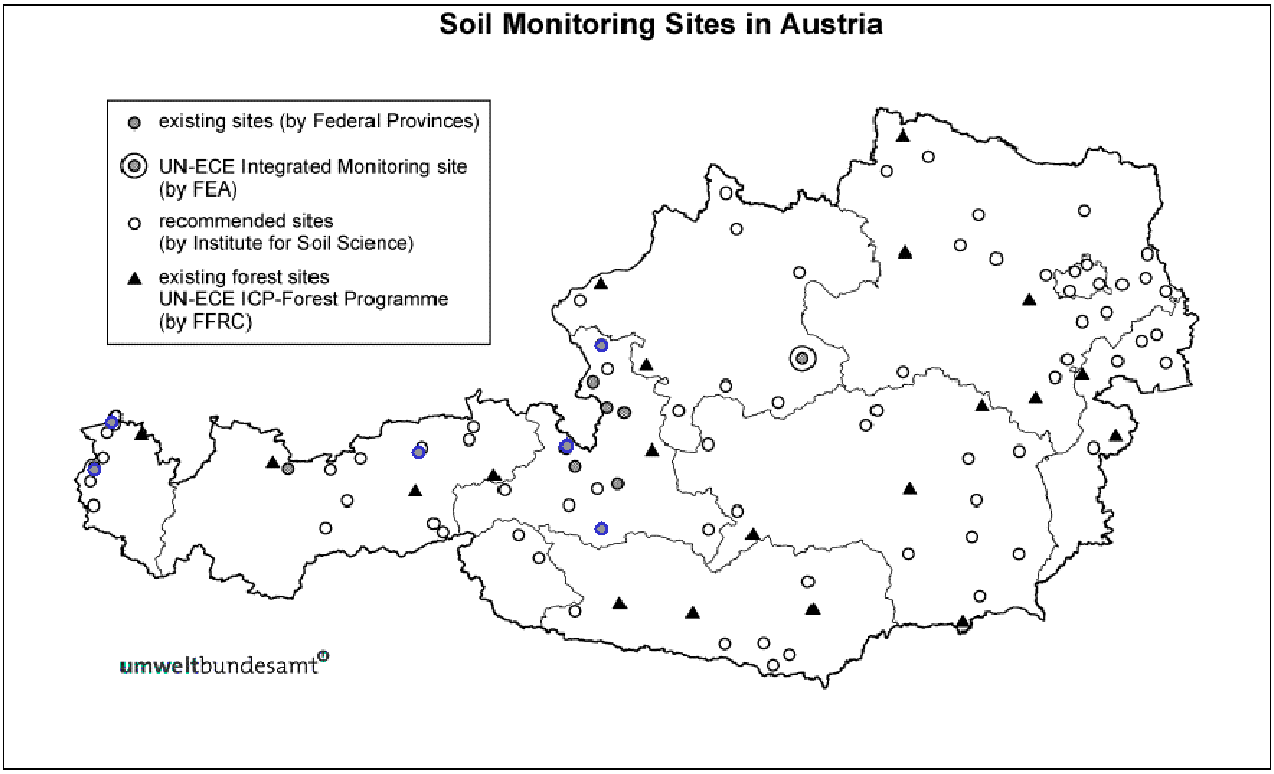

Figure 4: Soil Monitoring Sites in Austria

Soil Information System (BORIS)

A Soil Information System is necessary for effective soil conservation nationwide and for ensuring accessible information on general soil conditions, contamination and the sensitivity of soils to detrimental impacts. Detrimental effects on soils can be assessed more easily by means of a nationally standardised recording of spatial and point data in a Soil Information System. This provides the basis for an evaluation and projection system needed for effective soil protection.

Compared to many other European countries, Austria possesses comprehensive soil data. Yet, these data are structured heterogeneously, as they have been collected by different institutions with varying objectives. At the Federal Environment Agency, a pilot project (µBORIS) for the implementation of a national Soil Information System was carried out in order to test the possibility of realising a joint soil information system. In the city of Linz and its surroundings, data records from different investigations were linked (point data, spatial data/maps). Experience with the pilot project has clearly demonstrated that a combined evaluation of the selected data sets is possible (Schwarz *et al.*, 1994; Schicho-Schreier 1994).

In future, an integrated Soil Information System consisting of a combination of soil maps, the real estate database, soil data from Environmental Soil Survey sites and from Soil Monitoring sites will be a cornerstone for soil use and management.

Methods and Output

Since 1992 the Federal Environment Agency has been developing the Soil Information System, BORIS. The main tasks that have been fulfilled are the:

1. Preparation of a handbook, the 'Data Key Soil Science' (DKSS-Datenschlüssel Bodenkunde), to make data records form different investigations comparable. It was developed by the Federal Environment Agency and has been approved by the Austrian Soil Science Society (ASSS) (Schwarz *et al.*, 1999);
2. Development of a complex data model (Schreier *et al.*, 2001);
3. Transformation of the existing datasets according to the DKSS and the data model;
4. Implementation of access to the database via internet (BORIS EXPERT and BORIS INFO) for different user groups;
5. Establishment of the BORIS User Committee;
6. Annual meetings of the data owners;
7. Development of a model for data quality assurance (Tulipan *et al.*, 2001);
8. Implementation of an Internet based assessment tool (Freudenschuss *et al.*, 2002).

The Data Model offers special possibilities, e.g.:

1. It is an open system including approximately 600 different parameters (measurement information, site or soil description), which are described with all possible characteristics in the DKSS. Additional soil information can be added whenever necessary using new parameters.
2. Every single measurement is linked to a variety of information (the owner of the data, the analytical method used, etc.).
3. Information about sampling design, conditions of sample transport, handling and treatment of samples, etc. is available.
4. If replicate sampling or parallel sampling has taken place, this is documented for each sample.
5. The combination of soil description in terms of natural soil horizons and analytical data according to predetermined soil depths is easily possible.

Currently, the database holds a soil map of Austria (scale 1:750,000) and more than 1.5 million records from over 10,000 sites. These are data from all Environmental Soil Surveys of the Austrian provinces, the Forest Soil Monitoring Survey and data from more than 30 other special investigations e.g. in Brixlegg, Linz, Arnoldstein, Köflach-Voitsberg as well as from the Austrian-wide caesium investigation.

Building this extensive database was made possible by the constructive co-operation of the above mentioned Federal Provinces and the responsible institutions. Extensive work was necessary to prepare the individual data sets for the implementation into the database (checks of quality and correctness, translation according to DKSS).

Table 2 and Figure 5 give an overview of the all sites integrated in BORIS (December 2003).

Since 2001 BORIS provides access to soil information via Internet http://www.umweltbundesamt.at/umwelt/boden/boris/.

BORIS INFO is open to the public and allows detailed data queries about site and soil description as well as meta data about measurements for each site. Internet users can also get an overview of all the available information and provided data sets and links to data owners and literature references.

BORIS EXPERT is a complex instrument for data selection, assessment and evaluation and allows access to all data sets, also the analytical values. This expert tool is only accessible for a selected circle of institutions; primarily those institutions are concerned which have already provided relevant data for BORIS. Data access is restricted by passwords and data use is formally regulated by the BORIS User Committee.

An example for an Austrian-wide evaluation of soil contamination with caesium-137 is given in Figure 6. Austria was one of the countries most strongly affected by the Chernobyl fallout. The average contamination level in Austria amounts to 21 kBq $^{137}Cs/m^2$ (=21,000 Becquerel Caesium-137 per square metre). The map was drawn up by the Austrian Federal Environment Agency (FEA) and the Austrian Ministry of Health. It presents all the measured data for caesium-137 (Cs-137) in soils that are available. More than 2,000 results were used for producing the map. Approximately 200 of them were located in neighbouring countries close to the Austrian border (UMWELTBUNDESAMT, 1996). The Cs-137 data are available on the Internet.

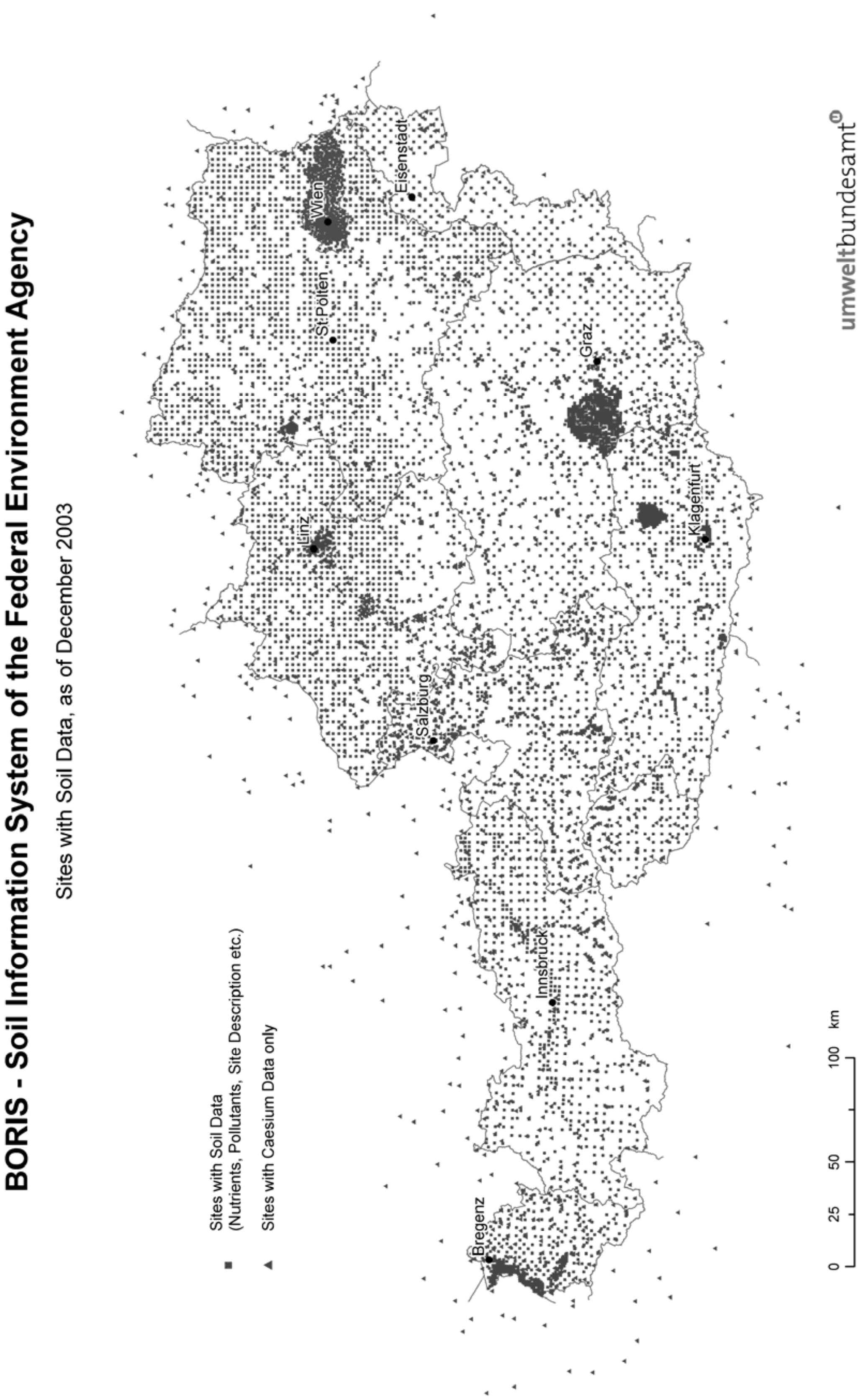
BORIS - Soil Information System of the Federal Environment Agency
Sites with Soil Data, as of December 2003
Sites with Soil Data
(Nutrients, Pollutants, Site Description etc.)
Sites with Caesium Data only
Wien
Eisenstadt
St.Pölten
Graz
Linz
Klagenfurt
Salzburg
Innsbruck
Bregenz
0
25
50
100
km
umweltbundesamt

Figure 5:

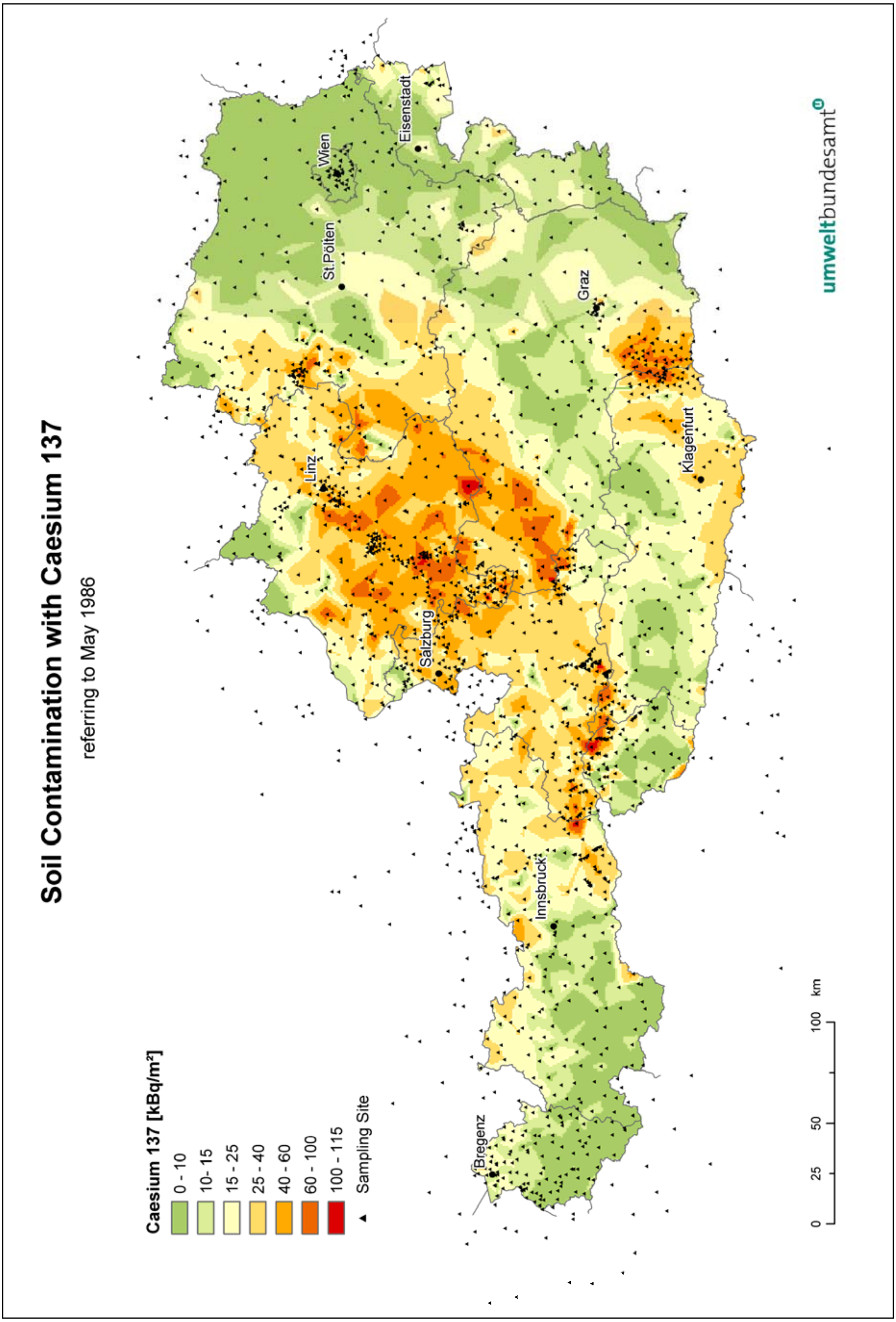
Soil Contamination with Caesium 137
referring to May 1986
Caesium 137 [kBq/m²]
0 - 10
10 - 15
15 - 25
25 - 40
40 - 60
60 - 100
100 - 115
Sampling Site
Wien
Eisenstadt
St.Pölten
Graz
Linz
Klagenfurt
Salzburg
Innsbruck
Bregenz
0
25
50
100 km
umweltbundesamt

Figure 6:

Table 2: Number of sites in the Soil Information System, BORIS (December 2003).

Provinces	Bgl	Car	LA	UA	S	St	Tyrol	Vbg	Vie	Abroad: near Austrian border	Total
ESS *	174	481	1,449	880	462	636	658	435	287		5,462
Caesium Data	53	164	519	387	291	249	319	119	39	233	2,373
Other investigat		498	449	188	150	360	63	4	42		1,754
FSMS**	16	75	97	69	44	134	66	13			514
Total:	243	1,218	2,514	1,524	947	1,379	1,106	571	368	233	10,103

* ESS (Environmental Soil Surveys). These datasets were provided by the Federal Provinces of Burgenland, Upper Austria, Lower Austria, Salzburg, Styria, Tyrol, Vorarlberg and Vienna (Municipal Department 22)

**FSMS (Forest Site Monitoring System) of the Federal Office and Research Centre for Forest (BFW).

Application of the Results

The comprehensive soil data of BORIS will be combined with soil maps (at different scales) and data sets of related subjects such as land cover, geology, water, cadastre, etc. These data provide a basis for:

1. A classification of soil data with comparable characteristics site or soil description, methods, sampling design, etc.);
2. Nationwide evaluations of soil data (pollutants, heavy metals, erosion);
3. Development and adaptation of standard values;
4. Combined evaluation with CORINE land cover data, Austrian Surface and Groundwater Monitoring System;
5. Soil assessment in communal and regional planning processes;
6. Decision-making with regard to land use planning;
7. Environment Impact Statements and Environment Impact Assessments;
8. Decisions on the spreading of sewage sludge and other organic waste;
9. Service to provincial authorities and data owners concerning data quality assurance and data documentation as well as the provision of an internet based expert tool for data selection and evaluation (BORIS EXPERT);
10. Aggregated data for international reports and projects;
11. Further international agreements and protocols for the reduction of trans-boundary pollutants and other inputs;
12. Translation of Austrian soil types into international classification schemes (FAO-System, WRB);
12. Scientific projects (e.g. basis for the development of pedo-transfer rules and pedo-transfer functions (e.g. with Artificial Neural Networks));
13. Finally BORIS can provide information for local, Provincial and Federal authorities, for the public and for the scientific community. The data transfer depends on the prior agreement of the data owners.

Outlook

The BORIS soil information system provides comparable data sets and IT-tools for data management, selection and evaluation. This facilitates the treatment of a great number of different soil protection aspects as well as nationwide statements. Further steps will be to combine the point related data of BORIS with spatial soil information.

The efforts towards the enlargement and intensification of the nationwide soil information system will be continued as well as the collaboration with European soil information networks, such as European Soil Bureau.

General Outlook

Soil survey and the collection of soil data in Austria are now well developed to the extent that the use of soil data for specific purposes or their link with other environmental data through GIS or other geo-statistical tools can be facilitated.

The BORIS database is a way to raise public interest in soils, to assess the status of Austrian soils and to promote the use of these data for the future development of sustainable land use.

The potential changes of soil conditions can be assessed more easily when further monitoring stations are installed.

All the above mentioned soil information can also be used in the co-operation with other European countries and European institutes. Co-operation has already begun and will develop further to harmonise the use and availability of soil information in Europe.

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Soil Survey in Belgium and its Applications

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History

The first soil map of Belgium was compiled in 1853 by A. Dumont (Tavernier, 1949) at scale 1:160,000 on commission of the Ministry of Agriculture. Belgium was subdivided into geological-agricultural zones: Polders, Sandy region, Loamy region, Silty-Loam region, Condroz, Famenne, Ardennes, Jura and Herve. It showed the broad agricultural potential of the country as reflected in soil texture and lithology of parent materials (Dudal, 1996).

The map of Dumont formed the basis for a new initiative by Malaise (Tavernier, 1949) who produced soil maps at scales of 1:200,000 and 1:60,000 between 1867 and 1871, also following an agricultural approach. At the end of the 19th century, the introduction of mineral fertilisers triggered new mapping initiatives based on chemical analysis of the topsoil.

As of 1947, a comprehensive systematic survey of the Belgian soil cover was initiated under sponsorship of the Institute for Encouragement of Scientific Research in Industry and Agriculture (IWONL/IRSIA) (Tavernier, 1949; 1950). A coordinating committee was established under the umbrella of the 'Soil Survey Centre' to prepare the soil and the vegetation map of Belgium. The soil survey was implemented through three regional sections in close cooperation with the Faculties of Agriculture of the universities of Gembloux, Gent and Leuven.

Soil Mapping

Scale

Map units were delineated on cadastral field survey maps at scale 1:5,000, which had the advantage of showing most parcel boundaries.

The base map with the soil types was then generalised on the 1:10,000 topographic base map, a coloured version of which was published at 1:20,000 scale along with a descriptive text on the soil geography of each of the 8,000ha map sheet.

On the basis of the detailed soil survey, a synthesis of the soil distribution in the country was prepared as a 1:500,000 scale map of the soil associations of Belgium (Tavernier and Maréchal, 1972).

Main techniques used

The first portion of the Belgian territory to be surveyed was the sea Polder area. Due to the young age of the sediments, the logical approach was to map sequences of strata based on a geo-morphological soil classification system. First of all, a differentiation was made in the Polder landscapes according to the age of fluviatile deposition. Within each landscape unit a distinction was made between sandy creeks and clayey backswamps, which were easily recognised in the field.

The geomorphological criteria of the previous system were not suited for the classification of soils developed in parent materials of Pleistocene or older age. Hence, a morpho-genetical system was developed and applied in different stages (e.g.

Livens, 1950; Dudal, 1955) to classify and map the major part of Belgium's soil resources.

Two broad landscape units were defined to stratify the soil cover: (i) plateau and slope positions and (ii) valleys and depressions. The soil series, which emphasises on topsoil texture, natural drainage conditions and nature of soil profile development, was the basic classification unit. Composition of and depth to geological substrata, presence of heterogeneous parent material, effects of historical management practices and topographic position were, amongst others, specified to yield soil phases and variants of the series.

Field observations were done by soil auger to a standard depth of 125cm unless obstacles (unpenetratable layer or rock) were encountered at more shallow depth. These observation points were mostly situated on the intersections of a more or less regular grid with a density ranging from 1 to 2.5 per hectare. The applied survey procedure can be categorized as a stratified probability sampling in which, according to the available background information, systematic sampling with different densities is conducted in different strata (Bregt, 1992).

Complementary to the augerings, formal soil profile descriptions and horizon sampling were implemented to support the interpretation of the soil survey. During early phases of the survey, 1 profile per $2km^2$ was described. When about half of the Belgian territory was surveyed, soil profile density was reduced and adjusted to terrain complexity and henceforth reduced in some cases to 1 profile per 4 to $8km^2$. The lower soil profile sampling density was compensated for by taking a large number of topsoil samples for assessment of granulometry, pH, $CaCO_3$ and organic carbon determinations. In all, some 15,000 soil profiles were formally described and analysed between 1947 and 1971, comprising some 75,000 soil horizons which were sampled for laboratory analysis. The following parameters were determined in most cases: granulometry, organic carbon, free carbonates, CEC, exchangeable cations, pH(H_2O), pH(KCl), free iron and mineralogy of the sand fraction.

Status of completion

At present 373 out of 441 map sheets have been published. The remaining soil maps, though unpublished (15 in Flanders and 53 in Wallonia), are available in black and white.

The Database

Baseline data

As of 1968, the major part of the data relating to 226 soil map sheets, covered by the profile investigation project, were encoded on Hollerith punch cards. (De Leenheer *et al.*, 1968). These data were transferred to a database on microcomputer (Van Orshoven *et al.*, 1988). They extracted additional data from the printed profile study reports such as geographic coordinates of the profile locations, added all the data for 40 additional soil map sheets, corrected or eliminated records with missing or unreliable information and finally decoded the punch card format into a ready-to-use format based on the Belgian soil classification system. Most of the profile data of the Belgian territory are now structured into a comprehensive relational database 'Aardewerk' (Van Orshoven *et al.*, 1988; 1993) comprising 13,033 fully checked soil profiles. Furthermore procedures are in place now for a parametric statistical characterisation of the soil units (Van Orshoven *et al.*, 1991).

Recently a large effort has gone into the digitisation of the 1:20,000 scale Belgian soil map. This has allowed translation of the map into various thematic and simulation maps. Profile data are thereto used to characterise the map units, which are considered as elementary land units. Van Orshoven *et al.* (1993) pointed out that, depending on the purpose, soil map units should be characterized in one of several ways. Class matching of profiles with soil map units is a simple and interesting approach when information is needed about dominant components of the map units only. For environmental applications, map unit impurities cannot be overlooked so that geo-matching is more appropriate, as it accounts for the inclusions in the map unit. However, the spatial extents of dominant soil types, associated soils and inclusions can be assessed only approximately due to the non-random or systematic spatial sampling scheme of the profiles, applied during the soil survey. Therefore, mixed-class geomatching with preset weights for dominant components and impurities may be a valuable alternative.

Derived data

In order to meet demand of modelling applications it soon became clear, that a number of important soil characteristics and properties were not readily available in the 'Aardewerk' database. Vereecken (1988) and Vereecken *et al.* (1989) developed multiple regression equations between basic soil characteristics available or computable from the database and the parameters of the 'Van

Genuchten equation' (Van Genuchten, 1980), which describes the soil moisture retention characteristic or pF-curve, and of the 'Gardner model' (Gardner, 1958), describing the hydraulic conductivity-pressure head relationship.

Hubrechts (1998) elaborated on the development of pedotransfer functions to predict thermal soil behaviour, based on physical soil properties.

The soil thermal regime is a factor of primary importance in determining the rates and directions of physical, chemical, biological and biochemical soil processes. Its quantitative formulation requires, in addition to thermal boundary conditions, the knowledge of the soil thermal properties: thermal conductivity, thermal capacity and thermal diffusivity. In view of the fact that experimental information on soil thermal conductivity and capacity is available from literature, Hubrechts focussed his research on soil moisture dependence on thermal properties. He developed an experimental procedure based on the 'cylindrical probe with finite length' on sandy and silty loam soils of Northern Belgium. The soil thermal conductivity could best be described by a non-linear tree parameter model, based on particle size distribution, dry soil bulk density and carbon content.

The soil thermal capacity characteristic could be described by a linear equation where the slope of the characteristic equals the volumetric heat capacity of water and where the intersect is the estimated volumetric heat capacity of the oven dry soil. Variability of soil thermal conductivity is high and needs further investigation based on quantitative soil structure assessment.

Numerous test cases of the combination of simulation models with the digitised soil map of Belgium has proven that we have a very valuable, powerful tool at hand which is capitalizing on a tremendous effort of the last 50 years (Diels *et al.*, 1996). More research and most likely some well-structured additional field sampling will be required to meet the high demands of present day environmental modellers which require new geo-referenced parameters that were not recorded during the early surveys.

Applications of soil data

The soil survey of Belgium was initiated just after World War II against the background of an urgent need for increased agricultural production (Dudal, 1996). Hence, the early applications of the survey were geared towards an assessment of the country's soil resources in terms of improved management, higher yields, optimised fertilisation and effective land use planning. Intensive research and experimentation were conducted to determine the soil suitability for major food crops, forestry purposes and later for horticultural produce. The latter research, which spanned a period of 20 years, was synthesised in a comprehensive overview of the results obtained (Vandamme *et al.*,1994).

The small-scale soil association map has been used to adjust the delineation of agricultural regions of Belgium, which are the basis of farm taxation, to plan regional land allocation or assess regional impacts of fertiliser use. With the digitisation of the soil data, the applications of the soil survey have been considerably broadened. In addition to agriculture, applications are being made in connection with environmental and various land use issues.

A few examples of topics for which the soil database has been or is being used are:

- Adjustments of land use in the framework of the European set-aside policy;
- Analysis of impact of agrochemicals on soil and water quality under different farming practices;
- Study of the influence of organic matter and agricultural practices on pesticide attenuation;
- Sorption and desorption kinetics of phosphorus in different soils;
- N_20 emissions from different soils;
- Nitrate leaching susceptibility of different soils (EU Nitrates Directive);
- Optimised use of surface and groundwater resources;
- Optimised fertiliser use through integrated specific site monitoring;
- Influence of soil acidification on the vitality of forests;
- Environmental impact assessment of different types of land use;
- Decision support systems for nature conservation and afforestation of excess agricultural land;
- Assessment of carbon contents, stocks and fluxes in view of climate and land use change modelling;
- Assessment of floodable areas and planning for controlled floodable areas.

The above applications reflect the evolution that has taken place over the years, moving from the interpretation of static soil characteristics to the inclusion of these data in dynamic simulation models, broadening the scope from increased agricultural production at farm level to the planning of effective land use at watershed and regional level.

Outlook

In the early stages of the soil survey, the diagnostic characteristics used to define soil series were selected against a background of a taxonomic soil classification. At the time these characteristics adequately served general purpose interpretations, mainly in the field of agricultural production. With the progressive intensification of agriculture, the increasing farm size, the competition for land among different sectors of the economy, the emphasis of land evaluation shifted from farm level to regional scales and from production factors to environmental concerns (Dudal, 1996).

It appears that the wider range of demands for soil data requires inputs and skills that surpass those that were provided through the early soil surveys. The introduction of modelling in land evaluation and the emergence of techniques to process digital information require the availability of quantitative and geo-referenced data.

Environmental protection is commonly related to an efficient management of soil and water resources. The early soil surveys did not record soil hydraulic parameters, which is now partly being remedied through transfer functions. The latter practice should be a transitional one, and should progressively be substituted by actual measurements. The same applies to other mechanical, thermal and biochemical properties. Dynamic modelling also calls for attention to variability of soil characteristics in space and in time, so that prognoses can be made about the effect of land use practices.

A comprehensive solution to environmental issues will require regional approaches. The soil maps at 1:20,000 scale are too detailed for a regional assessment and will need to be synthesised at smaller scales, e.g. 1:100,000 to 1:250,000. A methodology has been worked out to convert the detailed soil surveys into small-scale overviews (Vander Poorten, 1993).

Soil characteristics will need to be used as inputs for the study of soil forming processes and energy flow mechanisms. In-depth knowledge of present-day versus paleo-soil genesis is a must for thorough understanding of the soil cover and related processes at catchment scale. The efficiency of land use and the protection of the environment is closely related to water balances, erosion susceptibility, solute movements, the dynamics of trace elements and heavy metals (Halen *et al.*, 1991; Tack *et al.*, 1997; Van Mechelen *et al.*, 1995; Verloo and Willaert, 1989), nutrient cycles (Craenen *et al.*, 1997; 2000; Van Cleemput and Baert, 1981), and factors of plant growth (Van Ranst *et al.*, 2000).

The integration of the various factors of these processes must replace assessments made on the basis of single characteristics. A transition will need to take place from a hierarchical soil taxonomic classification to a relational and object-oriented assessment of soil resources. Geographic generalisation can be based on existing map unit boundaries, or on the processing of point observations using geostatistical techniques.

Soil information systems will need to incorporate the experience and knowledge of farmers, so that soil and land data can be interpreted in terms of suitabilities and limitations for different types of land use.

The true value of the soil survey can only be unveiled through the integration of the results with data, knowledge and technology developed in fields other than soil science. The concept 'Upgrading of soil maps' fits very well in this picture. It is illustrated in the next section using the example of flooding hazard and floodable areas.

Upgrading of soil maps

An early pedocentric definition of 'upgrading of soil maps' is given by Stiboka (1988): the extension of existing legend units, containing class information about diagnostic characteristics, with information about within-unit variability of those diagnostic characteristics and about other (non-diagnostic) physical and chemical characteristics and properties. In this respect, the basic data for upgrading are most often point data: additional field survey data like soil profile descriptions and horizon analysis data, which are specifically collected to serve the upgrading.

Similarly, soil map legend information can be extended with information retrieved from spatial data layers, which are established independently from the soil map units. Such upgrading is commonly based on GIS-overlay techniques and typically relate to land use and land use characteristics, relief parameters (altitude, slope and aspect), ground water characteristics, destination according to a spatial destination plan, climatological zoning, pollution levels.

A particular case of soil map upgrading consists of the transformation of soil maps into simulation maps. The information content of soil map units is then extended with the input information (initial state variables, boundary conditions and model parameters) which are necessary to operate process-based simulation models delivering quantitative, possibly probabilistic, soil property and land quality values for each simulation unit (Wösten *et al.*, 1985; Bregt *et al.*, 1989; Van Orshoven, 1993; Diels *et al.*, 1996). This type of upgrading generally requires a combination of the previous approaches.

According to the Stiboka definition (1988), upgrading is most meaningful if the within-unit variability of the additional characteristics, properties and qualities is smaller than the overall variability. It is obvious, however, that GIS-based upgrading or conversion into simulation maps, may yield indistinct data ranges.

Planning for controlled floodable areas based on upgraded soil maps

Flooding hazard is a land quality, which affects sustainable land use to an important extent. Flooding hazard assessment can be based on experience and expert judgement, or on information generated through empirical or mechanistic and deterministic or stochastic simulation models. As well for supporting expert judgement as for delivering input data for the models, soil maps are useful and need to be interpreted. Upgrading may be necessary to allow for a more functional interpretation. The following examples and cases are retrieved from current planning reality in Belgium.

Expert-based interpretation

On the highest level of abstraction, the morpho-genetic legend of the Belgian soil map distinguishes valley and depression soils from soils on slopes and plateaux. Valley and depression soils are soils without significant profile development. Due to the continuous sedimentation of soil particles through overland flow or river deposits, illuviation and eluviation patterns are not pronounced.

Using a number of expert rules as translation key, alluvial soils can be fairly well separated from colluvial soils. Those rules consider distance to water course and natural drainage class and texture class of the soils with respect to the regional context. The wetter the drainage class and the finer the granulometry, the higher the probability that a soil without profile development is an alluvial rather than a colluvial soil. Delineation of colluvial soils is also interesting to identify land units which may be subject to damage through mud accumulation originating from surrounding slopes. In this way the soil map legend allows for straightforward conversion into natural flooding hazard classes.

Table 1 presents the absolute and relative areas of alluvial soils, floodable by excess-water in water courses, and of colluvial soils, damageable by mud flow in the Demer river basin. For a minor fraction of soils without profile development (Regosols) no reliable distinction could be made between alluvial and colluvial origin.

Figures in Table 1 include built up and non-built up portions of the basin. Of course, the above interpretation is for rural areas, but not for urban agglomerations where no soil survey has been performed, due to the absence of soils *sensu stricto*. In order to assess the floodable character of these non-surveyed areas, an alternative approach is required. Expert-based interpretation of the topography and the topological relationships, which exist between 'incoming' and 'outgoing' alluvial soils along the water courses, is a possibility. Also historical topographic maps from the now urbanised area can be useful. On such maps, the non-surveyed portion is most often smaller than on the recent soil maps, enabling a further translation of map units (mostly land use indications) into the flooding hazard classification system. For example, wet pasture in the vicinity of a water course can be classified as belonging to the natural floodable zones. Figure 1 illustrates the combined approach followed for the town of Tienen located in the Demer river basin. Table 2 presents the corresponding area figures for the built up zones only (according to the soil map of 1950-1970) in the river Demer basin.

GIS-based upgrading

In order to take into account the influence of man-made infrastructures (dikes, sewers) and exceptional meteorological events, the natural flooding areas need to be upgraded with an inventory of recently flooded areas. The combination of both data layers results in a stratification of the territory into 4 nominal/ordinal risk classes, which can be refined by incorporating information on the cause of flooding (from rivers, from sea, colluviation, infrastructure failure, infrastructure under capacity). Subsequent overlay with, for example, land use maps or spatial destination plans yields information about the ability of a given area to be selected as a controlled flooding area.

Table 1: Floodable soils in the Demer river basin

	Description	Absolute area (km^2)	Relative area (%)
1	Demer river basin	1,918.5	100.0
2	Alluvial soils, floodable from the water courses	324.5	16.9
3	Colluvial soils, damageable by mud flow	129.0	6.7
4	Soils of alluvial and/or colluvial origin not included in 2 or 3	24.3	1.3

Table 2: Floodable zones in urban areas of the Demer river basin

	Description	Absolute area (km^2)	Relative area (%)
1	Demer river basin	1,918.5	
2	Built up areas in Demer river basin	196.3	100.0
3	Built up areas floodable from water courses	32.1	16.3
4	Built up areas damageable by mud flow	18.0	9.2
5	Other floodable and/or damageable built up areas	2.2	1.1

Absolute and relative areas of floodable zones in the built up portions of the river Demer basin, assessed using historical maps and topological and topographical interpretation criteria.

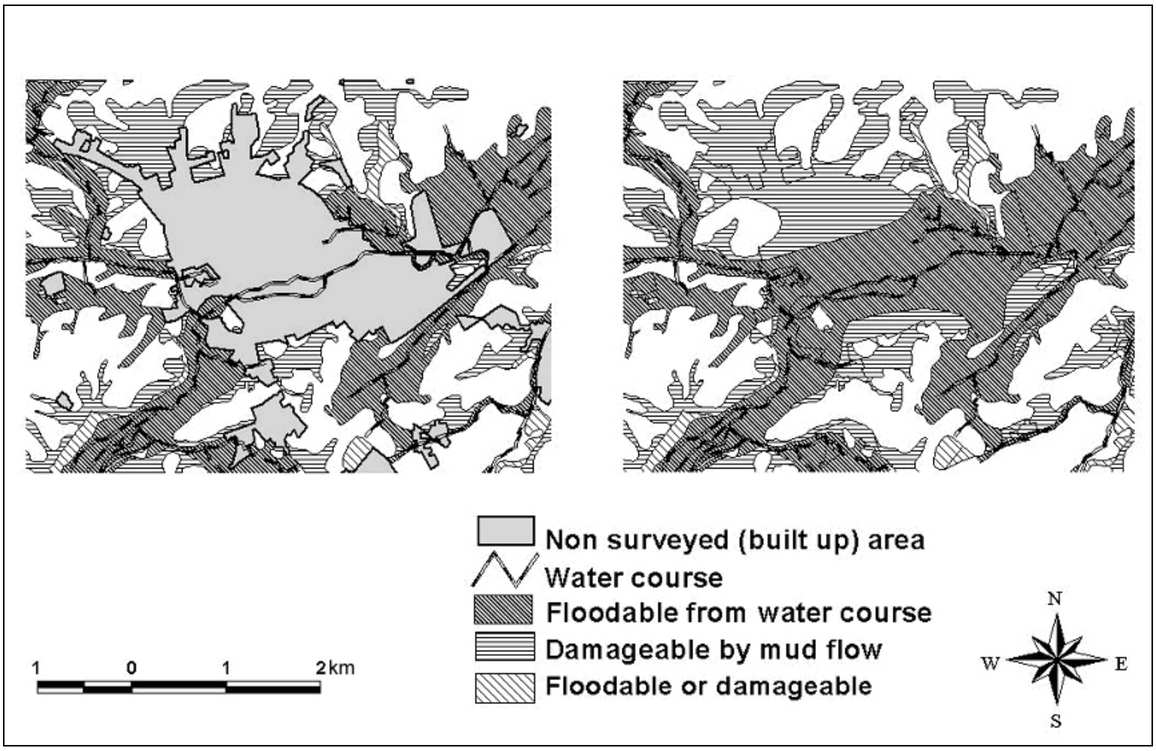

Figure 1: Floodable characteristics of non surveyed portions on the soil map

Upgrading using profile data, transfer functions and process models

A common model-based procedure to assess geo-referenced flooding hazard consists of the following steps:

(1) computing distributed overland flow and water inflow in the river for a number of probabilistic storm events;
(2) simulating the discharge wave of the river draining the study area, using a river simulation model;
(3) determining where and when the crest of the discharge wave is higher than the banks, dikes, gutter and stormwater pipe capacity;
(4) computing the volumes of water which are dispatched over the dike into the surrounding landscape and;
(5) simulating the water flow in the surrounding landscape using a 2D-waterflow model and a DEM.

Georeferenced soil information is required for steps (1) and (5) in order to characterise the water flow domain in terms of initial water content and of water storage capacity, infiltration rates, surface roughness as a function of time.

Since these more complex soil properties have not been determined during the Belgian soil survey, they need to be estimated using pedotransfer functions.

Predictor variables in most common functions are granulometric fractions, organic matter content, bulk density. In order to attribute these predictors to the soil map units a matching exercise between a soil profile database and the soil map needs to be performed. Altitude, slope and aspect of the grid cells composing the flow domain are derived from a DEM.

As a result, the information content of the soil map units is extended with multiple profile and horizon characteristics, enabling assessment of variability of these characteristics and with information, which is derived from a DEM. The extended soil attributes are converted by transfer functions into input information in the simulation models. DEM-derived attributes are directly fed into the simulation model.

Table 3: Absolute area of naturally floodable and/or recently flooded soils in the river Demer basin

	Naturally floodable		Not naturally floodable		Subtotal	
	km^2	%	km^2	%	km^2	%
Recently flooded	83.4	4.3	50.7	2.6	134.1	6.9
Not recently	241.0	12.6	1,543.4	80.4	1,784.4	93.0
Subtotal	324.4	16.9	1,594.1	83.0	1,918.5	100.0

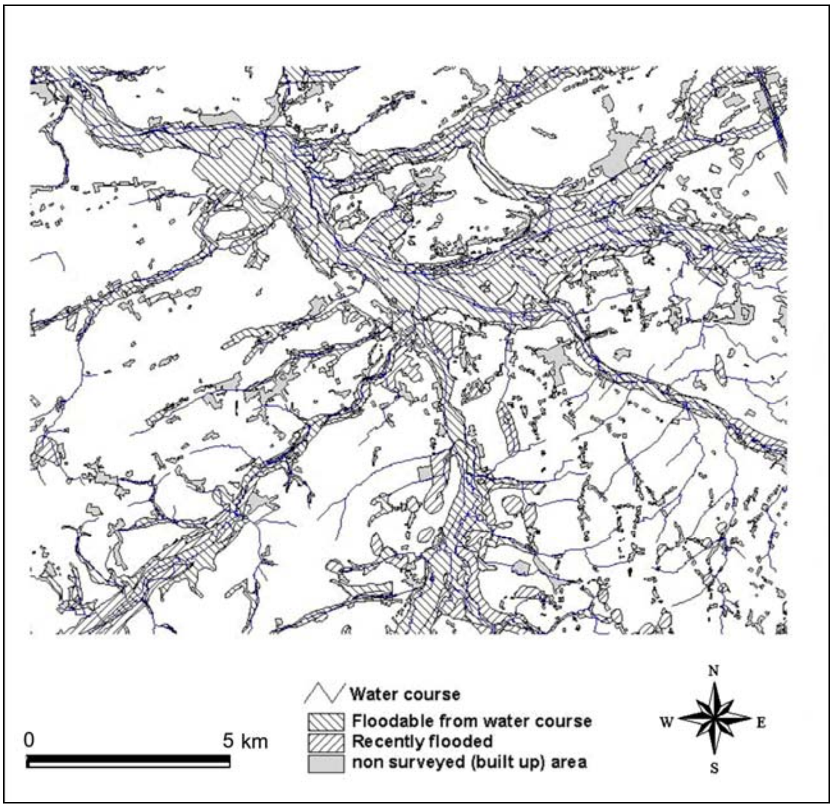

Figure 2: Naturally floodable and/or recently flooded areas in the north central part of the river Demer basin

Conclusions

Belgium has a well documented set of soil maps which is supported by a wealth of field data. Most data have been compiled into a comprehensive digital database, the applications of which have been increasing rapidly since its completion:

(1) Use as a historical data source, a baseline reference for archaeologists, soil conservation surveys, etc.;
(2) Characterisation of taxonomic soil classes and soil map units with typical values and measures of variability for diagnostic and non-diagnostic characteristics;
(3) Verification of regional differences between characteristics of soil units;
(4) Use of basic soil characteristics from the database as predictor variables for the estimation of non-systematically available soil properties;
(5) Combination of profile and other data to upgrade the soil map for assessment of FAO-style land qualities and conducting of ex-ante physical land evaluation studies and ex-post land performance studies.

Since its availability on microcomputer, the database has been extensively consulted by soil scientists in support of research projects and consulting activities.

More research is needed to re-interpret the existing soil maps in the light of new insights in soil dynamics. This will allow a better understanding of the soil cover as a system, which should be preserved at all cost for future generations. This research is pursued at the different Faculties and Colleges of Agriculture, Geology and Geography, the Belgian Soil Service and the land management institutions. The Belgian Soil Science Society serves as a forum of encounter, exchange of experience and promotion of international linkages.

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An overview of general Land and Soil Water conditions in Bosnia and Herzegovina

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General Situation

Bosnia and Herzegovina emerged from the 1992-1995 war with an almost totally destroyed infrastructure (electric power, water supply, sanitation, transport, and other systems), ruined industry and collapsed economy. About 2 million people were turned into refugees and displaced persons. About two hundred thousand were killed. Many rural areas, due to the fact that they were not militarily defended, were turned into demographic deserts, while the housing and economic facilities were almost completely destroyed, landscape deforested, cities devastated and heavily damaged. More than two million landmines were planted throughout the country, thousands of tons of various kinds of waste (municipal, construction, medical, etc.) accumulated and are still waiting to be disposed of, thousands of hectares of forests were destroyed or cut, vast areas of high quality agricultural land and pastures were devastated or contaminated.

The current state structure of Bosnia and Herzegovina (BIH) is regulated by the Dayton Agreement. The country is composed of the Federation BIH (divided into 10 cantons), the Republic of Srpska (RS) and the District of Brčko as separate administrative units.

Geography

Bosnia and Herzegovina (BIH) is geographically situated in southeast Europe, in the Balkan Peninsula, between 42° 26' and 45° 15' of northern latitude and 15° 45' and 19° 41' of eastern longitude. It covers 51,000km^2.

The country is largely made up of mountainous highlands in the south and the west, hilly lands in the centre and the north, and flat to undulating plains in the northeast, where most of the fertile agricultural lands are situated.

The agricultural activities in the other parts of the country are mainly limited to relative narrow alluvial valleys and on undulating to rolling hills.

Physiographically BIH can be divided as follows:

- Flatland or lowland areas (up to 300 meters above sea level), 13.3%;
- Hilly area (300-500 meters above sea level), and Hilly-Mountainous area (500-700 meters above sea level), 26.3%;
- Mountainous area (above 700 meters above sea level), Mediterranean-Mountainous area (700-500 meters above sea level), 57.2%;
- Mediterranean area (below 500 meters above sea level), 5.2%.

Climate

Bosnia and Herzegovina is situated in the northern temperate belt, at equal distance from the Equator and the North Pole, thus the climate is not dominated by only one type of weather. There are neither dry seasons nor harsh and long winters. In terms of climate it can be divided into three divergent regions with more or less sharp boundaries or moderate transition zones:

- Northern region;
- Hilly mountain region;
- Southern region.

Temperature

Northern region, with temperate continental climate and average temperature in January from –0.2^{o}C to 2.0^{o}C, in July 20^{o}C to 22^{o}C.

Hilly-mountains region, with variations of continental, high-mountainous and alpine climate, average temperatures in January from –0.3^{o}C to –7.4^o C, in July 10.2^{o}C to 21.2^{o}C.

Southern region, with characteristics of Mediterranean climate, average temperatures in January being 2.3°C, in July 22.5°C to 25.7°C, and precipitation of about 2,000mm.

The varying climatic conditions in BIH offer wide possibilities to the agricultural production, both in terms of crop choice and cultivation of land farming, fruit-growing, vine-growing, vegetable growing and forage crops and in terms of livestock production.

Hydrological cycle

About 3,871,900ha (75.7%) of the BIH territory drains via the Sava River to the Black Sea, and 1,241,000ha, (24.3%) drains via the River Neretva to the Adriatic Se)a. The boundary between these two catchments is obscured at the local level, especially in the south west, where rivers flow through karst areas.

The spatial variation of hydrological cycle (Figure 1.) is very characteristic for BIH. For instance, the mean annual precipitation in the southern region is 2.5 times larger than in northern region, and twice that in the central region. In the south, the mostly Mediterranean type precipitation is between 1,500 and 2,000mm of rain, potential evapotranspiration 900mm, actual evapotranspiration 600mm, potential water deficit or irrigation requirement 300mm and potential outflow or surplus from 900 to 1,400mm. It is interesting that the southern region has the most abundant precipitation, but also the highest water deficit, and highest water surplus in the absolute and relative sense.
The mean annual precipitation in *central region* of BIH is about 1,000mm, potential evapotranspiration 650mm, actual evapotranspiration 600mm, potential water deficit or irrigation water requirement 50mm and potential outflow or surplus 400mm. This region has a much better water-balance than the southern region.

In the northern region of BIH mean annual precipitation is about 800mm, potential evapotranspiration 700mm, actual evapotranspiration 600mm, potential water deficit or irrigation water requirement is 100mm and potential outflow or surplus 200mm. This region, with its continental climate characteristics, is more similar to the central than to the southern region regarding soil water cycle.

Land resources

The total area of BIH is 5.11 million ha, of which 50.3% is agricultural land (2,572,000ha) and 48.3% under forest.

Total arable land in Bosnia and Herzegovina amounts to 1,585,000ha or 62%; in the Federation 765,000ha and in the RS 820,000ha. The plough-land area amounts to 1,018,000ha or 19.9% of the total land. There are about 0.59 hectares of agricultural land per capita, of which 0.36ha are fields and gardens.

The land quality classes in Bosnia and Herzegovina are given in Table 1. The best quality land (classes I to III) covers 14.0%, of the territory of Bosnia and Herzegovina, class IV land covers 17.9%, class V 16.7%, class VI 31.75% and classes VII and VIII 19.4% (data according to SZS).

Forty-five percent of agricultural land is hilly (300-700m a.s.l.), of medium quality and well suited to semi-intensive livestock production. Mountain areas (> 700m a.s.l.) account for a further 35 percent of agricultural land but high altitude, steep slopes and lower fertility soils limit the use of this land to livestock grazing during spring and summer. Less than 20 percent of agricultural land (half of all arable land) is suited to intensive agriculture, most of it in lowland river valleys. The land base for agriculture is thus very limited in both quantity and quality. Natural water resources are more abundant, with many unpolluted rivers and readily accessible groundwater. Despite this abundance of water only about 10,000ha (0.1 percent of arable land) was irrigated before the war, an area which could be increased significantly.

Despite the fact that the BIH territory is mainly mountainous, until now little has been done to improve water and soil conditions in the upland areas. Excessive deforestation, inappropriate conversion of grass land to arable land and uncontrolled cultivation of sloping terrain are degrading the land even in the valleys and lowland regions where soils are of good quality. The large sums invested in the protection of flat areas (river course direction, embankments, outfall drains, pumping stations) remain ineffective if soil and water conservation measures, both of an agricultural engineering and technical nature, are not undertaken in the hilly-mountainous uplands. Such measures would contribute to revitalising the mountainous area and would provide better protection for the lowlands.

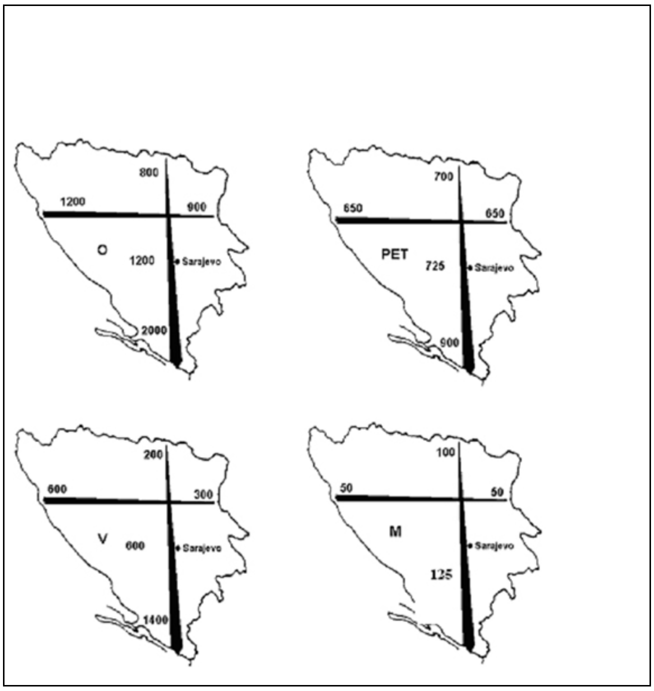

Figure 1: Scheme of spatial distribution of average annual precipitation (O), potential evapotranspiration (PET), surplus (V) and soil water deficits (M).

Table 1: Land quality classes in Bosnia and Herzegovina

SOIL CLASS	ha	%
I – III	717,600	14.04
IV	917,500	17.94
V	856,000	16.74
VI	1,627,400	31.83
VII – VIII	994,400	19.45
Total	**5,112,900**	**100.00**

Soils

The Basic Soil Map (BSM) Project was established in 1964 at the scale of 1:50,000 and implemented by Agropedology Institute from Sarajevo. For this purpose, the first Manual for field soil investigation was published. The BSM was developed on pedogenetic principles and lasted from 1966 to 1986. It was the largest pedological project in Bosnia and Herzegovina. Classification of soils is based on genetic-evolutionary principles, in which the type of soil was the basic unit of classification system. Map units including type, subtype, variety and even form. Morphological and lithological characteristics were the chief criteria. 1,176 different mapping units have been identified on the soil map of BIH. The total number of printed sheets is 116.

The soil map of BIH at scale 1:50,000 was made more than 20 years ago. Since then genetic-evolutionary classification has been through significant changes, which clearly can be seen from the terminology of the map units in the legend of the map.

There were two periods in development of the soil map, which differ from each other in inventory criteria, classification and methods. In the first period from 1963 to 1973, the national classification was based on genetic principles. In the second period 1973 to 1985, a new classification was adopted, which was influenced by international classifications, and this is readily apparent on soil maps made after 1973. In the second stage of mapping, application of modern methods were used such as telemetric research using aerial photography at various scales. At first, black and white photography was used, following by colour photography.

One of the very important tasks at the present time and in the future for the soil scientist will be to adapt the national classification to the FAO classification, and to carry out adjustments to the database of the BSM of BIH. Bosnia and Herzegovina is very rich in different types of soil whose characteristics very much derive from geology, morphology, climate conditions and other factors.

The *flat or lowlands* zone is found in the northern part of BIH and represents the most valuable land resource. There, the degree of development of primary food production is much higher than in the hilly-mountainous areas. The most common types of soil are: Stagnic Podzoluvisols, Fluvisols, Umbric Gleysols and Eutric Gleysols.

The *hilly zone* is more heterogeneous than the lowland zone in terms of soil. A considerable part of this zone has slopes above 13% and the processes of erosion are very marked. The erosion processes are further enhanced by inappropriate ways of farming, lack of water and soil conservation measures and preference being given to row crops (corn and potato) on such terrains. The most common types of soil are: Chromic Luvisols, Eutric Cambisols, Leptosols – Rendzic Leptosols and Vertisols.

In the *mountain zone* the erosion processes are present also, although these lands are mostly covered by forests and grasslands. As for sown crops, rye, barley, oats and potato dominate. The most common types of soil are: Dystric Cambisols and Dystric Regosols which are predominantly present, followed by Leptosols – Rendzic Leptosols and Regosols.

The Mediterranean zone, with its warmer climatic conditions, can grow a wide variety of crops and support intensive farming, so that as well as traditional arable crops, early vegetables are also being cultivated for the local markets. Fruit-growing and vine-growing are also developed here, so that this region is also called the region of southern crops. The most common types of soil are: Lithic Leptosols, Regosols, Leptosols – Rendzic Leptosols, Chromic Cambisols, Fluvisols in the river valleys, Umbric and Eutric Gleysols in the karst fields. In the swamps, Histosols are often present and these are important environmentally.

In summary the main characteristics of soils in Bosnia and Herzegovina are:

- Acid soils occupy more than 1/3 of the land;
- Humus content is low;
- Content of the most important fertiliser nutrients is low;
- Soils are generally shallow;
- Excess water on about 14% of the territory;
- Inadequate concern for improvement of fertility;
- Individual land holdings are small and fragmented;
- Erosion is a problem particularly on sloping land.

Land use change

The recent conflicts in the 1990s have had a major effect on land cover and land use in Bosnia and Herzegovina. The movement and displacement of people caused significant changes in the distribution and pattern of population on the ground.

There was a large land use (LC/LU) change during the war years 1992-1995. This change has been primarily reflected in the area of abandoned land and deforestation.

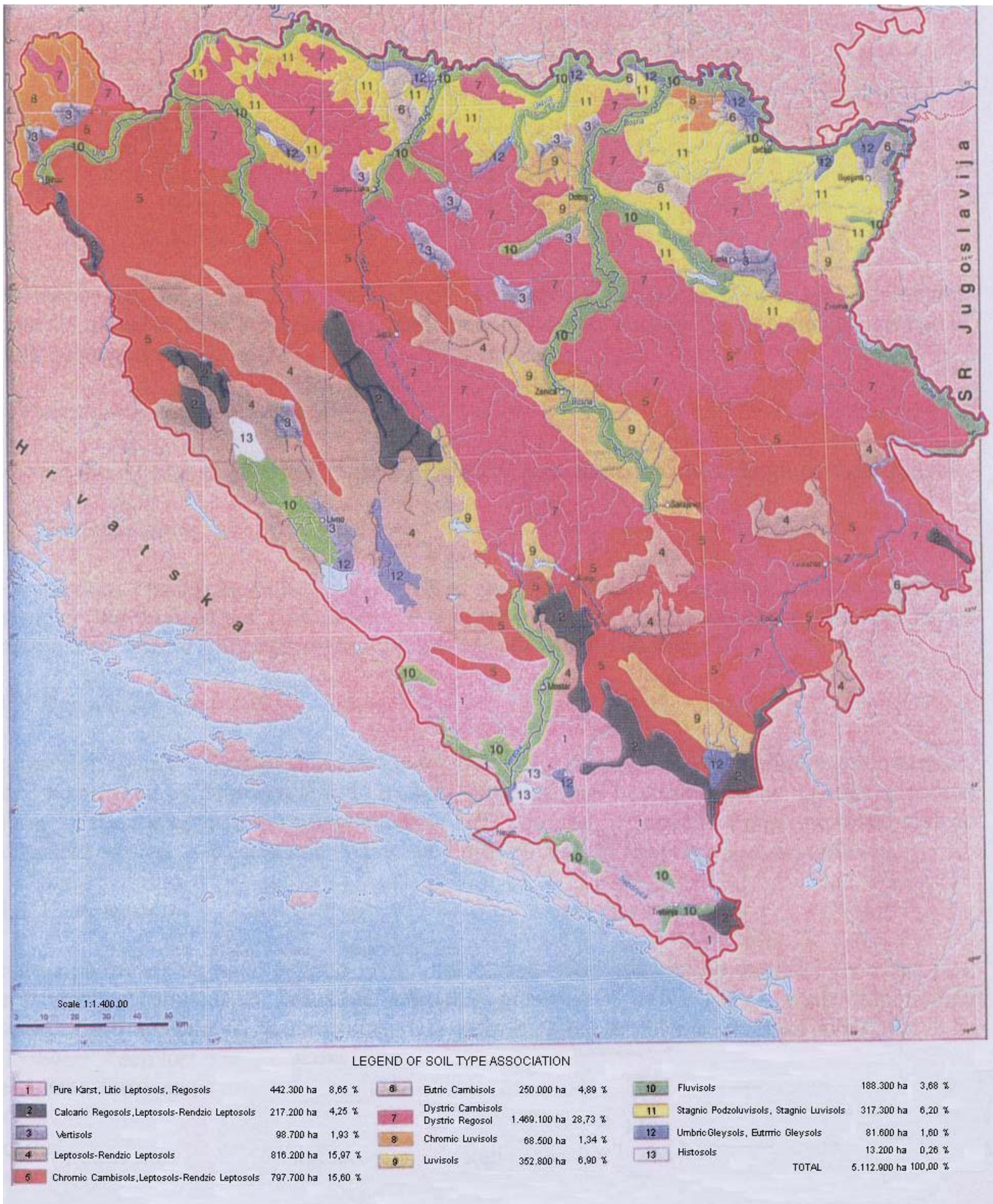

Figure 2: Soil Map of Bosnia and Herzegovina

Although before the war there was unused agricultural land in BIH because of migration of people from rural areas to towns and abroad, the amount of abandoned land greatly increased during the war. Economic considerations are another factor contributing to the increase of abandoned land. State farms leave significant areas of land uncultivated because they cannot sell agricultural produce profitably.

Significant deforestation occurred mainly during and after the war. Large areas of forest were cut and wood used as firewood as well as a source of funding for the war.

At present, it is estimated that 3,000 hectares of agricultural land are permanently lost to other land uses annually. It is often the most fertile and accessible cropland that is lost but there is no reliable record of these land use changes. Yet, the reliable and timely information on land cover and land use change is an essential part of sustainable land management. Given the limited availability of agricultural land in BIH, effective use of this land is essential for sector development.

Land-related constraints to sustainable agriculture

The land question in BIH can be looked at in four main ways:

- Considerable uncertainty over land rights, with obvious implications for investment;
- Fragmentation and small size of farm units (see table below);
- Poor or non-existent (some war-damaged) cadastral and legal registration systems;
- Mined land is a great risk for people. De-mining of the thousands of minefields may require many years to complete.

Whatever approach is adopted will be difficult. There is no common legal regime at BIH level for regulating land ownership. Entity laws do exist and regulate legal titles and registration of ownership over real estate, including land. Again however there are in practice three versions of real estate and land transaction legislation, one for the RS, and one for each 'Canton' within the Federation. Fortunately the main principles of all three are similar because the legislation rests heavily on ex-Yugoslav laws.

Any sense that this relative uniformity is an advantage must be illusory however, given that these roughly similar laws are likely to be applied very differently and also manipulated in each Entity or Canton. Moreover, land information and survey records are archaic or were destroyed during the war.

Pre-war (1991) Indicators of Land Access and Fragmentation can be seen in Table 2.

The average size of a rural household farm in the BIH is about 3.0 hectares divided between 8 and 10 plots. Moreover, for better understanding of the land related constraints to the land resources, it is useful to have the insight into the ratio of different categories of land use per inhabitant in relation to altitude in the layout of the landscape of Bosnia and Herzegovina, (Table 3).

Land market activity has to be increased as a means of addressing the problem of small farm size and fragmentation. Leasing should be encouraged by developing legally recognised, standard lease contracts, which protect both lessee and lessor.

Institutional reforms include continued international community support for the process of updating and reconciling the land book and the land registry, and computerising land records; amendments to inheritance law to prevent further land fragmentation; and the establishment of Land Development Boards for land use projects that require cooperative action (drainage, irrigation and land consolidation programmes, and the management of communal grazing areas).

Minefields are still one of the main constraints to the development of rural areas in BIH. Large tracts of strategically important agricultural land and forest areas remained mined after the war and therefore cannot be used. De-mining of the thousands of minefields may require many years to complete. Estimates do suggest that at current rates of de-mining, it might take several generations before rural areas are again safe.

The de-mining of agricultural land will be accelerated by establishing an administrative unit to: identify and prioritise land for de-mining, obtain requisite donor finance, and coordinate and monitor de-mining.

Table 2: Indicators of Land Access and Fragmentation

Farm size in ha	Number of Farms	Percentage of Total Area
Up to 1	180,673	33.93
1 - 3	178,138	33.45
3 - 5	86,272	16.20
5 - 8	56,115	10.54
8 -10	16,661	3.13
More than 10	14,669	2.75
Total	532,528	100.00

Source: Statistic Bulletin (1991)

Table 3: Different categories of land use per inhabitant

Ratio of land use		Height above see level in BIH	
Category	ha/capita	in m	in %
Ploughed fields and gardens	0.23	0 – 200	14.2
Total plough able land	0.36	200 – 500	29.0
Total agricultural land	0.59	500 – 1,000	32.1
		1,000 – 1,500	20.8
		1,500 – 2,000	3.8
		More than 2,000	0.1
		TOTAL:	100.0

[1]Precise population data is still lacking. Current estimates of total population range from 3.6 million (World Bank), to 3.7 million (Reconstruction and Return Task Force - RRTF).

Figure 3: Minefields information

Current de-mining costs range from US$2-7/$m^2$ depending on terrain,
density of vegetation, residual metal content in the ground, and the number of land mines discovered.

Following the guidelines and programmes developed by the Reconstruction and Return Task Force (RRTF), the resettlement of rural land will be supported by ensuring that the returnees, re-locating families and residents in resettlement areas have full access to available credit and extension facilities.

A clear agricultural policy response to the tragic problem of land mines in rural areas has yet to be developed. It is estimated that there are 17,000 mine fields and some 750,000 land mines remaining in BIH. More then 250,000ha of arable land is rendered inaccessible because of mines. As urban areas and infrastructure have priority for current de-mining activities, only 330ha of agricultural land had been demined by the end of 2001.

Mines are a great hazard to people that walk on afflicted areas for carrying out agricultural work or felling of trees. Indirectly, minefields are the cause of fires, spreading of weeds, erosion processes and other forms of degradation, directly related to plant production.

De-mining is therefore critically important not just from the human rights perspective, but is also as a pre-condition for long-term development and environmental protection.

Other constraints to sustainable agriculture

Land and water conservation are the major environmental issues for land use policy. There is a strong awareness of this imperative in FBIH as around 538,500ha (20 percent) of agricultural land has suffered some environmental damage. Of this area, around 90,000ha is agricultural land taken out of production before the war for mining, roads, human settlement, industry etc. War damage (trenches, fortifications etc.) accounts for a further 10,000ha and 180,000ha have been polluted by the impact of roads and power stations.

The cost of recovering these areas is probably prohibitive. Much more can be done to restore the remaining 258,500ha that has suffered a combination of erosion and fertility loss as a result of poor management. Guidance on management techniques such as deep ploughing, green manuring, liming and crop rotations would assist this restoration.

Overview: society's response to amelioration

Ongoing efforts to make inventories and assess the land resource base in BIH are clearly enlarging the knowledge base that will serve as a foundation for decision making on future land use. Bosnia and Herzegovina presents a diversified resource base offering opportunities for both quantitative and qualitative improvement of the agricultural production.

Recent legislation and policy intentions reflect a real concern to preserve land resources. Recommendations to train municipal authorities in the application of ‘ISO 14000 - Environmental Management Systems for Municipalities’ are underlining the genuineness of these pre-occupations. Actual discussions within local governments on priorities to de-mine agricultural land, and on the identification of ‘virgin’ land, i.e. not polluted, for promoting biological agriculture are other indicators of support for preservation planning.

International support

The FAO ‘Agricultural Sector Strategy Project’ (TCP/BIH/7821) was finalised in 1999 with the publication of a comprehensive medium-term strategy paper for the agricultural sector in BIH. The global objective of the strategy recognises the importance of optimising land use and preserving the natural resources base.

The Land Resources Inventory Project (GCP/BIH/002/ITA) was carried out from 2000 to 2002. The activities covered the entire territory of BIH. The development of a land use management model based on the Agro-Ecological Zoning (AEZ) methodology is a major achievement. The project is still active at a lower level with the main task to establish sustainable land use methodology in the three municipalities of BIH.

GTZ (German Cooperation) is presently involved in some pilot cadastral projects, addressing among other things the issue of land registration procedures. The major aim here is to build a modern cadastre that responds to the present needs of the country. In some pilot areas, new procedures to deal with the privatisation of state enterprises, including the land resources are being tested.

The United Nations Development Programme (UNDP) implements the Local Action Programme in the Brčko District (BLAP), hence gaining important experience in area-based development. With the technical assistance of FAO, this programme has also supported the Department of

Agriculture and Forestry with the preparation of a plan for the future use of the 'PD Posavina' state farm based on the optimal land use.

Through its Agricultural Strategy and Programming Unit (ASPU), the European Union supports policy and legislation development for a number of land-related issues. It is instrumental in the revision of the legislation on land restitution. Furthermore, many national and international NGOs are working in BIH in the sectors of agriculture and sustainable use of land resources.

Conclusions

The basic goals for the short term in soil use and management in Bosnia and Herzegovina are:

- Institutional strengthening in the domain of management, protection and use of land resources;
- Reduction of soil degradation.

Measures necessary for achieving these goals, e.g:

- Preparation of a unique strategy (policy) for the protection of soil at the national level;
- Preparation of a unique law on soil (protection, use and management), based on planned policy;
- Inventory of the current balance of soil in Bosnia and Herzegovina for the needs of strategic planning;
- Determination of the level of contamination in order to provide conditions for organic food production (institutional building of soil contamination monitoring procedures);
- Increase in fertility of intensively used soils with a soil fertility monitoring system;
- Establishment of a state or entity level agency or institute that would be in charge of the implementation of soil management and protection policy;
- Determination of the current and potential erosion of soil in Bosnia and Herzegovina and determination of protection measures (preparation of erosion and landslide maps);
- Classification of soil for sustainable management and use in agriculture and forestry;
- Determination of the quality of soil in order to outline priorities;
- Establishment of a systematic monitoring of soil, first within the Aple-Adria association, and then later within the European integration processes;
- Preparation of other soil maps in order to provide for better space management and increasing food and raw-material production;
- Establishment of a unique land information system (ZIS);
- Revitalisation of 'technogene deserts' of mines and thermal power plants;
- Raising the education level of the population on the importance of soil for sustainable development and future benefit of future generations;
- Preparation of programmes for activation of unused lands and changing limited areas on inclined terrains into orchards and forests in order to prevent erosion;
- Reform of the land registry and cadastral records.

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Soil Survey and Soil Mapping in Bulgaria

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Introduction

The structure of the soil cover of Bulgaria is a result of the evolution of natural processes from the Pliocene to the present day Sub Atlantic, including neotectonic and anthropogenic influences. The structure of the soil cover is additionally complicated by the variability of modern climate conditions. Five types of pedo-climate regimes can be distinguished in the country: cryo-udic, meso-udic, meso-ustic, meso-xeric and thermo-xeric (Boyadzhiev, 1967). As a result, 20 out of a total of 28 FAO soil map units can be found on the relatively small territory of Bulgaria (Boyadzhiev, 1994b). For the last 90 years, collecting, preserving, updating and using soil information have been the main aim of investigations involving soil survey, diagnostics, classification and mapping.

Soil Mapping

The organised systematic study of Bulgarian soils, commissioned by the Ministry of Agriculture, started under the guidance of Nikola Poushkarov in 1911. In 1913 Poushkarov presented the first soil map of the region of Sofia at a scale of 1:126,000. The first soil map of Bulgaria was prepared at a scale of 1:500,000 in 1931. This map showed the geographic distribution of the main soil units. The soil map of Bulgaria at a scale of 1:200,000, prepared by Koinov and Tanov (1956), identified a significantly larger number of soil units, compared to those identified in the map of 1931.

The monograph 'Soils of Bulgaria' (Antipov-Karataev *et al.*, 1960) collected all the available data on morphological, physical, chemical and physico-chemical characteristics of the main soil units. Systematic large-scale soil survey started in 1956.

A soil map of Bulgaria at a scale of 1:400,000 was published in 1968 (Koinov *et al.*, 1968). This map was based on the information obtained from the soil survey at a scale of 1:25,000 of over 65% of the country's territory. The map identified 67 soil units at group and subgroup level, soil texture class and degree of erosion. Figure 1 shows a reduced version of the digitised soil map of Bulgaria at 1:400,000 scale. After generalisation of the map at 1:400,000 scale, a soil map at a scale of 1:1,000,000 was compiled and published in the geographic atlas of Bulgaria (Koinov, 1973a). It distinguished 45 soil units. The geographic atlas of Bulgaria included also maps of the geographical distribution of the soils according to their texture (Koinov, 1973b) and soil reaction (Koinov, 1973c), both at 1:3,000,000 scales; maps at 1:2,000,000 scales of the soil geographical (Koinov, 1973d) and soil erosion regions (Koinov, 1974e); and the distribution of the soil resources within the administrative districts of the country (Koinov, 1973f). Soil survey at a scale of 1:10,000 started in 1971.

By 1988 the soils of Bulgaria had been mapped at 1:25,000 scale and the soil survey at a scale of 1:10,000 was in a progress. Currently, soil maps at a scale of 1:10,000 cover almost the entire territory of Bulgaria. In addition, soil survey and maps at scales from 1:5,000 to 1:1,000 cover land with particular problems, such as salinisation and pollution with heavy metals, arsenic, oil products or radionuclides. In 1994, the soil map of Bulgaria at a scale of 1:1,000,000 was completed based on the 1990 FAO revised legend. This map was prepared for incorporation in the soil geographical database of Europe at 1:1,000,000 scale (European Soil Bureau, 1998).

Soil information, databases and monitoring

According to the extended systematic list of the soils in Bulgaria, 200 soil units have been defined, each of them carrying coded information about profile depth, degree of erosion, classes of soil texture and stoniness, parent material, slope and land evaluation. The formula for coding the soil units is expressed as:

$$N^{a}\frac{L_{1,2,3,...}}{N_{1,2,3,...}}N^{b}, \qquad (1)$$

where: N^a is the land category, according to the Bulgarian land evaluation system; $L_{1,2,3,...}$ are codes for soil description; N^b is the field index and $N_{1,2,3,...}$ are the codes for texture classes, stoniness, parent materials, etc. The defined soil units are characterised by profile morphological description, particle-size distribution, pH and the amounts of total carbon, nitrogen, phosphorus and calcium carbonates, based on the data from 50,000 main soil profiles. In addition, the information for more than 250 soil profiles, representing the main soil varieties, is expanded by analytical data on the humus content, hydrological properties, chemical composition, Fe and Al status, CEC, base saturation, etc.

Archives maintained at administrative level have been created from the basic documents such as soil survey records, remote sensing information, laboratory data forms, climatic parameters, etc. All the relevant information is kept in special Soil Survey Books in the form of text, tables and maps. The enormously important information about the soil resources is now summarised and systematised by the National Soil Survey Service creating a Geographic Soil Information System (GSIS). Digitisation of the existing soil maps to the lowest taxonomic levels was an important step in building up the GSIS.

All paper and electronic records are deposited at the Research Institute of Soil Science and Agroecology, the National Centre for Agrarian Sciences, the Ministry of Agriculture and other government institutions.

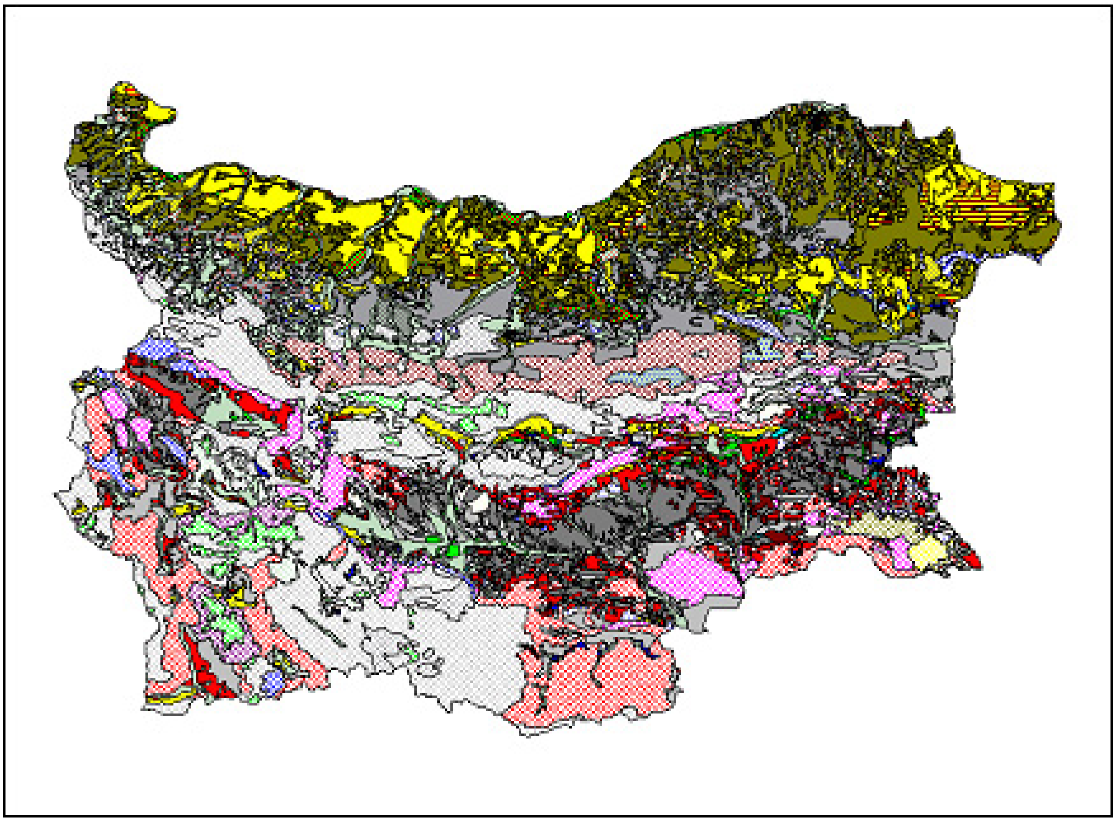

Figure 1: Generalised version of the digitised soil map of Bulgaria at 1:400,000 scale.

In addition to the soil survey, soil agrochemical survey and maps at a scale of 1:25,000 cover the arable land in Bulgaria. The records from the agrochemical soil survey include information about the total and available forms of the macro- and microelements and data of the main soil physical and chemical characteristics. The relevant information is updated periodically.

Monitoring of the soil resources in Bulgaria has been in a progress for some time. It is based on 146 SOTER units, selected in accordance with the digital soil and geological maps of the country. The soil monitoring aims at maintaining actual information about the soil vulnerability to different degradation processes, such as erosion, salinisation, acidification, water logging, heavy metal pollution and groundwater pollution. Monitoring points have been selected for collecting records of the background values and their modification due to different anthropogenic impacts.

Applications

Since 1956 the data from the large-scale soil survey have been used to compile soil maps of Bulgarian geographical regions at 1:50,000 scale (Koinov, 1956) and administrative districts at 1:100,000 scale (Koinov, 1965; Boyanov, 1975, 1976; Andonov and Kolchakov, 1982; Ninov and Andonov, 1984). Thematic maps of the whole of Bulgaria have been prepared also to facilitate the soil agro-ecological partition at a scale of 1:600,000 (Yolevski *et al*., 1980), land evaluation for crop production at 1:1,000,000 scale (Kabakchiev *et al*., 1985) and the distribution of waterlogged soils at 1:400,000 scale (Ninov, 1986).

Soil maps of some main catchments have been compiled for the purposes of diverse national and international research projects. Boyadzhiev compiled soil maps of Bulgaria at a scale of 1:3,000,000 according to the Soil Taxonomy (Boyadzhiev, 1994a) and the revised legend of FAO-UNESCO-ISRIC (Boyadzhiev, 1994b). An example of a thematic soil map is presented in Figure 2. The map of soil vulnerability to acidification was prepared by Stoychev and Kolchakov (1998), based on the soil survey records and the soil map of Bulgaria at a scale of 1:1,000,000. The main soil units are grouped according to their vulnerability to acidification on the basis of the data for pH (H_2O), cation exchange capacity (CEC), base saturation (BS), exchangeable acidity and clay content in the top layers of virgin and arable lands. The relevant soil survey data and the expert evaluations have shown that the soils could be classified in four broad groups:

First group - soils resistant to acidification

This group is characterised by pH>7.5, CEC>35 meq/100g, BS=100% and high content of carbonates from the top of the soil profile. The group includes Haplic Kastanozems (KSh), Rendzic Leptosols (LPr), Calcaric Fluvisols (FLc), Haplic Solonetz (SNh), Gleyic Solonchaks (SCg) and associated with them Calcaric Regosols (RGc), Lithic Leptosols (LPq) and Calcaric Phaeozems (PHc).

Second group - soils moderately resistant to acidification.

The main parameters of this group range as follows: pH 6.0-7.5, CEC 35-60 meq/100g, BS 85-95%, clay content >40% and domination of 2:1 clay minerals. The group includes Haplic Chernozems (CHh), Eutric Vertisols (VRe), Luvic Phaeozems (Phi), Chromic Luvisols (LVx) and the associated with them Eutric Regosols (Rge), Vertic-Chromic Luvisols (Lvxe) and Eutric Fluvisols (Fle).

Third group - soils poorly resistant to acidification.

The main parameters of this group range as follows: pH 4.8-6.0, CEC 25-35 meq/100g, BS 50-85% and content of exchangeable aluminium<10% of CEC. The group includes Haplic Luvisols (LVh) and associated with them, Plano Chromic Luvisols (LVxp), Plano Haplic Luvisols (LVhp), Eutric Cambisols (Cme) and Eutric Planosols (Ple).

Fourth group - soils non-resistant to acidification.

This group is characterised by pH<5.0, CEC<20 meq/100g and content of exchangeable aluminium >10% of CEC. The group includes Dystric Planosols (PLd), Dystric Cambisols (CMd), Humic Cambisols (CMu), Haplic Acrisols (ACh) and associated with them, Umbric Leptosols (LPu) and Lithic Leptosols (LPq).

The total area of the soils with pH<7 (groups I, II and III) occupies about 6.5 million ha, which is about 60% of the entire territory of Bulgaria. About two thirds of that land, 4.3 million ha, is vulnerable (non-resistant) to acidification (pH<5).

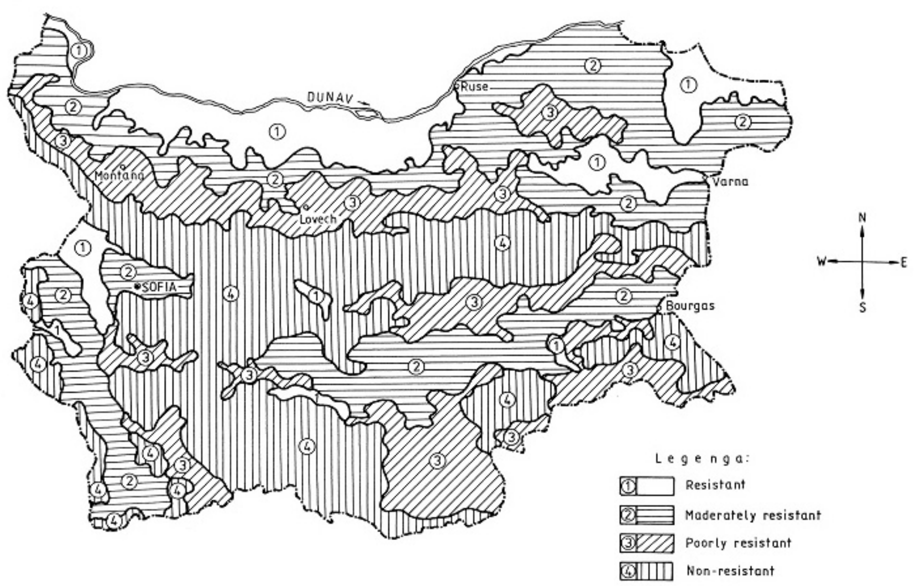

Figure 2: Map of the vulnerability of the soils in Bulgaria to acidification

The collected and updated soil information facilitates an evaluation of agricultural land on the basis of the actual and the potential suitability for different types of land use. The digital soil maps, including relevant soil, land evaluation and categorisation data, are successfully used nowadays for the purposes of land reform and land privatisation. The soil information is used also for land evaluation, road construction, various agricultural, urbanisation and economic activities, as well as to support agrarian reform and the new cadastre of agricultural lands, for which development is in a progress.

Outlook

The survey and collection of soil data in Bulgaria is now well developed. Further systematisation of all the available soil data in the GSIS will enable their linkage with other environmental data.

Eventually the GSIS will include all the data obtained from the soil surveys at 1:25,000, 1:10,000 and 1:5,000 scales, such as soil morphological and analytical characteristics as well as land description, for each soil mapping unit. This will facilitate the interpretation of all the data needed for making technical decisions and planning alternative variants for land use and compiling new thematic maps. With additional information about landscape and climatic elements, nutrient contents and different anthropogenic impacts, the GSIS will facilitate also predictions of land degradation risks and planning measures for soil conservation and land reclamation.

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Soil Resources of Croatia

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Introduction

Bearing in mind the Multifunctional Character of Agriculture and Land (MFCAL) approach, Croatia does not treat the development of agriculture and forestry merely as sources of food, timber and/or profits and separate from other functions and roles. All the functions and roles of agriculture and agricultural land are inextricably linked and equally important. In national parks and other protected and/or sensitive areas, the most important function is the environmental. In others it is the social function, providing profitable employment and maintenance of a planned and desirable demographic balance, or shaping a cultural landscape for recreation and tourism.

Following this approach, all the roles of soil are equally important because, after all, it is possible to buy food and other goods on the global market, but agricultural land, landscapes and plants in it are not subject to the same market forces.

Due to its varied climate, geological structure, relief and vegetation, most of the common European soil types can be found in Croatia.

Soil genesis depends primarily on the parent rock and prevailing climate. A layer of soil 30cm thick may form in 1,000 to 30,000 years on loose parent materials, such as sand, loess and marl. On limestone, a very common rock in Croatia, for a layer of soil 50cm thick to form (which is required for a good and fertile soil for agriculture) may take more than 1 million years. Due to such long formation time, Varallyay (1997) describes the soil as a 'conditionally renewable' resource, because although it may be renewed, this will not be possible within the human time scale.

Soil Survey

Soil investigations have a long history in Croatia and have never lagged behind the rest of Europe.

After the establishment of the Higher Royal Agricultural and Forestry School at Križevci in 1877, M. Kišpatić's 'Zemljoznanstvo' (Earth-knowledge) was published, as the first textbook of soil science in the Croatian language, and generally one of the first in the world. In 1891, the first laboratory for soil analysis was founded in Zagreb. Thereafter followed the establishment of the Department of Soil Science, Petrology and Mineralogy of the Forest Academy in Zagreb in 1910, later integrated into the Faculty of Agriculture and Forestry of the Kingdom of Yugoslavia in 1919 in Zagreb.

The most important role in the development of soil sciences in Croatia has been our famous soil scientist, plant physiologist and plant ecologist Mihovil Gračanin (1901-1981). The first organisation of Croatian soil scientists was the Yugoslavian section of International Society of Soil Science, whose first president in the period 1931-1940 was M. Gračanin. So, we take 1931 as the year of establishment of Croatian Society of Soil Science - CSSS. After World War II, CSSS continued its activities within the Yugoslavian Society of Soil Science, as a member of ISSS (now IUSS).

Versions of several soil maps at smaller scale have been prepared for the area of the former Yugoslavia, mostly for educational purposes. The work of Croatian authors Škorić and Bogunović is noteworthy in the production of the Soil Map of Yugoslavia at 1:2,000,000 scale, based on a map prepared for the Soil Map of Europe (CEC, 1985). This latter project was initiated by FAO at a scale of 1:1,000,000. Using the same maps and soil survey material, Bogunović (1997) prepared the Soil Map of Croatia at the scale 1:1,000,000, the first one produced after the independence of the country.

In the period 1964-1985, the General Soil Map of Croatia at scale 1:50,000 was prepared. This map was an epoch-making document, containing as it does data on physical, chemical and biological properties and the spatial distribution of soils of Croatia, collected with an observation density of approximately one soil profile per 1,000ha. This important document has analytical data for about 6,000 soil profiles and is the basic document on the Croatian soils. It was made using modern methods, with the application of aerial stereo-photographs, with the soils being depicted on sheets of a topographic map. The maps were printed, but some sheets, with areas extending into neighbouring countries and those on the Adriatic islands, were never printed due to lack of funds. It is now necessary to prepare a revised General Soil Map of Croatia - RGSMC, using the modern techniques of multispectral satellite images. Revision of GSMC is also justified because new soil survey material and interpretations have been collected since the first sheets were prepared (1964) and completed (1985).

It is also very important because environmental protection needs soil maps and since its planning is county based, the GSMC documentation should be used to prepare a separate soil map for each county of Croatia.

As part of regional soil studies, the preparation and printing of GSMC was accompanied by publication of regional monographs. Three monographs with maps have been published to date: Soils of the Upper Sava Valley, Soils of Slavonia and Baranja, and Pedosphere of Istria.

The comprehensive GSMC documentation, that contains printed material and unique manuscripts, is kept at the Department of Soil Science, Faculty of Agriculture, which is the centre of cartographic activities in Croatia. The data, which are waiting for up-to-date computer processing, represent a solid and reliable basis for developing an information system on the soils of Croatia.

The GSMC sheets, as well as other 'purely' topographical documents, were designated as 'officially secret' in the period prior to 1990 and, as a consequence, were not accessible for public scrutiny, particularly for international exchanges of information. Thus, the knowledge and information about Croatian soils circulated within a small-closed circle of professionals and remained inaccessible to the general and wide professional public. One of the consequences is that the awareness of the importance of the soil, and the hazards to which it is exposed, are only slowly penetrating the minds of professionals and the general public circles. Hence, the surprise with which information on the endangered state of the soils is received by the public.

Detailed soil mapping has also been carried out in the past. Large scale maps, at 1:5,000 or 1:10,000 scales, have been prepared for the needs of soil reclamation - drainage and irrigation of the agricultural land, as well as for afforestation. Silvicultural practices cover approximately 10-15% of agricultural land and a somewhat lower proportion of total forest soils. Detailed soil investigations, or interpretation of already completed research, were conducted for other, very different purposes, such as environmental effects in landscape planning, optimal silvicultural practices, establishment of fruit plantations and vineyards, building of reservoirs for hydroelectric generation, research in areas with degraded forest vegetation, exploration of localities exposed to strong erosion, assessment of soil pollution by heavy metals and choice of most suitable highway routes.

All these investigations have had specific targets, which have driven the research programme, methods of soil sampling and choice of analytical methods. Another common characteristic is that their results have remained in manuscript form although they contain valuable and unique data and ideas.

Thus, an imposing amount of diverse data and information on the distribution and properties of the soils of Croatia has been collected by modern methods since World War II.

Soil Databases

In some ways, Croatia is a natural 'soil museum'. The highest unit in the Croatian classification is the soil order, characterised by a specific type of drainage and genesis; automorphic, hydromorphic, halomorphic and subaqual soil order. The central and the most important unit of soil classification is soil type, characterised by the properties of the soil profile (number and sequence of soil horizons), genesis, evolution and main properties. The General Soil Map of Croatia at 1:50,000 scale is an inventory of Croatian soils.

The data in Table 1 refer to areas covered by different soil orders and the prevalent soil types. Useful information about soils in Croatia can be found at the on-line journal of the Faculty of Agriculture in Zagreb - ACS (Agriculturae Conspectus Scientificus) with free access to the full text of published paper http://www.agr.hr/smotra/issues.htm. Unlike its neighbours, Croatia has a high percentage of hydromorphic soils, in part because Croatia started

Table 1: Soil orders and main soil types of the Republic of Croatia (Bogunović, 1997)

No	Soil type	Area, ha	%
	I. Automorphic Soils	**3,153,432**	**56.631**
1.	Lithosol	32,703	0.587
2.	Regosol	70,698	1.270
3.	Colluvial soil	91,938	1.651
4.	Arenosol	667	0.012
5.	Chernozem	51,808	0.930
6.	Leptosol on hard limestone and dolomite (melanosol)	255,201	4.583
7.	Humic silicate soil (ranker)	86,944	1.561
8.	Leptosol, calcaric	420,184	7.546
9.	Vertisol	5,002	0.090
10.	Cambisol, eutric	172,495	3.098
11.	Cambisol, distric	316,184	5.678
12.	Cambisol, rhodic (Terra rossa)	245,289	4.405
13.	Cambisol on limestone and dolomite	474,959	8.530
14.	Luvisol	703,215	12.629
15.	Podzol	1,382	0.025
16.	Brown podzolic soil	7,393	0.133
17.	Anthropogenic soils	217,370	3.904
	II. Hydromorphic Soils	**1,617,640**	**29.050**
18.	Stagnosol	577,025	10.363
19.	Fluvisol	136,343	2.449
20.	Humofluvisol	89,901	1.614
21.	Pseudogley-gley	84,713	1.521
22.	Gleysol	499,526	8.971
23.	Humogley	64,555	1.159
24.	Hydroameliorated soil	163,000	2.927
25.	Peat soils (histosol)	2,577	0.046
	III. Halomorphic Soils	**532**	**0.010**
26.	Solonchak	121	0.002
27.	Solonetz	411	0.007
	IV. Subaqual Soils	**321**	**0.006**
28.	Gyttja and protopedon	321	0.006
	Rockiness	**796,459**	**14.303**
	Grand Total	**5,662,031**	**100.000**

investing in soil amelioration rather late and such investment unfortunately came to a halt after Croatia's independence.

Agricultural Regions

Agricultural regions are agroecological spatial units of the agrosphere, each with their specific climatic and soil conditions. Regions are in turn divided into subregions - smaller units that stand out by their specific climate, soils or relief, providing different conditions for crop growth and the basis for different farming systems. Albeit a small country, Croatia experiences different climates and has rocks with variable geological and lithological properties. Thanks to all these influences and a heterogeneous relief, Croatia contains a wide range of soils, with different degrees of fertility. As a result of this natural diversity, Croatia can be divided into three clearly defined regions - Pannonian, Mountain and Adriatic (Figure 1). Agriculture occupies 56.7% of the country, but the proportion of agricultural land varies from region to region (see Table 2).

In the period 1965-1991, there was a permanent decrease of agricultural and cultivated land. In that period the average annual loss of agricultural land was 7,235ha, or 20ha/day, most of which affected the soils of the highest quality. Croatia covers 5.7 million ha, of which 3.2 million ha is under agriculture. From region to region the use of soils differs a great deal (see Table 3).

The Pannonian region is the most important and the largest agricultural region in Croatia. However, Table 4 shows that the area of agricultural land per capita is the highest in the mountainous region, because of pastures and intensive depopulation caused by the recent war.

In spite of quite favourable agroecological conditions, yields of the main arable crops in Croatia are below the maximum possible (biological potential of varieties). The causes of yields lower than the maximum are as follows:

- Low natural fertility of soils and lack of amelioration 20%
- Low quantity or unfavourable distribution of precipitation 16%
- Unsuitable soil tillage 13%
- Unsuitable crop variety ….......... 16%
- Unsuitable crop density 14%
- Crop diseases and pests 10%
- Other factors ....… 11%

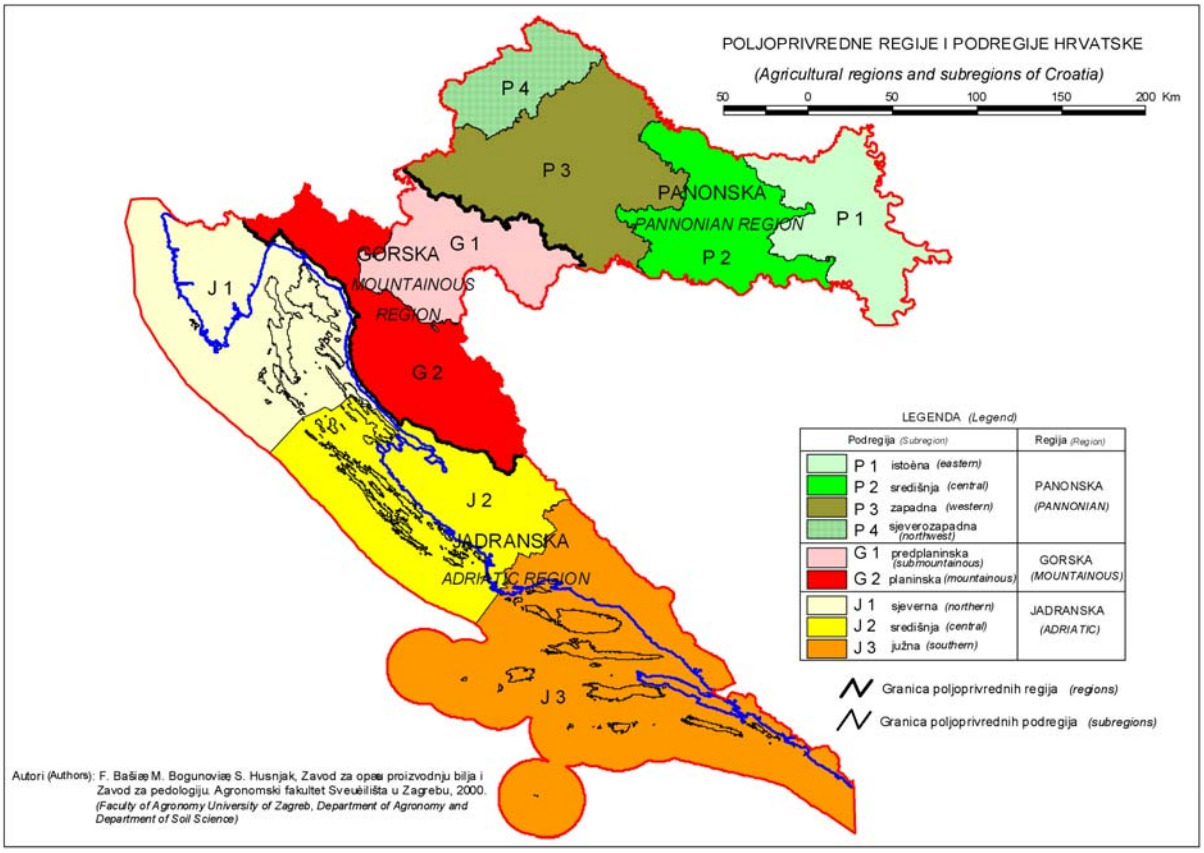

Figure 1: Agricultural regions of Croatia

Table 2: Land use in Croatia (ha and percent)

Region	Forests		Agriculture		Water		Settlements, Roads		Total	
	ha	%	ha	%	ha	%	ha	%	ha	%
Pannonian	904,617	38.5	1,643,844	51.2	38,267	71.7	30,702	68.9	2,617,430	46.2
%	34.6		62.8		1.5		1.2		100.0	
Mountainous	849,813	36.1	531,505	16.5	4,583	8.6	2,847	6.4	1,388,748	24.5
%	61.2		38.3		0.3		0.2		100.0	
Adriatic	596,840	25.4	1,037,467	32.3	10,509	19.7	11,037	24.8	1,655,853	29.2
%	36.0		62.7		0.6		0.7		100.0	
Croatia	**2,351,270**	**100.0**	**3,212,816**	**100.0**	**53,359**	**100.0**	**44,586**	**100.0**	**5,662,031**	**100.0**
%	**41.5**		**56.7**		**0.9**		**0.8**		**100.0**	

Table 3: Agricultural land and land use (hectares and percentage)

Region - Subregion	**Agricultural land**		**Arable land**		**Ploughland**		**Orchard**		**Vineyard**		**Meadow**	
Pannonian												
P-1 - Eastern	418,577	13	390,200	19	373,662	26	4,926	7	4,158	7	7,454	2
P-2 - Central	329,932	10	296,024	15	242,003	17	7,699	12	3,817	6	42,505	10
P-3 - Western	607,944	19	549,058	27	358,303	25	15,766	22	12,695	21	173,747	40
P-4 – North western	193,162	6	176,888	9	116,591	8	8,065	12	8,543	14	43,693	10
Total	**1,549,615**	**48**	**1,412,170**	**70**	**1,090,559**	**75**	**36,456**	**54**	**29,213**	**49**	**267,399**	**62**
Mountainous												
G-1 - Perimountainous	274,607	9	174,103	9	112,553	8	3,615	5	2,027	3	45,190	10
G-2 - Mountainous	318,619	10	127,607	6	58,857	4	1,366	2	318	1	70,000	16
Total	**593,226**	**19**	**301,710**	**15**	**171,411**	**12**	**4,981**	**7**	**2,345**	**4**	**115,190**	**26**
Adriatic												
J-1 – Northern	258,501	8	122,612	6	75,802	5	4,281	6	7,695	13	31,448	7
J-2 - Central	409,775	13	100,266	5	65,606	4	10,524	15	9,551	16	14,585	3
J-3 - Southern	366,266	12	82,575	4	53,829	4	12,425	18	11,342	19	4,975	1
Total	**1,034,542**	**33**	**305,453**	**15**	**195,237**	**13**	**27,230**	**39**	**28,588**	**47**	**51,008**	**12**
Croatia - Total	**3,177,383**	**100**	**2,019,333**	**100**	**1,457,207**	**100**	**68,667**	**100**	**60,146**	**100**	**433,597**	**100**

Table 4: Agricultural land per capita*

Regions	**Population**	**Agricultural land**		**Arable land**		**Ploughland**	
Subregions	No. of people	ha	ha/capita	ha	ha/capita	ha	ha/capita
P-1 Eastern	491,860	418,577	0.85	390,200	0.79	373,662	0.76
P-2 Central	382,360	329,932	0.86	296,024	0.77	242,003	0.63
P-3 Western	1,483,058	607,944	0.41	549,058	0.37	358,303	0.24
P-4 North-West	441,961	193,162	0.44	176,888	0.40	116,591	0.26
Pannonian Total	2,799,239	1,549,615	0.55	1,412,170	0.50	1,090,559	0.39
G-1 Perimountainous	169,921	274,607	1.62	174,103	1.02	112,553	0.66
G-2 Mountainous	81,330	318,619	3.92	127,607	1.57	58,857	0.72
Mountainous Total	251,251	593,226	2.36	301,710	1.20	171,411	0.68
J-1 Northern	484,853	258,501	0.53	122,612	0.25	75,802	0.16
J-2 Central	267,171	409,775	1.53	100,266	0.38	65,606	0.25
J-3 Southern	578,838	366,266	0.63	82,575	0.14	53,829	0.09
Adriatic Total	1,330,862	1,034,542	0.78	305,453	0.23	195,237	0.15
Croatia	**4,381,352**	**3,181,107**	**0.73**	**2,020,626**	**0.46**	**1,458,216**	**0.33**

*As per the census of 2001.

Soil Monitoring

Croatia has participated in the creation of the approach to organised and integrated soil protection within the Alps and Alps-Adria and Danube river regions. This approach includes three fields of activity:

1. Inventory of soil conditions - collecting of data on the kind, degree and intensity of damage;
2. Permanent soil monitoring - quantification and balancing of each soil damage process;
3. Soil information system - the data indispensable for correct decision making.

Though there is no uniform standardisation in Europe, there is tacit agreement on the following substances being monitored for the use of: mineral fertilisers, pesticides (chlorinated hydrocarbons, organic phosphates and carbamates), polychlorinated biphenyls, heavy metals and potentially toxic elements (Cd, Hg, Pb, Mo, As, Co, Ni, Cu, Cr, Zn, Mn, Ag, V, Al, Sb, Se and Sn), biostimulators (hormone preparations and thyreostatics), drugs (antibiotics, sulphonamides and other chemotherapeutic agents in veterinary medicine), nitrates and nitrites.

Although soils in Croatia are not strongly degraded, in general, there is no systematic evaluation of soil degradation. However, a classification scheme for processes of soil degradation has been devised (Table 5). This has been applied qualitatively to the regions od Croatia (Table 6).

All the intensive agricultural operations have involved usage of large quantities of agrochemicals (mineral fertilisers, pesticides, esp. herbicides, e.g. the atrazine group). Processes of anthropogenic soil and subsurface water degradation are as follows:

- Anthropogenic soil compaction and structural damage;
- Excessive tillage, through use of heavy machinery;
- Tillage in unsuitable moisture conditions;
- Decline in organic matter content and humus quality;
- Unfavourable changes in the organic matter regime;
- Improper recycling of organic residues;
- Lack of organic fertilisers;
- Soil acidification (leaching, mineral and liquid fertilisers, acidic deposition, air pollution);
- Biological degradation;
- Soil and water pollution.

Basic information on changing soil conditions are:

- Physical (structure, porosity, water holding and air capacity, compaction, etc.);
- Chemical (soil reaction, humus content, cation exchange capacity, contents of macro and microelements, nutrient leaching, heavy metals, etc.);
- Biological soil properties (number and species of micro-organisms, earthworms, etc.).

The main advantage of these data is that important soil properties can be quantified numerically. Regulations on agricultural soil protection from contamination from harmful substances (NN 15/92) minimise ecological risks and determine where and how much manure can be used. The existence of these data places Croatia in an advantageous position with respect to the requirement that soils should not be unduly exposed to contaminants, primarily heavy metals.

Accumulation of pesticide residues is an important topic mainly for agricultural soils and for other areas where pesticides are usually applied. There is no systematic monitoring of pesticides in Croatia with the exception of a few scientific projects studying problems of pesticide residue accumulation in soil. Water pollution by nitrates has been detected on sites where large quantities of poultry manure are used on acid, drained, light, gravelly soils of northwest Croatia.

Soil pollution by petrochemicals can occur in areas of oil and gas exploitation as well in areas where surface and underground transport of petrochemicals occur.

Because of different methodologies used for research it is sometimes very difficult to compare results.

Soil erosion prevention relies on the selection of adequate soil conservation measures and this requires thorough understanding of the erosion process. On sloping land, soil protection measures are necessary for sustainable land use.

Soil erosion caused by strong surface runoff, lack of permanent cover of crops, steep slopes, heavy rainfall and limited infiltration, results in considerable losses of organic matter and plant nutrients, silting of waterways, canals, and reservoirs (increasing costs because of more frequent cleaning), and increasing hazards of waterlogging and flooding (Table 7).

According of Racz (1992), central and coastal parts of Istria are worst affected, with 100-200t/ha of soil eroded annually, caused by the extreme erodibility of soil on flysh - Regosols, Rendzinas, etc.

Table 7: Categories of water erosion in Croatia

I. Extreme erosion	0.48%
II. Strong erosion	1.12%
III. Medium erosion	5.47%
IV. Weak erosion	15.95%
V. Very weak erosion	76.98%

Intensive erosion occurs particularly in the Pannonian region, as well as in the Mediterranean area, because of the orientation of cultivation up and down the slope. Furthermore, erosion has been exacerbated by changes in cropping in favour of maize. A particular problem is the erosion of soil material immediately after treatment with herbicides, especially atrazine.

Future Prospects

It is clear that sustainable land management in Europe, as well as the functions of soil, especially the surface soil layer, requires organised, integrated protection. This involves making an inventory of soil conditions, monitoring of harmful substances and processes in soil and establishment of an up-to-date soil information system. Only scientific research, based on quantitative data, can give answers reliable enough to solve the many problems facing the management of agriculture in future.

Table 5: Classification of soil degradation in Croatia

Type	Cause	Kind	Effects
I. **Reversible Damage** (Easily Restorable)	Practices of intensive agriculture	Degradation of physical properties Degradation of chemical properties Degradation of biological properties Degradation through improper amelioration	Soil compaction and Soil crusting Improper changes of water/air regime Soil structure destruction Decrease of soil permeability Acidification and Alkalisation Leaching of nitrates Eutrophication - water pollution Degradation of biological properties Adverse changes in earthworm activities
II. **Conditionally Reversible** (Difficult to Restore)	Soil pollution	Accumulation of heavy metals and potentially toxic elements Accumulation of PAH and residues of pesticide Petrochemicals in soil Radionuclide Acidic deposition and acid rain	Contaminated food unsuitable - mutagenic and carcinogenic Acidification Phytotoxicity Degradation of biological soil properties Environment. Impacts - water pollution
III. **Non-Reversible** Unrestorable	Soil removal and overlapping	Water and wind erosion Soil removal by mining industry brickyards, stone and gravel extraction Soil removal by root crops Soil covering by other soils Soil covering by trash, industrial waste and ashes Damage of soil by fire	Decreasing area of farmland Loss of part or whole soil profiles Change in soil profile Reduced yields of agricultural crops Increased soil heterogeneity Increased costs Putting other ecosystems at risk Disturbance during tillage
IV. **Irrecoverable** (Loss of soil, soil sealing)	Permanent change of primary use	Urbanisation Different industrial plants Traffic (roads, highways, airports) Power cable	Loss of productive land Decrease in food production Storage and movement of machinery

Table 6: Soil degradation in the regions of Croatia

Soil Degradation		**Regions and Subregions**				
Type	**Cause**	**Eastern Slavonia**	**North and North West**	**Low Karst Region**	**Mountainous**	**Coast, Islands**
I. **Reversible** (Easily Restorable)	Decreasing of humus	++	++	+	+	++
	Acidification	?	++	++	++	?
	Stagnation of water	++	++	-	-	-
	Deterioration of structure - compaction	++	+	+	+	++
II. **Conditionally Reversible** (Difficult to Restore)	Heavy metals	?	+	+	++	+
	Remains of pesticides	++	+	+	+	++
	PAH	?	?	?	?	?
	Radionuclides	?	?	?	?	?
	Waste water	++	++	-	?	+
	Waste gases	?	?	?	?	?
III. **Irreversible** (Unrestorable)	Water erosion	+	++	+	+	++
	Surface mining	+	+	-	-	+
	Barren material	+	+	-	-	+
	Ash	-	+	-	-	+
	Waste	-	+	-	-	+
	Car - camps	-	-	?	?	+
	Playgrounds, picnic area	-	+	-	?	+
IV. **Irrecoverable** (Loss of soil Soil sealing)	Building of settlements	++	++	+	+	++
	Building of plants	++	++	+	+	++
	Roads - highways	+	+	?	?	?
	Water accumulation	+	+	?	?	?
	Airports	?	?	?	?	?
	Power cable	+	+	+	+	+

++ Moderate and strong, + local and marginal, - not present or neglected, ? no data

Croatia, now at the crossroads of changing from collective farming to private ownership, requires extensive information on all branches of agriculture. For management of a modern ecological farm, the farmer needs an extension service and information about environmental risks and potential damage caused by some conventional agricultural practices so as to be convinced that sustainable practices are in his/her long-term interests.

The greatest challenge now is to make progress towards a more environmentally sound agriculture that can ensure economic profitability, in line with marketing development, whilst adhering to precise regulatory standards.

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Soil Survey and Monitoring in Cyprus

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Introduction

Cyprus is an island with an area of 9,251km^2. The topography includes two mountain ranges, one in the north and the other in the centre. Between them lies a plain. The cultivated area is estimated at 1,340km^2. The state forest land is 18% of the total area.

The Status of Soil Mapping in Cyprus

In Cyprus systematic soil studies and soil classification started in 1957, aimed at collecting information and data about the physical and chemical properties of soils.

The first soil classification system used was based mainly upon the formation, origin and parent material of the soils.

The first efforts to map the soils of Cyprus used topographical sheets at scale 1:5,000. The next step in soil mapping was the preparation of the General Soil Map of Cyprus at a scale of 1:200,000.

The soil classification system adopted was based mainly upon the formation, origin and parent materials of the soils, as with the previous mapping.

Accordingly, soils were classified mostly as Red, Sedentary and Alluvial or Colluvial soils. Usually an examination of the main horizons, A, B, C, D, together with soil physical and chemical analyses, was carried out in order to classify the soils of these groups into soil series identified by local names.

Red soils

In general, these have been classified into soil series according to the C and D horizons.

Sedentary soils

These soils were classified into soil series according to the type of parent material, which constituted the D horizon. Soil series have in many cases the same names as the geological formations.

Alluvial or colluvial soils

The classification is into soil series according to their origin and their physical and chemical properties. Local names have also been used for soil series.

Later, in 1970, the FAO soil classification system was introduced. Through this system a new effort was undertaken to establish a common international language in soil classification. Based on our observations and soil studies the following diagnostic horizons from the FAO system have been adopted: Mollic, Ochric, Argillic, Natric, Cambic, Calcic and Gypsic.

In order to separate soil units, some diagnostic properties from FAO (UNESCO) system were used and a number of soil orders and sub-orders recognised, corresponding to the following general definition:

Lithosols

Soils limited in depth by continuous coherent and hard rock within 10cm of the surface. Lithosols are divided into two sub-orders:

- Calcaric
- Eutric.

Fluvisols

Soils from recent alluvial deposits, having no diagnostic horizons other than an Ochric A or a histic H horizon.

Regosols

Soils from unconsolidated material, having no diagnostic horizons other than an ochric A horizon. Regosols and Fluvisols have been divided into calcaric and eutric sub-rders.

Rendzinas

Soils having a mollic horizon, immediately overlying extremely calcareous material.

Solonchaks

Soils having high salinity within 125cm of the surface (EC > 15mmhos). Solonchaks have been separated into Gleyic and Orthic sub-orders.

Solonetz

Soils having a natric B-horizon.

Vertisols

These soils have 40 percent or more clay in all horizons, developing wide cracks from the soil surface downwards. Furthermore, they have slickensides and unfavourable physical properties.

Cambisols

These soils have a cambic B-horizon and no diagnostic horizon other than an ochric or an umbric A horizon, a calcic or a gypsic horizon. Soils classified into Cambisols occupy extensive areas and are subdivided into the following sub-orders:

- Vertic
- Calcaric
- Calcic
- Eutric
- Chromic.

Luvisols

These soils have an argillic B-horizon and they are subdivided into:

- Vertic
- Calcic
- Chromic.

Land Use Classification

A land use map of Cyprus showing classes of agriculture use and natural vegetation is shown in Figure 1. A land suitability classification map of Cyprus has also been prepared mainly for agricultural purposes. Its main objective is to classify the land according to its suitability for irrigation.

New Soil Map

The new soil map of Cyprus, printed in 2002 at scale 1:250,000 (Figure 2), is based on previous classifications and was adjusted to the new FAO classification system (WRB, 1998).

During the last decades interest in soil surveys and mapping has been very limited due to the continuously diminishing contribution of the agricultural sector to the economy of the country - it is currently about 4% of the GNP.

In areas where soils have not been surveyed, other methods have been used, such as extrapolation, photo interpretation and the general soil map of Cyprus.

A number of important information sources have been used in the preparation of the new soil map of Cyprus:

Geological Map of Cyprus, scale 1:250,000

Geological survey has been used to identify parent material of the soils.

Other soil surveys

Soil surveys, carried out in different areas of the country at different times, are the most useful pool of information.

Many of these surveys were carried out by different soil scientists using in many cases different soil taxonomic systems. They were working on aerial-photos at scale 1:10,000 and preparing a soil map at scale 1:25,000.

The main purpose of each soil survey project was to cover the most fertile soils and all the agricultural development areas. The majority of the existing soil maps were prepared mainly for agricultural purposes. For soil mapping and other relevant soil activities, the Soil and Water Section of the Department of Agriculture is the only government section responsible.

Cyprus- cooperation

In Cyprus there is no specific institution dealing with soils and because of this it is important to establish technical scientific cooperation with other international soil centres. The study of calcareous soils was carried out in cooperation with the Federal Institute for Geosciences and Natural Resources, Hanover, Germany. About 36% of the total area of Cyprus is categorised as having slightly to high calcareous soils.

Recent Work

Using the newly secured data, a digital soil map of Cyprus has been prepared at scale 1:250,000 in collaboration with the remote sensing centre of the Ministry of Agriculture.

An extension of this work has been preparation of a soil map of Cyprus at scale 1:1,000,000 based on the creation of soil associations of the main group of soils.

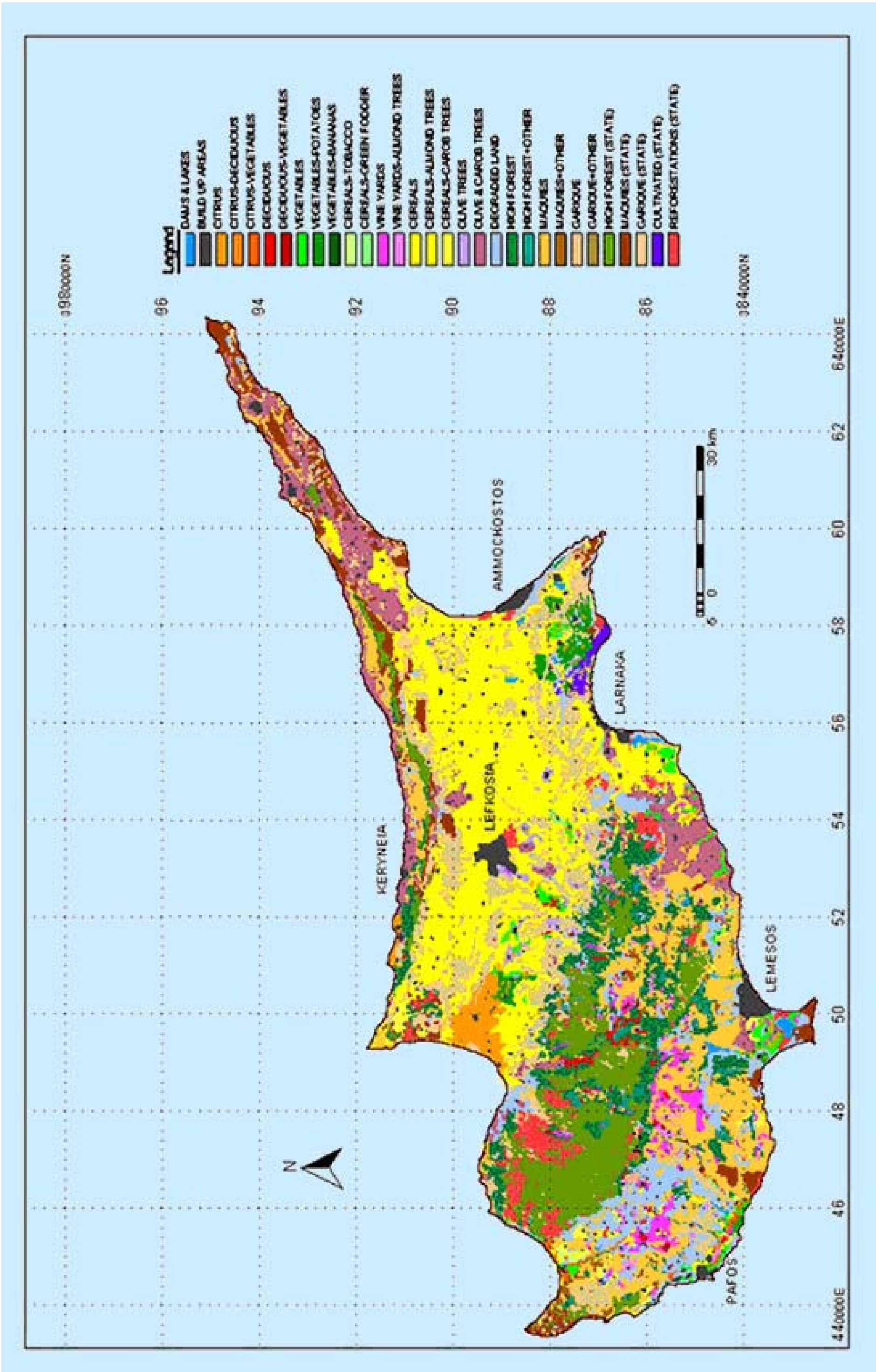

Figure 2: Land use map of Cyprus: natural vegetation & agricultural use

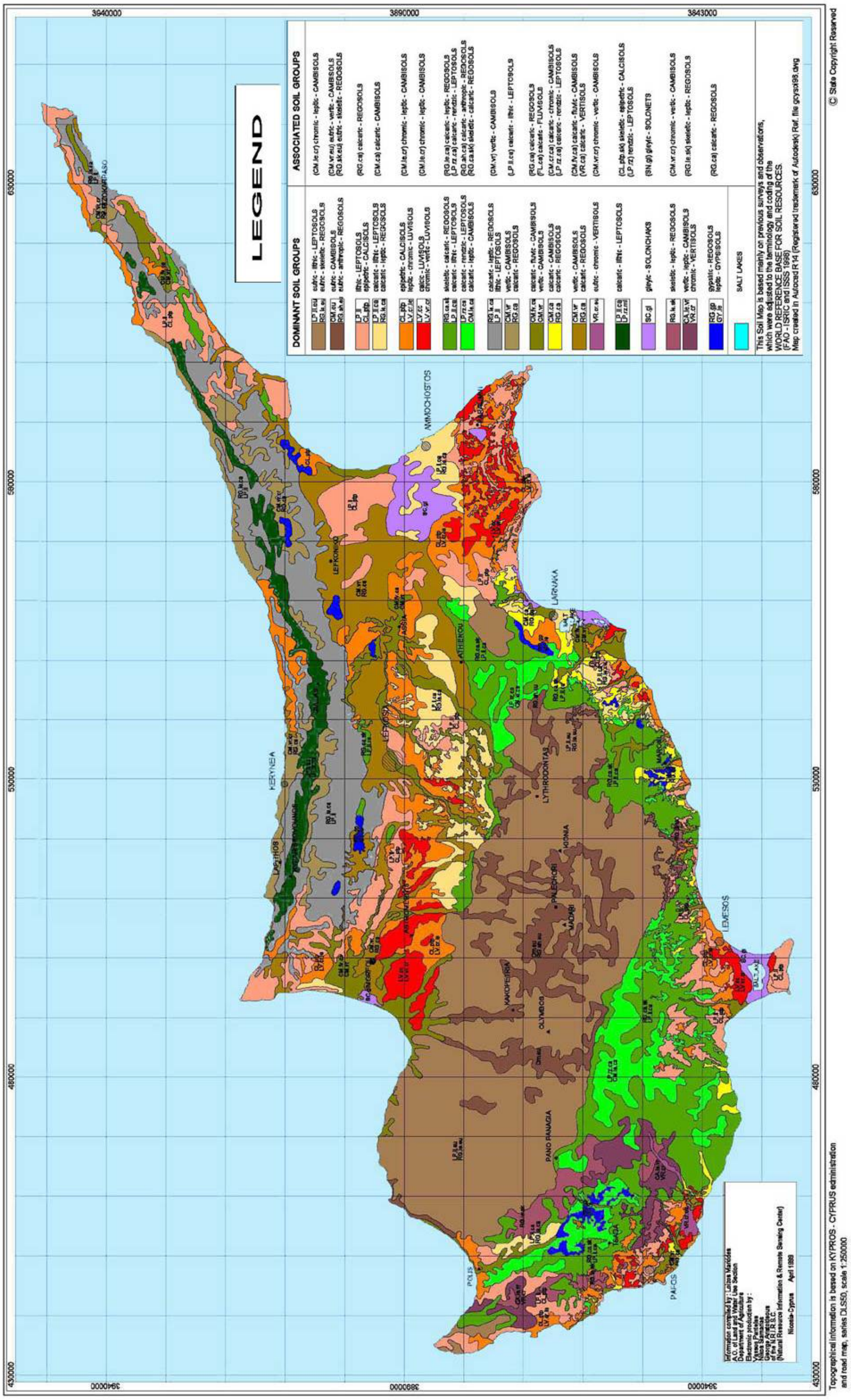

Figure 2: Soil map of Cyprus

This map was prepared for inclusion in the European Soil Database.

National and Regional Maps in a Global Context

The problems envisaged in adapting the national and regional soil maps using the global methodology of soil taxonomy include:

1. Various soils occupying small areas, as remnants of erosion, were mapped as associated soil groups. Other soils developed in depressions and on slopes of mountainous areas were also mapped as associations.
2. In a general soil map at small scale (1:250,000 to 1:1,000,000), where generalisation is necessary, small areas with different soil groups are blended. As a result, detailed information about the physical and chemical properties of these soils may be obscured.

Soil Monitoring

Monitoring activities are concentrated on establishing Nitrate Vulnerable Zones (NVZ) as required by the EC Nitrate Directive. A map showing the NVZs at a scale of 1:250,000 is in the final stage of preparation.

The next step will be to prepare a map showing the areas where sewage sludge can be applied.

Suggestions

The revised classification system of the FAO (WRB, 1998) seems to have improved the classification structures by the introduction of Soil Groups, Diagnostic Horizons, properties and materials. Using this terminology and coding, soils can be classified to a lower category level in an international system, which obviates the need to use local names of soil series names.

Problems that occur by the use of different scales can be overcome through using digital mapping. Surveys can be carried out at different detailed scales without any difficulty in the eventual printing of any scale map.

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Status of Soil Surveys, Inventory and Soil Monitoring in the Czech Republic

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Introduction

The Czech Republic stretches over an area of 78,870km^2, of which 54.35% is agricultural land (arable land 39.31%, grassland 12.01%) and 33.4% forests. The distribution of the main reference soil units is given in the Table 1.

Table 1: Distribution of soils in agricultural and forest areas (%)

Soil Group	Agricultural land (%)	Forest (%)
Leptosols	4.0	3.2
Arenosols	1.2	1.6
Fluvisols	5.9	2.4
Chernozems + Phaeozems	13.2	0.3
Luvisols+Albeluvisols	17.8	6.7
Stagnosols	6.7	12.0
Cambisols	45.1	58.8
Podzols	1.5	9.6
Gleysols+Histosols	4.6	5.4

Large Scale Soil Surveys

The soil survey in the Czech Republic has a long history. Agro-geological soil surveys started at the beginning of the 20th century. Soil bodies delineated on the maps (at scales 1:10,000-25,000) reflect practically soil series of soil families. Their profiles were displayed in the soil map margins. They were characterised by morphological features, soil texture and soil parent material. Since the 1920s, soil profiles have been linked to genetic soil types.

Systematic soil survey of agricultural lands at a large scale, using field sheets at the 1:10,000 scale, was implemented in the period 1960-1972 (Němeček *et al.*, 1967). The primary soil map for use on farms comprises taxonomic soil units (soil type+ subtype + variety), parent materials, erosion and accumulation. The separate soil map displays soil texture and rock fragments in the plough layer and their changes in the profile along with hydric groups of soils (temporary, permanent water logging, full saturation).

Soil maps were compiled for administrative districts at a scale of 1:50,000. On the soil map, the soil cover is grouped into regions, characterised by specific soil unit combinations, similar geomorphology, lithology and climate. A map of soil parent and underlying materials completes the set of district maps. This map represents a detailed Quaternary geological map, using the legend recommended by the Institute of Geology. The programme was entrusted to the former Soil Survey Institute and Soil Research Institute for Crop Production Prague-Ruzyně. Later reorganizations (1981, 1990) led to a merger with the Research Institute for Land Reclamation and later with the Institute for Soil and Water Conservation, Prague-Zbraslav, following its foundation.

Soil survey of forested areas, using field sheets at 1:5,000 scale, was carried out within the framework of the forest-typological mapping (1955-1975) by the Forest Management Institute Brandýs n. L. (Houba 1965, 1970).

In the Czech Republic, systematic soil survey at large scale has been completed for the whole country, except for urbanised areas. In the period 1972-1980, additional soil-ecological surveys of agricultural land were carried out (Klečka *et al.*,

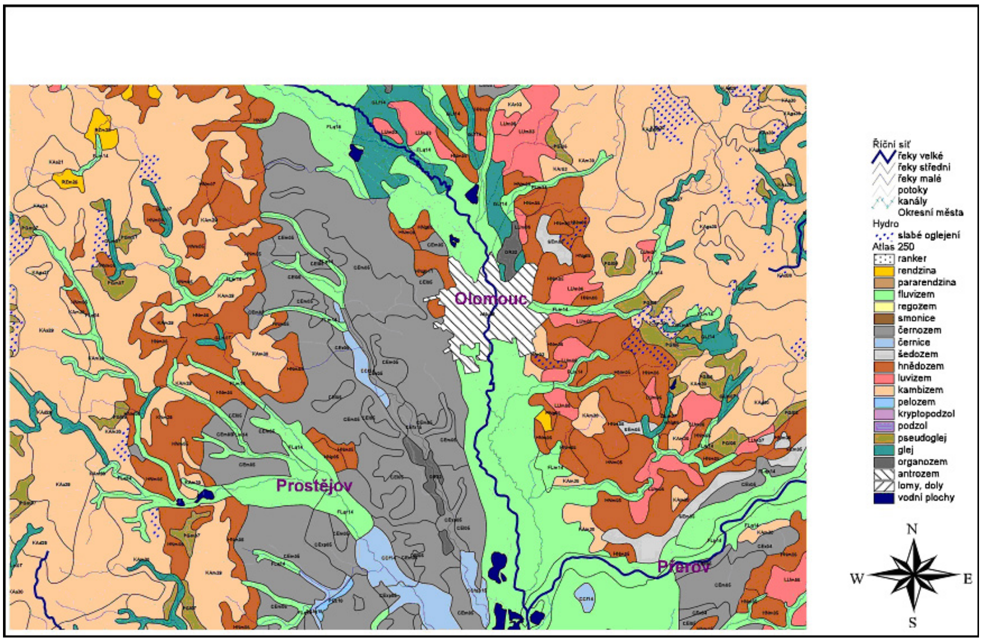

Figure 1: Example of soil map at scale 1: 250,000

1984) in the framework of the soil productivity rating, in cooperation with the Institute of Agricultural Economics. Soil-ecological maps (at present in a digital form) at a scale of 1:5,000 display grouped soil units - soil forms (76), relief features (slope classes, exposition), content of rock fragments, soil depth classes and 10 climatic regions. Concerning soil-ecological problems and the planning of forest management, the forest typological system (ÚHÚL 1991) was created, which involves defining 10 vegetation zones and 25 edaphic (16 trophic and 9 hydric) categories. Consequently, there exist two pragmatically oriented cartographic products, comprising soil and site information.

Medium and Small Scale Survey

Soil maps at scales 1:500,000 and 1:200,000 (modus 1:250,000) have been compiled. They are all based on the large-scale maps of agricultural and forest soil surveys. They have been digitised. Soil maps at a scale of 1:50,000 have been completed for half of the total area of the Czech Republic. A soil map at a scale of 1:1,000,000 was designed (1974) and revised (1996) for international cooperation. All Czech soil maps are based on soil taxonomic units and classification of parent materials.

For the SOVEUR project, a SOTER soil map at a scale of 1:1,000,000 was prepared. A soil map at a scale of 1:250,000 (Figure 1) is being transformed into the soil map using the SOTER methodology. In addition to soil taxonomic maps, some maps of single soil properties have been compiled, mostly at a scale of 1:500,000:

- Parent and underlying materials;
- Soil texture classes;
- Hydromorphic classes;
- Humus content (plough layer, depth 1m);
- pH (plough layer);
- CEC (plough layer);
- Base saturation (depth 0.6m);
- Background trace elements;
- Trace element contents in plough layers (Cd, Pb, Hg, Cr);
- Available nutrients (P, K, Mg).

Soil Classification in the Czech Republic

The soil classification used in soil maps at large, medium and small scales is based on a taxonomic approach. Soil mapping units of large-scale maps reflect 'pure' pedotopes and soil combinations. Soil maps at medium and small scales depict soil associations and regions and their dominance, The basic taxonomic classification used for large-scale mapping of agricultural soils is based on the use of diagnostic soil horizons and features (Němeček *et al*., 1967), derived from the 7th approximation of the Soil Taxonomy. The concepts of soil types, subtypes, varieties and soil forms reflect the systems not only in nomenclature, but also in concepts. The results of the unification efforts (Němeček, 1981; Šály, 1977; Hraško *et al.,* 1991; Němeček *et al.,* 1990; Macků and Vokoun, 1991) were used in the compilation of maps at small and medium scales.

Nowadays a unified soil classification system has been completed (Němeček *et al.*, 2001). The new Czech taxonomic classification system represents a unification of the classification of soils under different land uses. The main principles of the system are:

- To keep comparable soils with different uses (agriculture, forestry, no biological use) at the same high taxonomic level (reference class, soil type, subtype); these aims can be achieved when we make use of diagnostic horizons and features within the control section 0.25-1.20m (base saturation 0.2-0.7m in forest soils, 0.4-0.7m in agricultural soils, to avoid liming consequences);
- To qualify differences in topsoil between 0.0-0.25m from the mineral surface at variety levels (shallow melanic, umbric horizons, micropodzolization);
- To introduce ecological phases (humus forms of forest soils);
- To characterise anthropogenic impacts (contamination, erosion) on lands with different uses as degradation phases (contamination in Ap, F, H horizons);
- To introduce Anthrosols at the reference class level.

The devised taxonomic soil classification system is a multicategoric hierarchical system with the following taxonomic levels: reference classes (ending-sols), soil types, subtypes, varieties, subvarieties, soil-ecological phases, degradation phases. The interconnection with parent materials at any level represents the soil form.

The classification system can readily be correlated with the WRB except in the case of Stagnosols, as recommended by Spaargaren *et al*., (1994).

Classification of the Soil Cover

Whereas taxonomic soil classification has achieved a high degree of international unification, the principal problem of harmonisation of soil maps at approaches of the German soil classification (Mückenhausen *et al*., 1962). The influence of the German soil classification is also apparent in the classification of forest soils (Houba, 1965). But there were some small differences between the medium and small scales is the correlation of soil associations and soilscapes.

In the Czech Republic, an analysis of soil associations and regions has been published (Němeček and Tomášek, 1983). Soil associations are defined in terms of combinations of dominant, co-dominant, accompanying and accessory soil taxonomic units. They are characterised by the combination of extrinsic factors and land use. In the second variant (Němeček and Zuska, 1989) attributes of soil associations have been enriched by: soil rating, limiting factors, erosion hazards, soil workability. In the first version, 248 soil associations were identified in 13 soil regions; in the second version 243 associations in 11 regions.

The next step in our soil-geographical scheme is being implemented within the framework of the modified SOTER project, coordinated by ISRIC. The first version at a scale of 1:1,000,000 involves 8 geomorphic regions and 38 SOTER units, characterised by lithology and soil associations.

The SOTER map at a scale of 1:250,000 is being compiled. The first approximation involves 7 regions with deep sedimentary deposits and 8 regions covered with transported weathering products of hard and consolidated rocks. The first group of regions occurs on level geomorphic surfaces (alluvial valleys, terraces, plains, plateaux and flat hilly areas). The second group involves hilly areas, highlands and mountains, subdivided into flat and dissected ones. Symbols reflect geomorphology, lithology and the prevailing grouped soils (e.g. AV06f - alluvial valley, alluvial deposits, Fluvisols, PA02c - plains with aeolian deposits, Chernozems, MF08d - flat mountainous areas with transported weathering products of granites, hyperdystric Cambisols).

This first thematic SOTER layer is accompanied by the following layers at scale 1:250,000: geomorphic regions, parent materials, slope classes, and soil associations.

Soil Survey Interpretations

Soil survey interpretations, especially those based on pragmatic site classifications, are used for productivity assessments. The criteria include site productivity assessments on crops, grasslands, and forests on experimental plots and on their economic evaluation. Soil management in agriculture is supported by data on specific features of behaviour of biogenic elements in addition to soil testing.

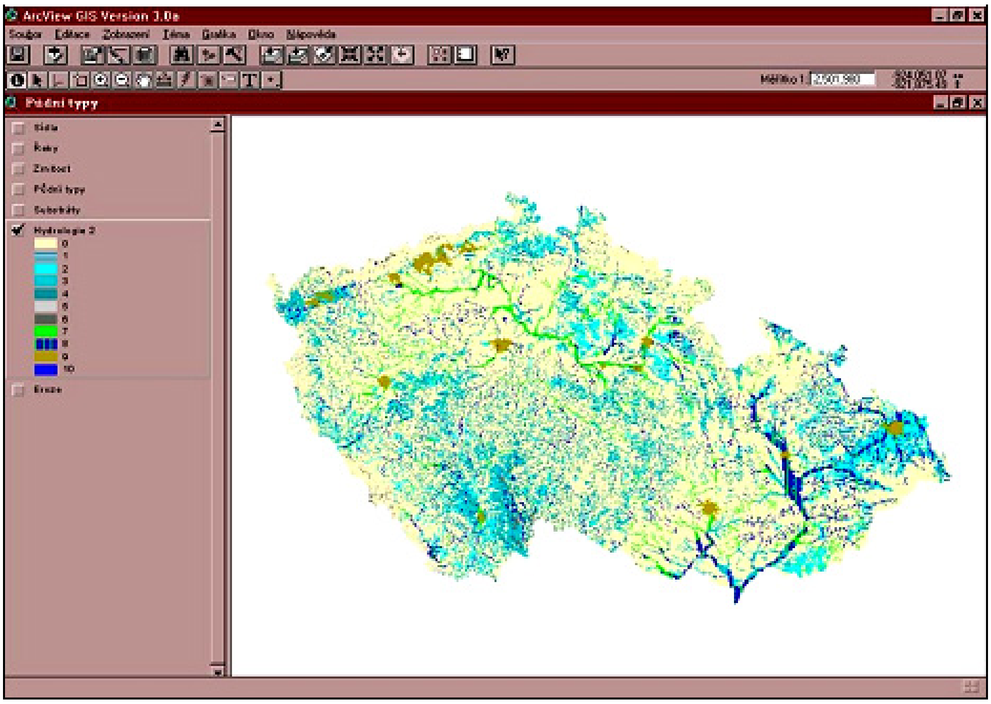

Figure 2: Hydromorphic groups of soils in Czech Republic

Attention was paid to N (prediction of mineralisation, nitrification, migration), P and K release, immobilisation - fixation (Neuberg *et al.*, 1990). The workability of soils can be derived from measurements of the specific ploughing resistance, correlated with soil texture, slope etc. For soil reclamation, detailed soil hydropedological surveys are carried out. They are supported by a more detailed classification of hydromorphic features and field and laboratory measurements of infiltration, hydraulic conductivity and retention curves.

Later, more attention was paid to interpretations, which concern soil degradation and soil pollution. For the assessment of soil vulnerability against water erosion, the USLE was adopted. For the main soil forms of subtypes, K values were derived (Zuska and Němeček, 1986).

Small-scale maps of background concentrations of trace elements are based on the matching of the upper limits of the content of trace elements in soil parent materials and the map of soil parent materials (Figure 3). Maps of soil vulnerability against trace elements reflect the application of the results of investigations into the mobility of trace elements in principal soil units and their transfer into crops after a simulated contamination of representative soils by soluble salts of trace elements. (Podlešáková and Němeček, 1997).

K_d values for atrazine (Figure 4) and other pesticides in Ap horizons, subsoils and both layers, have been derived within the framework of systematic research into pesticide behaviour. They were calculated from Freundlich adsorption isotherms. The effect of soil properties on adsorption was described by means of multidimensional regression and correlation analysis. The equation described the extent of the participation of clay, CEC, pH and C_{ox} on sorption of pesticides.

These soil characteristics were derived from the digitised map at the scale of 1:200,000 (Kozák and Vacek, 2000). Background values of trace elements have been derived for the main soil parent materials. The upper values of their variability are taken as contamination limits (except in the case of extreme geogenic contents). Soil specific critical contents and mobilities of trace elements in soils for the transfer pathway soil-plant (zoo-, phyto-toxicity) have been experimentally established. They will serve as limiting values for the protection of the quality and quantity of agricultural production (Podlešáková *et al.*, 2002).

Soil Inventory and Monitoring

Soil taxonomic units are taken for correlative sets of characteristics, which enable us to predict some other characteristics and qualities, that have not been determined directly. This procedure has limitations, especially concerning inputs of contaminants, nutrients, soil additives etc. An inventory of soil contaminants is very important for planning a monitoring network.

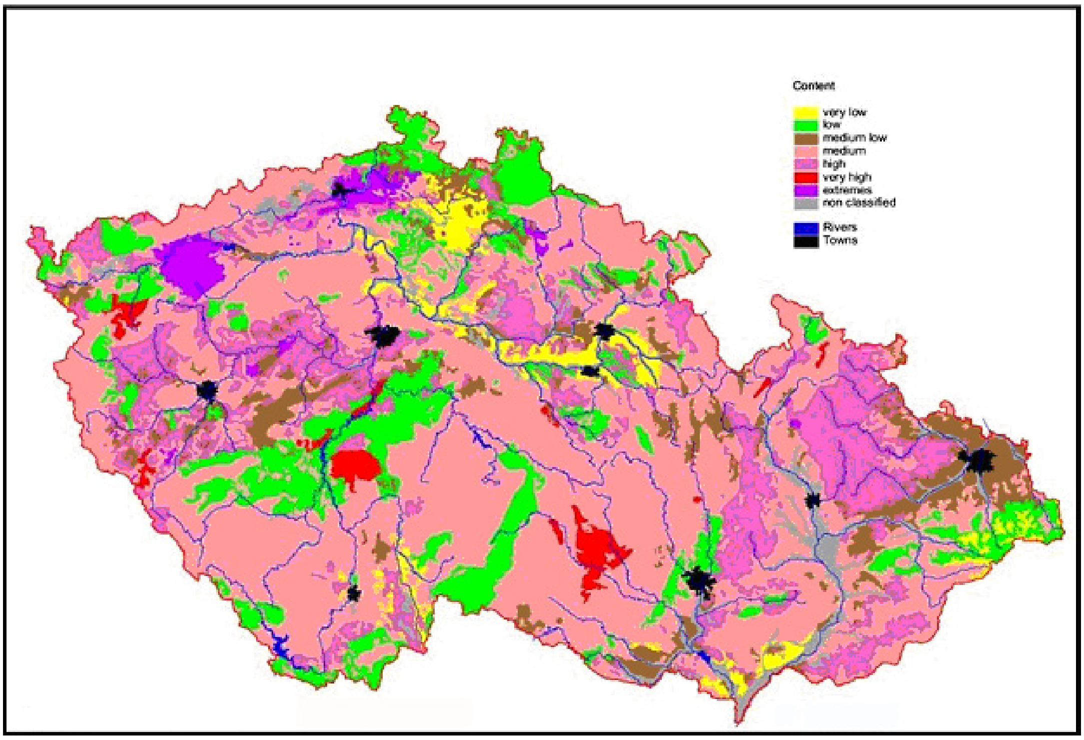

Figure 3: Small-scale maps of background concentrations of trace elements in soils (Co, Cr, Ni, V, Mn, Cu)

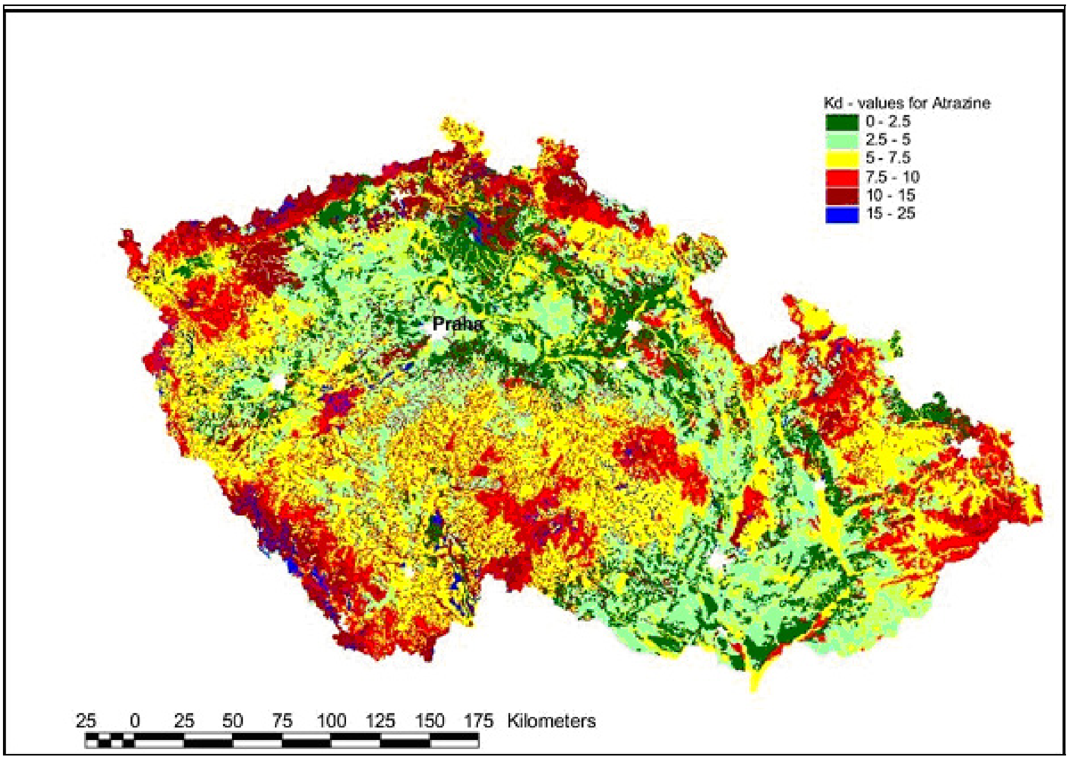

Figure 4: K_d values for atrazine in Ap horizons

An inventory of trace elements Cd, Pb, Cr (in 2M HNO_3 cold) and Hg (total content) has been completed for the Czech Republic by the Central The Research Institute for Soil and Water Conservation continues to make inventories of both trace elements (total contents) and organic xenobiotic compounds, preferentially in regions with expected local anthropogenic or geogenic loads. The results of these inventories are displayed in maps and stored in databases.

The aims were either to confirm or reject the anticipated high degree of soil pollution and loss of organic matter that developed during the period of intensification of agriculture and development of industry during the past 25-30 years. Neither accelerated soil pollution nor loss of organic matter (except in some Cambisols and drained soils) has been found. This kind of monitoring is based on the comparison of samples taken during the systematic soil survey and samples taken 25-30 years after the original surveys. It was found that higher levels of soil contamination occur only exceptionally as a result of the long-term process of industrialisation. Contaminated sites are found often in areas of Fluvisols, in the neighbourhood of some (mainly metallurgic) industry and in large cities. Retrospective monitoring is considered to be a tool to speed up the strategy for systematic monitoring.

Two separate systematic monitoring systems have been implemented in the Czech Republic:

- Monitoring of the agricultural land on 200 observation plots, which started in 1992 (Mazanec, 1996);
- Monitoring of observation plots in forests (Materna, 1996; Moravčík, 1996).

The Central Institute for Supervision and Testing in Agriculture has been entrusted with the monitoring of soils in agricultural use. The following soil properties are being monitored: pH, available nutrients (P, K, Mg), biogenic and hazardous trace elements (B, Be, Cu, Cr, Hg, Mn, Ni, Pb, Zn), CEC, C_{ox}, mineral N, microbiological and edaphalogical characteristics, and organic contaminants. The monitoring of soil characteristics is accompanied by the observation of atmospheric emissions.

Two systems of monitoring forest soils also exist.
The first system started at the beginning of the 1980s and was aimed at studying the input of S and N into soils and their direct effects (along with ozone) on 500 forests sites in endangered areas (Materna, 1996). Institute for Supervision and Testing in Agriculture.

The second system is being performed within the framework of the international cooperative programme (ICP) for forest monitoring. Monitoring sites are distributed on a regular grid for analysis: C, N, pH, CEC, exchangeable cations, base saturation, trace elements, composition of the soil solution taken by vacuum suction lysimeters.

Soil Information Systems

Soil information systems are generated in three complementary ways:

- Soil GIS for practical uses, mainly taxation and land tenure appraisal of agricultural lands and separately for forests;
- Databases of soil monitoring;
- Soil GIS (PUGIS) for development of concepts and international cooperation on different projects.

The last mentioned PUGIS (Kozák *et al.*, 1996; Němeček, 2000) is handled in the Department of Soil Science and Geology of the Czech University, Prague. PUGIS consists of:

1. Polygons of digitised soil maps (at scales 1:1,000,000, 1:500,000, 1:200,000, 1:250,000);
2. Thematic layers of geomorphology, climate, geology, vegetation;
3. Thematic layers of some soil properties (humus, base saturation, hydric groups, texture);
4. Attributes of soil associations and soil regions used in soil taxonomic maps and in a SOTER map;
5. Database of pedon characteristics of 2,500 selected profiles with a standardised set of characteristics and 250 profiles with additional data from agriculturally used soils.

At present the pedon database contains only the most representative soil profiles from the total 30,000 profiles with the following standardised set of analyses: pH, soil texture, $CaCO_3$, humus content, CEC, base saturation. The selected set of profiles includes additionally: exchangeable cations, effective CEC, exchangeable Al, free Fe and Al, clay minerals, humus quality, macro-and microelements, fundamental physical properties and micromorphological features. The pedon database of forest soils is progressing.

Conclusions

The whole of the Czech Republic (except urban areas) is covered by large-scale soil maps.

Generalised and digitised medium and small-scale maps of soil associations (1:500,000, 1:200,000, 1:250,000 (partly 1:50,000) are based on large-scale surveys.

The implementation of the pedon database is progressing.

The Czech Republic is ready to participate in the the 1:250,000 European Soil map project, in a modified SOTER system and in all related projects.

International collaboration should focus mainly on harmonisation of soil associations, soil - geomorphological relations and delineation of soil regions. The SOTER system at the scale of 1:250,000 should be adapted for more and more territories.

Acknowledgement

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Soil Mapping in Denmark

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Land Assessment History

In Western Europe, land utilization was accepted as the normal basis for taxation for centuries. Those who benefited from the land were expected to pay towards the general welfare of society as well as to contribute to financing rearmament and warfare and other facets of life. It was also accepted that a land or property tax should be graduated according to the size of a property and the value of its land.

During the Middle Ages, there were three different ways of assessing Danish land for taxation purposes (Mosbech, 1922; Pedersen and Steffensen, 1966): Number of "ploughs" (plough tax), amount of seed, and gold value. The first nationwide land assessment based on a systematic evaluation of the soil was King Christian V`s Great Danish Land Register of 1688. This land assessment classified the soils according to their potential yields for various crops, e.g. good soil for barley and rye or good soil for oat production.

The taxation (valuation) unit was the Danish term: "tønde (td.) hartkorn" (one barrel of hard grain(barley and rye)), and at Zealand the farmer had to pay 1 td. hartkorn for every 2 td. land of good barley and rye soil he owned or 1 td. hartkorn for every 4 td. land of good oat soil. This land assessment was used for more than 150 years.

At the beginning of the 19th century the need for an improved basis for national taxation was urgent as the Danish Land Register of 1688 had not been updated regularly and tax rates varied too unjustly among properties. This led to The Great Danish Land Register of 1844 (Rothe, 1844) which involved a comprehensive, detailed national survey followed by production of cadastral maps at a scale of 1:4,000. The land was evaluated according to the goodness of its soils and related characteristics.

The soils were valued according to a 24-point scale and the best soil was allotted the optimal quality value of 24. This soil was situated at Karlslunde between Roskilde and Køge on Zealand. The land assessment and the measured field sizes were the basis for determining the "hartkorn" values.

The principles of the national land assessment were outlined in 1802-05 but it took some time to complete due to several delays (Madsen *et al.*, 1992). Zealand, Lolland, Falster and Møn were assessed by 1813, Funen by 1820, and Jutland by 1826. Southern Jutland was, however, not assessed, except for the royal enclaves within Ribe county. Although most of the land register work and the definition of the "hartkorn" land values had been completed in 1826 it took almost 20 years before this new taxation system was fixed by law in 1844 (Jensen, 1944; Pedersen and Steffensen, 1966).

The Great Danish Land Register of 1844 was used as the basis for real property taxation for about 60 years. The new taxation legislation of 1903 terminated the use of "hartkorn" as the taxation unit, replacing it by the commercial, rateable value of real estate property as of today.

Although property evaluation following the 1903 Tax Reform Act was based on commercial value, there was still a desire to undertake a new national land assessment and renew the "hartkorn" values. This was partly because "hartkorn" was still used in connection with land parceling up to the 1960s, and because there was disagreement over the main principle on which to base real estate assessments.

Hence, from time to time, land surveyors and building societies called for a new national land assessment to be undertaken (Sørensen, 1930; Brink, 1926; Pedersen, 1932).

Thus in 1949, the Ministry of Agriculture appointed a Land Assessment Commission, whose task it was to lay down the guidelines for trial assessments to be carried out in every local authority. This commission had amongst its members, agricultural scientists, farmers, land surveyors, chartered surveyors, and representatives from the National Land Register Office. It worked for about 20 years and based on approximately 25,000 test land assessments a report with recommendations for a new nationwide land assessment was sent to the Parliament in 1970 for approval (Jordboniteringskommissionen, 1970). Unfortunately, the proposal was never approved and soon to be forgotten.

In 1974 a land assessment of Bornholm was carried out based on texture, slope and drainage conditions and maps were constructed at scale 1:50,000 (Mathiesen, 1974). The best soil was allotted the value 39. This land assessment differed both from the principles laid down in 1844 land assessment and those of the 1949 Land Assessment Commission work, because the land assessment values were not directly related to the yield potential. Thus there is no direct link between assessment values and yield potential.

Heather investigation

In the thirties there was an increasing interest for information on suitability of heather for agriculture and afforestation. At that time heather covered more than 5% of the country. The investigation was carried out from 1938 to 1952 by the Danish Land Development Service and in total 160,020 ha were investigated. (Hove, 1962).

Systematic bog investigation

During the First World War the Danish peat resources were intensively utilised because the supply of foreign fuel failed. In early twenties it was decided to carry out a national bog and peat assessment to determine the amount and quality of Danish peat resources. This survey was carried out by the Danish Land Development Service (Hedeselskabet) during a twenty year period and terminated in 1942. A total of 1625 bogs larger than 5 ha were investigated. (Thøgersen, 1942).

Danish Soil Classification 1975-90

From the end of the 1930s until the 1970s, more than 300,000 hectares of agricultural land were lost to other land uses. Some of this land was converted to new forest plantations. Urbanisation increased rapidly after the Second World War, and much agricultural land was lost to new housing and industrial estates, new recreational areas such as summer house areas and the space required for infrastructure.

The Regional Planning Act of 1973, and the Local Planning Act of 1975, heralded the start of physical and environmental planning in Denmark. By this time, it had become apparent that agricultural land needed to be part of the overall planning process and that there was a need for a nationwide soil mapping programme. Thus, in 1974 the Danish Ministry of Agriculture appointed a commission consisting of 8 members, whose function it was to establish a soil classification procedure.

This commission consisted of experts from soil research centres, universities and agricultural organisations. Its members were called upon to determine the procedure for the practical development of a soil classification in accordance with five basic requirements:

1. The areas should be classified on the basis of permanent or stable characteristics.
2. There should be a national standard code of reference that would make it possible to classify soils as uniformly as possible.
3. The results should clearly illustrate the range of fertile and infertile soils.
4. The results should be mapped in such a way that they might be used in future planning at all levels.
5. The classification should be completed within a reasonable time limit (a maximum of three years).

The majority of experts believed that it was best to make a classification focussing upon a few important soil factors such as topsoil texture, slope and overall drainage conditions. Essentially, the work would make use of existing data, supported by textural analysis of the plough layer, but no link was made to the enormous work made by the 1949-commission. In order to benefit from local knowledge on soil conditions, local extension workers from agricultural organisations were to be consulted. These consultants would be able to advise on sites at which to carry out soil sampling and to delineate areas of identical soil types.

In December 1975, the Department of Soil Classification (Sekretariat for Jordbundsklassificering, SfJ), was set up in the town of Vejle in East Jutland. Its task was to organise and undertake the work of the Danish Soil Classification.

Table 1 Definition of soil classes and soil types

Colour Code	Soil type	JB-nr.	Percentage by weight					
			Clay < 2 µm	Silt 2-20 µm	Fine Sand 20-200 µm	Total Sand 20-2000 µm	Org. Mat. 58.7 % C	Lime $CaCO_3$
1	Coarse Sandy Soil.	1	0-5	0-20	0-50	75-100	≤ 10	≤ 10
2	Fine Sandy Soil.	2			50-100			
3	Clayey Sandy Soil.	3	5-10	0-25	0-40	65-95		
		4			40-95			
4	Sandy Clayey Soil.	5	10-15	0-30	0-40	55-90		
		6			40-90			
5	Clayey Soil.	7	15-25	0-35		40-85		
6	Heavy Clayey Soil or Silty Soil.	8	25-45	0-45		10-75		
		9	45-100	0-50		0-55		
		10	0-50	20-100		0-80		
7	Organic Soil.	11					> 10	0-90
8	Calcareous Soil	12					≤ 10	> 10

Prior to this date, the county of North Jutland had already been classified (Mathiesen, 1975), and this county together with Bornholm was initially excluded from further classification. A databank was established at SfJ comprising two main departments:

1. Soil Map Department producing the basic data maps;
2. Geographical Database Department storing all the collected data, such as texture analyses.

The classification work led to the collection of entirely new data stemming, in particular, from the texture analysis of soil samples from the plough layer or subsoil. Additionally, a slope classification map was compiled from old, detailed topographic maps. Drainage conditions were examined and recorded and, finally, existing surface geology maps created by the Danish Geological Survey - (today known as GEUS) were revised in order to meet the requirements of the Danish Soil Classification.

Samples for texture analysis were taken at about 36,000 sites (approximately 1 sample per km^2) from a depth of 0-20 cm and at selected sites also from a depth of 35-55 cm. No soils were sampled in urban and forest areas. The samples were taken by local agronomists in cooperation with the staff at the SfJ in Vejle. In the laboratory, texture, organic matter and calcium carbonate were determined on all samples and the results stored in databases (Mathiesen, 1980).

The agricultural land was classified into eight soil types according to the texture of 0-20 cm depth. Each soil type was then assigned a map colour code (1-8). The remaining areas were divided into urban areas and forest areas. The soil types were further subdivided into 12 soil classes (JB 1-12) (see Table 1). The eight soil types were delineated on maps by local agronomists in cooperation with the staff at the SfJ. In this way the mapping benefited from local experience.

The agricultural land was classified according to slope:

1) 0-6°
2) 6-12°
3) more than 12°

Experiments had shown that in class 1 mechanised tillage was carried out without any problems, in class 2 minor difficulties might arise, whereas in

class 3 mechanised tillage was almost impossible (Landbrugsministeriet, 1975).
By 1980, approximately 400 soil maps at a scale of 1:50,000 were available. The maps were published in colour with soil types printed in brown or yellow colours, the forests printed in green and the urban areas in white (Nørr and Platou, 1984). The dominant geology was shown for every 25 ha as a notation in the upper right corner in a grid. The slope classes were indicated by hatching (shading).

Investigations to Enhance Soil Maps

A landscape map has been delineated on topographic maps at a scale of 1:100,000. The boundaries between different landscapes were drawn on basis of the contour lines, former landscape maps, and geological surveys published at a scale of 1:100,000. The country has been divided into 9 different landforms: 1: Salt marsh, 2: Raised seafloor, Littorina, and younger marine foreland, 3: Late glacial raised seafloor. 4: Dune landscape. 5: Saale glaciation landscape, 6: Outwash plain, 7: Weichsel moraine landscape, 8: Reclaimed area, 9: Rock.

Based on information from geological surveys (field determinations) the texture of the soil at 1 metre depth was classified as sandy or clayey. It has not been possible to set up an exact limit of clay content between the two types, but clayey subsoils normally contain more than 15% clay, sandy ones less than 10%.

The wetlands were delineated from old topographic maps (1:20,000) showing the extent of wetlands 60-80 years ago. The old topographic maps were preferred to later ones because of the recent decrease in wetlands due to drainage. The wetlands included bogs, river valleys, salt marsh areas, littorina deposits and younger marine forelands. They cover roughly 20% of the country.

In Jutland the water quality in some aquifers can be impaired by strong acidity and a high concentration of dissolved iron. This is due to the presence of iron sulphides in such an amount that acid sulphate soils develop when the land is drained. As iron sulphides are only stable under anaerobic conditions, acid sulphate soils will only be present in wetlands. Mapping of potentially acid sulphate soils was carried out in the years 1981-84 (Madsen *et al.*, 1985a and Madsen and Jensen, 1991). Approximately 8,000 soil profile descriptions have been made based on augering, and approximately 16,000 samples have been analysed. In the laboratory the lime-free samples were placed freely exposed to the air and pH was measured after 2, 8 and 16 weeks. If pH dropped below 3, the samples were considered to be acid sulphatic in nature. In the lime-containing samples the amount of pyrite and calcium carbonate was measured. Based on these results it was decided whether the samples were acid sulphatic or not. Soil maps were then elaborated dividing the wetlands into four classes based on the frequency of profiles containing acid sulphatic samples.

A second generation soil map

In the early 1990s, the county of Western Zealand decided to make a new plan for agriculture in the region. To support this, there was a need for more detailed soil information than that provided by The Danish Soil Classification, e.g. for calculation of the demand of water for irrigation and for delineation of sensitive areas according to drinking water quality (groundwater protection). Thus a project was initiated to develop the existing soil maps to provide more detailed information on texture.

The principle for construction of the second generation soil maps at a scale of 1:50,000 was to combine already existing topographical, geological and landscape maps to delineate specific geographical units having the same soil type. Based on analytical data from different sites within the county the map units were assigned a soil texture at three depths according to the JB-system shown in Table 1. The three depths were 0-30 cm, 30-60 cm and 60-120 cm (Fransen and Madsen, 1998).

Pedological investigations

Several soil profile investigations have been carried out during the last decades. Among these, two large investigations will be described briefly. In relation to the establishment of the main gas pipeline system from the North Sea across Denmark in 1981-84 (Figure 1), pedological investigations along the lines were carried out (Madsen and Jensen, 1988). About 800 detailed profile descriptions and about 8,000 soil profile classifications were made.

In order to improve the efficiency of nitrogen fertilisers used in Danish farming, the Danish Agricultural Advisory Centre established a nationwide 7 km grid. The grid was established in 1986 and contains approximately 850 intersections. At all the intersections pedological investigations were carried out from 1987-90 by the Bureau of Land Data (ADK) in cooperation with the Geographical Institute at the University of

Copenhagen. This led to the establishment of The Danish Soil Profile Database.

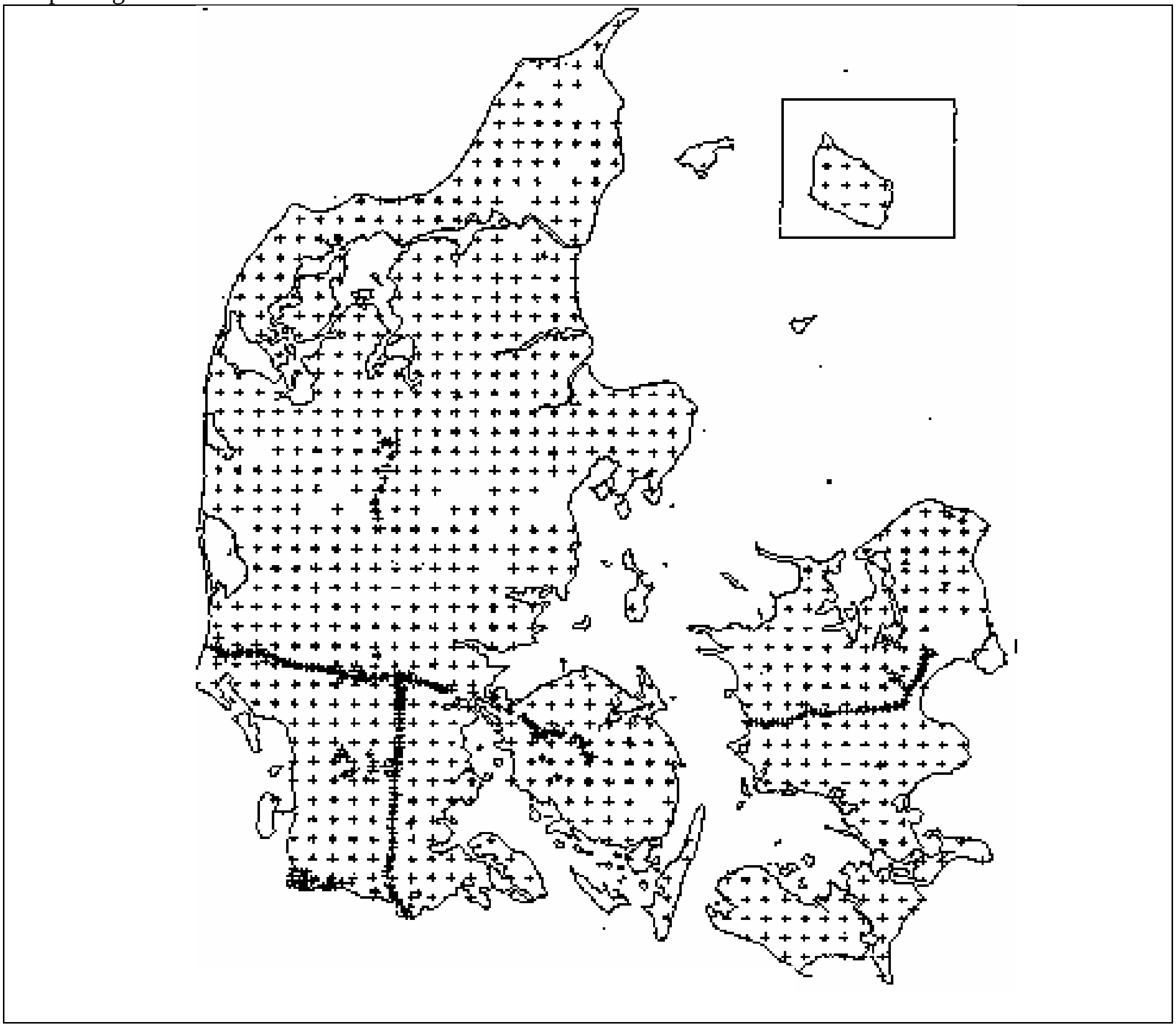

Figure 1: Location of Profile pits

Monitoring

At all intersects in the 7 km grid, 50m x 50m test plots were established, in which the content of inorganic nitrogen was determined twice a year at four depths. On the basis of these data the farmers are advised on their use of N-fertiliser (Østergaard, 1990) In the beginning of the nineties, 393 sites from the 7 km grid were selected to represent Danish soils in the Danish heavy metal monitoring programme. For comparison twenty additional fields with sewage sludge application were selected.

The samples were analysed for arsenic, cadmium, chromium, copper, lead, mercury, nickel and zinc (Jensen *et al.*, 1996). It is recommended that this monitoring programme is repeated in 10 years time.

In 1998 funding was granted for the project: 'Monitoring the environmental impact of modern agriculture with respect to phosphorus, copper, zinc and pesticides in relation to management'. One of the components of this project is to resample and reanalyse the grid points in the 7 km grid to determine whether the content of these substances have changed during the past 12 years.

Use of Soil Information

The Nationwide Danish Soil databases have been widely used for planning of rural land at county and national level. Initially, the soil information was used in respect to the protection of valuable agricultural land around expanding urban settlements. Later it was also used in agricultural water planning (Madsen and Platou, 1983; Holst and Madsen, 1986; Holst and Madsen, 1988). It has also been used for mapping wind- and water erosion (Madsen *et al.*, 1985b, Hasholt *et al.*, 1990), nitrate loss from farmland (Børgesen *et al.*, 1997), areas giving rise to ochre pollution (Madsen *et al.*, 1985a, Madsen and Jensen, 1991),

and marginal land (Madsen and Holst, 1987; Svendsen and Pedini, 1987).
In the last 5 years there has been an increasing interest in soil data from European authorities, and the Danish soil databases have been used as the national input to various European projects. In 1998 The European Soil Bureau completed the compilation of the Soil Map of Europe at a scale of 1:1,000,000 and the European Soil Profile Analytical database. The part of the project concerned with Danish soils was compiled by GI and ADK.

In 1995 25 Danish profiles from the Danish 7km grid were selected as a part of the European monitoring for forest health programme (Madsen and Olsson, 1995).

In 1997 and 1998 data were supplied to a European research project IMPEL (Integrated Model for Predicting European Land Use). The Danish Institute of Agricultural and Fisheries Economics was the Danish participant in this project.

In 1998 the project 'Using existing soil data to derive hydraulic parameters for simulation models in environmental studies and in land use planning' was completed with the production of a joint European database known as HYPRES (Hydraulic Properties of European Soils). This project was financed by the European Commission (Wösten *et al.*, 1998). DIAS was the Danish party in this project.

Other Soil Mapping Activity

Mapping the surface geology

Mapping the surface geology of Denmark is the responsibility of the Danish Geological Survey (GEUS). This important activity started in 1888, and at present, about 90% of the country has been mapped. Figure 2 shows those parts of the country that have been mapped so far.

Mapping of the surface geology is based on augering using a one-metre auger. Samples are taken at a depth of approximately 1m and classified directly in the field. The classification is based on lithology, texture, organic content, colour and landscape characteristics. Any abrupt change in the genesis of the soil material taken from the top metre is registered. The density of the borings across the landscape is approximately one sample per 4 hectares
National Ordnance Survey maps (scale 1:20,000) were the main reference source for the field investigations. Fieldwork maps were formerly only 1/9 size of the Ordnance Survey maps and had to be redrawn to meet the Ordnance Survey format. These earlier manuscripts, along with field work records, represent GEUS's original mapping material. However, the 1:25,000-scale maps subsequently introduced during the 1970s were found to be ideal for fieldwork, and since then GEUS has used this scale.

The redrawn field maps provided the source material for the final "GEUS First Series" published in map sheets at a scale of 1:100,000. Half of the country has been published at this scale. Other parts of the country have been surveyed, but maps have not yet been published. The introduction of the 1:50,000 scale has meant that GEUS now produces coloured maps at this scale. These are published partly as "Series A" and partly as a different map series. For example, the mapsheet 1215 IV "Viborg" has been published as "Map Series No. 1, 1986". In 1989, on the basis of surface mapping and borehole data (geological basic data maps), GEUS issued a four-part, national surface geology map at a scale of 1:200,000.

Danish Forest Site Classification

In early 1990s, a system for forest site classification and mapping of afforestation areas was developed in a co-operation between The Danish Forest and Nature Agency and the Department of Earth Sciences, University of Aarhus. The system is inspired by the German site classification system used in Lower Saxony. In the field one auger boring is made per hectare and supplemented with one soil profile with matching analyses on all the soil types present in the area.

The area is then subdivided into site types. An ecological code is assigned to each site type. This code gives to the forester information on water supply, nutrient supply, parent material and site specific factors such as layers restricting root growth, etc. Based on these maps a sensible selection of tree species can be made.

The system is in operation at the Danish Forest and Nature Agency and a few thousand hectares are mapped each year (Sørensen and Dalsgaard, 1993).

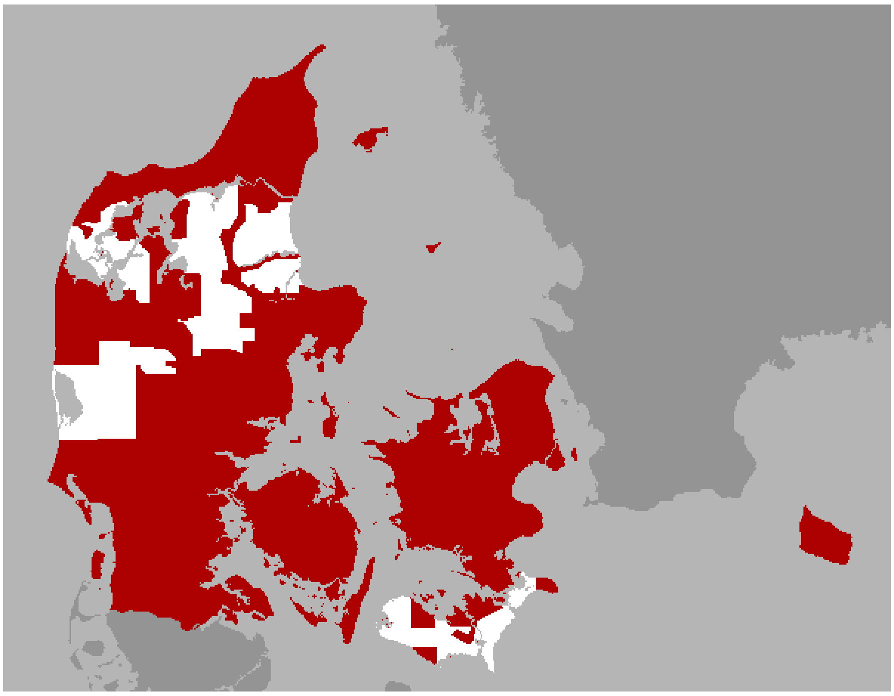

Figure 2 Surface geology maps of Denmark
[published areas shown in red]

Future Tasks

During the seventies and eighties much effort and money was put into small scale soil mapping in Denmark. Very little progress was made in detailed soil mapping, except for the work done in connection with the Danish Forest Site classification. In the beginning of the nineties large farms and private companies started to use the concept of precision farming. The interest in this has grown since then. In 1998 a research programme on precision farming was launched and this has led to an increase in interest in detailed soil mapping.

In 1998 DIAS and GI together with other research institutes received funding for a land assessment project, the aim of which is to develop a new concept for land assessment taking into account both continuous and abrupt changes in the soilscape. The practical goals for the project are:

1. Establishment of the framework for a Danish soil series system on the basis of the DIAS database and the Danish Pedological Soil Classification System
2. Development of a new paradigm for a detailed survey (1:10,000 scale).
3. Quantification of soil variability in relation to mapping units, landform, topography and parent material.

The key to sustainable land management is detailed resource information, and in recent years there has been a marked increase in the demand for such information. This is in response to the necessity of implementing the environmental policies of Danish government authorities, on, for example, set-aside, nitrogen application and afforestation, which have been effective for some years.

However, efficient implementation of present policies requires more detailed soil information than available, but this is not recognised by the authorities. It is the hope that the necessity for adequate, detailed soil information is appreciated by government authorities in the near future.

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Soil Information and Its Application in Estonia

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Historical Background

Data in *Liber Census Danae* from 1241, preserved in the Danish State Archives, Copenhagen (Taani, 1996), together with the additional oral information from Herbert Ligi, late professor of History at the University of Tartu, about the existence and drawing of agricultural maps in the Swedish period, indicate that the description of productive properties and morphology of soils, as well as their recording, was taking place in Estonia already in the 13th-16th centuries.

However, data about soils of the Estonian area were published first in 1645 (reprinted in 1649, 1688 and 1757) in the second chapter of *Stratagema Oeconomicum* (Gubert, 1688) in connection with economic and management issues. Besides Braun Land, Grau Acker and Grau Land, three black soils were also described: Schwarze Erde, Schwarz Acker and Schwarz Land. As a result of translation by Lomonosov (1747), the first of the three came to enrich not only Russian but also world soil classifications under the term Chernozem. It means that contemporary Chernozem as a type of steppe, forest steppe, and prairie originates from Livonian (Southern Estonia and Northern Latvia) oak stands.

Land assessment, which started in 1681 in South Estonia, was undertaken in Island Saaremaa in 1766, and continued again in South Estonia in 1901 (Vint, 1959). For the entire area, land assessment was completed in full accordance with the respective Act of 1923.

In 1803, the Department of Agriculture was established at the Faculty of Philosophy of Tartu University (founded in 1632). Soil science formed a part of its curriculum and the first Johann Wilhelm Krause delivered lectures on soils in 1806 (Reintam and Tarandi, 1980). In 1829, Friedrich Schmalz, Krause's successor, initiated the teaching of soil science, and in 1836 also agrochemistry as special academic subjects. Since that time, i.e. for 175 years, soil science has been included in official study programmes at the University of Tartu and at the Estonian Agricultural Academy (later the Estonian Agricultural University).

From 1830, Schmalz taught also evaluation and classification of soils using his own manual (Schmalz, 1824). His ideas both about teaching and science were developed by all his successors (G. P. A. Petzholdt, C. G. F. Hehn, W. Knierim, G. B. Brunner, A. D. L. Thomson, S. K. Bogushevski) up to the foundation of an independent Department of Soil Science, Plant Nutrition and Agrochemistry at Tartu University in 1919 (Reintam and Tarandi, 1980; Reintam, 1998). This Department is the predecessor of the present-day Institute. Its first head, Anton Nõmmik, who graduated from St. Peterburg University was a member of the Dokuchaev Scientific Committee. The first Estonian-language textbook was already published before the foundation of the Department (Eisenschmidt and Hünerson, 1916).

Vassili Dokuchaev, the founder of genetic soil science, organised two expeditions (1876 and 1881) in Estonia (Reppo and Valdek, 1963), the results of which were included in Russian Chernozem published in 1883. The soil chemical analyses for this study were performed at the Department of Chemistry of Tartu University by

Professor Carl Schmidt (Krupenikov, 1981; Reintam, 1998). K. D. Glinka separated rendzinas, degraded rendzinas and podzolic soils in his soil maps of Estonia. On the basis of different geological databases and soil assessments, carried out over a long period, special generalised maps were initiated in the early 1920s.

Soil Mapping

Excellent geological sketch maps had been compiled already by the middle of 19th century (Orviku and Viiding, 1986), but a more intensive geological surveying took place in the 1920s. Under the guidance of Karl Orviku, maps (1:200,000 scale) of Paleozoic bedrock, Quaternary deposits and geomorphology were compiled at the Institute of Geology of the Estonian Academy of Sciences until 1953. Based on the results of large-scale field and laboratory studies and drilling programmes, the Estonian Geological Survey compiled updated, more complete maps, in 1975 of the same scale (Raukas and Teedumäe, 1998).

A large number of complementary maps with a focus on geomorphology, hydrogeology, engineering geology, distribution of mineral resources, geological structures and several other aspects were also compiled, most of which are presented in the monograph by Raukas and Teedumäe (1998). The last documents produced by the Geological Survey of Estonia were maps of geological bedrock (Suuroja, 1997) and Quaternary deposits (Kajak, 1999) at the scale of 1:400,000. The latter maps were compiled using the data of geological mapping at scales of 1:200,000 and 1:50,000.

Geobotanical mapping at large scale (1:42,000) was initiated by Teodor Lippmaa in 1934 and completed under the guidance of Liivia Laasimer in 1956 (Laasimer, 1958, 1965). These activities involved the use of data on soils and their properties. These exceptionally detailed geobotanical map sheets were generalised at the scale of 1:200,000 and were finally published at scale of 1:600,000 (Laasimer, 1965). The whole geological and geobotanical database created prior to and simultaneously with soil studies has been used as a basis for soil mapping, especially in its initial stages.

The first comprehensive soil map at the scale of 1:800,000 was compiled by A. Nõmmik in 1923 and reprinted later (Nõmmik, 1923, 1926, 1938). This map reflected both the agrogeological and genetic ideas then in soil science. At the same time, several medium-scale soil maps for separate counties were compiled (Kask, 1975). Estonia, with its rendzinas, brown forest soils and podzolic soils was represented also on the Soil Map of Europe by Stremme (1927).

On the basis of previous geological, geobotanical and soil research and land evaluation, as well as on the basis of his own long-term studies, Alfred LiIlema published a soil map at a scale of 1:400,000 (Lillema, 1946) which qualifies as partly genetic in the modern sense. This map was later generalised and published at the scale 1:1,500,000 (Lillema, 1960). In the late 1940s, key mapping by separate agricultural enterprises producing map sheets at 1:10,000 and 1:50,000 scales respectively, was started on the initiative of Osvald Hallik and under the guidance of Alfred Lillema. Mapping of soil acidity and need for liming also began (Hallik, 1941, 1948).

In Estonia, systematic large-scale soil mapping was launched in 1949 with involvement of students of agronomy. From 1954, a special survey was carried out under the supervision of the Ministry of Agriculture. Aerial photographs were used as the basis for this activity. Up to 1992, the soil cover of Estonia was mapped by the Department of Soil Survey of the former Institute of Estonian Agroprojects (both closed today), using the scale of 1:10,000. Besides the inspection of arable land, forests and other civil territories, completed in 1989-91, the remaining former Soviet military areas were also studied. On the basis of this large-scale survey, aggregated medium-scale maps (1:50,000; 1:100,000) for all counties and for some natural regions were compiled during 1954-1990. At the same time, small-scale maps (1:200,000; 1:500,000 and 1:1,500,000) were also produced (Rooma and Reintam, 1976; Kokk et al, 1989; Rooma and Voiman, 1996; Rooma, 1996). In the case of the map compiled by Rooma and Reintam (1976), FAO-1974 nomenclature was used alongside traditional local soil taxonomy**.**

In line with the activities of the European Soil Bureau in 1995 (King *et al*. 1995; Madsen and Jones, 1995), a digital (GIS processing by A. Kull) soil map of Estonia, 1:1,000,000, compiled on a topographic basis with FAO-1990 nomenclature in Legend, was produced by I. Rooma and L. Reintam (1998). This map distinguishes twenty-nine soil map units (SMU) with various combinations of associated soils. Since Gleysols and Histosols cover 34 and 23% of the territory, respectively, (Reintam, 1995), they are represented in 17 and 15 SMUs. Eutric Gleysols predominate in eight and Histosols in five SMUs.

Within the SOVEUR Project, advised by ISRIC (Batjes, 1997; Batjes and van Engelen, 1997), a soil map of 1:2,500,000 was produced by I. Rooma and L. Reintam. This map served as the basis of a soil degradation map of Estonia produced within SOVEUR in accordance with ISRIC methodology. Large-scale soil maps (1:10,000) were used as the basis for the gradual generalisation of maps at scales of 1:500,000; 1:1,000,000, and 1:2,500,000. The latter map distinguishes thirteen SMUs.

Simultaneously with large-scale mapping, assessment of soil quality was carried out (Figure 1) with quality estimates (on a 100-point scale) given for each soil polygon. An agrochemical survey, initiated in 1928, focused on the measurement of available phosphorus and potassium in arable soils. The results were discussed in the unpublished dissertation of Kaarel Tarandi in 1956 as well as in a large number of papers published before and after the defense of this dissertation. Between 1957 and 1989, large-scale (1:10,000) agrochemical mapping was performed to establish the status of available nutrients, pH and humus content in arable soils (Kärblane, 1996; Järvan *et al*., 1996). Since 1965, besides P and K, also available Ca, Mg and some microelements (B, Cu, Mn, Co) have been included in the list of the survey.

Within the Geological Survey of Estonia, medium-scale geochemical mapping was carried out in the 1980s-1990s (Petersell and Ressar, 1993), as a result of which it was possible to compile geochemical atlases of the humus horizons of soils for industrial North-East Estonia and later also for the entire territory of the republic (Petersell *et al.*, 1994, 1997). The maps (1:400,000) represent the spatial distribution and numerical values of about thirty microelements and heavy metals.

A map of Estonian mires (1:600,000) for the characterisation of peat resources was issued in 1961 (Truu *et al*., 1961). In addition, data for Estonian peat resources were systematised, mires were studied by counties (1971-1989), and a map at a scale of 1:400,000 was compiled (Orru, 1992, 1995; Orru *et al*., 1993). Also, a new inventory of wetlands with an updated database and maps (1:300,000) was carried out (Paal *et al*., 1998).

Soil Database

The total area of Estonia comprises 45,215.4km^2 of which inland water bodies account for 4.6%. The area covered with soil is 43,135 km^2. As a result of large-scale mapping, 119 soil varieties have been distinguished. More than 500 combinations of textural status have been described. The spatial distribution of soils is presented in Table 1. About 10,000 profiles (1 profile per 330ha) have been sampled and analysed for characteriation of mineral soils.

The results of these activities have been statistically processed and presented in Estonian Soils (Kokk *et al*., 1974-1987). On the basis of these materials, supplemented with some other sources (Kitse, 1978; Kitse and Leis, 1996; Reintam, 1973a), as well as the unpublished database of the Institute of Soil Science and Agrochemistry, Estonian Agricultural University, eleven Tables of Proforma I (Madsen and Jones, 1995) with multiprofile measurements and determinations, and 37 Tables of Proforma II with measurements of individual reference profiles have been presented. One reference profile represents about 89,500ha of mineral soils. Six well-selected reference profiles were studied and analysed within the American-Baltic Joint Project on soil classification and genesis (Calhoun *et al*., 1998).

Soil maps at scales 1:1,000,000 and 1:2,500,000 were digitised prior to their incorporation in the European and SOVEUR databases, respectively. The soil map of 1:500,000, compiled by Igna Rooma and Vello Voiman using Estonian nomenclature in the Legend, was converted to USDA Soil Taxonomy by Raimo Kõlli and Illar Lemetti, and digitised at Cornell University, USA, under the guidance of Ray B. Bryant. The medium-scale map of 1:200,000 is only partly digitised; final digitisation of large-scale (1:10,000) maps was finished in 2001 at the EO Map in accordance with the order of the Estonian National Land Board (Figure 2).

Soil Monitoring

The first studies on the temporal and spatial changes in soil properties were carried out in experimental fields of fertilisation and agro technology during the first decades of the last century. Special investigations were initiated in the 1960s within the International Biological Programme (IBP). Seven basic forest areas together with arable land, three-field rotation, and a large number of complementary forest and arable areas served as the framework of IBP activities in Estonia.

The results were published in the series Estonian Contributions to the International Biological Programme (Frey *et al.*, 1970, 1971a, 1971b; Frey, 1977, 1979) as well as in the Transactions of the Estonian Agricultural Academy (Reintam, 1970, 1971, 1973a, 1975; Kõlli, 1974), in the Oak Ridge National Laboratory Publications (Olson *et al.*, 1983), and in numerous individual papers.

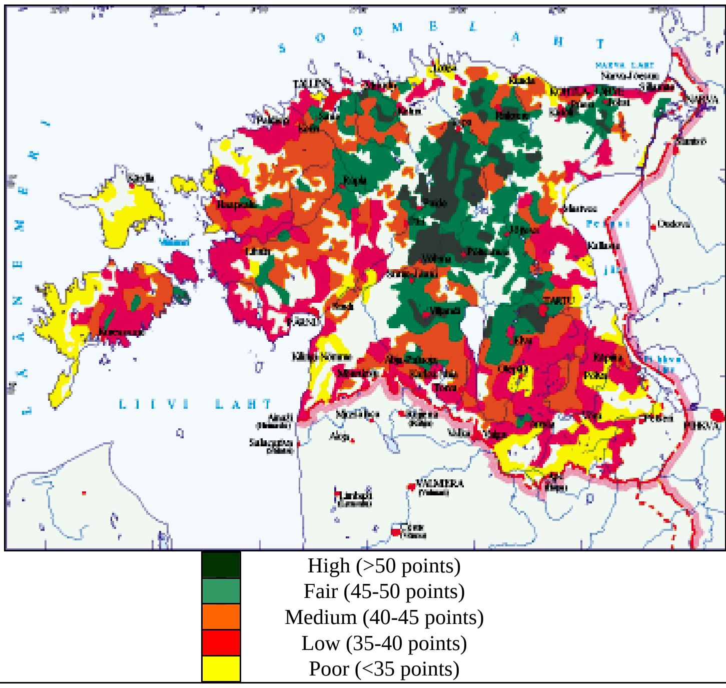

Figure 1: Quality areas of arable soils
(R. Kokk, reproduced from Atlas of Estonia - Rooma, 1996)

Repeat studies on several former IBP and some other plots were conducted in 1986-2000 to establish the changes that had taken place in soil properties and status during 20-35 years. Part of the data from these studies, both on forest and arable soils, have been published in several individual papers, part are in press, and part are still in the stage of analysis and processing.

The dynamics of the ground water table, water and air relationships, and physical and chemical properties of Eutric Gleysols and Carbi-Gleyic Podzols have been investigated prior to their drainage and 11-13 years after these management procedures (Paas, 1981, 1985, 1986). In connection with changes in land use, neglected drainage systems have caused continued gleying and waterlogging in previously drained areas (Soovik *et al.*, 1996).

Geochemical monitoring of Estonian soils has been carried out by the Geological Survey of Estonia in two series in 19 and 25 study areas and the results obtained published (Petersell *et al.*, 1996). The results of the annual Estonian Environment and Estonian Environmental Monitoring programmes, published both in Estonian and English by the Ministry of the Environment, contain information about changes in soils established by geochemical monitoring, monitoring of arable soils performed in 1983-1994, and by monitoring of forests and forest soils.

In the framework of the forest monitoring system, Haplic Podzols, Dystric Albeluvisols, Stagnic Luvisols and Gleysols were studied in 91 plots representing the areas of the most important tree species (Norway spruce, Scotch pine and silver birch) in Estonia (Asi and Sepp, 1997). The character and thickness of the epipedon, changes in organic carbon, nitrogen, actual acidity, acidification, alkalinisation due to flue gases and dusts from power plants, as well as in heavy metals (Pb, Cd, Zn) have been studied. These investigations are continuing in the framework of forest monitoring by the Centre of Forest Protection and Silviculture.

Monitoring of arable soils was initiated by the former Agro-Industrial Committee of the Estonian SSR in 1983. On Rendzic Leptosols, Cambisols, Luvisols and their Stagnic and Gleyic subtaxa as well as on Gleysols, nineteen experimental areas with 79 study plots and 3,160 sites were established by the former Soil Survey. Changes in their epipedon, content and pool of humus, bulk density, soil reaction, and content of available P and K were studied. In all areas 3-5 reference profiles were described and sampled in addition to the above framework of the monitoring system. By 1993, the Soil Survey had succeeded in carrying out two (in places three or four) periods of monitoring.

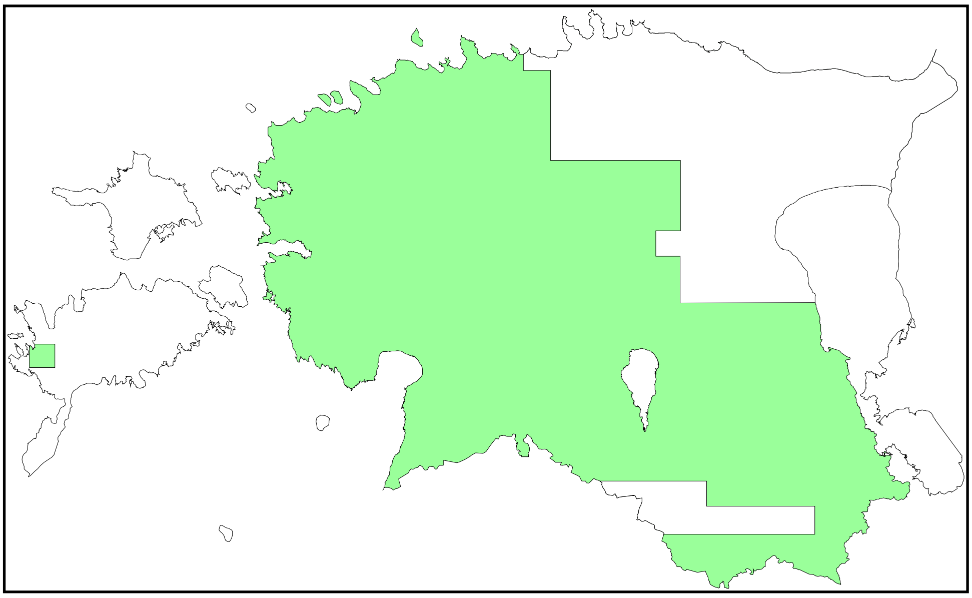

Figure 2: Large-scale (1:10,000) soil maps in Estonia

(green area - maps and a database digitised up to 2000; uncoloured area - GIS processing of large-scale maps completed in 2001)

Table 1: Distribution of soils (% area)

Soils	Total	Forest area	Arable area
1. Rendzic Leptosols on limestone	1.2	0.8	0.8
2. Calcaric Regosols on pebble till	4.7	1.9	9.0
3. Calcaric Cambisols	4.2	1.7	9.7
4. Calcaric Luvisols	2.4	0.9	6.3
5. Stagnic Luvisols and Planosols in complex	5.9	1.6	15.1
6. Albeluvisols	3.0	2.7	3.3
7. Podzols	1.6	3.8	-
A. Total dry and normal-moistened soils	23.0	13.4	44.2
8. Gleyic Leptosols	1.6	0.6	2.1
9. Gleyic Cambisols	3.3	1.4	4.8
10. Gleyic Luvisols	4.0	1.7	7.2
11. Stagni-Gleyic Luvisols and Gleyic Planosols	3.6	2.0	6.2
12. Gleyic Albeluvisols	2.0	1.6	1.9
13. Gleyic Podzols	0.9	2.2	-
B. Total *Gleyic* soils	15.4	9.5	22.2
A+B. TOTAL AUTOMORPHIC SOILS	38.4	22.9	66.4
14. Rendzic Gleysols	1.4	0.7	0.9
15. Calcaric and Eutric Gleysols on till	10.0	10.0	7.0
16. Eutric and Dystric Gleysols on aqueous deposits	11.1	10.1	8.2
17. Podzolic Gleysols	2.9	4.1	0.8
18. Carbi-Gleyic Podzols	2.2	5.1	-
C. Total *Gleysols*	27.7	30.0	16.9
19. Mollic and Histic Gleysols	4.7	5.3	2.5
20. Carbi-Histic Podzols	1.6	3.1	-
D. Total *Histic* soils	6.3	8.4	2.5
21. Eutric Histosols	13.8	16.1	7.8
22. Eutri-Dystric Histosols	3.7	6.9	0.1
23. Dystric Histosols	5.7	13.7	-
E. Total *Histosols*	23.2	36.7	7.9
C+D+E. TOTAL HYDROMORPHIC SOILS	57.2	75.1	27.3
24. Eutric and Mollic Fluvisols	1.4	1.0	0.8
25. Salic Fluvisols	0.7	0.3	-
F. TOTAL FLUVISOLS	2.1	1.3	0.8
26. Eroded and deluvial soils	2.1	0.1	5.5
27. Others (Anthrosols, etc.)	0.2	1.0	-

Unfortunately in the mid-1990s, large-scale monitoring of arable soils was stopped as a consequence of the closure of the participating institutions (including the Soil Survey).

Only some of these results have been published (Kokk *et al.*, 1987, 1988, 1989) because of a change in attitude towards soil as a resource and the decision to cease developing agriculture. The concise manuscript versions of the research, written by Rein Leet in 1994 and by Ragnar Kokk in 1995, were both presented to the Estonian National Land Board and to the Ministry of the Environment. Dynamic studies of soil organic matter (including annual fluxes of falling debris and its transformation) were initiated already some decades ago (Kõlli *et al.*, 1996) and are continuing on a series of specially founded toposequences in different soil cover types.

Application of Soil Information

Forest site typology was elaborated with a special account of soil information (Lõhmus, 1984). Soils have served as a basis for all vegetation classifications (Paal, 1997), as well for various management activities (Karoles, 1995). The existence of a large number of publications in agronomy, forestry, land reclamation, amelioration, economy, ecology, archaeology, landscape geography, etc. gives evidence of the wide application of soil information. The division and description of landscape regions in Estonia have been based also on soils (Tammekann, 1932; Varep, 1964; Arold, 1993). In compiling a large-scale landscape map, detailed soil information from large-scale surveys was used by Ivar Arold.
As an essential component of large-scale mapping, maps of agronomical (forestry) status and measurements (1:10,000) have been compiled (Figures 3 & 4). These maps distinguish the following three agrogroups of soils: A - medium textured automorphic and well drained gleyic soils which are well suited to field crops; B - light and/or heavy textured automorphic, slightly arid and/or over damp soils, poor drained gleyic and fair drained.

Gleysols which are reasonably suited to field crops but well suited to grassland husbandry; C - eroded soils of different types, drained Histosols, and undrained Gleysols which are unsuitable for field crops but suitable for grassland husbandry.

The Legend of these maps provide numerical data about soil taxa, textural classes, quality classes, as well as recommendations for land management, reclamation, amelioration, agrotechnology and land use (Reintam *et al.*, 2003). The suitability of the soil for crops has been elaborated by the former Soil Survey on the basis of perennial yields from the network of experimental institutions as well as from model agricultural enterprises (Valler, 1973, 1975). Matrix tables (Table 2) were elaborated and presented for assessment of suitability of soils for agriculture and for detailed characterisation of agrogroups (Kõlli, 1994). A database of large-scale agrochemical mapping has served as a basis for fertilisation and liming.

No amelioration activity (drainage) programme was designed and constructed without a detailed (1:2,000 or 1:2,500) survey being carried out against the background of general large-scale mapping. Since the machinery carrying capacity of more than 800,000ha of arable soils is less than 140kPa, special recommendations have been applied for deep subsoil loosening and crop rotation. There has been a decrease in soil compaction as a result of changes both in land use and in the types of machinery used today.

Erosion risk is reflected on soil maps of all scales, as is its control. As the majority of the Estonian territory is largely flat and soil texture is loamy, water and wind erosion do not present a natural hazard. Developments of grassland husbandry in the recent past and modern changes in land use have resulted in a decline of erosion even on the end-morainic hills of Southeast Estonia. Recent investigations have identified the presence of tillage erosion, which was not previously recognised. Investigations of soil erosion and soil properties have been widely used in landscape ecology where estimation of nutrient runoff on the catchment level is based on the analysis of critical sources combined with land use and climate characteristics (Mander *et al.*, 2000).

Data on the acidification of some sandy forest Podzols and on the alkalinisation and contamination with heavy metals in the region of oil shale and power industry in Northeast Estonia have been partly applied in economic management. Detailed soil information has been employed also for estimation of cases where critical loads of atmospheric deposition (sulphate and nitrate/ammonia) for different ecosystems may exceed the observed deposition (Oja and Kull, 2000). Although the chemicals applied in agriculture have not polluted the soils, they represent a risk for water even today.

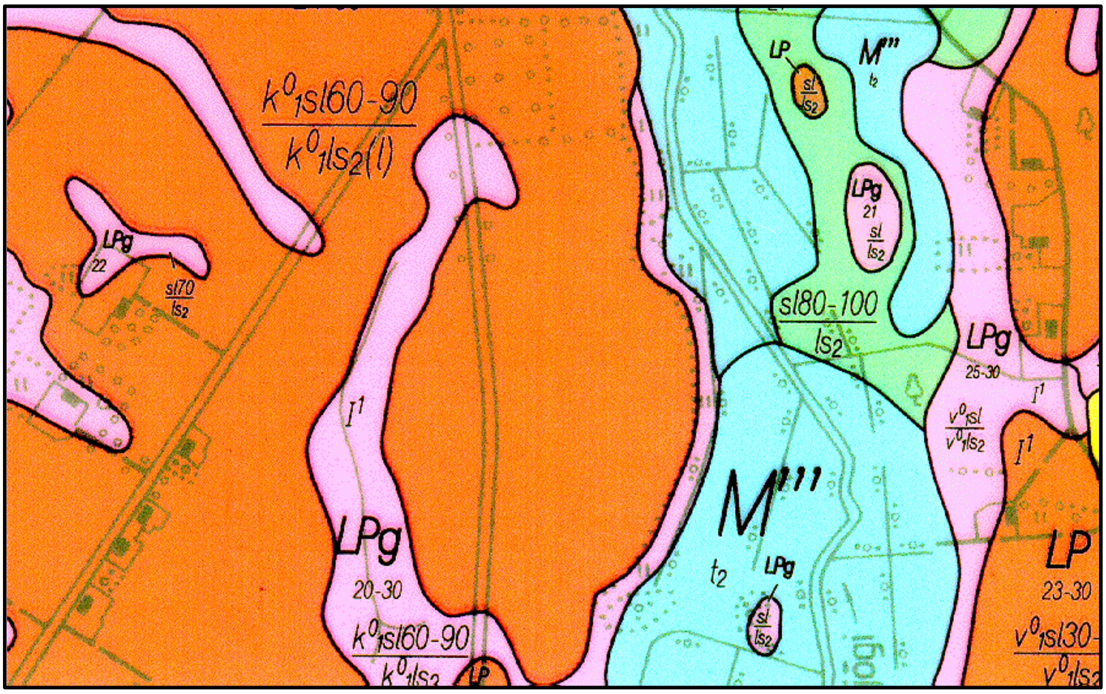

Figure 3: A fragment of a large-scale soil map (1:10,000) of Southeast Estonia.

LP, LPg, etc. - soil codes: LP - Stagnic Luvisols, LPg - Stagni-Gleyic Luvisols, GI - Eutric Gleysols, M - Terric Histosols; 23-30, etc. - thickness of humus horizon (cm) within polygon; data in the form of a formula - soil texture and presence of small (v - 1-10cm, k - 10-20cm) stones to a depth of 100cm: in the numerator - texture and depth of topsoil, in the denominator - texture of subsoil to 100cm; sl - loamy sand, ls - sandy and silty loam, t - peat (t_2 - moderately-decomposed, t_3 - strongly-decomposed); I, etc. - degree ($2-5m^3ha^{-1}$ of stones) of stoniness with large-sized stones (1 - stone sizes 20-40cm).

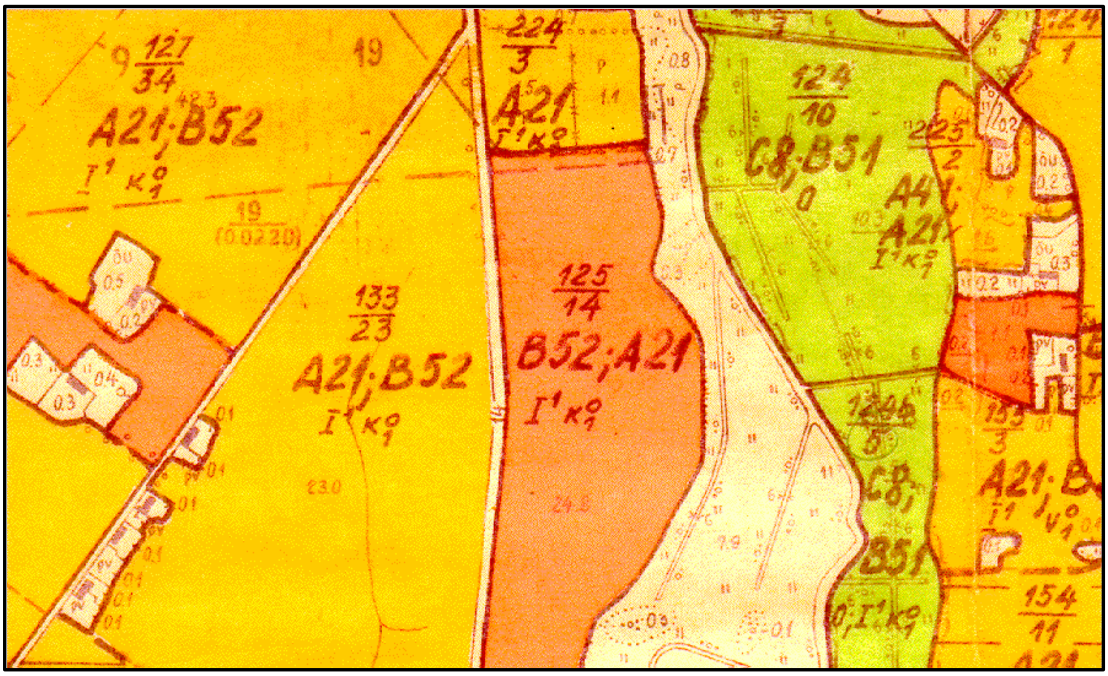

Figure 4. A fragment of an agronomical map equivalent to the soil map in Figure 3.

A, B, C - agrogroups of arable land (explanation in text); A21, B52, etc. subgroups of arable land distinguished on the basis of soil properties and drainage status: e.g. B52 - medium-textured undrained Stagni-Gleyic Luvisols; I, II, etc. - degree of stoniness with large-sized stones; 1, 2, 3 - size of stones; k^0_1, v^0_1, etc. - degree of stoniness with small stones; k^0, v^0 - igneous rocks, k, v - calcareous rocks; numerical in the form of formula: in the numerator - number of a land use unit, in the denominator - area of a respective land unit, ha.

Table 2. Selected examples of soil suitability (0-10) for crops derived from the original matrix table (Kõlli, 14)

Soil code*	Main agricultural crops**															
	B	R	W	O	Po	F	FG	M	L	Me	Lu	Sw	Pe	Rc	Bw	Fr
LPk	6	5	5	5	4	2	4	4	8	7	0	4	3	4	0	4
ARb	6	6	4	5	6	3	5	5	4	3	9	4	4	5	7	6
RGc	9	9	8	8	6	4	7	7	10	10	0	8	6	6	1	8
CMc	10	9	10	10	9	9	9	9	9	10	8	10	9	9	7	9
LVc	10	9	10	10	9	9	9	9	9	10	8	10	9	9	7	9
LVh	9	9	8	8	10	10	9	9	4	8	8	9	9	9	8	9
LVj	9	10	9	9	10	10	9	9	4	8	8	9	7	9	8	9
LVg	9	9	9	9	8	7	9	10	4	8	9	9	8	8	7	9
PLe	7	7	10	9	6	7	9	9	3	7	8	9	6	10	0	7
PZh	6	7	4	5	7	3	5	5	4	3	10	4	4	5	7	7
PZg	7	8	6	8	8	7	8	9	3	6	8	6	4	5	6	8
GLe	9	9	10	10	8	6	9	10	5	9	7	10	9	9	7	8
GLm	6	6	5	7	4	4	10	10	0	5	0	4	5	7	0	4
HSs	7	7	5	8	4	4	9	7	0	5	0	3	5	6	0	4

* Gleyic soils, Gleysols and Histosols are regarded as well drained.

** B - barley, R - winter rye; W - winter wheat; O - oats; Po - potato; F - flax; FG - field grasses; M - mixed crops; L - lucerne; Me - melilot; Lu - lupine; Sw - summer wheat; Pe - pea; Rc - red clover; Bw - buckwheat; Fr - fodder roots (mangel, turnip, etc.).

Increase in urbanization is characteristic of the Northern part of Estonia, but it is evident also in other localities. For various reasons, soil quality has not been taken into consideration in order to control this activity of contemporary soil degradation. Several local industrial enterprises and former Soviet military installations play an important part in soil contamination and pollution. Since the extent and the character of the military-induced processes have become evident only recently (Raukas, 1999), the respective database has not yet been used. Detailed data on soil degradation, induced by oil shale and phosphorite mining both by chamber-and-pillar and open-cast-quarry methods, have been employed in procedures of forest and agricultural rehabilitation. The capacity of the soil cover for environmental protection has been attracted attention within the last decade (Kõlli, 1999).

Based on the soil database and on the legislative experience related to other natural objects (ecosystem components) of the biogeophysical (chemical) environment, a draft Soil Act was created in 1999 after a preliminary presentation of its concepts (Raukas and Ratas, 1999). The thirty-seven articles of the draft Soil Act cover the following items: tasks, regulations, object (soil) characterization, investigation and classification of soils; assessment of soil status and expected negative impacts; regulation of management; limitations due to property rights; rehabilitation of injured (contaminated, degraded) soils; control, inspection and responsibility. The draft Soil Act has been submitted to the Ministry of the Environment for presentation to the Parliament (Riigikogu).

Perspectives and Suggestions

The principal problem is re-establishment of the Soil Survey under the Ministry of the Environment. The only existing reliable institution, the Institute of Soil Science and Agrochemistry, Estonian Agricultural University has insufficient resources to update large-scale soil database, to carry out monitoring of forest and arable soils, to study modern soil and production processes and regimes and turnover of substances in plant-soil systems, and to control contamination and degradation phenomena of soils.

As a consequence of privatisation, the size of land property has diminished, and a more detailed (at least 1:5,000) survey and/or digitised updating of former large-scale soil maps by complementing them with corresponding database are needed. Soil data available by GIS should be organized in a system where they would be integrated in the planning of agricultural land use and forest management as well as in the Quaternary subsoil and meteorological databases. Land privatisation, changes in ownership and new concepts of taxation need a contemporary rearrangement of soil assessment features.

The rapid decline of agriculture and progressive fallowing of arable soils are relatively spontaneous processes, depending not so much on the productive capacity of soils but rather on the financial and/or physical ability of owners. In such a situation, studies with a changed focus as well as a pedosociological database appear to be needed in the near future. Serious problems have arisen in connection with the intensification of clear felling and degradation of forest soils due to the passage of heavy machinery transporting timber. Seasonal restrictions for clear felling, even for plantation thinning, should be established with regard to soil specific properties. This position both on tree felling and conversion of land to urban has been expressed also in the draft Soil Act.

Importing of basic foodstuffs (which can cause several problems for local producers) appears disadvantageous to Estonia, where local production is feasible and has a long tradition.

Although soils can produce food and fodder in any field and/or garden, they represent an indispensable but slowly rehabilitating resource of natural wealth. A database on soils must be constantly updated and referenced if it is to contribute to national well-being. For this reason as well as for the sake of further advancement of European cooperation, agriculture and sustainable forestry should be preserved, and the Soil Survey re-established in Estonia.

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Status of Soil Mapping in Finland

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Introduction

Soils of Finland have been formed quite recently (<12,000 yrs B.P.), after the Weichselian glaciation. Owing to rather weak development, the soils have been nationally classified and mapped according to texture and content of organic matter, and little attention has been paid to pedogenic classification. Therefore Finland is quite broadly presented in the Soil Map of the World and in the Soil Map of Europe. Finland is covered mainly by maps of Quaternary deposits at different scales (1:20,000-1:1,000,000). The Quaternary deposits of about one third of the county have been mapped at scale 1:20,000 while the map at scale 1:1,000,000 is the only one to cover uniformly the whole country. During the last five years, the national soil classes have been related to the FAO and WRB systems and to Soil Taxonomy. In 2000, work began to compile a new nation-wide map and database about the Quaternary deposits and soils at scale 1:250,000 to conform to the requirements of the Georeferenced Soil Database for Europe. This project is planned to be completed by the end of 2008.

Soil Classification

The national soil classification of Finland is based on texture and organic matter (Aaltonen *et al.*, 1949). The soils are separated into three main groups: till soils (moraine); sorted mineral soils (gravel, sand, fine sand, silt and clay) and organic soils, including mull (organic matter, 20-40%), peat (organic matter>40%); and gyttja (a mixture of sedimentary organic and mineral material). Little attention has been given to developing a genetic classification, a decision to some extent justified on the grounds that the soils are young (formed in Quaternary deposits) and formed under rather cold conditions. This national classification serves the practical soil-related activities in Finland well but makes it difficult to present soil data from Finland in an international context.

During the last ten years, requests to supply information about the soils of Finland to the European Union using international classification systems have been frequently received. MTT Agrifood Research Finland (formerly Agricultural Research Centre of Finland) has provided the data on Finnish soils for the European Soil Map at scale 1:1,000,000 according to the FAO/UNESCO classification system (FAO, 1974). The material is based on data prepared for the Soil Map of the World project in the 1970s.

Within the territory of Finland, the following classes of the FAO/UNESCO system (1974) are recognised:

Orthic Podzols	49%
Dystric and Eutric Histosols	28%
Vertic and Dystric Cambisols	7%
Dystric Lithosols, Dystric Regosols	2%
Dystric and Vertic Gleysols	1%
Other Soils	13%

More recent work suggests that Arenosols, consisting of weakly podzolised soils, also exist but are included as Podzols in the Soil Map of Finland. Regosols, consisting of silty soils with weakly developed B horizons, may occupy a larger area than previously expected. In turn, the area of Histosols may be less extensive than previously assumed, if the thickness requirement for organic horizon is strictly followed (Yli-Halla and Mokma, 2002). Data from typical soil profiles have also been supplied for the European Soil Profile Analytical Database.

Soil Mapping

Systematic collection of soil information started in Finland in the late 1800s when the Geological Survey of Finland began mapping the Quaternary deposits. The mapping of soils for agricultural purposes by the Agricultural Research Centre started in the 1920s.

The Geological Survey has published maps at scales of 1:100,000 and 1:400,000, and a summary map at a scale of 1:1,000,000. The Agricultural Research Centre published its early soil maps at 1:50,000 or 1:100,000 scales. Since the end of the 1940s, the scale of 1:20,000 has been used. In the maps of the Geological Survey, soil type to a depth of 1m is indicated whereas in agro-geological maps the soil type of the plough layer is primarily shown.

In 1972, a collaborative committee representing the National Board of Survey, the Geological Survey of Finland and the Agricultural Research Centre of Finland, was formed and the mapping activities mentioned above were combined. Surveyors of the National Board of Survey were trained to collect soil information when updating the basic topographic maps. It was estimated that the entire country would have been surveyed within 30 years, at scale 1:20,000 or 1:50,000. Initially the joint work progressed rapidly, but in the 1990s, due to economic recession, the work was practically stopped and did not restart.

Mapping of about one-third of the country was completed at scale 1:20,000 or 1:50,000 (Figure 1). About half the cultivated land, located mainly in the southern part of Finland, has been mapped for soil types. Printed maps were produced during the early years of soil mapping but nowadays the soil information is stored and retrieved in digital form, and maps are produced only for a specific area on demand.

New Project: 1:250,000

In the late 1990's, the Geological Survey of Finland started to develop methods for a project to produce a new country-wide map and database of the Quaternary deposits of Finland at scale 1:250,000, using modern GIS techniques and utilising previous soil maps of different scales and numerous other data sources. The glaciofluvial deposits, till formations, sedimentation basins and geomorphological features are delineated using a digital elevation model (DEM). Other data include remote sensing data, digital orthophotos and topographic data. The geological soil data layers are combined using GIS-techniques and ArcMap software.

The surface soil is mapped mainly by interpreting airborne geophysical data. The procedures have been developed within this project. With the help of the low altitude aero-geophysical electromagnetic and radiometric data, the occurrence of fine-grained sediment layers and wetlands as well as thickness of peat deposits are identified. The soil in the surface layer, and at the depth of one metre, are defined for each polygon according to Finnish soil classification system. The results generated this way are verified mainly using data on soil types obtained from soil testing of agricultural land and from forest soil surveys and with limited amount of field work. The FAO and WRB names are derived for the soils and the database will conform to the manual of ESB (European Soil Bureau, 2002). The production process has been briefly described by Talkkari and Nevalainen (2003).

MTT Agrifood Research Finland, as a member of the ESB Network, is responsible for the FAO and WRB classification and for the production of the database according to the ESB manual. Finnish Forest Research Institute also produces and makes available information on forest soils. The results of soil samples analysed for the agricultural soil mapping and forest soil inventories are used as a source of data included in the database. The agricultural dataset consists of texture determinations of some 28,000 samples and plenty of basic chemical soil data, only part of which is currently in a digital form. Some soil profiles are also analysed during the on-going project. The project was actually launched in 2002 and is planned to be completed by the end of 2008.

Soil Monitoring

Summaries of soil test results have been the most important datasets about the concentrations of macronutrients (except N), some micronutrients and the distribution of soil types in agricultural land. (e.g. Kähäri *et al.*, 1987). The data have been based on samples sent by farmers to obtain recommendations for fertiliser use. The soils are not tested annually but commonly at 5-year intervals, and the annual mean values are drawn from samples of different fields. Because at least 80,000-100,000 samples have been analysed annually, it is assumed that the mean values are, however, representative and the trends reliable.

A more systematic monitoring was started in 1974, when some 2,000 samples were collected from agricultural land all over Finland (Sippola and Tares, 1978). Samples were analysed for pH, organic carbon, calcium, lead, magnesium, nickel, phosphorus, aluminium, boron, cadmium, cobalt, chromium, copper, iron, manganese, molybdenum, sodium, strontium and zinc.

Table 1. Means of chemical characteristics of agricultural soils (n=705) in 1998 and the changes between 1974-1987 and 1987-1998

Parameter	Mean 1998	Change 1974 to 1987	Change 1987 to 1998
		%	%
Bulk Density, kg dm^{-3}	1.00	0.0 N.S.	$+4^{***}$
Org. C, %	8.3	+4 N.S.	-9^{***}
Ca, mg dm^{-3}	1,436	+0 N.S.	$+7^{**}$
K, mg dm^{-3}	111	$+10^{***}$	-2^{*}
Mg, mg dm^{-3}	202	+2 N.S.	$+7^{*}$
P, mg dm^{-3}	13.1	$+16^{***}$	$+22^{***}$
S, mg dm^{-3}	25.0	-	$+28^{***}$
Al, mg dm^{-3}	493	+4 N.S.	-1 N.S.
B, mg dm^{-3}	0.59	$+62^{***}$	-5^{*}
Cd, mg dm^{-3}	0.08	$+31^{***}$	+4 N.S.
Co, mg dm^{-3}	0.64	$+19^{***}$	-4^{**}
Cr, mg dm^{-3}	0.36	$+17^{***}$	$+7^{***}$
Cu, mg dm^{-3}	4.5	$+32^{***}$	$+15^{***}$
Fe, mg dm^{-3}	742	$+10^{***}$	$+3^{**}$
Mn, mg dm^{-3}	58	-2 N.S.	0 N.S.
Mo, mg dm^{-3}	0.06	$+27^{***}$	-12^{**}
Ni, mg dm^{-3}	0.98	-2.0 N.S.	+1 N.S.
Zn, mg dm^{-3}	3.0	-22.2^{***}	$+22^{***}$
pH (H_20)	5.8	+0.18 $units^{***}$	-0.04 $units^{***}$

t-test: * = (P>0.05); **=(P>0.01); ***=(P>0.001); N.S.=not significant

The acid ammonium acetate extraction method at pH 4.6 (Vuorinen and Mäkitie, 1955) was used to extract macronutrients (except N) and the acid ammonium acetate-EDTA method (Lakanen and Ervio, 1971) for micronutrients (except Boron) and heavy metals. Boron (B) was extracted with hot water. Sampling was repeated in 1987 on a subset of the same fields (1,320 fields, Ervio *et al.*, 1990) and in 1998 (705 fields, Mäkelä-Kurtto and Sippola, 2002).

The results of these surveys show that soil pH remains at a low level (Table 1). There were some changes attributable to the abundance of liming (Table 1). Concentration of P has increased as a result of intensive use of fertilisers, but this trend will probably not be repeated in the next survey, owing to much decreased use of P fertilisers during the last 10 years. Concentration of water extractable boron had increased from 1974 to 1987, due to general use of boron-containing NPK fertilisers, but no more in the latter period, because the concentration in the fertilisers was adjusted.

The concentration of extractable soil copper increased by 32% in 1974-1987 and some more from 1987 to 1998. This is most likely due to increased copper fertilisation, strongly advocated by the fertiliser manufacturer. The same reason applies to the increase in zinc concentration in 1987-1998. Of the harmful elements, the concentration of cadmium increased due the use of cadmium-containing raw phosphate to prepare fertilisers in some of the years in the period 1974-1987. During 1987-1998 only low-Cd fertilizers have been used, and there is no marked change in the Cd concentration of soil.

There are also other sets of spatial soil data of Finland such as those collected in the ICP Forest programme by the Finnish Forest Research Institute, Baltic Soil Survey and the FOREGS Geochemical Baseline Mapping Programme, the last two conducted by the Geological Survey of Finland. All these have been carried out only once, and, thus, they are baseline surveys at the moment.

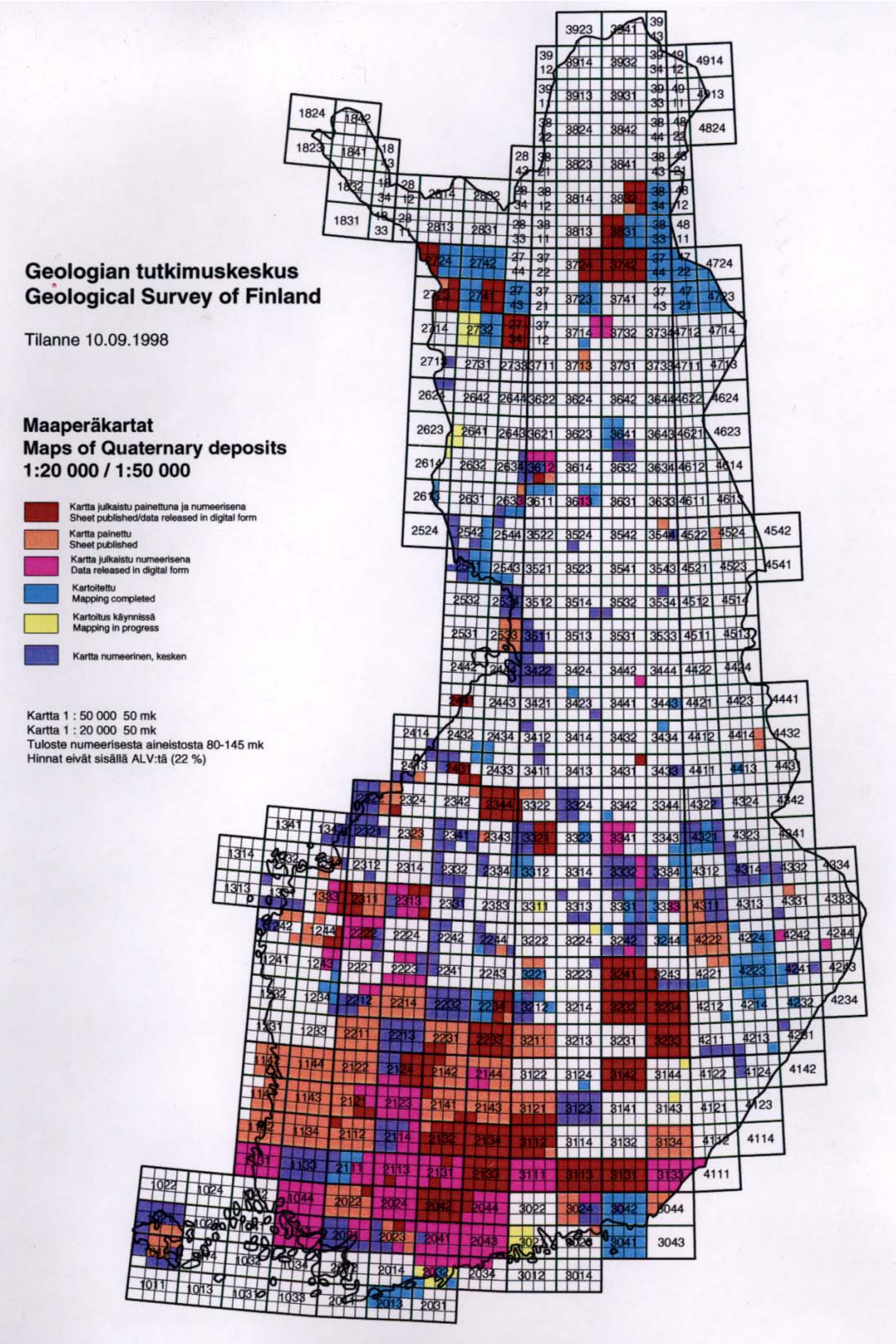

Figure 1: Maps of Quaternary Deposits in Finland

Applications of Soil Data

Land use planning by different authorities is currently the main user of soil data. Most of the current uses in Finland serve soil and water protection with soil data being combined with other environmental data such as land use, topographic and ground water information. Soil vulnerabilities to different threats have been derived by combining soil maps and information on the hydraulic conductivity of the particular soil types. This information is needed when, for example, allocating land for different industries, in land use planning in general and when approving or rejecting certain activities to be established in given areas. In these environmental assessments, soil information is used in combination with information on ground water reserves.

The area of peatlands (peat layer>30cm) in Finland is 7.2 million hectares (15% of land area). Combustion for energy is the major use of peat, and there are large power plants utilising peat in Finland. In horticulture, peat is used as a growing medium in greenhouses. Mires have been identified from maps, and further investigated for the volume of peat. Thematic maps of the peat reserves have been prepared (Lappalainen and Hänninen, 1993).

National inventories of sand and gravel resources have been made by the Geological Survey of Finland on the basis of maps of Quaternary deposits.

Erosion risk and nitrogen leaching on a catchment scale have been modelled partly on the basis of 1:100,000 and 1:20,000 soil maps (Laine and Rekolainen, 1996) in Southern Finland and erosion and leaching risk maps have been prepared. In this approach, information from soil maps is combined with topographic and land use maps. In this way, the impact of different measures (e.g. establishment of riparian buffer zones, use of reduced tillage) on water quality and nutrient loading from agriculture has been assessed (Rankinen *et al.*, 2001). Data on the different horizons of soil profiles have been used when modelling the transport of phosphorus and eroded material (Tattari *et al.*, 2001) and pesticides (Seppälä and Yli-Halla, 2001) from agricultural land. This information is needed in the development and implementation of the Agri-Environmental Support Programme under which farmers receive subsidies for carrying out measures to reduce agricultural loading of waters.

Acid sulphate soils cause acidification of coastal rivers particularly on the western coast of Finland, a problem that has been aggravated by intensified drainage. Acid sulphate soils have been identified in order to be able to assess the size of the problem and to direct the remedial measures in a cost-effective way. The potential areas of acid sulphate soils have been identified from soil maps, and the areas sampled and studied in more detail. Examples of such inventories, utilising soil maps, include those of the Kyrönjoki catchment (Erviö, 1975) and the Sirppujoki catchment (Palko *et al.*, 1985). Recently a national estimate of the area of acid sulphate soils was published (Yli-Halla *et al.*, 1999).

Agricultural uses of soil maps were important particularly in the 1940's and 1950's when new land was intensively reclaimed for agriculture. Soil surveys by the Agricultural Research Centre of Finland were started in order to identify potential agricultural land areas, thus facilitating an increase in agricultural production as the need arises. Soil information has also been used in crop suitability modelling, providing a guide to the most suitable crops for a given area. The environmental uses have almost surpassed the traditional agricultural uses of soil maps.

The summaries of soil test results have been effectively utilised by the fertilizer industry to adjust the ratios of nutrients in the compound NPK fertilizers according to the changes of phosphorus and potassium in cultivated soils. Also the level of boron has been adjusted on the basis of the trends in soil test results.

Existing soil information has been valuable in the selection of suitably representative sites for field experiments and knowledge of the properties and distribution of the soils has facilitated the uptake and application of research by the Extension Service. A range of agricultural management practices is required on the diverse soils of Finland.

Outlook

There is an increasing need for soil data for environmental impact assessment. The authorities are often faced with the fact that sufficiently detailed soil information (particularly in digital form) does not exist in the area of interest. Better supply of soil data is required also as a consequence of the EU Thematic Strategy for Soil Protection and the forthcoming Directive on Soil Monitoring.

Computerised methods for data handling and advanced techniques for preparing soil maps and databases are now available, and they can effectively be used for the production of soil databases, if sufficiently verified and supported with measured data. The recently launched project to produce a map and database of soils and quaternary deposits at scale 1:250,000, conforming to the manual of the European Soil Bureau and expected to be completed by the end of 2008, will make soil data of Finland nationally and internationally more available.

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Soil Mapping and Soil Monitoring: State of Progress and Use in France

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Introduction

The Soil Survey Staff of France was founded in 1968 within INRA (National Institute of Agronomic Research) to ensure the co-ordination of the national soil mapping and monitoring programmes in France in a mainly agricultural context. During the last ten years, environmental problems have arisen and consequently led to an increase in the need for soil information. However, at the same time, the resources allocated to these programmes have been significantly reduced (King *et al.*, 1999).

Considering this new context and the need for a good knowledge about the spatial distribution of soils, and the evolution of their properties, a new structure was created in 2001 to re-organise soil mapping and soil monitoring programmes in France. This new structure, called Scientific Group about Soils (GIS Sol) is constituted by the Ministries of Agriculture and Environment, the French Institute of Environment (IFEN), the organisation about environment protection and energy control (ADEME) and INRA. The Soil Survey Staff of France became then a single unit within INRA, the Infosol Unit, with the aim to realise the actions of the GIS Sol.

The objective of the GIS Sol is to develop an information system about the spatial distribution of French soils and the evolution of their properties. The two main priorities are the 'Regional Soil Survey' programme with the objective to have a complete coverage of France by 2010, and the development of a Soil Quality Monitoring Network.

This will be made possible with the help of some public and private organisations that are partners in these programmes: research institutes and universities, professional organisations, land development companies, etc.

The aim of this paper is to give an overview of the national soil mapping and soil monitoring programmes in France and their present state of progress.

Soil Mapping

The soil mapping programmes in France have been re-organised in a single multiscale information system called I.G.C.S. (survey, management and protection of soils). This programme can be subdivided in three main sub-programmes following the level of applications of the soil surveys:

- The 'Regional Soil Survey' (R.R.P.), the aim of which is to provide soil information for regional decision makers;
- The 'Pedological Map of France' (C.P.F.), that forms the basis for detailed research of soil spatial variability in representative areas;
- The 'Reference Area' (S.R.), the objective of which is to undertake detailed soil mapping at a local level on representative areas and for specific application purposes.

The objective of the 'Regional Soil Survey' (R.R.P.) programme is to develop geographical databases on soils that could give information about the nature, locality and properties of soils at a regional level for decision makers. This programme was launched in 1990 by the Ministry of Agriculture (Jamagne *et al.*, 1995). The geographical precision of data must support mapping at a scale of 1:250,000 (Bornand *et al.*, 1989).

Up to now, two Regions and eight Departments have been completed, and soil survey has been done in 18 Departments on which computerisation is on-going (Figure 1). Soil survey is ongoing in sixteen Departments and will begin in 2004 in another Region and three Departments.

A test of data transfer to the European system is under way in the Côte-d'Or Department in Burgundy (Finke *et al.*, 1998).

The 'Pedological Map of France' (C.P.F.) programme constitutes the first national programme of soil mapping, which led to the creation of the Soil Survey Staff of France in 1968 (Jamagne *et al.*, 1995). Its first objective was to have a complete coverage of the French territory by soil maps at a scale of 1:100,000. Considering the difficulty to fulfil such an objective, it was decided to re-orient the C.P.F. programme giving preference to the formalisation of spatial distribution patterns of soils within areas considered representative of the main French soil systems. This will be done through three main actions:

1. To store the available information, including means to computerise the existing and on-going soil maps and accompanying notes to avoid loss of knowledge;
2. To realise soil surveys of insufficiently known areas, to have a complete review of the French soil systems (King and Saby, 2001);
3. To develop scale transfer methods to be able to use the information from these areas on the areas surveyed at a broader scale.

Up-to-now, 22 maps at a scale of 1:100,000 have been published and 13 maps are being prepared (Figure 1). Computerisation is ongoing for 14 maps, and soil survey is ongoing for a further 5 maps.

In the 'Reference Area' (S.R.) programme, soil survey at very high resolution (1:5,000 to 1:10,000 scale) is performed on small areas representative of specific soil systems, for a specific application, i.e. drainage, irrigation, waste spreading, etc. (Favrot, 1987; Cam *et al.*, 2003). The detailed characterisation of the nature and the properties of soils in the reference area supports the definition of a soil typology and relative practical recommendations for soil use. The 'Regional Soil Survey' is then used to define the region where the results of the reference area can be extrapolated (Lagacherie *et al.*, 2001; Oballos and Lagacherie, 2003). It is finally an important tool for helping local people in identifying in the field the type of soil and in choosing the appropriate practice.

The Soil Geographical Database of France at a scale of 1:1,000,000, that has been revised in the framework of European projects (Jones *et al.*, 1998; Le Bas *et al.*, 1998a), constitutes the present synthesis of the knowledge about spatial variability of soils for the whole of France. When complete, the Regional Soil Survey will be used to update the Soil Geographical Database of France at 1:1,000,000 scale.

Soil Monitoring

In forested areas, a network was created more than 15 years ago, in the framework of the International Concerted Programme about impacts of atmospheric pollution on forests (ICP Forest). This monitoring programme is based on measurements realised at two levels. The first level is constituted by a 16km by 16km grid, on which soil quality measurements have been undertaken since 1994 to assess the soil chemical status and the vulnerability of the soils to air pollution (Vanmechelen *et al.*, 1997).

In France, the level I represents 540 plots covering the wide range of ecological conditions observed in French forests (Badeau *et al.,* 1999). Beyond the single description of chemical soil status required for ICP Forest, a very detailed ecological description for each plot was undertaken resulting in one of the most important datasets ever obtained in France on forest ecology.

In 102 plots of this level I network, a long-term monitoring system for forest ecosystems called RENECOFOR was created by the National Forest Office (ONF) in 1992 constituting the second level of ICP Forest in France (Ulrich, 1995). The objective of this second-level network is to determine the key factors of the functioning of forest ecosystems.

Two soil profiles are systematically studied and analysed for each plot. A set of parameters is monitored each year following a standard sampling scheme. With respect to the 'Catenal' sub-system (total acid load of atmospheric origin), atmospheric deposits have been measured in 27 parcels since

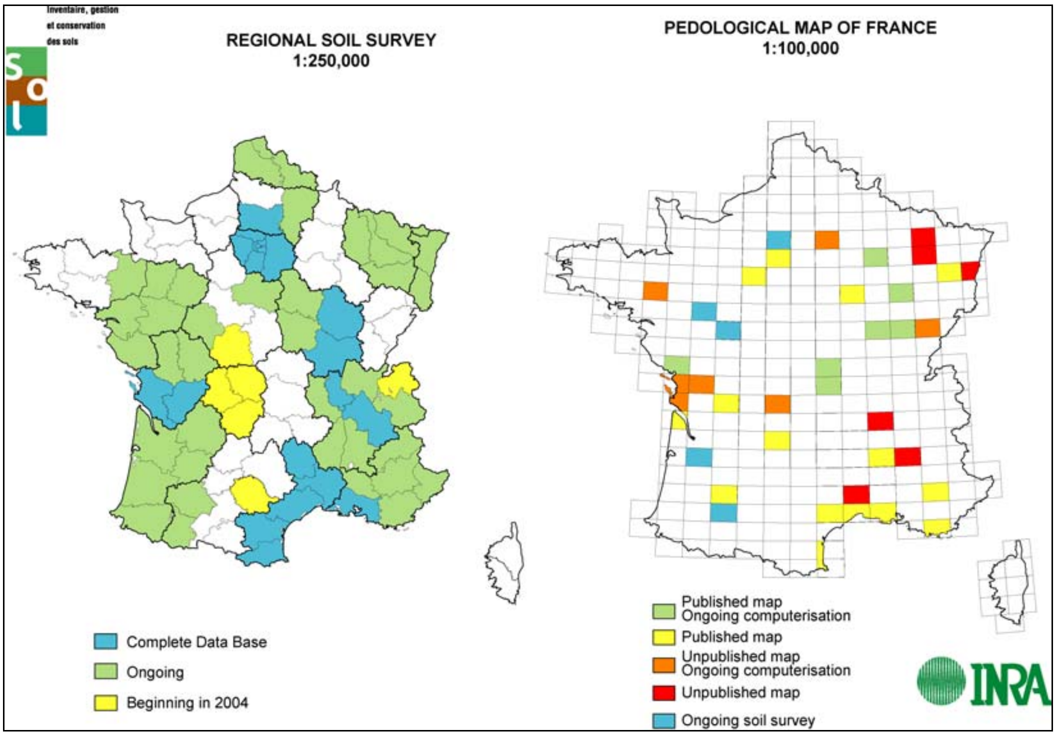

Figure 1: State of progress in 2003 of C.P.F. and R.R.P. programmes.

1993, and measurements are conducted on soil solutions taken from 20 to 70cm depth from 17 parcels. This network has shown the importance of deposits of nitrogen (from 4 to 15kg/ha/year) by rain.

In 1983, the Ministry of Environment created a 'Soil Quality Observatory' (O.Q.S.), the aims of which were to assess the present state of soils, and to monitor their changes for improvement and implementation of a soil protection policy (Martin, 1993). In spite of the important methodological contribution of this programme, its results were disappointing. An analysis by several organisations in 1998-1999 of the difficulties encountered in the O.Q.S. programme led to a proposition for a new monitoring programme.

This programme was launched in 2000 (Arrouays *et al.*, 2003) and is based on several actions:

- Development of a network of sites on which to have a spatial assessment of changes for France: the Soil Quality Monitoring Network (R.M.Q.S.);
- Creation of several research sites on which detailed studies about the processes involved could be undertaken by researchers;
- Use of soil and land use information with GIS to define models and pedotransfer functions.

A study has been undertaken to define the most representative configuration for the Soil Quality Monitoring Network (R.M.Q.S.) for a reasonable cost (Arrouays *et al.*, 2001b). A network based on a 16km by 16km grid representing 2,150 sites for non-forested areas has been chosen (Figure 2). It is a representative sampling of the main soil systems and land uses in France. This configuration has the advantage of being compatible with the ICP Forest grid. New measurements for each plot every 5 years have been foreseen. All the analyses are performed in only one laboratory from INRA.

For each site, a set of analyses (particle-size distribution, bulk density, C, N, pH, trace elements, etc.) and a complete description of the profile are performed, also with information about the past activities, the environment, etc. All the samples are stored in a specific place for conservation. New analyses can then be realised on the samples in the future.

The objective is to establish all the sites by 2007.

Soil Databases

The computerisation of the soil survey data leads to the development of a specific information system that stores, in a GIS, the spatial location of surveyed data (polygons for mapping areas, points

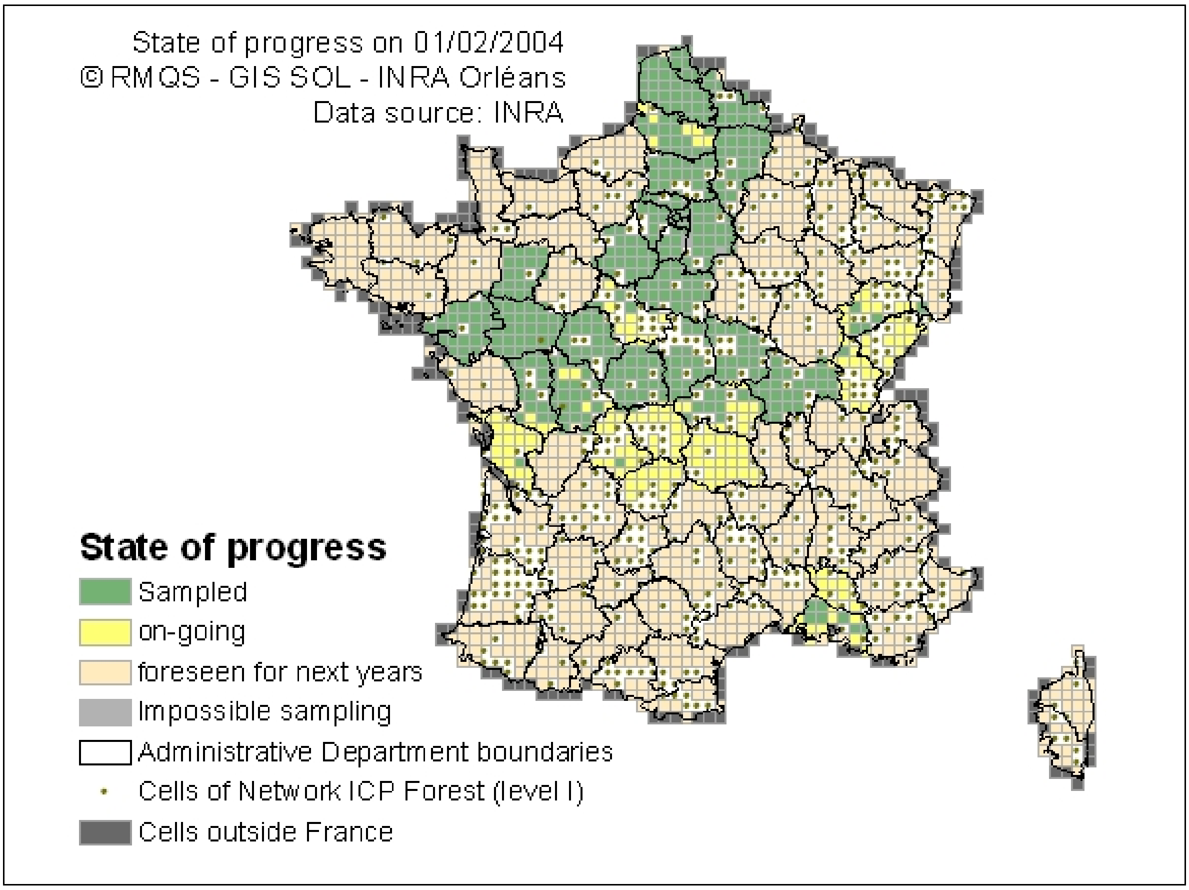

Figure 2: Location of monitoring sites of the R.M.Q.S and ICP Forest programmes.

for profile data) and in a specific database, called DONESOL, the descriptive information for soil mapping units, soil typological units and horizons, and the description and the analyses for the profiles (Gaultier *et al.*, 1993). This structure is common for all the soil surveys whatever their resolution.

DONESOL also stores information about soil studies performed on French territory (location, type of study, authors) and about the soil specialists in France (Favrot, 1994; Favrot, 1997). This information will soon be available through an Internet site that is under development.

DONESOL is presently being modified to be able to store also all the data coming from the Soil Quality Monitoring Network (R.M.Q.S.). This will maintain compatibility between the data coming from soil surveys and those coming from the monitoring programme.

Other databases have been prepared in conjunction with, or in parallel to, the DONESOL database. Generally, these databases have been compiled in the context of specific research projects. They deal with trace elements, carbon content, and water properties of soils. Their purpose is to acquire reference data about French soils to be able to estimate natural trace element contents, carbon stocks or pedotransfer functions for hydrodynamic properties.

A specific work is undertaken to store in a specific database, called the Soil Analyses Database (BDAT), the soil analyses carried out by private laboratories in France (Walter *et al.*, 1997; Schvartz *et al.*, 1998). About 250,000 analyses are realised each year, mainly for farmers.

Considering the amount of analyses and their diversity of origin, they represent a great source of information about the variability of topsoil horizons in cultivated areas both in space and time. They include some parameters that are influenced mainly by human activities like carbon content, pH, nutrient content, etc.

All the private laboratories, having an agreement with the Ministry of Agriculture were asked to deliver the results from their analyses. A first collection of data was performed for analyses realised between 1990 to 1994, and 300,000 analyses were then collected.

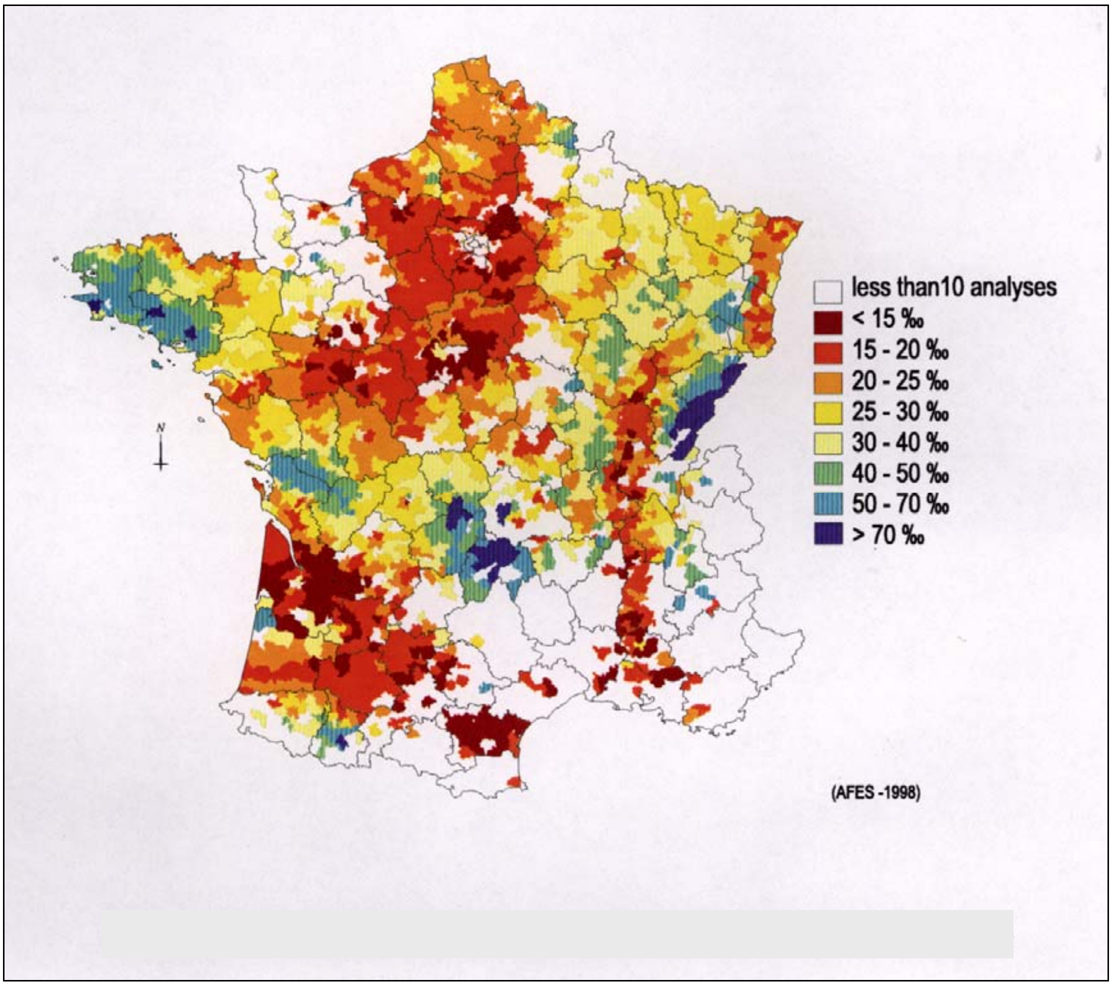

Figure 3: Organic matter content of the surface horizon in cultivated areas, extracted from the BDAT (District statistics for the period 1990-1994)

A second data collection is being undertaken now for the analyses performed between 1995 and 2000. The analyses are referenced spatially to the commune from where the sample was taken. Statistical analyses are performed at the county level. Each variable can be expressed in the form of maps or statistical tables and these documents have confirmed spatial distributions that are often known but have never been quantified, especially for variables that are difficult to determine in conventional mapping work (Figure 3).

Use of Existing Soil Data

Much effort has been directed to convince the national authorities of the importance of taking into account soils for many purposes. This led to the creation of the GIS Sol that gives a boost to soil survey and to soil monitoring activities in France. However, for many of these activities, and particularly for soil survey, national funding is not sufficient and other sources of financial support have to be found (regional authorities, professional organisations, etc.). One way to convince these organisations to finance these activities is to demonstrate how soil data can be used.

At the national level, the Soil Geographical Database of France, at 1:1,000,000 scale, represents the only source of data that covers the whole country. In spite of its low resolution, this database has been used for many purposes such as erosion risk assessment - see Figure 4 – (Le Bissonnais *et al.*, 2002), assessment of grassland production (Donet *et al.*, 2001) and estimation of carbon stocks in soils (Arrouays *et al.*, 2001a).

At the regional or local level, many applications are undertaken. A recent study was realised asking the regional soil surveyors about the request for soil data for which they were responsible. The first results of this study show that the applications are mainly for agricultural or agri-environmental purposes: crop production, irrigation management (Cousin *et al.*, 1998), risk of nitrate or pesticide leaching (Saby *et al.*, 1999), erosion risk assessment, fertilising with urban composts (Legros *et al.*, 1991), etc., and are increasing from year to year. There is also an increasing diversity of users but generally with a lack of ability to use soil data directly.

For 80% of the demands, users ask to have thematic data. A great effort is being undertaken to develop tools that can help soil data users. One important research field in that domain concerns pedotransfer functions that allow estimation of non-available information from soil survey data, particularly for deriving input soil variables to models (Donet *et al.*, 2001; Bruand *et al.*, 2003). Work is also undertaken to give information to users about uncertainties, especially with the development of methods using geostatistics, fuzzy logic, etc. (Lagacherie *et al.*, 1997; Le Bas *et al.*, 1998b; Cazemier *et al.*, 2001).

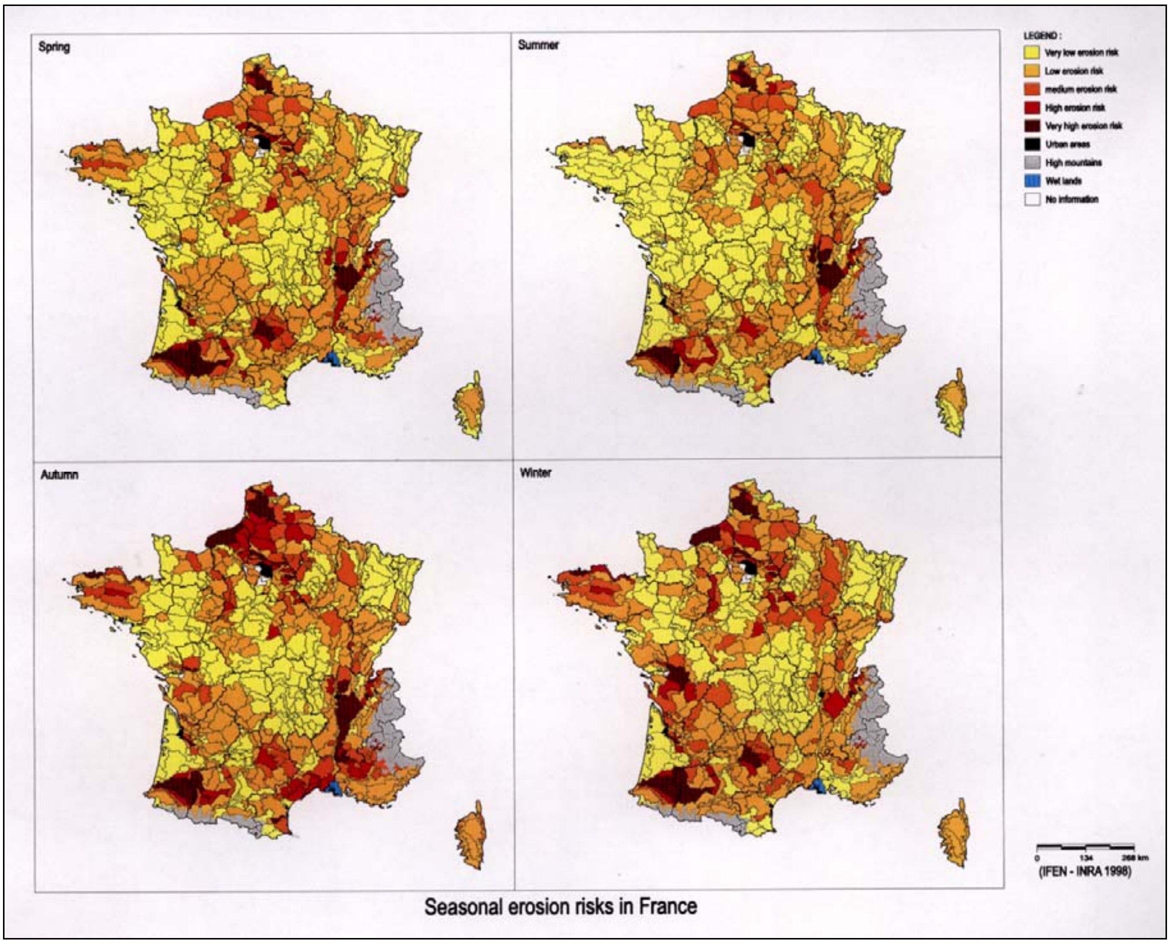

Figure 4: Maps of seasonal erosion risk in France.

Perspectives

Regional soil survey is continuing in order to obtain exhaustive and integrated information for the whole France. The scale of 1:250,000 is appropriate to answer users' needs at national or regional level. However, such a scale is insufficient to respond to all kinds of demands that are highly varied and require greater precision. To respond to this demand for precise information, considerable resources are needed, but at this time, no national plan is foreseen to allocate the necessary resources. It is thus necessary to develop tools that could help detailed soil survey or that could fill in the gaps.

One way was proposed through the new orientation of the C.P.F. programme, which aims to develop a knowledge base about representative soil systems and their functioning, and scale transfer methods that enable local organisations to apply this knowledge to their area of interest. Another way, mainly to answer to the increasing needs for detailed soil surveys at the level of agricultural plots, is to develop the use of new techniques like spatial positioning and its use with appropriate agricultural techniques (precision farming), geophysics and digital elevation models (Chaplot, *et al.*, 2001; Bourennane and King, 2003; Michot, *et al.*, 2003).

Concerning soil monitoring, the creation of the R.M.Q.S. network is an efficient tool that could give information about the status of soil quality and its evolution. But, monitoring needs to have several measurements at the same place but at different time steps. For the moment, only one series of measurements has been done. It is thus necessary to have the resources to undertake new series of measurements for the R.M.Q.S. sites and also for forest sites. These two networks will give an overview of the evolution of soil quality but will not give information on the processes involved in such evolution.

It is thus necessary to extend research on specific sites for analysing specific processes. In this context, a research programme (GESSOL) whose aim is to establish the scientific tools and bases to assess, monitor and even restore soil quality, was launched by the Ministry of Environment. First results were presented in 2002 (AFES, 2003) and a new programme was launched in 2004 in order to estimate better the impacts of agricultural practices on soil and water qualities.

Finally, it is recognised that all current or future programmes will be of interest only if the data gathered are distributed as widely as possible and in the most instructive manner possible. This implies the continuation of research in the field of combining spatial data and in that of error propagation when different data sets are combined. In addition, there is a need to develop methods for structuring and distributing information, in particular using modern computer technologies (Web, CD-ROM). It is also necessary to obtain more information on user needs in order to develop the tools that can most efficiently respond to these needs.

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Soil Information for Germany: the 2004 Position

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Introduction

The first country report on the status of soil information in Germany was prepared by Oelkers (1991), operating as the head of one of the 16 federal state soil surveys of Germany. A national geological authority was in place, but not active for soil information within Germany.

Starting 1991, the Federal Institute for Geosciences and Natural Resources (Bundesanstalt für Geowissenschaften und Rohstoffe, BGR) in Hannover established the first elements of a German soil information system (Vinken, 1992). Eckelmann and Hartwich (1996) reported on ‘Soil Mapping in Germany and the FISBo BGR Soil Information System’ as part of a documentation of the status of soil surveying in Europe.

As outcome of a workshop on ‘Land information Systems’ in Europe, held at BGR 1996, a very detailed view on soil information systems developments for planning the sustainable use of land resources in Europe was published (Heineke *et al.* 1998). Later Eckelmann (1999) reported on the state of soil survey in Germany in European context.

Background

This report presents the ongoing activities of BGR on soil information, against the background of discussions on soil protection at political and societal levels in Germany and the EU that has led to an increased demand for pedological information.

At national level, the first German *Act On Soil Protection* (BGBl. I, 1998) was put in force on March 1, 1999. As a result, availability and quality of data related to soil have become priorities at national and individual state levels in Germany.

At European level, the European Commission adopted a proposal for a new environmental strategy 'Environment 2010: Our Future, Our Choice'. Amongst other areas, the proposal stressed the importance of soils due to nature and biodiversity. Succeeding this strategic frame and according to the needs that soil protection has to be built on sound information and assessment, the official Communication ‘Towards a Thematic Strategy for Soil Protection’, from the Commission to the Council and to the European Parliament, was published in April 2002.

This document came to the conclusion that available data on soil are not sufficient with regard to significance, accuracy and comparability and do not allow detection of trends and changes in the threats to soils.

BGR Soil Information System: Objectives and Structure

Against this political background, BGR has continued to structure and complete its soil information system FISBo BGR. Because in Germany soil surveying is influenced by the federal character of the republic, the cooperation between the soil surveys of the component states of Germany has high priority for all national work. A working group consisting of the heads of each state soil survey, and of the national soil survey of the Federal Institute for Geosciences and Natural Resources (BGR), coordinates most of the pedological work, with the main object to publish the new soil mapping guide KA5 and to publish a German wide coherent soil map at scale 1:200,000. The chair of this working group is presently at BGR.

As soil protection at national level in Germany is coordinated by the Environmental Agency UBA at Berlin, many of BGR activities are influenced by the needs of this institute. This is why BGR and UBA are continuously coordinating their work in the relevant areas of interest (Eckelmann and Glante 1999).

The German soil information system FISBo BGR is one of a number of linked geoinformation systems, e.g. geology, soils, hydrology. Together they form a geoinformation network, which enables broad interdisciplinary evaluation of different topics. The principles of the BGR Soil Information System, in its early stage and relations to other systems, have been described by Eckelmann *et al.,* (1995) and Eckelmann (1996). FISBo BGR's detailed objectives are to:

- Extend and provide a database of soil information in cooperation with the German federal states according to the needs of politics at national and EU level, of research areas and for data users e. g. from agriculture and all other affected disciplines;
- Analyse this database to answer requests for information from the federal government (e.g. for preparing presentations of the current situation);
- Make possible the compilation of basic and thematic maps for prognosis and for drafting guidelines at administrative level;
- Provide a basis for answering questions submitted by European Union agencies or international bodies;
- Provide a basis for cooperation with other research institutions (e.g. for nationwide analyses).

The following main structural components are being developed at BGR continuously, analogous to the information systems of the individual German states:

- Spatial database that maintains a number of already existing soil and related maps including the geometric-topographical data;
- Soil profile and laboratory database that contains both the observations of soil surveys as well as the results of all soil chemical and physical analyses;
- Method database that defines the data processing techniques (e. g. for determining groundwater recharge, water retention and filter functions, soil productivity) underpinning interpretation of soil maps and the relevant principal and supplementary data.

With respect to increasing cooperation with organisations of the European Union, these structure components become more and more adjusted to those of the European Union level. This demonstrates above all the need for compatible data field registers, data sets and methods.

Soil Mapping Methods

The methods on how to prepare soil maps at different scales are documented in the 4th edition of the German Soil Mapping Guide KA 4 (Arbeitsgruppe Bodenkunde, 1995). This guideline includes the German soil taxonomy and also the data keys, symbols and all parameters used in soil mapping and site description. Together with the definition of the principles of the soil information system (Heineke *et al.,* 1995), these data keys are assigned to data fields to be used in digital management.

From its tradition, the German Soil Mapping Guide KA 4 deals only with the German Soil Taxonomy. There are no links to international soil taxonomies, e.g. to the FAO soil names (FAO, 1990; FAO-UNESCO, 1990) or to the WRB-Classification (FAO, ISRIC and ISSS, 1998). However, these links have become more important in the last years, particularly at the European Union level. Consequently, BGR and the German state soil surveys revised the version KA 4 and integrated the WRB-Classification into the German Soil Mapping Guide, KA 5, which is presently in the final stage of preparation.

There are also other guidelines existing in Germany for special soil mapping, e.g. mapping of forest sites, as already mentioned by Oelkers (1991). Soil maps compiled by using these special mapping guides are integrated into the geological survey's soil mapping activities as far as it is possible. Naturally this requires transformation of all available data into the standard form as given in the Geological Survey's German Soil Mapping Guide.

Progress in Soil Mapping

Zitzmann (1994) documented soil maps existing in Germany. The information that he obtained, showing the availability of 1:25,000 to 1:200,000 soil maps, emphasised the problem of incomplete coverage. Besides these scales, several state geological surveys published soil maps at scales of 1:5,000 and 1:10,000, but actually, soil mapping in detail is at very low levels due to reduced staff and budget at many institutes.

Following the interest to have available soil information of the whole of Germany, many state soil surveys published soil maps at scales from 1:300,000 to 1:500,000. Although these activities could improve soil information, the availability of soil maps at identical scales and quality is still unsatisfactory with respect to national requirements.

To solve this problem, the individual state soil surveys and the national soil survey of BGR agreed on a programme to compile and publish a joint 1:200,000 Soil Map of Germany. The Production of this map is coordinated by BGR and the status is described below.

In addition to this scale, the spatial database established at the FISBo BGR needs to hold soil maps in order to fulfil its duty for the federal government as well as for cooperation with the European Union. These maps for national and international needs, and representing the digital soil geographical databases, include (Behrens *et al.*, 1998):

- Digital Cartographical Database of Europe (EURODB) to serve as the basic map;
- 1:200,000 soil map as the joint base map to be compiled jointly with the individual state soil surveys;
- 1:1,000,000 Soil Map of Germany as the most important geographical database for national requirements (Hartwich *et al.*, 1995);
- 1:1,000,000 EU Soil Map, representing the German part of the Soil Geographical Database of Europe at a scale of 1:1,000,000;
- Soil Regions map at a scale of 1:1,000,000 to show landscape relations and to give an overall view of soil information;
- 1:2,000,000 Soil Map, representing a part of the Hydrological Atlas of Germany;
- Soil Regions Map of Europe at scale 1:5,000,000, which has been drawn up in cooperation with the European Soil Bureau.

The main objective in soil mapping nationwide is at least to compile and have available *a nested system* of soil maps at different scales, which can be used for a wide range of applications, for all cooperation between the federal state, the national level and the EU.

To enable interpretation, e.g., to derive land suitability information, it was necessary to include non-soil data into the spatial database of FISBo BGR. The most important was a digital elevation of this model, which is available on a 50-meter grid, as well as climate and land use information at various scales and projections.

Although these data are processed in the BGR FISBo system, they remain part of other, linked information systems, e.g., geomorphology and climate, which are maintained and updated by their respective owners. Together, these various systems form a geoinformation network that permits broad interdisciplinary evaluation of data for different purposes.

The 1:200,000 soil map

In order to coordinate the production of a 1:200,000 soil map for Germany, BGR and the sixteen state soil surveys have produced a 1:200,000 scale mapping Manual including the following elements:

- Guidelines for soil map units and soil profile descriptions including flow charts showing all steps to be taken by the state soil surveys of Germany as well as those taken by BGR;
- Data sheets with 42 data fields for data collection related to the soil units of the 1:200,000 soil maps;
- Rules for amalgamating soil survey maps to other scales;
- General legend for the standardised 1:200,000 soil map;
- Soil Regions Map of Germany at a scale of 1:1,000,000.

A system of landscape relations has been defined for Germany to ensure that the soil surveys describe similar soil units for the 1:200,000 soil map in a comparable way. This hierarchical system classifies landscapes according to geology, morphology, climate, and vegetation.

Areas with generally similar geology and morphology are defined, and within these areas climate, water regime and relief show only limited variation.

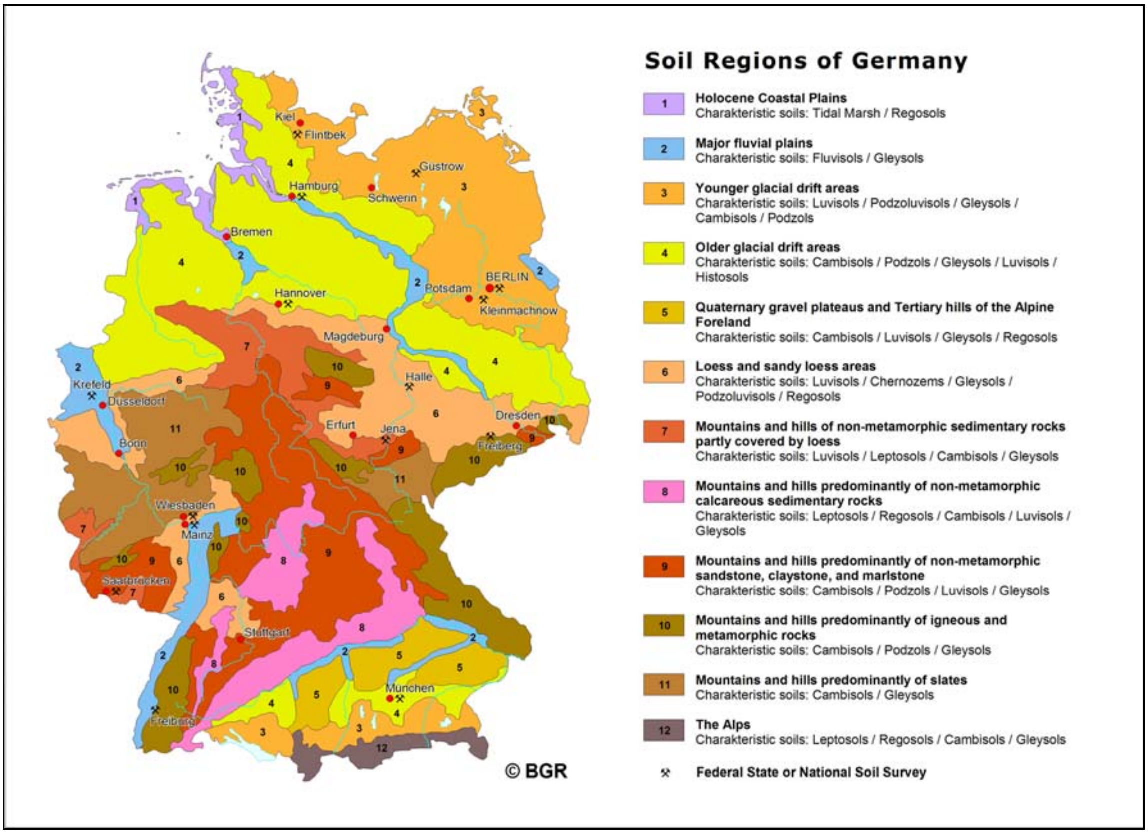

Figure 1: Soil regions of Germany; locations of Soil Survey Institute

Parent material and soil genesis in such an area also vary little, and this in turn permits dominant soil types to be defined for each area. Such an area is called 'Bodenlandschaft' or 'soil landscape'.

On a higher hierarchical level, several soil landscapes are united to form a 'Bodengroßlandschaft' or 'Soilscape' (after Dudal *et al.*, 1993), and several of these form a 'Bodenregion' or 'Soil Region', of which there are twelve in Germany (Figure 1).

When drafting the 1:200,000 soil map, soil scientists pay attention to ensuring that similar soil landscapes have similar soil inventories, or the soil landscape boundaries would need to be changed. Using this procedure, it will be possible to produce consistent 1:200,000 soil maps in cooperation with the state soil surveys of Germany.

The production of the 1:200,000 scale soil map, coordinated by BGR, has until today led to fifteen printed maps. The overview in Figure 2 shows the status and planned procedure for publishing during 2004. In addition to this printed version, a 1:200,000 Soil Database is continuously built, containing harmonised soil information for all relevant and representative soil profiles of each soil map unit. At least, these data collection will form a single common database for all German soil maps at that scale. This procedure will eventually enable translation of this soil information to the WRB standard. The WRB standard, as it is described by the 1:250,000 European Union Soil Map Manual (ESB, 1998), is the EU wide accepted taxonomy.

The 1:1,000,000 soil map

Until the soil map at scale 1:200,000 is available for the whole of Germany, the digital 1:1,000,000 Soil Map of Germany is the most important part of the spatial database and is integrated in the FISBo BGR Soil Information System, available to science, administration and industry.

In addition to the characteristic soil profiles ('Leitprofile'), thematic maps dealing with nationwide problems of soil use and soil protection have been derived. The 1:1,000,000 scale makes the soil map especially suitable for evaluating problems at both national and European Union level.

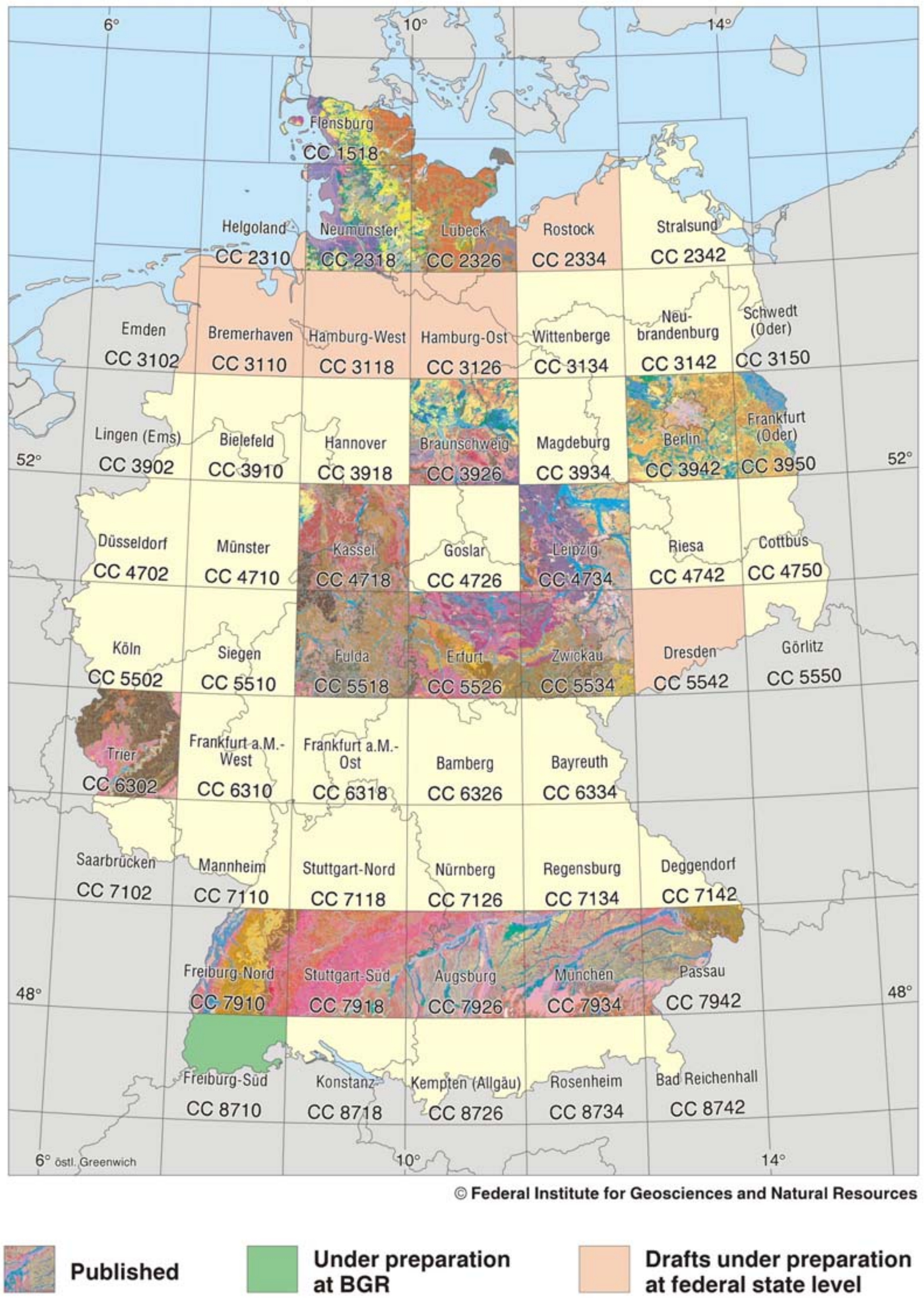

Figure 2: Status and programme of soil mapping at 1:200,000 scale in Germany

In the course of preparation of thematic maps, the needs of some users made it necessary to improve and complete the 1:1,000,000 spatial database with more precise information with respect to land cover. This work is presently being done using the CORINE Land Cover data set. The first step, elaborated in close cooperation with the forest agencies in Germany, is almost ready for the

forestry land use type. It has led to changes in the description of the variability of all soil map units.
Other improvements have been made using geomorphological and climatological information, so that the 1:1,000,000 spatial database will be at least an optimised solution for the coming years.

Soil Profile and Laboratory Database

The soil profile and laboratory database of the FISBo BGR is organised as a relational database. It stores all soil attribute data extracted from point observations of fully described and analysed reference profiles in sets of tables for later retrieval. Links between the tables are maintained through primary keys. Based on the standard software (i.e. MS SQL Server), soil and other components (e.g. vegetation) may readily be added to or removed from the database as required. Depending on regional or national needs, the soil database may be set up according to various soil classification systems. In addition to the German system, the WRB classification (FAO, ISRIC and ISSS, 1998) and the FAO soil classification system have been included so far. The latter has been done in order to cater specifically for international cooperation. Similarly, a soil database was developed according to the U.S. Soil Taxonomy (widely used in Asia and the Americas).

In a further step towards harmonisation of global soil information (Van Engelen and Wen, 1995), BGR also adopted the terminology and components of the Multilingual Soil Database (SDBm Plus; FAO and CSIC, 2002) for its FAO soil database version.

One essential purpose of the harmonised, site-specific soil data is to develop representative soil profiles for small scale soil maps for making spatial interpretations on various themes. Additionally, this soil profile and laboratory database can be used to create pedotransfer functions, which relate different soil properties to one another or to soil texture (Bouma and Van Lanen, 1987). The pedotransfer functions are essential for creating standardised data sets from inhomogeneous data.

With reference to the Federal Soil Protection Act (BBodSchG) (BGBl. I., 1998) and to the associated ordinance (BBodSchV) (BGBl. I., 1999) it is necessary to improve information on soil threats in Germany. The Federal States continuously give support to the BGR soil profile and laboratory database with additional data from their state level. Such cooperation is a welcome procedure, enabling BGR to answer questions at the national level.

In order to reach comparable soil data all over Germany, the individual state soil surveys and BGR have agreed to common 'Guidelines for Taking Soil Samples' (Ad-hoc-AG Boden, 1996). The 'Documentation of Laboratory Methodes' (Ad-hoc-AG Boden, 2000.b) aims at harmonising analytical methods. The methods database itself is designed so that it can easily be updated and further methods and information can be added.

Contents and Use of a Method Database

Processing of pedological data, e.g. to make interpretations of soil maps on various themes or to analyse specific topics, requires not only the availability of the necessary data within an efficient information system, but also well defined methods to be applied from a digital method database. The method database contains algorithms to derive land qualities from pedological base data (e.g. maps).

The methods themselves consist of pedotransfer functions (in modular form). These pedotransfer functions, once established as reliable and accurate, permit key parameters (relationships) to be calculated, thus, greatly simplifying the data required in modelling (Wagenet *et al.*, 1991). Furthermore, the methods collected in such a method database must be programmed according to a single system so that they can be used by both BGR and the German state soil surveys.

An up-to-date documentation of a large number of methods has been published (Ad-hoc-AG Boden 2000.a), based on a first documentation of Hennings (1994). This set of methods was prepared by a joint working group of the soil surveys of the German individual states and the BGR, set up to study various methods for processing basic pedological data, to assess these methods, and to compile suitable documentation.

The methods are restricted to calculating specific soil properties, parameters or functions and determining the vulnerability of the soil to specific hazards:

- Potential susceptibility to compaction;
- Retention capacity for heavy metals;

- Vulnerability to erosion by water;
- Groundwater recharge;
- Nitrate retention capacity;
- Potential agricultural yield;
- Vulnerability to erosion by wind;
- Vulnerability of forest soils to acidification.

All of the methods in the method database are deterministic models based on simple empirical relationships. Sometimes these models considerably simplify the physical and chemical processes concerned and provide only an approximate estimate of the parameter of interest. Information about the kind of input data needed, the appropriate scale, and whether the result is qualitative or quantitative is given for each method, so that the different methods available in the method database for the same applicable parameters can be compared.

To give easy access to updated versions of the method documentation and to new documented methods, BGR and the Ad-hoc-AG Boden developed a download area on the web: http://www.bgr.de/saf_boden/SAF/index.html.

Example: annual water percolation rate

A key parameter which needs to be determined for putting into effect the EU Water Directive is the average annual water percolation rate from the soil. This primarily reflects the soil water regime and is preferentially determined using methods from soil science. In addition to its quantitative significance for groundwater-sourced drinking water supplies, water percolation is a crucial factor in the movement and leaching of nutrients and toxins. The water percolation rate is therefore a critical input parameter for qualitative aspects of water protection in particular.

Determining the water percolation rate requires information on soil properties, climatic data, and the current type of land use. The determination of long term averages in the past was based on the gradual development of simple empirical equations. The disadvantage was that they were all only valid for a limited spectrum of field conditions or could only provide sufficiently accurate results for certain parts of Germany.

To improve the situation, BGR launched a research project with the aim of removing the weaknesses in the previous method and developing a new alternative method applicable to the whole of Germany. To this end, model calculations were conducted with a water regime model for a number of locations with different soil and climatic conditions. The results of all the scenarios were evaluated using multiple regression analysis to derive new regression equations enabling the reliable estimation of water percolation rates in the soil for the whole of Germany.

The results of the new method were tested on long term regional drainage data from selected catchment areas of different size, land use, soil properties and geomorphological and climatic conditions. The good correlation between the measured and the calculated values revealed that the new expressions matched the requirement for a method valid for the whole of Germany.

The new method was used for the first time for a nationwide thematic map on soil protection in a map of annual average percolation rate from the soil at a scale of 1:2,000,000 incorporated in the new Hydrological Atlas of Germany (HAD; BMU 2000).

Use of the Soil Information System

The various soil information systems are used to advise the German Federal Government and the individual state governments on the needs of the German Soil Protection Act. This requires close cooperation with the environmental agencies of the individual states and the German Government. The information systems are applied to develop pedotransfer functions and varyingly complex methods for evaluating soil data.

As an example the FISBo BGR serves for the determination of spatially representative background values for topsoils, subsoils and bedrock. A concept was developed and applied that is based on a differentiation of background values according to soil parent material as a first priority. In topsoils the background values are distinguished in second order by the reference parameters land use and regional settlement structure. In the subsoils from solid rocks they are further differentiated according to their loess content. For soils from unconsolidated deposits the effect of pedogenetic processes (enrichment, impoverishment) are considered. The determination of background values for bedrocks requires no further differentiation (Utermann *et al.*, 1998; Utermann *et al.*; 2003; LABO, 2003).

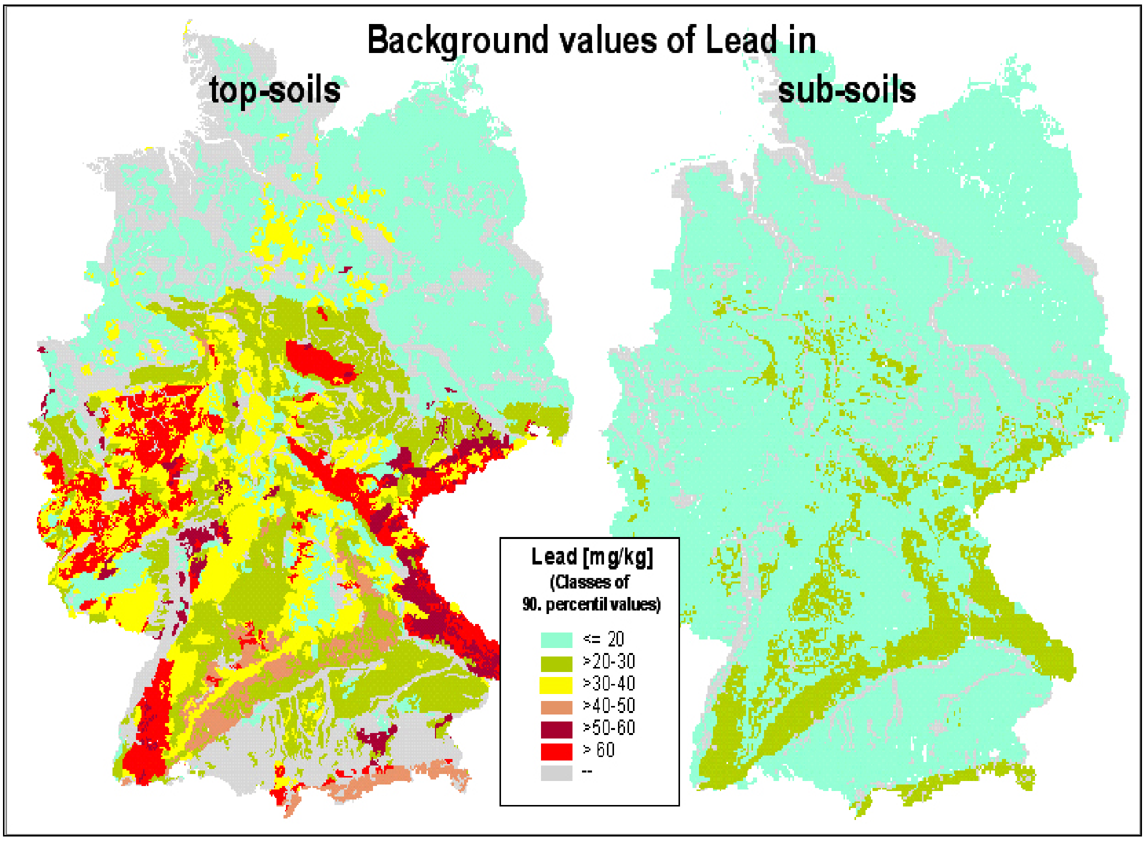

Figure 3: Background values of lead in German top soils and subsoils

Site specific soil data were brought together from different sources (soil data from Federal institutions and institutions of the Federal States) taking into account minimum requirements and aspects of data harmonisation. Spatial information is given by the small scale (1:1,000,000) digital map of soil parent materials (MPM 1,000) which is based on the 1:1,000,000 Soil Map.

Based on information from about 5,000 soil profiles representative background values for topsoils, subsoils and bedrocks could be determined for the dominating groups of soil parent material in Germany with a current spatial coverage of about 90% (see for examle background values of lead in top soils and subsoils in Figure 3).

Another example of a current application of the FISBo BGR is the compilation of spatial information on soil texture and organic matter in German soils. In the case of soil texture, data are related to soil landscape units composed of the soil map of Germany. For soil organic matter additional climate regions and main types of land use are taken into account.

The structure of the FISBo BGR is to be developed further for example for the special needs of developing countries. It will then be possible for data from technical cooperation projects to be processed in the project area as well as in BGR and be used in a global soil information database. It will also be a basis for cooperation with other institutes at global level and particularly with the European Union against the background of the ongoing Soil Thematic Strategy.

BGR contribution to the new hydrological atlas of Germany

BGR has contributed several maps at a scale of 1:2,000,000 to the Hydrological Atlas of Germany, published by the Federal Ministry of the Environment (BMU 2000). This new atlas provides up-to-date information, presenting basic and aggregated data, as well as giving an insight into the scientific methods used.

The first BGR Contribution was the Soil Map, prepared from the existing 1:1,000,000 Soil Map

of Germany (BÜK 1000), showing the soil associations in Germany in 60 map units.
The following thematic maps on soil water were also submitted in 2000: (a) Depth of the effective rooting zone; (b) Field capacity down to a depth of 1m; (c) Available field capacity in the effective rooting zone; and (d) Air capacity in the effective rooting zone.

The CORINE land cover of the Federal Statistics Office, a digital landuse information set derived from satellite data, from which mainly the areas of agricultural and forestry land use were taken, was intersected with the 1:1,000,000 soil map to prepare the cartographic base map for the soil water maps. The values for the soil water parameters were derived from soil texture, bulk density, and humus content and subdivided into five classes.

The soil water parameters provide basic information about the capacity of the soil to retain water, the rate of drainage, and the plant availability of the soil water. Together with climate data, conclusions can be drawn about the suitability of a site for a specific crop or the risk of lowered yield during dry periods.

The sixth contribution to the new atlas was a map of annual average percolation rate from the soil as mentioned above.

This atlas makes it possible for the scientists, those involved in water management, politicians and lay persons interested in the environment to quickly recognize large-scale relationships and to access sources of further information. The maps can be used at the state, federal, and EU levels, providing valuable information in the fields of water and environmental protection.

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Soil Survey in Greece

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Introduction

Soil survey in Greece was initiated in the 1930s. Over the ensuing years it has followed several stages of development. Programmes have been interrupted several times and restarted by different agencies, such that there has never been a continuous programme likely to result in the complete mapping of the country. Soil classification and mapping designation schemes have varied. Classification schemes used have included the Russian system (Glinka, 1927), the 1938 USA system (Thorp and Baldwin, 1938), the French system (Aubert and Duchaufour, 1956), Soil Taxonomy (Soil Survey Staff, 1975, 1999) and the FAO system (FAO/UNESCO, 1990).

Currently, soil mapping is carried out by the National Agricultural Research Foundation (NAGREF) of Greece and Universities, at a number of different scales. Soil maps at reconnaissance scale have been produced for various parts of the country, mainly to provide a scientific basis for agricultural development at a regional scale. A series of maps at a detailed scale has been produced by the Soil Reclamation Service in cooperation with the Soil Laboratories of the Ministry of Agriculture. These maps were mainly of arable bottomlands and the units were adapted to provide information suitable for drainage and irrigation advice. The Forest Service has undertaken land mapping of the hilly and mountainous areas of the country at a 1:50,000 scale. Such maps are used to plan the sustainable development of non-agricultural lands. The Forestry Land Map at 1:50,000 scale has been completed for the whole of Greece. The map sheets are available to the public and digitization is almost complete.

Summaries of the mapping progress for the period to 1989 are to be found in Aggelides and Theocharopoulos (1991) and for the period to 1994 in Yassoglou (1996). Progress in the last fifteen years (to 2003) is described below.

Present Status of Soil Mapping

Small scale mapping

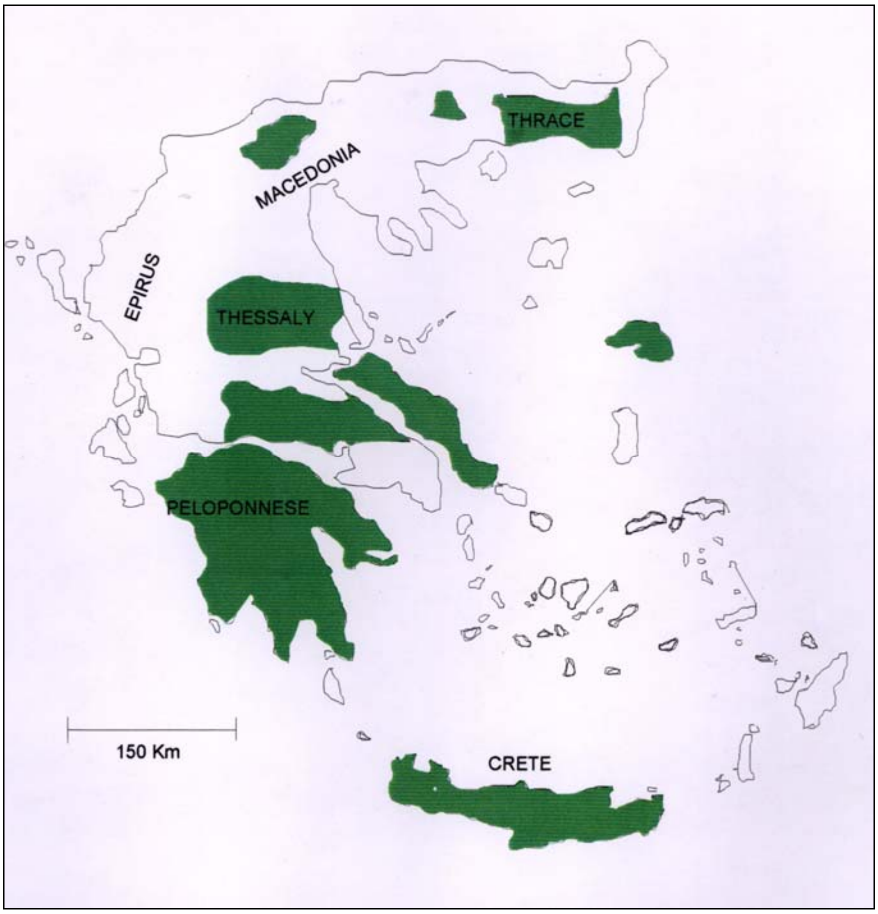
A soil association map at 1:500,000 scale has been prepared for the whole country. Its mapping units have been designated on the basis of geology, geomorphology, physiography, vegetation zone and land cover. An algorithm was developed for overlaying the parameters (Yassoglou and Kollias, 1989). The map was checked and corrected in the field. A 1:1,000,000 map, prepared by uniting similar units from the 1:500,000 map, has been incorporated in the European Soil Bureau Database.

Reconnaissance and semi-detailed mapping

The areas mapped at semi-detailed and reconnaissance scales (1:50,000 to 1:300,000) amount to roughly 4 million hectares or about 31% of the total country. Much work is required to bring them to currently acceptable standards because of the different methodologies and classification systems used over the years. The number of profiles analysed is not exactly known but is estimated to amount to a few hundred. Figure 1 shows the areas within which this type of soil mapping has been conducted.

Land mapping

The Greek Forest Service has conducted land mapping based on the site parameters: geology, physiography, vegetation, degree of human interference, soil depth, soil erosion, aspect and slope. The mapping units are defined parametrically and drawn on to 1:50,000 maps using parametric overlaying (Nakos, 1983). Each map is checked and corrected in the field.



[since this map was produced, soil surveys have been made of: the Middle part of Chios (Xios), at 1:50,000 scale; most of the islands of Samos and Limnos; part of Epirus; West Central Greece; and some other areas]

Figure 1: Areas within which reconnaissance soil surveys have been conducted.

In the course of the mapping programme, more than 2,000 profiles have been described, sampled, analysed and classified according to the Soil Taxonomy and FAO systems. These data are now stored in computerised databases.

The total area mapped is estimated to be more than 10 million hectares, almost 100 percent of the hilly and mountainous lands and 75% of the total area of the country. Land mapping is not strictly soil mapping but it is a useful reference for the construction of soil maps in the hilly and mountainous areas of the country. The land maps are valuable for developing sustainable land use schemes in the uplands.

Detailed soil mapping

Detailed soil mapping has so far been confined to low lying agricultural lands and the surrounding hills. The field sheets on which the soil boundaries are originally drawn are at scales ranging from 1:5,000 to 1:15,000. The published map scales range from 1:5,000 to 1:20,000. Some of these maps have been digitised.

The soils are grouped into taxonomic units according to a combined taxonomic and parametric system. They are first classified to the level of Great Soil Group according to Soil Taxonomy (Soil Survey Staff, 1975 and subsequent modifications, e.g.) and then further subdivided according to a number of soil parameters. The parameters used are those that play key roles in the performance and management of the soil, such as landscape characteristics, drainage, texture of each soil horizon or of soil depth increments (0-25cm, 25-75, 75-150cm), slope, evidence of erosion, abundance of carbonates, and specific limitations which, if present, strongly affect soil performance. The symbol of the mapping unit includes coded taxonomic, soil and landscape notations.

The map is drawn in the field by the soil surveyor on an aerial photograph or on a large-scale topographic map. Profiles are sampled and analysed and stored in databases.

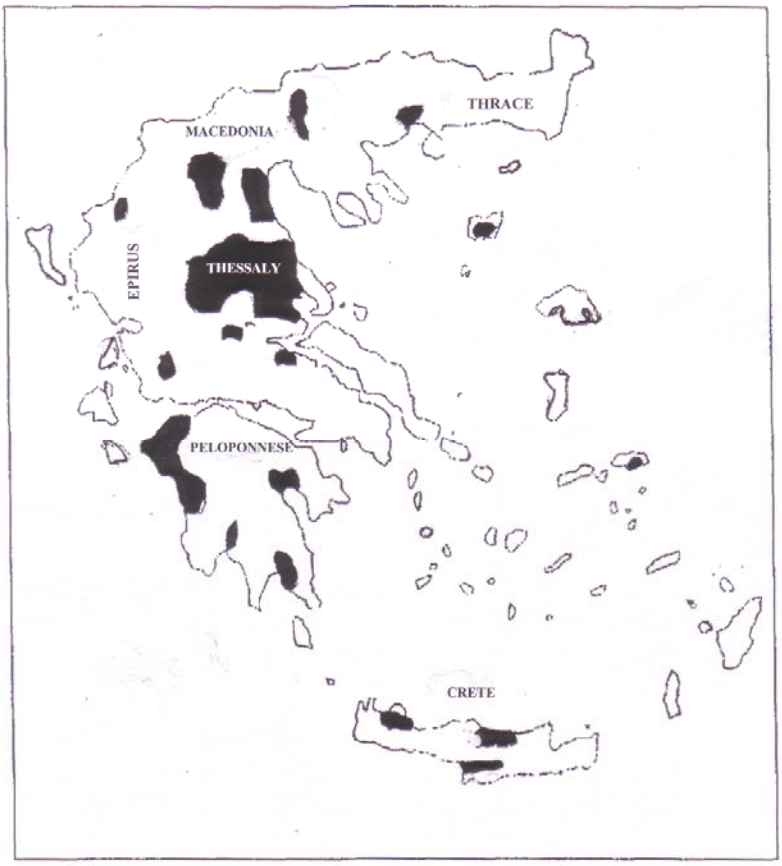


Figure 2: Areas within which detailed soil surveys have been conducted.

The area mapped in detail covers approximately 780,000 hectares, corresponding to about 39 percent of the high quality agricultural land and 6.0 percent of the whole country. The areas mapped according to standard soil survey procedures are located within the boundaries sketched in Figure 2. There are also many small areas in Central Greece and in the Central Peloponnese, where detailed soil surveys projects have been completed by NAGREF but are too small to show on Figure 2.

Several non-standardised soil surveys, with scope limited to the needs of irrigation projects, cover about 2 million hectares of the agricultural lands. The mapping units of these surveys do not meet the standard requirements, the data collected are incomplete and they have not been recorded in electronic databases. However, they could provide some valuable information. This type of mapping has now been replaced by standard soil surveys.

The rate of detailed mapping has slowed in recent years because of a lack of an ongoing strategy for national mapping. At present soils are mapped on request by local authorities to meet the needs for information to plan irrigation, environmental management, agricultural management and land planning.

Databases

Soil databases exist in a number of institutions, where topological and semantic data are stored (Theocharopoulos *et al.,* 1992; Kollias and Malliris, 1990). Soil profile data included are area, horizon designation and depth, textural class (sand, silt, clay), cation exchange capacity, exchangeable cations, organic matter, pH, carbonates, total nitrogen, electrical conductivity, bulk density, soluble salts, sodium saturation. Water infiltration, permeability and bulk density are occasionally recorded.

These databases reside at the following institutions:

1. Soil Mapping and Classification Institute in Larissa. The GIS systems in use are ARC/INFO and LASER-SCAN
2. Agricultural University of Athens, where data are stored in ARC/INFO.

3. NAGREF Soils Institute of Athens using the ORACLE database management system and ARC/INFO GIS Software.
4. Agronomy Department of the University of Thessaloniki, using ARC/INFO.
5. Institute of Mediterranean Forest Ecosystems and Wood Technology in Athens, where only semantic data are stored in the database.
6. NAGREF Soil Science Institute of Thessaloniki, ARC/OINFO

The weak points of the Greek soil databases are that they are not interlinked and data are not freely available to the public. A National Project is under progress through which all geographical data will be digitized and stored in a National Data Base such as to be available in the public. Part of this project is the digitization of soil and forestry maps.

Soil Monitoring

At present little systematic soil monitoring exists in Greece. Some monitoring is being conducted by the Institute of Mediterranean Forest Ecosystems in Athens as part of a research project funded by the European Union.

Use of the Soil Databases

The usefulness of soil data has not been recognised in the past to the degree that it deserved. This has been due mainly to lack of knowledge on the part of users on how to apply soil information and inadequate teaching of soils in curricula of agronomists and foresters. Another reason has been the fact that soil survey reports were in the hands of a small number of governmental services and prospective customers were unaware of their existence and usefulness. However, there are recent signs of a much better appreciation of soil data by local authorities and communities. Davidson *et al*. (1994) and Theocharopoulos *et al.* (1995) have studied the use of GIS in soil survey and land evaluation, in Greece. The main uses made of the soil databases described in the sections below.

Land reclamation

The primary use made of the databases is in relation to land reclamation and improvement. Soil topological and semantic data have significantly contributed toward the development of intensive irrigated agriculture in more than 60% of the valuable Greek bottomlands.

The databases have been used in the setting of priorities and the designing and operating of irrigation works. Mapping units have been classified into irrigation classes according to the system developed by the US Bureau of Reclamation (1953) based on soil, topographic and drainage deficiency levels. Irrigation networks were constructed in soils classified as highly irrigable. Soil data have been used in determining the water needs of major irrigated agricultural crops.

Soil data such as morphology, slope soil depth, texture, surface and subsurface water permeability have been used in designing and constructing drainage systems in the flood basins of the country.

Saline and sodic soils have been reclaimed on the basis of soil chemical, physical and morphological data provided by soil studies conducted on behalf of the Soil Reclamation Service.

Crop selection

An important part of the detailed soil survey reports has been land evaluation in terms of the suitability of soil and climate for the major crops grown in the country, and land capability and suitability maps.

Soil mapping units have been classified into relative suitability classes on the basis of related morphological, physical, chemical and climatic parameters. The procedures followed are mainly qualitative, based on the system developed by Sys (1985). Models of quantitative evaluation have been applied in only a few cases (Danalatos, 1993) while Davidson *et al.* (1994) studied the use of Boolean and Fuzzy set methodologies for land evaluation in Greece.

National and local strategies of crop selection can be developed and implemented on the basis of soil-climate suitability along with consideration of present and projected economical, social and political conditions prevailing in local, national and international environments. It is hoped that soil maps will play an important role in land use change and protection of the environment, in the framework of the new Common Agricultural Policy.

Land quality, degradation and environmental assessments

Soil data have been used in the assessment of land quality and erosion risks (CORINE, 1992). Soil parameters used, along with vegetation index and climate quality for the determination of land quality classes, were soil texture, depth, drainage and slope angle. Erosion risk was assessed from soil texture, soil depth, stoniness, slope angle, land cover and climatic erosivity.

Lands were classified into one of the following classes of potential and actual land quality and erosion risk: none, low, medium or high classes. Respective maps and tabular data have been stored in the CORINE database.

Detailed soil survey data have been used in determining 'Environmentally Sensitive Areas' (ESAs). Emphasis has been given to the assessment and mapping of soil erosion and desertification risks. Such pilot assessments have been conducted in the Greek Island of Lesvos as shown in Figure 3 (Kosmas, *et al.*, in press), in Italy and in Portugal. Soil indicators used were parent material, texture, depth, drainage, rock fragments and slope.

The implementation of the National Action Plan to Combat Desertification, which has been recently prepared (Yassoglou, 1999), is expected to make extensive use of the existing soil databases. A 1:1,000,000 scale potential desertification map (Figure 4) has been prepared, based principally on the interpetation of the 1:1000,000 ESB European soil database.

The main applications are likely to be in the selection and delineation of priority areas, in the decisions to be made on the kind and extent of interventions and in the estimation of cost/benefit ratios for sustainable management of the soil resources and regional development. Soil surveys have provided basic data for regional planning in several areas of Greece.

The NAGREF Institute of Soil Mapping and Classification in Larissa has prepared a number of reports on the environmental impacts of various development projects. The expected changes in the performance and the effects of the construction of major public works on the soil environment have been evaluated on the basis of soil maps and on the related soil data provided by the soil survey reports.

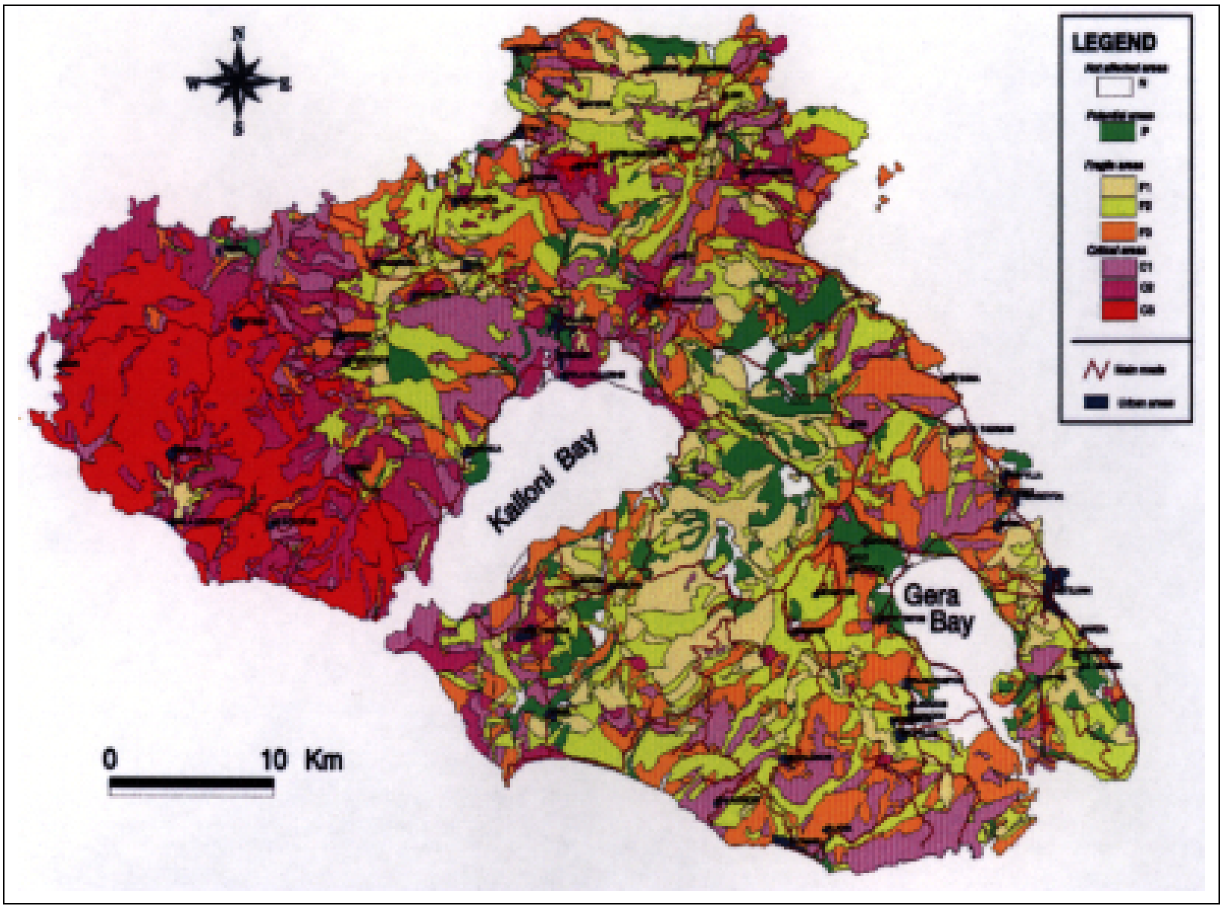


Figure 3: Map of areas sensitive to desertification for the Island of Lesbos
(source: Kosmas et al. In press)

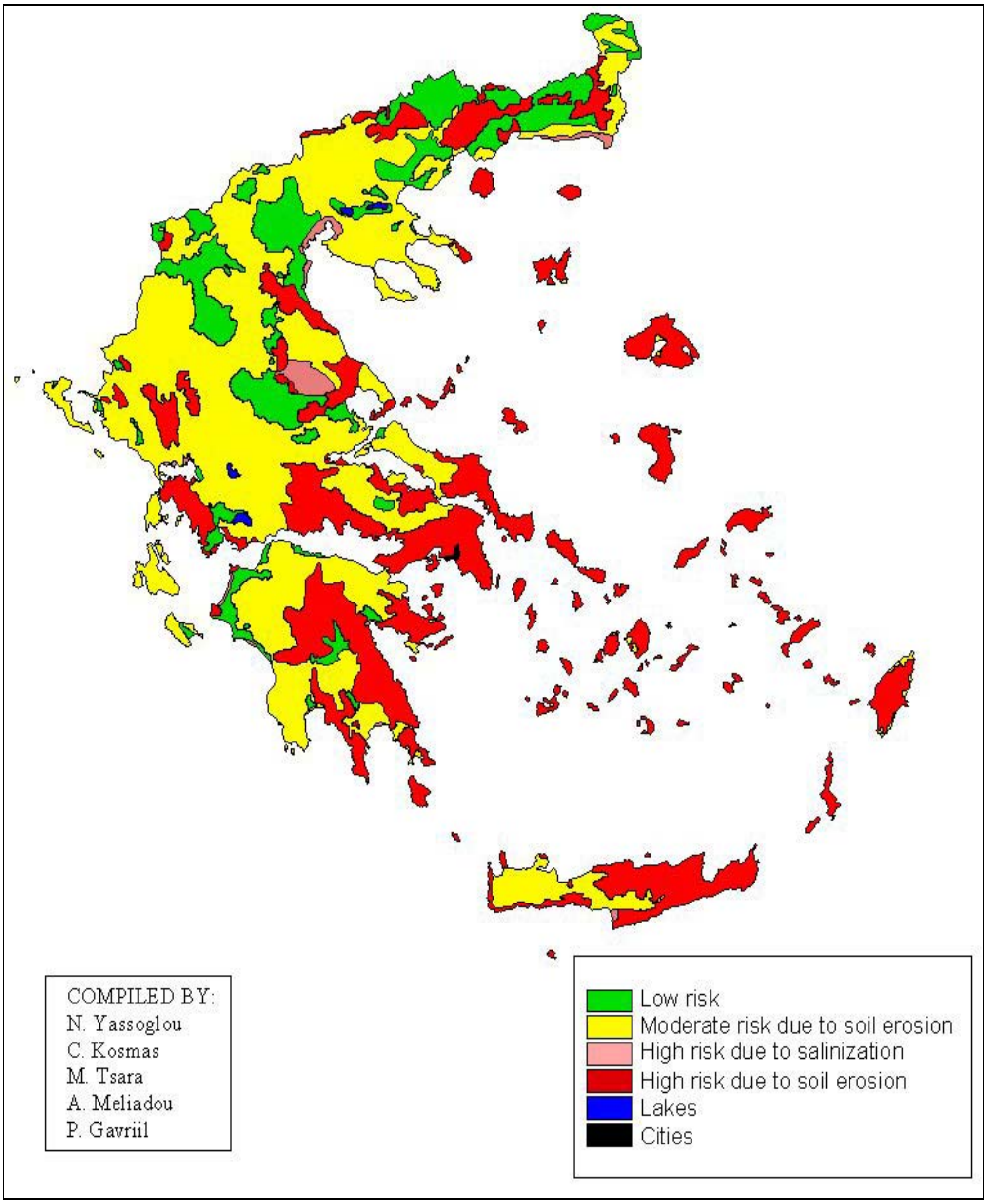


Figure 4: Potential desertification risk map of Greece compiled on the basis of soil mapping units, climate, and vegetation (source: Greek National Committee to Combat Desertification)

Application of fertilisers

The 1:1,000,000 soil database has been used for assessing the suitability of agricultural soils for fertilisation with urea (Yassoglou, 1990). The mapping units were characterised as low, medium and highly suitable and a map has been prepared. These assessments were used to estimate the projected quantities of urea fertiliser that Greece could consume annually.

Data contained in soil survey maps and reports have been used in the application of site specific fertilisation. The private company «VELESTINO» has introduced this programme in combination with the production of blended fertilisers.

The amounts of fertilisers required are estimated and the mode of application is prescribed for each farm and each major crop. The basis of this work is the morphological and physical properties of corresponding soil typological units, the results of soil tests and the requirements of the specific crops. About 3,000 sites have been tested so far and appropriate fertilisation practices have been prescribed in each one of them. This programme also contributes toward better environmental practices, by reducing the chances of over-fertilisation and contamination of ground water with nitrates.

A team of experts of the National Agricultural Research Foundation (NAGREF), the Agricultural University of Athens and the National Committee for Combating Desertification has developed an empirical sytem for nitrogen fertiliser applications to various crops, which will reduce the risk of nitrate pollution of groundwater aquifers. The system is based on the interpretation of the soil map, on plant parameters and experimental data. It has been applied in the respective National Action Plan. Table 1 and Figures 5 and 6 are examples of results obtained by the application of the system.

Table 1: Recommended Nitrogen fertiliser and irrigation water applications for cotton in the Thessaly Plain , Greece

Soil Class	Total Nitrogen kg/ha	Applications	Total irrigation mm	Applications
I	8	3	400	13
II	13	3	350	10
III	11	3	300	8
IV	2	1	200	8
V	Not	suitable	for	Cotton
VI	11	3	400	13
VII	11	3	350	10
VIII	8	3	300	8

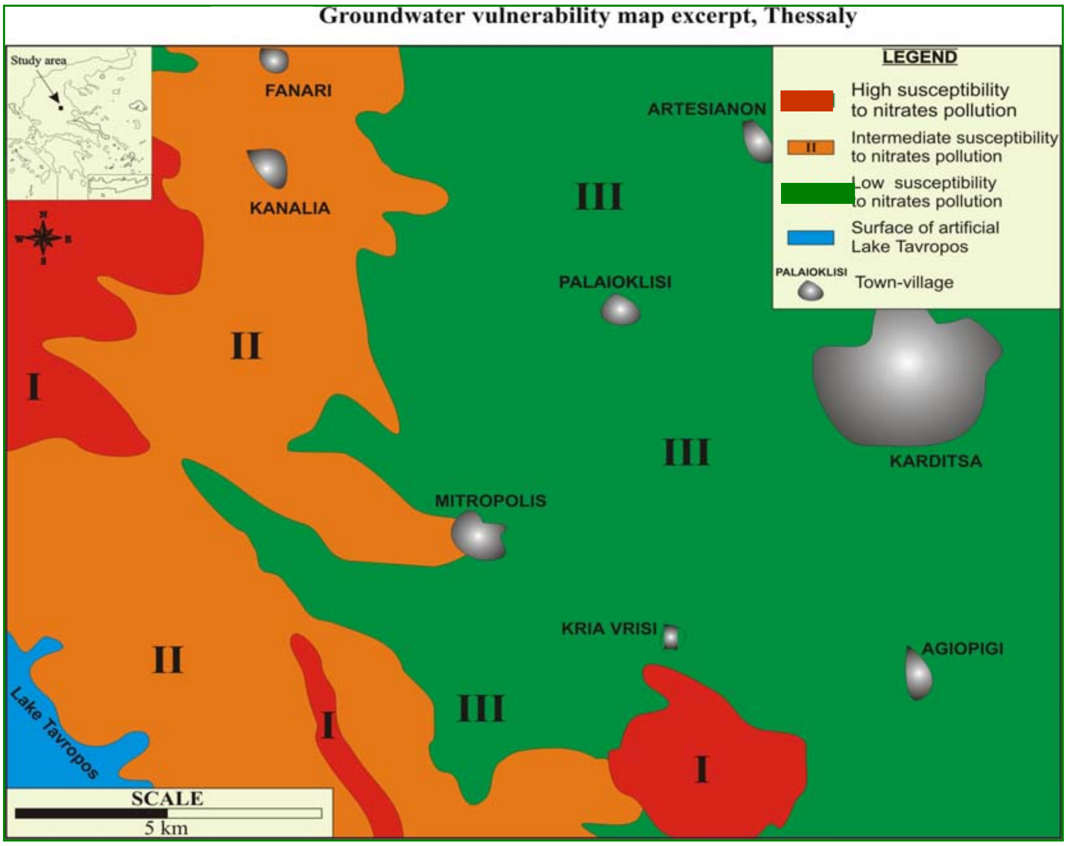


Figure 5: Map of potential risk of nitrate pollution of groundwater in the agricultural area of Karditsa, Thessaly, Greece.
(Courtesy: Th. Karyotis and D. Pateras)

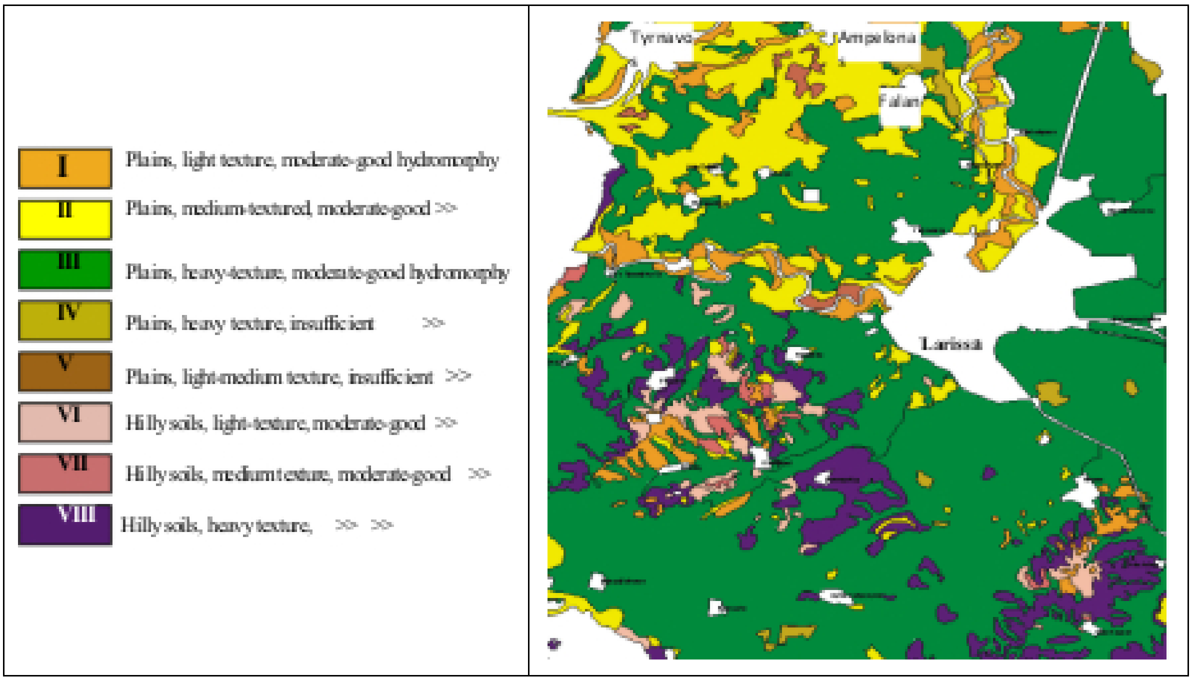


Figure 6: Map of soil classes containing soil mapping units receiving same nitrogen and irrigation treatments. Larissa, Thessaly, Greece (Courtesy :Th. Karyotis and D. Pateras)

Forest management

Land mapping has provided basic data for better forest management. Site characteristics, such as parent material, physiography aspect, soil typological unit, soil depth, slope and surface stoniness, employed in the description and designation of land units, are used in classifying forest sites into suitability classes for various species. Such information has also been used in the selection of sites for intensive management and reforestation (Nakos, 1984)

Other uses

The Government has been engaged in farm consolidation due to the fact that a serious inefficiency of Greek agriculture is the high degree of farm fragmentation. Soil surveys have been used on some occasions in reallocations of land. This application must be expanded to secure more efficient farming and to prevent injustices and complaints on the part of the farmers.

Soil survey data have also been used in archaeological studies (Yassoglou and Nobeli, 1972). Soil maps and profile data have contributed in identifying locations of buried settlements and structures, old land use patterns and past population densities.

Outlook

There is increasing interest in soil information in Greece, which needs to be taken seriously and satisfied. The following recommendations would go some way in improving the quality and availability of soil information:

1. The importance of soils should be taught at all levels of education;
2. Soil survey reports should employ modern technologies, contain instructions for the users and become more user-friendly and widely available to the public;
3. Mapping units should have a more pronounced bias towards practical applications. They should be easily recognised and understood by a wide spectrum of users. The 1:250,000 Soil Manual prepared by the European Soil Bureau (ESB, 1998) is an example, which could be further improved and expanded;
4. Soil mapping groups should establish close ties with local, national and international bodies, and seek new sources of funding for soil mapping projects;
5. Soil databases should be improved and extended, and links secured at national and international levels;

6. Agricultural areas, which have not been mapped, should be mapped across the whole country, at least at one scale;
7. There should be experiments with new technologies for collecting, classifying, and interpreting soil information;
8. A permanent and well-organised national soil monitoring system, linked to respective databases, should be initiated as soon as possible

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Soil Survey and Soil Monitoring in Hungary

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Rational Land Use and Soil Management

Rational land use and soil management are important elements of sustainable agricultural development. Soils represent a considerable part of the natural resources of Hungary. Their rational utilisation and conservation, and the maintenance of their multipurpose functionality, have particular significance in the Hungarian national economy and in environment protection (Várallyay, 1994a).

Data Requirements

The scientifically-based planning and realisation of sustainable land use, the introduction of site-specific precision technologies for biomass production, the maintenance of the favourable and desirable multifunctionality of soils and the conservation of soil, water and nature require:

- Adequate information on soil: exact, reliable, 'detectable' (preferably measurable), accurate and quantitative territorial data on well-defined soil properties with the characterisation of their spatial (vertical, horizontal) and temporal variabilities, on soil processes and pedotransfer functions and on land characteristics;
- Comprehensive knowledge on the existing relationships among natural conditions, soil and land characteristics and the soil biota, native vegetation and cultivated crops (plant responses), including the partial and integral impacts of influencing factors and their mechanisms;
- Application of existing (verified and validated or 'calibrated') simulation models for the prediction of the potential consequences of various human actions and for the selection of the most appropriate alternative measures and most efficient technologies for their realisation.

In Hungary, soil science (and the related earth and environmental sciences) can provide this information for policy- and decision-makers, planners and land users on various levels (Várallyay, 1989, 1993, 1995; Várallyay *et al.*, 1998).

Hungarian soil science, soil survey and soil analysis practices have successfully served agricultural development, the planning and organisation of crop production and environment control (rational land use and cropping pattern; control of limiting factors of soil fertility and soil degradation processes, moisture and nutrient regimes, soil and water pollution, biodiversity, landscape deterioration).

Soil Forming Factors

In Hungary detailed information is available on the various natural factors as a result of long-term observations, survey and mapping activities (The National Atlas of Hungary, 1989). The most important databases and monitoring systems are as follows:

- *Meteorological data.* Systematic and regular measurements from 1850. Basic meteorological parameters are registered at 160 observation points; 18 stations are equipped for detailed atmospheric-chemistry measurements and 4 EMEP stations for continuous atmospheric monitoring;
- *Hydrological data.* Regular records on the quantity and quality of surface waters (rivers, creeks, canals, lakes, ponds, reservoirs) from the first decade of the century; regular measurements on groundwater conditions (depth of water table; chemical composition of the groundwater) for 600-1,000 groundwater-testing wells are available from 1935, including 50 piezometer installations;

- *Geological data.* As a result of the 160-year geological survey, the 1:200,000 geological map of Hungary was prepared as well as a great number of various thematic geological, hydro-geological, geochronological maps in larger scales for different regions of the country;
- *Geomorphological data.* In addition to the 1:200,000 geomorphological map (geomorphological types, subtypes and varieties) of Hungary a series of regional maps was prepared, indicating the geomorphology pattern of smaller territories at larger scale using digital relief models in recent years.

Soil forming factors (geology, climate and weather conditions, surface and subsurface hydrology, natural vegetation, human activities) show high spatial and temporal variability. Their combined influences create an extremely heterogeneous physico-geographical environment for soil formation processes, which results in the mosaic-like variability of soils and their properties in Hungary (National Atlas of Hungary, 1989; Szabolcs and Várallyay, 1978; Várallyay *et al.*, 1985). This is illustrated well by the development of the following soil sequences:

- Chrono-sequence: according to the time elapsing from the last deposition of alluvial, colluvial or aeolian sediments, giving possibility for soil formation;
- Topo-sequence, catena: according to the variation in relief, drainage conditions and moisture regime (intensity and character of wetting; the influence of groundwater on soil processes; hydromorphic character);
- Another type of topo-sequence is the erosion sequence, according to the rate of water erosion and sedimentation on the various parts of slopes in an undulating hilly landscape;
- Leaching sequence: according to the rate of downward filtration (due to high atmospheric precipitation and/or surface seepage) results in the different intensity of leaching of soluble compounds or clay minerals and various rates of profile differentiation;
- Salinity-alkalinity sequence: according to the water soluble salt content and its profile distribution; the rate of profile differentiation; the depth and ESP of the 'solonetz' B-horizon; and the hydromorphic character of the soil.

The soil cover of Hungary shows a 'super matrix' of these sequences with their numerous combinations and transitional formations. Within the national programme on the 'Assessment of the Agro-ecological Potential of Hungary' (1978-1981) (Láng *et al.*, 1983) an updated evaluation of soil resources was made by the author's team on the basis of all available soil information (Várallyay *et al.*, 1985). Later, all these bodies of information were organised into a computerised GIS database-AGROTOPO, in RISSAC (Várallyay, 1993, 1994a,b, 1997; Várallyay *et al.*, 1998; Várallyay and Molnár, 1989).

Soil Mapping

A large amount of soil information is available in Hungary as a result of long-term observations, various soil surveys, analyses and mapping activities on national (1:500,000), regional (1:100,000), farm (1:10,000-1:25,000) and field level (1:5,000-1:10,000) during the last seventy years. Thematic soil maps are available for the whole country at the scale of 1:25,000 and for 70% of the agricultural area at the scale of 1:10,000 (Várallyay, 1989, 1994a).

There are at least three reasons why this rich soil database has been developed: the small size of the country (93,000km²); the great importance of agriculture and soils in the national economy; the historically 'soil loving' character of Hungarian people, and particularly Hungarian farmers.

Soil maps

In Table 1 the most important thematic soil maps in Hungary are summarised, indicating their content, scale, author and date of preparation (Fésûs *et al*., 2000; Szabó *et al*., 1996, 1998; Várallyay, 1989, 1993, 1994a,b; Várallyay *et al.*, 1985,1994, 1995, 1998). The maps can be divided into three main groups.

Large-scale maps (Nos. 1-5 in Table 1)

In the 1:25,000 scale 'Kreybig' practical soil maps the soil reaction, carbonate and salinity/alkalinity status are indicated by colours; physical-hydrophysical characteristics and depth of the soil by rasters; the organic matter, total P_2O_5 and K_2O content, depth of the humus horizon and depth of the groundwater table by a code number; and the soil type (according to 'Sigmond's soil classification) with Roman numerals (Várallyay, 1989).

Table 1: Thematic soil maps and related databases in Hungary

No.	Map	Scale	Date of preparation	Prepared for	Content	Author(s)	References
1.	Practical soil maps	1:25,000	1935-1955	the whole country per topographical map sheets	m, tm, fd, ld, e	Kreybig and coll.	Várallyay, 1989
2.	Large-scale genetic soil maps	1:10,000	1960-1975	50% of the agricultural land of Hungary, per farming units	m, tm, fd, ld, e	Collective	Szabolcs, 1966
3.	Soil evaluation new genetic soil maps Revision of genetic soil maps	1:10,000 1:10,000	1985-1991 1985-1990	15% of the agricultural land per topographical map sheets 22% of the mapped area	m, tm with code numbers, fd, ld	Collective	
4.	Soil conditions and the possibilities of irrigation	1:25,000	1960-1970	present and potential irrigated regions	6 thematic maps, fd, ld	Collective	Szabolcs *et al*., 1969
5.	Large-scale maps for amelioration projects	1:5,000-1:10,000	1960-	amelioration projects (occasionally)	m, e	Collective	
6.	Soil factors determining the agro-ecological potential	1:100,000	1978-1980	the whole country per topographical map sheets	m (with an 8-digit code), c	Várallyay, G., Szücs, L., Murányi, A., Rajkai, K., Zilahy, P.	Várallyay *et al*., 1985
7.	Agro-topographical map	1:100,000	1987-1988	the whole country per topographical map sheets	m (with a 10-digit code), c	Várallyay, G., Molnár, S., Szücs, L.	Várallyay and Molnár, 1989
8.	Hydrophysical properties of soils	1:100,000	1978-1980	the whole country per topographical map sheets	m, c	Várallyay, G., Szücs, L., Rajkai, K., Zilahy, P.	Várallyay *et al*., 1985
9.	Status of soil erosion	1:75,000	1964	agricultural lands of hilly regions of Hungary	m	Stefanovits, P.	
10.	Limiting factors of soil fertility	1:500,000	1976	the whole country	m	Szabolcs I., Várallyay, G.	Szabolcs and Várallyay, 1978
11.	Main types of moisture regime	1:500,000	1983	the whole country	m, c	Várallyay, G., Zilahy, P., Murányi, A.	Várallyay et al., 1985
12.	Main types of nutrient regime	1:500,000	1983	the whole country	m, c	Várallyay, G., Szücs, L., Molnár, E.	Várallyay, 1985
13.	Soil erosion	1:500,000	1960-1964	the whole country	m, tm, e	Stefanovits, P., Duck, T.	Stefanovits, P., 1964
14.	Salt affected soils	1:500,000	1970-1974	the whole country	m, e	Szabolcs, I., Várallyay, G., Mélyvölgyi, J.	Szabolcs et al., 1969
15.	Susceptibility of soils to acidification	1:100,000 1:500,000	1985-1988	the whole country	m, c	Várallyay, G. Rédly, M. Murányi, A.	Várallyay *et al*., 1993
16.	Susceptibility of soils to physical degradation	1:500,000	1985-1988	the whole country	m, c	Várallyay, G., Leszták, M.	Várallyay, G., Leszták, M., 1990

Remarks: m: soil map; tm: thematic map; fd: field description; ld: laboratory data; e: explanatory booklet; c: computer storage

On the 1:10,000 scale genetic soil maps, the most important soil properties (soil type, subtype and local variant according to the Hungarian soil classification system; pH and carbonate status; texture; hydrophysical properties; salinity - alkalinity status; organic matter resource; N, P and K status) are indicated on separate thematic maps (cartograms); and recommendations are summarised in additional thematic maps for rational land use and cropping pattern; soil cultivation; rational use of fertilisers; soil moisture control, including water conservation practices, irrigation and drainage; soil conservation practices for water and wind erosion control, etc. (Szabolcs, 1966).

The large-scale maps of the possibilities and limitations of irrigation indicate the soil types, subtypes and local variants and parent material; physical-hydrophysical soil characteristics; salinity/alkalinity status of the soil (salt content, ion composition, ESP, pH); groundwater conditions (depth and fluctuation of the water table; salt concentration, ion composition and SAR of the groundwater) on separate thematic maps. On this basis two additional map sheets were prepared on 'the critical depth' of the water table and 'critical groundwater regime'; and on recommendations for irrigation practices and groundwater management (Szabolcs *et al*., 1969).

Large-scale (1:5,000, 1:10,000) maps are used for various soil amelioration projects. Large-scale soil maps (and related databases) will have a 'renaissance' in the near future because the new land ownership structure, the rent-a-field system and the developing land market requires more detailed information on land/soil resources than ever in Hungarian history. The new soil/land evaluation system requires detailed soil/land information, convertible to existing or planned EU-standards.. Site-specific precision agrotechnologies (soil moisture control, water and nutrient supply, soil and environmental pollution control) necessitate data on soil and land characteristics that are adequately precise.

Medium-scale maps (Nos. 6-9 in Table 1)*.*

In 1978 a national programme was initiated by the Hungarian Academy of Sciences for the 'Assessment of the agro-ecological potential of Hungary' (Láng *et al*., 1983). In this programme a 1:100,000 scale map was prepared in RISSAC onfthe soil factors determining the agro-ecological potential (Várallyay *et al*., 1985). On the map, seven soil factors (soil type; parent material; soil reaction and carbonate status; soil texture; hydrophysical properties; organic matter resources; depth of the soil) were indicated with an 8-digit code number.

Later the map was completed with two additional soil characteristics (clay mineral associations and 'soil productivity index') and the contours of the nine soil characteristics were printed on the 1:100,000 scale topographical map (indicating relief, surface waters, land use, infrastructure, etc.). The agro-topographical map was digitised and organised into a GIS-based soil information system (Várallyay and Molnár, 1989).

The map of the categories of the hydrophysical properties of soils was also prepared at the scale of 1:100,000. The 9 main and 17 subcategories indicated were defined by the following soil characteristics: texture; saturation percentage (SP); field capacity (FC), wilting percentage (WP), available moisture range (AMR); infiltration rate (IR), saturated hydraulic conductivity (K), unsaturated capillary conductivity; and by the layer sequence of the soil profile (Figure 1; Várallyay *et al*., 1985).

1:75,000 scale maps on the status of soil erosion (strongly, moderately and slightly eroded lands; areas of sedimentation; territories under the influence of wind erosion; parent material) were prepared by Stefanovits (1964) and his team in the 1950s for the agricultural lands of hilly regions in Hungary.

Small scale maps (Nos. 10-14 in Table 1)

.1:500,000 scale genetic soil map (Stefanovits and Szücs, 1961).
1:500,000 scale thematic soil maps (Nos. 10-14 in Table 1) for Hungary:

- Salt affected soils;
- Soil erosion (Stefanovits, 1964);
- Main types of moisture regime;
- Main types of nutrient regime;
- Limiting factors of soil fertility and soil degradation processes (Pásztor *et al*., 1998a; Szabó *et al*., 1998) (Figure 2) (Szabolcs and Várallyay, 1978).

1:1,000,000 to 1:5,000,000 scale soil maps for various international programmes (Várallyay, 1989, 1994a, 1993):

- 1:5,000,000 FAO/UNESCO World Soil Map;
- 1:5,000,000 GLASOD Map (GLobal Asessment of SOil Degradation);
- 1:5,000,000 World Map of Salt-affected Soils;
- 1:1,000,000 Soil Map of Europe.

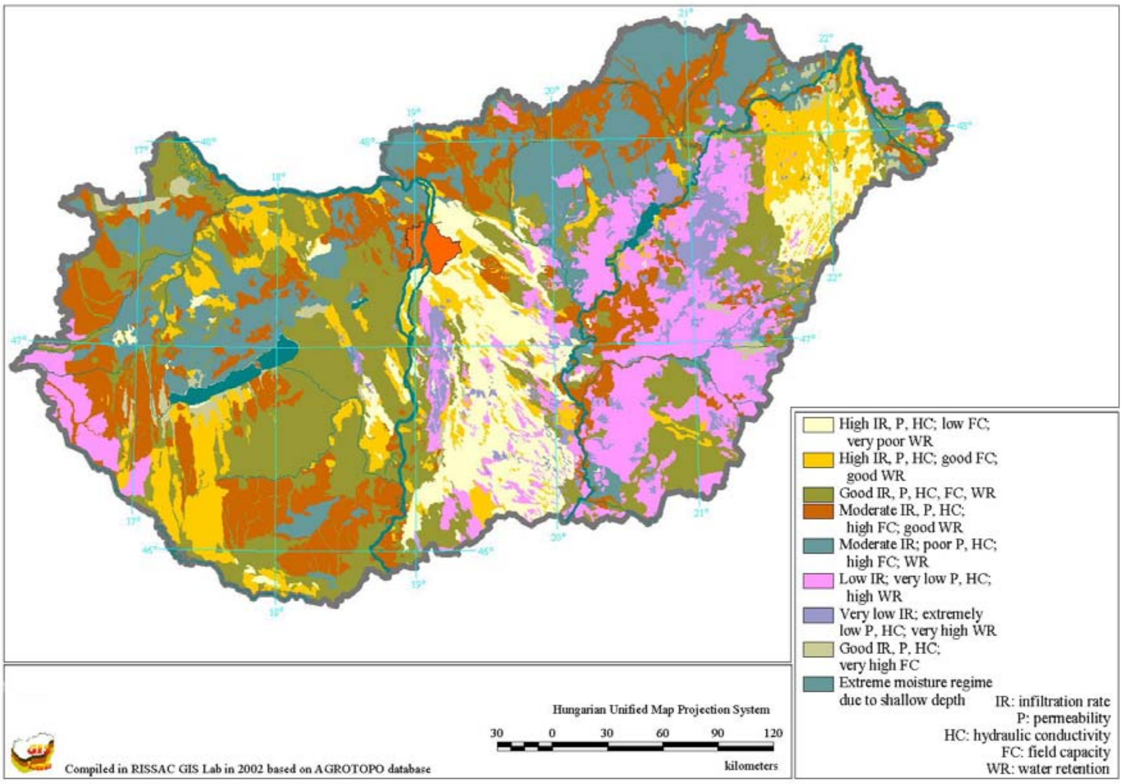

Figure 1: Categories of the hydrophysical properties of soils

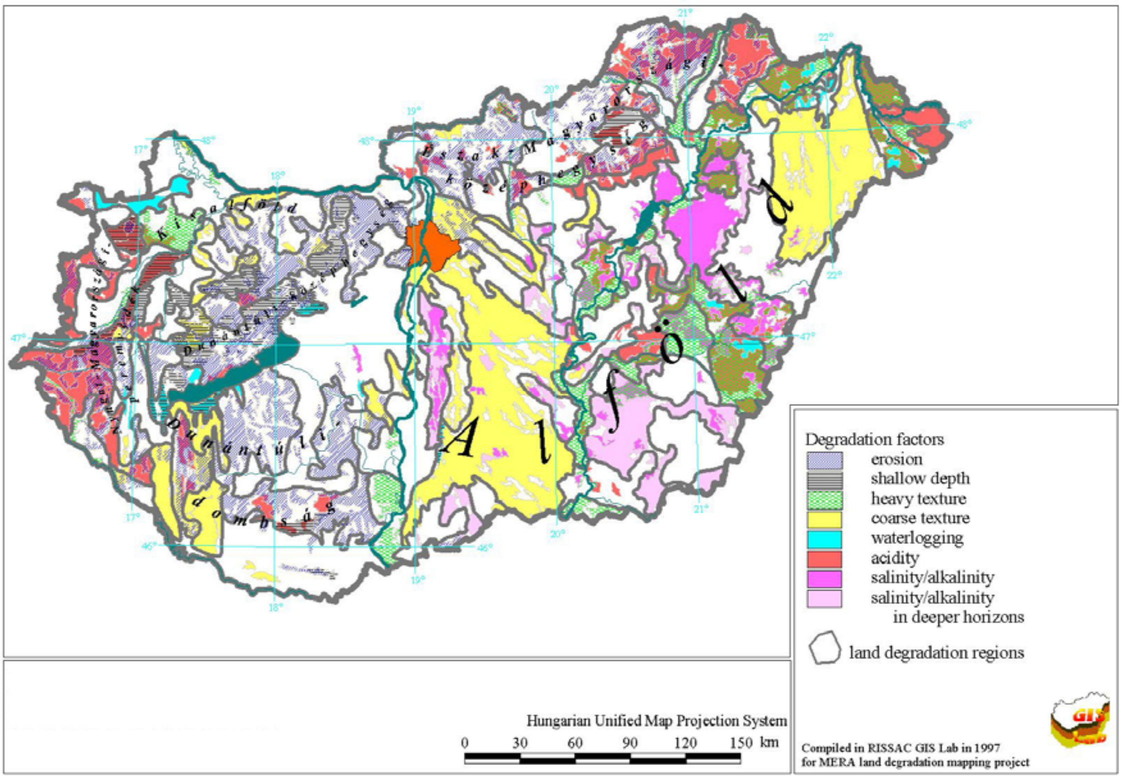

Figure 2: Limiting factors of soil fertility and soil degradation processes

Soil susceptibility/vulnerability maps

In recent years, special attention has been paid to the characterisation of soils from the viewpoint of their sensitivity/susceptibility/vulnerability to various natural and human-induced stresses (Várallyay *et al*., 1993, 2000; Pásztor *et al*., 1996, 1997, 1998b; Flachner *et al*., 1998).

In Hungary soil susceptibility maps have been prepared for:
- Water and wind erosion (Stefanovits, 1964);
- Acidification (Várallyay *et al*., 1993);
- Salinisation/alkalisation/sodification (Szabolcs *et al*., 1969);
- Physical degradation (such as structure destruction, compaction and surface sealing) (Figure 3) (Várallyay and Lesztták, 1990);
- Vulnerability of soils against various pollutants (e.g. hazard of nitrate leaching etc.).

Within the frame of a multilateral internal cooperation of 13 Central and Eastern European countries, a 1:2.5M database has been established on the present state of soil pollution and on the SOil Vulnerability of EURope (SOVEUR) to combat various stresses (soil degradation, soil pollution) in 1998-2000 (Várallyay *et al*., 2000).

Soil Information and Monitoring Systems

Systematic monitoring systems have been established to register soil changes (Fésûs *et al*., 2000; FAO, 1994; TIM, 1995; Várallyay, 1993, 1994a,b; Várallyay *et al*., 1994, 1998).

Soil fertility monitoring system

A soil fertility monitoring system (AIIR) has been established to provide a soil and agronomy database for rational soil management and plant nutrition. In the system the most changeable soil characteristics (pH, $CaCO_3$ and organic matter content; saturation percentage (SP); total salt content; total and mobile N content; available P, K and Ca content; soluble Mg, S, Cu, Zn, Mn content) have been measured in the topsoil (0-30cm soil layer or the ploughed horizon; later in the 30-60cm layer as well) of about 100,000 agricultural fields covering nearly 5 million hectares (the total agricultural area of the 93 thousand km² of Hungary is about 6.5 million hectares) in 3-year cycles.

The programme, in three phases, started in 1978 (I: 1978-1981; II. 1982-1985; III: 1986-1989) but stopped before completing the third phase. The data were computer-stored by agricultural field (their average size was about 50ha at that time), without inner boundaries of the maximum 12ha sampling sites, where 'average samples' (composed from 30-30 sub samples) were collected in two replicates for laboratory analysis (Várallyay, 1994).

Microelement survey

In this system, in addition to the above mentioned basic soil parameters, the 'total' (interpreted as a potential 'pool') and 'soluble' (interpreted as mobile and plant available) content of 20 elements were determined in the 0-30, 30-60, 60-90cm soil layers of 6,000 soil profiles, representing nearly 5 million hectares of agricultural fields. Element contents were determined in 5 various extractants: 0.1 N HNO_3, 0.02 N $CaCl_2$, ammonium lactate-EDTA, $(NH_4)_2SO_4$ and LAKERV. On the basis of the analytical data 1:2,000,000 scale thematic maps were prepared for Cd, Co, Cr, Cu, Hg, Mo, Ni, Pb. The planned cycle was 3 years, but the programme stopped after the first cycle (1987-1988) because of financial limitations (Fésüs *et al*., 2000; Várallyay, 1994a).

In later years all existing soil data were organised into computerised soil information systems.

Soil Information System

Soil Information System (HunSIS=TIR; Csillag *et al*., 1998; Kummert *et al*., 1989; Várallyay, 1993) contains, in addition to the basic topographic information, point information on the characteristics of soil profiles and their different layers and diagnostic horizons; territorial information (1:25,000 scale thematic maps) on the most important soil and land characteristics; and validated models on pedotransfer functions, soil processes and soil-plant-environment relationships. The system was prepared in RISSAC for Pest County (one of the 19 administrative regions of Hungary, covering about 6,500km²).

Agrotopographical database

Digitised data (AGROTOPO; Várallyay *et al*., 1998) include agro-topographical maps at scale 1:100,000 (Table 1, No. 7) organised into GIS.

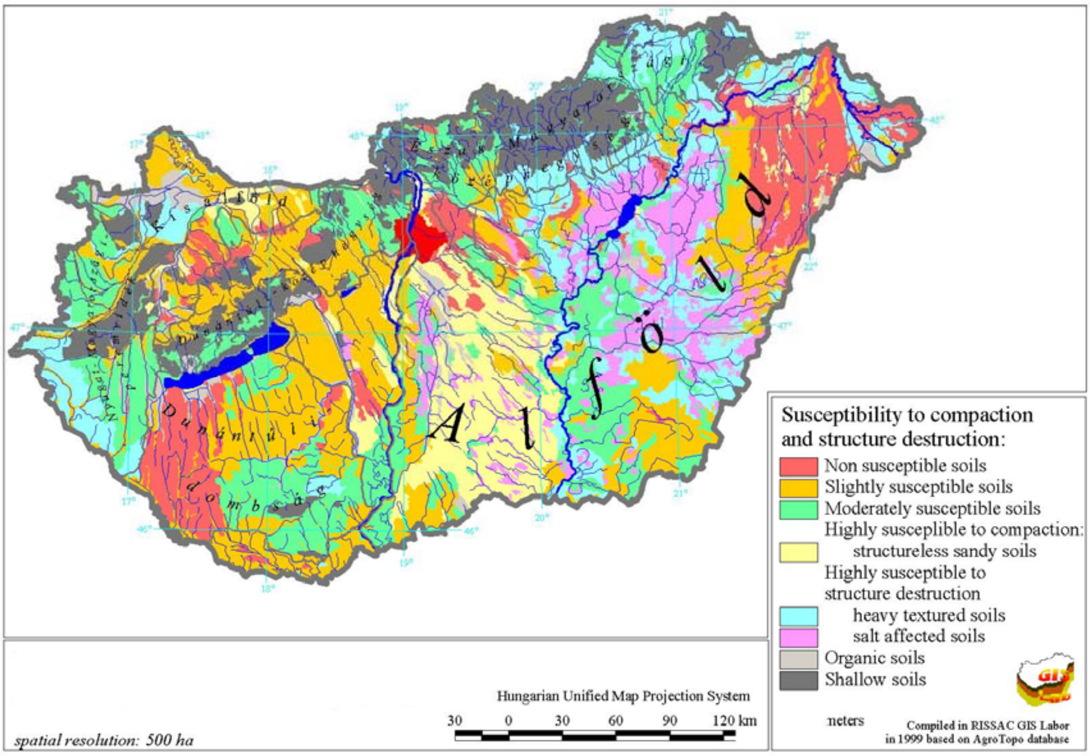

Figure 3: Susceptibility of Hungarian soils to physical degradation

Soil Information and Monitoring System (TIM)

The Soil Information and Monitoring System (TIM) is an independent subsystem of the Integrated Environmental Information and Monitoring System (KIM), which is under development (Várallyay, 1994a, TIM, 1995).

Based on physiographical-soil-ecological units 1,200 'representative' observation points have been selected (and exactly defined by geographical coordinates using GPS): 800 points on agricultural land, 200 points in forests and 200 points in environmentally threatened 'hot spot' regions [representing 12 different types of environmental hazards or particularly sensitive areas, such as: degraded soils; ameliorated soils; drinking water supply areas; watersheds of important lakes and reservoirs; protected areas with particularly sensitive ecosystems; 'hot spots' of industrial, agricultural, urban and transport pollution; military fields; areas affected by (surface) mining; waste (water) disposal affected spots; Figure 4].

The 'representative' sampling sites were selected by regional soil experts on the basis of all available soil information (profile descriptions, results of laboratory analysis, long-term field observations, maps, etc.) and on their local experiences.

The forest and the 'hot spot' sampling sites were selected in cooperation with regional forest land-site experts, environmentalists and experts of the given environmental hazards. The sampling period is 15 September-15 October each year. The first sampling was in 1992. In the monitoring system, some soil parameters are measured every year, some others every 3 years or every 6 years, depending on their stability (Table 2). In addition to the existing soil maps and maps on the various physico-geographical factors, new techniques (geostatistical analysis, remote sensing, etc.) will be applied to extend point into territorial information when appropriate.

According to the basic concept, TIM is an independent but integral mosaic (subsystem) of the Environmental Information and Monitoring System (KIM).

The database management and the hardware-software configuration of the system:

- Guarantee the compatibility of TIM with other subsystems of KIM, which are under development now (e.g. for the atmosphere; surface-and sub-surface water resources; geological deposits and mineral resources; biological resources and biodiversity; landscape; human resources and socio-economic aspects of the environment; etc.);

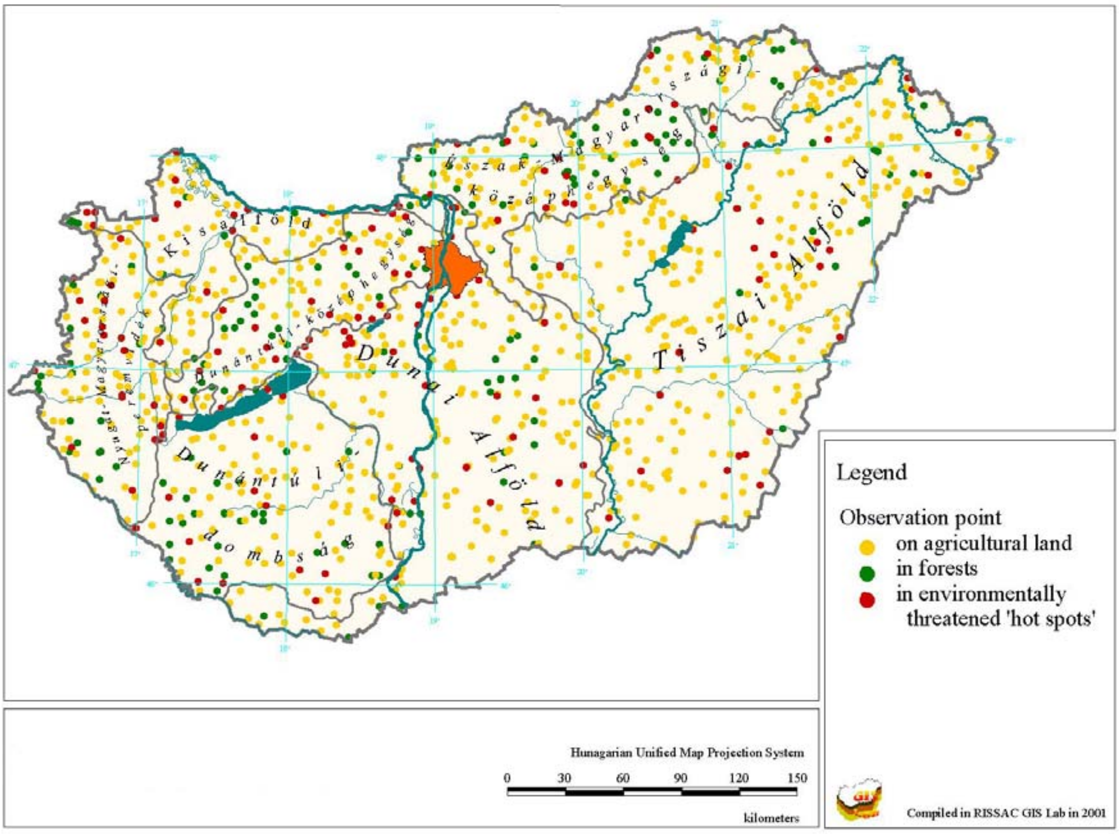

Figure 4: Hungarian soil information and monitoring system TIM

- Establish potential conversative connections to similar international systems for the joint regional, continental and global actions of sustainable development;
- Give opportunities for the development of various environment-related user-friendly expert systems for scientific applications and for public uses.

Multipurpose Applications

The properly organised hierarchic soil database (global, continental, regional, national, sub regional, local, farm, field level) represents a comprehensive scientific basis of the various level Plans of Action for sustainable land use and soil management. It offers wide-ranging opportunities for the spatial quantification and comprehensive analysis-modelling-evaluation of soil properties, pedotransfer functions and soil process determinations:

- Soil fertility and soil productivity for various crops;
- The vulnerability of terrain and susceptibility of soils to various natural and anthropogenic impacts and environmental hazards (water and wind erosion; acidification; salinisation-alkalisation; soil structure destruction, compaction; biological degradation; unfavourable changes in moisture and nutrient regimes; soil toxicity; pollution of surface and subsurface water resources; landscape deterioration);
- Degradation and decline of forest and grassland ecosystems; and the forecast of potential future changes due to the impacts of natural factors and human activities, assuming various plausible scenarios.

There is a wide range of practical use of soil databases and monitoring systems (Várallyay, 1993, 1994b, 1995, 1997; Várallyay *et al.*, 1995-1996, 1998):

- Assessment of the state of the environment and its long-term global/regional changes;
- Inventary inclusion of environmental 'hot spots' (environmentally sensitive, valuable, protected ecosystems and their land-sites; highly polluted areas with susceptible soils; etc.); risk assessment of environmental hazards; impact analysis of various human activities;
- Protection, conservation, rational use and management of natural resources (surface and subsurface waters, soils, biological resources, etc.);

Table 2: Soil characteristics
determined at the basic observation points [I, M] of the soil information and monitoring system for environmental control TIM [HUNGARY]

Soil characteristics		at start t_o	yearly	3 yearly	6 yearly	Remarks
Morphological description of the soil profile		+				
Particle-size distribution		+				
Texture (SP)		+				
Hygroscopic moisture content (hy_1)		+				
Total water storage capacity (WC_T-pF_0)		+				on undis-turbed soil cores
Field capacity (FC-pF 2.5)		+				
Wilting percentage (WP-pF 4.2)		+				
Available moisture range (AMR=FC-WP)		+				
Saturated hydraulic conductivity		+				
$CaCO_3$ content	if>5%	+			+	
	if 1-5%	+		+		
	if <1%	+	+			
$pH(H_2O)$	if $CaCO_3$>1%	+		+		
	if $CaCO_3$<1%	+	+			
pH(KCl)	if $CaCO_3$>1%	+		+		
	if $CaCO_3$<1%	+	+			
Hydr. acidity (y_1) if $CaCO_3$%=0		+	+			
Exch. acidity (y_2) if $CaCO_3$%=0		+	+			
Total water-soluble salts (in salt-affected soils (sas))		+	+			
1:5 water extract analysis [pH, EC; CO_3^{2-}, HCO_3^-, Cl^-, SO_4^{2-}, Ca^{2+}, Mg^{2+}, Na^+, K^+] (in sas)		+			+	
Phenolphthalein alkalinity(in sas)		+		+		
Depth of the humus horizon		+			+	profile
Organic matter content		+	+			
CEC (cation exchange capacity)		+			+	
Exchangeable cations (Ca^{2+}, Mg^{2+}, Na^+, K^{2+})		+			+	
Total N		+		+		
NO_3-NO_2		+	+			
'Available' plant nutrients [P, K, Ca, Mg; NO_2-NO_3; Fe, Cu, Zn, S, Mn]		+		+		
Potentially toxic elements [Al, As, B, Cd, Co, Cr, Cu, Hg, Mn, Mo, Ni, Pb, Se, Sn, Sr, Zn]		+		+		
	'total'	+				
	'mobile'	+		+		
Cellulose-test	as indicators of soil 'bio-logical' activity	+		+		
Dehydrogenase activity		+		+		
CO_2 production		+		+		
Natural radioactivity		+		+		
'Average depth' to the groundwater table		+	+			
Chemical composition of the groundwater [pH, EC, CO_3^{2-}, HCO_3^-, Cl^-, SO_4^{2-}, NO_3^-, PO_4^{3-}, Ca^{2+}, Mg^{2+}, Na^+, K^+] [micronutrients] [micro pollutants]		+	+			

- Exact description, quantification, modelling and forecast of soil processes for their efficient control and the prevention of undesirable changes, such as soil degradation processes, soil pollution, extreme moisture and nutrient regime;
- ‘Objective’ land (soil and terrain, ‘land-site’) evaluation, taking into consideration the multifuncionality of soils (media for biomass production; storage, buffering, filtering and detoxication function; habitat of biota);
- Optimalisation, regionalisation (zonation) of land use (including non-agricultural land use) and cropping pattern;
- Elaboration of regional and national strategies (concepts, main directives, general guidelines) for rural development, sustainable biomass production and rational environment protection; efficient (effective, easily adaptable, widely applicable, transferable) technologies for rational land use, agricultural water management, agrotechnics, amelioration and remediation (including site-specific precision farming and soil-related waste management);
- Development and formulation of economically viable, socially acceptable and environmentally sound land use policy and legislation measures.

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Soil Survey and Databases in Iceland

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Introduction

Icelandic agriculture is characterised by the use of extensive rangelands for grazing and the making of hay for winter feeding. Cultivated land is of limited extent. Iceland has therefore traditionally put more emphasis on mapping vegetation resources rather than the soils.

The history of soil science in Iceland is relatively young. Geologic aspects of the soils received considerable attention early on with the study of volcanic ash layers, but dating of soils by volcanic ash layers was pioneered by the Icelandic geologist Sigurdur Thorarinsson (1961).

The first comprehensive map of of Icelandic soils was printed in 1959 at a scale of 1:750,000 (Nygard and Johanesson 1959). Other soil survey efforts were localised and this map together with Johannesson´s monograph on Icelandic soils (1960) remained the only complete survey of Icelandic soils until this year.

In response to request made by the European Soil Bureau and other international agencies, the Agricultural Research Institute is now completing a soil map in the scale of 1:500,000.

Soil Mapping in the Past

The pioneer work by Johannesson (1960) established a framework for the classification of Icelandic soils that is still valid. The soil map that was included in his monograph is attributed to Ivar Nygard who started this work in 1951, but after Nygard's death, Johannesson completed the map in co-operation with the US Soil Conservation Service. The map was printed by the U.S. Geologic Survey in 1959, but was included with both the Icelandic and English versions of Johannesson's monograph on Icelandic soils (1960). The monograph was reprinted in Icelandic by the Agricultural Research Institute in 1988.

The underlying basis for Johannesson´s and Nygard´s work was the US soil classification system (Baldwin *et al.*, 1938).

Johannesson established a classification system based on 23 mapping units, but the soils were devided into three major groups, the freely drained soils (silt loams), poorly drained soils (peat soils) and the soils of the deserts (stony alluvial, aeolian, lag gravel, etc). At the time of Johanesson´s studies, the unique properties of Andosols were only beginning to be realised, which limits the present applicability of this work.

It is noteworthy, however, that Johannesson wrote in his monograph: "*…is the fact that many silt loam soils have some characteristics like those of the volcanic ash soils in other countries, for instance those of Japan, and thus perhaps might be considered as close relatives to or even as members of the so-called Ando soil group..*"

After the work of Johannesson, emphasis was mainly on agronomic aspects of Icelandic soils, such as fertilisation of hay fields and draining of wetland soils. Noteworthy is Helgason's comprehensive account of soils of South-west Iceland (1963; 1968). Two Ph.D. dissertations added considerable knowledge on the basic characteristics of Icelandic soils in the eighties by Ólafsson (1974) and Guðmundsson (1978). The Agricultural Research Institute is still involved in soil evaluation for fertiliser recommendations, and has carried out extensive research related to soil fertility. The results have been reported both in specialised reports and as scientific papers (e.g., Palmason *et al.*, 1996; Palmason and Helgason, 1996).

Several attempts have been made to map soils in localised areas (e.g. Helgason and Gudbergsson, 1977; Gudbergsson and Olafsson, 1978), drawing much from the basis Johannesson provided. Gudbergsson (1982) made an outline for the classification of wetland soils (Histosols).

Current Soil Mapping Activities

Soil Taxonomy and FAO World Reference Base

Soil mapping needs to be based on a suitable soil classification system. The Agricultural Research Institute collaborated with Texas A&M University and the USDA-NRCS to provide a new perspective on Icelandic soils for this purpose, with detailed analyses of several representative soil pedons (Arnalds, 1990; Arnalds *et al.*, 1995; Arnalds and Kimble, unpublished data; Wada *et al.*, 1992). These studies show that Icelandic soils are Andosols and Andic integrates of other soil groups to a large extent. More recent overview of Icelandic soils was published by Arnalds (1999a).

The soils of the barren areas in Iceland are quite different from the typical Andosols and Histosol that cover other parts of the country. Arnalds (1988; 1990) and Gudmundsson (1991) have published studies on these soils. Arnalds and Kimble conducted a detailed analysis of ten representative pedons of Icelandic desert soils but the results are still being analysed.

A steady input of eolian materials and occasional tephra additions cause the organic carbon content to be lower than 25% in many of the wetland soils, resulting in Andisol (US-Soil Survey Staff, 1998) rather than Histosol classification (Arnalds *et al.*, 1999). The desert soils are also often classified as Andisol because of their high volcanic glass content.

The current edition of the US Soil Taxonomy (US Soil Survey Staff, 1998) has therefore the disadvantage in relation to the classification of Icelandic soils that it fails to distinguish between some of the major soil types at the highest level because of dominating andic influences.
This can also be judged as a benefit, demonstrating the dominating influence of andic soil properties of Icelandic soils.

Applying the FAO soil classification (FAO, 1998) system involves similar problems as for the US system in that many contrasting soils are classified the same at the highest level as Andosols. The wetland soils often do not meet the criterion for Histosols because of relatively low organic content and the dominance of volcanic glass in desert soils often excludes Arenosols, Fluvisols, Cambisols and Regosols as soil groups. However, Thorsteinn Gudmundsson (1994) found that the FAO legend (FAO-UNESCO, 1988) provided a good framwork for mapping soils in Iceland. He translated and adapted the FAO system for use in Iceland.

The Icelandic adoption of the FAO scheme for the soil groups (Gudmundsson, 1994) does not fully correlate with the FAO World Reference Base (FAO 1998) for reasons stated above. Its use may therefore cause problems in relating Icelandic soil information at an international level although, with modifications, it is well suited for domestic use.

Current soil mapping effort

The Agricultural Research Institute is currently making an effort to produce a soil map in 1:500,000. Soil classification issues have not been resolved yet. A preliminary version of this map is published with this paper (Figure 1). The soil information underlying the map is drawn from published and unpublished literature on Icelandic soils, which currently is being compiled for a databank and an overview publication. Some general characteristics are presented in Table 1.

Soil analysis generally follows standard methods designed for Andosols such as described by Blakemore *et al.*, 1987. Soil descriptions generally follow US methods (e.g., USDA-NRCS 1998).

The geographic information is mainly drawn from three sources:

1. *Vegetation maps*. Vegetation reflects soil conditions, especially the distinction between wetlands (organic soils), freely drained vegetated Andosols and the deserts.
2. *Soil Erosion digital databases* (see later in the paper). This information gives a good geomorphological overview of the desert surfaces, and is the primary source for their geographic information.
3. *Infrared satellite images* (LANDSAT TM). They are used where there is a lack of vegetation information. The images also provide the base map, correlated with Iceland´s current map projection system.

Table 1. General characteristics of major soil classes in Iceland. Common ranges.

Soil Class	km^2	Depth m	OC %	pH in H_2O	Oxalate Al+1/2Fe%	Clay %	CEC Meq/100g	H_2O 15 bar
Brown Andosols	43,770	0.5-1.5	2-10	5.5-6.5	3-8	15-40	10-40	30-60
Organic Andosols	8,600	0.5-5	5-30	4.5-5.5	>2	?	30-60	60-120
Vitric Andosols	18,600	0.2-0.5	0.5-1.5	6.5-7.0	1-2	5-15	5-15	5-15
Leptosols‡	4,540							
Sandy Andosols†	15,090	0-2	0.2-2	6.5-7.0	0.3-0.8	1-5	2-10	1-10

‡ No data available

† Area (km^2) includes both Sandy Andosols and Sandy Andosols/Leptosol complex.

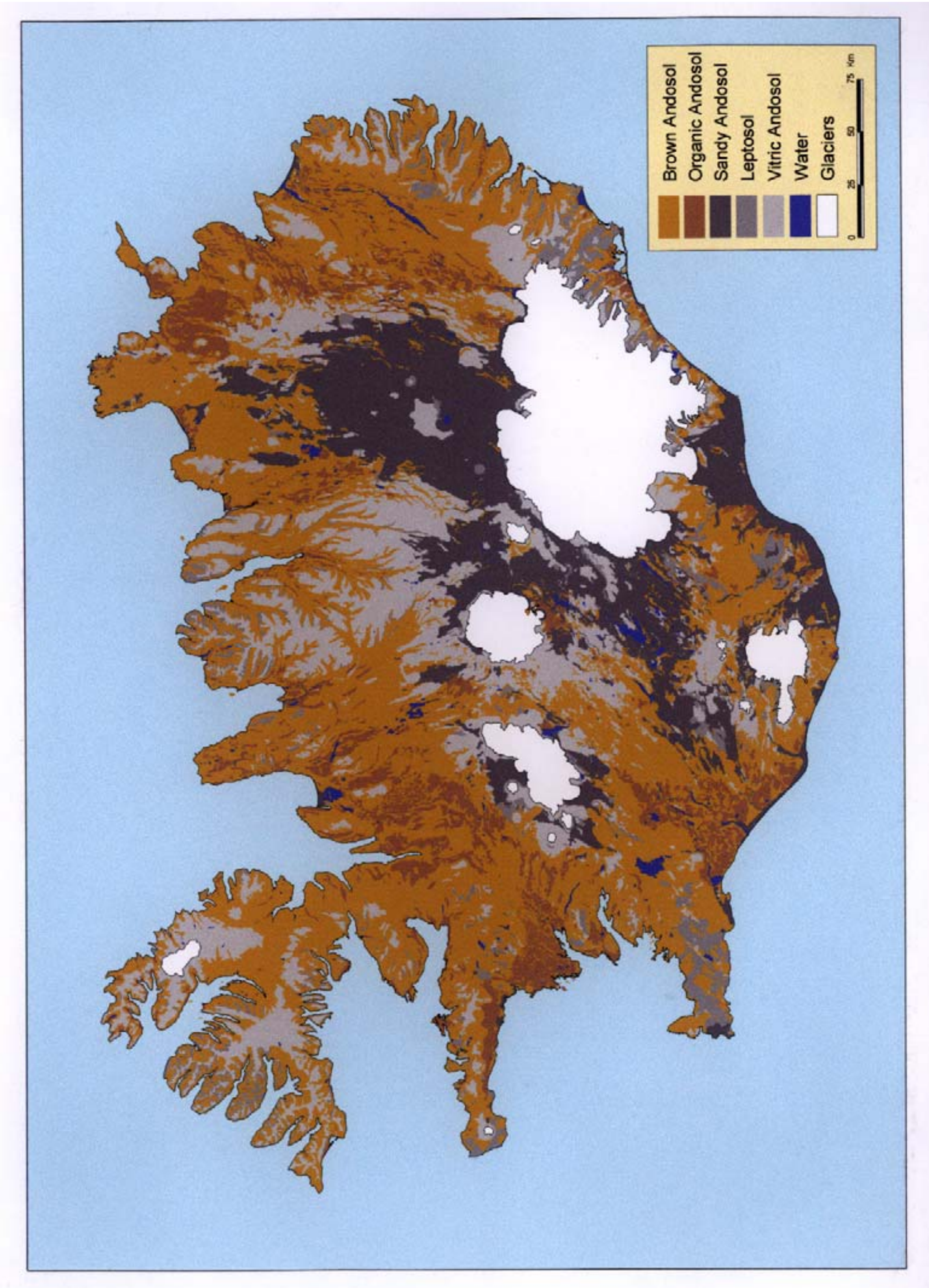

Figure 1: Soil map of Iceland at 1:500,000 scale.

The map was constructed using Arc/Info GIS software. The soil classes used in the map are as follows (note the class names are only suggestive at this stage and are subject to further development):

1. ***Brown Andosols***. These represent the typical Andosols of Iceland. They are usually freely drained and have developed in eolian and tephra materials that typically form a 80-200cm mantle that has accumulated over an older surface (usually glacial till or lava). They are rich in allophane clay minerals, and ferrihydrate, but volcanic glass is also in abundance near the most active volanoes. Distinctive volcanic ash layers are common.
2. ***Organic Andosols***. These soils are found at poorly drained sites (bogs and mires), and often grade into Histosols. They most likely classify as Histosols in areas furthest away from eolian sources. The Organic Andosols are typically 50-500cm thick with 5-30% C content. Volcanic ash layers are common.
3. ***Vitric Andosols (or Gravelly Andosols)***. These soils are desert soils poor in organic matter compared to the classes above. They meet the criterion for Andosols (and Andisols) because of abundance of volcanic glass materials and other andic characteristics. The Vitric Andosols grade into Regosols (away from eolian tephra sources) and Leptosols.
4. ***Leptosols.*** These soils are found on scree slopes, recent lava surfaces, and on lava surfaces where erosion processes have removed Brown or Organic Andosols from the top.
5. ***Sandy Andosols.*** Sandy surfaces are common in Iceland near glacial margins and on glacio-fluvial floodplains. Eolian processes have often carried sandy materials long distances from their sources, increasing the size of sandy areas. The sand is largely composed of volcanic glass.
6. ***Leptosol/Sandy Andosol complex.*** This is a special class as this combination is very common in Iceland. It occurs where there is an abundance of sand on lava surfaces (due to eolian processes and volcanic ash fall). The sand covers the depressions while bedrock (lava surface) sticks out where the surface rises.

Two other soil classes can readily be applied into this system, but can not be included on a map at such a coarse scale. These are ***Gleysols*** and ***Fluvic Andosols*** (which grade into Fluvisols, Gleysols and Regosols).

Andosols in Iceland cover all together about 80,000km^2 and therefore make up a substantial proportion of the Andosols in the world. The areal extent of Brown Andosols represents an overestimate for two reasons. One is that desert areas /patches are common within areas dominated by the Brown Andosols. The second is that the land classification system used includes some areas within this class where the soils are too shallow to meet the criteria for Andisol/Andosol. At this point, it is not possible to account for this error.

The three desert soil classes dominate about 38,000km^2, (actual extent is somewhat larger for the reason given above). They have vast potential for carbon sequestration associated with ecosystem restoration (Arnalds *et al.* 1999). No data is available for the Leptosols yet.

National Soil Erosion Database

Soil erosion and degradation has been a major problem in Iceland since the arrival of man about 1,100 years ago. The extent and severity of soil erosion in Iceland has been mapped at a scale of 1:100,000, by the Agricultural Research Institute and the Icelandic Soil Conservation Service. Erosion processes in Iceland are extremely varied and conventional methods designed for estimating erosion in cultivated areas are of little use.

The erosion assessment is based on classification of erosion forms that can be identified in the landscape (Arnalds *et al.*, 1997). The ARI-SCS erosion database is made of about 18,000 polygons. Each polygon is characterised by one or more erosion forms. Erosion severity for each of the erosion forms was estimated on a scale from zero to five, five being considered extremely severe erosion (Table 2).

The overall results indicate the severity of erosion in Iceland, the scale of which is comparable only to very degraded, arid areas of the world. The combined total of considerable to very severe erosion is >50% of the country when high mountains and glaciers have been excluded. Much of this severe erosion occurs within the deserts, but severe erosion is also degrading large tracts of the remaining vegetated areas (see Arnalds *et al.*, 1997; Arnalds, 1999b).

Soil erosion continues to be monitored and mapped by the Icelandic SCS, in areas where it is most severe, but now at a larger scale (1:5,000 to 1:25,000).

Table 2. Overview of soil erosion in Iceland.

Erosion severity/map units	Km^2	% Iceland	$\%^*$
0 No erosion	4,148	4	5.2
1 Slight erosion	7,466	7	9.4
2 Moderate erosion	26,698	26	33.7
3 Considerable erosion	23,106	23	29.2
4 Severe erosion	11,332	11	14.3
5 Very severe erosion	6,375	6	8.1
High mountains	9,794	10	
Glaciers	11,361	11	
Waters	1,436	1.4	
Other	1,010	1	
TOTAL	102,721		100

*: High mountains, glaciers, waters and 'other' excluded.

Vegetation Mapping

Although detailed soil maps have not been made for Iceland, much effort has been made to make vegetation maps. It was concluded around 1960 that vegetation maps would give more information about Icelandic nature than would soil maps, bearing in mind the major use of the land for grazing. It was expected that each of the vegetation mapping elements reveal information on the underlying soils.

Mapping of the vegetation was conducted by the Agricultural Research Institute but the programme has recently been relocated at the Institute of Natural History. Vegetation mapping has been completed for about 2/3 of the country at a scale of 1:40,000 in the highlands and 1:25,000 in lowland areas. Icelandic vegetation was split up into five major categories where drainage is the most influential factor.

These categories are divided into 14 associations and about 100 mapping elements. Deserts are mapped separately. The methods were described in detail in a special issue of the Journal of Agricultural Research in Iceland (Thorsteinsson, 1982). Much of this data has been digitised and the Institute of Natural History has recently published a new vegetation map for all of Iceland in the scale of 1:500,000.

Outlook

A central database for Icelandic soils is being established. The main use for soil data is related to soil fertility for hay production. Detailed soil research has also provided fundamental understanding to explain why the soils are extremely vulnerable to erosion. The national erosion database is used for various purposes such as land use planning, reclamation strategies, and policy-making.

Soil science is still a young science in Iceland. Few Icelandic scientists have higher degrees in soil science. This is reflected in all too sparse research efforts. The Agricultural Research Institute has plans to increase its current research on the formation and basic properties of Icelandic soils.

Currently, there is no systematic monitoring of soil fertility and quality, but plans have been made for such activities. Mapping of soil resources will become more important with increased emphasis on GIS databases for land capability assessment and land use planning in Iceland. Improved basic understanding of soil behaviour will also become important in the near future for maintaining soil quality and for monitoring pollution.

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Application of Soils Data to Land Use and Environmental Problems in Ireland

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Introduction

The National Soil Survey of Ireland was established within the Agricultural Institute in 1959. This marked the first real attempt to survey, classify and map the soil resources of Ireland in a systematic manner. From the beginning, modern scientific methods were used to classify the soils but emphasis was also placed on the interpretation of the results for agricultural development in particular and for land use planning in general.

The basic programme of land resource appraisal in Ireland has operated at three levels of organisation:

1. Detailed studies of experimental stations and also extension experimental sites (at 1:2,500 scale).
2. Detailed reconnaissance studies of counties (at 1: 126,720 scale) where the soil series is the unit of mapping.
3. A combination of detailed reconnaissance and general reconnaissance to derive a national picture, the General Soil Map of Ireland in 1969, at a scale of 1:575,000. The soil association is the unit of mapping.

The major emphasis in the soil survey programme was directed to detailed reconnaissance on a county basis. Soil mapping was carried out on maps of 1:10,560 scale, which were reduced to 1: 126,720 for publication (Lee, 1991).

Soil Mapping

Progress

Some 44 % of the country has been surveyed and mapped to date (Figure 1). Complete reports on nine out of twenty six counties have been published together with reports on a number of regions and districts. Fieldwork has also been completed in three counties, and also some work has been conducted in several other counties. Publications can be grouped into County Surveys, An Foras Taluntais (Agricultural Institute) Farms, Department of Agriculture Farms, other farms and miscellaneous areas.

The first Generalised Soil Map of Ireland was published in 1969 but the information for many areas was not very reliable. A 10-year programme was then started, the aim being to produce an improved version at the end of that period. This was achieved in 1980 with the publication of a second edition of the Generalised Soil Map (at 1:575,000 scale) together with an explanatory bulletin. A Peatland Map of the country together with an explanatory bulletin was published in 1979, at the same scale. In December 1988 a decision was taken to discontinue the field programme (Coulter *et al.*, 1996a).

Soil Database

The research programme at Johnstown Research Centre changed in 1988 from one that was mainly concerned with soils and land use to one mainly relating to environment and land use. A Soil Survey GIS programme was initiated in 1988 with a view to capturing existing soil maps in digital form to facilitate the environmental brief, and so that geocoded data collected in environmental surveys and experiments could be related to soil survey data.

ARC/INFO was chosen as the most appropriate GIS software because of its widespread use within soil research institutes in the European Communities, and because of its native Dbase data management system was most compatible with information technology standards in research centre. The programme involved digitisation of existing soil survey and related maps, creating databases of soil information and linking the digital maps and databases.

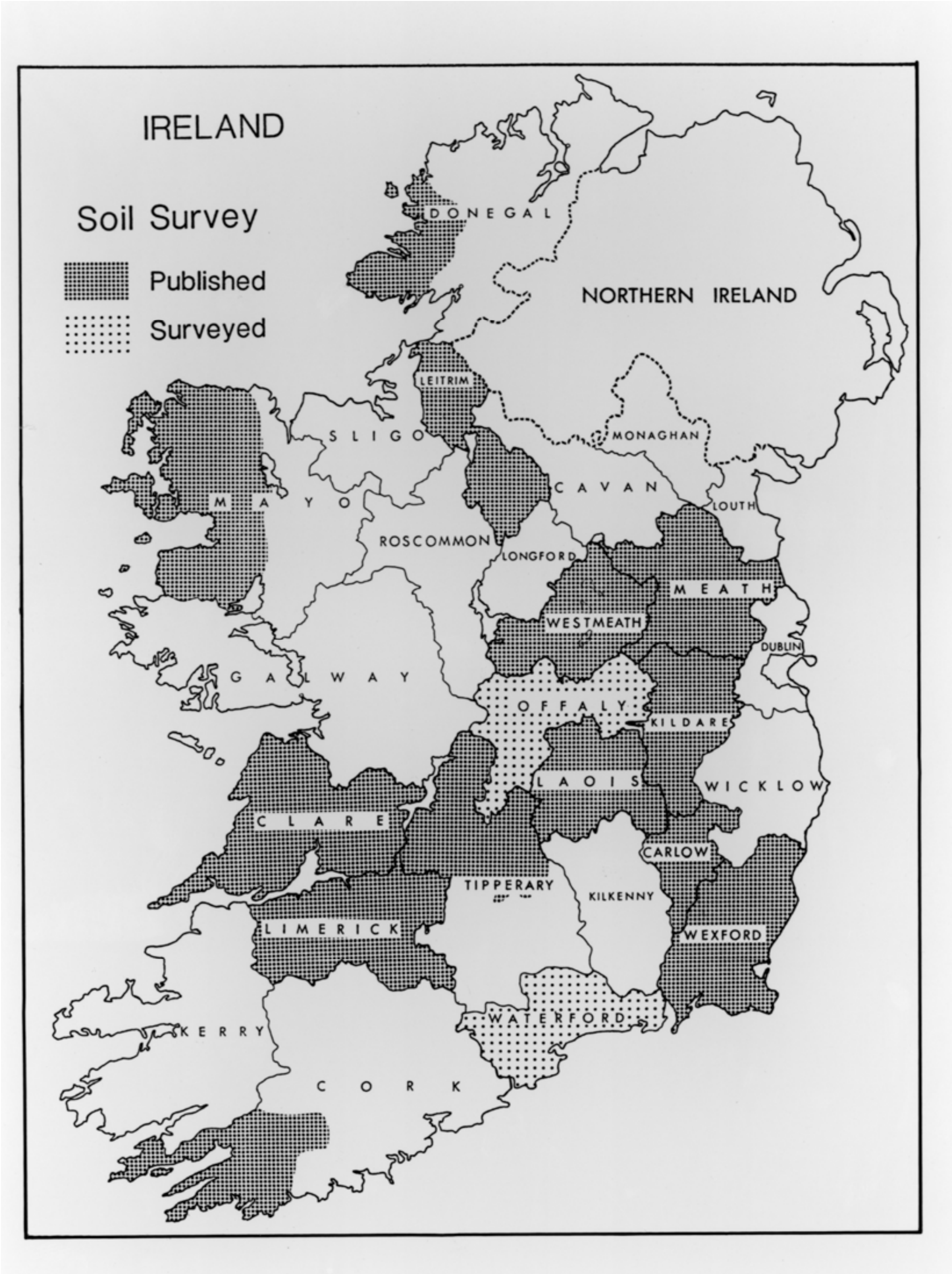

Figure 1: Progress of Soil Survey in Ireland.

The General Soil Map of Ireland published in 1980 at a scale of 1:575,000 (Gardiner and Radford, 1980a, 1980b) has been digitised, and a soil information base constructed. An earlier version of the General Soil Map of 1972 is also available in digital form from the EEA Task Force (CORINE) as part of the Digital Soil Map of Europe (Platou *et al.*, 1989) which was designed for printing at a scale of 1:1,000,000.

Applications of Soil Data

Soil Suitability for Waste Disposal

Quantitative assessments of soil hydrological regimes are required to reduce the risks in the design and management of waste disposal systems. Current research (Diamond, 1997) aims to measure the soil hydrological regime at selected benchmark sites and to examine the relationship with soil morphological characteristics, e.g gleying, texture, structure.

Differences between soil series are evident, particularly in respect to poorly drained soil series. The results for these series imply a high run-off risk compared to the free draining soils in which the risk is negligible. This has serious implications for environmental risk management. The research has direct application to developing codes of good practice to minimise run-off of phosphorus from farmland, which has a significant capacity for water pollution.

Land Use Management

Ground water vulnerability maps have been derived from the digitised General Soil Map of Ireland and combined with data on diffuse sources of nitrogen (N) to provide a composite ground water nitrate pollution risk map for the country. Using GIS techniques, a methodological procedure has been developed to predict nitrogen from animal manures and chemical fertilisers and release by mineraliosation of organic matter of cultivated soils (Coulter *et al.*, 1996b).

The aim of the research was to develop a computer-based system incorporating land use trends, soil characteristics, topography, fertiliser usuage and major and minor nutrient levels, for use in monitoring and predicting those areas vulnerable to environmental pollution and to provide a basis for land use decision making. The initial phase of the research has concentrated on nitrogen/environment interaction and N inputs from livestock manures, chemical fertilisers and release by mineralisation of organic matter.

Uncultivated soils were considered to be the most significant sources of N with potential risk of losses to groundwater. A six-category system of susceptibility to ground water pollution was elaborated for the country. The most vulnerable areas were shown to be located in the south and east.

Areas of varying sensitivity of groundwater pollution from N have thus been defined. Similarly, there has been ongoing research to determine the susceptibility to phosphorus losses from farmland.. This information in turn has been important in the Nutrient Management Planning at farm level through the involvement of the advisory service. The research has also helped to identify those areas where monitoring of water should be concentrated.

Geochemical Survey

To date 295 soil monitoring points have been identified, in the south-eastern part of the country, representing 22% of the land surface of the country, and soil samples collected and archived. The soils have been analysed for agronomically important soil parameters and for a wide range of environmentally sensitive heavy metals and related elements including arsenic, cadmium, chromium, cobalt, copper, lead, manganese, mercury, nickel, selenium and zinc. In addition the soils have been analysed for persistent organic chemicals including organo-chlorines insecticide and PCB residues. The results have been statistically analysed to determine means and frequency distributions, and maps produced showing spatial distribution of each of the measured components (McGrath, 1996).

It is anticipated that the information generated will be of use in the following areas:

1. ***Food:*** in the establishment of a credible database to assess and serve as a basis for the promotion of the cleanliness of food.
2. *Health:* to identify locations where there are excesses of heavy metals, in particular, cadmium and mercury, which can have negative effects on food quality and to delineate areas where there may be an excess of elements such as molybdenum and selenium, or a deficiency of copper, selenium and cobalt with deleterious effects on grazing livestock.
3. *Baseline information and waste disposal:* to provide the background information required for the evaluation of baseline surveys or for the disposal of wastes (eg. Sewage sludge) to soil.

Major and Trace Elements in Soils

Coulter *et al.* (1997) produced a National Report on the concentrations of major and trace elements in Irish soils which contains a series of distribution maps of such elements. The following are included: lime requirement (LR), potassium (K), copper (Cu), molybdenum (Mo), cobalt/total manganese (Co/Mn), zinc (Zn) and iodine(I). The Report includes both national and county maps showing element status averaged within 10 km^2 squares according to the national grid. The maps included were constructed from data collected between 1989 and 1995. The Report and maps have important practical applications for Extension Farm Advisers.

Other Applications

These have been described by Lee (1991) and are summarised below:

1. *Agricultural Land Classification:* A national map of livestock grazing capacity at a scale of 1: 575,000 has been produced together with a number of county maps at a scale of 1:126,720 of grass and cultivation suitability and grazing capacity. These have provided an invaluable base for planning land use production targets.
2. *Soil fertility research:* The Soil Survey has provided a framework for soil fertility research through the rational selection of benchmark study sites and the extrapolation of findings on nutrient responses to analogous areas. It also provides an important basis for delineating areas of trace element deficiency and toxicity with respect to plant and ruminant production.
3. *Regional planning and development:* Soil maps have been used to establish agricultural production capacity targets for planning purposes and for general land use strategy development. Examples include Strategy Development Studies for the South-West, North-East and Midland Regions and also the Leitrim, West Cork and West Donegal Resource Surveys.
4. *Afforestation:* A national generalised map of forest potential at a scale of 1: 575,000 has been produced as also have more detailed assessments at 1: 126,720 scale. These maps have been invaluable for land planning for forestry in Ireland.
5. *Drainage and reclamation:* The work of the Soil Survey has provided important information relevant to drainage design, such as depth and spacing of field drains and on the suitability of different drainage and reclamation techniques.
6. Disadvantaged Areas: The soil maps have been used to delineate difficult land areas qualifying for inclusion under the EC Disadvantaged Areas Directive.

The Future

Looking to the future, one of the main aims in Ireland is to continue the existing research programmes to establish a land information system based on soil, climatic, land use and agronomic data. This will provide better organisation and evaluation of available data for planning. It will aid decision making in the context of resource use and improve management at regional and farm levels, leading to improved technical efficiences.

The land information system will allow the development of a framework for modelling land use, waste management and fertiliser use systems based on a number of information technology modules. Generally the system will facilitate the effective transfer of information from research to a wide range of users.

The Need to Revive Soil Survey

Traditionally, soil survey in the Republic of Ireland has emphasised the genetic development of soils. The modern demand is for applied soil survey information gathered in a cost effective way to establish and manage targets. The chemistry of the soils in relation to phosphorus fixation and mobility and the use of models to predict soil moisture, leaching and seepage are obvious applications. These require a knowledge of fundamental soil properties such as mineralogy, soil moisture characteristics, permeability, etc. The traditional texture classification for fine grained soils must be supplemented by plasticity data.

Because in the course of soil survey some fundamental and dynamic properties of soil have been measured, the expected behaviour of soils under a range of management practices could be modelled. To complete this work would underpin public confidence in soil technology and in Teagasc as a provider of high quality reliable scientific data with a multi-purpose use.

Forest Soils Classification and Productivity

A major new project (Bulfin, 1998) has commenced with the following objectives:

1. To develop on a national basis a digital forestry soil classification and productivity ranking.
2. To provide the necessary soils information to the Indicative Forest Strategy, used by the Forestry Service in guiding the location and character of new afforestation at county, regional and national level.

GIS and remotely sensed data from digital air photography, Land Parcel Identification System, Digital Elevation Modelling and Drift Geology will be used to create Landscape Units with unique suites of soil. Existing soils information will be used to ‘train’ the satellite imagery procedures. The process will allow transfer from full soil mapping into areas with little soils information.

Environmental Risk Assessment for Agriculture

Due to production inefficiencies that all industries experience, agricultural practices can also adversely affect environmental quality. The probability, or relative risk, that these adverse impacts will occur is determined by a complex interaction among many factors, over some of which the farmer has little or no control.

Up to now there has been no rational procedure in Ireland to assess these interactions in a way that could provide advice to farmers, local authorities, and others for preventing or minimising the adverse effects of farming at specific locations.

New research at Johnstown Castle is directed towards changing this situation by developing a ranking procedure based on relatively easy to determine physical landscape features, farming practices, soils, land cover, weather and water resource network. The procedure incorporates topographical, hydrological, and soil type factors in addition to controllable factors such as levels of nutrient usuage, timing and method of nutrient application. An adequate soil database will be an essential prerequisite to the development of the system.

The Hill Environment

Due mainly to climatic and topographic factors, 85% of the hill and mountain soils of the west of Ireland are susceptible to erosion if overstocked. Low-level blanket peat is also susceptible to erosion. Approximately 23% of the total Irish sheep population of 8.5 million are in the hill sheep system. Research is required to ensure the economic sustainability of livestock production without detriment to the soil resource.

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Soil Mapping and Soil Monitoring: State of Progress and Use in Italy

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Institutional Framework

At national level, numerous institutions are active in the many fields involving soil information issues, for example: Ministries of Agriculture and Environment, Agency for Environment Protection and Technical Services, university soil science departments, Experimental Institute for Soil Study and Conservation, centres of the National Research Council, as CNR-IRPI). The National Committee for Soil and Soil Quality Observatory, which works within the General Directorate for Rural Development of the Ministry of Agriculture, 'deals with proposals for a system of national and regional soil services, in order to preserve and increase the productivity of agro-forestry soils'. However, an administrative body that ensures the co-ordination of soil mapping and monitoring programmes in Italy, and deals with the multiple functions of soil resources, is not clearly identifiable.

It is mainly at regional level - Italy has twenty administrative Regions - that soil survey staff are operating as centres for soil surveying, mapping and for information system implementation. Furthermore the Regions provide for broad interdisciplinary use (e.g. for application purposes) and dissemination of soil information. In cooperation with the different national institutions, staff in the Regions are also involved in the inter-regional harmonisation of soil information and of developing criteria for a great variety of applications. The different Regional Administrations employ from one or two up to about ten soil scientists who cooperate with professionals, private companies, research and experimental institutions and universities.

Soil Mapping and Georeferenced Databases

Background

Since the mid-1960s, when the Committee for the Soil Map of Italy produced a 1:1,000,000 scale soil map of the entire country (Mancini, 1966; revised in 1985 for the EC Soil Map), no national survey programme existed until 1998-1999. During that time, a programme to construct a Soil Map of Italy at 1:250,000 scale began. Previously, no coordinated surveys had been performed by different institutions, at different scales and with different purposes. Many Regional Administrations had started systematic soil survey programmes, mainly at scale 1:50,000, in the 1980s, and some of them had almost succeeded in covering the whole regional territory of agricultural interest (mainly plain and hilly territory).

However, for the most part, the information gathered was characterized by broad concepts, which were a consequence of the direct or indirect links with the school of soil science of the University of Florence (Mr. Mancini). Soil maps and profile descriptions were seldom printed or accessible, and had yet to be introduced into databases (Costantini *et al.*, 1999).

Programmes aimed at achieving national coherence

Over the last five years, soil survey activities, as well as soil mapping and building soil databases, have significantly increased. This has been mainly aimed at supporting European and national policies, through coherence of databases at the different levels - regional, national and European.

In 1998-1999 several programmes at 1:250,000 scale started:

- 'Ecopedological map of Italy' (Rusko *et al.*, 2003): carried out by European Soil Bureau on behalf of the Italian Ministry of Environment between 1998 and 2001 (http://www.atlanteitaliano.it/); at present it remains the only exhaustive national coverage available at 1:250,000 scale;
- 'Soil Map of Italy': carried out by the regional soil survey teams; reference at national level: Ministry of Agriculture (http://web.tiscali.it/no-redirect-tiscali/adanto/forum/ardoc.htm); work started in 1999; 1st version now available for about ten Regions;
- 'Pedological Methodologies' for the Soil Map of Italy: coordinated by the Experimental Institute for Soil Study and Conservation (http://www.soilmaps.it/); work started in 1999 and ended in 2002.

In order to reduce the overlapping of activities and the duplication of efforts, specific agreements were signed among most of the institutions involved. The Italian version of the Manual of Procedures (Version 1.1) for the new Georeferenced Soil Database of Europe (ESB, 1999) had been just published and it was used as a common reference framework for the three projects. The basic assumption has been that the Italian soil databases must be implemented through a series of approximations which correspond to subsequent quality levels (Figure 1); instead of aiming at a theoretically 'perfect' soil map and database, the efforts are focussed on taking into account urgent matters and priorities for practical purposes and soil data applications.

Ecopedological Map of Italy

The 'Ecopedological Map of Italy' can therefore be conceived as the 1st approximation of the 1:250,000 scale soil database of Italy; its main purposes were to assess soil erosion risk (Van der Knijff et al., 1999, 2002) and to analyse the relationship between soil and vegetation. Only a few of the mandatory attributes requested by the European Manual of Procedures were supplied (e.g. attributes describing soil mapping units are: major landform, regional slope, altitude, dominant slope, land use and parent material; attributes describing soil typological units are: WRB classification and, only for agricultural soils, topsoil texture, topsoil stone/gravel abundance, depth to obstacle for roots, water retention capacity of the rootable depth).

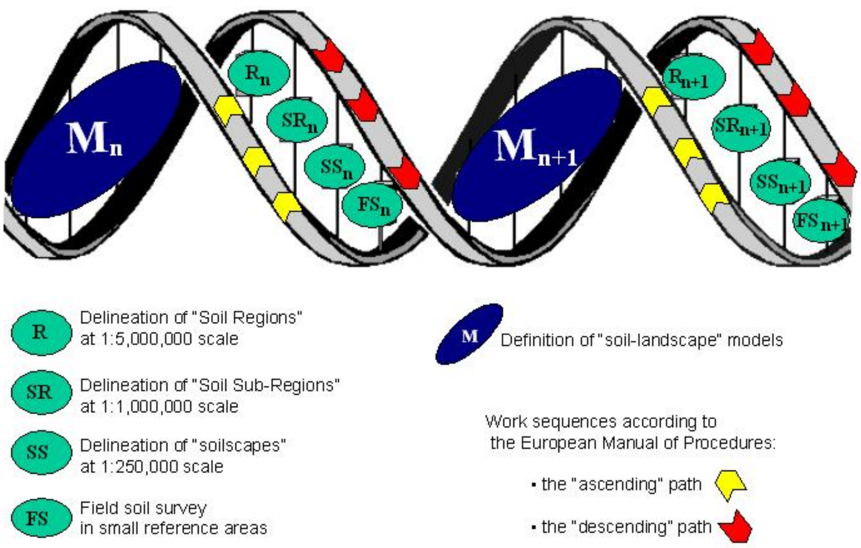

Figure 1: The implementation of the Italian soil databases at 1:250,000 scale has been performed along a 'helix' process through a series of approximations

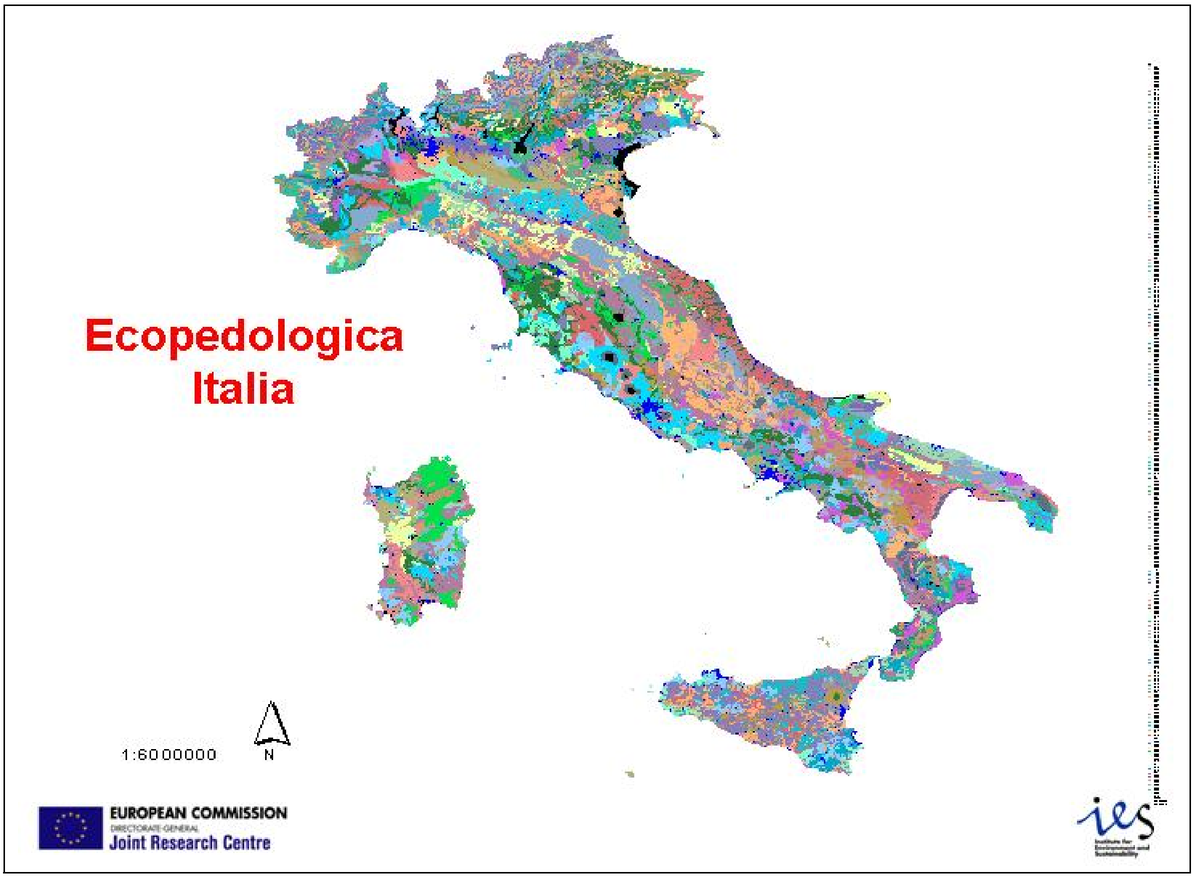

Figure 2: 1st approximation of the 1:250,000 scale soil database of Italy: the 'Ecopedological Map' (Rusco *et al*., 2003)

Soil mapping unit delineation and description were based on both screening, aggregation and use of existing data, and elaboration of the digital elevation model, satellite images, geological and land cover maps, with a minimum of integration with field soil survey (Figure 2).

Soil Map of Italy

The increase in the specificity and the accuracy of the information that is being made available in the 2nd approximation of the 1:250,000 scale soil database of Italy (i.e. 'Soil Map of Italy') is so relevant that it would be appropriate to consider this one as a new database, instead of an updated version that incorporates new elements of knowledge from the former one. Field soil survey enabled soil scientists to define, for each 'land system' or 'great soilscape', specific 'soil-landscape' models, to predict the spatial arrangements of soil typological units from landscape features (i.e. to extrapolate point data to areas); landscape features (e.g. parent material, morphometry, land cover, etc.) were locally classified according to their relevancy to locally predict the spatial arrangements of soils.

In the main, an integration of traditional and relatively new soil mapping techniques was used. For example, to analyse the morphometry in the Alps of the Veneto Region, using a 30m digital elevation model, an unsupervised fuzzy clustering technique was applied, classifying data on elevation, flow accumulation, slope gradient, plan and profile slope curvature. The resulting classifications were mainly used to check delineation boundaries, the 'traditional' delineation approach, by aerial photo interpretation, being considered more effective (Figure 3) due also to the necessary synthesis process when working at such small scales. For each 'Soil Sub-Region' relationships between soil forming factors and soil types were laid out in tables, describing the present understanding of the soil spatial organization models (Vinci *et al*., 2003).

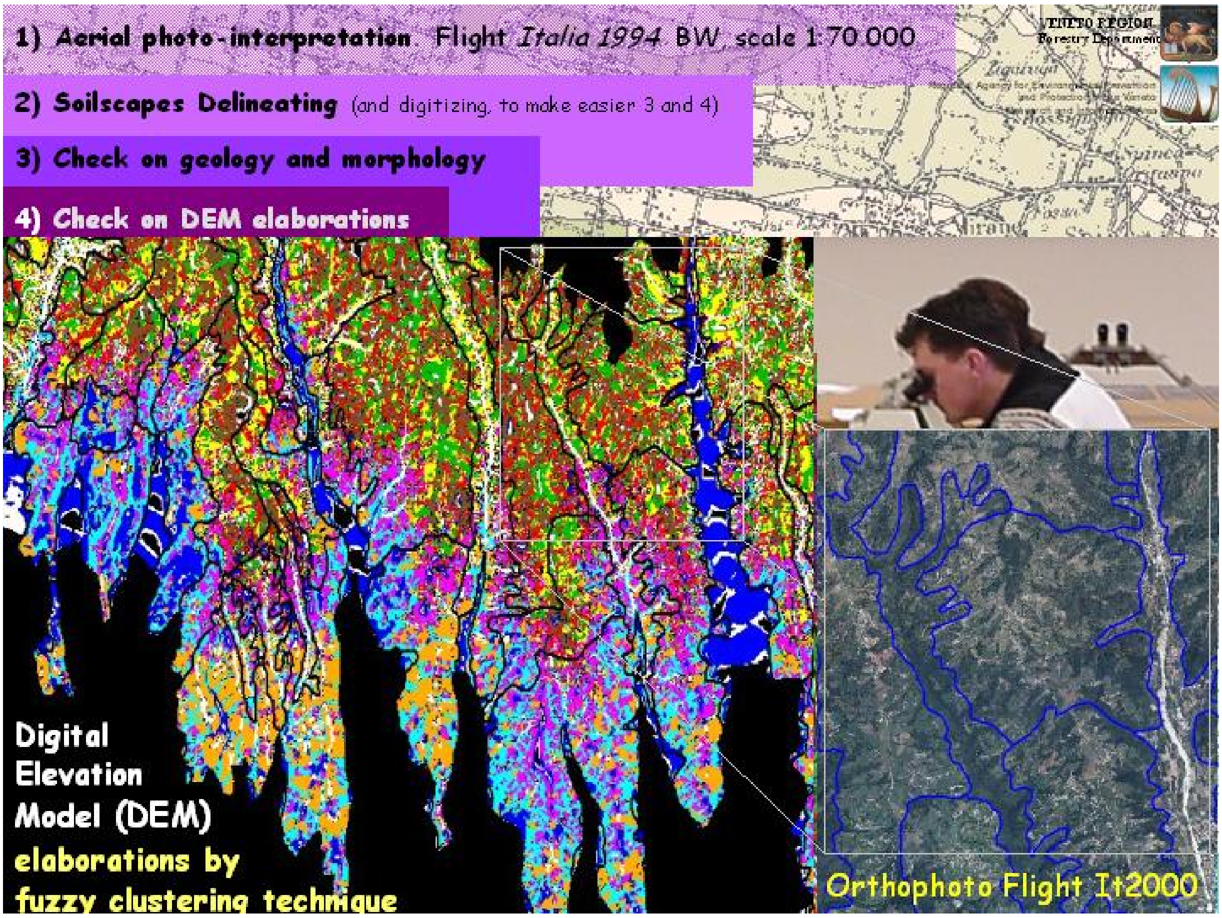

Figure 3: For pre-zoning in different 'soilscapes', the 'traditional' way of working was integrated with relatively new soil mapping techniques

Compared with the attributes requested by the Manual of Procedures for the new Georeferenced Soil Database of Europe, in the 'Soil Map of Italy' supplementary criteria have been used to describe and to differentiate soil typological units and soil mapping units.

However, as in the 'Ecopedological Map of Italy', efforts have been made to ensure as accurately as possible the coherence with formats of the European Manual.

Pedological Methodologies

Even if the work for the 'Ecopedological Map of Italy' and 'Soil Map of Italy' had to start before or at the same time as the programme on 'Pedological Methodologies' for the Soil Map of Italy, relevant inconsistencies were avoided by co-operation between the programmes and the institutions involved.

Because of the different possibilities of co-operating, the different documents that have been produced by this programme are not shared alike with the various regional soil survey staff. For example, a Soil Survey Manual was produced within the 'Pedological Methodologies' programme. Afterwards, several regions developed their own guidelines, in order to take into account regional specificities. These local guidelines are consistent but do not match the generalSoil Survey Manual perfectly.

Similarly, the implementation of different regional soil databases, that have to be integrated with their regional information systems, have been aimed at consistency with the National and European ones.

Some examples of the results obtained (see http://www.soilmaps.it/) can be found in the following documents:

- 'Descending' work sequence for soilscape pre-zoning (June 2000);
- Soil Survey Manual (2000);
- Criteria for making the Soil Map of Italy at 1:250,000 (July 2000);
- Italian Soil Regions Database (2001);

- Methodologies for soil information dissemination (June 2001);
- A land system database of Italy (2003);
- CNCP2002 Software: soil database for storing and managing point data and soil typological units (June 2003).

Soil Monitoring

Following the indications coming from the European Environment Agency in 2001 and from the Soil Thematic Strategy Technical Working Group on Monitoring, the Italian National Topic Centre (NTC) on Soil and Terrestrial Environment, promoted by the Italian Environmental Protection Agency together with some Regional EPA, conceived a project for a national soil monitoring network (SMN).

The proposal points out that to set out a reliable soil monitoring network there are four fundamental layers of information to be considered:

- Land use (e.g. derived by means of remote sensing);
- Soil typological units and their spatial distribution, as represented in soil maps;
- Results of widespread monitoring data on organic and inorganic contaminants, together with some basic soil characteristics such as pH, organic carbon, CEC;
- Results of monitoring on pressure-impact relationship in some representative sites to increase information about soil degradation processes.

Site selection is the first issue in order to build the soil-monitoring network; the NTC points out two parallel and complementary approaches based on the type of degradation:

- Systematic investigation on a regular grid: in order to give representative data requires a large number of sites, and the number of parameters to measure has to be limited because of high costs; it is more suited for monitoring inorganic and organic pollutant contamination;
- Typological approach based on stratification of soils according to land use and soil type; this is more appropriate for monitoring soil degradation processes (e.g. erosion, organic carbon losses, nitrates and pesticides leaching, etc.) in sensitive areas, but it is feasible to be performed only at a few representative sites.

The application of the typological approach has to take into account the information that is available. As outlined by the NTC guidelines, evaluation of the representativity of monitoring sites has to be considered according to:

- Soil types referred to different pedo-landscapes;
- Main types of land use;
- Combination of soil type and land use;
- Different soil degradation processes and different exposure to contamination.

In particular, for the soil type the following issues have to be considered:

- Soil functional behaviour with regard to main degradation and contamination processes;
- Taxonomic classification (USDA Soil Taxonomy and FAO-WRB) trying to group together similar soil types as result of pedogenetic factors (e.g. parent material);
- Relationship between soil and landscape and between soil and climate, that influence soil functions.

The NTC proposal defines the national key sites, to be used as reference for the national monitoring network and the validation of methodologies, and the reference sites, to be used for the deepening at regional level, that could be also identified as specialist sites when used for the monitoring of one or more specific threats.

Key National sites should number from 1 to 4 for each of 20 Italian regions giving a total of 55 sites, backed up by from 4-37 reference sites per region, giving a total of 429 sites. In this way, the grand total of sites is about 480, giving a density of 1 site for per 625km^2, and this is deemed adequate for a 1:250,000 scale national-European level.

Interregional Harmonisation of Soil Information

According to the European Manual of Procedures, Soil Typological Units (STU) and Soil Mapping Units (SMU), with their underlying Soil-Landscape models, should be rationalised within large ‘natural’ regional units. These units, called ‘Soil Regions’, have similar geologic, morphologic and climatic factors that were responsible for the differentiation of soils. According to tests performed in Italy (Figure 4), the ‘Soil Region’ approach has proved to be a good framework. However, the synchronization of the activities of the different staff is needed. Given their present organization, this approach is realistic only in the long-term. Therefore, according to the principles of the Proposal for a Directive of the European Parliament and of the Council, on establishing an infrastructure for spatial information in the Community (INSPIRE, COM/2004/516/FINAL), a common European Grid Reference System for Reporting and Statistical Analysis is adopted in pilot projects. The grid system is easy to manipulate, hierarchical and based on same area units.

As far as analytical methods are concerned, official Italian standard methods for chemical and physical soil analyses are in existence and applied accordingly. They do not closely correspond to the ISO-formats that are requested by the Manual of Procedures for the new Georeferenced Soil Database of Europe. Among the current intra and inter-laboratory activities for quality control and assurance (QC/QA), a preliminary work for correlation between national and ISO-methods has been done; however further development is necessary to derive a sufficiently accurate correlation procedure.

Use of Existing Data

To support European, national and local policies, a wide range of applications have been carried out, by cooperating in the broad interdisciplinary use of soil information, in integration with other spatial information. Below are some examples of applications (Figure 5):

- Assessment of land capability and of suitability of land for different crops, grazing, forestry and horticulture;
- Assessment of hazards to the environment (e.g. in terms of nitrate leaching, pollution, desertification);
- Assessment of threats to soil (e.g. erosion (see Grimm et al., 2003), pollution, compaction, salinization; decline in organic matter);
- Assessment of water regimes in terms of drainage and irrigation requirements.

To describe pixels in terms of dominant soil information, each regional service can use its own data and models (e.g. local 'Soil Typological Units' and 'Soil-Landscape Models'); metadata (following ISO specifications) is being produced and regularly updated to describe each information layer related to each specific grid unit.

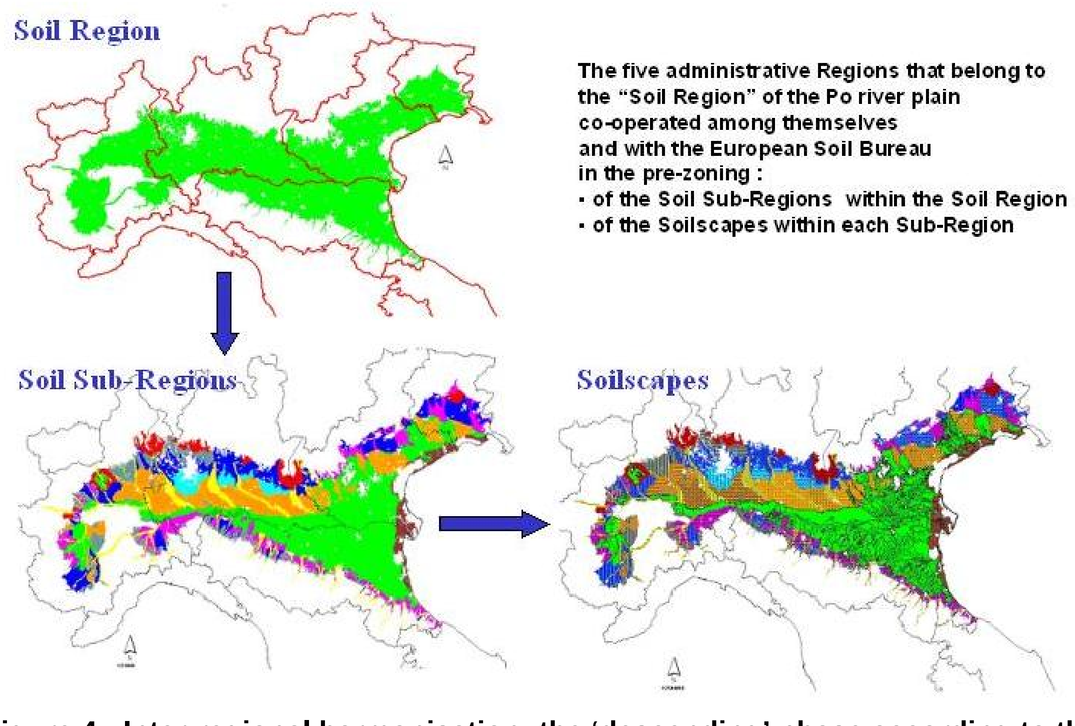

Figure 4: Inter-regional harmonisation: the 'descending' phase according to the 'Soil Region' approach (European 'Manual of Procedures')

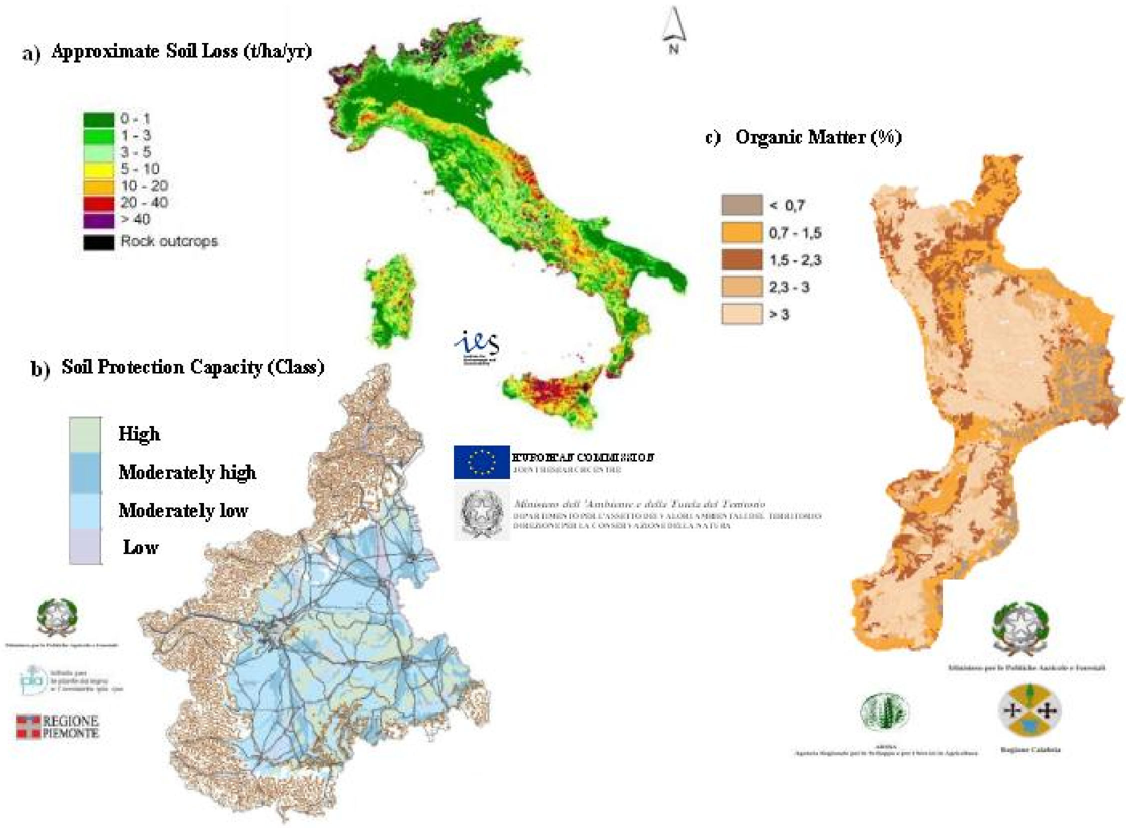

Figure 5: Current examples of application of the Italian georeferenced soil databases at 1:250,000 scale

Centring efforts on harmonising policy-relevant information is in this way more realistic in the short-term.

The geographical variability of soil and the close interface between soil status and local conditions require soil assessments to have a strong built-in local element. A bottom-up approach, by generalising local perceptions and evaluations of soil resources, is therefore envisaged.

Conclusions

The Italian system of national and regional services dealing with soil is not clearly structured. However, excessive duplication of effort and dispersion of activities are avoided because of the current level of co-operation amongst most of the institutions involved. The main advantage of the present organisation seems to be flexibility, so that practical results are achieved and adjusted to priorities.

In the short-term, the effectiveness of the Italian soil survey system should be checked on the application of the new Common Agricultural Policy and of the soon to be defined directive for soil protection. For each application, specific soil information should flow from regional soil surveys into national and European levels. This will facilitate both planning and carrying out of the actions concerned, and the monitoring of their results.

Both valorisation of local knowledge and consistency of information, at National and European level, are pursued. Instead of the homologation, the aim is coherence among methods and comparability of data and of the assessment outcome.

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Soil information in Latvia

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Introduction

The Republic of Latvia lies on the eastern coast of the Baltic Sea between 58° 05' - 55° 40' N in NS (extension: 210km) and 20° 58' E - 28° 14' E WE (extension: 450km) direction. The total area of Latvia is 64,589km^2 of which 62,046km^2 are land and 2,543km^2 inland-water. The length of the State boundary is 1,900km, of which 1,400km is on land, including 343km with Estonia in the north, 282km with the Russian Federation in the east, 167km with Belarus in the southeast and 567km with Lithuania in the south. The length of the coastline is 494km.

Latvia is located on the NW edge of the East European Plain that is characterized by slight variations in elevation. Relief of Latvia is characterized by low hypsography (0-312m above sea level - a.s.l.). About 44% of Latvia is at or below 80m a.s.l., 76% up to 120m and 24% above 120m a.s.l. Only 1.6% of the territory is located above 200m a.s.l. The average elevation is 87m a.s.l. The highest point is Gaizinkalns (312 a.s.l). The present day topography was mainly formed as a result of the Pleistocene glaciation, particularly the last Baltic (Weichselian) event. Despite the low hypsography, some parts of the uplands have remarkable relief.

Land resources of Latvia (2003) are as follows: agricultural land totals 2,474,400ha, including arable land - 1,832,200ha, permanent crops - 291,000ha, pastures and grasslands - 613,100ha; non-agricultural land totals 3,984,500ha, including forested land - 2,877,200ha (Agriculture in Latvia, 2003).

Soil research and the systematic collection of soil information in Latvia started in the late 1800s after the opening of Riga Polytechnical School (the first high school in Latvia). In the beginning, the main interest was inventory of agricultural soils, assessment of fertility and the development of criteria for fertilizer use.

The first soil fertility map was elaborated by Professor G. Thoms for the Polytechnical School's research farm, Peterhof (area 225ha), in 1880 (Barbalis, 1970).

The genetic approach of soil science was introduced by Professor J. Vitins, scholar and collaborator of Russian soil scientist K. Gedroits in the 1920s. Soil science moved through different periods with different intensity. The main areas of research and data applications were genesis and mapping of soil parent material and topsoil, soil chemical composition, soil classification, soil evaluation, soil improvement, degradation (especially erosion) control and soil fertility testing. Institutes involved in soil research and data processing also changed over the years. Currently the main institutions in soil research and knowledge transfer are the University of Latvia, Latvia University of Agriculture, the State Land Service and the Agrochemical Research Centre.

Soil Classification

Soil classification always had a special place in soil research in Latvia. It was a driving force for the investigations of fundamental soil processes and features in conjunction with the detailed inventory of Latvia's soil resources and the development of data applications.

The history of scientific soil classification started in 1927 when Prof. Janis Vitins grouped all the soils of Latvia into two major types: *mineral soils* and *organic soils*. For mineral soils four stages of development were separated: (1) Rendzinas, (2) Brown soils, (3) Slightly altered mineral soils, and (4) Strongly altered mineral soils. Organic soils were subdivided into three groups: (1) Water table on the level of soil surface, (2) Soils with shallow water table, and (3) Soils with deep water table but ponded by surface water.

The next scheme of soil classification was proposed by Prof. Karlis Krumins in 1930, with 4 major classification units (types) and 11 secondary classification units. Later, this classification was revised several times and became more detailed. All of these classifications were based on a genetic approach and soil genesis was the main factor for separating soils into classification units and assigning soil names.

A new official list of the agricultural land soil classification was introduced in 1981, which was used in the last soil survey. It consisted of 15 types (main categories) and 33 subtypes (second level) classification units. These soil classification units were also used as soil mapping units for soil survey at the scale 1:10,000, still the basis for soil maps that are in use in Latvia today.

Recently, the Soil Society of Latvia revised this scheme, and now the recommended list of soils consists of 12 types and 54 subtypes. The new scheme includes all soils of Latvia: in agriculture use, forest soils, soils strongly altered by man (anthropogenic), etc. The genetic approach is still used in this classification scheme, but some changes of horizon designations and definitions of diagnostic properties are moving it towards the FAO principles. For international communication, Soil Taxonomy, FAO Legend (1990) and WRB (1998) are accepted and used.

Soil Mapping

Soil mapping has rather a long history in Latvia. Activities leading to more systematic mapping of agricultural land started in 1930s when the government launched a programme for real estate evaluation after extensive land reform which took place in Latvia after World War I. Under this scheme the following soil maps were produced.

- Country level at scale 1:200,000;
- Regional level at scale 1:75,000;
- Farm level at scale 1:5,000.

Up to World War II, field mapping had been completed for only 6 out of 18 regions, and publication only for three regions. Based on these materials the first generalized soil maps of Latvia were published at the scale 1:400,000 in 1945 and 1958.

After World War II, all family farms were nationalized and merged into large state or collective farms (average size - about 5,000ha of agricultural land). Such a farming profile was characteristic for Latvia until 1990 when, due to social and economical changes, the private farms were re-established. Over this period, agricultural soil survey was performed three times and was carried out simultaneously with land evaluation (see Table1). The first cycle of agricultural soil survey in Latvia began in the 1950s and was completed in 1969. All agricultural soils were investigated and maps were made for every farm (state, collective, research, training, etc.), that was in operation at that time. Small land users in the rural areas (supplementary farms, cooperative orchards, recreation area, etc.) were included on the map of a neighboring large farm.

For every farm three different maps at the scale 1:10,000 were prepared:

- Map of soil types, subtypes and textural classes.
- Land use type (arable land, orchards, pastures, etc.) and land evaluation map.
- Soil water conditions and status.

The second soil mapping cycle was carried out from 1972 to 1976 when additional areas were included in agricultural production, due to the realisation of an extensive land reclamation programme in Latvia. This survey was carried out (mapping of new areas, corrections) only for those territories that were affected by reclamation activities. During 1981-91, a new more advanced soil survey programme was started. It was intended to cover all Latvia but was completed only for the farms of 10 administrative regions (out of a total of 26 regions) and then the activities were stopped because of economic constraints.

The soil mapping in the second cycle also covered only land in agricultural use. For every large farm the following materials were prepared.

- Soil survey, land use type and evaluation, analytical data print outs, calculations and characterization of technological properties of soil (water status, stoniness, relief, degree of cultivation, erosion intensity, slope);
- Soil map (scale 1:10,000). Soil types, subtypes; textural classification for topsoil and subsoil, depth to carbonates;
- Land evaluation map (scale 1:10,000). Land evaluation expressed in numbers (1-100), land suitability for cultivation of different crops (cereals, potatoes, sugar beet and/or flax); stoniness of the soil.

Forest soils and the soils in other non-agricultural use have not yet been mapped in Latvia at the 1:10,000 scale. In small-scale surveys, the extent of soils in forested land is usually determined based on the forest growing type.

Table 1: Large scale (1:10,000) soil mapping and agricultural land evaluation in Latvia

Administrative region	Soil mapping (field activities)			Renewal of Maps
	1st cycle	2nd cycle	3rd cycle	
Aizkraukles	1964-1966	1977	1989	-
Aluksnes	1960-1961	1977-1978	1985	1996
Balvu	1960-1961	1971; 1978	1987	1996-1997
Bauskas	1960; 1962; 1965	1976	1991	1999
Cesu	1966-1967	1978	1981-1983	1995-1996
Daugavpils	1962; 1966	1976-1978	1988	-
Dobeles	1965	1976	1990	-
Gulbenes	1959-1961	1979	1986	1996-1997
Jelgavas	1961-1967	1971; 1978	1990	-
Jekabpils	1965-1967; 1961	1975; 1978	1988	-
Kraslavas	1966-1969;1960	1977	-	1994
Kuldigas	1959-1960; 1964	1976	-	2001
Liepajas	1961; 1963-1964	1978	-	2001
Limbazu	1961-1962; 1966	1975; 1978	-	1995-1996
Ludzas	1961;1963;1968; 1972	1977	-	1995
Madonas	1963-1965	1976-1978	1989	1997-1999
Ogres	1964	1975-1976; 1978	-	1997
Preilu	1962; 1965-1966	1978	1986	1997-1998
Rezeknes	1959-1960; 1965-1966	1977	-	1994-1994
Rigas	1961-1963; 1966-1967	1978	-	1995-1996
Saldus	1960-1961; 1964	1972-1973; 1978	-	1999
Talsu	1964-1965	1975-1976	-	2000
Tukuma	1963-1964	1976	-	1999
Valkas	1961-1863	1974; 1978	1983-1984	1996
Valmieras	1961-1963	1973-1974; 1977	1987	1997
Ventspils	1961	1979	-	-

Notes:

Renewal of maps and land evaluation surveys - actualisation of information, redrawing of maps, part - digitisation.
Additionally at the end of the 1980s 11 administrative regions (Aizkraukles, Bauskas, Cesu, Preilu, Jekabpils, Limbazu, Ogres, Rigas, Tukuma, Valkas, Valmieras) were mapped at the scale of 1:100,000 (agricultural land and forests).

Parallel to soil survey, extensive soil fertility testing was done in Latvia in the post-War period, which included 5 cycles (coverages) of agricultural land for the whole country.

Based on the general soil map and the special scheme of soil sampling/analysis, Soil Fertility maps were produced which included information about the main topsoil (0-20cm) parameters: reaction (pH), organic matter, plant available phosphorus and potassium content. For some territories, more detailed information was prepared including micronutrient content of the soils. Systematic soil fertility mapping was also stopped in 1991 and now it is realized only for selected farms. Since 1991 there have been no more significant field activities for soil survey at the State level. Taking into consideration the new situation in the countryside and current need for soil-related information (farming, real estate evaluation, territory planning, economy planning, environment issues, etc.), the resurrection and renovation of old soil maps and survey reports is taking place and digital soil maps are being produced. The State Land Service is the responsible institution for these activities.

Besides detailed soil maps that are intended mostly for use at the local scale, some small-scale maps have also been prepared. The most recent is Soil Map of Latvia at the scale of 1:1,000,000, with accompanying Soil Profile Analytical database. It is a part of the Soil Geographic Database of Europe and Soil Profile Database of Europe and is more suitable for modeling and information supply purposes at the regional scale (European Soil Database on CD - ROM, 1999).

Geochemical Survey of Latvia

A geochemical survey of the country was performed by the State Geological Survey of Latvia at the scale of 1:500,000 in 1996-2000. Soil samples were collected from 10m × 10m areas located in the centre of 5km × 5km grids. Soil samples at each of 2,547 sampling points were taken from A (H, O) and C horizons.

Thirty seven chemical elements (Ag, Al, As, Au, B, Ba, Bi, Ca, Cd, Co, Cr, Cu, Fe, Ga, Hg, K, La, Mg, Mn, Mo, Na, Ni, P, Pb, S, Sb, Sc, Se, Sr, Te, Th, Ti, Tl, U, V, W, Zn) were determined by ICP-ES using extraction with hot (95°C) HNO_3+HCl+H_2O solution (24h digestion). Field activities, laboratory analysis and data processing has been completed but not yet published.

Soil Monitoring

More recently, monitoring programmes have become an integral part of environmental data collection and investigation. In 2002, the Government approved the new Monitoring Programme of Latvia, to cater for national needs and international agreements (including EU directives) for environment related information. Soil and its spatial and temporal changes is a segment in these research programmes.

Soil information, including chemical element concentrations, is a part of the Regional Programme for forest monitoring. Currently investigations are concentrated in two polygons (Taurene and Rucava) but it is planned to extend this number to six. Soil studies are also included in the framework of the Integrated Monitoring Programme, currently with two experimental polygons in forest ecosystems established in which, besides other factors, soil and soil water studies are conducted.

The most extensive land and soil related programme is the Agricultural Land Monitoring programme which is designed as an information base, including long-term observations regarding anthropogenic impact on agricultural land.. The programme is focused on the promotion of land conservation and the sustainable and economically reasonable use of land.

The Agricultural Land Monitoring programme is designed as a three-level integrated system, with different levels going on simultaneously. It has the following structure (Vucans *et al*, 1996, Karklins *et al*, 1998, Livmanis *et al*, 2002).

1st monitoring level: Long-term observations carried out since 1992 on the research plots set up permanently on the most representative soils, farming profile and climatic conditions of Latvia. The objective is to obtain reliable and integrated information about soil parameters (physical, chemical and biological properties, erosion, pollution), soil productivity and yield quality depending on soil management, fertilizer use, and farming profile for making recommendations to control anthropogenic impact on agricultural land. Observations were carried out on 12 research units covering 20 soil variations of Latvia (see Table 2).

2nd monitoring level: Agricultural land monitoring on sample farms. It is expected that the sample farms represent more common farming systems, soil and climatic conditions of Latvia. They were selected in cooperation with State Land Service, Department of Agriculture and Agricultural Advisory Centre. The monitoring activities are carried out by agreement between farm owner/operator and the State Land Service. The State Land Service has the responsibility for land evaluation, renewal of soil maps and periodic soil testing (every 3 years for intensive production farms and every 6 years for others).

Table 2: Parameters and regularity of monitoring (1st level)

Monitoring Objectives	Parameters	Frequency (years)	
		Minimum	Desirable
Chemical properties	Soil pH, available P and K Organic matter Exchangeable cations, CEC	every year 3 -	 every year 6
Physical properties	Bulk density	every year	
Biological status	Mesofauna Epigeic fauna	every year -	 every year
Pollution	Heavy metals: Pb, Cd, Ni, Cr, Zn, Cu	6	3
Yield	Crop productivity and quality Heavy metals in crops	every year every year	
Plant nutrient balance	Field data history Plant nutrient (NPK) balance in soil	every year every year	

Table 3: Parameters and frequency of monitoring on the sample farms (2nd level)

Monitoring Objectives	Parameters	Frequency (years)	
		Minimum	Desirable
Chemical properties	Soil pH, available P and K Organic matter	3 - 6 3 - 6	3 3
Physical properties	Bulk density (on heavy soils)	-	3 - 6
Pollution	Heavy metals: Pb, Cd, Ni, Cr, Zn, Cu	6	3
Plant nutrient balance	Field data history Plant nutrient (NPK) balance in soil	every year every year	

The soil test parameters include pH, organic matter, plant available phosphorus and potassium for all soil samples and micronutrients, heavy metals and soil physical properties for some selected areas (see Table 3).

The farmer's responsibility is to make a reliable field history for every field, which has been (or is planned to be) tested. Parameters, like crops grown, fertilizers and pesticides applied, soil management used, yield harvested, are included in these records.

Around 190 sample farms have participated in this programme. The total acreage of these farms is 8,911ha including 6,268ha of agricultural land. Almost all of them are family farms. The majority of the sample monitoring farms is participating in another programme coordinated by the Agricultural Advisory Centre - farm economic register and analysis. Integration of both programmes to support farming studies in Latvia has important advantages.

3rd monitoring level: Land use monitoring at the rural municipality level. These activities started in 1995 in all 512 rural municipalities of Latvia. This includes monitoring how land users are following state and municipality rules and regulations regarding land use and conservation. All agricultural land, including small holders' land, is designated under the auspices of the monitoring programme. The main issues to be monitored are as follows.

- Land use according to the title;
- Weed control by land user. Evaluation of weed invasion;
- Controlling whether one land user is diminishing another user's land quality and thereby restricting land use rights and interests;
- Controlling actions which might lead to land pollution with chemicals, household and production wastes;
- Controlling water management according to local regulations and interests of society;
- Soil conservation. Protection of soil humus when undertaking construction works;
- Dynamics of agricultural land acreage, soil quality and other changes with time and human activities.

Detailed monitoring is done on at least one third of agricultural land acreage in every municipality annually. Therefore, a full set of information is obtained within a 3-year period. The local rural municipality has responsibility to make decisions and to take measures against persons not following land use legislation.

This programme was started in 1992 and continued until 2001. It is planned to restart it according to the improved standards of the new Monitoring Programme of Latvia and within its framework. Part of the information will be obtained using CORINE Land Cover methodology. Unfortunately due to economic constraints, this part of the monitoring is currently suspended and therefore the flow of new information has ceased. Another factor is uncertainty about the methodology to be used in monitoring programmes where soil information is obtained. Different monitoring programmes use different soil sampling schemes and analytical methods, which seriously limits data compatibility.

Soil Databases

Several soil databases of different scope, amount of information and extent of data computerization are maintained in Latvia. The State Land Service maintains the main archive of soil survey and land evaluation performed in Latvia within the period 1959 up to the present. Unfortunately, most of the information belonging to the period before the 1990s is stored 'on shelves' which limits its active use. The Agrochemical Research Centre maintains the computerized Soil Fertility database of Latvian agricultural land - *AGRO*. This database has two parts: (1) soil testing results from 1965 to 1990 when the soil fertility testing was performed on a country-wide scale and (2) results from 1992 up to the present, involving the results for the land of family farmers on which the soil testing was done. These databases are used to produce the national soil fertility surveys, giving the status and trends of the main fertility parameters. Several institutions have smaller databases, developed for the processing and storage of information obtained in the monitoring framework programmes. The Soil Profile Database of Latvia is under development in Latvia University of Agriculture where Latvia's Reference Soil Profile descriptions will be stored.

The above-mentioned soil databases at present do not comprise a unique information system for the whole country. Some of the databases are already out of date in practical terms and there is an acute need for their substantial renovation. Data stored are in different formats, partly because of the time interval over which the data were collected, partly due to weak coordination between institutions in the process of database development and partly because of changes in methods and approach used in soil investigations. A very small part of information is available in a format according to methodical guidelines recommended internationally. This gives serious limitations for active soil information use at the national scale and especially internationally.

Applications of Soil Data

Soil data applications have several purposes and levels. The most active users are probably farmers, agricultural and forestry oriented entrepreneurs generally. They are encouraged to make sustainable use of land resources at farm level, according to the principles of Good Agricultural Practice, which is determined by the Nitrate Directive of the European Union (EEC/91/676) and its Latvian equivalent. Additionally, starting from 2004, more specific environmentally oriented regulations are applied to the farms located in the vulnerable zones. Basic soil maps at the scale 1:10,000 (for agricultural land only) are the main sources of information. These materials include the general information about soils, as described above in the Soil Mapping section, and are available in the municipal, regional or central offices of State Land Service.

The National Planning Strategy of Latvia and the regulations on Territory Planning are also areas of soil data use. Territory Planning is a State launched programme that determines the territorial zoning in accordance with accepted land use restrictions. It defines the purposes and activities for which the specific territory can be used in the future. In the process of territory planning, land and soil as its component, is an essential factor that should be considered for setting objectives for its feasible use. Therefore harmonization between the interests of an individual land user and society should be reached for sustainable and balanced development of the country and its regions.

At least three main aspects that are closely related to soil quality (therefore need soil information) are considered in the process of territory planning in rural areas:

- Delineation of prime agricultural land areas with restriction of their transformation for other land use type;
- Delineation of marginal agricultural land areas, which are recommended for afforestation;
- Delineation of vulnerable zones where some restrictions of land management (tillage, fertilizer and pesticide use, etc) are applied.

Evaluation of real estate in the rural areas is the next programme at state scale where detailed information about land qualities is necessary, including the soil component. Evaluation results are used mainly for taxation policy and nowadays, also for land property restoration and compensation, privatization, ownership changes, which are important in the process of economic and social transition.

Environmental studies, monitoring and management as well as soil conservation, including policies, administration and management are also areas of soil data applications. Realization of Directive 2000/60/EC (Water Policy) may considerably raise the interest in availability of high standard soil data sets.

For the assessment of the conceptual framework, definition of potential needs, setting of objectives for future developments, coordination of institutional activities the National programme - *Development of guidelines for Integrated Latvia Soil Information System* was established in 1999 (Development of Guidelines, 1999). This is expected to be a long-term working plan to build up an effective and well-balanced (in terms of needs, standards and realization costs) soil information system.

Data Compatibility

Data compatibility seems to be a serious obstacle for information exchange internationally as well as within the different research programmes and cycles at national level. Soil investigations require determination of physical and chemical parameters, which can be obtained using different methods and procedures. For a long period until

1990, Latvia used methods as well as interpretations that were standardized in the former Soviet Union and differ significantly from those used internationally. Therefore all survey materials as well as most research data are in this format.

Table 4 gives a brief comparison of soil parameters commonly used for soil diagnosis and determination methods in Latvia and recommended internationally (Van Reeuwijk, 1995). For example, determination of soil texture, which is used as a fundamental soil parameter, has significantly different determination and interpretation criteria. It is also the case with cation exchange capacity, soil exchangeable bases, and some other parameters.

The tendency to keep the data homogenous and ensure their continuity is probably the main reason why there is still no official standard in Latvia, which could solve this problem for data collection in the future. Some research is performed to determine correlation between different analytical methods, and some methods of data transformation from previous to internationally recommended methods have been proposed (Karklinsh, 1993, Karklins, 1996a, 1996b, 1997).

Outlook

Soil diagnosis and classification according to the WRB and Soil Taxonomy has been started and comparative studies of the international systems and national classification is ongoing (Karklins, 2002), but still this information is very limited. Several publications were prepared to introduce the principles of internationally recommended soil diagnosis systems (Karklins, 1995, Karklinsh and Moberg, 1997, Karklins, 1999).

It is likely that two systems to classify Latvia soils will be maintained: firstly, a National system, for local use with application of soil information in a national context; secondly, some improvements and modifications to the National system, bringing it more closely in-line with the international systems such as WRB and Soil Taxonomy. This will facilitate research and development projects and international communication, as well as be valuable in organizing databases where unique and internationally harmonized definitions are necessary.

It is likely that all needs for well-coordinated and advanced soil information for use at the national level and internationally, could be catered for by the *Integrated Soil Information System*. This could merge the spatial georeferenced data in the form of digital soil maps with attribute databases. The first discussions about the need for and general layout of this system are going on in Latvia currently.

The future development of the Latvia Integrated Soil Information System is more focused on the introduction of internationally recommended methods of soil diagnosis: description of soil profiles, physical and chemical methods of analysis and data interpretation. Despite the problems associated with data compatibility, the previous soil information, and the experience and routines common for data users, the necessity for information exchange is a force for change to the traditional system.

The main tasks for development of the Latvia Integrated Soil Information System are land inventory and resources evaluation, soil mapping, particularly of parameters important for environmental assessment and risk analysis, natural (e.g. vegetation) and economic resources (e.g. production capacity), inventory and assessment. To meet the requirements of different aspects and needs of stakeholders - decision-makers, administrators, business people, farmers, environmental specialists - the main components of such a system must include a spatial database, an analytical database, an information database and appropriate pedotransfer functions, that permit the modeling of natural processes.

Table 4: Soil test methods used in Latvia and internationally

Used in Latvia	Recommended by FAO
Soil colour	
Descriptive	Munsell Soil Colour Chart
Soil texture	
Soil grouping based on the two parameters: physical clay particles < 0.01mm physical sand particles 0.01-1.00mm Fine earth fraction < 1.00mm	Soil grouping based on the three parameters: clay particles < 0.002 mm silt particles 0.002-0.05mm sand particles 0.05-2.00mm Fine earth fraction < 2.00mm
Water retention	
Not used	Soil water content at a given soil suction
Soil pH	
1M KCl, soil/solution ratio 1:5	1M KCl, soil/solution ratio 1:2.5
Organic carbon	
Tyurin's method. Similar to Walkley - Black	Walkley - Black method; Recently - dry combustion
Carbonate equivalent	
HCl treatment or gas volumetric	The same
Exchangeable bases (Ca, Mg, K, Na)	
Extraction: Ca and Mg by 1M KCl K and Na by Ca lactate buffer (pH 3.6)	Extraction by NH_4OAc
Cation exchange capacity, CEC pH 7	
Not commonly used	Percolation by NH_4OAc
Effective cation exchange capacity, ECEC	
Summation of basic cations and exchangeable acidity	Summation of the cation concentration Ca+Mg+K+Na+Al+H extracted by NH_4OAc and KCl
Exchangeable acidity	
Kappen's method. Extraction by 1M NaOAc, pH 8. Titration by 0.1M NaOH	Percolation by 1M KCl. Acidity is measured by titration and Al - using AAS
Basic cations	
Method of Kappen-Gilkovich. Extraction by 0.1M HCl, soil/solution ratio 1:5. Titration by 0.1M NaOH	Sum of Ca+Mg+K+Na by NH_4OAc extraction
Base saturation	
Calculated from values of exchangeable acidity and sum of exchangeable cations	Percentage of the exchangeable bases from effective ECEC
Extractable acidity	
Not used	Extraction with a $BaCl_2$-TEA buffer at pH 8.2. Titration of residual base with acid
Extractable iron, aluminum and silicon	
Ammonium oxalate extraction at pH 3	The same
Soluble phosphorus	
Extraction by Ca lactate buffer solution at pH 3.5 (DL-method)	Extraction by 1% citric acid solution

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Soil Survey and available Soil Data in Lithuania

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Introduction

The Republic of Lithuania is mainly flat (51%), separated by highlands (21%) and plateaus (29%). Lithuania is situated in the middle of Europe, with an area of 65,305km^2, 58,794km^2 of which is covered by soils (Eidukevicene, 2000). According to data of the State Land Cadastre for January 1999 the total agricultural land in Lithuania is 3,496,761.27ha. These data include all areas used for agriculture. About 1,605,689ha are in private ownership.

Soils are the main natural resource of Lithuania and, because of this, agriculture is a very significant contributor to the GNP. Lithuania has 99km of Baltic Sea coastline, and borders Latvia (610km) in the north, Byelorussia (724km) and Poland (110km) in the east and south, and the Kaliningrad Region of the Russian Federation (303km) in the southwest. Currently the country is divided into 10 counties, 44 districts and 12 municipalities. The total number of inhabitants is 3,704,800 (1998), of which the rural population is 32% and the urban population 62%. The population density is 56.7 people per square km. The capital of Lithuania is Vilnius, with 578,600 inhabitants. Other major cities are Kaunas with 415,800 inhabitants, Klaipeda - 202,300, Siauliai - 147,100 and Panevezys - 133,600. Average life expectancy for men is 65 years and for women 76 years.

The first development in soil science and plant nutrition research in Lithuania started in the 16th century, related to valakas land reform in the Grand Duchy of Lithuania (Eidukeviciene, Eitminavicius, Eitminaviciute at al., 2000). Within these developments there are the elements of applied knowledge about the earth and some additional knowledge about its quality. Professor Michel Oczapowski (1788-1854), at Department of Agriculture of the Vilnius University, made the first classification of local soils with emphasis on their physical properties. These activities were related to agro-geology as was the case in western universities. In 1832 after Vilnius University closed, the activities of the Department of Agriculture were also stopped. Almost a century later in 1922, in an independent Lithuania, agricultural studies were renewed at Kaunas University, and in 1924 at the Stephen Bathory University in Vilnius, which at that time was occupied by Poland.

The research on applied soil science and plant nutrition was started at the beginning of institutionalisation of these sciences - at the Academy of Agriculture (the institution of higher education, 1924) and at the Agricultural Investigation Office (1938). Prof. Viktoras Ruokis (1885-1971) founded the Lithuanian school of pedology. Prof. Juozas Tonkunas (1894-1968) laid the foundations for field trial methods. Various experimental stations both at the Academy at the Institute of Agricultural Research and in the places with different soil cover of Lithuania, have been established.

After World War II, the fundamental and applied soil science and plant nutrition research started in Lithuania. They were, and still are, developed at the Lithuanian University of Agriculture (Prof. Bronius Baginskas, 1903-1991), the Lithuanian Institute of Forestry, the Lithuanian Institute of Agriculture, the Institute of Ecology (Dr. Habil. Ona Atlavinyte, 1916-1991) and the State Land Survey Institute (Vaicys, 2000).

Soil Mapping in Lithuania

Maps of Quaternary deposits and geomorphology of different scale were compiled and recently updated at the Institute of Geology and Geological Survey of Lithuania. The agro-climatic data for the whole area of Lithuania have been collected and stored in the Lithuanian Survey of Meteorology.

This information can be used for the application of Lithuanian Soil Database (LTdDB) by special agreement.

Soil maps of Lithuania are mainly based on the results of large-scale field drilling, profile description, sampling and laboratory analysis mainly at the State Land Survey Institute (VZI). The activities of the Department of Soil Science of VZI, amongst others, include field soil survey at various scales and land evaluation for land reform now going on in the country. The VZI and other institutions hold very large soil research and land use data sets, covering more than 3 million ha and experimental data of plant nutrition and fertiliser application of different arable soils, collected during the last 40 years of soil survey and scientific research activities.

This information is stored in the form of maps, tables and published papers in archives. However, none of these institutions has a database to store and manage this valuable information, and a comprehensive computerized soil information system is now needed. This would enable a proper inventory of data quality to be set up and timely application of soil data to the pressing environmental and land use problems that confronts Lithuania today.

The Agrochemical Research Centre (ATC) of the Lithuanian Institute of Agriculture (LZI) holds the data and general maps of pH_{KCl}, liming requirements, contents of available P, K (4 periods of investigation), Mg, microelements and organic matter. LZI, as well as the Department of Soil Science and Agrochemistry of Lithuanian University of Agriculture (LZUU), has agricultural crop yield data from experimental plots of plant nutrition with different amount of fertiliser applications.

The Department of Soil Science and Agrochemistry of LZUU also deals with the new Classification of the Soils of Lithuania LTDK-99, that conforms with soil cartography methods, the systematisation of the soil cover structure and with the legend of FAO-UNESCO World Soil Map (1990, 1997) and World Reference Base for Soil Resources (WRB, 1998). The Lithuanian Forest Research Institute (LMI) and the Lithuanian Forest Inventory and Management Institute have some data sets of research and investigation into soils under the forests.

The VZI, LZI, LMI and LZUU hold very large soil and land use data sets, covering more than 3 million ha together with experimental data relating to application of fertilisers on arable land with different soils, collected during 40 years of soil survey and research.

In 1992-1995, an active scientific Research Programme on ‘Soil Cover Systems of Lithuania to Adopt FAO-Unesco Soil Classification’ has been set up at LZUU. In 1993, the attribute database of Fertiliser Experiments (plant nutrition) (TBDB version 1.0) of ATC was set up. Version 1.1 of TBDB was finished in 1995. Also in 1995, the main part of the attribute Lithuanian Soil Profile Analytical Database (LTdpaDB) was set up. The main problems still are that almost all data are not geo-referenced and not standardised in terms of description and analyses.

Land Reform is under way in Lithuania, and emphasis on rural development and particularly on environmental pollution is also ongoing. However, none of the institutions mentioned above has a DBMS/GIS to store and manage fully developed attribute TBDB and LTdpaDB databases and other environmental information on soils. To store and manage this valuable information, a comprehensive computerised Lithuanian Soil Database (LTdDB) is now needed. This would enable the proper inventory of data quality and timely application of quantitative soil data to the pressing environmental and land use problems that confront Lithuania today.

There is a need to have a soil information system accessed through a user-friendly menu-driven query and retrieval system, which is operated as an on-line service to extension offices of the Ministry of Environment of the Republic of Lithuania and the Ministry of Agriculture of the Republic of Lithuania. The scientists and technical specialists could use such a database to gain information about specific points and areas as well as other soil attribute data.

Data Type and Volume

The LZUU, VZI, LZI and LMI in Lithuania have been and still are the principal centres for soil and crop science and for the investigation of the agricultural environment of Lithuania. At these institutions there are now about 75 soil scientists, of whom 6 are professor doctor habilitates, 21 are associate professors, 25 doctors of sciences, and 23 are soil scientists. At the Soil Department of VZI, the Agrochemical Research Centre, the Voke and Vezaiciai Branches of LZI, the Soil Science Department of LMI and the Department of Soil Science and Agrochemistry of LZUU with some support have ongoing research on:

- Properties of soils, evaluation of productive space as a basis for regional distribution of crop production;
- Hazards of erosion and industrial pollution soil environment and factors affecting crop and agriculture plant yields and their regional distribution;
- Environmental factors affecting the effectiveness of fertilisation;
- Nutrient balance in plants and soils;
- New varieties of cereal and fodder plants and their yield potentials;
- Land evaluation;
- Research on soil cover structure systematisation and soil cartography methods for formalisation of soil mapping;
- New Classification of the Soils of Lithuania LTDK-99 to adopt the World Reference Base for Soil Resources (WRB, 1998).

Scientific research and the information based on collected data in VZI, LZI, LMI, LZUU and in some other institutions involved in agricultural, environmental and soil research in Lithuania has been published nationally and internationally. Soil data for Lithuania under VZI, LZI, and LZUU control is stored in the form of manuscript-maps, tables, diagrams and some in published papers in archives. This information has been used as a basis for the production of soil maps for Lithuania at different scales (1:10,000, 1:50,000 and 1:300,000). In wider use are the manuscripts of:

- Soil (type and variety) maps at various scales (1:10,000-about 10,000 maps for each former farm up to 1991; 1:50,000 - 44 maps, for each region; 1:300,000 - 1 map for the whole country (Juodis, Kasperaitis *et al*, 1985);
- The maps of soils of the forest area of Lithuania at scale 1:10,000 (under the control of LMI and other forest research institutions);
- The Map of the Relief of Lithuania at scale 1:300,000 - 1 map covering the whole country;
- The Morphoisographic Map of the Land-Surface of Lithuania at scale 1:250,000;
- The Map of Organic Matter Content in Soils of Lithuania at scale 1:300,000 - 1 map for the whole country and some areas mapped at a scale of 1:10,000.

In addition to the above (basically soil maps based on the genetic soil classification used in Lithuania until 1996) there are also:

- Soil-agricultural maps at 1:10,000 scale - about 10,000 sheets, with soil texture, wetness and stoniness;
- Land evaluation maps at scale 1:10,000 defining the quality of the soils in terms of agricultural usefulness;
- General maps of pH and lime requirements, and contents of available P, K, at the scale of 1:10,000 for former farms until 1991, and (for some areas) Mg and trace elements.

Point Soil Data

The analytical data for 7,000 soil profiles as well as detailed soil profile descriptions are representative of the major agricultural and forest soils covering about 4 million ha of arable and forest land in Lithuania. These data contain the main soil properties:

- Soil texture (STX, N. Kacinsky method);
- Humus content;
- pH_{KCl}, exchangeable and potential acidity;
- Content of mobile Al;
- Base cation contents, contents of available P, K, and Mg (major plant nutrients);
- Calcium carbonate content.

They include also:

- Point data of physical properties (mainly bulk density) of soils at 100 points;
- Point data of chemical composition of soils at 200 points;
- Point data of total chemical composition of the clay fraction at 100 points;
- Point data of heavy metals and trace elements As, Cd, Cr, Ni, Pb, Se, V, Co, Cu, Mn, B, Mo and Zn, also S content in soils;
- Point data from experimental plots.

Data of the yield of different agricultural crops and plants are from 2,000 experimental sites with different applications of fertilisers in all prevailing soils throughout Lithuania. All these data come from over 1,000,000 points located throughout all Lithuania. The greatest sampling density was in experimental stations and vegetable and fruit growing farms.

There are also point data of the yield of different agricultural crops and plants from 2,000 experimental sites with different fertiliser application rates on representative soils throughout Lithuania. Now, there are some positive changes - more institutions (Geological Survey of Lithuania, Institute of Geology and Geography and others) are involved in some research on soil science also.

GIS-based Soil Maps

As mentioned already, over the past decades in our country research has been conducted into soil properties. The programme for developing a Land Resources Information System of Lithuania (LTlrIS) has been started with the support of FAO. VZI has successfully carried out pilot studies in two administrative regions. It was also used to introduce the new Classification of the Soils of Lithuania LTDK-99 (Buivydaite, Vaicys, Juodis, 1996, 2001) and the creation of the first Soil Database of Lithuania (LTdDB) based on Geographic Information Systems (GIS) – see Figures 1 and 2).

The proper study of the terrestrial environment, of which the soil is the central component, requires the ability to integrate and manipulate a large amount of data from various points of landscape, i.e. spatial data. This is in recognition of the fact that much of the relevant data needs to be captured in computer compatible format, and this task will take a long time to complete. For Lithuania, about 1,100 soil map sheets (at 1:5,000, 1:10,000, 1:50,000 scale) needed to be digitised or scanned and vectored. In the view of the very large initial costs of collecting the information, it is highly desirable that all relevant already collected data should be stored in a computerised database. There is need to continue with the creation of a comprehensive LTLIS and an integrated part of it – LTdDB. After completing it for the whole country, the establishment and use of LTLIS would facilitate the best strategy for use and proper management of arable land and better protection of the environment in Lithuania.

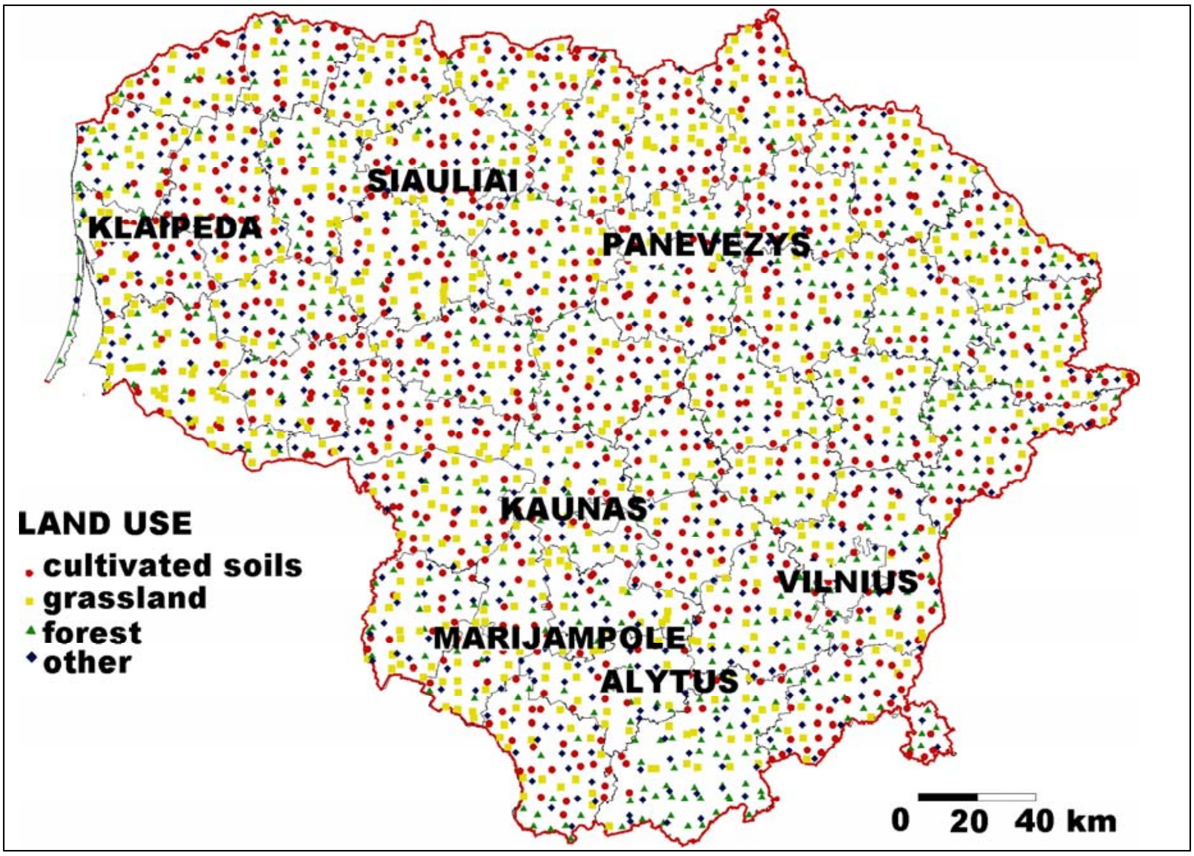

Figure 1: Land use at the sampling sites

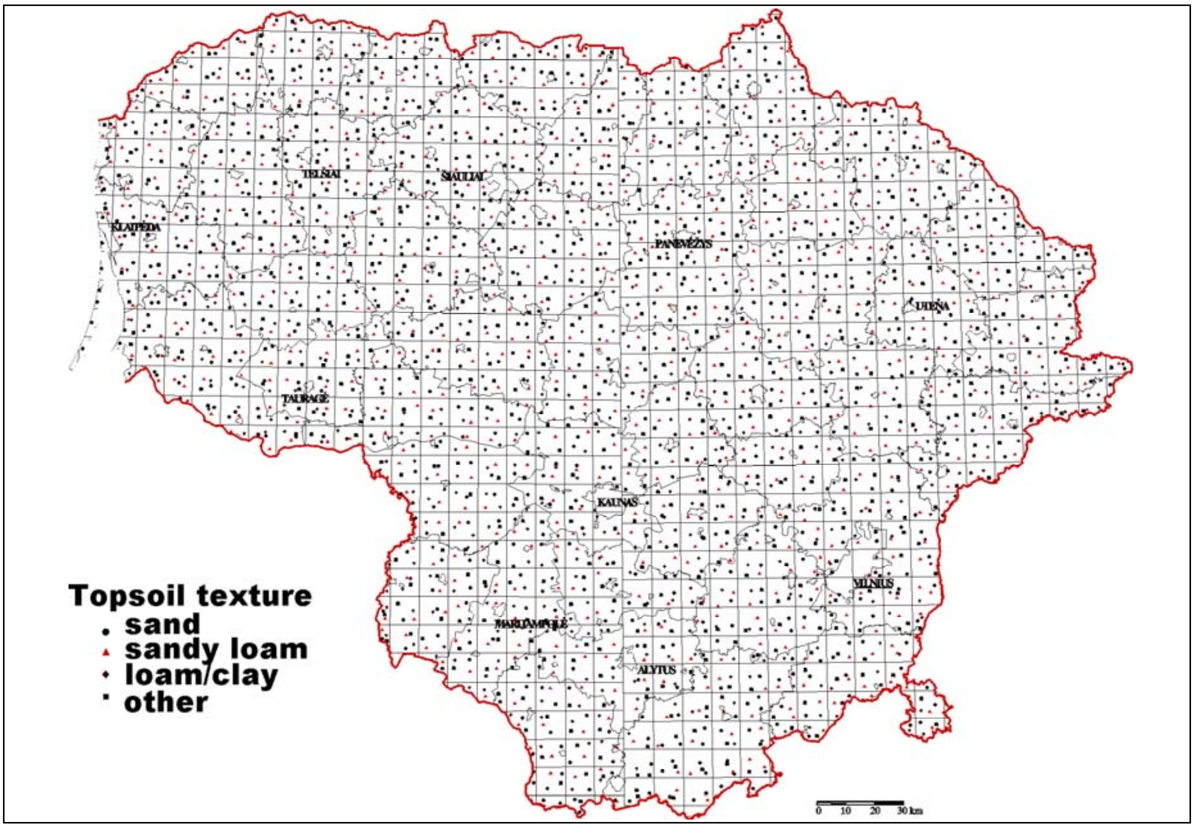

Figure 2: Topsoil sampling sites

LTLIS also would be beneficial for agricultural productivity and food quality through the improvement of the institutions involved in consulting and advisory activities. As a system, LTLIS is needed for land management to ensure sustainable land use not only for agriculture, but also for safe application of waste materials, land consolidation, soil erosion and estimation of other types of soil degradation. Specific needs would centre on the protection of land from degradation, whilst maintaining productivity, and minimising pollution. The ready use of LTdDB would allow the best strategy for use and proper management of arable land and better protection of the environment in Lithuania.

New Classification of soils

A soil classification system is not a natural thing that can be devised for particular uses. In Lithuania several different systems have been used. Sometimes it has been the goal of soil scientists dealing with soils, with different understandings, how to determine the nature of the soils of the country. One of the main approaches has been presented in the Systematic List of Soils of the Baltic States, published in 1953 in Pocvovedenije. This system, with corrections in 1965, 1979, 1992 and updates in 1996, has been used until now and is currently used as General Systematic List of Soil Typological Units (STU) of Lithuania TDV-96. Now, the new Classification of the Soils of Lithuania LTDK-99 based on FAO-Unesco Soil Map of the World revised legend (1990, 1997) and WRB (1998) has been developed.

The New Classification of the Soils of Lithuania has resulted from the research carried out at the Soil Science and Agrochemistry Department of Lithuanian University of Agriculture since 1992 (V.V. Buivydaite), since 1994 in the Department of Forest Soils, Typology and Hydrology of Lithuanian Forest Research Institute (M. Vaicys), and since 1996 in the Soil Department of the State Land Survey Institute (J. Juodis). The work has been done with the support of the members of scientific working group - R. Sleinys (Voke Branch of the Lithuanian Institute of Agriculture), M. Eidukeviciene (Klaipeda University), J. Jasinskas, J. Grybauskas, A. Juozokas, K. Gustaitis (State Land Survey Institute), J. Mazvila (Agrochemical Research Centre of the Lithuanian Institute of Agriculture) and B. Jankauskas (Kaltinenai Experimental Station of the Lithuanian Institute of Agriculture).

During the development, specific questions on Lithuanian terminology of soils has been discussed and worked out with A. Motuzas (Soil Science and Agrochemistry Department of Lithuanian University of Agriculture).

The efforts and success of the Lithuanian Soil Science Society in organising field expeditions for the soil scientists of Lithuania with the participation of leading soil scientists from Latvia, Estonia, USDA, UK, FAO, France and the European Soil Bureau have been important. With the support of the M. Vasiliauskiene (Department of Agriculture and Forest of Lithuanian Academy of Science) several scientific conferences on soil classification has been organised.

The genetic soil classification of Lithuania used in agriculture and forestry since 1953 has been newly revised and correlated following the creation of the Lithuanian Soil Database in 1996 and the setting up of the General Systematic List of Soil Typological Units (STU) of Lithuania TDV-96. It has 98 STU and been used as a background for the new comprehensive classification of soils of Lithuania. During the work on the first version of the soil classification, major soil groups and subgroups have been included with FAO-UNESCO Soil Map of the World, 1990, and later on, with the latest version of the Classification of the Soils Lithuania DKL-99 - with Soil Map of the World Revised Legend with corrections and updates, 1997. As a basis for third and lower level soil typological units, the World Reference Base for Soil Resources (WRB 1998) has been used. WRB has been developed to help encourage all scientists and agriculturists to use the same soil nomenclature; to use the same basic system, and third level soil typological units for more detailed work is proposed. It is intended to ensure that soil information is easily available and can be interpreted for use by land users (farmers), planners and scientists.

The usefulness of a set of soil names depends on a common understanding among the users. It is a fact that some soil properties irrelevant to one user may be important to another. Each significantly different group of users is therefore likely to need a special classification system. Economists, engineers, and pedologists may also classify soils but in very different manner.

In Lithuania, there are probably no two soils that are identical in all respects. The name of the soil in LTDK-99 means only that specified soil properties are within stated limits. In WRB, enough variation is allowed for a name to be given to extensive soil areas in spite of differences in some properties. A particular Lithuanian soil name means that the soil has certain specified properties.

In the new publications the soils of the country (Lithuanian Soils, 2000, 2001) are described also on the basis of the WRB explanation of diagnostic and other horizons, diagnostic and some other properties, diagnostic and other soil materials. Other characteristics in relation to the soil name, soil colour and clay content might be among the differentiating characteristics for a particular soil.

On the basis of these characteristics and organic-matter content there are also explanations of the soil master horizons and/or layers. There are 12 major groups of soils in Lithuania - level I of the classification: Regosols (RG); Leptosols (LP); Cambisols (CM); Luvisols (LV); Planosols (PL); Albeluvisols (AB); Arenosols (AR); Podzols (PZ); Gleysoils (GL); Histosols (HS); Fluvisols (FL); Anthroposols (AT).

There are given explanations of the formative elements of soil typological units of the 46 soil subgroups - level II of the classification. Additional characteristics are associated with 188 soil typological units of level III, 12 units of level IV and 43 differentiations at soil phase level. For the particular group of soils, the soil phase would apply to a soil having differentiating characteristics, and it is in the soil definition.

During the last decades of soil investigations a great deal of information has been gathered about each soil of the country - descriptions of the physical and chemical properties, of its various uses, of its response to management. The New Classification of the Soils of Lithuania is designed to simplify this mass of information and make it manageable. Although on different levels it has 235 STU, the system is organised in such way that the above-mentioned knowledge and research material on soils is arranged in a meaningful way. It emphasises important points and ignores irrelevant details.

It was not easy to combine the taxons of genetic classification with the World Soil Map Legend and WRB, because the old classification of soils of Lithuania in some cases was too detailed, in other cases too coarse. Also there was much discussion on differentiation of the Cambisols and how to place them as the one of the prevailing soil groups.

The New Classification of the Soils of Lithuania LTDK-99 is based on soil investigations in the field, the fundamental and applied sciences expected to be the important reference guide for soil survey and evaluation of land resources for sustainable land use in the country, until in future the soil classification will again be changed to a new system. As knowledge increases, kinds of classification will be developed in the next century by using fuzzy maths, fractals and perhaps chaos theory.

In this research, soil micro-organisms will be included, because the measurement of specific respiration and other techniques has greatly increased knowledge of differences in soil micro fauna and flora in recent years. The use of precision farming will avoid excessive pollution. Flexible soil classification will help to name rapidly changing soil features and the important thing is to be ready to adopt and change as new soil science information becomes available.

Soils of Lithuania

The parent materials of soils in Lithuania vary in the age and genesis, the most common being Quaternary deposits. The thickness of these deposits varies from less than 10m in northern Lithuania to 200-300m in the Zemaiciai and Baltija Heights, with many being 80-120m thick. Glacial deposits are: morainic, glaciofluvial and limnoglacial, and, in some places, there are alluvial, Eolian and organic deposits. These deposits support a great variety of soils and a complicated soil cover in Lithuania.

Gleyic Albeluvisols and some Dystric soils which are formed on materials low in carbonate and deeply leached loamy deposits, predominate in Western Lithuania. In Eastern Lithuania, Albeluvisols predominate on soil parent materials of light texture and here distinct erosion processes are prevalent. In Central Lithuania, the soil parent material and the soil surface layers contain more carbonate and are less leached; here Calcaric Cambisols are common. Calcaric Luvisols, Gleyic Luvisols, and in some places Eutric Gleysols, on loam, clay loam and clay are widely distributed.

Preliminary estimates show that Albeluvisols occupy 30% of the country, Luvisols 27%, Cambisols (13%), Arenosols (12%), Podzols (11%), mainly in forest areas, and Gleysols and Histosols (5.3%) in the depressions.

Soil Degradation

Major production constraints in the country are physiography, acidification and low fertility. Other types of soil degradation taking place in Lithuania include: acidification, erosion and contamination by heavy metals and organic pollutants. These are described in the following sections, but estimated one third of agricultural land is in hilly regions, some of which are not suitable for cultivation.

Soil acidification

A significant danger for soils and the natural environment is caused by the gradual intensification of the acidification process resulting from a decline in the application of lime and the effect of acid rain. This process in Lithuania has been heightened during the past 10 years when the area of liming has declined. It is now time to establish monitoring plots in areas prone to acidification, and to apply lime where required. According to the State Environmental report of 1998, in the previous last 5 years there was a 3.1% increase in acid soils.

Table 1: Soil acidity in Lithuania

pH_{KCl}	Area (ha)	Area (%)
<4.5	23.5	0.9
4.6-5.0	113.9	4.3
5.1-5.5	286.8	10.9
5.6-6.0	453.2	17.2
6.1-6.5	535.6	20.4
>6.6	1,217.8	46.3
All	2,630.8	
Acid soils		
<5.5	424.2	16.1

(source: Lithuania, MoE 1996)

The data in Table 1 indicate that 46.3% of the soils in Lithuania are either very close to neutral (pH_{KCl} =6,6-6,9) or neutral (pH_{KCl} =7.0) but more than 16% of soils are acid and, if under agriculture, must be limed.

Soil erosion

The major cropping rotation is barley + under sowing, perennial grasses of the first year, perennial grasses of the second year, winter crops and potatoes, vegetables or sugar beet. Comparatively rarely, the monoculture system is adopted but in small plots.

The largest areas of slightly eroded soils are in the regions of the moraine highlands - from 12.4% of the area in the Svencionys-Narocius highlands up to 21.8% in the Suduva highlands. Slightly eroded soils are quite extensive (16.6%) in the sandy South-eastern plain.

In some areas of the Baltic highlands, from 19.6% up to 29.8% of soils in agricultural use are moderately eroded. In the Central Zemaiciu highlands and Eastern Lithuanian plateaux eroded soils constitute about 5.7-7.2% of the area. (Soils of Lithuana, 2000).

Severely eroded soils occur more frequently in the plateaux and highlands of Eastern Lithuania (1.6-7.7%).

Contaminated sites

In Europe, during recent years, significant damage has been caused to the environment in some areas. There are sites contaminated with a range of different materials. One of the priorities in many countries is to estimate the danger to the environment from these sites, to identify the polluting materials, and to develop measures to decontaminate the sites.

The international project on Mapping of Soil and Terrain Vulnerability in the Central and Eastern Europe (SOVEUR Project) helped to evaluate the natural geochemical patterns and changes caused by anthropogenic and technogenic activities in Lithuania. In the future there is need to show even small polluted sites of Lithuania using, for example, the SOTER Database (Batjes, Van Engelen, 1997) and methodology of the SOVEUR Project (Van Lynden, 1997).

Monitoring and treatment of contaminated soils is an urgent issue, and one that is very costly to manage.

Pollution by heavy metals

The degree of soil contamination with heavy metals of some areas of forest soils and topsoils of agricultural and other landscapes in Lithuania has been investigated and determined by M. Vaicys (1975), Pauliukevicius (1988), R. Sleinys and P. Rimselis (1993), J. Lubyte *et al*. (1994). But very little attention has been paid to the whole spectrum of trace elements, although they are important for plants, animals, human beings as nutrients or, on the other hand, potentially poisonous in high or even very low concentrations (Kadunas *et al*., 1999).

Table 2: Soil contamination by heavy metals (mg · kg)

Heavy metals	0-20cm	20-40cm	40-60cm
Cr	1.6-38.8	2.2-36.4	1.6-33.6
Cd	0.2-1.0	0.2-1.0	0.2-1.0
Pb	4.4-23.0	4.0-18.0	2.6-17.0
Ni	1.8-32.6	2.4-31.0	2.4-31.6
Cu	0.8-56.0	2.4-31.0	2.4-31.6
Zn	6.6-58.8	6.6-56.8	6.6-60.2

(source: Lithuania, MoE 1996)

According to state monitoring data of 1993-1997, the average amount of heavy metals in topsoils 0-20cm (Table 2) are: chromium 10,7 mg/kg of soil, cadmium - 0.46, lead - 11.9, nickel - 9.9, copper - 6.9, zinc - 28.5, iron – 8,209 mg/kg of soil.

Pollution by organic pollutants

According to data of the State Plant Protection Agency, 1,566.9t of pesticides were used in Lithuanian agriculture in 1998. Most were herbicides - 1,136,002t (72.5%), fungicides - 12.5%, insecticides - 1.9% and other types of chemicals. In the last decade, the use of pesticides has fluctuated. According to the State environmental monitoring data, only in one soil sample were herbicides found to be over the limit. Data shows that only at very few points is there high pollution by pesticides, such as simazine. Only in a very small number of soil samples were significant amounts of insecticides like DDT and other pollutants found. In some samples there were only traces of such materials found.

Use of Fertilisers

Recently, the quantity of fertilisers and chemicals used in agriculture (Table 3) has been reduced but there is potential for it to increase again in the future.

Table 3: Mineral fertilisers consumed in 1996 (kg/ha of crop area, 100% active)

Crops	In private farms	In agricultural companies
Winter crops	58	66
Summer crops	54	79
Flax	67	91
Sugar beet	89	318
Rape	66	144
Potatoes	74	134
Vegetables	103	247
Fodder crops	49	31

(source: Agriculture of Lithuania 1996. Department of Statistics. Vilnius 1997)

The principal measure for reducing the environmental impact of pesticides should be through the development of a control system for hazardous materials and products. The framework for a control system for these materials in Lithuania should encourage not only control of the use of chemicals but also more efficient use of fertilisers and development of low-impact application techniques, as well as a search for more fertiliser efficiency.

Anthropogenic Influence on Soils

The western and eastern parts of Lithuania are characterised by a low amount of available phosphorus, whereas the central part of Lithuania is enriched with phosphorus. The anthropogenic impact and especially diverse reclamation activities such as cultivation of Terric Histosols, drainage of Gleysols or other gleyic soils, liming, application of mineral fertilisers have been and in some places now are among the most active soil forming factors changing the properties and functions of natural soils. Histosols are particularly sensitive to this impact. The amount of phosphorus and potassium in the soil now depends on its application. In the investigated areas the concentrations of these substances are very variable.

In previous years, another problem in agriculture has been caused by intensive cattle breeding, particularly wastes from major breeding complexes. The Ministry of Agriculture has encouraged the regulation and reconstruction of these complexes to include collection of animal wastes, discharge or land spreading of these wastes, and technologies for their use.

Estimation of soil degradation and pollution in Lithuania

The recent data from the geochemical mapping of all administrative districts of Lithuania has been collected between 1994 and 1997 by the Geological Survey of Lithuania (Kadunas *et al*., 1999). Soil samples (total 2700) were collected in the fields of Lithuania (the country has been divided into 10x10km squares, 696 in number) during the summers of 1995 and 1996 from the topsoil. The topsoil samples collected were transported to the laboratory where their pH_{H2O} value was measured with a J-200 ionometer. The samples were then dried at room temperature and sieved through a 1mm sieve. Analyses were conducted at the laboratory of the Geological Institute. The following analytical methods were used: DC-Arc Emission Spectrometry, using the DFS-13 spectrograph, MD-1,000 microdensitometer (Co, Cr, Cu, Mo, Ni, Pb, Sn and Zn concentrations); XRF using ARF-6 X-ray-spectrophotometer (As concentrations).

Concentrations of metals in topsoils

Basic research on topsoils of Lithuania shows that the concentrations of metals in places reasonably distant from the bigger towns, for example, does not reach the B-value of the original standards adopted in the Netherlands for soil contaminants (Moen and Brugman, 1997). Geochemical mapping data has been used for estimation of soil degradation, contamination and pollution for the SOVEUR Project (1997-1999). It is very important to know the location of soils with measured metal concentrations in relation to the EU recommended maximum permissible levels, now set as (in mg/kg of dry matter) 3,300, and 300 for Cd, Pb, and Zn, respectively.

As data for topsoils of Lithuania show, the average concentrations of metals are greater in loamy and clayey soils than in sandy soils (Tables 4, 5). Other research on the soils in Lithuania has shown that in the humus layer (0-20cm) there are the following average quantities of heavy metals: chromium - 10.7, cadmium - 0.46, lead - 11.9, copper - 6.9, zinc - 28.5, manganese - 253, iron 8,209 mg/kg (Soils of Lithuania, 2001).

Table 4: The values of metals in topsoil of Lithuania (average in ppm)

Soil texture	Cr	Co	Ni	Cu	Zn	As	Mo	Sn	Pb
Sand	25.1	3.5	9.4	6.5	22.2	2.1	0.61	2.0	15.5
Sandy loam	35.7	5.0	13.8	9.6	28.9	2.9	0.67	2.2	14.9
Loam-clay	44.0	6.4	18.0	11.4	35.7	3.6	0.71	2.3	15.3
Peat	21.2	3.6	12.1	10.6	39.9	1.9	0.88	1.6	36.2
All groups	31.7	4.7	13.3	9.5	31.5	2.6	0.72	2.0	16.6

Source: V. Kadunas, R. Budavicius, V. Gregorauskiene, V. Katinas, E. Kliaugiene, A. Radzevicius, R. Taraskevicius. Geochemical Atlas of Lithuania. Geological Survey of Lithuania, Geological Institute. Vilnius 1999

Table 5. Median values of metals in topsoils on parent material of different genesis, ppm

Soil texture	Genetic type of soil parent material	Cr	Co	Ni	Cu	Zn	As	Mo	Sn	Pb
Sand	Limnoglacial sediments	23.4	3.2	8.7	23.4	20.0	1.4	0.60	1.9	16.2
	Glaciofluvial sediments	20.7	2.9	7.5	20.7	17.3	1.5	0.60	2.0	14.5
	Eolian sediments	18.3	2.5	7.0	4.9	17.4	1.7	0.58	1.7	14.5
	Glaciofluvial sediments of Nemunas glacier marginal forms	20.8	2.9	8.2	6.8	17.2	1.6	0.58	1.9	15.7
	Glacigenic sediments of Medininkai glacier	23.1	3.4	8.6	6.8	18.9	2.1	0.62	2.1	15.0
Sandy loam	Limnoglacial sediments	41.4	5.2	14.5	10.3	29.1	2.8	0.67	2.2	14.5
	Basal moraine of North Lithuanian phase	37.4	5.6	15.0	9.7	28.4	3.8	0.70	2.4	16.0
	Basal moraine of Middle Lithuanian phase	35.9	4.9	13.5	8.5	27.2	2.9	0.68	2.1	14.0
	Basal moraine of South Lithuanian phase	36.1	4.9	14.4	10.5	29.4	3.2	0.70	2.2	14.5
	Glacigenic sediments of Medininkai glacier	26.2	4.5	8.5	7.7	28.3	2.8	0.63	2.0	14.4
Loam – clay	Limnoglacial sediments	50.5	6.4	18.1	12.1	35.1	4.0	0.69	2.3	15.3
	Basal moraine of north Lithuanian phase	41.6	5.5	16.5	9.4	29.4	3.7	0.66	2.2	14.2
	Basal moraine of Middle Lithuanian phase	44.1	5.7	17.0	11.6	32.5	3.3	0.69	2.3	14.3
	Basal moraine of South Lithuanian phase	38.4	5.4	15.4	9.5	29.5	3.6	0.69	2.1	14.1
	Glacigenic sediments of Medininkai glacier	32.6	4.6	10.7	8.6	32.2	3.5	0.66	1.95	14.6

Source: V. Kadunas, R. Budavicius, V. Gregorauskiene, V. Katinas, E. Kliaugiene, A. Radzevicius, R. Taraskevicius. Geochemical Atlas of Lithuania. Geological Survey of Lithuania, Geological Institute. Vilnius 1999

The Need for Collaboration and Corporate Policy

Lithuania is progressing towards integration into the European Union's political and economic structures. One of the conditions of EU membership will be need to harmonise the country environmental policies and legislation with those of the EU. Many of the Lithuanian environmental standards set by the Ministry of Environment already meet some of the EU requirements and in several cases are even higher than those set by the EU. Specific environmental goals or objectives to address environmental problems currently facing Lithuania are identified for the short and medium term in environmental Action Programmes. Lithuania participates in the conventions which play important roles in shaping environmental policy – Convention on Transboundary Air Pollution, Convention on Climate Change, Convention on Biological Diversity, Combat Desertification Convention and others. A seven-year strategy for the development of sustainable agriculture in the environmentally sensitive gypsum karst region in Northern Lithuania was adopted by the Government in 1993 and commenced the same year.

In Lithuania as well as in other countries following the World Commission on Environment Development (1983), Agenda 21 of the Earth Summit, World Soil Charter and other conventions, European Commission directives and European Soil Bureau recommendations, there is need to have ready access to good information on soils. In its absence, it is difficult to answer the questions raised by the Climate Change Convention. Only those countries that have 1:250,000 or larger scale soil maps based on good standard soil profile description and laboratory data are able to do that well. A good example for Lithuania was the collaboration on the Soil Geographical Data Base of Europe (1998, 1999). The needs of collaboration comply strongly with Lithuanian corporate policy, the main objectives of which are:

- To continue to review available soil data;
- To continue to develop methodology for geo-referencing data;
- To continue to develop routines for database development and data validation;
- To test data capture and preliminary modelling capabilities;
- To test the range and validity of suitability and risk assessment models;
- To test the operation and quality of system outputs;
- To identify polluted areas over the country;
- To test the design of the LTdDB with a view to the further development of LTLIS;
- To train the staff to operate the system.

The proper study of the terrestrial environment, of which the soil is the principal component, requires the ability to integrate and manipulate a large amount of data from various points of landscape, i.e. spatial data. In view of very large initial costs of collecting the soil information needed for the Lithuanian Land Resources Information System (LTlrIS) interactive with the Geographical Information System (GIS) and operating suitable databases, it is highly desirable that all relevant soil data already collected in the country should be stored in a computerised database. All this may include the following components:

- To maintain soil survey field work and set up one National organisation, which would be responsible for surveying, documenting, and researching the agricultural land and all soils of Lithuania;
- To contribute to the State Environmental Monitoring, responsible for monitoring of soils and agricultural products;
- To seek to establish a reference base for the assessment of land quality that would provide a scientific basis for soil protection and contribute to identifying and solve existing problems of soil degradation in Lithuania;
- To contribute a scientific base to secure adequate food, timber and other soil based needs while ensuring sustainable land use in harmony with the environment and causing minimum damage to it;
- To strengthen links with policy makers and legislators in Lithuania, European Union and elsewhere, to assist in policy development in our country and ensure that policies and legislation are supported by the best available scientific information;
- That results would be freely available and published in Lithuanian and international journals. Reports would also be published and made available to Lithuanian agriculturists, planners, policy makers etc. and the EU. Some of these reports would take the form of progress reports for meetings, some would be documentation for the LTdDB-LTLIS;
- Providing a scientific basis for the most suitable and sustainable land use in the future;
- Establishment of an objective basis for the management of soil pollution by administrators, policy makers, and those responsible for agricultural development;
- Establishment of a monitoring and research programme for agro-ecosystems, which can be extrapolated to other parts of Lithuania;
- Narrowing the gap between scientists, managers of agriculture, farmers, and policy makers, and the supply of necessary information to assist decision makers.

Soil is an ever-changing system. The need for new methods of soil research, for new information to be integrated, and the need to be socially responsible for sustainable development of our country make not only theoretical but also practical sense. In Lithuania, there are areas where from point to point in accordance with conditions of drainage, erosion and parent material, soils vary very much. In such areas it is not enough to use geographic methods of soil cartography. There is need to adopt updated soil cartography methods and terrain modelling. Such a perspective allows a systematic appraisal of soil cover and division of the land surface into integral territorial units (systems) for investigation.

There is a need for participation in international projects and consultations with soil scientists from the countries with soil research centres that have been mapping soils and are experienced in the systematic collection and storage of information on soils and sites (including descriptive and analytical information). It is important to meet the needs of national policies and the obligations arising from participation in international projects on soil research and mapping of soil vulnerability for soil degradation. It is also important to set up Lithuanian standards adapted to the requirements of EU countries.

Conclusions

In recent years, the International Union of Soil Science, FAO, and other international bodies, have been stressing that it is important to develop information about conditions of degradation of chemical and physical properties of soils, roles of soils in global climatic change, better utilisation of information on soils, the needs for protection of underground and surface water against pollution, as well as for wider consideration of the properties of soils for the needs of sustainable management of particular areas. Besides presentation of the map of the soil cover it is also important to interpret the acquired data.

Already existing information on soils of Lithuania may be sufficient for some needs, but additional investigations are required to support the needs of the other areas. Because over the past two decades, responsibility for the organisation of soil survey has passed from central government organisations to independent institutes, universities and private sector consultancies, there is a grave danger of a lack of uniformity of methodology, use of different classification systems, and a general lack of coordination between the mapping groups. Bringing together the information from these different sources into an integrated system will prove increasingly difficult as more and more information is collected. Therefore, it is necessary to create a geocoded or georeferenced soil information system of Lithuania that would use contemporary information technology.

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Soils of the Republic of Macedonia: Present Situation and Future Prospects

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Introduction

The Former Yugoslav Republic of Macedonia is situated in the Balkan Peninsula, in the southern part of the temperate zone, and on the borders of the subtropical zone, between $40^0 50'$ and $42^0 20'$ N latitude and $20^0 27'$ and $23^0 05'$ E latitude. The northern part of country borders the Republic of Serbia and Montenegro, in the south with Greece, in the east with Republic of Bulgaria and in the west with Republic of Albania.

The Republic of Macedonia is small (25,713km^2, Table 1), but it shows great natural diversity, though mountains occupy nearly 80% and basins 20% of the country (see also Figure 1).

Table 1: Landforms

Type	Area (km$^{2)}$	%
Water	488	1.9
Plains	4,900	19.1
Mountain	20,325	79.0
Total	25,713	100.0

According to Filipovski (1995), the Republic of Macedonia can be divided into four geotectonic entities: the Western Macedonian Zone, Pelagonian Massif, Vardar Zone and Serbian-Macedonian Massif. The relief is very heterogeneous, with numerous relief forms, with different expositions and inclinations, and with great differences of altitude (from 40 to 2,764m above sea level). The division into mountains and basins of lower relief category (undulating-hilly, sloping and flat relief) is of great significance for the regionalisation.

In the Republic of Macedonia, there are numerous geological formations of heterogeneous petrographic-mineralogical composition. The mountains are composed of non-calcareous hard rocks, including quartzite, and various silicate rocks: acidic, neutral, basic and ultrabasic rocks; as well as calcareous rocks such as pure limestones, marbles and dolomites.

Basins are composed of loose and lightly cemented sediments, and a small quantity of young volcanic rocks. Undulating-hilly terrains in the basins are composed of sea and lake sediments (Mesozoic, Paleogenic, Neogenic, diluvial (superficial) deposits) The sloping terrain consists of colluvial and some fluvioglacial deposits.

The relief modifies the influence of zonal climates. The country is under two zonal climates (Mediterranean and temperate-eastern continental) and one local (mountain) climate. These three climates combine with the relief and altitude to create eight vertical climatic belts (Filipovski *et al.* 1996):

- Sub-Mediterranean (50-100m above sea level);
- Continental-sub-Mediterranean (to 600m, 897,000ha or 34.9% of the territory);
- Warm-continental (600-900m, 740,000ha or 27.45% of the territory);
- Cold-continental (900-1,100m, 342,000ha or 13.3%);
- Piedmont-continental-mountain (1,100-1,300m, 250,000ha or 9.7%);
- Mountain-continental (1,300-1,650m;
- 269,000ha or 10.4%);
- Sub alpine-mountain (1,650-2,250m;
- 97,000ha or 3.8%);
- Alpine-mountain (over 2,250m, 17,000ha or 0.5%).

The vertical climate belts are at the same time climate-vegetation zones with different soil types and evolution sequences. They are, in fact, climate-vegetation-soil belts.

In the Republic of Macedonia, there is a great number of plant associations as a result of the heterogeneity of natural conditions. The occurrence of 7 vegetation zones with different climate-zonal forest associations and one zone of grass association has a great role in the process of regionalisation.

Hydrographic conditions show an influence on soil genesis, properties and geography through surface flows (river systems and erosion), floods and waterlogged lands, groundwaters and irrigation. The soils formed directly under the influence of erosion and strongly eroded soils cover 27.1% of the territory of the Republic of Macedonia, and together with those that are indirectly formed under its influence, cover 41.2%.

Table 2: Agricultural area, 2002

Type		ha
Cultivated	Total	598,000
	Meadows	56,000
	Vineyards	28,000
	Orchards	16,000
	Arable (incl gardens)	498,000
Pastures		636,000
Ponds, reed-beds, fishponds		2,000
Agriculture	Total	1,236,000

Source: Statistical Yearbook of the Republic of Macedonia, 2002

Table 2 shows the categories of agricultural land amounting to 48% of the country. Table 3 shows areas under various categories of arable cultivation. In Table 4, land cadastral and capability classes are listed.

Hydrographic conditions have caused the formation of 199,800ha of hydromorphic soils including alluvial soils. This amounts to 7.8% of the whole territory of the Republic of Macedonia. The ground waters contain very little salt, most often less than 1,000mg/l. Only in some basins, where there are halomorphic soils, are the waters more saline. Under these influences, 3,200ha of halomorphic soils have been formed, and salinisation and alkalinisation appear in an additional 8,000ha. Under the influence of salinised paleogenic sediments, the most salinised ground waters in the Balkans are found in Ovche Pole.

Table 3: Arable land, 2002

Category	ha
Fallow & uncultivated land	146,000
Sown area	350,000
Cereals	221,000
Industrial crops	34,000
Vegetable crops	60,000
Fodder crops	35,000
Nurseries	2,000
Arable (incl. gardens)	498,000

Source: Statistical Yearbook of the Republic of Macedonia, 2002

As there are no direct measurements of the age of the soils, i.e. of the time influence over which pedogenesis took place, conclusions are derived on the basis of morphology and level of evolution.

Man is a very important factor in changing the soils in the Republic of Macedonia, because The country was settled a very long time ago and it is a country of ancient civilisations. Many soils were anthropogenised to different levels.

Soil classification

The soil cover of the Republic of Macedonia is very heterogeneous, with great changes over small distances. Almost all relief forms, geological formations, climatic influences, plant associations and soils that appear in Europe (with the exception of podzols) are represented. More than thirty soil types are found in Macedonia (Table 4).

Using the classification of Skoric *et al*. (1985) and according to the monograph 'The Soils of the Republic of Macedonia' – (several volumes 1995, 1996, 1997, 1999), the following soil types have been established: lithosols, regosols, arenosols, colluvial soils, rendzinas on hard limestones and dolomites, rendzinas, rankers, vertisols, chernozems, chromic cambisols, red soils (terra rossa), brown soils on limestones and dolomites, brown forest soils, illimerised soils, brown podzolic soils, alluvial soils, fluviatile-meadow soils, hydromorphic black soils, gleyic soils, peat soils (histosols), pseudogleys, solonchaks and solonetz.(Table 5).

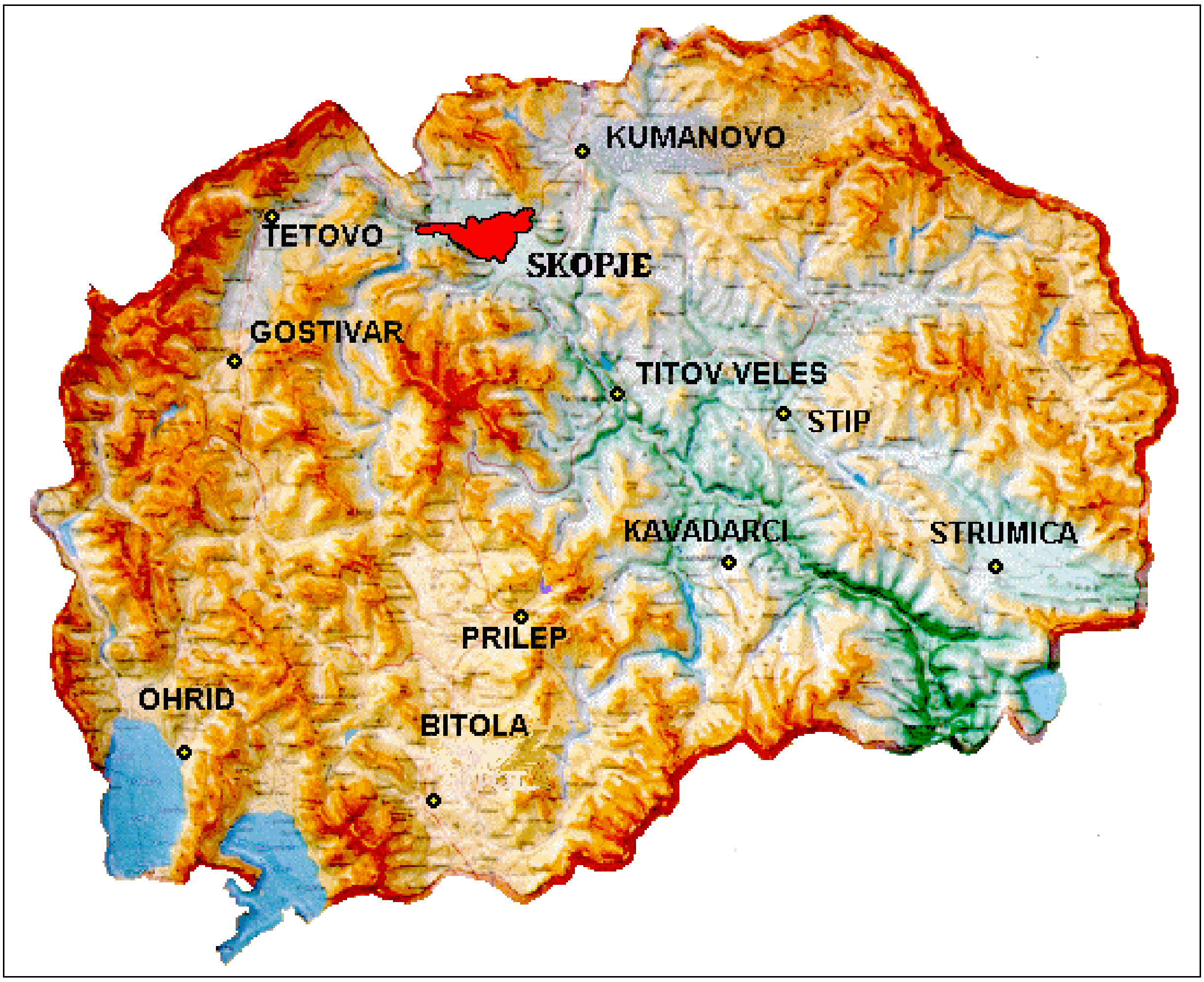

Figure 1. Geographical map of the Republic of Macedonia

Table 4: Cadastral classes (hectares)

(ha)	Cadastral classes								Total
	I	II	III	IV	V	VI	VII	VIII	
Fields	10,969	24,780	47,068	67,507	73,097	72,733	62,379	59,429	417,962
Vegetable -gardens	596	1,142	1,189	831	758	529	9	0	5,054
Orchards	938	2,617	3,765	3,549	2,269	610	73	0	13,281
Vineyards	552	2,863	5,801	5,519	2,818	982	727	12	18,774
Meadows	559	3,101	7,574	10,657	8,483	6,950	3,779	1,691	42,830
Pastures	818	1,848	7,815	21,923	20,689	18,627	12,072	7,019	90,800
Forests	825	3,438	11,095	30,290	25,405	17,725	6,202	2,606	97,586
Swamps	83	208	186	34	1	0	1	1	514
Total	15,375	39,997	84,493	140,310	133,520	118,156	84,742	70,758	687,352
%	2.24	5.82	12.29	20.41	19.43	17.19	12.33	10.29	100.00

Table 5. Soil types and complexes, ha (%)

Soil types and complexes	ha	%
I. Mountain soils		
Lithosols	13,053	0.51
Lithosols and eroded eutric and distric cambisols	299,068	11.63
Lithosols and cinnamonic forest soils	54,200	2.11
Lithosols, regosols and rankers	12,006	0.48
Rankers	232,897	9.06
Rendzinas on hard limestones and dolomites	221,441	8.61
Brown forest soils (dystric and eutric cambisols)	729,618	28.38
Brown soils on hard limestones and dolomites	92,944	3.62
Total	**1,655,227**	**64.40**
II. Soils of lake terraces and of undulated hilly relief		
Regosols	92,705	3.60
Regosols, rendzinas and cinnamonic forest soils	218,583	8.50
Regosols and luvisols	6,346	0.25
Vertisols	61,900	2.41
Rendzinas	2,100	0.08
Chernozems	32,800	1.28
Cinnamonic forest soils	113,359	4.41
Cinnamonic forest soils and luvisols	4,068	0.16
Luvisols	21,617	0.84
Total	**553,478**	**21.53**
III. Soils of colluvial fans		
Colluvial soils	159,593	6.19
Total	**159,593**	**6.19**
IV. Soils of the plains		
Alluvial soils	130,207	5.06
Fluviate-meadow and gley soils	39,395	1.53
Peat and peat-gley soils	28,100	1.09
Pseudogleys	2,100	0.08
Halomorphic soils	3,200	0.12
Total	**203,002**	**7.88**
Total for the Republic of Macedonia	**2,571,300**	**100.00**

In preparing this study, we used many research papers including: Mitkova *et al*. (1995, 1996, 1998, 2000, 2003), Mitrikeski (1995); Mitrikeski *et al*. (2001, 2002, 2003); Filipovski *et al*. 1985).

Lithosols

Lithosols are spread throughout the hilly-mountain zone and those over acid compact rocks dominate. They most frequently contain more than 50% coarse fragments, very small clay content (under 5%) and are normally very shallow, with low water capacity. These lithosols are well aerated and warm for the given climatic conditions and contain 1.7% humus on average in the A horizon. The pH in the water averages 6 over acid rocks and 6.25 over basic rocks. The cation exchange capacity is very low (8eqmmol in 100g soil). The soils are not used for agriculture.

Regosols occur in basins, mainly on undulating terrain, over paleogenic, neogenic and diluvial sediments. Depending on the substratum over which they are formed, these soils are very heterogeneous in mechanical composition. The regosols formed over residuum from acid rocks contain on average: 27% coarse fragments, 3% clay, 13% silt and 17% clay + silt. Sandy soils prevail, covering 83% of the area.

Silicate carbonate regosols over tertiary sediments contain on average: 8-9% coarse fragments, 17% clay, silt 28% and 45% clay + silt. The physical properties of carbonate regosols are: porosity 50%, water capacity 38%, air capacity 11%, wilting point 15% and available water 23%. The chemical properties also show heterogeneity. The regosols formed over residuum from acid rocks are without carbonate and contain around 2% humus. pH in water is on average 6.2, cation exchange capacity is 11.5, S = 4.5eqmmol in 100g soil and V = 38.7%. Silicate carbonate regosols over tertiary sediments contain more than 2% humus and 16% $CaCO_3$ on average. Their reaction in water is averages pH 7.7. Some of the regosols are under xerophilic hilly pastures. The rest are used intensively for agricultural purposes.

There are very small areas of *arenosols,* formed on sand from the Vardar River that has been transmitted and deposited with the help of strong winds in the Vardar valley.

Colluvial soils

Colluvial (diluvial) *soils* are intensively used in the agriculture. They have very heterogeneous texture. On average, these soils contain: 10% coarse fragments, 10% clay, 20% silt and thus sand dominates (70%). The average value for porosity is 44%, for water capacity 34%, for air capacity 10%, for wilting point 11% and for available water 23%. They are also heterogeneous in their chemical properties.

Lithosols contain on average 2% humus. The reaction of the surface soils in this group is as follows: neutral (44.7%), acid (42.7%), with a small number alkaline (12.6%). Dystric colluvial soils have a low cation exchange capacity (less clay, with more illite and kaolinite), which is on average 17eqmmol in 100g of soil, and the base saturation is 78%.

Rendzinas

Rendzinas on hard limestones and dolomites are found on all the mountains of appropriate substratum: calcitic limestone, calcitic marble, dolomites, dolomitic marble and calcitic-dolomitic marble. The soils are relatively rich in clay owing to the high content of clay in the silicate residuum. The average clay content amounts to 11% in the organogenic soils, 18% in the organomineral soils and 26% in the brown rendzinas. The humus content is highest in the organogenic rendzinas (19%), whereas the other subtypes contain on average 10% of humus.

The highest pH values have been recorded for the organogenic soils (an average of 7), followed by the organomineral (6.9); the brown rendzinas are the most acid (pH 5.8). The soils are characterised by high cation exchange capacity (an average of 51eqmmol/100g soil). The base saturation percentage is high (on average,98%). The ratio of humic: fulvic acids is 0.80. There is a high content of humic acids bonded with Ca.

Rendzinas are most frequently found in the valleys in the central part of Macedonia, which is also the driest part, up to 800m above sea level. The texture of these soils is heterogeneous and is conditioned by the substratum. On average, they contain some coarse fragments (7%) with particle-size fractions as follows: coarse sand 13%, fine sand 39%, silt 26% and clay 22% on average. Their micro aggregates and macro aggregates are stable.

The average porosity values amount to 49%, the water capacity 38% and the air capacity 11%. These soils contain an average of 2.6% humus in the A horizon. In calcareous rendzinas, the A horizon contains an average of 11% $CaCO_3$ and the C horizon 25% $CaCO_3$. The average pH of the A horizon is 7.8. The cation exchange capacity amounts to an average of 25.0eqmmol/100g of soil, and the base saturation percentage in non-calcareous rendzinas amounts to 96%.

Rankers

Rankers are characterised by their heterogeneous texture. They are rich in coarse fragments (average 21%). They contain small amounts of clay (an average of 7%). The different particle size fractions are as follows: coarse sand (43%) followed by silt, while clay is least common. The stability of the micro aggregates is above 90%, and the stability of the macro aggregates is 70-80%. The most stable are the macro aggregates of 1-5mm diameter.

The porosity of the rankers varies between 46 and 60%, the water capacity from 37 to 44%, and the air capacity from 11 to 16%. The chemical properties are heterogeneous. The average quantity of humus is 8.5%. The average C:N ratio is 11. The pH of the rankers varies from 3.5 to 7.7 (average 5.4). The average cation exchange capacity is 27eqmmol/100g of soil. The humus in the rankers is rich in insoluble remains and mobile fractions of humic and fulvic acids. The ratio of humic to fulvic acids in dystric rankers is 0.7 to 0.9, and in the eutric rankers it is above 1.

Vertisols

Vertisols are identified as intrazonal, lithogenic topogenic soils. They are found together with other types of soil; depending on the parent material, with regosols, rendzinas, chernozems and cinnamonic forest soils, and on basic compact rock with lithosols and vertic rankers. The texture of vertisols is characterised by the following features: low coarse fraction (4% on average); the clay fraction dominates (clay + silt = 60%); clay is the dominant soil separate (40%) in the fine earth; there is little coarse sand in the vertisols (9%), more silt (21%) and fine sand

(30%); clay textures prevail and there is no texture differentiation.

Coarser macro aggregates dominate (above 3mm and especially above 5mm). The air capacity is low (2.7 to 6.5%, with an average of 4.2%). Aeration is low in wet conditions. Vertisols are characterised by high plasticity: the upper limit is 79%, the lower 38%, and the plasticity number is 41%. The A horizon contains an average of 3.5% humus and an average of 5.3% $CaCO_3$ (calcareous vertisols). The mean pH value for all Vertisols is 7.2.

The exchange capacity is high and amounts on average to 38eqmmol/100g soil. Mean values of exchangeable alkaline cations are: Ca=56%, Mg=27%, H + Al=15%, K=1.0%, and Na=0.7%. Exchangeable Mg cations dominate in the Vertisols on serpentinite and gabbro. These soils are characterised by a high percentage of humic acids, among which few are free. They contain little fulvic acids. The ratio between the humic and fulvic acids is high (1.75, and varies from 1.1 to 2.6). These soils contain a high percentage of insoluble organic remains.

Chromic cambisols

Chromic cambisols (cinnamonic forest soils) are found in the regions influenced by a Mediterranean climate, under xerophilous and thermophilous oak vegetation. They occupy undulating hilly (fluviodenudational) relief up to 900m and lake terraces in the valleys, on tertiary sediments, particularly neogenic lake sediments and certain more recent ones. They can be found on Mesozoic and Paleogenic (Eocene) sediments and less frequently on compact basic rocks and pyroclastic sediments.

The solum of these soils is 50-100cm deep. The texture of the soils has the following composition: relatively low content of coarse separates (average 10%); in the A horizon the sand content (coarse + fine sand) dominates over the clay content (silt +clay) and amounts to 60% on average. The profile shows clear textural differentiation: the (B) horizon contains 1.7 times more clay than the A horizon. The micro- aggregates are very stable. There are clear differences between the physical properties of the A and (B) horizons. For example, the average values in the A and (B) horizons are as follows: for the bulk density 1.4 and 1.5 respectively; porosity 49% and 45%, water capacity 39%, and air capacity 10% and 5.5%. The humus content in the A horizon is very variable and is about 6-7% under forests, 4% under pastures, and in the cultivated soils averages 2.6%.

The average pH value in H_2O is 6.4 in the A horizon and 6.6 in (B) horizon. The cation exchange capacity (T) is on average 22eqmmol/100g soil. This value is higher in the (B) horizon. The sum of the exchangeable bases (S) is relatively high (an average of 18.0eqmmol/100g soil) and the same is true of the base saturation percentage (V), 83%.

The humus composition has the following characteristics: a high content of humic acids (30%), with those bonded with calcium prevailing, a reduction in the quantity of humic and an increased quantity of fulvic acids in the (B) horizon, so that the relation between them in the A horizon amounts to 1.27, and in (B) to 0.84. According to its composition, the humus can be classed as mull.

Red soils

Red soils (terra rossa) covers very small areas. It is found in those parts of the Republic of Macedonia influenced by a Mediterranean climate. The soils form on the mountain karst relief, most often up to 600m above sea level. The solum of the red soil is 30 to 70cm thick. They contain less than 10% skeletal material. The clay fraction dominates in the fine earth (average 38%). There is very little coarse sand (average 5.5%) and most of the sand is fine sand (27%), and silt (30%).

These soils are characterised by textural differentiation. In the (B) horizon there is 1.32 times more clay than in horizon A. The (B) horizon meets the FAO-UNESCO criteria for an *argic* horizon. The micro- aggregates and macro aggregates are stable. The humus content in the forest areas is on average 5.5% but can be as low as 2.5%, and in the (B) horizon it averages 3.6%. The average pH value in the A and B horizons is 6.9,. Neutral soils dominate absolutely.

The cation exchange capacity is high (on average in horizon A it is 35.5eqmmol/100g soil. The sum of exchangeable bases (S) is high (30eqmmol/100g soil) and the base saturation percentage (V) is also high 88%. The humic : fulvic acid ratio is 0.85 in the A horizon and 0.47 in the (B) horizon.

Cambisols

Brown soils on limestones and dolomites (calco-cambisols) are found only in the limestone and dolomite mountains in the Central mountain zone, at an altitude of 600 – 1,600m. The average depth of the solum is 56cm. The texture has the following characteristics on average: 12% skeletal material; physical clay (clay + silt) prevails (60%). The textural differentiation is clear. The (B) horizon contains 1.37 times more clay than the A horizon.

The average humus content in the A horizon is 7%. The solum is not calcareous. The pH in water is close to neutral (average 6.5). The cation exchange capacity is high (for the A horizon, on average, 39eqmmol/100g soil). The sum of exchangeable bases (S) is high (33eqmmol/100g soil in the A horizon) and the base saturation percentage (V) is also high, at around 84%. The humus composition has the following characteristics: there is a low percentage of insoluble residue (32-33%) and a fairly high percentage of humic (29%) and especially fulvic acids (38%). The ratio of these acids is fairly narrow (0.77 in the A and 0.67 in (B)).

Brown forest soils are the most widespread soil type in the Republic of Macedonia. They account for approximately 1/3 of the mountain territory of the Republic. As climatic-zonal soils, they are found on all forms of mountain relief, all aspects and inclinations at altitudes between 800 and 1,800m. They form on compact quartz rocks, as well as on a number of compact acid, neutral basic and ultra basic silicate eruptive and metamorphic rocks and, over small areas, on carbonate-free silicate sediments.

As far as the climate is concerned, these soils can be found in four vertical climatic zones: cold-continental, piedmont-continental-mountain, mountain-continental, and sub alpic. These soils are found under a number of associations in the oak, beech and subalpic regions. The texture of the soils is heterogeneous: sandy loams, loams, and clay loams prevail.The skeletal content is quite high (average 25%) in the A and (B) horizons. The clay content averages 9% in the A and 12% in (B) and textural differentiation is low. On average, the (B) horizon contains 1.28 times more clay than the A horizon; argilogenesis is low and there is 1.24 times more clay in the (B) horizon than in the C. The sand content (coarse + fine sand) accounts for 2/3 of all the particle-size fractions. Coarse aggregates dominate in these soils (46% of the aggregates are larger than 3mm).

The macro aggregates show high stability (82.5% in the A horizon and 77.7% in the (B) horizon. The soils are characterised by high porosity (54% in the A, 41% in the (B) horizon on average). They have moderate water retention capacity (37% in A, 33% in (B)). The aeration is very high (17%) in the A and 13% in the (B). The chemical properties vary within broad limits, depending on the parent material, altitude, climatic-vegetation zones.

The organic horizon contains approximately 19% humus. The mineral soils are also rich in humus: 6.6% on average in the Ahorizon. The soils are non-calcareous, with pH averaging 5.6 in the A horizon and 5.5 in the (B). Acid and moderately acid soils thus dominate. The cation exchange capacity in the A horizon is an average of 25 and in the (B) horizon an average of 20eqmmol/100g soil. The sum of exchangeable bases (S) is low: 13.5 in the A horizon, 9.9eqmmol/100g soil in the (B) horizon (B, so that V is around 50%, but it varies depending on the subtypes

The humus has a distinctly different composition in different horizons. The insoluble residue is the most dominant followed by the fulvic acids, while the humic acids come third (the ratio is 1:0.48:0.41); the ratio between the quantity of the humic acids and the fulvic acids is below 1 (in the A horizon 0.87 and in the (B) horizon 0.51).

Luvisols

Eluvial-illuvial soils (luvisols) have the following characteristics: the skeletal content is fairly low (9%). The sand fraction dominates and accounts for 2/3 of the particle-size fraction; physical clay dominates in the Bt horizon, where it accounts for 54%; the clay content in the A horizon averages 15%, and in the Bt 36%. The microaggregates show high stability. The stability of the macro- aggregates is greatly reduced in the cultivated soils (45%), especially of those under 1mm.

The porosity in the Ap is 45%, and lower in the Bt (37%), with high percentage of capillary pores. The water retention capacity in the A horizon is 31%, and in the Bt 35%. The chemical properties show heterogeneity and differentiation with profile depth. The average humus content in the A horizon A is 2.7%. The average pH values in H_2O indicate moderate acidity (5.8 in the A and 5.7 in the Bt). The cation exchange capacity in the A horizon averages 16 and in Bt 24eqmmol/100g soil. The sum of exchangeable bases shows similar differentiation (6.8 in the A and 15.5eqmmol/100g soil in the Bt). The C:N ratio of the humus is 11.2 in the A horizon, and 7.0 in Bt.

The areas of *brown podzolic soils* are small and not sufficiently studied as yet. This is the soil type accounting for the smallest area amongst the

mountain soils. In the Republic of Macedonia, they appear in the vertical zone between 1,500 and 2,200m. The texture has the following characteristics: a considerable quantity of coarse fragments: in A/E 27%, in B_1 32%, in B_2 43% and in the C, 52%. The sand content on average is 32% in the A/E, 32% in B_1, 25% in B_2, and 21% in the C.
The clay content is low, with an insignificant textural differentiation. In the organic horizon, there is an average of 23% humus, 9% in A/E, 6% in B_1, and 3.4% in B_2. The C:N ratio is 14 to 15 in all horizons. The horizons have a highly acid reaction, the pH in water averaging 4.5 in the A/E, 4.7 in B_1, 4.9 in B_2 and in the C, 5.0. The cation exchange capacity is 37eqmmol/100g soil on average in A/E horizons. A very important characteristic of these soils is the extremely low content of exchangeable bases: only 3.2 in the A/E horizon, 1.6 in the B_1 horizon, 1.0 in B_2 and 1.1eqmmol/100g soil in the C horizon. The base saturation is, therefore, very low: 9% in the A/E horizon, 6% in B_1, 5% in B_2 and 8% in the C horizon.

Fluvisols

Fluvisols (alluvial soils) cover approximately two-thirds of the flood plain surface and are among the best-known soils in these parts. They are characterized by their highly heterogeneous texture. The dominance of loamy soils (86%) indicates their favourable texture. The average texture is a follows: fine sand 51%, silt 30%, clay 10%, and coarse sand 9%. There are few coarse fragments (4%). In the surface horizon, these soils contain an average of 2% humus.

Of the entire area of alluvial soils, non-carbonate soils make up 62%, and carbonate soils 38%. The average CEC of the soils is 19 in the top layer, while the S is 16eqmmol/100g of soil; consequently, the average V is 82%. Salt content is low (below 0.2%), with predominance of Ca and Mg bicarbonates.

Fluviate-meadow soils (humofluvisols) cover a significantly smaller area than alluvial soils. Most of the profiles are loamy (85%), and only 15% of are clayey soils. The average particle-size content is: fine sand 42%, silt 30%, clay 16%, and coarse sand 12%. In the A horizon , the humus average is 2.4%, and the C:N ratio approximately 10. The average CEC of the A horizon is 19,and S is 16eqmmol/100g of soils, so that V is 83%. The salt content is low.

Hydromorphic soils

Hydromorphic black soils: Fifty seven per cent of these soil are clay soils and 21% are clay loam soils. The content of individual soil separates is on average as follows: fine sand 32.4%, clay 29%, silt 28%, and coarse sand only 11%. Micro aggregates are stable, macro aggregates are unstable. The C:N ratio varies from 6 to 13. The average CEC of the soils is 44 and S is 38eqmmol/100g of soils, so that V is 94-98%. The humus composition is characterised by the following properties: high prevalence of humic and fulvic acids, high content of insoluble residue, domination of an inert (stable) component of humus, and a high degree of polymerisation.

Swampy gley soils: The texture of these soils is also heterogeneous. Among them, loamy classes predominate (76%), followed by clay classes (24%). They contain very few coarse fragments (2.5%). Soil separates appear on average as follows: silt 36%, fine sand 36%, clay 21%, and coarse sand 6.5%. These soils are rich in humus (an average of 6% in the A horizon. The average pH in carbonate gley soils is 7.7, while in non-carbonate soils it is much lower, 6.2. The average CEC is high, 30, in the A horizon, and S is 20eqmmol/100g of soils, so the V in non-carbonate gley soils 69%. The salt content is very low.

Histosols

Peat soils (histosols) cover approximately 700ha. The total volume of peat is 8,000,000 cubic metres. The peat soils in the Republic of Macedonia are mainly lowland (90%) and eutrophic,. There are no climatogenic (ombrogenic) soils. The soils are characteried by low real density, rather low bulk density, high total porosity, high water holding capacity, high wilting coefficient, low capillary rise of water, pronounced swelling and shrinkage, low carrying capacity and hardness, high compressibility, high specific heat and strong thermal conductivity in a most environments. Also, these soils are characterised by high organic matter contents with a low degree of decomposition, high total content of nitrogen, high C:N ratio, high CEC, high buffering, absence of toxic Mn and Al ions in the presence of an acid reaction, and low quantities of nutrients per peat volume.

Pseudogleys

Pseudogleys. The total surface of these soils is small (several thousand ha) and has not been precisely established. The texture is highly differentiated. The average ratio of clay content between the lower and upper horizons is 2.7, varying between 2.1 and 4.5. Chemical properties also reveal similar differentiation.

Halomorphic soils

Halomorphic soils have specific properties by which they differ from non-halomorphic soils. They exhibit significant changes over small distances. A number of halomorphic soils are vertically heterogeneous with some of their properties changing significantly with depth. The salt can emerge as spots on the fertile non-halomorphic soils and can spread through anthropogenic salinisation and alkalisation. Halomorphic soils contain larger quantities of salts and exchangeable sodium ions than other types of soil and they can have strong alkaline reaction. They are characterised by low or no productive capacity, but can be reclaimed.

These types of soil are not extensive, covering only approximately 11,000ha in the Republic of Macedonia. More than 90% of halomorphic soils are formed in alluvium, and only very rarely from colluvial deposits. Saline Eocene deposits have an indirect influence on the genesis of these soils. In terrain with such deposits, halomorphic soils are formed when the ground water is close to the surface (meso-depressions, slopes). The dry matter in the water extracts of these deposits amounts to 0.813% on average with Na_2SO_4 predominating, and with the presence of boron (1.8mg/l). As it passes through these deposits, the ground water becomes richer in salts, particularly in Na_2SO_4 and boron. The parent material because of its properties (salt content and composition, $CaCO_3$ and $CaSO_4$ contents, clay content and composition), influences the properties of the solum.

The influence of the parent material is combined with topographic-hydrographic conditions. The ground- waters in the solonchak soil types contain considerably more salts (38.2g/l on average, with a maximum of 107g/l. This quantity of salts is not to be found elsewhere on the Balkan Peninsula. Salts in solonetz groundwaters amount to only 0.90g/l. The neutral salts (sulphates and chlorides) prevail in solonchaks, with the sulphates dominating.

Soil Monitoring

Unfortunately, the Republic of Macedonia has still not established soil monitoring programmes. This is the result of insufficient financial support for this complex and expensive work.

Future Prospects

- Elaborating and digitising of pedological maps at the scale 1:50,000;
- Mapping of locations where soil degradation is occurring;
- Establishing of a soil monitoring system;
- Introduction of a Soil Information System;
- Introduction of a law to regulate maximum permissible limits of harmful substances in soils;
- Defining of resources that cause soil pollution;
- Introduction of law for soil fertility control;
- Preventing activities of negative soil degradation by implementing measures for positive anthropogenisation of soils;
- Defining of regions for healthy food production.

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Soil Survey and Soil Mapping in the Maltese Islands: the 2003 Position

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Soil Survey

Unlike other European countries, Malta does not have a tradition of soil survey and monitoring. Until now, Maltese agriculturalists, environmental managers and rural planners have had to rely on sporadic and fragmented sources of information in order to make decisions about the use of the country's soil resources. It was only recently, in response to the ever-increasing requirements for soil information to address environmental, agricultural and land planning issues, and as a result of the metamorphosis caused by the process of EU accession and alignment to the Acquis Communitaire, that the first-ever systematic soil survey of the Maltese Islands was initiated by the newly established National Soil Unit.

History

In his report on Agriculture in Malta to the Government of Malta, Dawson Shepherd, (1920) remarks that no exact soil survey had been made of the Island, and that he could not find any attempt at systematic soil analysis. It was in fact D.M. Lang who in 1960 was responsible for the first detailed study of the soils of Malta and Gozo (Lang, 1960). This soil survey was carried out in 1956-57 for the then Colonial Office, and finalised in 1960 with the publication of the soil map of the Maltese Islands at a scale of 1:31,680 (2 inches to 1 mile). The objective of Lang's soil survey was to provide basic descriptions of the soils and to map their distribution as an aid to agricultural planning. In view of this he mapped differences in chemistry, physics, and biology of the soil, as reflected in soil colour, texture, and structure, in conjunction with the landscape type.

In the soil survey carried out by Lang, the soils were described using Kubiena's classification system (Table 1).

The resulting soil map shows the distribution of 13 mapping units, 9 of which are designated as being characterised by a single 'soil series' and 4 of which are 'complexes' or 'sequences' in which a number of soil series occur in a complex and often unpredictable pattern. The soil series concept used by Lang was largely based on geological criteria, as was the case in many soil studies at that time. The individual soil series were defined to incorporate the wide range of soil depths and textural classes that could be found on individual geological parent materials. The map was based on detailed field observations within two areas comprising about 25.9km^2 in total. The remaining 290km^2 of the Islands were mapped from aerial photographs and occasional 'ground-truth' observations along traverses. The accompanying report describes the soil map units and their broad characteristics, gives a classification of the soil series, and a set of qualitative descriptions of soil profiles. This soil map has remained in use until recently.

Although the concept of sustainable use and management of the terrestrial environment in Malta has only recently started to emerge as a specific goal, Malta is nowadays in a position whereby it has registered significant progress in environment protection and sustainable management of land resources. The need was felt for spatial information in the form of soil physical and chemical properties that could be used in existing European - wide interpretative environmental models. It was also necessary that any soil information would be compatible with current European classification systems.

In the light of these developments, Lang's soil map and report were unsatisfactory not only because they were based on methodology that has been superseded, but also because the rapid expansion of urban areas since the 1960's has markedly changed the Maltese landscape in and around these new urban areas, particularly where topsoil material from the development sites has been used to create new terraces or to augment and deepen existing ones. In several of the impact assessment studies carried out during the process of screening Maltese legislation in relation to the Acquis, the importance of assessing the soils of Malta was highlighted repeatedly. The first State of the Environment Report for Malta (Axiaq *et al*., 1999) identified the need to survey the soil resources, and to develop a tool for the management of soil information as one of the most urgent priorities that the government should not only encourage but also fund.

Soil Information System for Malta

The Development of a Soil Information System for the Maltese Islands: MALSIS LIFE 00 TCY/M/036, has proved to be a major turning point in establishing a wealth of soil information and equipping Malta's public sector with the technical expertise to describe, assess, monitor and manage soils in a sustainable way. This major project is co-funded jointly by the LIFE Third Countries programme and the Maltese Ministry for Rural Affairs and the Environment. MALSIS is planned to fulfil both the national requirements for soils information in Malta, and the broader need to integrate this data within the information structures of the European Soil Bureau (ESB) and wider international initiatives. The project was launched in 2002 and is being implemented with the external technical assistance of soil survey, laboratory and information system specialists from the National Soil Resources Institute (NSRI) of Cranfield University in the UK. The project was completed in February 2004, however, it will map the direction for the future work programme of the Maltese soils office.

Soil Surveys

The MALSIS project comprises three stages of soil survey and soil resources assessment. The first stage consists of a national grid-based inventory of the soil resources at 1km interval, totaling approximately 280 sites in Malta, Gozo and Comino (Figure 1). The precise grid survey at these pre-selected geo-referenced target sites was initiated in June 2002 and was completed during the 14-month period that followed. The soil survey methodology adopted follows the FAO Guidelines for Soil Description (FAO & ISRIC, 1990) with minor adaptations to reflect local conditions. A set of site and soil characteristics were described from shallow pits dug in the field up to a depth of 80cm. These characteristics provide information on the site in terms of agricultural land use, height of terrace, cropping pattern, irrigation, slope, etc., and soil properties: colour, texture, depth, horizons, structure, penetration, mottles, stones and roots. This information is recorded on field/soil survey cards and is used to describe the soils in terms of texture, mineralogy, lithology and landscape. The soil profile descriptions were used to classify the soils of Malta and Gozo using the World Reference Base for Soil Resources (WRB), (Figure2).

According to a first approximation, six soil reference groups were identified, and Calcisols were recognised to be the dominant soil group in the Maltese Islands (Table 2). As more results become available, it is expected that the qualifiers of the soil units will be refined on the basis of laboratory criteria.

Table 1: Classification of Maltese soils according to the system by Kubiena

Division	Class	Type	Sub-type (qualified)	Variety	Locality/Series
A. Sub-aqueous					
B. Semi-terrestrial	BA. Semi-terrestrial raw soils BD. Salt soils	VI Rambla	12.Chalk Rambla		Ghadira Alcol
C. Terrestrial	CA. Terrestrial raw soils	XXIII Syrosem	50.Carbonate raw soil		Fiddien, San Lawrenz, Nadur, Ramla, part S.B.
	CC. Rendzina-like soils	XXV Rendzina	60.Humid Rendzina	(36)Protorendzina Mull rendzina	Malta E. Malta P.
			61.Xerorendzina	Xerorendzina	San Biagio, Alcol, Tal-Barrani
	CE. Terrae Calxis	XXXIII Terra	74. Terra fusca	(47) Earthy terra fusca	Xaghra, Tas-Sigra
			75. Terra rossa	(48) Siallitic terra rossa	

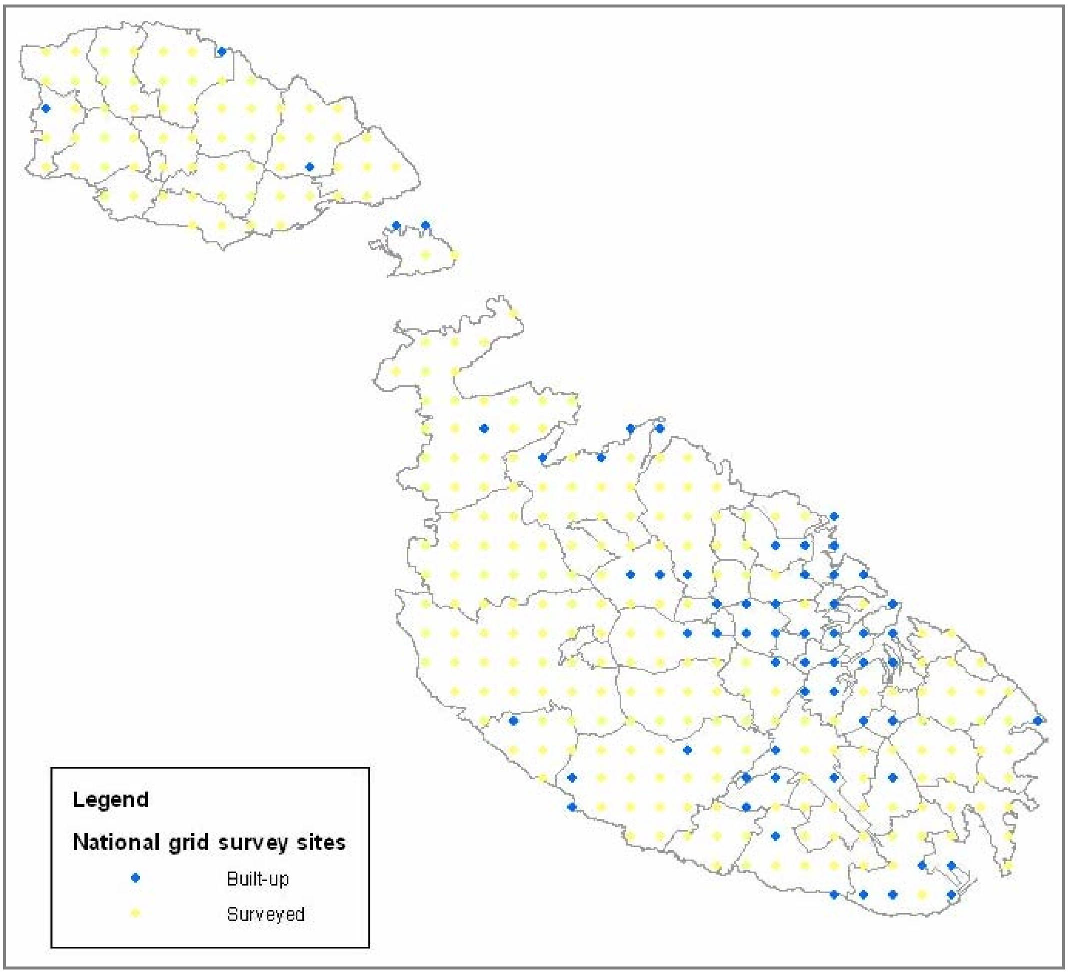

Figure 1: Geo-referenced locations of national grid survey

Table 2: Soil units identified in the national grid survey of Malta and Gozo

Soil Reference Group	Soil Unit	Number of sites	% of total (272 sites)
Leptosols	Calcari-Lithic Leptosols	5	2
	Calcaric Leptosols	35	13
	Calcic Leptosols	1	0
Vertisols	Calcic Vertisols	16	6
	Eutric Vertisols	4	1
Calcisols	Epileptic Calcisols	32	12
	Endoleptic Calcisols	50	18
	Hypocalcic Calcisols	18	7
Luvisols	Chromi-Calci-Epileptic Luvisols	13	5
	Chromi-Epileptic Luvisols	2	1
	Endolepti-Chromi-Calcic Luvisols	13	5
	Chromi-Endoleptic Luvisols	9	3
	Chromi-Calcic Luvisols	3	1
Cambisols	Calcari-Epileptic Cambisols	13	5
	Endolepti-Calcaric Cambisols	3	1
	Calcaric Cambisols	3	1
Regosols	Calcari-Epileptic Regosols	24	9
	Calcaric-Anthropic Regosols	19	7
	Endolepti-Calcaric Regosols	6	2
	Calcaric Regosols	3	1

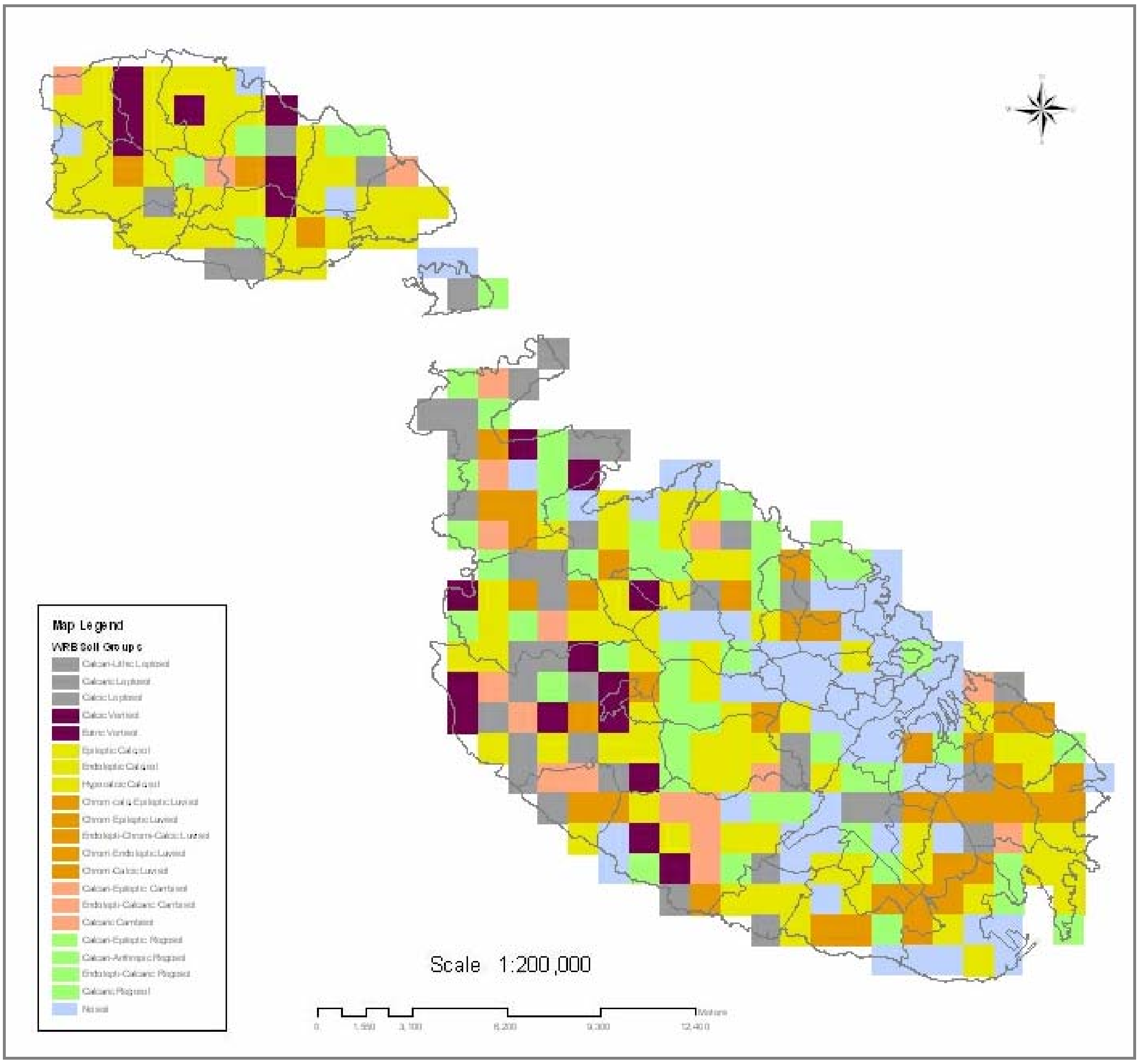

Figure 2: Classification of Maltese soils according to the WRB system

The national grid survey at 1km interval was preceded by a reconnaissance survey along four west east transects across the island. These transects crossed the limestone/calcareous shale sequence from oldest to youngest rocks and also incorporated the deep colluvial soils found in some of the broad ancient valleys on the Island. The objectives of the reconnaissance survey were to identify the major soil landscapes and to make reliable judgements on the range and variability of soils within each of these landscapes. This has enabled the Maltese Islands to be positioned into the current version of the Soil Map for Europe derived from the 1:1,000,000 scale (JRC, 2001).

In Malta the spatial pattern of soil types is very intricate, both in semi-natural and agricultural areas, and different soil types often occur within a single field or within a distance of few metres. In order to be able to use the soil inventory for supporting land management and policy development, it was necessary to identify broader areas of land, which, whilst containing a range of soil types, are likely to have a similar and distinct set of management characteristics.

These so-called soil landscapes contain a range of soil types with a defined relationship within the landscape (Figure 3). Within these parameters, the second stage of the MALSIS soil survey programme was designed to characterise the small-scale variability of important soil properties and limitations within these landscapes and to provide a basis for estimating the uncertainty associated with measurements of soil properties at any specific point. This 'free soil survey' has been ongoing since May 2003, and it is anticipated that it will involve the survey of approximately 320 sites, 240 in Malta and a further 60 in Gozo (Figure 3). It will study the relationships between parameters such as soil depth and texture both within and between man-made terraces and with inferred landscape position (foot-, mid-, upper-slopes).

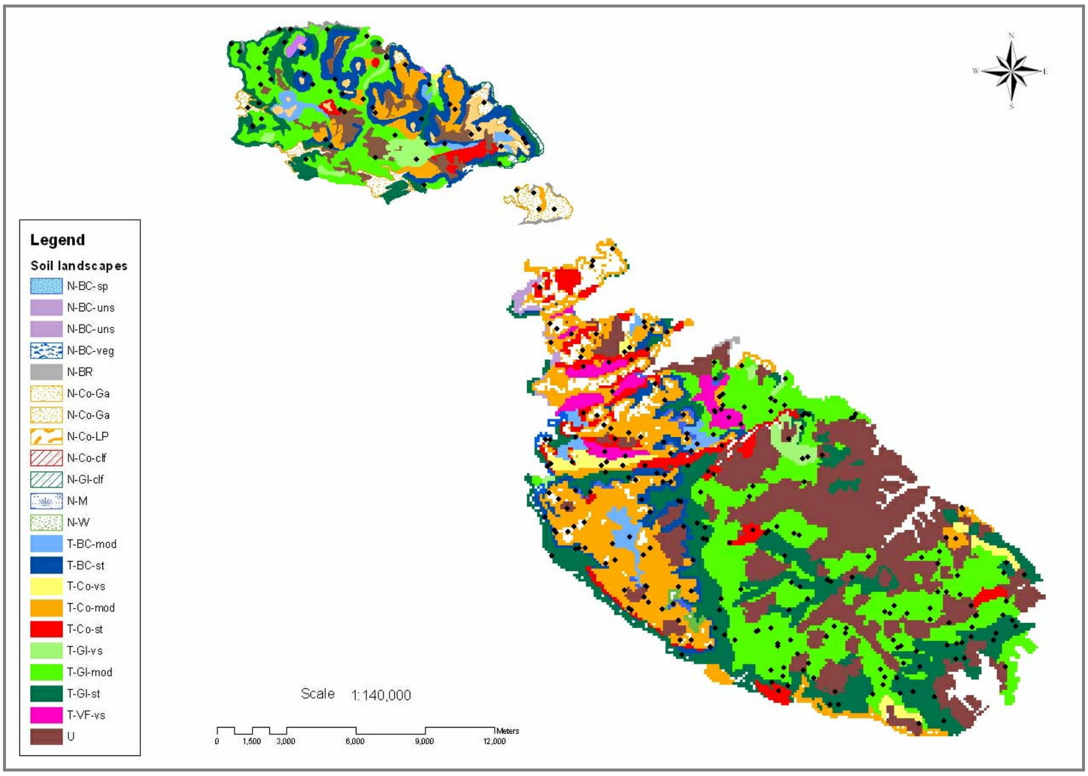

Figure 3: Soil landscapes and location of soil variability sites for free survey

Soil Databases

The soil information system presently in use has been partly developed within the scope of the MALSIS project. The system was designed to store, manipulate and output soil attribute data derived from point observations of fully described and analysed profiles. The information system incorporates two MS Access databases: Agrilab, a laboratory information management system, and Malsis, which stores and retrieves soil profile data (Figure 4).

Another module, MalsisAdmin, facilitates export routines from the two databases and links data pertaining to the geo-referenced profiles and the soil samples laboratory values using unique site reference and laboratory numbers.

The Maltese soil information system contains soil properties datasets derived from site investigations, limited soil profile descriptions, and laboratory analysis. Available data consists of site and soil profile characteristics of approximately 350 sites, and soil physical and chemical properties of about 800 samples (Table 3). The system enables data to be queried, filtered, and mapped using desktop GIS (ArcView). Each variable can be expressed in the form of a map or statistical tables, illustrating distribution patterns that have never been studied at national scale before. The results (Figure 5) show that 51% of the agricultural and semi-natural land in the Maltese Islands has a soil plough layer horizon (0-15cm) that contains less than 2% OC (3.4% OM).

Table 3: Soil properties datasets for different soil survey samples

Soil properties	**National grid survey**			**Local sites investigations**			**Soil variability survey**
				Maghtab	South east area		No analysis have been carried out so far
	B	H1	H2	B	H2	B	
Bulk density		✓	✓				
Characteristic parameters group 1: pH, inorganic carbon, organic carbon, cation exchange capacity, particle size analysis)	✓		✓				
Characteristic parameters group 2: organic carbon, cation particle size analysis)	✓	✓	✓				
Salinity/soluble salts (electrical conductivity)	✓		✓	✓	✓	✓	
Trace and heavy metals (Cu, Zn, Pb, Cr, Ni, Cd, Hg)	✓		✓	✓	✓	✓	

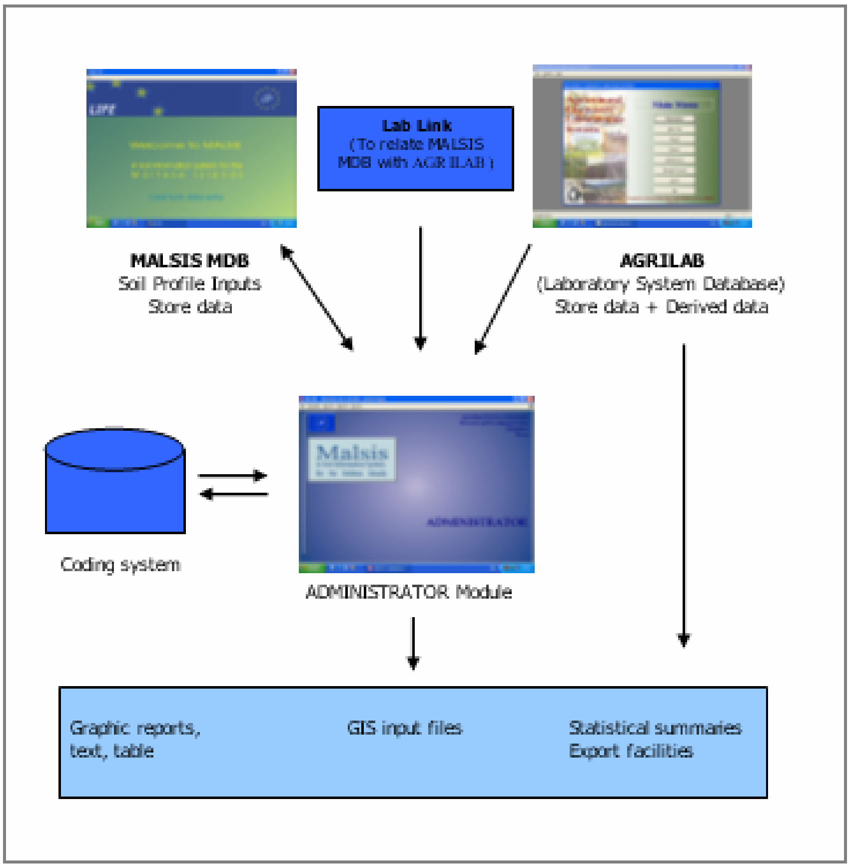

Figure 4: Structure of the Maltese soil information system

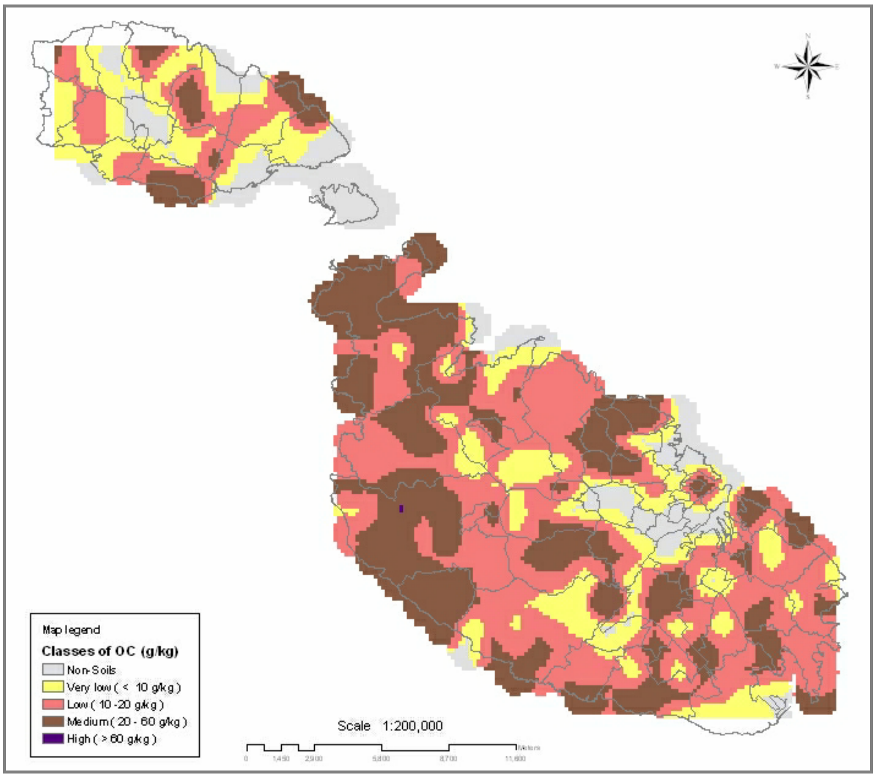

Figure 5: Distribution of organic carbon levels in Malta and Gozo (data interpolated by kriging)

Although data on the content of trace and heavy metals in topsoils and subsoils is still incomplete, preliminary findings (Figure 6) show that the highest levels of copper have been found in the south east region of Malta where treated sewage effluent is used for irrigation. Most of these levels, however, are below the upper limit value for soils with a pH >7 as stipulated in the Sewage Sludge Directive, 86/278/EEC (EEC, 1986). The outputs of the national grid survey at 1km interval have not shown any extensive contamination by heavy metals, but at this stage it is premature to draw any conclusions since results are still being obtained.

Soil monitoring

To date, there exists no comprehensive soil-monitoring programme for the Maltese Islands. One of the primary objectives of the MALSIS project, however, was to achieve the required institutional, technical and administrative capacity for soil monitoring through the establishment of the National Soil Unit. The National Soil Unit is a newly set up structure within the Ministry for Rural Affairs and the Environment with moderate expertise and facilities for soil survey and soil laboratory analysis.

The national grid inventory will serve as a basis for selecting reference monitoring sites for future soil quality monitoring programmes that are specified in accordance to European and national soil monitoring legislative requirements. It is anticipated that ongoing monitoring programmes will entail detailed survey investigations at 5km intervals and local investigations in environmentally sensitive areas. Two such environmentally vulnerable sites have already been selected and sampled at high density in the local sites investigations (stage three of the MALSIS field programme of activities). These sites will be monitored at a frequency of three years.

The areas that were selected are the south east area of Malta receiving treated sewage effluent from the San Antnin Sewage Treatment Plant and the agricultural land surrounding the land-based landfill at Maghtab in the north east part of the Island (Figure 7). The sampling strategy at Maghtab was based on systematic sampling along five line transects, yielding a total of 50 topsoil samples; a judgemental sampling approach was adopted in the south east area, where sampling sites were differentiated according to the types and rates of agricultural inputs (effluent, bio-wastes, manures) that can be correlated with the level of contamination. Another 50 topsoil and subsoil samples were collected from this area.

Applications of soil data

The MALSIS soil information system will serve as a baseline for developing national environmental protection strategies and guidelines for better land and soil management. The primary and derived soil properties will be used to assess the soils' susceptibility to erosion, the groundwater vulnerability to diffuse contamination from agricultural sources, to assess the land in terms of its capability for defined uses, and to facilitate the process of land use planning. MALSIS will also provide the foundations for a system of nationwide monitoring of soil quality and soil threats, such as required by the EIONET network and the proposed Directive on Soil Monitoring.

Already at this early stage in its generation, the information derived from the soils properties databases is being used to underpin rural land use planning, conservation and development programmes such as:

- The elaboration of a Code of Good Agricultural Practice and a Nitrate Action Programme for the Maltese Islands to prevent and combat nitrate pollution of freshwaters from agricultural sources;
- The production of groundwater vulnerability maps;
- The development and implementation of agri-environment measures within the Rural Development Plan for the Maltese Islands;
- The development of a strategy for the promotion of organic farming in the Maltese Islands;
- The development of a national waste management strategy, with emphasis on the land application of bio-wastes;
- The assessment of agricultural land suitability for viticulture.

Future prospects

In many ways, Malta's status as a candidate country for EU accession has facilitated and accelerated the process of alignment to European standards of environmental protection, particularly in the protection of water and air. Soils, however, are still misplaced within the all-encompassing terrestrial concept, and have not yet received their deserved importance as a distinct resource with unique specific functions.

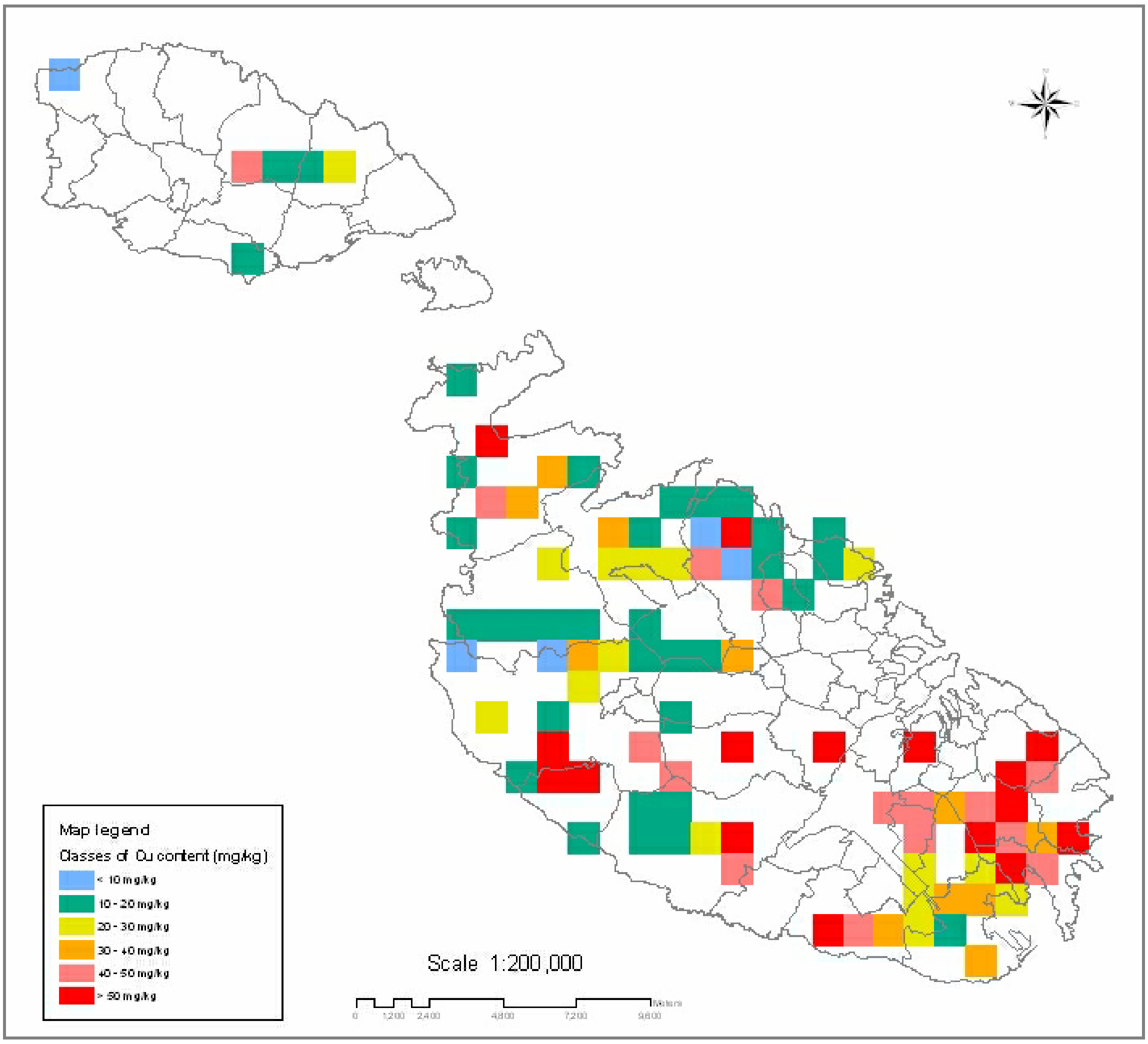

Figure 6: Copper levels in Maltese soils

This is evident, for example, from a review of existing strategies and policies of the major resource protection entities in Malta that target water, air, mineral resources and energy but not soil. The fact that the only primary legislation that protects soils is not only outdated, but also grossly generic and ineffective, is another indicator that soil has not achieved the importance it merits in a small island with high erosion vulnerability and limited potential for renewal of the soil resource base. Large-scale public initiatives, such as the MALSIS project, however, are a prognosis that the materialisation of the European soil policy into legislation will provide the necessary impetus for soil assessment - management - protection driven actions to solidify faster in the coming years.

As a public entity, the National Soil Unit will continue to receive the necessary budget allocation to progress with its programme of soil survey, laboratory analysis and soil mapping. It is envisaged that the soil properties data derived from the field and laboratory components of the MALSIS project will be leased to potential users. This, together with participation in funding programmes, will generate sufficient revenue for the set-up of on-going monitoring programmes aimed at assessing the soils' quality via suitable indicators. In the context of recent endeavours, the future of soil survey, mapping and monitoring in the Maltese Islands appears to be more prospective than it has ever been in past years.

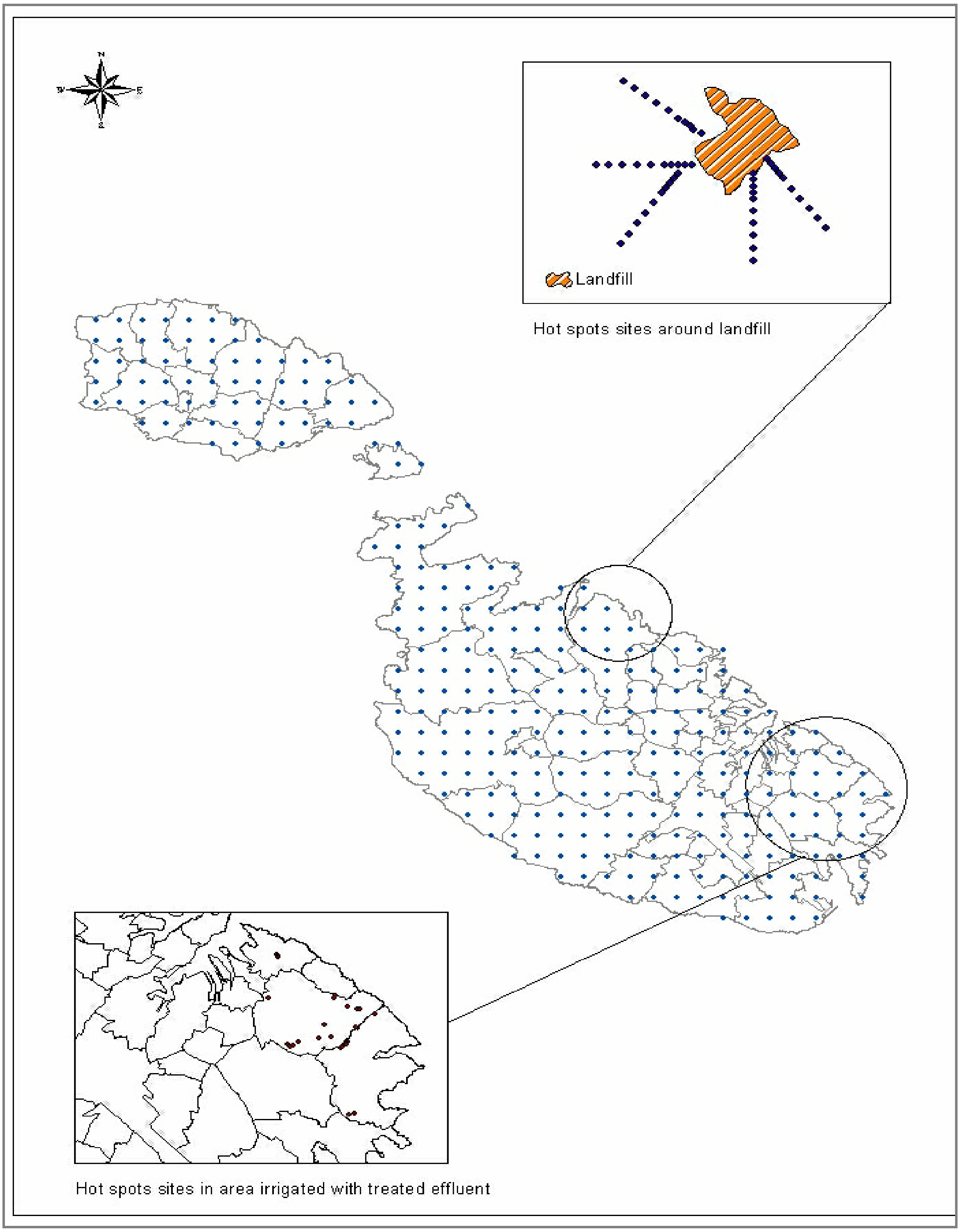

Figure 7: Location of survey sites in environmentally sensitive areas

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Development and Perspective of Soil Survey in the Netherlands

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History

The history of soil survey in The Netherlands has three important phases, each with its own characteristic approach or perspective:

1837 - 1943: the geological approach;
1943 - 1983: the pedological approach;
1983 - present: re-discovery of the soil map.

1837 - 1943: The Geological Approach

This period was recently described by Felix (1995). At the start of the period (1837-1877) various geologists produced maps that described the surface geology. They used lithological legends with descriptions that sound very familiar, e.g. sandy soil, clay soil and peat soil.

The most important contribution came from Dr. Winand Staring. Between 1857 and 1867 he produced the first Geological Map of the Netherlands (1:200,000). The map's legend showed 60 lithological units. In its time it was a very innovative map, as it was the first one to show for an entire country the various unconsolidated Pleistocene and Holocene deposits.

From his geological map Staring derived two other maps: a 'School Map' for educational purposes (1860) and an 'Agriculture Map'. In the 'School Map' the number of lithological units had been reduced to 19. Another very important derived product was a generalised Geological Map at scale 1:500,000.

This map was published in 1877 as part of a national atlas that was also used in schools. This geological map distinguished seven major lithological units, each unit having its own distinct colour.

Between 1877 and 1960 all school children came to learn that yellow stood for sandy, blue for clay, etc.

From 1877 to 1918 no soil maps were produced. However, two groups of researchers contributed to the advancement of soil science: geologists and soil chemists. The geological input concerned knowledge about the composition of rocks and minerals, whereas the soil chemists were interested in soil fertility.

Between 1918 and 1943 a growing distance between geologists and soil scientists seems to have occurred. Geologists and geological maps could not sufficiently answer agricultural questions and soil science stepped in to bridge the gap.

A very important step was the approach to soil survey developed by W.A.J. Oosting. His approach was based on integration of local geology, geomorphology, vegetation and soil forming processes. This landscape-oriented approach would later be adopted by Edelman and become a cornerstone of Dutch soil survey, which is the main output of the next period.

1943 - 1983: The Pedological Approach

De Bakker (1995) has given a description of this period. He distinguishes two important phases in this period which can be described as:

- The physiographic phase;
- The morphometric phase.

During the physiographic phase soil survey went through an exciting period. All early soil surveys concerned areas with Holocene fluvial and marine deposits. The soils in these areas showed clear relationships with geogenesis, geomorphology (relief), vegetation and land use, which formed the basis of each legend.

The awareness of these ‘physiographic’ relations formed the clue to the analysis (survey) of the area. Each new survey area was an exciting ‘terra incognita’, but with the master key of physiographic analysis to unlock it. Consequently, each area finally received its own specific physiographic soil legend.

This phase had various periods and products of national and international importance. The discovery of the importance of soil survey information for agriculture and rural development led to the foundation of a National Soil Survey Institute (‘Stiboka’) in 1945. Prof. Dr. C. H. Edelman, who had stimulated and guided all early soil surveys, became its first director.

It was also Prof. Edelman who took the initiative to organise the first Congress of the International Soil Science Society after the Second World War in 1950 in the Netherlands On this occasion he published ‘Soils of the Netherlands’ (1950), a book containing also a provisional soil map of the Netherlands, scale 1:400,000. This map is the first ‘modern’ soil map of the Netherlands. Edelman combines the early work of Staring, the lithological units, with ‘his’ physiographic approach.

To bring the provisional soil map to a conclusion, it was decided to publish a map at scale 1:200,000. Fieldwork was carried out in the years 1952-1954, but the map itself was published in 1965 (Stiboka). In the meantime much more attention was given to soil information, especially measurable profile characteristics and soil classification. In other words, the morphometric phase had begun.

This gives the 1965 map a dual nature: on the one hand it still shows physiographic elements, on the other hand many subdivisions in the legend are based on ‘new’ variables, such as content of calcium carbonate, texture and % organic matter in clay soils. This dual nature makes the 1965 map the symbolic end of the physiographic phase and a clear indicator of a more morphometric future.

The morphometric phase was triggered by the fieldwork for the soil map, scale 1:200,000. The rapidly increasing knowledge about soils called for more standardisation and co-ordination. The need for a soil classification system also became apparent. In line with international developments a morphometric approach was chosen.

In the physiographic approach geogenesis and landscape development are diagnostic, whereas in the morphometric approach it is the soil properties resulting from geogenesis and landscape development that are diagnostic. The morphometric approach culminated in a Dutch soil classification system (De Bakker and Schelling, 1966) and a legend for a new systematic soil survey of the Netherlands at scale 1:50,000. The first sheet of the soil map at a scale of 1:50,000 was published in 1964, the last one in 1995.

1983 - present: Re-discovery of the Soil Map

During the 1980s certain developments had considerable impact on soil survey and the use and interpretation of soil survey results (maps and data). These developments were:

1. A marked increase in agricultural production;
2. A deteriorating environment;
3. A growing competition for the limited space of the rural areas;
4. An explosive development in information technology.

The strongly increasing agricultural output was to a considerable degree based on higher inputs of nutrients and pesticides. This caused, amongst others, phosphate saturation of soils, followed by leaching of phosphate to groundwater and surface water, which in turn contributed to eutrophication of these waters and disturbance of aquatic ecosystems.

Another effect was leaching of nitrate to groundwater, with negative effects on its suitability for drinking water. The growing population with its increasing welfare and its new concern for environmental quality, led to new claims on the use and quality of the rural areas and its natural resources.

Recreational use, nature development and concern for biodiversity and water quality all contributed to the introduction of measurable quality criteria for soils and groundwater and to the introduction of legal restrictions on the amount and time of application of manure and fertilisers.

This impressive array of problems and measures stimulated research into the actual soil physical and soil chemical processes governing the fate of nutrients and pesticides in soil, groundwater and surface water. The results of process oriented research, e.g. various models, were quickly applied in a regional context to predict developments or evaluate policy measures aimed at reduction of phosphate saturation, nitrate leaching, etc.

Table 1: Overview of national soil maps

Name	Publication	Scale	GIS-version
Geological map of the Netherlands	1867	1:200,000	no
Geological map of the Netherlands	1877	1:500,000	no
Provisional soil map of the Netherlands	1950	1:400,000	no
Soil map of the Netherlands	1960	1:200,000	no
Soil map of the Netherlands	1964-1995	1:50,000	yes
Soil map of the Netherlands	1985	1:250,000	yes
Generalised soil map of the Netherlands	1986	1:1,000,000	yes

All this new research caused a new and growing demand for soil information:

- Process-oriented models for the description of the transformation of chemical compounds in the soil or for the description of water and solute transport through the soil require process parameters derived from soil profile data through pedotransfer functions;
- Regional environmental studies (nutrients, pesticides, water management) need spatial soil information to describe the initial or current soil status and to derive the above process parameters.

Soon it also became clear that the type of soil information collected so far, and the way in which it was collected, could not produce all the required data or the desired quality of data. As the regular 1:50,000 scale soil survey neared its conclusion, the focus was gradually reset, resulting in:

1. A new programme for upgrading the national soil database;
2. A new programme for the development of an ecological soil survey and land evaluation;
3. The development of new methods for collecting soil data based on spatial statistics (e.g. geostatistics);
4. The development of new methods to transfer existing soil information into new data (pedotransfer rules and functions);
5. The execution of commissioned soil surveys tailored to the needs of the client.

All this could only be realised due to rapid developments in information technology. The development of GIS, process-oriented models and the integration of GIS and models were of overriding importance in this phase.

Present State of Soil Survey

The present state of soil survey has been described earlier (van der Pouw, 1996; van der Pouw and Finke, 1999). The essential facts are that the national soil survey was completed in 1995 and various national maps of smaller scale were also derived. Table 1 gives an overview of existing national soil maps, including the historic maps reported in the Sections above.

Soil Information at National Level

The core of present national soil information is the 1:50,000 scale soil map. However, before this map was completed there was a need for a more up-to-date small-scale map. Therefore Steur *et al.* (1985) compiled a new map at a scale of 1:250,000. This map was mainly derived by simplification and generalisation of the 1:50,000 soil maps, for which at the time about 70% of the fieldwork had been completed. Other, more detailed soil maps and some additional fieldwork were used to obtain the remaining 30%. Subsequently Steur (1986) produced a generalised soil map at a scale of 1:1,000,000. This map was the basis for the Dutch contribution to the soil map of Europe at a scale of 1:1,000,000 (CEC, 1985).

Upgrading of National Soil Information

The national soil survey at a scale of 1:50,000, which started in the early 1960s, was directed towards collecting and interpreting soil information for agriculture and forestry production purposes. Obviously this systematic information was not capable of meeting the soil information demanded by models and regional studies of a different focus, e.g. leaching of excess nutrients or possibilities for nature development.

The strategy for coping with this problem was twofold:

1. Try to use the existing information as much as possible, using new pedotransfer functions and expert knowledge;
2. Start a new survey programme aimed at upgrading the existing information.

Van der Pouw (1996) reported in some detail about the preparation and execution of the upgrading programme. The main actions are:

1. Revision of groundwater depth classes of the 1:50,000 soil map;
2. Probability sampling of mapping units of the 1:50,000 soil map;
3. Collection of new data.

Revision of groundwater depth classes

The average level of the groundwater table in the Netherlands has fallen during the past decades. In some areas it has fallen 50-100cm (Finke *et al.*, 1998). From the beginning of the national soil survey scale 1:50,000 in the early 1960s the Dutch soil maps not only showed the soil units but also featured groundwater depth classes that indicated the average annual mean highest and mean lowest groundwater table. As a direct consequence of the falling groundwater table, the 'wet' groundwater depth classes on the older map sheets are gradually becoming obsolete. Moreover it was found that some of the earliest map sheets were of poor quality. To combat this situation the following action was taken, in chronological order.

Revision of groundwater table maps

This revision took place for a number of older map sheets using the traditional field approach to surveying groundwater depth classes. This approach leaves the soil boundaries as such in principle unaltered. A typical example of this approach was the revision of a large part of the province of Drenthe.

Entire revision

An entire revision covers all aspects of the map legend, i.e. soil types, groundwater depth classes and special features. Only one map sheet was entirely revised, using the traditional field survey approach.

Development of new methods

While revising groundwater-table maps and the entire revision, it became clear that it was not feasible financially to carry out the remaining revision by the traditional methods employed for the national 1:50,000 soil map. Finke *et al.* (1995) therefore developed alternative methods for revision of the information on groundwater depth class. These methods offer a range from low cost and low reliability of results to high cost and high reliability.

At the high end of this cost range, a grid cell ($25x25m^2$) based remapping method for 1:10,000 scale maps was designed that produces maps of various aspects of groundwater table dynamics. One of these aspects is the traditional groundwater table class, other ones are maps of quantitative parameters such as Mean Highest Watertable and fortnightly expectations of water table depth troughout the year (constituting the regime graph for each grid cell).

This method is based on the use of measured water table depths at various places and time periods. These point data are then interpolated, using various sources of geographical information such as the soil map, digital elevation models and the location of drainage networks, etc. As the mapping method is geostatistical in nature, it quantifies the uncertainty of most of the mapped parameters. Thus maps of the uncertainty are produced as well, which allows for indentifying areas where the maps can or should be improved.

The development of these methods ranging from low cost and quality to high cost and quality allows a method for revision to be selected which best suits both the purposes of revision and available funds. Moreover, Finke *et al.* (1994) also designed a statistical procedure to compare the differences between the present groundwater table depth and the depth classes shown on the existing soil map sheet. For this it uses actual data from time series on groundwater levels from the national monitoring network of the Netherlands Institute of Applied Geosciences TNO (NITG -TNO; see below).

Determination of areas in need of revision

The procedures developed allow objective answers to two important questions:

- Which areas are in need of a revision of groundwater depth classes?
- What is the order of importance (priority ranking) of these areas?

This analysis was restricted to the Pleistocene part of the Netherlands as most of the Holocene part, the 'polder district', has controlled groundwater levels. The results of this analysis was that about 290,000ha urgently needed revision of the groundwater table maps.

Execution of revision

At first, a provisional revision of 290,000ha was completed, using cost-effective methods (Finke *et al.*, 1994). After this, national and regional authorities ordered the production of very detailed (1:10,000) maps of the water table (Figure 1) in 1,790,000ha (i.e. 55% of the Netherlands). Hereby the remapping method using digital elevation models described above was applied (Finke *et al.*, 2004).

Probability sampling of mapping units

The method of probability sampling is described by De Gruijter and Ter Braak (1990) and Finke *et al.* (1996). The final goal of this sampling programme is to cover all soil features described by the legend of the 1:50,000 scale soil map (Van der Pouw 1991, 1996). Therefore the probability-sampling programme has to cover the three sections of the soil legend for:

- Describing and coding the soil units;
- Groundwater depth (GD) classes;
- Special soil features.

A mapping unit code combines the relevant codes from these three sections.

At the start of the probability-sampling programme, the focus was on sampling of the soil units. This turned out to be a large task and therefore a time-consuming, expensive operation.

Consequently the strategy was changed and the units of the groundwater depth classes, of which there are fewer, are being sampled. The probability sampling of this section is finished and provides our national soil information store with a unique database: statistically reliable information on a number of basic soil variables (e.g. pH, CEC, organic matter content, etc.) together with a set of about 1,450 geo-referenced profile descriptions. The sampling method also permits the construction of variograms for these variables.

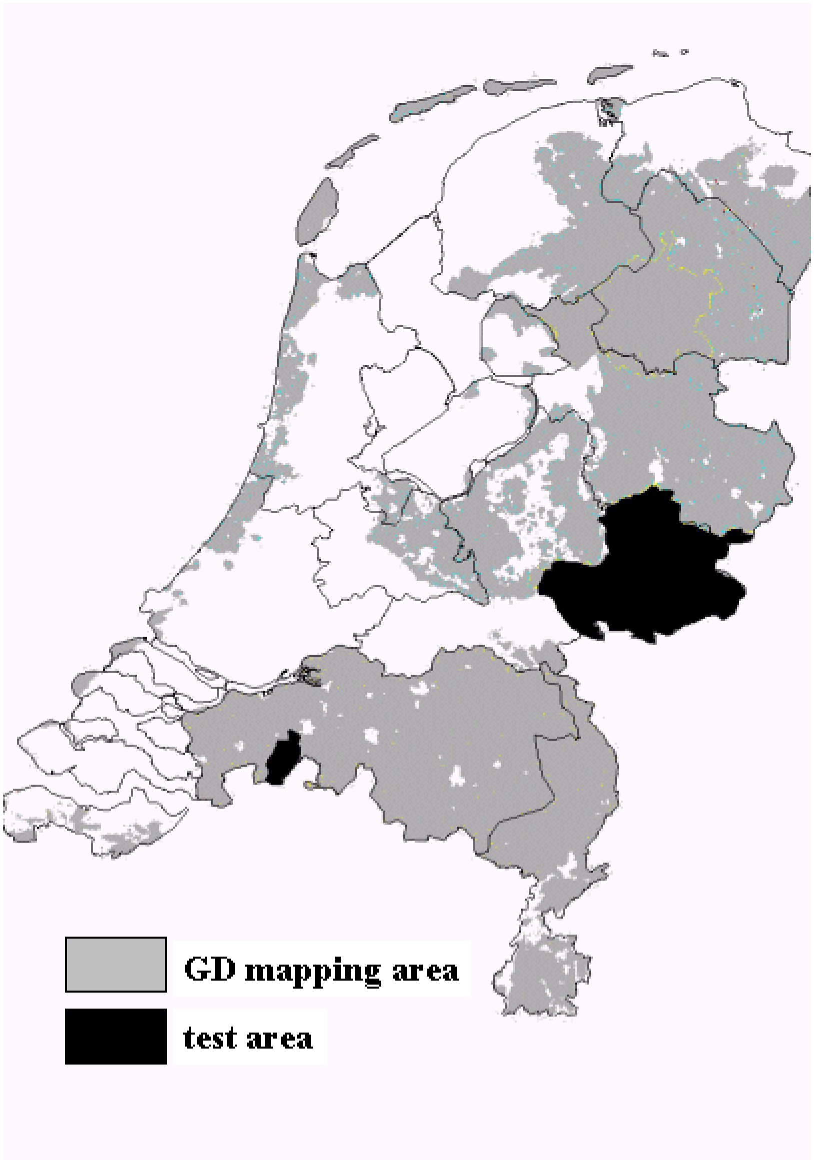

Figure 1: Extent of 1:10,000 watertable re-mapping projects

Collection of new data

The probability-sampling programme is also used for the third objective, that of the upgrading programme, i.e. the collection of new soil data. This involves, for instance, the determination of oxalate-extractable Fe and Al as well as phosphate on all samples. Together with the mean highest groundwater level these parameters determine the Phosphate Sorption Capacity and the degree of Phosphate Saturation at each sampled location.

These parameters are of eminent importance in the assessment of eutrophication hazards of surface waters that may be caused by manuring and increasing groundwater levels to abate human-induced drought. The samples are stored to allow for the future determination of other parameters such as heavy metals, following the same statistical sampling design.

So far, the resulting soil parameter database has been used for a statistically sound assessment of carbon stocks for the Kyoto reports, for the parametrisation of national-scale nutrient fate models and for the reliable estimation of acreages of phospate-saturated agricultural soils.

Soil Information at Detailed Level

Detailed surveys have ‘always’ been an important activity of Dutch soil survey, and have been executed as commissioned projects from the beginning. Since the mid-1980s, maps and profile descriptions have been digitised. Digital detailed soil maps now cover about 250,000ha (Figure 2).

The growing competition for space and environmental quality of the rural areas also had consequences for the national ‘Service for Land and Water Management’ (DLG) which is in charge of the execution of rural development and reconstruction projects. Since the early 1990s DLG has been giving more emphasis to the interests of environmental quality and nature development. Similarly, DLG has recently started to evaluate the consequences of the Malta Agreement on the protection and survey of our archaeological heritage.

As DLG is also the major organisation for commissioning detailed soil surveys, these surveys naturally became more linked to the same subjects. This stimulated the development of a more ecologically based soil survey and land evaluation and the development of a survey integrating archaeology, soil inventory and landscape genesis, including historic land use. Recently DLG commissioned the first projects in these two new fields.

National Soil Monitoring *sensu stricto*

This type of soil monitoring is only carried out by the National Institute of Public Health and Environmental Protection (RIVM). It conducts a national soil quality monitoring programme ‘Soil monitoring and diagnosis’ to generate information on the actual quality and its trend in the soils of The Netherlands.

The results are of great importance to the Institute's consultancy task with respect to environmental matters to the Dutch Government, i.e. the preparation and evaluation of policies on the abatement of pollution, eutrophication and acidification. Sampling is carried out once every five years (van Duijvenbooden, 1993) and focuses on rural areas.

In 1994, 20 intensively managed cattle farms (i.e. farms with a high phosphate production) and 20 forest sites (deciduous, pine and mixed vegetation) on sandy soils were sampled. Concentrations of heavy metals, polycyclic aromatic hydrocarbons (PAHs), organochlorine pesticides and triazines in the topsoil (0-10cm) and the litter layer of the forest sites have been reported (Groot *et al.*, 1998).

National Monitoring of Shallow Groundwater

When the subject of soil monitoring is broadened to include monitoring of the level and quality of the upper phreatic groundwater, then very much more monitoring is required. In view of the reciprocal influences of soil quality on the one hand and level and quality of the shallow groundwater on the other hand, it seems justified to cover also shallow groundwater under the umbrella of soil monitoring.

Groundwater level

The Netherlands Institute for Applied Geosciences (NITG-TNO) maintains a long-term national groundwater monitoring network, which presently comprises approximately 15,000 observation points.

All data are stored in a GIS which is accessible on-line and which is used for the planning and the evaluation of the aquatic infrastructure, to evaluate effects of groundwater extraction and water conservation policies and for a wide variety of scientific research on water quantity and quality.

Figure 2: Location of detailed soil surveys with digitised maps & databases

Groundwater quality

The National Institute of Public Health and Environmental Protection (RIVM) also conducts a National Groundwater Quality Monitoring Network (NGMN), comprising about 400 locations. It was established by 1984:

1. To determine the quality of the groundwater per land use and soil type and to construct maps;
2. To detect changes in the groundwater quality.

Groundwater is sampled annually and analysed for a number of anions and cations, amongst others, chloride, nitrate, ammonium, total phosphorus, dissolved organic carbon, pH, electrical conductivity (EC) and a number of inorganic micro-components (including Zn, Al, Cd).

Van Drecht *et al.* (1996) give a detailed account of Dutch groundwater quality based on monitoring results over the period 1984-1993, while Reijnders *et al.* (1998) over the same period concentrate on nitrate and aluminium because of their relevance to the environment and public health.

Some important conclusions include:

1. Average nitrate concentrations in shallow groundwater are under the target value for nitrate N (5.6g/m^3) in the west of the country and in the river areas constituted by clay and peat;
2. Average nitrate concentrations in the sandy areas in the east of the country are higher than in the west. Concentrations in the east in shallow groundwater under maize are significantly higher than the target value;
3. The highest concentrations of aluminium are also found in the sandy areas in the east. Under maize on sand the concentrations are significantly higher than the drinking water standard (200mg/m^3).

Long-term Monitoring Programme of Forest Health

Every 5 years, the health of a substantial number of forests in The Netherlands is assessed by evaluating soil quality (i.e. acidity, eutrophication status) and its effect on canopy growth, etc. These data are entered in the national soil database and are also incorporated in European Forest Soil Monitoring programmes.

Use of Soil Information

It can be stated with some certainty that 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.

This is partly due to the value and quality of the data with respect to these uses, and partly to the fact that the data are easily available. Below, three typical examples of the use of soil data at the national scale are briefly described.

Definition and Implementation of N-restriction Policy

The Dutch Ministeries of Agriculture, Nature and Fisheries, and of Housing, Spatial Planning and the Environment, have been using the digital Soil Map of The Netherlands, scale 1:50,000, to classify areas where surface application of organic manure is not allowed. Classification was based on the surface texture of all map units of the soil map.

The resulting maps became an appendix to the Law (Staatsblad 385, 1991, Bijlage I) and were used for field inspection. Recently a refined classification was made with the purpose of mapping dry sandy lots with agricultural use at a scale of 1:50,000. These lots may be subject to more strict N-restriction policy in the near future if current policies fail to satisfy environmental thresholds.

Aquatic Outlook Project

The Dutch Ministry of Public Works and Water Management commissioned a study on the effect of present and future nitrogen and phosphate emissions from agricultural areas to Dutch surface waters (Boers *et al.*, 1997). Soil and groundwater table maps, soil physical and soil chemical data as well as pedotransfer functions were used to parametrise and to validate N, P and H_2O fate models.

These models were:

1. DEMGEN to compute water balances.
2. ANIMO to compute the behaviour and transport of P and N in the soil based on animal manure, fertiliser applications and computed water balances. Among the processes considered, crop uptake, mineralisation and immobilisation, nitrification, denitrification, sorption on and desorption from the soil complex, surface and subsurface runoff and leaching to surface water and groundwater are the most important.

The models were used to explore the effect of the Dutch manure policy up to 1993 and of five alternative future N, P and water policy options between 1985 and 2045 on (predominantly) surface water quality. Results, taken with permission from Boers *et al.*, 1997 (as in Figure 3), can be summarised as follows:

1. The present manure policy, POLICY95, resulted ultimately in a computed reduction of nitrogen runoff by 34%. This reduction was almost completely realised by 2015. The computed phosphate runoff stabilised during the period until 2045;
2. The considerably lower manuring in the ENVIRONMENT variant led to a realisation of the current emission reduction targets for nitrogen (50% reduction in 1995 and ultimately 70%, both compared to 1985). The current emission reduction targets for phosphate (50% reduction in 1995 and ultimately 75%, both compared to 1985) were not met by the ENVIRONMENT variant. The reason for this is the historical loading of the soil, which determines the runoff. Even in the ENVIRONMENT variant, phosphate loading of the soil still increased, albeit at a slower pace;
3. Continuation of the manure application of 1993 resulted in a continued computed increase of phosphate and, to a lesser extent, nitrogen runoff.

Environmental Outlook Project

The Dutch Ministry of Housing, Spatial Planning and the Environment regularly commissions studies in which attention is to be paid to the effects of proposed and intended policy efforts on CO_2, NO_x, NH_3, phosphate and nitrogen emission levels and on subsequent levels in the air, soil and groundwater.

This work is carried out every four years by the National Institute for Public Health and the Environment (RIVM), and evaluates both national policies and the Dutch status in the context of European Legislature.

The soil data used are comparable to those of the Aquatic Outlook Project and are included in a wide variety of models. For an extensive description of this project and its results reference is made to Albers (1997).

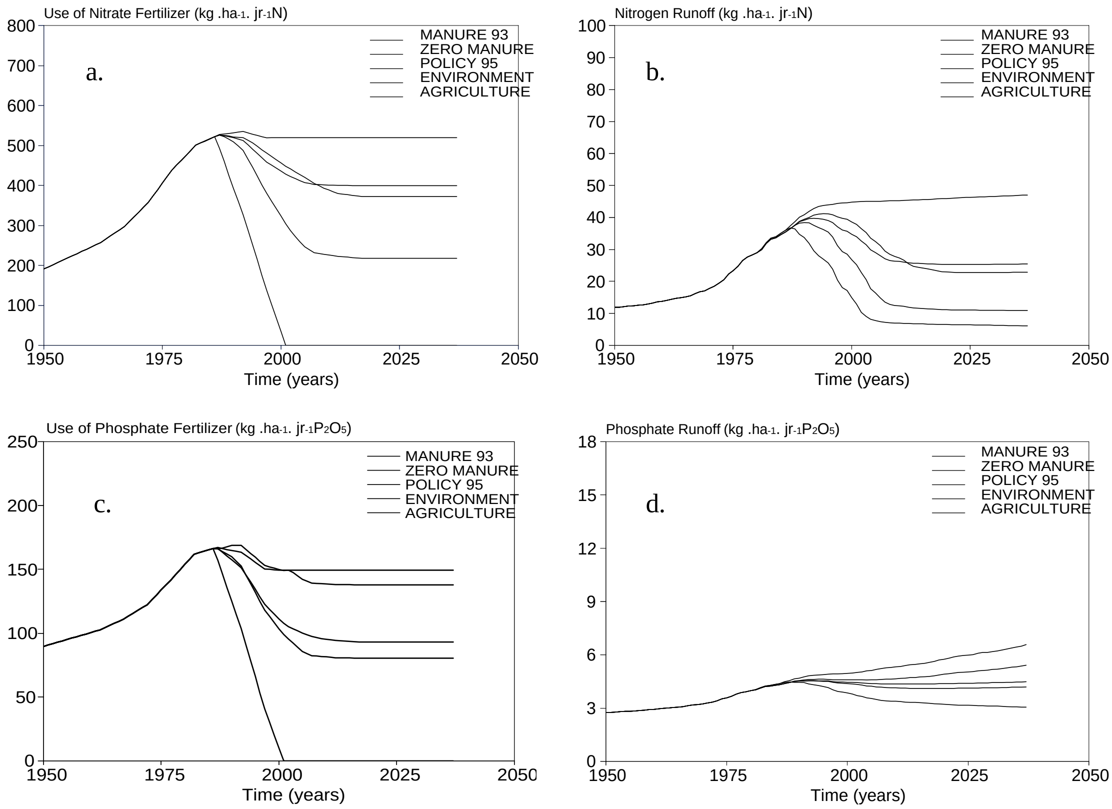

Figure 3: Average use of N (a) and P (b) fertiliser in Dutch agriculture and average runoff of N (c) and P (d) to Dutch surface waters from arable land.

[Reproduced with permission from Boers *et al*., 1997.]

Future

The application range for soil data collection is widening. A brief overview of changing activities with respect to data collection, the use of new and existing data and of the consequences of developments in information technology is given below.

Data Collection

Soil inventories become ever more tailored to the wishes/questions of regional stakeholders. New developments are:

- ecological soil mapping (soil mapping in conjunction with vegetation mapping and the description of humus profiles);
- ecohydrological system analysis (soil mapping as part of the definition and interpretation of hydrological systems and their analysis for nature development possibilities);
- archaeological soil surveys (aiming at the identification of archeological sites and reconstruction of prehistorical landscapes);
- landscape reconstruction surveys (soil mapping as a tool in reconstructing the geomorphological and cultural history of a landscape).

Development of New Relevant Databases and Data use

Very recently a national database with digital elevation data has become available. The density of information is about 16 sites per ha, which allows for detailed spatial analyses prior to a detailed soil survey. The availability of detailed digital elevation models improves the quality and cost efficiency of soil surveys and is already being applied routinely in the mapping of groundwater depth dynamics, and geomorphological surveys.

Soil databases become less an end-product and more an intermediate product in conjunction with their application in rural planning projects. This involves operational methods to upscale information and to estimate process parameters for simulation models.

Information Technology and Data Availability

The role of Information Technology during soil surveys is increasing:

- Global Position Systems, field-digitisation and attribute coding of soil maps help to reduce cost and to increase quality of the production process;
- The quality of soil data and its documentation in meta-information databases via the internet becomes ever more important;
- The accessibility of digitised soil maps and databases to the public with Internet technology was recently implemented. For the future it is foreseen that soil data users will be able not only to access but also make on-line interpretations of soil data via the internet.

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Soil Survey in Norway

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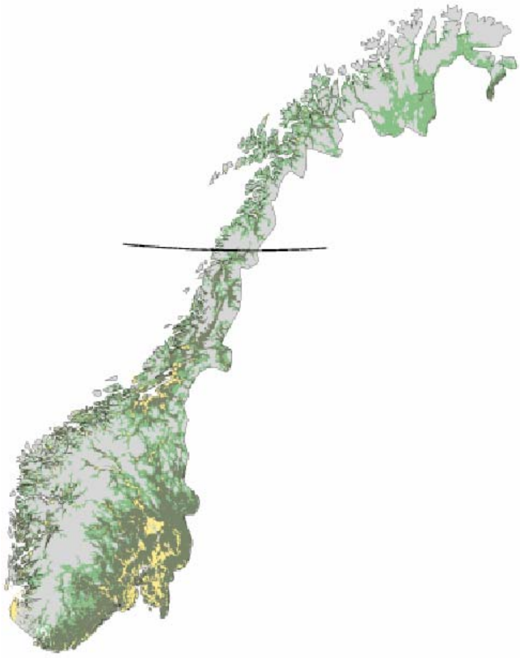
Introduction

The geography of Norway has an important influence on land use. A relatively long and narrow country, Norway stretches along the Atlantic from 58° N to 71° N. A mountain range divides the country into an Atlantic western and a continental eastern part. The climate varies from nemo-boreal along the south coast to sub-arctic in the mountains and in the north. Only 3% of the country is under agricultural cultivation, the other main land use being 22% in production forest and 75% as mountain land, glaciers, lakes and built-up areas.

Cereal production is mainly located in the southeast and in the centre of the country. The warm Gulf Stream makes agriculture also possible further north. Dairying is localised along the coast to a considerable distance to the north. Including associated activities, agriculture accounts for about 10% of Norwegian employment (Royal Ministry of Agriculture, 1993). Figure 1 provides information about the distribution of agriculture and forests.
The policy of the government is to keep and develop economically viable local communities in the countryside as far as possible.

A programme to map land use of all areas below the tree line at a scale of 1:5,000 was started in the early 1960s. Both actual and potential use were mapped and the information assembled included degree of wetness, soil depth, stoniness, and organic soils in non-agricultural areas. Slope was also important in estimating potential use. Information was assembled about forest and other non-agricultural areas that had potential for agriculture. Some separate soil mapping was carried out at that time but it was mainly geological in character.

The development of a Norwegian soil information system started in the early 1980s. In 1988/1989 an algae disaster caused the death of many marine biota in the North Sea and Skagerrak. The pollution of water by nitrogen and phosphorus was identified as the cause for the huge increase in poisonous algae. The European countries bordering the North Sea agreed on a plan to reduce this pollution (North Sea Declaration). In Norway reduction of erosion was prioritised by government and a programme to map the soils of the watersheds feeding into North Sea and Skagerrak was established.



Yellow: agricultural areas
Light green: deciduous forest
Dark green: coniferous forest

Figure 1: Distribution of forests and agriculture

A brief description will be given about the soil information system, the system for monitoring of soils and some applications of the soil data.

Soil Mapping of Agricultural Land

The Norwegian Soil Information System contains digital soil maps linked with a soil type database containing soil and terrain properties and a soil profile database that includes analytical data relating to the soil types mapped (Nyborg and Klakegg, 1998; Solbakken *et al.*, 1999). The different soil types are defined on the basis of major soil properties, climate, and placement in the World Reference Base of Soil Resources - WRB (Nyborg and Solbakken, 2003).

The Norwegian Institute of Land Inventory is responsible for carrying out the soil mapping and the development of applications of the data. The fieldwork includes mapping the distribution of soil types by stereoscopically interpreting aerial photographs, and verification and identification of soil types in the field using a soil auger.

The boundaries of the soil types are drawn directly on the photographs, and later digitised and stored in a GIS. The soil types are described in soil profile pits and sampled for chemical and physical analyses. Soil type data, profile descriptions and analytical data are stored in a database. The field data and the digital data are both subjected to quality control routines to ensure the accuracy of the soil maps as far as possible.

The soil survey staff includes eight soil scientists and geologists, and about 25 field workers. The field season is from April to November. About 150 km^2 agricultural land is mapped each year, and the Soil Information System currently covers 40% (4,600km^2) of the country's agricultural land.

The soil mapping activity has been concentrated on the grain production areas in the southern and southeastern parts of the country, and in the Trondheimsfjord area in mid-Norway. The activity is moving more and more inland and north to areas where grass production is the major agricultural land use. Figure 2 gives information about the areas with an existing soil map.

Soil Monitoring

Norway contributes to the European Forest Monitoring programme. Information on forest vitality is gathered annually from fixed points, lying in a grid system of 9km x 9km.

The soil at each sampling point is described and samples taken for chemical analysis. This inventory will be repeated after a certain period so as to obtain information about trends. Particular emphasis is given to monitoring changes in the content of nitrogen, sulphur and some heavy metals. There is also an additional monitoring system based on sampling of the plough layer in agricultural areas for the farmers for analysis of crop relevant parameters.

Figure 2: Soil mapped area

All information is stored in a database at the Centre for Soil and Environmental Research. Information about these parameters can be retrieved per municipality. Farmers are given advice on what to do in situations in which deficiencies occur.

Applications

In the planning of a mapping programme in Norway, attention is paid to whether there is a balance between costs and benefits. The Norwegian Soil Information System is organised in such a way that the information is of benefit to different users. As the basic soil map is difficult to use directly, several thematic maps and models have been developed to make the soil information more available for society. The main users of the information are national, regional and local authorities but it is also used by research institutes and private enterprises, such as banks and consultancies.

The number of applications of soil information is currently increasing. The main applications are in the field of land use planning and management, improvement of the economic position of agriculture and environmental impact analysis. A short description of some applications, some of which are under continuing development, is given below. At present all important applications lie on the internet (http://jord.nijos.no) and farmers and different authorities can use them for planning purposes.

Reduction of Soil Erosion

Soil erosion in Norway mainly occurs in autumn and spring. In autumn, heavy rainfall on an already saturated soil can cause soil loss through run off of water. In spring, erosion is caused by heavy snowmelt, sometimes in combination with a frozen (sub)soil.

To reduce erosion, the government has set as a priority the reduction of the area under autumn ploughing in regions susceptible to soil erosion. The farmers receive compensation for ploughing their land in spring. The amount of compensation is related to the erosion risk level of the particular areas. The following measures can be subsidised:
leaving cereal fields under stubble during autumn and winter - covering drainage ways with vegetation using catch crops.

From 1989 – 1996 the area of stubble land under the regulation increased from 3,000ha (1989) to 110,000ha (1996), the latter amounting to 31% of the area of cereals. Recently the farmers have also been able to receive a subsidy when land in the higher erosion classes is no longer used for arable farming land but maintains a permanent vegetation cover. All regulations are on a voluntary basis. Figure 3 shows how the system functions (Nyborg and Klakegg, 1998).

The USLE (Universal Soil Loss Equation) model was adapted to Norwegian conditions to develop soil erosion risk maps (Rekolainen and Leek, 1996). Erosion risk maps are produced based on soil and slope characteristics. A soil tillage map based on soil texture and drainage, giving information on possible soil tillage methods, is also produced. The erosion risk and the soil tillage map are then combined into a third map which provides information about available tillage methods to be used in the task of reducing soil erosion. Local and regional authorities are the main users of the information on erosion risk analysis.

Improvement of Agricultural Productivity

Cereals, potatoes and grasses are the main agricultural crops in Norway. Production possibilities are related to climate (temperature, length of the growing season and rainfall distribution), soil type, and factors influencing workability (slope and stoniness).

Land capability models for cereal, potato and grass production have been developed for Southern Norway. Currently the models are being improved by including climate factors. An Agro-Ecological Zone map for Norway is under development, which will provide information about the possibilities and limitations of different cropping systems.

The land capability models give information about the potential biological production level and about the most important production limiting factors. In Southeast Norway, long dry spells during summer can reduce agricultural production and introduction of irrigation systems can improve the socio- economic position of agriculture in this region.

The preservation of the more productive soils for agricultural purposes is part of the political agenda. Agricultural areas, important for food production, are in many cases close to the more densely populated areas but it is often cheapest to use agricultural land for infra-structural and building purposes. Land capability maps are used in impact assessments, and are mandatory in the planning phase of larger development projects. The strategy is to keep the best agricultural land for agricultural production.

Besides the earlier mentioned applications, new ones are regularly emerging. Some are related to the more marginal areas, where information on soils can contribute to the improvement of the socio-economic situation of the local communities. A short description of the following applications is given below:

1. Land use planning and management at a regional level;
2. Reduction of the risk of winter injury to sub-arctic perennial grassland;
3. Prediction of yield losses after flooding.

Regional Land use Planning and Management

The change in agriculture has been enormous in the last few decades and this has had a large impact on the cultural landscape, environment and bio-diversity. Protection of the cultural landscape is seen to be more and more relevant, and a nationwide monitoring programme of the cultural landscape has been started.

Several interest groups claim the need for a different use of the same area. To be able to make the right decision, authorities need to have information on the type of land use that best safeguards the future sustainable existence of the natural resources and the community. In planning future land use at a regional level, analysis of soil types, land capability, structure of agricultural properties and land use change in the past, will be important. Both agricultural and landscape development can be planned and included as an element in rural development using this information base. Some counties are already active in the development of systems for integrated land management. Agricultural properties belonging to one owner are sometimes scattered and reallocation may be necessary.

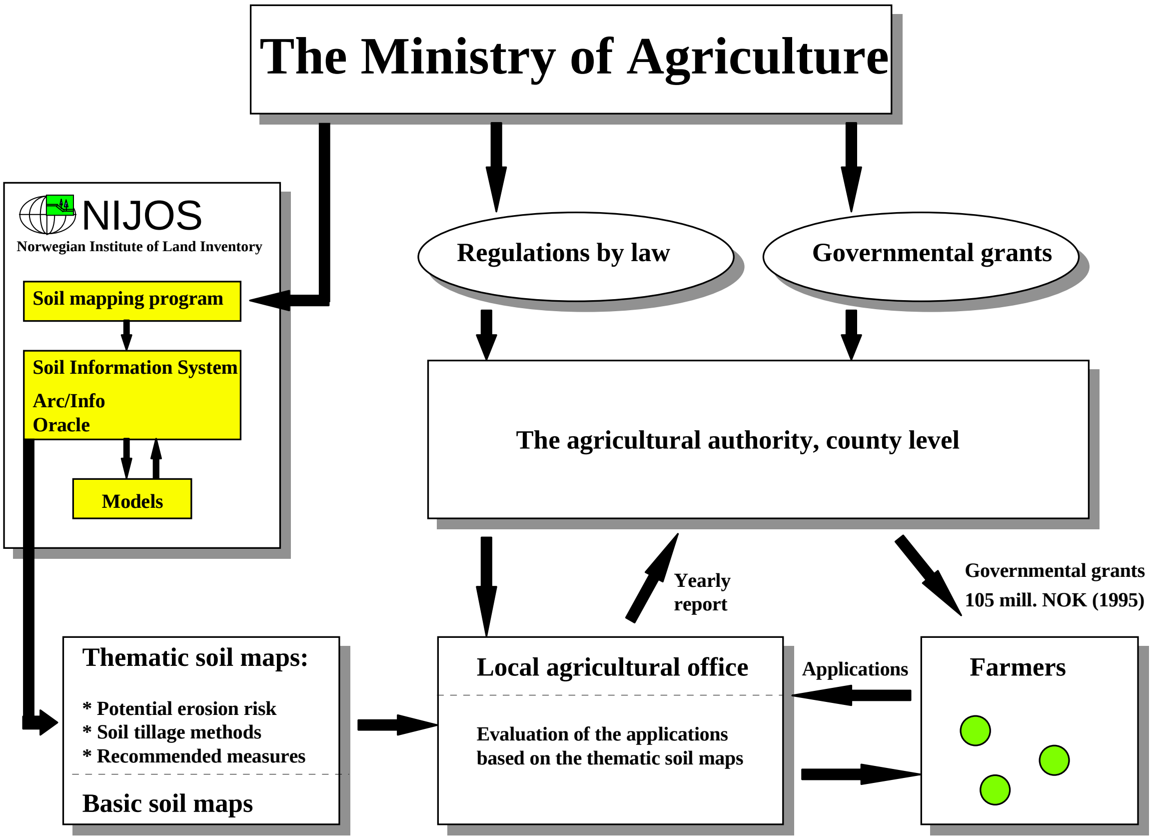


Figure 3: Use of the Soil Information System in the measures against soil erosion.

For this process a validation of the involved areas is needed. Information on soils is an important basis for judging the (potential) productivity and limitations of an area. A new system for validation of agricultural properties is under development using information on soils as a basis for the validation process (Christensen, 1999).

An Environmental Impact Assessment is required in the planning and decision making process of large infra-structural works. Information on the consequences of such works on landscape, agricultural productivity and environment is needed. Soil data are basic in the impact analysis on agriculture. The potential archaeological value of the areas under consideration also needs to be recognised. Soil data are used in planning the archaeological survey as efficiently as possible. It is known which soil types are unlikely to preserve archaeological artefacts; on the other hand some soil types with a long historical use can sometimes contain artefacts.

In general, Norwegian agriculture uses relatively low amounts of pesticides. However, leaching of pesticides to surface- and ground water is increasingly recognised as a problem (Tiberg, 1998). An experimental project is being carried out which relates soil types and the risk of leaching of certain pesticides. When this information becomes available for both authorities and farmers, the best land management plan to reduce negative environmental impacts can be selected. The same is the case in reducing nitrogen and phosphorus leaching. Currently each farmer is obliged to keep nutrient budget details. The strategy is for a well balanced fertilisation scheme, for which information on soils and crops is needed in order to calculate expected nutrient uptake.

Soil maps are also used to evaluate the possible use of sewage waste on agricultural land. Assessment of the amount of sewage that should be applied to a particular piece of land will require information on the existing levels of heavy metals in the soils.

Reduction of Risk of Winter Injury in Sub-arctic Perennial Grassland

In the three most northern counties, dairy farming and grass production are the most common agricultural activity. Regularly large areas with perennial grassland die back due to winter injury. In both 1995 and 1998, 80% of the grassland died in some of these areas. In 1995 authorities paid €7.5 million in compensation to the farmers in these counties.

During warm spells in winter, snow melts, and rain- and melt water may later freeze in depressions of the terrain. The grass becomes covered with a thick ice layer, preventing the escape of assimilation products; the grass becomes damaged and dies. Damage also occurs from fungi, especially under more continental climatic conditions. Under a thick and stable snow cover several fungi (Fusarium nivale, Typhula incarnata, T. ishikariensis and Scleriotina borealis) can develop and attack the grass.

Winter injury can also be caused when the assimilation process in spring starts while the ground is still frozen. The grass becomes nutrient deficient especially after a hard winter and dies. Thus a complexity of factors, with climate, soil and farm management as most important elements, cause winter injury. An increasing intensity and frequency of damage has been observed, indicating that climate, soil and farm management conditions are becoming less adapted to each other (Anon, 1997; Arnoldussen, 1998).

Research has identified that the risk of winter injury is related to the natural drainage of the soil types, the steepness of the slope and the (micro) topography. A model, based on the macroclimatic conditions, soil and slope characteristics, has been developed to predict the risk of winter injury. By adapting farm management, improving drainage and/or changing land use, the farmer can reduce the risk of winter injury and/or the degree of damage. Both the model and the set of remedial measures needs further refinement, but the possibilities for improving the situation look promising.

Predicting Yield Losses in Agriculture after Flooding

In 1995 large areas in Southeast Norway were subject to flooding. Flood damage to agricultural crops is caused both by submergence and loss of soil nutrients. To predict yield loss, a model was developed based on soil characteristics and duration of the flooding time. For each risk class a set of measures is given to reduce the yield loss as much as possible.

Authorities can use the model by calculating the total expected damage, or to plan the most suitable land use for areas regularly affected by flooding.
The model can also be used to plan a controlled flooding of agricultural areas to prevent larger damage in the areas lying more downstream, which are often more dense populated areas. Farmers themselves can use the information to take adequate measures to reduce the risk of yield loss (Haraldsen and Øverbø, 1999).

Outlook

To keep and develop a viable rural area, and on the other hand reduce the potential negative impact of agriculture on the environment and landscape, a system for sustainable land management needs to be developed. In the planning process, which concerns all available natural resources, analysis of soil, land capability, landscape and land use will be needed. Decision models predicting the effect of land use change on environment, landscape and agriculture need to be developed. The impact of a range of land management scenarios can then be evaluated and the most optimal situations chosen.

Conflicts between different interest groups are likely to increase. Already conflicts between sheep farmers, foresters, hunters and groups responsible for the management of the wild animals of prey (bear, wolf, lynx and wolverine) are not uncommon. A system for sustainable land management can be used in the development of an ecological infrastructure, safeguarding biodiversity, landscape and tourism.

Planning of land abandonment and land extensification is also likely to become a topical issue. Nowadays land abandonment is a slow and mostly a hidden process and is not recognised as a problem. Consequences in the longer term, however, are large; the landscape will turn into forest and local communities will find it more difficult to survive. Information on natural resources, including soils, will be needed if regulation of the abandonment/extensification process becomes necessary.

Soil data are essential in planning modern land management, and integration of different data sources will be more and more necessary. Many of the developments mentioned above have international (transboundary) consequences, reinforcing the need for the future establishment of international standards and databases.

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Soil Survey, Soil Monitoring and Soil Databases in Poland

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Introduction

The main objective of this report is to present the current situation with respect to investigations in soil science. However, organisational aspects are also discussed, since even the best achievements cannot last long if the organisation fails.

Some historical reflections are also presented. The report is limited to the basic issues relating to soil science and soil survey, the monitoring of soils, and the development of soil databases, which has seen dynamic changes in recent years. The report concludes by describing the utilisation of available soil data as well as outlining perspectives for the future.

Modern soil science started in Poland towards the end of the 19th century. This birth of soil science and its first period of development were influenced by the political situation which then existed in Poland. Since some misconceptions exist in the world literature concerning that period, we will briefly correct these in this report.

Until the year 1914, the Russian, Austrian and Prussian empires occupied the Polish lands. On the part of the lands occupied by Russia, the Polish Kingdom existed, an administrative unit with a relatively high degree of autonomy. Within the Polish Kingdom it was possible to teach and issue publications in Polish. The Soil Science Laboratory at the Museum of Industry and Agriculture existed in Warsaw. The soil science laboratory performed field and laboratory tests of soils and results of them were published in Reports of the Warsaw Scientific Society.

At the beginning of the 20th century the laboratory was headed by Sławomir Miklaszewski. After 1914, the laboratory was transferred to the Warsaw University of Technology and it became the base for the Soil Science Laboratory at the Faculty of Agricultural Engineering. Sławomir Miklaszewski was also its head.

At the same time, schools with the official Russian language existed in the Polish Kingdom, where students of mainly Russian origin were educated. The High School of this type, The Institute of Agronomy and Forestry, existed in Puławy, when after 1864 the tsar authorities removed the Polish students from this University and replaced the Polish language with Russian. The name of the city was also changed into 'Nowa Aleksandria'. W. Dokuczajew (1891-95) and M. Sybircew (1894-1900) were professors in 'Nowa Aleksandria' (that is to say in Puławy).

The Dokuczajew climatic theory and the division into zonal and non-zonal soils, proposed by Sybircew, had stronger influence on the development of Polish soil science than any other development.

Sławomir Miklaszewski, who was familiar with the West European School of agro-geology and the climatic theory of Dokuczajew and Sybircew, developed the original approach to classification of soils of Polish land. According to his opinion, within the relatively small area of Poland, classification of soils could not be based on climate alone. The agro-geological approach was too simplified. Therefore, he proposed to apply, at higher taxonomic levels, division of soils according to dominant factors. He distinguished three groups of soils: quartz-siliceous soils, carbonate soils and humic soils. He distinguished soil types at the lower levels and used local names, which could be understood by farmers.

Thus the name 'rendzina' became popular for soils developed in carbonate rocks and Sławomir Miklaszewski became known as the 'father' of the rendzina. Miklaszewski presented the principles of the modern soil science in successive books 'Soils of Poland' issued in 1906, 1907 and 1912. Maps of soils of the Polish Kingdom at the scale of 1:1,500,000, which are considered as the first constructed soil maps of Poland, were attached to these books.

Agricultural chemistry and agricultural experiments were developed prior to genetic soil science. Soil science adopted some methods of soil investigation, which had been applied in agricultural chemistry (for example, Miklaszewski stated that seasonal variability of pH occurs in arable soils). Agricultural chemists and researchers were expected to perform tests on the full soil profile instead of investigating the upper layers only.

In 1912, Miklaszewski proposed, in the programme of soil science investigations for the whole of Poland, to investigate all types of soils, to standardise soil names (at that time, the same soil was called 'rendzina' on one side of the Vistula River and 'borowina' on the other) and to develop detailed maps for the whole country.

It was also stated that agricultural experiments should use the same names for similar soils and the same methods of experiments so that the results of investigations could be successfully transferred to soils of similar properties. A special version of the soil map of Poland was developed for the needs of agricultural experiments. Principles developed by Miklaszewski directed long-term soil science investigations in Poland.

Other important factors, which have influenced soil science investigations in Poland, include:

1. Dominance (about 80%) of soils developed in postglacial deposits. The division of parent rocks should not be limited to the term 'postglacial'. The age of deposits is considered in divisions (various glaciations and phases, which are related to the content of carbonates and to the depth of decalcification), the type of accumulation (front, bottom, slit, outwash), as well as periglacial processes. The relationship between the morphogenesis of postglacial areas and the soil cover was confirmed;
2. Dominance (almost 50%) of soils developed in sands. Therefore, for cartographic and practical purposes, one granulometric category, 'sands' (coarse texture) was not sufficient. In detailed cartography, four granulometric categories were used, since each is related to the various qualities of agricultural soils or the quality of forest units;
3. Considerable areas are covered by organic and organo-mineral soils of various genesis and properties. Therefore, one category of organic soils was not sufficient (Histosol). It was necessary to perform investigations concerning the genesis, transformations and properties of organic soils. Detailed divisions were made with respect to the hydrogenic process, the type and the level of breakdown of organic substances, processes of mineralisation, fecundity of waters and participation of mineral substrates;
4. Practical needs for utilisation of information concerning soils. Besides the conventional ways, soil science investigations were also influenced by:

    - Taxation of soils of real estates for the needs of bank credits;
    - Valuation of soils during land consolidation;
    - Evaluation of soil quality for the land cadastre;
    - Investigations of soil properties for drainage purposes;
    - Inventory of soil cover for urban and regional planning;

- Investigations of soils for forest management purposes;
- Investigations of soils, as the part of large projects concerning environmental monitoring, water erosion, protection of water resources, physical, and geographical investigations.
- The need to unify methods within international projects, such as the FAO World Map of Soils, European Soil Database 1:1,000,000; SOTER etc.

Soil Survey

Soil survey comprises fieldwork, cartography and analytical determinations. Surveys at national level have been based on unified principles and have included investigations on selected areas for various, non-standard, purposes during the last fifty years.

The soil maps that exist were developed using the soil classification that was obligatory at the time of survey. This was not a legal requirement, but it was assumed that the use of the classification of soils, developed by the Polish Soil Science Society (PTG), was obligatory in Poland. In 1956, the Commission of the Genesis, Classification and Cartography of Soils of this Society developed the lists of soil maps at 1:100,000 and 1:300,000 scales as well as 'The Natural and Genetic classification of soils with particular respect to arable soils'. The classification did not distinguish lessivé soils (later Luvisols), but it separated other types of soils and provided a detailed division at the level of parent rock and granulometry.

In 1965, due to the need for the mapping of soils at 1:5,000 scale, the Ministry of Agriculture adopted a listing of soils for inclusion in soil agricultural maps. This contained more types and subtypes than were contained in the genetic classification of the PTG of 1956. This list included, among others, pseudo-podzolic soils (corresponding to lessivé soils).

Similarly, the Soil Science Committee of the Polish Academy of Science, before development of the soil map of Poland at scale 1:500,000, adopted, in 1969, a more comprehensive list of soils for the legend of this map than were contained in the existing genetic classification. In 1966, the Commission of Forest Soils of the PTG developed a classification more adjusted to specific properties of forest soils. New units, such as lessivé and pseudo*glejowe* soils, were distinguished in this classification.

In 1969, work was started on a new classification with four hierarchical divisions and, in 1974, the new Systematic of the Soils of Poland was published. It distinguishes 35 types and 78 subtypes of soils and was characterised by the same level of detail of parent rocks and granulometry as the classification of 1956. Using diagnostic criteria, this system attempts to combine morphology and genesis of soils and an ecological approach.

Some difficulties inherent in the utilisation of archive soil maps led to the need to interpret soil units according to the present criteria. Correlation tables facilitated this process. Such tables have been developed for appropriate units of the Systematic of the Soils of Poland and units for the FAO legend, Soil Taxonomy and in soil characterisation in neighbouring countries.

Soil maps, which cover the whole country, have been prepared as part of the following activities:

Soil Map of Poland, 1:300,000

The Soil Map of Poland at 1:300,000 was developed as a result of the activities of all soil research centres in Poland in the period 1949-1961. An atlas containing 27 sheets of this map was published in 1961.

Types and subtypes of soils, distinguished on the map, corresponded to the classification of 1956. The map was produced as a result of fieldwork, performed using 1:100,000 scale topographic maps, available geological maps and partial soil maps. During this difficult post-war period, the work was conducted in pioneer conditions. Some working teams had to buy horses and carts to conduct fieldwork, since there was no other form of transport in many areas of Poland at that time. This map is characterised by simplified typology, but it is still a valuable source of data concerning parent rocks and granulometry of soils.

In parallel to the soil map,, the land evaluation map at the scale of 1:300,000 and thematic overlays presenting erosion hazard, soils recommended for drainage and soils recommended for afforestation, were also produced. Only the genetic soil map was published.

Land cadastre

Besides borders and sizes of land parcels, the Polish land cadastre contains data concerning land use and quality of soils. Therefore, in the process of generation of the land cadastre, besides surveying measurements, soil maps at the scale of 1:5,000 were also produced in the period 1955-68. Data directly included in the land cadastre included soil classes based on soil quality. However, it was envisaged that data on the types and subtypes of soils would be more widely applied in the future. Data on parent rocks and granulometry were also included in maps of soils (which are officially called 'Classification maps').

The maps were produced directly in the field. Soils were defined based on soil profiles and map units were delineated with the use of auger borings and

interpretation of landscape elements. The recommended accuracy for delineation of map unit boundaries was ± 15m. For each cadastral unit, documentation including a map and description of profiles was produced.
Morphological investigation of profiles included: granulometry, presence of carbonates, gley-free features, groundwater table, humus content evaluation, water conditions, soil suitability for typical crops, and impacts of physiographic and climatic factors on the quality of soils. The result of this evaluation was the specification of the type and subtype of soils and soil classes according to soil quality. The table of classification criteria included separate parts for arable lands, meadows, pastures and forests. Eight land evaluation classes in arable lands and six classes for each of meadows, pastures and forests, were distinguished.

The potential yield, that could be achieved in the case of similar crop types and fertilisation, was the basic criterion for evaluation of soil quality in arable lands. Since data concerning yields of soils were hardly available or they were characterised by low reliability, practical determination of classes was based on soil properties correlated with characteristics of soils (mainly granulometry, humus content and water regime).

In the case of forests (only private forests were regulated by provisions concerning the land cadastre), classification criteria were based on properties of soils and settlement types of forests.
Classification maps and data from the cadastre (areas of soils in particular classes) are official documents. Taxes, compensations for expropriation, fees for non-agricultural and non-forest use of lands, are based on these data. They can also be used for other purposes including the support for specification of lands during land consolidation processes or for specification of market values for the needs of taxation.

According to regulations concerning the cadastre, these maps should be updated every 5 years. In practice, property boundaries are updated first, then updating of land use types and soil data is performed less frequently. Such updating takes place after considerable changes in soil properties, as, for example, after drainage or within areas damaged by industry. Because of this, the level of reliability of data presented on such maps is limited. Names of types and subtypes of soils require recoding to the current Systematic Division of Soils, since they were specified according to the classification of 1956.

Soil-Agricultural Maps

Many potential users of soil maps for the cadastral purposes, other than soil scientists, poorly understand the symbols used on them for classifying soils. Therefore, the Ministry of Agriculture began to publish new maps in 1965, which were called the *soil-agricultural* maps. The basic components are soil suitability units that include soils of various origins and characterised by various properties, that are similar from the agricultural standpoint. Wheat, rye (oats in mountainous areas) and fodder crops (in the case of soils with excessive moisture) were assumed in the rotation: 3 years wheat, 3 years rye, 1 year intermediate and 2 years in fodder crops. A three-crop rotation was distinguished in mountainous areas.

Maps at 1:5,000 scale were the basis for development of soil-agricultural maps. Class boundaries, as well as described soil profiles, were interpreted according to special diagrams and the soil-agricultural map at the scale of 1:5,000 was amended after fieldwork. Qualification criteria were based on properties of soils, correlated with suitability for cultivation of indicative crops. Description of map units on the 1:5,000 soil-agricultural map contain a symbol for the soil suitability unit, the type and subtype of soil, granulometry for 0-50, 50-100, 100-150cm depth and, additionally, the land evaluation class. The map base contains roads, hydrography, built-up areas and borders of land parcels.

Three soil suitability units (1z, 2z, and 3z) are distinguished for meadows and pastures. The map also specifies areas which are not suitable for agriculture (RN), forests and wastelands.

Documentation was developed for each cadastral unit, which included a map (on a transparent film), results of amending fieldwork, descriptions and records of areas. The maps are stored in district (powiat) surveying and cartographic documentation centres and they are available like other cadastral documentation.

In the course of amending fieldwork, profiles for typical units were described and sampled for further analysis from the 'so-called' pattern profiles. For the entire country, 5,700 profiles were analysed at soil laboratories for granulometry, pH, organic matter, exchangeable acidity, Al, CEC, exchangeable Ca, Mg, K, Na, $CaCo_3$ and plant available P, K, Mg.

The database, which contains descriptions and results of analyses of these 5,700 profiles, is located at the Institute of Soil Science and Plant Cultivation (IUNG) in Puławy.

It was assumed initially that soil-agricultural maps would be used mainly for planning agricultural production, in accordance with the agricultural suitability of soils. The users were to be agricultural consulting services and farmers. In practice, the users also included specialists in drainage, urban planning and protection of land. Such maps were produced for all agricultural areas in Poland.

Soil-agricultural maps at the 1:25,000 scale for all districts (powiats) (about 350) in Poland were produced based on 1:5,000 scale maps. Maps with additional symbols corresponding to types of parent rocks were also produced for 60% of the territory of Poland.

The maps produced at the scale of 1:25,000 were used for the production of 1:100,000 scale soil-agricultural maps for 49 provinces (voivodships). In the majority of cases, coloured maps with broad statistical records (annexes), referring to a municipality (gmina) as the reference unit, were printed. Some maps at 1:100,000 scale are already available in the digital form.

The advantage of 1:25,000 and 1:100,000 soil-agricultural maps is that they cover the agricultural lands of the Poland. However, two considerable limitations concerning utilisation of these maps exist: their low cartographic quality and the progressive dating of these maps.

Maps at scale 1:500,000

In 1972, the Polish Soil Science Society and the Soil Science Committee of the Polish Academy of Science, using technical facilities of IUNG, published the soil map of Poland at scale 1:500,000. Its legend consists of 52 units, including 14 types and subtypes of soils, 21 types of parent rocks, 6 classes of texture and 2 additional symbols. The average area of a contour on this map is greater than 10sq.cm. Contours are poorly correlated with other elements of the environment, in particular, with geomorphologic features.

Based on the 1:500,000 scale (genetic) soil map as well as on 1:100,000 scale soil maps, the IUNG in Puławy developed the soil-agricultural map of Poland at the scale of 1:500,000. A digital form of this map is available and the content includes the same data as maps produced at larger scales. It is a valuable basis for the planning of agricultural production for the entire country.

Maps of forested areas

Soil-agricultural maps do not include data concerning soils within forested areas in state forests. In the case of forested areas, soil data may be found in the documentation that has been developed for the needs of forest management plans. Such documentation contains the soil and forest-mapping units at 1:5,000 scale.

In the case of the development of a complete map of soils at the scale of 1:25,000, for a community or a district, the above mentioned maps of soils and forest units, at 1:5,000 scale, may be used. However, in the case of smaller scales (1:100,000, 1:250,000) this is not technically possible and information concerning the soil cover may be obtained as a result of modelling, with the use of data included in geological, geomorphological and topographic maps, and from satellite photographs.

Other Products

This is a rather large group comprising soil maps at various scales, produced as annexes to regional monographs, soil maps of national parks, reservations and other protected areas, soil maps of big urban agglomerations, maps for designing drainage of soils, maps for agricultural and forestry experimental stations and soil maps in geographical atlases, should be mentioned.

Only two groups from these products will be described here:

1. Maps as annexes to monographs and soil maps of protected areas: in the majority of cases the content of such maps exceeds the list of soil units resulting from the official Systematic of Soils in Poland. They often propose introduction of new subtypes of soils or other taxonomical units which better present specific features of the soil cover of the region of special importance, and which are based on analytical data of wider content than in the case of the usual cartography of soils. Such maps introduce some new elements into the discussion concerning theoretical bases, some of which have been included later in the official Systematic of

Soils. There is no complete list of information on such maps or of the areas covered.

2. Maps in geographical atlases play an important role in popularisation of knowledge concerning soils and in transfer of information concerning the soil cover of the country. Conventional printing techniques do not facilitate information transfer capabilities. The scale of these maps ranges from 1:3,000,000 scale to 1:1,500,000. Knowledge of generalisation methods of maps produced at larger scales is not sufficient for appropriate editing of such maps; complex, holistic consideration of soils as elements of the landscape and of their location within the landscape is required. Maps in atlases can reveal relationships within the landscape, because of the existence of thematic maps. However, such maps (geology, geomorphology, and vegetation, soils) have been produced with insufficient attention to neighbouring thematic elements, so interpretation of the landscape is not as explicit as it could be. The new landscape approach, which has been introduced by SOTER and by the term 'soilscape', will lead to greater coherence of thematic natural maps produced for the needs of atlases. Such an approach may already be observed in the recent Map of Soils of Poland in the Atlas of the Republic of Poland, published in 1994.

Atlases produced for teaching pupils, both at primary and secondary schools, do not explain scientific terminology, in particular international terms used in soil science. There is scope for more input from soil scientists in the production of maps and documentation for education at all levels.

Soil Databases

The first attempts to develop data banks for soils were started in Poland in the 1970s at the Polish Soil Science Society. The concept of the BIGLEB System (the soil data bank) was initiated. The range of data was developed together with dictionaries, classification of attributes, and technology for geocoding in the pre-raster and pre-vector cartography era. This technology was based on elementary georeferenced data fields. It was assumed that the spatial resolution of data would correspond to the 1:500,000 scale.

Development of some modules of the BIGLEB System was successfully completed and the system was continued until the era of microcomputers (PC). However, the fact that potential users and decision makers were not prepared to use the data in numerical form, as well as the lack of permanent financing and rapid acceleration of computer technology, has led to the BIGLEB System being considered only as an interesting period for soil database development in Poland.

Geographic Soil Database in Poland

The Geographic Soil Database in Poland at 1:1,000,000 scale, developed as a component of the European Soil Database (v 1.0), is the most important soil database. In 1999, work on a similar database at the scale of 1:500,000 began. This database was to be developed according to the same rules as the 1:1,000,000 database, but with higher spatial accuracy and with some new attributes, such as soil suitability units, land evaluation classes, etc. A method of 'densification' of the existing 1:1,000,000 database was proposed instead of commencing all work from the very beginning. Such 'densification' consists of delineation of new polygons with the use of DTM, geomorphological 1:500,000 scale maps, geological 1:500,000 scale maps, 1:300,000 scale maps of potential vegetation, satellite photographs and CORINE Land Cover.

All the materials mentioned above have been developed in digital form, therefore modelling can be applied. It was assumed that this new database, which is required for analysis performed at the national level, would be completed in 2002.

The Odra River Basin database

For an area larger than 100,000sq.km, covering the Odra River basin, a database at the scale 1:250,000 was developed according to the ESB methodology. There is a possibility that voivodships located within this river basin will have a database that will cover entire units of administration. Development of the database for the Odra River Basin created the chance for six research centres to gain new experiences and to transfer to a new stage of digital technology.

Database for production of soil-agricultural maps

As mentioned in the Surveying Section, the database for 5,700 profiles, described and analysed in the course of production of soil-agricultural maps, was developed at the IUNG in Puławy. Many properties of soils recorded in this database are now out-of-date, but the database itself is a reference point for investigations concerning changes in soil properties and relationships between various soil properties.

Bank of mineral soil samples

The Institute of Agrophysics in Lublin has developed a bank of mineral soil samples based on 1,000 profiles. It includes data on location and basic properties of soils and is available via the Internet.

Database of marginal soils

The database of marginal soils of Poland was developed as a result of a research project at the Institute of Land Reclamation (IMUZ) in Falenty. At present it covers several pilot areas. It was developed from data drawn from soil-agricultural maps. It may be used, among others, for planning new afforestation.

Database of marsh characteristics

The database concerning characteristics and value of marshes, which occur on green areas, has been developed and is maintained at IMUZ in Falenty.

Soil Monitoring

In the 1970s, the Polish Soil Science Society developed the design for soil monitoring. In order to have a valuable reference point for changes that occur in soils, the network of the so-called soil pattern areas was designed; they were located in forests, within groups of plants where changes are small. A full inventory of vegetation, landscape elements and soil properties for each of such pattern areas was made. Full documentation was developed for a small number of pattern areas. At present, the monitoring of soils is performed separately for forest and rural areas.

Monitoring of Forests

Monitoring of forests has been formally operating in Poland since 1984. It was started from measurements of air pollution for 2,000 measuring points. In 1991, monitoring of forests became part of the State Environmental Monitoring.
In 1994, coordinated by the Forest Research Institute, permanent observation areas were created in various types of forests and the monitoring of soils commenced using unified methodology.
Investigations of soil profiles are planned for 8-year periods and include: soil types, texture, pH, sorption capacity, C, N, P, S, exchangeable K, Ca, Mg, Al, Fe, Mn. The results of the monitoring of soils, vegetation, fauna and air are published on Internet pages of the Forest Research Institute http://bazy.ibles.waw.pl/bazy/monitor/monitoringlasu.html).

Monitoring of the properties of arable soils

Monitoring of the properties of arable soils of Poland was started in 1995. Development of the concept and implementation was directed by the IUNG in Puławy. The network, consisting of 216 soil profiles, is located in places representative for all regions in the country with, on average, one profile representing an area of 650sq.km.

Documentation was developed for all profiles and the first analysis of samples taken was performed in 1995, and again in 2000. Successive samples will be taken every 5 years. Characteristics of profiles and results of analyses are stored in the 'Soils' (Gleby) database, which exists at the IUNG in Puławy, and includes the basic morphological properties of soils and the results of 51 analyses.

Individuals and institutions that are interested in these results may obtain both the absolute and interpreted values for comparison with average and permissible values. Monitoring of chemical properties of arable soils of Poland is one of nine subsystems of the State Environmental Monitoring.

Use of Soil Information

Soil information is used in two ways: obligatory utilisation of data with respect to legal regulations, and data use relating to the existing needs and from users' invention. In the first group, the largest recipients and users of data are: the cadastre, protection of arable and forestlands, physical planning. Utilisation of soil data for the cadastre is discussed in the 'Soil Survey' Section.

Protection of arable and forest areas is regulated by Act of Parliament. Conversion of agricultural or forested lands for non-agricultural purposes requires approval from the local government or the central administration. Issuing the permit as well as fees for removal of lands from the agricultural or forest production, depends on the quality of soils. Calculations are based on land evaluation classes, recorded in the cadastre.

Before development of physical management plans, a series of studies must be performed. Soil conditions do not have the highest priority during the decision on how land should be used. Therefore, many valuable soils are still taken for non-agricultural purposes. It is possible that Geographical Information Systems, spatial analysis and modelling, performed with the use of GIS technology, will permit full consideration of soil conditions in physical planning.

Development of Geographical Information Systems

Development of Geographical Information Systems for municipalities (gmina), districts (powiats) and regions is the ideal opportunity for placing the 'soil' thematic layer in these systems. Development of such layers allows updating of the soil data and the possibility of generalising soil mapping units.

Soil erosion

Measures to control soil erosion fall within the wider area of soil protection. Besides soil parameters, proposed changes in land management and other activities aimed at reducing soil erosion consider many other factors, such as land use, terrain relief, climatic data, types of agrotechnical activities. Soil databases often contain data on these parameters and they can be used directly to evaluate erosion and to develop measures to combat it.

Unfortunately, though pilot projects to control erosion and rehabilitation of eroded soils are performed, only a small proportion of soils at risk of erosion are subjected to conservation measures.

An inventory of soils at risk of erosion has been made based on the 1:1,000,000 scale maps that exist, in both analogue and digital forms. A digital version was developed under the MARS Project, using a modified USLE approach, a soil database at 1:1,000,000 scale, a DTM, land cover maps and climatic data.

Evaluation of production agriculture

Evaluation of agricultural areas of Poland according to the scale 1-100 points, with consideration of climatic data and terrain relief, was developed at the IUNG in Puławy. The 1:1,000,000 scale map and statistical records, by administrative units, have been published. Maps of soil suitability for the most important cultivated crops have also been developed. However, the user base from research organisations exceeds that from the administration and agricultural production communities. Elements of the Common Agricultural Policy (CAP), which are gradually being introduced in Poland, expose the limitations of agricultural production rather than its stimulation. Therefore, evaluation maps will prove more useful for future planning than for the present operations.

Yield prediction

Yield prediction is still performed by means of statistical methods and investigation of test areas. Soil parameters are not considered in this case. However, experimental models of yield prediction for green areas and for arable lands, have been developed in Poland, based on satellite data, meteorological data and selected soil parameters. The soil database at the scale of 1:1,000,000 has been used for testing models.

Modelling of pollution of ground and surface waters

Scientists and administrators responsible for water protection are aware of hazards from pollution and they have knowledge about modelling such phenomena. Practical activities in protection zones around water abstraction points are restricted to sporadic tests of chemical composition of surface waters. In some experimental areas, the chemical composition of water flowing from drainage systems in spring has been investigated.

Hydrological models for river basins exist, but parameters used for these models are acquired from maps by means of conventional methods. Acquisition of data used for specification of structures of river basins, from satellite photographs, as well using GIS technology for modelling purposes, is still in the early stage. Soil data are also combined with satellite Landsat TM data for delineation of the so-called boundary conditions (ecotones), thereby reducing distribution of surface pollution and transfer of pollution into surface waters. Soil parameters are indirectly (land use) and directly (texture) considered for calculation of the intensity of the vertical drainage.

Precision agriculture

Precision agriculture cannot be applied without appropriate digital information concerning soils. The small size of farms as well as the type of machinery used for the needs of agriculture does not support the development of the precision agriculture. The first attempts at research institutes, as well as attempts financed by producers of agricultural machinery, were undertaken on large farms. It is assumed that demands for information concerning soils for the needs of precision agriculture will not be high in the near future.

Afforestation of the country

An increase in afforestation of the country will be ongoing for the next 25 years. The delineation of lands for new afforestation is based on consideration of 20 parameters. The three most important parameters are terrain relief, climate and soil. Soil data (texture, stoniness, rockiness, depth of soil, and erosion hazard) may be acquired from soil-agricultural maps at the scale of 1:25,000.

Models for the delineation of so-called marginal soils and models of the terrain evaluation with respect to new afforestation have been developed. The models take into account the spatial organisation of the landscape and economics data as well as soil data.

Education and scientific research

Education and scientific research generate demands for many types of information on soils. These demands are too varied to be fully discussed here.

Drainage of arable lands

In the past, designers of drainage systems for arable lands were important recipients of results of soil investigations. Information concerning soils is used in the delineation of areas that require drainage, as well as for calculation of intervals between drainage pipes. Following the existing soil-agricultural maps, the results of amended fieldwork were used for these purposes. Some attempts concerning utilisation of aerial photographs for investigation of soils for water amelioration projects have also been made. Recently the scope of drainage work has been reduced considerably.

Estimation of the scope of the use of information concerning soils in agricultural experiments and consultancy is difficult. Both types of activities are limited due to financial shortages and if soil data are used, they are from the existing soil-agricultural maps.

Organisation

Institutions, which deal with soil science, are placed in three broad sectors: scientific research and education, administration, economy.

Scientific research is performed by universities, research institutes under the Polish Academy of Science and other research institutes under government ministries.

Soil science institutes (institutes or laboratories) exist in Agricultural Universities in: Szczecin, Poznań, Wrocław, Warszawa, Kraków, Lublin, Bydgoszcz, Olsztyn) and in classical universities, at faculties of geography, biology or earth sciences (Warszawa, Toruń, Lublin, Kraków, Wrocław, Łódź) and at the Warsaw University of Technology.
The scientific research performed is mainly devoted to studying the chemical and physical properties of soils, protection of soils, genesis and classification of soils. Each of these entities also performs regional research work, which results in production of many soil monographs and maps. Some organisations have begun investigations in the field of modern cartography of soils and soil information systems. The Warsaw University of Technology is a leading centre of excellence in these aspects.

Among research institutes under ministries, the most important are the IUNG in Puławy and the Laboratory of Soil Science of the Forest Research Institute in Sękocin. The Institute of Environmental Protection also performs investigations concerning degradation and restoration of soils. Research is also performed in connection with physical geography, geology of the Quaternary period, ecology and other natural disciplines.

At the Polish Academy of Science, the leading entity in the field of soil science is the Institute of Agrophysics in Lublin, which mainly (but not exclusively) deals with physical properties of soils and changes in properties of soils resulting from mechanical cultivation. The Institute of Agrophysics issues the periodical *International Agrophysics*. The discussion forum for researchers, who are active in various sectors, is the Polish Soil Science Society (which publishes Soil Science Annual and Works of Scientific Commissions of the PTG), and the Committee of Soil Science of the Polish Academy of Science (which publishes the Polish Journal of Soil Science).

At the administration level, soil science is represented by individual employees of the Ministry of Agriculture and of the Ministry of Environment. They are responsible for preparation of materials for modification of legal acts and for development of new legal documents, unification of methods and supervision of activities financed by the state budget. The soil scientists employed at the Ministry of Environment have recently initiated works concerning the strategy for soil protection in Poland. It is unfortunate that, within the economic transformation process, soil science at the Ministry of Agriculture as well as at the Ministry of Environment has been subordinated to other issues, considered to be more important from the economic point of view.

Soil specialists are employed at the regional_level (in voivodships) and in districts (powiats) as inspectors, responsible for the protection of agricultural and forests areas. They prepare responses to applications and make and calculate fees for the change of use of agricultural and forest areas.

In voivodships and powiats, soil scientists are employed to update soil classification maps for the needs of cadastre and prepare soil science documentation for other applications. The undertaking of such work is the subject of licensing and requires professional qualifications. The latter group is qualified in implementation not administration and is not large, being now only 10-30% of the number of soil scientists that developed classification maps for the cadastre 40 years ago.

Perspectives

The perspectives for the next 20 years are focussed on the following issues:

1. Widening of the scope and modernisation of methods of teaching of soil science at universities;
2. Development of the new version of the systematic of the Soils of Poland, meeting three difficult requirements:
   a) More detailed reference to the European and World systems,
   b) Objective approach to development of criteria for distinguishing entities,
   c) Understanding users demands from outside genetic soil science;
3. A concept for, and implementation of recording of, the ‘baseline’ conditions of the basic properties of soils, with the use of existing maps, analytical data, monitoring and specially performed tests;
4. Development of soil databases within Geographical Information Systems, from the municipal to the state levels;
5. Development of examples of spatial analyses and models, showing the influence of soil parameters on production and ecological processes in the basic ecosystems, depending on economic situation;
6. Analysis of soil functions aimed at validation of soil as an element of the environment;
7. Development of simulation models of the behaviour of soils, with increase of extreme climatic phenomena;
8. Development of a concept for the creation and functioning of a state soil science service, responsible for inventory, monitoring and protection of soil cover

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Progress of Soil Survey in Portugal

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History

Soil survey in Portugal began in the last quarter of the 19th century though it was not until 1939 that systematic soil survey began. In the 1930s some soil and suitability for irrigation maps were published, for example, the soil mapping and classification of 'Campina de Faro' (Algarve) and the suitability of the soils for irrigation, made by Luis Bramão in 1935.

The Estação Agronómica Nacional (EAN) was established in 1936 and in 1939 one of the tasks of its Department of Soil Science was to make a Soil Map of Portugal at a scale of 1:25,000, using soil series as a mapping unit. The EAN published the soil map of Portugal at a scale of 1:1,000,000 in 1949.

Following this, in 1950, soil survey responsibilities were moved to a new organisation, the Serviço de Reconhecimento e Ordenamento Agrário (SROA), which later came to be named 'Centro Nacional de Reconhecimento e Ordenamento Agrário' (CNROA), the National Centre for Soil Survey and Land Planning. CNROA was a government department of the Ministry of Agriculture, Fisheries and Food (MAPA) working under the coordination of the National Institute of Agrarian Research (INIA). It was the state department with responsibility for soil mapping.

CNROA was closed in 1993 at which time some soil science staff were transferred to the Soils Division of the Instituto de Estruturas Agrárias e Desenvolvimento Rural (IEADR), later on (1995) Instituto de Hidráulica Engenharia Rural e Ambiente (IHERA) and (2002) Instituto de Desenvolvimento Rural e Hidráulica (IDRHa), but many people retired without being replaced by new staff. From this time, the Soils Division focused its efforts on surveying areas between the Tejo and Douro rivers, which needed updating, and editing the maps related to the field survey already completed.

Soil Mapping

Bessa (1991) and Gonçalves (1996, 1999) have provided recent accounts of the progress of soil survey in Portugal. The following sections are an update.

Small scale mapping

The first approximation of the Soil Map of Portugal, at a scale of 1:1,000,000, was published by Estação Agronómica Nacional in 1949 and was presented at the International Congess of Soil Science in Amsterdam, The Netherlands, in 1950. The final version of the map was published in 1973 by SROA as a contribution to the European Soil Map (Cardoso *et al.*,1973).

A Soil Map at a scale of 1:5,000,000 was published in the 'World Soil Map' in 1990 (Fonseca et al., 1990). The map was obtained from a simplification of the 1:1,000,000 scale map with modifications and adjustments to take account of the new FAO legend of 1988.

Large and Medium Scale Mapping

Systematic soil mapping begun in 1958 was carried out by the Serviço de Fomento Agrário, SFA, at a working scale of 1:25,000, with publication at a

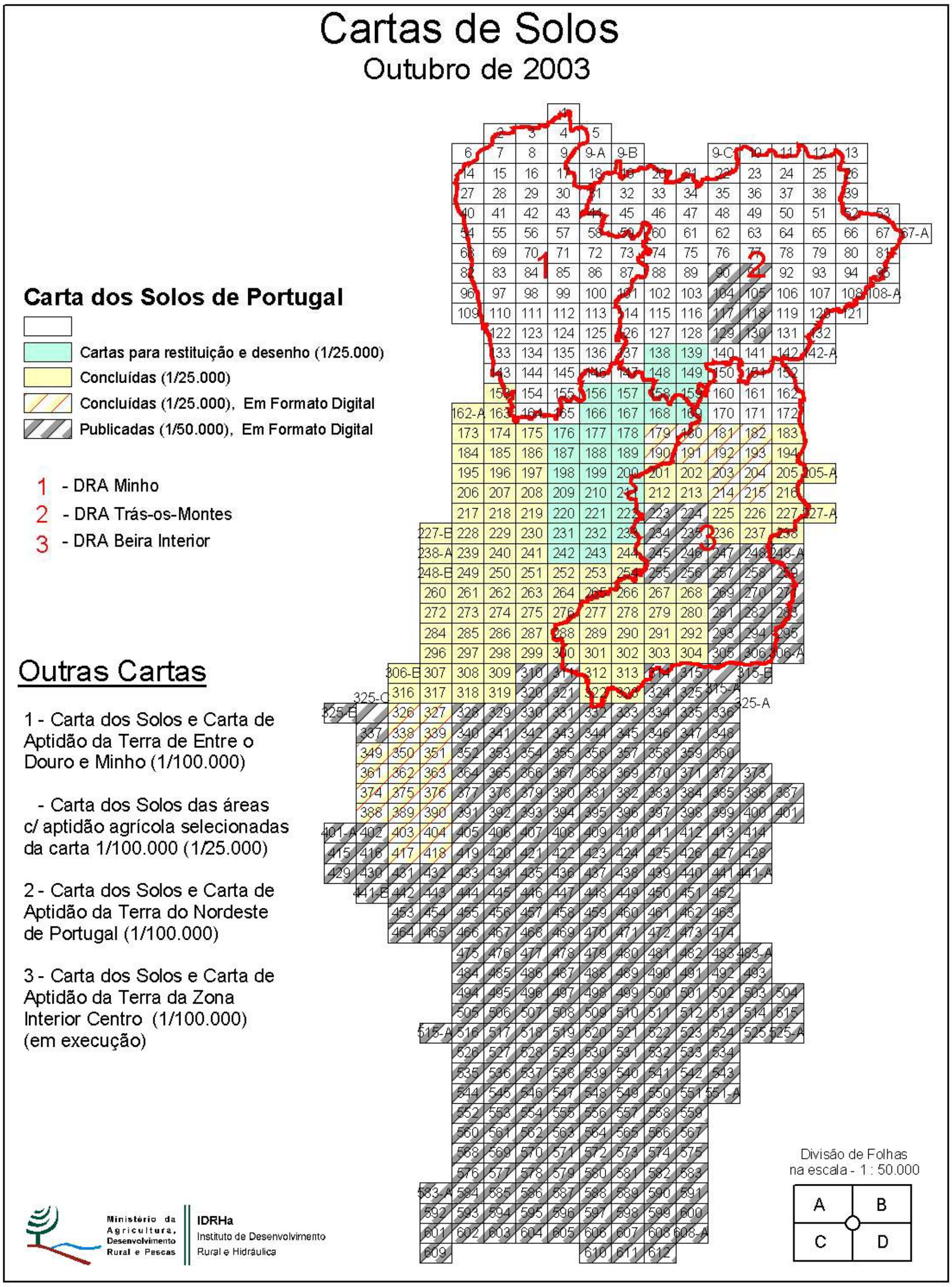

Figure 1: Soil maps of Portugal

scale of 1:50,000. The soil mapping unit, based on the national soil classification, was the Soil Family.

The soil maps were used as a basis for Land Capability Maps, and the aim was that there should be a Land Capability Map linked to each soil map to impress on government the usefulness and importance of the soil mapping programme.

The Land Capability Maps alerted government to the fact that in only 28 percent of the mapped area there were few or no limitations for agricultural use and measures ensued to promote rational soil

use. The mapping of the soils of southern Portugal (south of the Tejo river) was completed in 1965 (Cardoso, 1965).
These maps, in total 89 sheets, and the associated Land Capability thematic maps, are now available in colour at 1:50,000 scale for 55 percent of Portugal. The soil and land capability maps are also available at a scale of 1:25,000 (working version) but only in paper or transparency form without legend. This latter series of maps are now digitised and can be reproduced (Figure 1).

Various internal problems with the national soil service have delayed the systematic soil mapping of the remaining areas of the country. Coupled with this, morphological and analytical data were insufficient, so during the 1980s the soils of 'Trás-os-Montes', north-east of Portugal, were mapped at a scale of 1:100,000 (see Figure 1) according to the FAO-UNESCO Legend, and this map is available in coloured form (Agroconsultores-COBA, 1991) and also digitised. The initiative was from Vila Real University and the study was carried out by a private firm.

During the 1990s, mapping of the 'Entre Douro e Minho', north-west region, has also been carried out at a 1:100,000 scale see Figure 1, 1 with the same methodology, promoted by the Agricultural Regional Directorate and also executed by a private firm, and it is available in printed colour and digital forms (Geometral-Agroconsultores, 1996). In the same area some 350,000 hectares of agricultural soils are also mapped and digitised at a 1:25,000 scale.

The private enterprises that executed the soil mapping of these two regions, have in addition, mapped 40,000ha of agricultural soils in various parts of the country, at a scale of 1:10,000 scale for irrigation projects.

Great part of the area between the Douro and Tejo rivers was also mapped, at 1:25,000 scale, and the majority of Soil and Land Capability maps are already digitised. Within that area, Central inland region (see Figure 1, 3) is actually being mapped at 1:100,000 scale with the same methodology as in the northern areas, the soils classified according to the World Reference Base for Soil Resources. The deadline for completion of the work is December 2004 and it is being performed by Geometral-Agroconsultores.

Soil maps are also available for the islands of Madeira at 1:50,000 scale in printed and digital forms (Pinto Ricardo, 1992) and for Porto Santo at 1:25,000 scale in colour printed form only (Franco, 1994).

In the last years, a soil reconnaissance characterisation based on the 1:25,000 soil map has been carried out for an area of 190,000 hectares to select areas to be mapped at 1:10,000 scale for the future Alqueva irrigation perimeter. About 800 soil profiles were described and analyses made of samples from each horizon or layer in more than 100 profiles.

Soil Monitoring

Soil erosion has been monitored on an experimental site in Vale Formoso, Alentejo since 1960 (Mota Ferreira *et al.*, 1984). It is the oldest experimental site in Europe applying the methodology of Wischmeier and colleagues. One of the objectives of the experiment has been to test the application of the Universal Soil Loss Equation-USLE (Wischmeier *et al.*, 1958; 1978) to local Portugese conditions in order to advise on soil conservation measures. There are fifteen plots (20.0 x 8.33mm), with slopes varying from 10 to 20% and orientated from east and south-southwest. The soil studied, a Chromic Luvisol, has been subjected to different crop rotations (vegetation cover) and management practices. Soil loss, run-off, infiltration and, more recently, the loss of nutrients are being investigated.

Soil Database

Data from representative soil profiles have been collected to support soil mapping. Available data include: soil texture (International Classification), organic carbon and organic matter contents, total N, C/N ratios, carbonate content, free iron content, exchangeable cations, cation exchange capacity, clay type, bulk density, water holding capacity, water content at pF 2.0, 2.7 and 4.2, and saturated hydraulic conductivity. The soil hydraulic data were obtained from disturbed soil samples. Only in the most recent soil mapping at scales of 1:10,000, 1:25,000 and 1:100,000 have undisturbed samples been collected. These data are to be found in various reports and scientific papers, and were included recently in the SPADE 2 Project the objective of which is to provide, for each country in the European Union, a land use-specific dataset of soil primary properties relevant to each soil typological unit (STU) of each soil map unit (SMU) included in the 1:1,000,000 soil geographic database for Europe v. 3.2.

At the Soil Science Department of Estação Agronómica Nacional, soil hydraulic properties of the main soil units of the country have been measured in undisturbed samples for the establishment of a database of such properties and development of pedotransfer functions (Gonçalves, 1998; Gonçalves *et al*., 1997; 2001).

Some of that information was included in the database of soil hydraulic properties of European soils (HYPRES) (Wosten *et al.*, 1998). Actually, about 200 horizons or layers from 80 soil profiles were analysed for soil hydraulic properties. For the soil water retention curve more data is available but until now only those soil horizons with both soil water retention and hydraulic conductivity data are included in the database.

Applications of Soil Maps and Databases

The knowledge of soil properties gained over the years has been vitally important in the development of thematic maps including the following:

1. Land Capability map;
2. Land Suitability maps for irrigation;
3. Soil nutrient status;
4. Delimitation of the National Agricultural Reserves (RAN);
5. Delimitation of the National Ecological Reserves (REN);
6. Soil erosion risk and land resource maps of Portugal for the CORINE programme;
7. Soil erosion map and land resource maps of Algarve as part of the Transfrontier Algarve-Andalucia Project (CORINE programme);
8. The European Soil Map at a scale of 1:1,000,000.

Soil data have been used to: develop irrigation projects (Baixo Vouga, Mondego valley, Lezíria, Xévora, Sotavento, Algarvio); undertake surface- and ground-water studies and environmental impact studies, for example in the case of the future Alqueva irrigation project; make fertiliser use recommendations; support public works, evaluate changes in land use and problems associated with sewage sludge disposal; support the execution of national and international research projects.

Outlook

There is an increasing demand for soil information at all scales to address land use and environmental problems. Soil survey information is increasingly being used for purposes that were originally unforeseen. This has often led to a gap between the available information andwhat is really required.
The completion of the unfinished soil survey projects needs to be given high priority and there needs to be more investment in data collection activities because some of the existing soil information is obsolete and because new information is required.

It is important to develop a geo-referenced soil database for Portugal which should include the morphological description of soil profiles and the corresponding analytical data, linked to a geographic information system to make available to all users national information about soils to support their better management, protection and use.

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Status of Soil Mapping, Monitoring, and Database Compilation in Romania at the beginning of the 21st century

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Generalities

Romania is a medium-sized country ($23.83x10^6$ ha), located in the southeastern part of Europe. Physiographically, plains and tablelands occupy 49.3 percent of the country area, hills occupy 30.2 percent, and mountains 20.5 percent.

Agricultural land occupies more than 62 percent of the country, forests 28 percent and other uses occupy about 10 percent. In Romania, the following structure exists for acquiring, processing and interpreting soil data:

- For agricultural soils: The Research Institute for Soil Science and Agrochemistry (ICPA-Bucharest), at nation-wide level, and 37 District Offices for Soil Surveys and Soil Testing, at regional level;
- For forest soils: The Research Institute for Forestry and Forestry Management.

Historical Background

The interest in soil resources in Romania goes back to the beginning of 18th century, when one of the Moldavian Kings, and a late renascentist scholar Dimitrie Cantemir, described the soils of that country as being '*black and full of saltpetre*' (Florea *et al.*, 1968).

Scientific study of Romanian soils is more recent, dating back to the second half of the 19th century. Those responsible included agronomists Ion Ionescu de la Brad (1860, 1866, 1868), St. Radianu (1889), Vlad-Cârnu Munteanu (1900). Maps including data about soils were drawn first by a geologist (Matei Draghiceanu, 1885).

These works were strongly influenced by the agro-geological and agrochemical schools, which at that time were dominant in Western Europe.

Modern soil science was introduced into Romania at the dawn of the 20th century (1906) by G. Munteanu Murgoci, a learned man and an enthusiastic researcher in the field of Geology, Geography and Pedology. Murgoci was amongst the first scientists from Europe who became aware of the advantages offered by the new concept of soil promoted by V.V. Dokuchaev and his disciples. For a long period, soil science and soil survey in Romania developed according to the Dokuchaevist concept.

However, Murgoci and his collaborators (E. Protopopescu Pache, P. Enculescu, and Th. Saidel) and also their followers (N. C. Cernescu, N. Bucur, M. Popovat, *et al.*) set up an original soil science school reflecting both the conceptual developments concerning soil survey methodology, soil classification, soils mapping systems and soil data interpretations. In parallel, the application of soil science for both agricultural (Gh. Ionescu-Sisesti) and forestry (C. D. Chirita) developed strongly.

The first soil map of the Romania Old Kingdom as existed before the First World War, was produced at a scale of 1:2,500,000 (Murgoci ++et al.,1911). After the First World War, a map of the extended Romania at a scale of 1:1,500,000 (Enculescu, et al., 1927) was produced. These maps were further accompanied by some correlative maps of vegetation for the Old Kingdom and the entire country (Enculescu, 1924, 1938) or with climatic conditions (Cernescu, 1934).

Soil Mapping Methodology

From the beginning, soil mapping was based on the concept that the soil is a component of the landscape, and that variations in soil cover characteristics are determined by changes in one or more of the factors of soil formation.

As far as the concepts of diagnostic soil horizons and diagnostic soil properties are concerned, soil-mapping methodology focused on the intrinsic soil profile properties. This does not mean that the factors controlling soil formation are considered less important. Their variation in the landscape, and the place where their changes correlate with changes in the soil cover characteristics, are the main criteria used for delineating soil bodies or soil associations on the map.

Field mapping is essentially based on landscape: variation of landform and topography, relevant vegetation communities, changes in surface lithology, etc. The pit inspections and auger borings serve mainly for describing and characterising soil bodies.

For large to medium scale surveys (larger than 1:50,000), a complex methodology, consisting of 3 volumes, (coordinated by Florea. et al., 1987) for making and interpreting soil survey is used by Romanian pedologists. This methodology comprises 275 parameters and indicators concerning soil, relief, climate, vegetation, surface lithology, morphological, physical, chemical and soil testing characteristics, etc. A wide range of interpretations is also provided: e.g. soil rating, land capability for different uses, e.g. arable or forest, and soil classifications for different purposes: irrigation, drainage, erosion control, etc.

Kinds of soil mapping

In Romania, soil survey activities are carried out in three fields of interest: general soil resource inventory, agricultural lands and forest lands. Although these kinds of soil mapping are essentially similar and interrelated, they differ both in purpose and some methodological aspects.

General soil resource inventory

This kind of soil mapping is oriented to nature and was initiated by Murgoci and his collaborators at the beginning of the 20th century. The concept is that of surveying not only the soil but also all soil forming factors and physical conditions: landforms, surface lithology, vegetation, hydrology, land use and human impacts. Different kinds of soil degradation, e.g. erosion, water logging, salinity, pollution, are also surveyed and mapped.

For these reasons such soil mapping has been called 'complex soil mapping' (Florea, 1964). Field survey is supplemented by physical and chemical analyses: e.g. texture, bulk density, organic C, pH, total N, nutrients, base saturation, etc.

The most general resource inventory mapping has been carried out at scales 1:50,000 to 1:100,000, and maps cover about 80% of the country. Only the mountainous region has been mapped at smaller scales (e.g. 1:200,000) or at reconnaissance level with key areas surveyed at larger scales.

This kind of survey has resulted in soil maps at scales 1:50,000, 1:100,000, 1:200,000, 1:500,000, 1:1,000,000 and 1:1,500,000

Soil mapping of agricultural lands

This activity began in the 1960s and developed in parallel with the general soil inventory mapping described above. It focused on agricultural land and, for this reason, the field surveys were made mostly at large or very large scales (1:10,000 and 1:5,000). The territorial unit is generally that of a commune or of a farm.

The methodology of field mapping is generally the same as that used for general soil mapping inventory. The surveys were oriented to meet the needs of agriculture. The soil mapping of agricultural lands would need to be updated every 15-20 years. Practically all agricultural lands have been mapped at some time, but only about half of the arable lands (ca. 4.5 million ha) have been mapped for a second time.

The large-scale soil maps for agricultural purposes have a particular structure. For each delineation, the information is recorded in the form of a formula with data concerning not only the soil, but also landforms, slope, aspect, surface lithology, groundwater depth, erosion, landslides, etc.

The soil delineation described in such a way becomes what is a called 'pedotop' (Florea *et al*. 1987), which is somewhat similar to the 'soilscape' defined in literature. When provided with climate data the 'pedotop' becomes an 'ecologically homogenous territory' or 'TEO' (Teaci, 1980).

The 'pedotop' and 'TEO' are the elementary units for soil conservation and soil improvement as well as for soil rating, soil suitability and land evaluation.

Forest soil mapping (forest site mapping)

This activity started in Romania at the beginning of the 1940s and is linked to the name of C.D. Chirita, founder of the Romanian forest soil science and a ceaseless promoter of soil science in general.

Although conceptually similar to the inventory and agricultural soil mapping, forest soil mapping focused mainly on ecological aspects of the land and soils. Field survey identifies, delineates and characterises ‘sites’ as ‘ensembles (areas) that are relatively homogenous with respect to climate, landform, lithological substrate and soil, in which a specific type of forest vegetation can grow’. Special attention is paid to the soil moisture regime, which is defined in qualitative terms (e.g. wet, dry, moist) and according to seasonal variations.

All these elements determine the productive timber capacity of the area, the efficiency of the land use, and the silvo-technical and technological measures aimed at improving the growing conditions of the forest vegetation (Chirita, *et al.*, 1964; Chirita, 1972). For afforestation or re-afforestation purposes in different terrain (e.g. strongly eroded soils, sandy soils), forest nurseries, special forest crops etc., the forest site mapping is conducted at scales of 1:10,000 or 1:5,000.

For the management of forests that have not yet suffered significant degradation, forest site mapping is undertaken at medium scale (1:50,000). In this case of estimation of ecological characteristics of an area, the indicators given by the forest vegetation itself are used together with indicators about soil, climate, landform and lithological substrate.

However, this method is not applicable to forests found in a latent state of degradation. Human impacts upon forests will increase and it will be necessary to place emphasis on information about climate and soil directly. Considering the declining state of Romanian forests, it will be necessary to survey all forested lands (6.6 million ha) at a scale of 1:10,000.

Soil maps

At the end of the 20th century, Romania possessed an almost complete and integrated system of soil, typological, factorial (correlative), regional and interpretative maps (Tables 1 and 4).

Soil map at a scale 1:200,000

This map represents the most important achievement of soil survey activity in Romania. The surveys were made between 1963 and 1994, but some field work had started in the 1950s.

The coordination was initially assumed by N. C. Cernescu and from 1967 onward by N. Florea. The field work, compilation and printing were carried out at the Geological Institute and after 1970 at the Research Institute for Soil Science and Agrochemistry.

The soil map of Romania at a scale 1:200,000 comprises 50 sheets in colour (Figure 1) and has a general legend with 470 mapping units. Although the Romanian Soil Classification underwent several changes during the production of this map, the general legend incorporates correlation between different periods. Each sheet comprises: (a) 1:200,000 soil map with the kinds of soils and topsoil texture; (b) legend of soils and of topsoil texture; (c) two maps at a scale 1:500,000 with landforms, surface lithology, and geobotanical and climatic data respectively; (d) several cross-sections showing the relationships between soil cover, relief, surface lithology, and ground-water depth.

The 1:200,000 soil map was used as the base for compiling the 1:1,000,000 scale soil map of Romania, which has been included in the European Soil Database (1998). It also provides an almost complete pedological information base for the 1:250,000 Georeferenced Soil Database of Europe planned by the European Soil Bureau.

The smaller scale soil maps at 1:500,000 scale (1971-1973) and 1:1,000,000 scale (1964, 1968, 1978) represent syntheses of the existing field pedological information at the time when they were compiled. The mapping units are mostly soil associations and they comprise information about topsoil texture (the soil map 1:500,000 and 1:1,000,000-1964) and general surface lithology (soil map 1:1,000,000-1978).

In some cases, regional soil maps and factorial maps (usually at small scale) have been made. The regional maps emphasise the general pattern of the soil cover (related to the main physiographic conditions) while the second portrays the spatial distribution of some environmental factors important in soil genesis (landforms, surface lithology, etc).

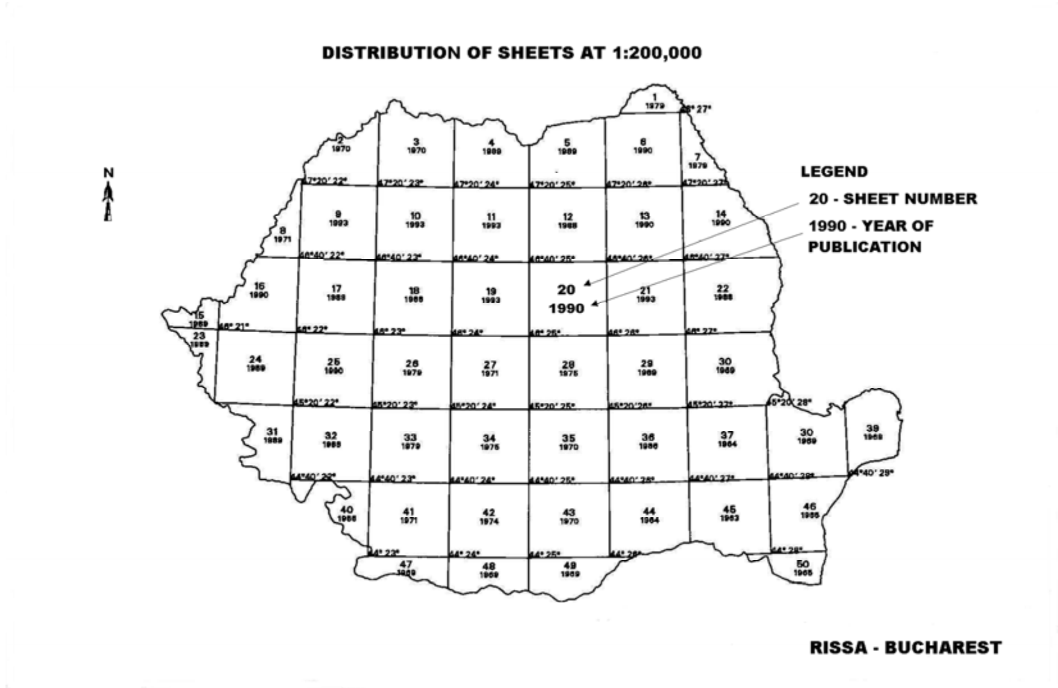

Figure 1: Soil map of Romania

Table 1: System of soil typological maps, regional and factorial maps used in Romania (adapted from Florea, 1999)

Type	Content	Scale	Area of use
1.1. soil (typological)	-spatial distribution of soils as geographic entities identified according to the national system of taxonomy	a) Nation wide level -1:50,000 (only agricultural land) - 1:200,000 - 1:500,000 - 1:1,000,000 b) Communal/ district level - 1:5,000 (locally, special purposes) - 1:10,000 - 1:25,000 - 1:100,000 (Danube Delta)	- soil resources inventory - interpretative maps;
1.2. factorial (correlative)	-spatial distribution of some environmental factors, important for soil genesis, soil management and soil behaviour prediction	various (usually small scales)	- interpretative maps
1.3. regionalisation	-relatively larger geographic areas with a complex soil cover and of size depending on the map scale	≤ 1:1,000,000	- interpretative maps

Soil Quality Monitoring

A system of soil quality monitoring has been established in Romania since 1977. It was an integral part of the National System of Environment Quality Monitoring (Rauta and Carstea, 1983). Because of some deficiencies of organisation (lack of a fixed systematic network of points for observations, no adequate range of soil parameters to be monitored, a. o.) the system was not able to provide the expected results. Therefore, starting from 1992 a new integrated system for monitoring the quality of both agricultural and forest soils was implemented (Rauta *et al*. 1998, Dumitru *et al*., 2000).

This new system (Figure 2) is structured according to the rules of Convention on Long Range Transboundary Pollution and consists of:

- A fixed grid 16km × 16km that covers the entire country (1 point/256sq.km) and which

comprises 942 sites (soil profiles), 670 of which are within agricultural areas and 272 are in areas of forest soils;
- At every intersect on the network, a square 400m × 400m is defined within which different soil and terrain parameters are recorded and monitored.

The common operations carried out, comprise:

1. At each site, soil profile characterisation and sampling (a bulked sample of disturbed soil material resulted from 20-25 individual samples for the uppermost 10cm and 3 individual samples for each underlying horizon; 2-4 undisturbed soil cores for each horizon are also taken);
2. Centralised storage of soil samples and physical and chemical analyses on them;
3. Data processing and interpreting.

The measured soil parameters are generally those commonly used in soil surveys to which some indicators concerning soil pollution are added (Table 2).

The frequency of measurements/observations is normally every four years, but annually where points fall in areas with soil degradation problems. The field and laboratory data are gathered and processed by the Research Institute for Soil Science and Agrochemistry (I.C.P.A.) in close co-operation with District Offices for Soil Surveys and Soil Testing Studies.

Since 1977, national reports concerning soil quality state have been compiled and forwarded by RISSA to the Ministry of Agriculture, Waters, Forests and Environment. In parallel, such reports are compiled at district level by District Offices for Soil Surveys and Soil Testing. Until now these reports refer only to agricultural lands. (Table 3). In future, information about forest land, as long as such data become available, will be included.

Concluding Remarks

The density of the observational sites (1 per 256 esq.) of the soil quality monitoring system in Romania seems to be satisfactory for interpretations at European level. However, at national level the 16km × 16km grid is too coarse to take into account the high variability of the soil cover and the fragmentation of the agricultural (especially arable) land after the application of land reform in 1990. At the present time, a network of 4km × 4km for agricultural lands and one of 8km × 8km for forestlands would be able to satisfy the requirements of an efficient soil quality monitoring. Therefore, there is a drive to start to improve the density of the 16km × 16km grid at least in regions where the present-day sites fail to represent properly the soil cover of the area in which they occur.

Soil Databases

Point databases

Among these databases the following three are the most important**:**

Database of soil profiles (PROFISOL) (F 77 programs on minicomputer, Paradox and MS Access applications on PC).

The functions provided (Canarache *et al*., 1998, Vlad *et al*., 1997) are:

- Data entry/updating/retrieval for each profile;
- Data validation;
- Calculation/estimation of input data if missing by use of pedotransfer functions;
- Calculation of new data (not input data);
- Calculation of data for predefined depths;
- Statistical processing on groups of profiles;
- Transformation of measuring units;
- User reports printing;
- Management of code dictionaries.

A large range of soil physical properties, including bulk density and soil water properties was introduced in the late 1950s for special purpose surveys, and later extended to current soil survey. The first such database (Mielcescu *et al*., 1977) was established specifically for soil physical properties, but later it was extended and at present is included in the general database, PROFISOL, which makes use of the Access software (Canarache *et al*., 1998; Vlad *et al*., 1997).

The soil texture classification in Romania is based on the ISSS particle-size classes (< 0,002mm diameter for clay, 0,002-0,02mm diameter for silt). There have been several such classifications in earlier times, but in the last thirty years a texture triangle defining 6 classes and 21 subclasses has been generally used. An approximate correlation of this classification with the USDA one is possible (Canarache, 1964).

The other soil physical properties, mostly determined on undisturbed soil cores, include bulk density, total porosity and its components, soil water retention (at least at pF 0.2 and 4.7), field capacity, saturated hydraulic conductivity and standard resistance to penetration. Pedotransfer functions allow estimation of the soil water properties, either the Van Genuchten parameters

(Simota and Mayr, 1996) or classical soil moisture constants (Canarache, 1993a).
Some mechanical soil properties (Canarache, 1990; Canarache, 1993b), where not measured, are estimated by pedotransfer functions, using clay content and bulk density as the main input variables. Data for over 4,200 soil profiles are at present stored in PROFISOL, of which all profiles have general and physical data (over 200 data fields), 450 profiles also have chemical data (over 125 data fields) and 170 profiles have all types of data (ca. 1,000 data fields). The acquisition period was 1956-1999.

Table 2: Soil quality monitoring parameters used in Romania

Parameter	Depth (cm)
A. Common to all soils	
I. Disturbed soil samples	
Particle size	entire profile
Structure stability (water)	0-50
pH (water)	entire profile
Organic matter	0-50
N total	0-50
Available P	0-50
Available K	0-50
II. Undisturbed soils cores	
Field moisture	entire profile
Bulk density	entire profile
Resistance to penetration	entire profile
Saturated hydraulic conductivity	entire profile
Water content at pF=0	entire profile
Total porosity	entire profile
B. Specific parameters	
I. Base unsaturated soils	
Sum of basic cations	0-50
Hydrolytic acidity (at pH 8.3)	0-50
Exchangeable Al	0-50
(only samples with pH water $<$ 5)	
Cation Exchange Capacity (CEC)	0-50
Base saturation (V)	0-50
II. Base saturated soils (V = 100, pH H_2O = 7.4-8.5 with earth-alkaline carbonates, without soluble salts)	
Calcium carbonate ($CaCO_3$)	entire profile
III. Soils with soluble salts which frequently contains earth-alkaline carbonates and/or gypsum (Base saturation = 100)	
Total soluble salts	entire profile
Exchangeable Na (me /100g soil)	sodicised samples
Na saturation (VNa)	sodicised samples
Salt composition	samples with total soluble salts
	content $>$ 0.09-0.17%
IV Special parameters	
Heavy metal content	0-20
(Cu, Zn, Pb, Co, Ni, Mn, Cr, Cd)	
Soluble S	0-20
Soluble F	0-20
HCH, DDT	0-20
Number of bacteria	0-20
Number of fungi	0-20
Dehydrogenase activity	0-20

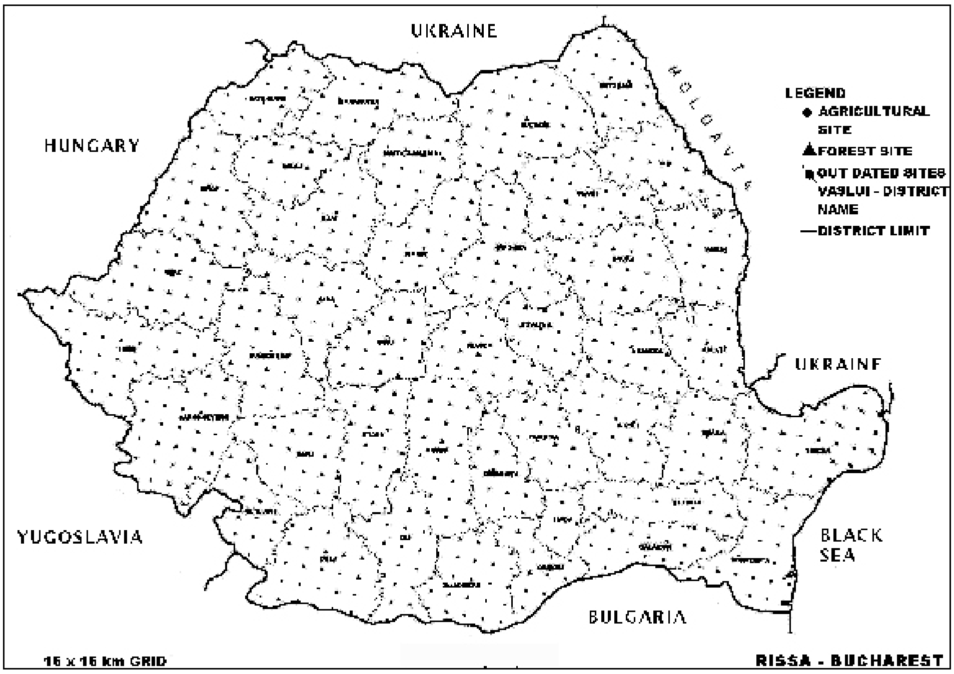

Figure 2: Soil monitoring sites in Romania

Table 3: The main restrictive factors for the productive capacity of agricultural soils in Romania (Dumitru *et al*., 2000)

Kind of restriction	area, 10^3ha
water deficit	7,100
waterlogging	3,781
water erosion	6,300
landslides	702
wind erosion	378
stoniness	300
salinity	614
human induced compaction	6,500
natural (inherited) compaction	2,060
crusting	2,300
excavations	15
waste pollution	18
chemical pollution	900
low or extremely low humus content	8,620
strong and moderate acidity	3,437
high sodicity	222
low and very low content of available P	6,258
low content of available K	781
low content of N	5,088
trace elements (zinc) deficiency	1,500

Database of the National Integrated Soil Monitoring System

This database contains soil profiles as defined in the PROFISOL database and also includes some specific data according to the methodology of the Pan-European network (16km × 16km grid) for soil monitoring. For each horizon: 4 physical parameters, 12 chemical parameters (heavy metals, soluble sulphur and fluorine, pesticides, etc) and 5 microbiology parameters are recorded.

The 942 soil profiles, located on agricultural and forest lands for monitoring purposes, have been described and analysed, resulting in about 300 data items for each. Processing has permitted calculation of data for pre-defined depths and different syntheses and prognoses (Rauta *et al*., 1998).

Pedogeochemical database

This database, stored on PC under Paradox (Lacatusu and Lungu, 1997), contains profiles as defined in the PROFISOL database together with eight geochemical measurements (total forms of heavy metals) for each horizon. Data on about 1200 profiles (ca. 200 items of data per profile) have been stored. Data processing on groups of profiles provides 7 statistical parameters: abundance classes based on frequency histogram, geochemical threshold, abundance index, (local zone), loading/pollution index, etc. (Lacatusu, 1997).

Georeferenced databases

a) Database of agricultural land units at 1:50,000 scale

This database (Tapalaga *et al*., 1997a) contains the following main items:

- Homogenous land unit characteristics: land unit identification, relief, climate, ground- water, parent rock/material, soil name, technological characterisation, current and potential land suitability (25 crops and land uses);
- Land units (subunits) referring to: district, commune, owner groups, land-users, homogeneous land unit, main river basin;
- Comprehensive data at commune level for four main land uses and total agricultural land: land area, mean current suitability mark and mean current suitability class.

Stored data: the whole agricultural land (ca. 14.5 million ha of the country (more than 125,000 homogenous land units). Acquisition period: 1953-1975.

b) Database of land units at 1:10,000 scale.

This database (Marian *et al*., 1997), comprises FORTRAN77 programs running on a minicomputer and under MS Access on PC and contains the following main data:

- Homogenous land unit characteristics: identification data, relief, climate, hydrology, soil taxonomy, soil properties, anthropogenetic parameters;
- Land units/sub parcel areas, referring to: district, commune, farm, six types of land use, cadastral parcel, homogenous land unit.

Stored data: over 40 percent of the agricultural land of the country (over 50 percent of the arable land). *Acquisition period* 1980-1998.

The functions provided are:

1. Data entry (validation, data retrieval/updating);
2. Calculation of soil rating for 24 crops and also for orchards, vineyards, grasslands and rice fields;
3. Calculation of parameters for technological characterisation; data aggregation (areas, averages of land suitability);
4. Reporting, printing.

The system of soil rating includes seventeen main qualitative and quantitative indicators as follows: annual temperature and annual rainfall, ground-water and surfacewater gleying, salinity/sodicity, topsoil texture, soil pollution, slope, landslides, groundwater depth, liability to inundation, total porosity, $CaCO_3$, soil reaction, physiologically useful volume, humus reserve, excess of moisture.

Additionally five other ancillary indicators (aspect, microrelief, permeability, profile texture and base saturation) are considered. Each of these indicators receives a value from 0 to 1 depending on influence on crop growth. The final score is obtained by multiplying by 100 the product of the values. The rating mark or score may be a value between 0 and 100. This is the so-called ‘natural rating mark’. When there are some land and soil improvements (e.g. drainage, irrigation) this mark is multiplied by a super unitary coefficient and becomes ‘enhanced rating mark’. The rating mark is further adjusted according to economical constraints and is transformed into an ‘economic or cadastre rating’.

c) Database for monitoring soil-testing qualities

This database (Tapalaga *et al*., 1997b) contains for each district the following data: five soil quality classes using five parameters (pH, N, P, K, humus) for five land uses,. *Stored data*: the whole agricultural land of the country. *Aquisition period:* 1987-1995. Provided functions: data entry/validation, data retrieval, reports, printing.

GIS applications

As a result of different investigations (Vintila *et al*., 1991; Munteanu and Vasile-1992; Munteanu and Zota, 1994; Vlad, 1994; Vintila *et al*., 1991) a Geographical Information System for Romanian soil and land resources has been defined. At the present time, the following layers have been stored (using digitisers and scanners for geometric data entry) using ARC/Info and GRASS software.

Scale 1:2,500,000

- SOTER units, (Munteanu *et al.*, 2000,) with attributes relating to landforms, lithology, soils, etc. and human induced soil degradation (physical and chemical deterioration, soil pollution, etc.).

Scale 1:1,000,000

- Districts and sub-districts (with attributes for each of four land uses and total agricultural land: land area, mean current suitability, suitability class);
- Localities, roads, railways, main rivers (all partially entered);
- Main geomorphological units;
- Ecoregions (attributes: areas of land use, land suitability class);
- Pedogeoclimatic microzones (attributes: identification areas, climate, relief, soil);
- Pedological map (soil associations).

Scale: 1:500,000

- Vegetation map:types of plant associations (Dragu *et al*. 2000)

Scale 1:200,000

- Soil cover of the whole country is already entered; attributes: soil type\subtype, erosion, gleying, sodification, texture;
- Soil-terrain map-ROMSOTER-200 (Munteanu, *et al.*, 1997) adapting SOTER methodology. Attributes: 16 general data, 32 soil mapping units data and soil typological units data, 78 soil profile data; different pilot areas have been used to obtain thematic maps;

Scales 1:10,000 and 1:25,000

Some pilot areas have been studied in relation to different land characteristics and have been checked for classification and integration of satellite images using GIS.

Applications of Soil Maps and Data

Use of soil maps

The soil map alone is used mainly for making soil resources inventory or to assess the geographical distribution of soils. For other uses, a system of interpretative and special maps has been developed (Table 4).

The system is designed to help with various practical problems as follows: local and regional land use planning, environmental protection, assessing land suitability for different crops and use, soil amelioration and reclamation, land taxation, assessing soil vulnerability to different kinds of impacts (including vulnerability to pollution), inventory of several kinds of soil degradation and agricultural landuse restrictions e.g. soil erosion, excess of moisture, soil salinity/sodicity.

The most important interpretative and special maps are described in the following sections.

Soil erosion

A at scale 1:500,000 of soil erosion (Florea *et al.*, 1976) contains basic information concerning distribution and intensity of water and wind erosion, landslide and erosion risk. The soil erosion map is the main source of qualitative and quantitative general information concerning soil erosion both at nationwide level and at district (judet) level.

In connection with this soil map, two other interpretative maps at a scale 1:500,000 have been also compiled:

- *Hazard of erosion, landslides and floods map,* (Munteanu et al., 2000c) at a scale 1:1,000,000, shows the present-day status and the risk of occurrences of these phenomena. It is used mainly for rural and urban infrastructure development.
- *The standard soil loss rate map* for agricultural lands and grasslands, and *soil erodibility map* respectively (Vatau *et al.*, 1993a).

Excess moisture - waterlogging

Maps of Excess of moisture, ie degree of waterlogging, at scales 1:1,000,000 (Florea et al., 1972) and 1:500,000 (Florea *et al.*, 1978b) show the geographic occurrence, at national and district level, and intensity of the three kinds of excess of moisture: from groundwater, rainfall and by floods. The classes are defined according to intensity and the subclasses according to the nature (source) of the excess moisture.

Salinity

A soil salinity map at scale 1:1,000,000 (Florea, 1996, unpublished) shows the geographic distribution of the three main kinds of salt affected soils: saline soils (solonchaks), sodic soils (mainly solonetz) and saline/sodic soils. For saline soils the kind of dominant salt is also specified.

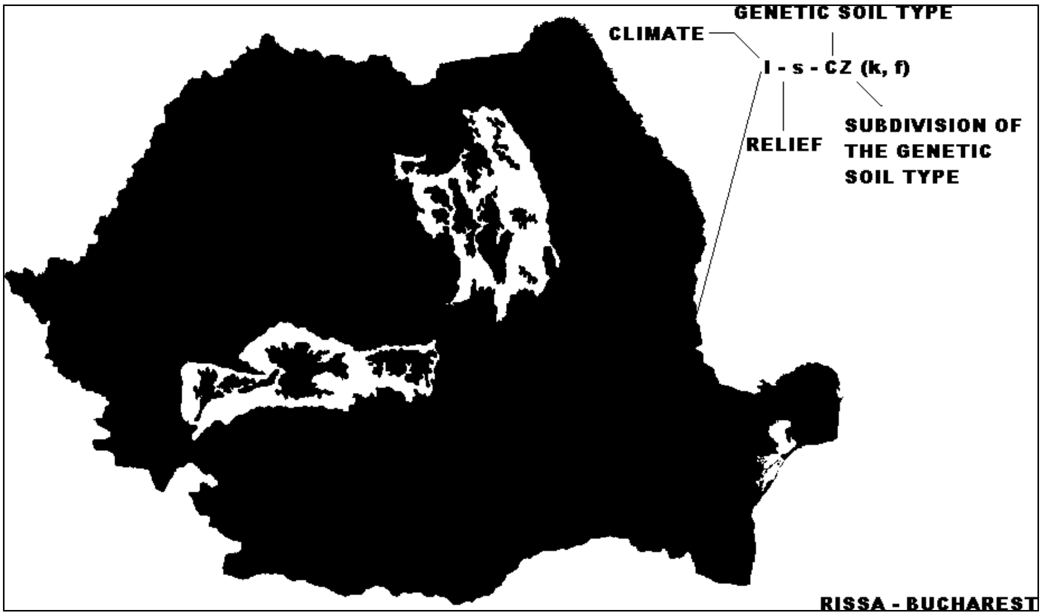

Figure 3: Ped-geo-climatic microzones map of Romania

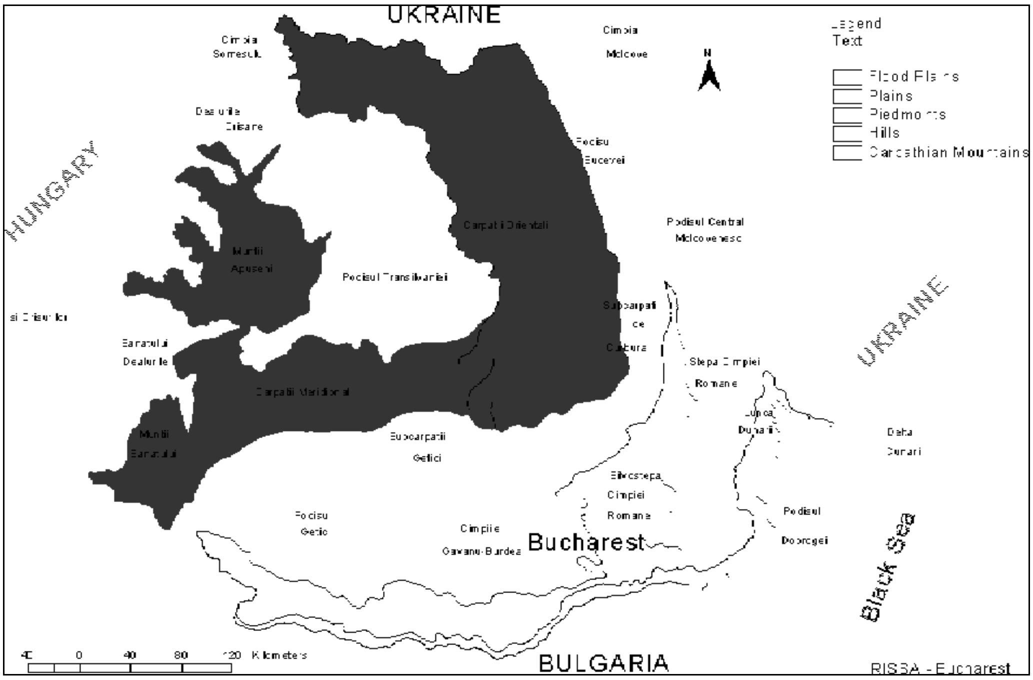

Figure 4: Ecoregions map of Romania

Pedogeoclimate

Pedogeoclimatic microzones (Florea *et al.*, 1989) are delineated on an agricultural use-oriented map at a scale 1:500,000 based on the general pedological, geomorphological, and climatic maps. It represents a relatively detailed regionalisation map in which the territory of Romania is divided into some 400 polygons (100 mapping units) (Figure 3).

The pedogeoclimatic microzones are used for regional and district applications relating to land use planning, environment protection and soil degradation inventory:

Agricultural ecosystems

The Agricultural ecosystems map (Teaci *et al.*, 1999) comprises a set of twenty one so called 'agro ecosystem units' separated on the basis of landforms, soils, climate and present-day land use. It was constructed to support the best agricultural management practices and to serve as a basis for technological transfer.

Ecoregions and Geosystems

The Ecoregions map (1994) at scale 1:1,000,000 represents the main ecological subdivisions (Figure 4) of Romania according to vegetation, landforms/lithology and soils. It has been designated as a tool for planning environment and biodiversity conservation measures at nationwide and regional level. Besides the above described maps in Romania, there is a wide range of other kinds of maps e.g. soil resources, soil evaluation, land capability, physical and technological, pedogeochemical, geotechnical, soil evolution, and soil vulnerability maps.

Of particular interest is the *geosystemic units map*. A geosystemic unit has been defined by Florea et al., (1996) as: 'a complex terrestrial formation which occupies a well defined area, within which different components (or subsystems) of nature, (or nature, population and economy) show specific systemic interrelationships and act as a single entity with the neighbouring geosystems and the outer-space'.

Concluding Remarks

The Romanian System of soil maps, correlative and/or interpretative maps, is developed sufficiently to respond to a large range of users. However, the different soil maps are not yet well correlated with each other, a problem that can only be solved by building an integrated national geographical soil information system.

Use of soil profile database

At the present time, the most frequently used part of the Soil Profile Database (PROFISOL) is that containing soil physical property data. These data have been used when preparing specific soil survey reports for land reclamation and engineering projects (Canarache and Dumitru, 1986), as well as in various research projects on changes in soil physical properties in long term field experiments (e.g. Canarache 1979; Dumitru *et al*., 1999). Available soil moisture properties are used in agro-meteorology (Apetroaie and Canarache, 1977).

A general review of the soil physical properties of the main soil types of the country, based on the PROFISOL database, has been included in a textbook on soil physics (Canarache, 1990a). Processing of the database has facilitated general estimations and general maps at a scale 1:1,500,000 (unpublished) on soil moisture properties (Canarache, 1970), draft resistance to ploughing (Canarache *et al*., 1981), soil compaction (Canarache *et al*., 1984), and suitability for various tillage systems (Canarache and Dumitru, 1991).

Currently, GIS is being used to process existing soil physical data for various uses. Application of an original simulation model and of the DSSAT procedure for a case study in southern Romania (scale 1:200,000) led to a comparison of the efficiency of different farming systems under the present socio-economic conditions in this country (Simota, 1998). Attributes referring to soil physical properties are introduced (Dumitru, 2000) in the existing 1:1,000,000 pedo-geoclimatic microzoning of Romania (Florea *et al*., 1989), and preliminary results were obtained, using appropriate pedotransfer functions, on estimation of soil compaction (Canarache *et al*., 2000a), workability and trafficability (Canarache and Dumitru, 2000b), and sensivity of soil to drought (Canarache, 2000c).

An expert system for land evaluation, ExET,(Vlad *et al*., 1997) has been developed. It uses data from the PC database of land units at 1:10,000 scale. The database of land units at 1:50,000 scale was used for different district or nationwide soil/land studies. The database for soil testing qualities is annually used by the Ministry of Agriculture Forests, Water and Environment, for nationwide decisions on fertiliser use and distribution.

The Romanian Soil Database System is well developed, though many of its components are not yet fully operational. To design an integrated and well-interrelated nationwide soil and land information system, without duplication of different subsystems, requires an interdisciplinary design team. Good modular structuring of a system/subsystem/application feature can facilitate the development process, and solve such problems as: utilisation requirements, development and distribution amongst different people, development team changes, etc.

The most important problem is that of updating the information content. With the exception of the soil monitoring database, both the soil maps and soil profile database (PROFISOL) are at least 15-20 years old and some information dates back to the 1960s.

Outlook

Towards the end of nearly a century of activity by the soil science community in Romania, an almost complete nationwide system exists of soil correlative, interpretative and special maps that embrace all fields of interests of agriculture, forestry and environment. In parallel, a Soil Monitoring System has been put in place and an integrated Soil Profile Database is nearing completion. The future of these activities is concerned with:

Table 4: System of interpretative and special maps (partly adapted from Florea, 1999)

Type	Content	Scale	Area of use
1. soil and land resources evaluation	- soil rating / soil suitability for different kinds of agriculture uses and crops, including orchard and vineyards - classes of potential production, and cadastre maps with soil quality of agricultural land - soil suitability for different forest species	- 1:10,000 (4,5 mil ha) of arable area - 1:50,000 of the whole agricultural area (14,5 mil. ha) - 1:5,000-1:10,000	soil resources management land taxation land price land use planning forest resources management
2. land capability	-grouping of soil and terrains depending on their capability for agricultural and forestry uses	- 1:200,000; 1:500,000 for some districts - 1:10,000; 1:50,000 locally	-land use -soil management
3. agro- ecological and ecological (geosystems, pedogeocli-matic microzones agroecosystems, ecoregions)	-grouping of soils and terrains according to ecological conditions	1:500,000; 1:1,000,000	- land use planning - rural development - environment protection
4. physical and agro-technological	-grouping of soils on their physical properties (e.g. texture, bulk density, compaction, water holding and available water capacity permeability etc) and their technological behaviour (e.g. resistance to ploughing)	- various, occasionally	-soil management
5.pedogeo-chemical	-heavy metal content in the upper horizons and throughout the soil profile	1:3,000,000	-soil management -soil protection against pollution
6. pedotechnical (geotechnical)	- grouping of soils according to their behaviour in the cases of other uses than agriculture and forestry: corrosivity of buried metallic implements, waste disposal, railways, high ways and buildings construction, etc.	- various, occasionally	-rural and urban development -industrial infrastructure development
7. restriction (including human induced degradation) maps	-geographic distribution and intensity of some limiting conditions (soil erosion, waterlogging, salinity, etc)	1:500,000 1:1,000,000	-soil management -land use planning
8. soil evolution	-grouping of soils according to the risk of degradation when used for agricultural purposes	Various	-soil management
9. soil vulnerability	-grouping of soils according to their capacity to hold different pollutants	1:3,000,000	-soil management -soil protection against pollution

1. Developing an operational and integrated Soil Geographical Information System at a scale of 1:200,000. At district (judet) and commune level, this system needs to be developed at scales of 1:50,000 and 1:10,000 respectively;
2. Updating the large scale mapping information about agricultural lands to satisfy the needs of data according to the present-day structure of land holdings in Romanian agriculture;
3. Improving soil survey methodology, both technically and conceptually, by introducing into soil mapping, remote sensing, GPS, informatics and other modern techniques and by strengthening ecological and socio-economical aspects in soil survey activities and interpretations.

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The Status of Soil Surveys in Serbia and Montenegro

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Introduction

Classification and cartography in Serbia has passed through different phases of development. Most of the research was performed in the period 1965-1970. The territory of West and North-west Serbia, a part of the drainage basins of the rivers Velika Morava and Mlava, Vojvodina and a part of East Serbia were mapped at scale 1:50,000. There are no reliable data from that period all relating to the precise definition of individual classification units based on the chemical indicators (e.g. adsorption complex of the soil, etc.). After 1972, the research was continued based on the Ohrid (1963 and 1971) and Belgrade (1972) agreements which identified the fundamentals of the methodology for the design of the soil map of Yugoslavia at 1:50,000 scale.

Soon after this, the framework classification of soils in Yugoslavia was proposed (Skoric et al., 1973), based either partially or entirely on the concepts valid at that time in Europe (Dudal *et al.*, 1966; Dudal, 1968); Muckenhausen, 1962). Based on the above classification, during the period from the late 1970s to mid 1980s, the cartography of soils in Yugoslavia was intensively conducted. In Serbia in 1983, the financing of this project was stopped, so that even today there are about 700,000ha of unmapped soils (region of South Serbia, borders of the boundary with Macedonia, Bulgaria and Kosovo).

Also, during the 1970s the soil map of Kosovo and Metohija at a scale of 1:50,000 was completed (1974), although it had very little in common with the nomenclature and taxonomic units defined by the soil classification in 1973. During 1999-2000, the 1:50,000 scale soil map of Monte Negro was completed, based on the classification of 1985.

Table 1 presents the data on the main soil types in Serbia with the areas, and intensity observations (see Figure 1, Soil map of Serbia and Monte Negro and Figure 2, Drainage, infiltration and other properties of the soils of the Danube Basin in Serbia and Monte Negro). The data are based on the analysis of the actual cartographic material, complemented by data from other sources.

In order to facilitate international communication and development of the national system of soil classification in Yugoslavia, the Classification of Soils in Yugoslavia by Skoric *et al.* (1985). Unfortunately, this classification was applied in Serbia only sporadically, because the practice of soil cartography had ceased.

Instead of soil cartography, another project, ‘Control of fertility and determination of the contents of dangerous and harmful substances in the soils of the Republic of Serbia’, was undertaken. This research has now been completed on about 3.2 million ha and involves pesticides, heavy metals and microbiological activity.

Development of the large scale soil surveys

The outline of the methodology for the production of physical plan documents was finished by mid-1996 (Antonovic *et al.*, 1997), together with a number of Instructions and Manuals for the construction and maintenance of the Base Plan for agricultural land protection, regulation and use. The plan was designed for the municipalities at 1:25,000 scale, but the concept of the Base Plan can be extended to the farm level (see Chapter V Data Model Flow Chart of the IS).

The Methodology and the Information System begin with the concept of open systems whereby individual problems, e.g. soil conservation, are considered within the scope of the conditions and processes in the natural and socio-economic environments.

The Methodology also contains the document 'Regulation of the Base Plan for Agricultural Land Protection, Regulation and Utilisation', which determines in more detail the content and procedure of passing, verification and monitoring of the Base Plan documents.

Table 1: Main soil types (ha) and main limitations to use

Soil type	Area in h	Restrictions (Intensity and type)
Lithosol	107.000	Unproductive soil
Aeolian sands (Arenosol)	86,000	Severe restrictions due to excessive filtration; poor to medium productive soil
Rendzinas	~ 527,000	Severe to medium restrictions
Black earth on limestone (Calcomelanosol)	~ 155,000	Severe restrictions
Humus-siliceous soil (Ranker)	572,000	Severe restrictions
Chernozem (Phaeozem)	1,200,000	Without restrictions
Smonitza (Vertisol)	780,000	Moderate restrictions
Brown soil on limestone (Calcocambisol)	~ 350,000	Severe to medium restrictions
Eutric brown, typical- brown forest soil- (Eutric Cambisol)	560,000	Moderate restrictions
Dystric brown (Dystric Cambisol)	~ 2,280,000	Severe to very severe restrictions
Illimerised soil (Luvisol)	~510,000	Moderate to medium restrictions
Pseudogley (Planosol)	538,000	Moderate to Severe restrictions-conditionally productive soil
Podzol	~ 17,000	Severe to very severe restrictions
Alluvial soil (Fluvisol) Meadow soil (Humofluvisol) Hydromorphic black earth and Marsh-gley (Humogley, Eugley)	~ 760,000	No restrictions to serious restrictions-conditionally can be highly productive soils
Solonchak and Solonetz	233,000	Severe restrictions
Peaty soil (Histosol)	~ 3,000	Moderate to Severe restrictions
Deposol	~ 50,000	Moderate to severe restrictions (unproductive soil)

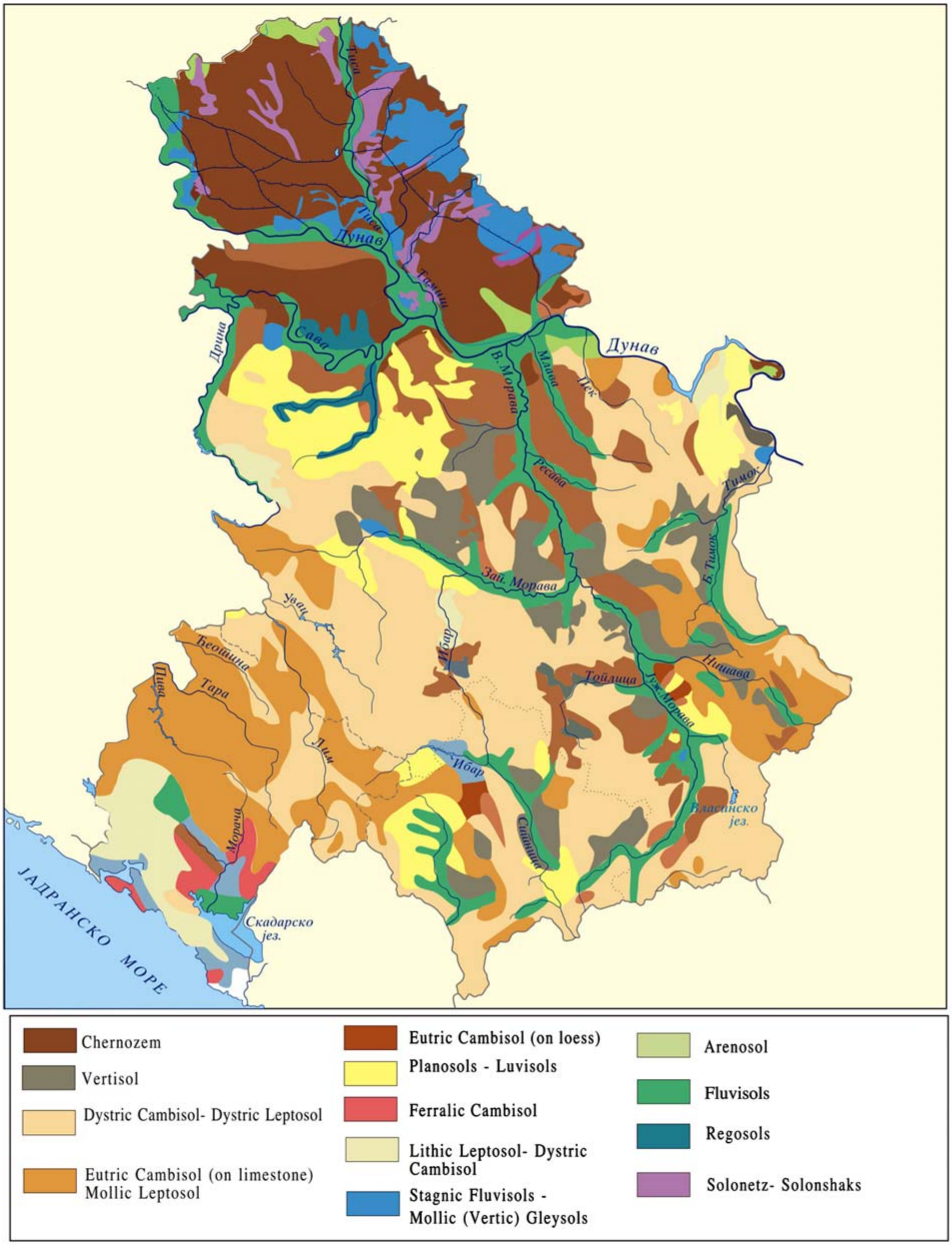

Figure 1: Soil map of Serbia and Monte Negro

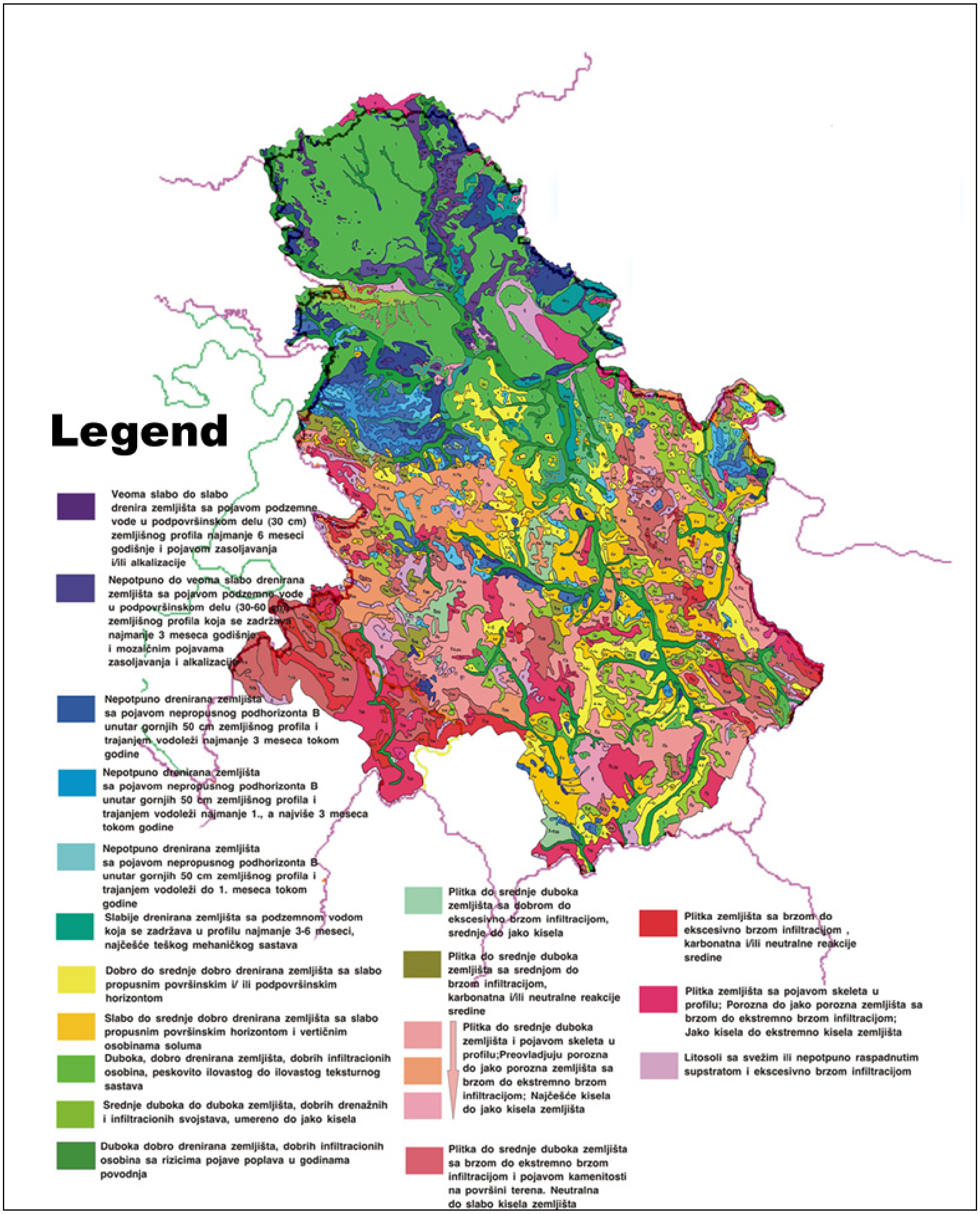

Figure 2: Drainage, infiltration and other properties of the soils of the Danube Basin in Serbia and Monte Negro

Structure and Content of Base Plan Documents

The Base Plan consists of several documents regulating the important issues relating to the integral system of land management in Serbia. The 'Regulation of the Base Plan for Agricultural Land Protection, Regulation and Utilisation' consists of the following:

- Contents of the Base Plan;
- Necessary data on the creation of the Base Plan;
- Optimal set of information sufficient for the description of agricultural land;
- Instructions for Base Plan;
- Information system on agricultural land protection, regulation and utilisation (IS);
- Procedure of construction, verification and adoption of the Base Plan;
- Monitoring of the development of the Base Plan;
- Monitoring and execution of the changes of agricultural land.

The first five articles of the document are:

1. Contents of the Base Plan

The Contents of the Base Plan section provides details of the structure of the documents of the Base Plan and prescribes the rules that must be adhered to during its use.

2. Necessary data

The necessary data for producing the land management Base Plan consist of:

2.1 Soil data;
2.2 Horizon data;
2.3 Soil sample;
2.4 Water sample;
2.5 Air sample;
2.6 Plant sample;
2.7 Data concerning the cadastre at the community level;
2.8 Data concerning the cadastre at the parcel level;
2.9 Geology (Landform);
2.10 Geomorphology ;
2.11 Hydrogeographical data;
2.12 Climate data;
2.13 Vegetation ;
2.14 Geodetic data.

The data from 2.1 to 2.8 are given in tabular form, the data from 2.9 to 2.13 are in the form of thematic maps and the data in item 2.14 are in the form of digitised geodetic maps.

3. Optimal assembly of information

The optimal information for the description of agricultural land includes the following characteristics:

3.1 Geology;
3.2 Landform;
3.3 Hydrogeography
3.4 Climate;
3.5 Vegetation;
3.6 Soil;
3.7 Water;
3.8 Erosion;
3.9 Pollution;
3.10 Land (soil) protection;
3.11 Land management;
3.12 Land utilisation;
3.13 Land (soil) value;
3.14 Territorial units.

The characteristics from 3.1 to 3.14 are given in the form of thematic maps and the information in item 3.14 is in tabular form.

The following documents must also be provided:

3.15 Proposal of activity plan;
3.16 Appraisal of financial need;
3.17 Source of financial resources;
3.18 Expected effect;
3.19 Evaluation of the economic efficiency.

The detailed contents of the optimal assembly of information are given separately in the Methodology for the Design of Foundations for Agricultural Base Plan.

4. Agricultural Base Plan

The instructions are an integral part of the foundation of the agricultural Base Plan, describing the procedures for the production of some parts of the Plan. The total number of instructions is 25. They can be divided into Instructions for providing the data (11) and Instructions for forming the characteristics of the particular land characteristics, its conservation, management, utilisation, evaluation, etc. (14).

5. Information System

The information system is created to collect, store, analyse and present the information on agricultural land.

I. Basic functions of the Information System

The Information System (IS) includes several important functions, such as:

5.1 General support for management, especially:
5.1.1 Define and maintain the regulation and standard of management;
5.1.2 Create and maintain the data about the land.

The general support for management includes the legislative and scientific and technical support. Another function of the IS is to:

5.2 Create and maintain the data on land, especially that of geology, landform, hydrology, vegetation, soil, microbiology, erosion and pollution characteristics.

In addition to area characteristics, land can be described by the characteristics of terrestrial units, such as: location, demography, livestock, agricultural machines, regulation measures, crop production and the characteristics of vegetation condition.

The Information system also supports the following functions:

Land protection function, through the evaluation of hazard, protection and monitoring.

Land regulation function, through the following functions:

- Land consolidation reducing erosion risk;
- Soil drainage, irrigation;
- Improvement of physical characteristics of soil;
- Improvement of chemical characteristics of soil;
- Improvement of biological characteristics of soil;
- Technical and biological recultivation of soil;
- Technical regulation of the terrain;
- Conversion of non-cultivated into cultivated soil.

The sub-functions of land regulation are as follows:

- Evaluation of suitability of land regulation;
- Land regulation planning;
- Monitoring the effects of land regulation.

Land use function, through the following functions:

- Evaluation of suitability for crop production using land use data;
- Crop production planning;
- Monitoring crop production through space - time and transfer functions.

II Model processing of the IS

The IS enables description of the system functions through systems analysis. Systems analysis is based on the concept of a connection between internal and external parts of the system. Furthermore, systems analysis starts from the concept that the whole system can be described using only elemental operations or sequences, followed by their selection and iteration. Systems analysis describes the logic and structure of data flow in the system.

III Data flow chart of the IS

The IS also provides the data flow chart, based on the principle ‘who from’ and ‘towards what’.

The flow charts describe separately the problems of land management, land protection, land regulation, land utilisation, creation and distribution of information, geodetic-cadastral and cartographic support.

IV Data Model of the IS (the Object - linkage model)

The model used in IS of Land Space in Serbia is Entity - Relationship - Attribute (ERA) model. The structure of the ERA model is as follows:

- Object (entity)- Relationship- Object attribute or linkage value.

In addition to the above well-known concept, the following new concept is also introduced:

- Type of weak entity which depends on another entity or another weak entity;
- Type of existential entity, as a type completely dependent on another entity;

- Type of identification dependent entity which cannot be identified with its own attribute, but the attribute of another entity is used;
- Type of existential and identification dependent entity, as a mixed dependent entity;
- Type of preceding entity, when entity is time dependent on another entity;
- Type of mixed entity - relationship entity, which is used in situations when it is necessary to realise the relationship in who participates and also other relationships. This entity is especially favourable in the aggregation of entities.

V Data Model Flow Chart of the IS

This part of IS describes the relationship between the objects. Objects are classified according to type and class into:

- Dotted (punctual) objects;
- Line objects;
- Surface objects;
- Group of characteristics as a part of joined object characteristics.

In this way the procedure of making the space discrete is carried out and the characteristics are attributed. These are the sizes:

- 25km^2 5,000m x 5,000m;
- 1km^2 1,000m x 1,000m;
- 1ha 100m x 100m;
- 1 are 10m x 10m;
- 1m^2 1m x 1m.

VI Model Resource of the IS

The IS model consists of the following elements and principles:

- Architecture of IS;
- Database of IS;
- Model of data processing;
- Model of system openness;
- Hardware;
- Software or program support system;
- Personnel and organisation support system.

The software or program support system is based on the following operating systems:

- WINDOWS XP;
- UNIX.

The following operating system is proposed for the workstation:

- WINDOWS XP-PROF.ED.;
- UNIX.

The following relational system for general purposes is proposed:

- ORACLE;
- DB 2;
- SQL Server;
- SYBASE.

For the management of spatial data, the following are proposed:

- ARC INFO;
- INTEGRAPH;
- MAPINFO;
- R-MAPPER.

VII Implementation, development & finance

These issues are fundamental to setting up the IS.

Soil maps at medium and small scale

Since 1985, the future of soil research and development has been discussed in the light of protection of land and its management. The most significant results in soil classification were the adoption of the new concepts of international classification: Keys to Soil Taxonomy, Soil Survey Staff, 1998; World Reference Base for Soil Resources (WRB), 1998; and Global and National Soils and Terrain Digital Databases (SOTER), 1995, Nachtergaele, *et al.*, (2000). A new classification of soils in Yugoslavia was proposed (Antonovic and Protic, 1997; Antonovic and Protic, 1998).

Taking into account the degree of development of SISLC (Information System on Land Cover of Serbia), construction of middle and small scale soil maps has focused on harmonisation of the database type and structure, as well as on the objectives presented in the Manual of Procedures, Version 1, Georeferenced Soil Database for Europe, (ESB. 1998, 2000).

1. A preliminary phase of basic document consultation, such as: the soil region map at scale 1:5,000,000, topographic, geological, forest and vegetation maps, DEM, aerial photographs and satellite data (SPOT, Landsat). These documents allow the establishment of a

pre-zoning of the area in different pedolandscapes;

2. Generation of soil and other thematic maps using DEM (1x1km, gtopo30, Figure 3 and Figure 4) and AVHRR satellite images (1.1km x 1.1km), with geostatistical control of the maps of the wider area of Serbia and Monte Negro. This includes the extrapolation of the values of a parameter in one area to discrete spatial units with unknown values of the same parameter in another area. Accordingly, the initial phase includes elaboration of the method and combination with a field survey to define and delineate soilscapes.

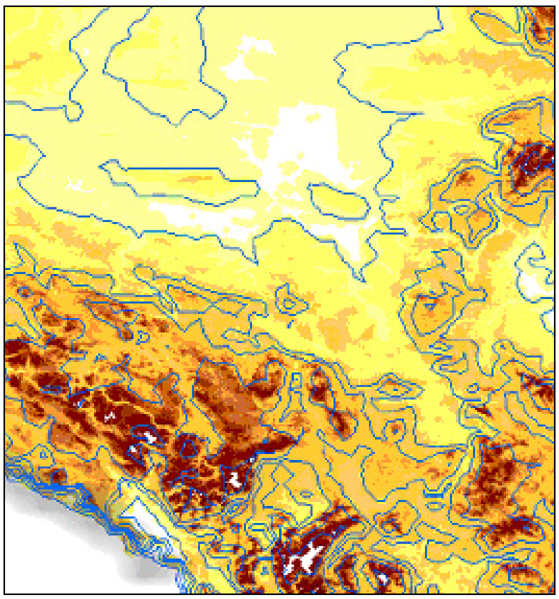

Figure 3: GTOPO30 DEM (1kmx1km)
[NASA, USGS Data Center,
Distributed Active Archive Center]

3. A phase of systematic survey (not soil mapping per se) with surface observations and borings in order to improve the delineation and definition of soilscapes and to investigate the soil bodies that occur in a soilscape; This phase and the following phases have not been realised in Serbia.
4. A phase of information acquisition to characterise soil bodies. In this phase, soil profiles (which are to be acquired) will be sampled to a depth of at least 1.50m or to a lithic contact if shallower.

To achieve this, the Institute of Soil Science in Belgrade has designed two special types of software in Windows.

1. The first software, Region EXTR v 2.1, automatically extracts data from the basic matrix with the given co-ordinate values of the samples in the grid (DEM or AVHRR data model). This program extension enables important functions in the data manipulation, i.e. in the analysis of land parts, to be achieved.
2. The other software, Program RastDEM v 1.8, is intended for the assessment of the value of DEM data for the given co-ordinates, based on the set of known DEM values for the given co-ordinates. The main application of the program is to reduce the sets of different types of soil data, which in general correspond to different sets of co-ordinates, to the values that correspond to one set of co-ordinates.

Figure 5 presents the program Region EXTR v2.1, and Figure 6 is the program RastDEM v 1.8. Figure 7 presents an example of the common set of co-ordinates with the conversion of DEM model into 1.1km x 1.1km resolution of the basic data model (AVHRR, i.e. in this case, NDVI values for the ten day period 20/30 April 1992).

A spatial organisation model is built with the objects horizon, soil body, soilscape and soil region. Since the way of georeferencing differs for each of these components, the database contains three types of tables:

(i.) Tables describing the spatial relations between soil regions, soilscapes, soil bodies and horizons (topological dataset).
(ii.) Tables describing the properties of horizons, soil bodies, soilscapes and soil regions (semantic dataset). Tables describing the geometry of soilscapes and soil regions (geometric dataset).

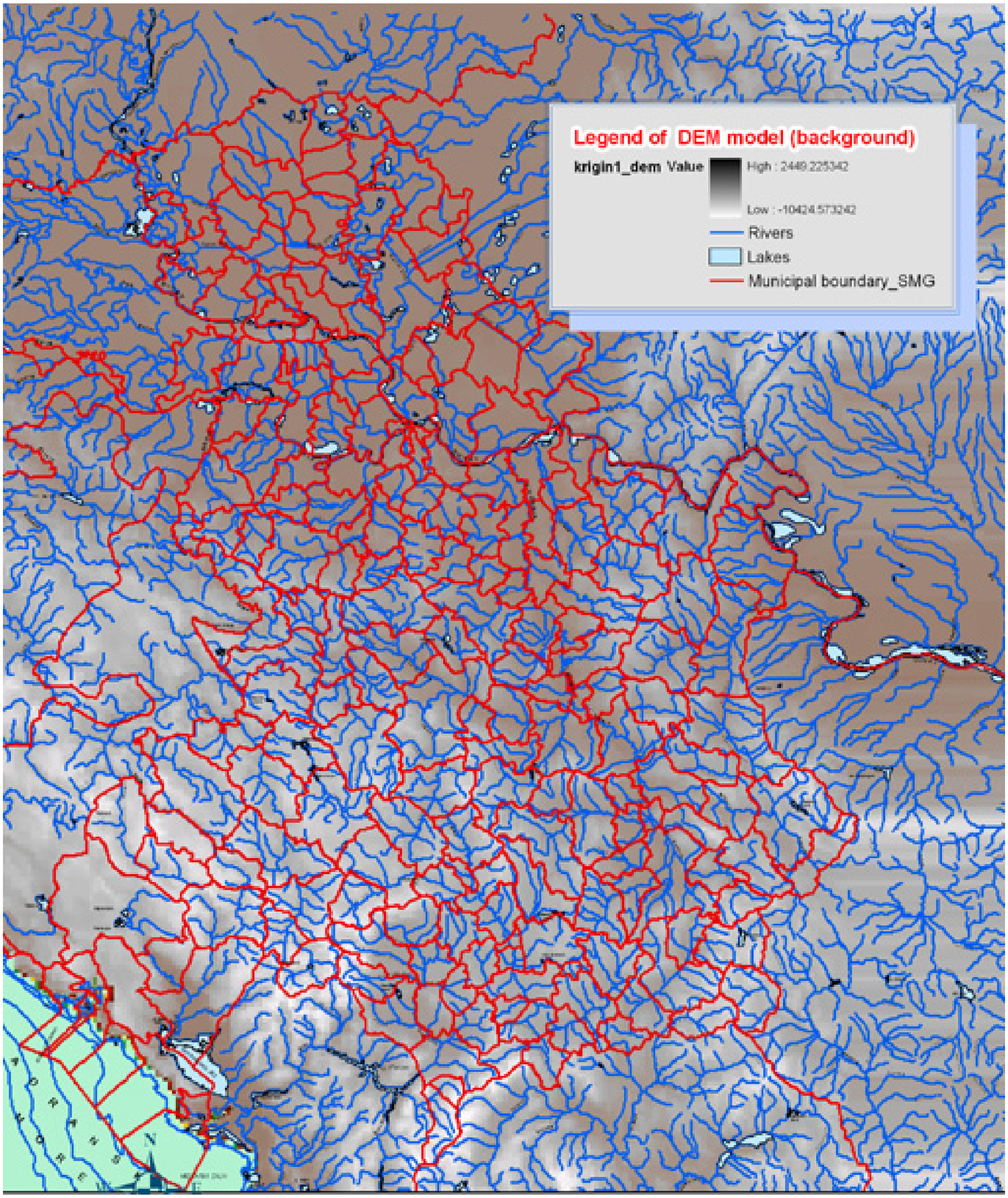

Figure 4: DEM (Digital model of the terrain) for the region of Serbia and Monte Negro+Country and Municipality boundaries+Hydrography

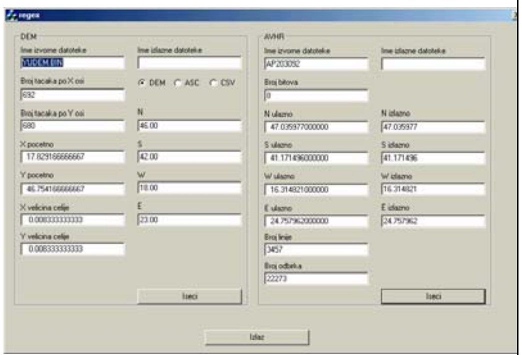

Figure 5: Program Region EXTR v2.1

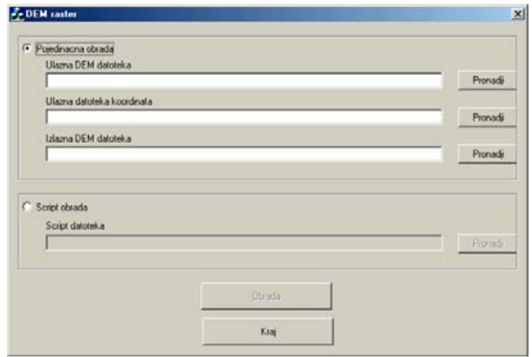

Figure 6: Program RastDEM v 1.8

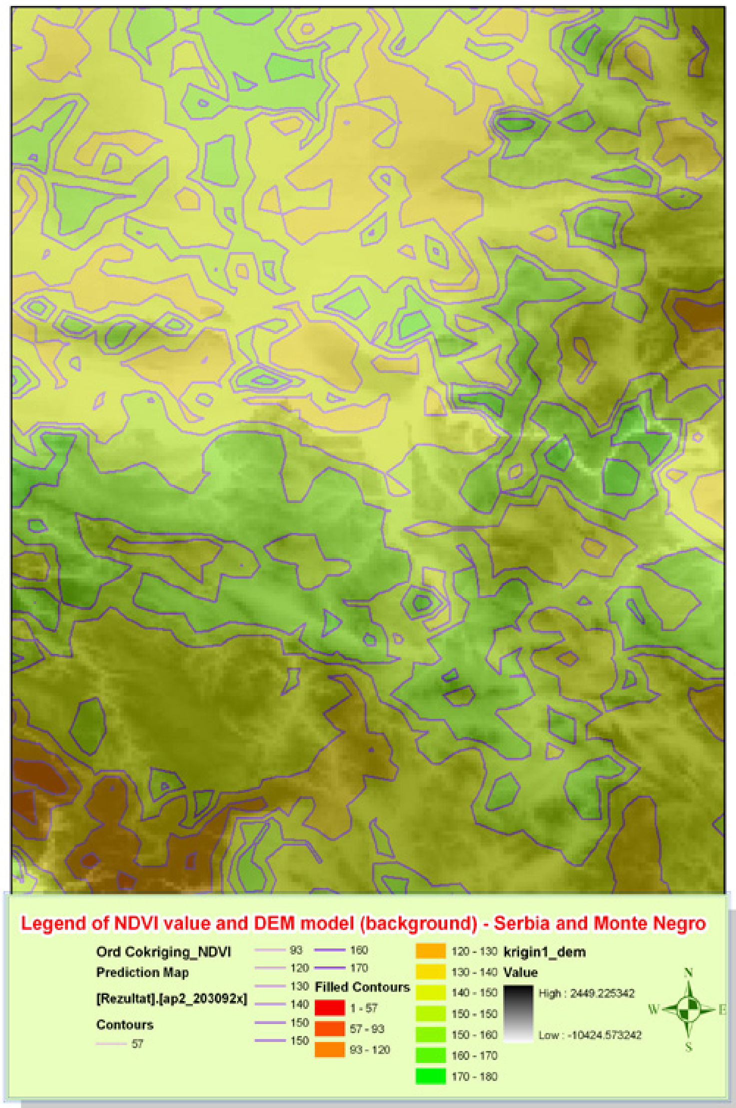

Figure 7: DEM + Normalised Difference Vegetation Index- NDVI (April-20/30-1992), EOS Land Processes Distributed Active Archive Center (LPDAAC)

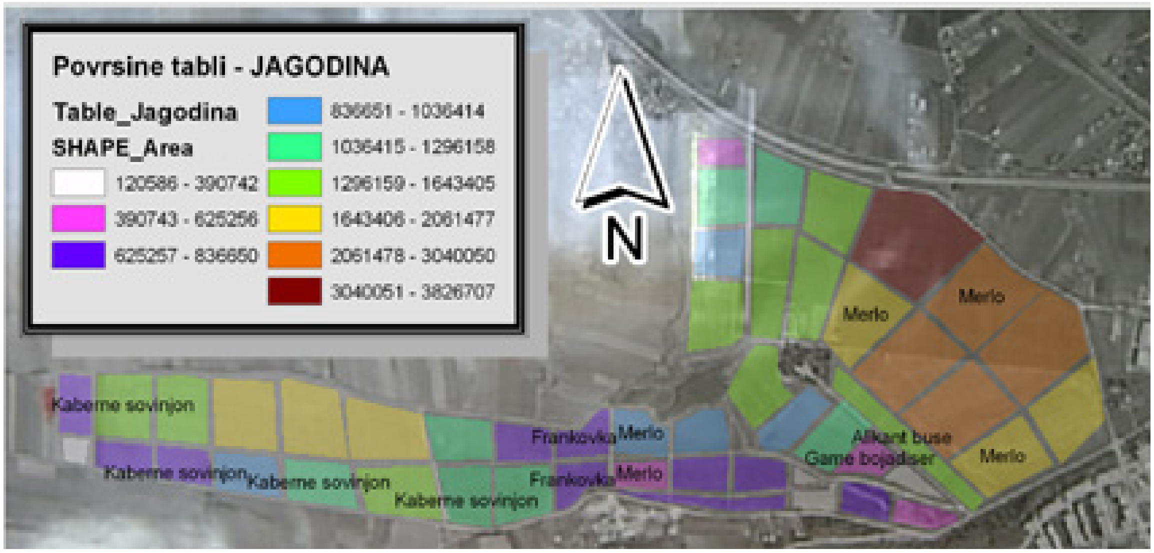

Figure 8: Arc table of the vineyard near Jagodina, Serbia

In Serbia, along with the work on the new soil classification, there was also research that contributed to the methodological aspects of the analysis of spatial components (Protic and Protic, 1990; Protic. and Protic, 1998; Protic and Antonovic, 2001), similar to those reported by (Bell *et al.,* 1992; Bourennane *et al.*, 1996; Budiman *et al.,* 1999; Burrough *et al.,* 1971; Burrough, 1989; De Gruijter, 1977; De Gruijter and McBratney, 1988; Dobos *et al.*, 1999; Goovaerts, 1992; Groenigen van, 2000. Huggett, 1975; Ibanez and De Alba,., 2000; Lagacherie, *et al.*, 1995; Lagacherie and Voltz, 2000; Lark, 2000a; Lark, 2000b. McBratney and De Gruijter, 1992; McBratney, 1998; Odeh, *et al.*, 1991, 1994, 1995).

Soil inventory and monitoring

In the past ten years the study of heavy metal concentrations in soils has been intensified. According to the European Soil Bureau (Bullock, *et al.*,1999; King and Thomasson, 1996), several EU and EFTA countries have study programmes of heavy metals in soils, e.g.: Austria, France, Germany, Ireland, the Netherlands, Sweden and Great Britain. Heavy metals in soils are also studied in Hungary, Poland, Czech Republic and Slovakia. In parallel with the assessment of heavy metal concentrations in soils, significant research focuses on the risks for plant production and/or effects on animals and humans (Muller, 1997).

Unlike in previous papers (Adriano, 1986; Chlopeck *et al.*, 1996; Jakovljevic *et al.*, 1997; Kabata-Pendias, 1984, 1993; McGrath and Loveland, 1992), the problem of heavy metals is now being treated increasingly in the framework of Information systems. Models of soil suitability assessment are increasingly being applied for different purposes, e.g. soil susceptibility to erosion (thereby leading to diffuse pollution), contamination and acidification; combining the results from these models with spatial soil data aloows the construction of thematic maps (Blum *et al.*, 1999; Proctor *et al.*, 1998; Finke *et al.*, 1998; Stuczynski *et al.*, 1998). Compared to the previously, the main difference is that heavy metal threat is regarded as a continuous system in space and time.

In Serbia, the study of heavy metals in the soils started in a significant way in early 1992. During the project‘, financed by the Republic Fund for the Protection, Utilisation, Enhancement and Management of Agricultural Soils in Serbia and the Ministry of Agriculture and Water Management, in only two years of research, soils of 869,000ha in the northern part of central Serbia were sampled and analysed.

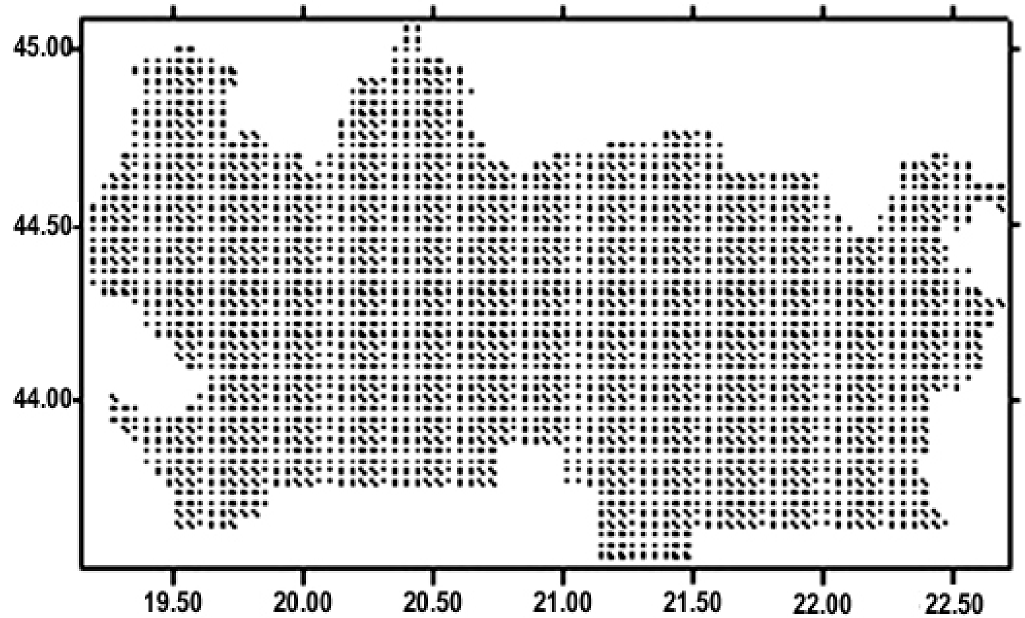

Figure 9: The Grid of soil sampling (Phase V of Project, 2003)

During 2002 another 500 localities (phase III) in, 500,000ha, were sampled and analysed. Phase IV (400,000ha) and phase V (500,000ha) of the macro project are ongoing., The study will then have covered a total of 2.6 million ha in central Serbia (Figure 9). Overall, this inventory has been completed on about 4.2 million ha. The research was performed in the early nineties in Vojvodina, but unfortunately heavy metal determination was done using hydrochloric acid, so that the comparisons are not possible with later results.

This quantifies the condition of soils in Serbia, (Mojasevic *et al.*, 1999; Mojasevic *et al.*, 2003; Protic *et al.*, 1997; Protic *et al.*, 1997; Protic *et al.*, 1997; Protic *et al.*, 1998; Protic *et al.*, 1999; Protic *et al.*, 2002).

Soil sampling

The soil was sampled to a depth of 0-25cm in the grid of 1,000ha (10km^2).

Laboratory methods

The parameters of soil fertility were determined by the following methods:

- pH in H_2O and nKCl - electrometric method;
- $CaCO_3$% - volumetric method;
  - Humus % - Kotzman method;
- Phosphorus (P_2O_5)- Al method;
- Potassium (K_2O) - Al method.

The following analyses were made to assess the biogenic content of the soil:

- Total number of micro-organisms, on the agar soil extract (thinning method, Pochon, 1954);
- Total number of fungi, on the Capek medium , thinning method;
- Total number of actinomycetes, thinning method on Krasiljnikov medium;
- Ammonifiers, by using solid and liquid nutritive media;
- Free nitrogen fixers: *Azotobacter spp*, method with silicogel, Ashby substrate, method of spontaneous culture and Tchan's method;
- Dehydrogenation activity: spectrophotometric method after Lenhard, modified after Talman (1968).

Soil samples were analysed for heavy metals and trace elements. The contents of ten elements were measured:

- Cadmium (Cd), chromium (Cr), nickel (Ni), copper (Cu), lead (Pb) and zinc (Zn) were determined by extraction with HNO_3 + H_2O_2 on AAS (Atomic Newsletter, Vol. 15, No. 3, 1976).
- Fluorine (F) - by extraction with 1M HCL, with 1M sodium sulphate and 0.2 EDTA, and

reading by ion-selective electrode, method (Kruffel and Egger Co., 20 Whippang Rd., Moristown, N.J. 07960, USA).

- Mercury (Hg) and arsenic (As) - by extraction with $HNO_3 + H_2O_2$, reading on AAS, by the technique of cold vapours (Atomic Newsletter, Vol. 15, No. 3, 1976).
- Boron (B) was determined colorimetrically with curcumine after extraction with hot water (ratio 1:2).

Pesticides and other organic pollutants were determined by supercritical extraction (SFE) HP7680A, with the corresponding computer and program support. The extraction was by CO_2 in the supercritical state, modified by absolute methanol 5%MeOH and CO_2. Soil extracts were chromatographed in two ways: by electron capture detector for the detection of organochlorine pesticides and by nitrogen and phosphorus detector for the detection of nitrogen and phosphorus compounds (triazine herbicides and organo-phosphorus insecticides).

The phases of the project include the determination of the residues of 18 pesticides in the soil (4.4 DDD, 4.4 DDE, 4.4 DDT, Aldrin, αHCH, βHCH, γHCH, lindane, diazinon, dieldrin, endrin, heptachlor, heptachlor epoxide, alchlor, atrazine (see Figure 12), prometrin, simazine, terbutrin).

The Project Results

The results of the study of soil fertility indicators on 1,377,000ha (phases I-III), within the scope determined by the samples in a grid $10km^2$ (1,000ha) shows that the classes of nutrient supply are formed around different values of centroids, as follows: the first class (centroid) are the soil samples (entities) with $CaCO_3$ content about the value of 0.16%, humus about 5.37%, K_2O about 25.74mg/100g soil, P_2O_5 7.32mg/100g soil and pH_{KCl} about 5.3. The number of entities (count) at the same time denotes the area of a class in 1,000ha, Figure 10.

Based on the study of the soils in Serbia (the first three Phases of the Project) and the available knowledge of hazardous and harmful substances it can be concluded that food production can be performed without risk on approximately 80% of the analysed area of Serbia, (Figure 11). On the remaining 20% of the area, it is necessary to organise food production to reduce the risk (e.g. by crop selection) and/or by occasional to continuous control of soil and plant quality.

The research of microbiological properties confirms the previous conclusions that individual parameters show a very irregular distribution within the analysed datasets. It was found that the abundance of fungi is far more stable in the soils than the dehydrogenase activity. Considering the relation of dehydrogenase activity and individual classes and the normal distribution for the values of dehydrogenase, it can be concluded that the soils on serpentine represent a particularly different ecological-edaphic environmentcompared to other soils of the study area.

During Phase III, the analysis covered the presence of pesticides, which by their persistence or current application are significant contaminators of the soil.

In the analysis of the residues of 18 pesticides in the soils, there were no unexpected findings. The occurrence of DDT and its metabolites and Lindane g HCH is related to their use in forest protection, while somewhat higher values of the residues of triazine active substances were detected in the soils used for arable crop production.

Conclusion

The current state of cartographic research in Serbia is hampered by:

- Results of soil analysis methodologies which do not correspond to FAO and WRB criteria;
- Lack of uniformity of the published cartographic material;
- Differences in the taxonomic classification of the soil;
- Different criteria applied in individual periods of work on soil cartography in the definition of the structure of the classification system, etc.

Therefore it can be concluded that the existing information base needs updating and the classification and cartographic units should be identified based on the accepted methodologies and standards, especially in the construction of medium and small scale soil maps.

The development of large-scale soil surveys together with the Soil Information System should be supported as the basis for the introduction of the system of decision making and land management in Serbia, first of all at the municipality level, but also at farm level. More than 90% of the territory in Serbia is now owned by peasants in private holdings.

The Macroproject of the Republic of Serbia 'Control of soil fertility and the assessment of the content of harmful and hazardous substances in the soils of the Republic of Serbia' will be completed during the next two years. This will facilitate planning and macro spatial analysis, both in the optimisation of production of high quality food, and at the level of risk assessment. In addition, measures should also be undertaken to reduce soil degradation to the level of sustainability.

Acknowledgement

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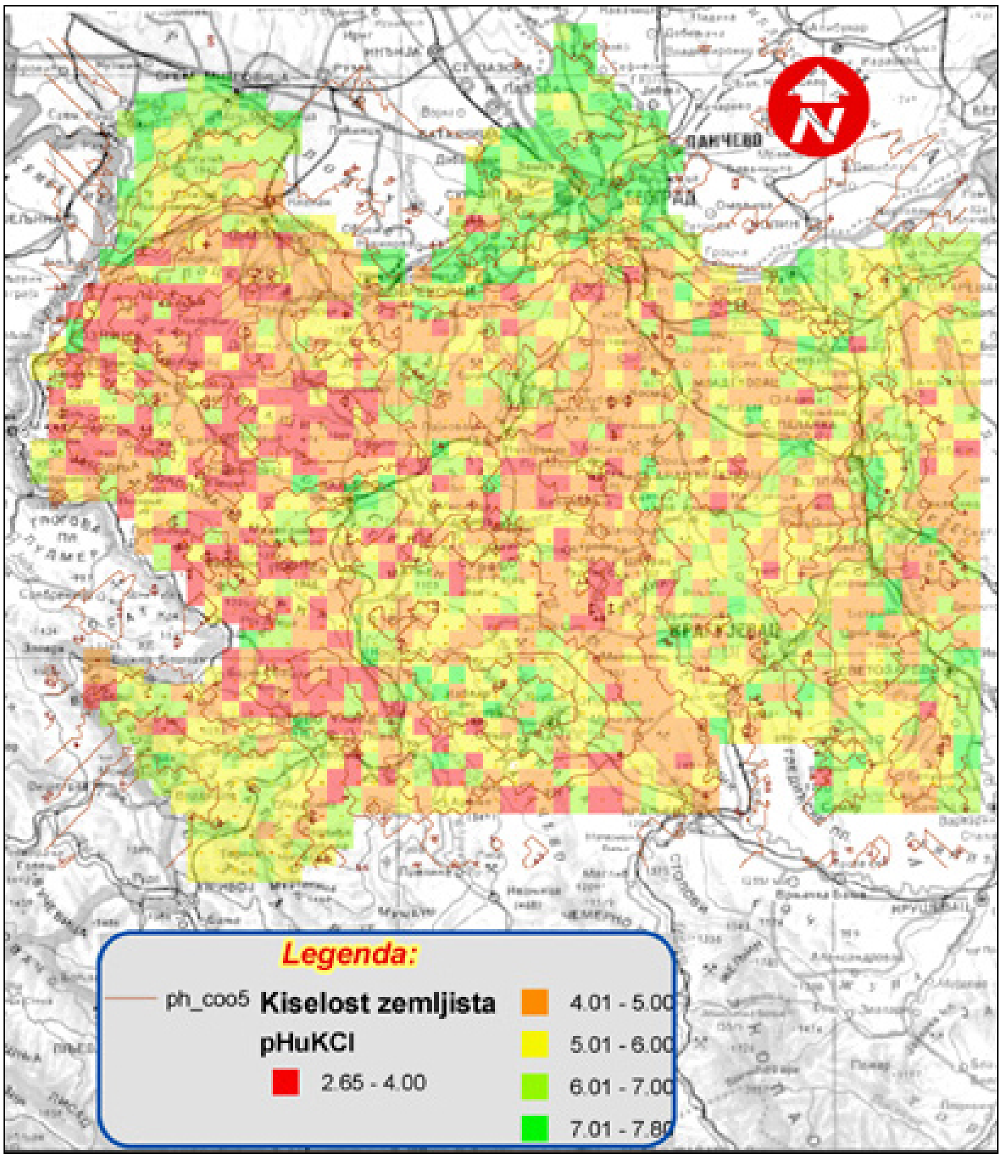

Figure 10: Raster map of soil pH_{KCl} in central Serbia after phase IV of the Project

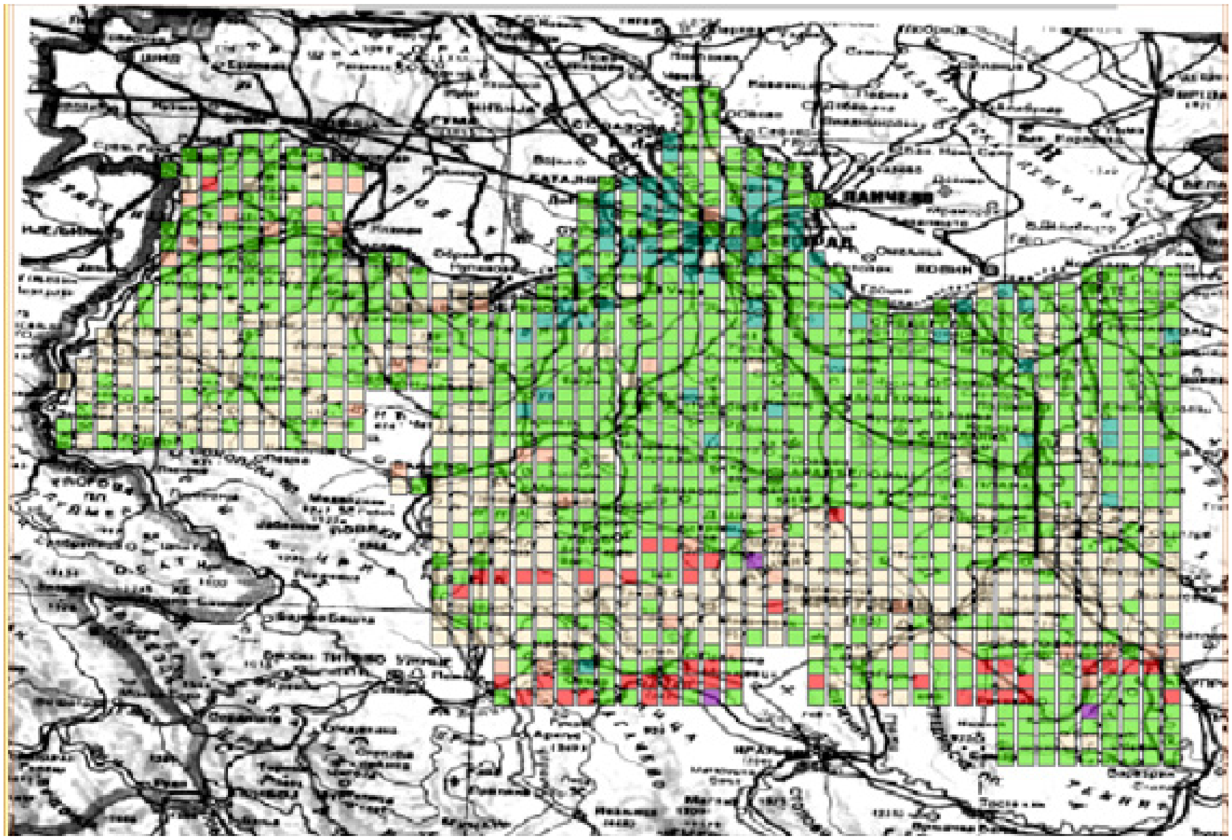

Figure 11: Classes (6) of heavy metals separated by aggregation by K-means procedure

Variables	Cluster Means				
	Clust 1	**Clust 2**	**Clust 3**	**Clust 4**	**Clust 5**
pH_{KCl}	5.36	4.58	6.64	6.24	7
humus	5.52	2.66	2.96	3.27	3.39
P_2O_5	7.566	4.20	10.45	31.09	12.25
K_20	26.12	17.98	22.48	36.95	30.39
$CaCO_3$	0.236	0.070	1.891	0.794	21.55
Count	**209**	**633**	**306**	**215**	**14**

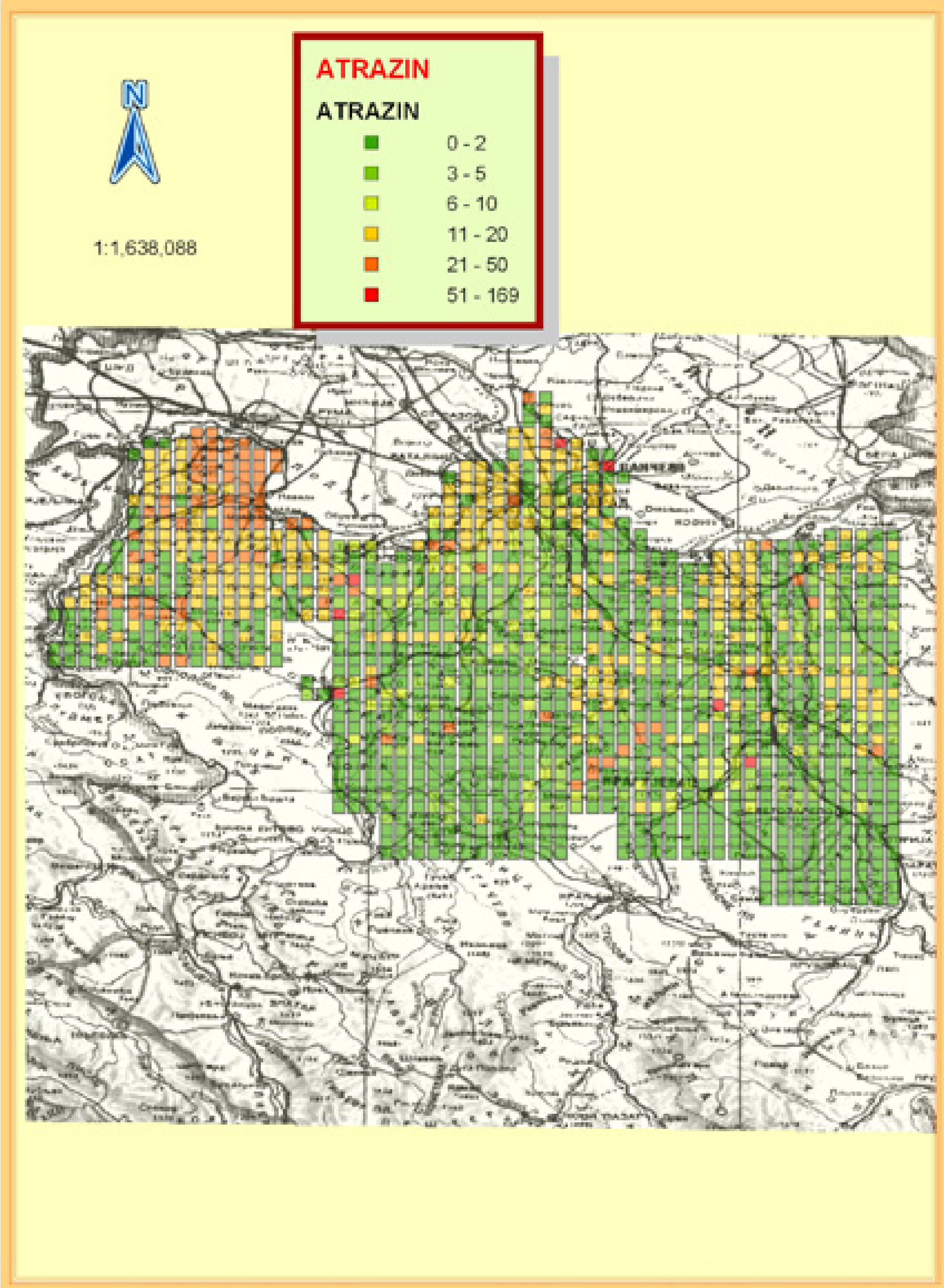

Figure 12: Raster map of the residues of atrazine in the soils of central Serbia, after Phase III of the Project

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Soil Survey and Managing of Soil Data in Slovakia

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Introduction

During the last decades the quality of the environment has become an increasingly important issue, especially in industrialised countries. It is important, therefore, to assess the influence of human activity (especially industry, agriculture, etc.) on the quality of the main components of the environment.

Long-term continuing wasteful exploitation of natural resources, extensive pollution of the air, water, and soil have influenced all aspects of environment also in Slovakia, although not as severely as in some other countries. To understand all these problems and to find solutions, much research needs to be done. One of the basic tasks is to establish the permanent monitoring of environmental changes, especially in the soil.

Slovakia has accepted the Recommendation of the European Committee (EC) n. RENV (90) 1 on European strategy in environmental conservation (1990), whereby EU Member States are recommended to establish permanent monitoring of all the components of their environments.

Soil Information System

The Soil Information System is based on information obtained from research directly on the land or after sampling and laboratory analysis.

The Soil Science Information System, elaborated and permanently updated by the Soil Science and Conservation Research Institute, includes immense data holdings on soil and associated components of the environment. During the last 15-20 years, there has been gradual linkage of the soil science information system with the systems of the other institutions (e.g. Research Institute of Agriculture and Food Economics, Immovable Register).

The foundation of the modern information system - including Geographical Information Systems (GIS) - in the Institute is already in place in the form of ARC/INFO workstations running under UNIX, with PC ARC/INFO and ARC/View also on-line. These platforms are the basis for running the GIS applications necessary for earth surface analyses, ecological studies and modelling.

Soil Mapping

The whole of Slovakia has been surveyed and mapped. The first Soil Map of Slovakia was published in 1973 at scale 1:500,000. The second edition of the soil map (at scale 1:400,000) was published and digitised in 1993.

Digitised map set

- Soil map of Slovakia, scale 1:400,000;
- Evaluation of soil-ecological unit (SEU) maps, scale 1:5,000 (10,000 sheets);
- Žitný ostrov soil map, scale 1:100,000;

- The map of soil properties of the Žitný ostrov, scale 1:50,000;
- Soil maps of Slovakian regions (1:5,000);
- Farming land of Slovakia evaluation map, scale 1:50,000;
- Map of soil erosion (by both water and wind) of Slovakia, scale 1:500,000;
- Water courses of Slovakia, map at scale 1:500,000;
- Water erosion risk of agricultural soils, scale 1:500,000;
- Wind erosion risk of agricultural soils, scale 1:500,000;
- Agricultural soil productivity in Slovakia, scale 1:500,000.

Soil Databases

- PC-AISOP Automated Soil Information System comprises data of pedological and agrochemical soil properties from selected profiles;
- The Soil Evaluation Information System, a range of information about soil-ecological conditions, including soil evaluation. Its three main components are:
    - Evaluation data bank - BDB
    - Base of digitised soil-ecological maps
    - SEU units.

The information in the evaluation data bank (BDB) includes background data of the Slovak Republic's soil resources as a whole. All background data needs to be updated so as to take account of all dynamic processes running through the whole economy, together with the most recent findings from regional soil and economic research. The dissemination of information to the land users gained from agricultural practice or from research projects should be in parallel.

The starting point for the evaluation of agricultural soils was the *Complete Soil Survey* (KPP) made in the period 1960-1970 for the whole of the Slovak Republic, using a unified methodology. Using detailed pedological surveys, the most important soil properties were ascertained and incorporated into maps - soil morphological units, subtypes and soil textural categories, percentage of humus and carbonates, soil pH, properties of the sorption complex, available phosphorus and potassium levels, stoniness (gravel and stones), parent material and, in part, erodibility rate (data in AISOP).

Mapping of the Soil-Ecological Units (SEU) started in 1973, based on detailed soil survey. In parallel, research into soil production parameters was conducted.

These activities resulted in the formation of a permanently updated and detailed Soil Evaluation Information System. It is based on supplementary land surveys. Supplementary soil surveys have also been made as part of the research tasks of the Institute, according to soil user and owner requirements. In this way, the evaluation data bank has been updated as well as the contents of the soil-ecological units on the map (scale 1:5,000), i.e. database of SEU digitised maps.

The evaluation data bank is an operational component of the present subsidiary system for soils and taxation of land used for agricultural production. It is important for formulating:

- Subsidies distribution;
- Tax determination for farming land;
- Official rents for farmland lease;
- Official soil appraisal for owner relationships;
- Soil appraisal for subsidies for farmland.

Application of soil data

The soil-ecological units on the SEU maps have been interpreted using GIS to prepare maps of:

- Soil morphological units;
- Texture;
- Soil erodibility;
- Mean land value according to soil quality - soil value;
- Taxation soil group (for purposes of tax levy for soils);
- Delimitation of soil resources;
- Soil-ecological regionalisation.

The outputs from the database necessary for various projects and agricultural soil protection programmes are exported into almost all the GIS systems used in Slovakia. The evaluation information system uses a 7-digit code to express the evaluation of each soil-ecological unit (SEU). Each SEU is determined by its soil-climatic properties, which are expressed by the code combination, the 7 characters in the code being fixed for the properties assessed or measured. The code includes data on climatic region, soil morphological unit, slope and aspect, stoniness, depth and soil texture. Through their combination, approximately 6,000 SEU codes have been established.

The system has been supplemented by an economic component.

XX XX X X X 7-member code of SEU

Code of climatic region	00-10
Code of main soil unit	00-99
Code of slope and exposition	0-9
Code of stoniness and depth	0-9
Cod e of texture	1-5

For the soil-ecological units, optimum-use categories have been established from 1977 to the present for cultivation plans, reclamation measures, plant nutrition, yield prediction, and the value of soil ($1m^2$) has been established.

The physical map set of the SEU (ŠMO 1:5,000) was digitised during 1988-1992. The database of the SEU maps includes X, Y co-ordinates of polygons describing the borders of the SEU areas (forests, water areas, infertile and built-up areas, etc.). Furthermore, it includes co-ordinates of map sheet corners and identity data (SEU numeric codes, other area symbols).

Evaluation of farmland

The 7 digit codes in the SEU database were used to make maps of farmland quality by grouping evaluation units into 9 groups, according to the scale of charges for withdrawal of permanent farmland from the agricultural soil resources pool. The first four groups (categories) are the soils with the highest productivity potential and they are protected according to the Act no. 307/1992 of Statute book.

The SEU units with physical, chemical and site properties suitable for plant growth, form groups 1-4. As a rule, the soils in these groups are mostly of moderately heavy texture but can include some lighter as well as heavier soils, and are medium to deep. Topsoils are variably gravelly, with no waterlogging, and not subject to water or wind erosion or other limiting features. As a rule the soils in these groups are Haplic Chernozems, Fluvi-gleyic Phaeozems, Eutric Fluvisols, Orthic and Stagno-gleyic Luvisols. They cover 544,129ha and encompass 328 SEU units.

Groups 5-7 have moderate productivity and include light textured, medium stony and moderately deep soils, shallow soils on loose substrata in dry climatic regions, clayey soils in depressions, light Eutric Regosols on blown sands, markedly gleyic subtypes in deep soils with few stones in cold climatic regions, and heavy gleyic Fluvisols in moderately cold and cold climatic regions. These groups cover 1,203,837ha and encompass 4,500 SEU units.
Groups 8 and 9 include soils with lower productivity, distributed over 619,634ha and comprising 2,051 SEU areas. The basic restrictions in these groups are slope, depth, stoniness (above 50% skeleton) and water logging. Thus, these two groups include shallow very stony soils on slopes of 7-12^o, waterlogged peat soils, saline soils, soils with a northerly aspect on slopes greater than 7^o, in cold climatic regions, soils not suitable for agriculture on slopes above 25^o, and extremely shallow and undeveloped soils. The maps range in scale from 1:50,000 to l:500,000.

Erosion risk on farmland

The most significant process of soil degradation is erosion by water or wind. The factors controlling erosion are soil, slope, rainfall and vegetation cover. Land use, particularly arable, can be dynamic, and so erosion risk is usually expressed as a potential, i.e. erosion that will occur without the conservation effects of plant cover.

Risk of water erosion has been calculated according to the Universal Soil Loss Equation (USLE) of Wischmeier and Smith (1978). The factors were calculated for conditions in the Slovak Republic using the evaluation codes of the soil-ecological units (SEU) - rainfall, slope and soil erodibility. For the vegetation/cover factor, values with lowest effect were adopted. The calculations were made using the SEU´s database area for the Slovak Republic. Water erosion risk has an annual frequency.

Wind erosion risk is relevant only for sandy and loamy-sand soils, only at the end of the winter period and early spring, when very dry conditions can prevail. Wind erosion risk is not calculated annually, but only for the long-term. For wind erosion, the method of Janeček was used. It is relevant for the textures listed above, under minimal soil moisture and in Slovakia’s warmest regions. The calculation is implemented for all the SEU´s in the regions, based on texture in the SEU database for Slovakia. The maps of both water and wind erosion are utilisable at scales in the range 1:50,000 to 1:500,000.

The land evaluation data bank (BIS) is used in co-operation with the Research Institute of Agriculture and Food Economics for soil value calculations under various agricultural practices for the purposes of subsidies and taxes. In 1996, the data bank was updated. Also, for the area of SEUs in cultivated arable lands and permanent grassland, mean values and total soil values were established. Further possibilities for BIS maps include graphical interpretations at SEU boundaries, soil texture, climatic regions, mean values of SEU, etc.:

- At the cadastral level, scales 1:5,000 and 1:10,000;
- At the national or regional level, scales 1:20,000 and 1:200,000;
- At the national level (of the whole of Slovakia) scales 1: 500,000 and 1:1,000,000;
- For research purposes, governmental, administration and agricultural activities.

Soil Monitoring System

The soil monitoring system in Slovakia is a part of environmental monitoring legislation, passed by the Government of the Slovak Republic (Resolution number 620 from 7th September, 1993).

History and structure soil monitoring

Development of the soil monitoring system by the Soil Science and Conservation Research Institute in Bratislava, began in 1992 under the general soil monitoring system (agricultural, forest and alpine soils together) guided by the Ministry of Environment and the Ministry of Land Management. General soil monitoring has been included in the programme of the Universal Environmental Monitoring programme. The Slovak Centre for Soil Information was established in the Soil Science and Conservation Research Institute in 1994.

The soil monitoring system in Slovakia has also involved the Central Checking and Testing Institute in Agriculture, Bratislava, and the Research Institute in Forestry, Zvolen.

Soil monitoring network

The soil monitoring network in Slovakia was constructed on ecological principles and includes the monitoring of all soil types and subtypes, climatic regions, emission regions and relatively clear regions, lowlands, hilly lands, basins and highlands. The majority of the monitoring sites are located in places where special soil profiles (with detailed analytical documentation) had been located during the General Soil Survey (1961-70).

The network consists of 424 monitoring sites (Figure 1), of which 313 sites are in agricultural use (arable land, meadows and pastures) and 111 sites are in forested areas. In addition to these basic sites, 21 key monitoring sites have also been used for research study, introduction of new methods, problems of spatial variability, etc.). All the monitoring sites are geodesically located and recorded on the map at a scale of 1:5,000.

Soil sampling

Each monitoring site is circular in shape, with a radius of 10m and an area of 314m^2. Soil sampling started in 1993. Samples are taken at standard depths of 0-0.10m, 0.20-0.30m and 0.35-0.45m, but the depth is adjusted to characterise the main soil horizons. The basic monitoring cycle is 5 years, but more dynamic soil properties (physical properties – bulk density, porosity; agrochemical properties – pH, Al, available nutrients – phosphorus and potassium) are monitored annually at key monitoring sites.

Soil properties monitored

The following main soil degradation processes are monitored:

- Soil pollution;
- Soil acidification;
- Soil alkalisation and salinisation;
- Available nutrients P and K;
- Soil organic matter development;
- Soil compaction;
- Soil erosion.

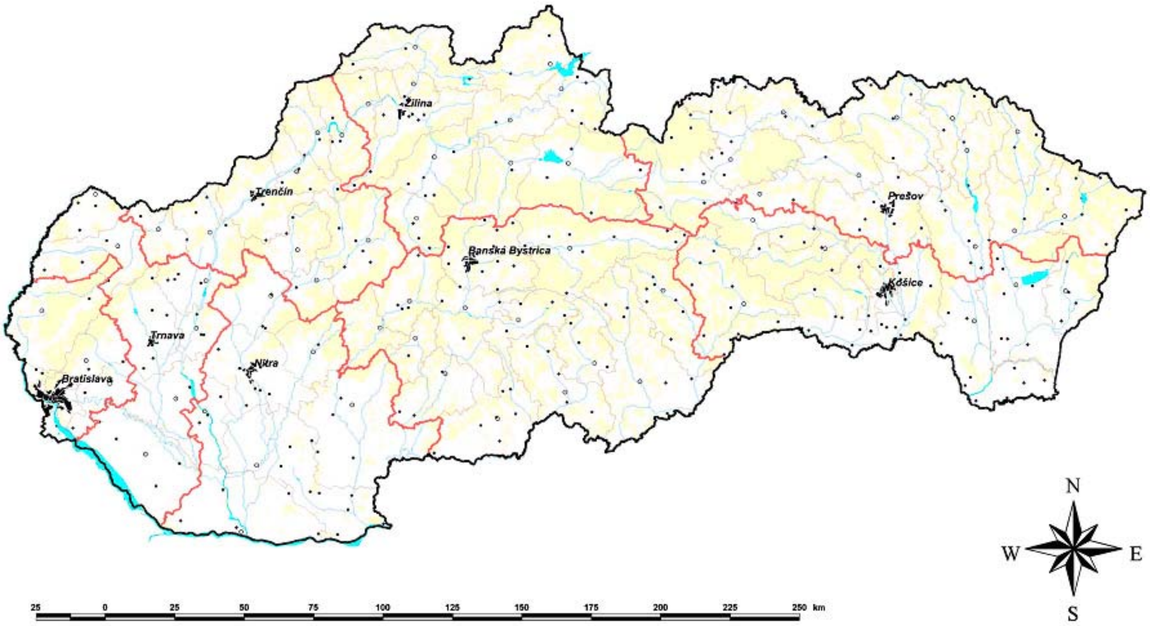

Figure 1: Monitoring localities for digital database of soils

The dynamics of these processes is evaluated mainly through the change of the following characteristics:

- Risk trace element concentrations (Pb, Cd, Cr, As, Hg, Cu, Zn, Ni, Se, Co) – total content;
- Risk trace element concentrations (Cd, Pb, Cr, Ni, Cu, Zn, Co) extracted with 2M HNO_3 and 0.05 M EDTA;
- As (extracted with 2M HCl);
- Organic pollutants (PAH_s, PCB) by chromatographic methods;
- N_t according to Jodlbauer's method;
- pH value (with H_2O, 0.2 M KCl and $CaCl_2$);
- Available nutrient P and K (P: extraction with $C_6H_{10}CaO_6 \cdot 5H_2O$, K: extraction with $(NH_4)_2 C_2O_4 . H_2O$ and CH_3COONH_4;
- Organic carbon (oxidometrically with chromium/ sulphuric acid);
- Electric conductivity in saturated soil paste;
- Physical properties (bulk density, porosity, maximum capillary capacity) in $100 cm^3$ cylinders;
- Soil compaction (by Eijkelkamp penetrometer);
- Soil erosion intensity (by $^{137}C_s$ and remote sensing methods).

Soil monitoring database

The soil monitoring results are presented in numerical, tabular, graphical and mapped outputs by the Soil Information Centre in Soil Science and the Conservation Research Institute, Bratislava. The basic soil monitoring information in Slovakia is also available through the Internet http://www.iszp.sk/ in the Slovak Environmental Agency, Banská Bystrica.

Soil compaction

From the data obtained, it can be concluded that of the parameters evaluated, soil physical properties have changed for the worse, especially in Chernozems and Luvisols (the soils most cultivated by machines) but less so in Cambisols and other soils.

Texturally, the soils most resistant to compaction are the sandy soils. On the other hand, the loamy soils also have a high susceptibility to compaction. Finally, the clayey soils are often compacted naturally and are generally not as susceptible to further compaction.

Soil compaction evaluation

Soil compaction evaluation was assessed from:

1. Point results from direct soil compaction measurements at soil monitoring sites. Evaluation of compaction is based primarily on soil morphological unit and secondly on soil texture, using results from 188 localities in the whole of Slovakia (Figure 2).
2. The database of soil ecological units. The database contains data from 18,000 localities over the whole of Slovakia. Each locality is evaluated from a soil ecological unit point of view. These data were obtained during detailed monitoring of soils in Czechoslovakia in the 1960s.

Heavy and very heavy textured soils are evaluated as primarily compacted. Moderately heavy soils with an *argillic* horizon have a high susceptibility to secondary man-made compaction, but, to a degree, they are also primarily compacted. The following soil subtypes belong to this category (FAO 1970 in Hraško *et al.*, 1991): Fluvi-eutric Gleysol, Fluvi-mollic Gleysol, Stagno-gleyic Luvisol, Albic Luvisol, Dystric, Stagno-gleyic and Gleyic Planosol, Eutric Gleysol, Stagno-gleyic Cambisol.

Secondary compaction, caused exclusively by human activity, occurs in very intensively exploited soils with high fertility potential such as Fluvisols, Chernozems, Fluvi-haplic Phaeozems and Orthic Luvisols. These soils are predominantly of medium heavy texture.

Point results were processed according to the Lhotský *et al.* (1984) evaluation of soil compaction, supplemented by that of Zrubec (1998) (Table 1). Figure 3 shows the influence of soil compaction on agicultural productivity.

Table 1: Evaluation of soil compaction; the critical values of soil physical properties

Soil Property	**Soil textural category**					
	Clay	Clayey	Loam	Sandy loam	Loamy sand	Sand
Bulk density (g.cm-3)	>1.35	>1.40	>1.45	>1.55	>1.60	>1.70
Penetrometric resistance (MPa) * related to soil moisture (% of weight)	2.8 - 3.2 28 - 24	3.2 - 3.7 24 - 20	3.7 - 4.2 18 - 16	4.5 - 5.0 15 - 13	5.5 12	6.0 10
Porosity (% of volume)**	< 48	< 47	< 45	< 42	< 40	< 38
Minimal air capacity (% of volume)	< 10	< 10	< 10	< 10	< 10	< 10
Maximal capillary capacity (% of volume)	>35	>35	>35	-	-	-
Clay content (≤ 0.001mm)	>30	>30	-	-	-	-
Plasticity index	>25	>25	>25	-	-	-

Notes:

* if the actual soil moisture content does not fit with the proper moisture interval it is necessary to add to the measured resistance value 0.25MPa (in case of higher soil moisture), or to take away 0'25 MPa (in case of lower moisture content)

** 10 % of volume is the average value. For different crops this value changes:

Root crop - limiting porosity is 12% of volume

Cereals - limiting porosity is 10%

Fodders - limiting porosity is 8%.

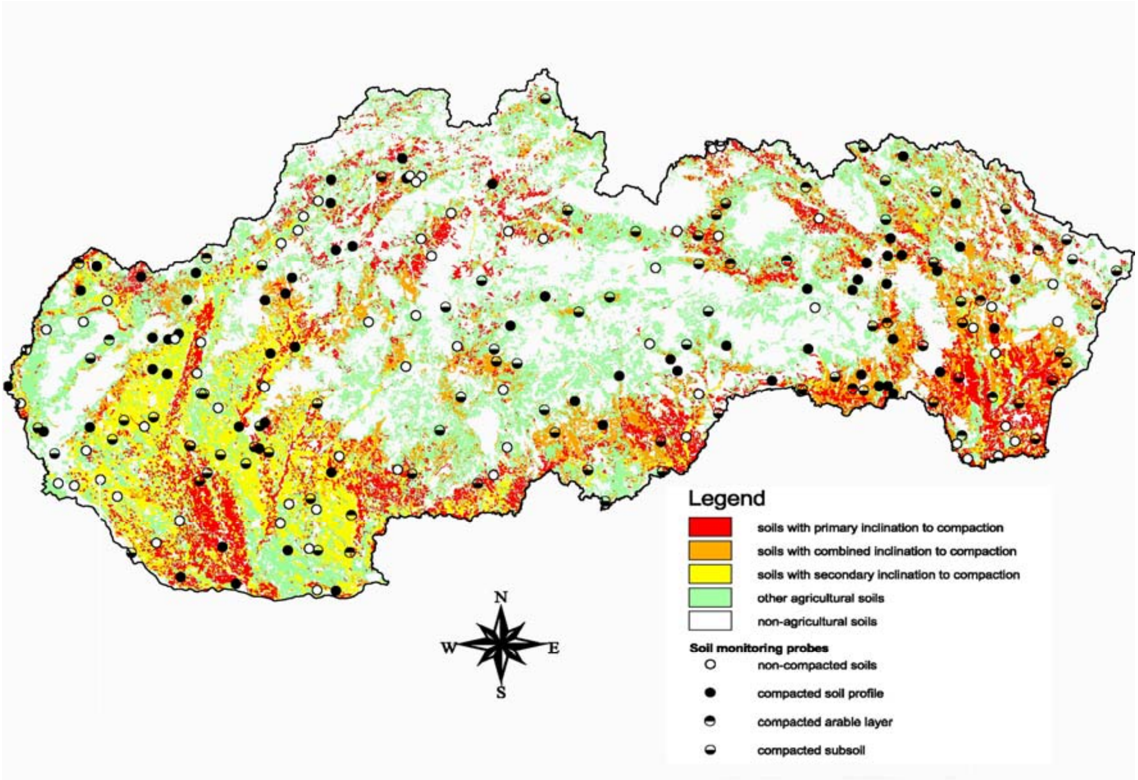

Figure 2: Agricultural soil susceptibility to compaction and actual state

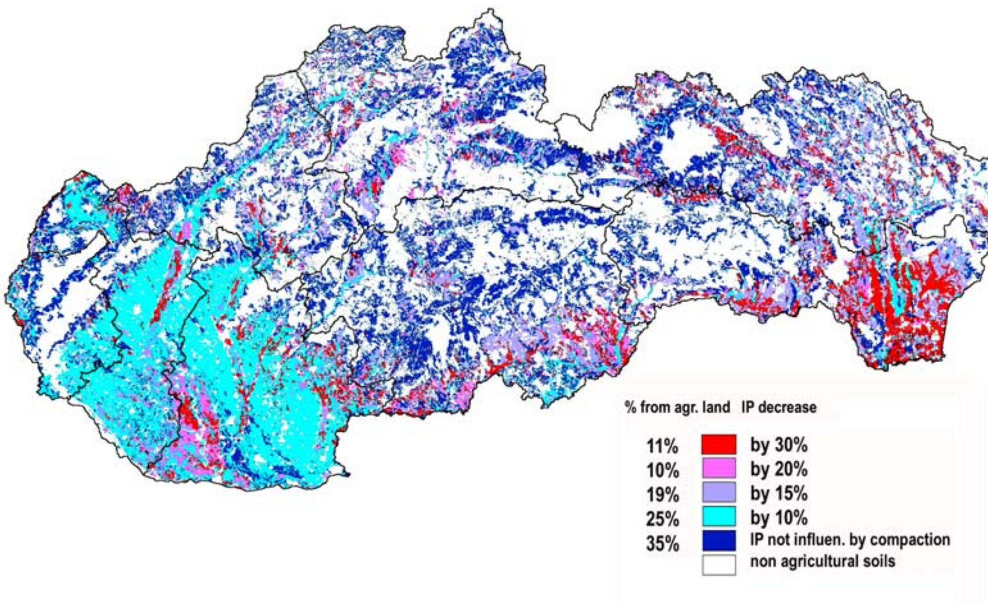

Figure 3: Influence of soil compaction on productivity index of agricultural soils

Soil erosion

Soil erosion is a very serious problem. Intensity of soil erosion depends on the silt fraction and soil organic matter content as well as slope and land use. A review of potential and actual water erosion of farm land in Slovakia is given in Table 2. Figure 4 shows potential erosion by water but in addition, approximately 5% of agricultural soils suffer to a medium degree and 2% suffer strongly from wind erosion (Figure 5) in Slovakia (Linkeš. et. al., 1997).

Changes in soil conditions in Slovakia since 1993

Domains of monitoring

- Soil pollution and soil acidification: no significant change; slight tendency, mostly on acid soils and substrates;
- Soil alkalisation and salinisation: no significant change;
- Available nutrient P and K content: decrease mostly on cultivated and arable soils by about 10-30 % (influence of low fertilisation level during last period);
- Soil organic matter: decrease on cultivated and arable soils;
- Soil compaction: deterioration of physical properties especially on Chernozems and Haplic Luvisols;
- Desertification phenomena (as a result of global climate change): slightly and sporadically occurring in the most warm and dry regions of Slovakia (increase of groundwater mineralisation, respective decrease of groundwater level).

Table 2: Potential and actual water erosion of farming land

Extent of erosion	Potential erosion (%)	Actual erosion (%)
Without erosion	27	27
Slight erosion (< 4t/ha/year)	18	49
Medium erosion (4-10t/ha/year)	20	21
Strong erosion (10-30t/ha/year)	18	2
Extremely strong erosion (>30t/ha/year)	17	1

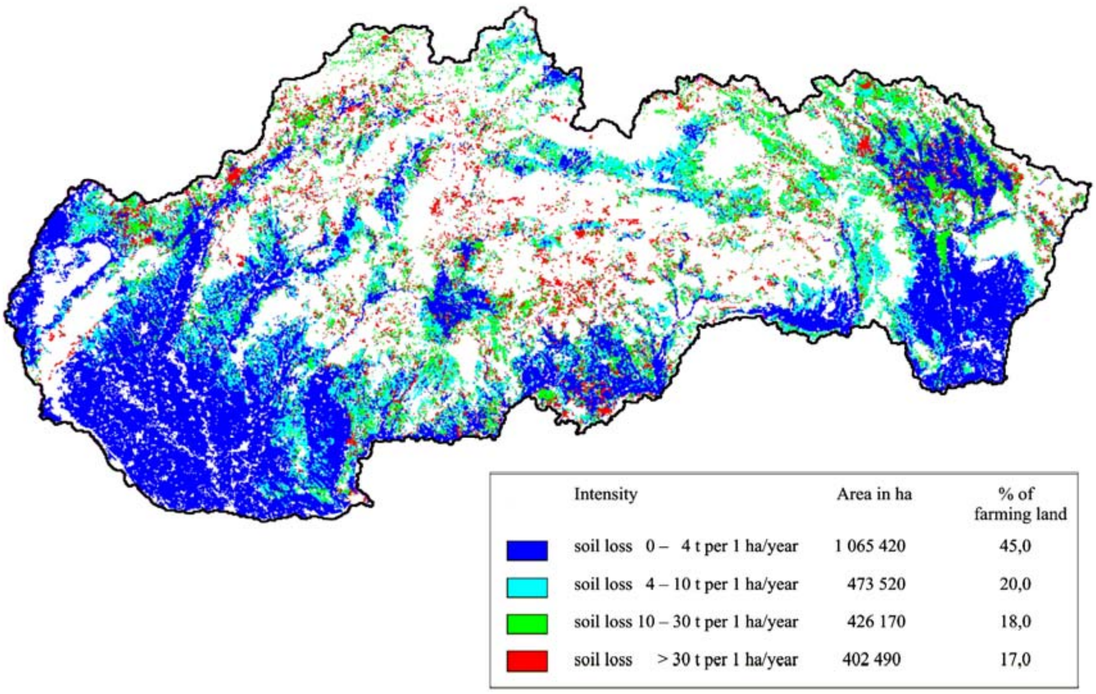

Figure 4: Potential water erosion risk on Slovakian agricultural soils

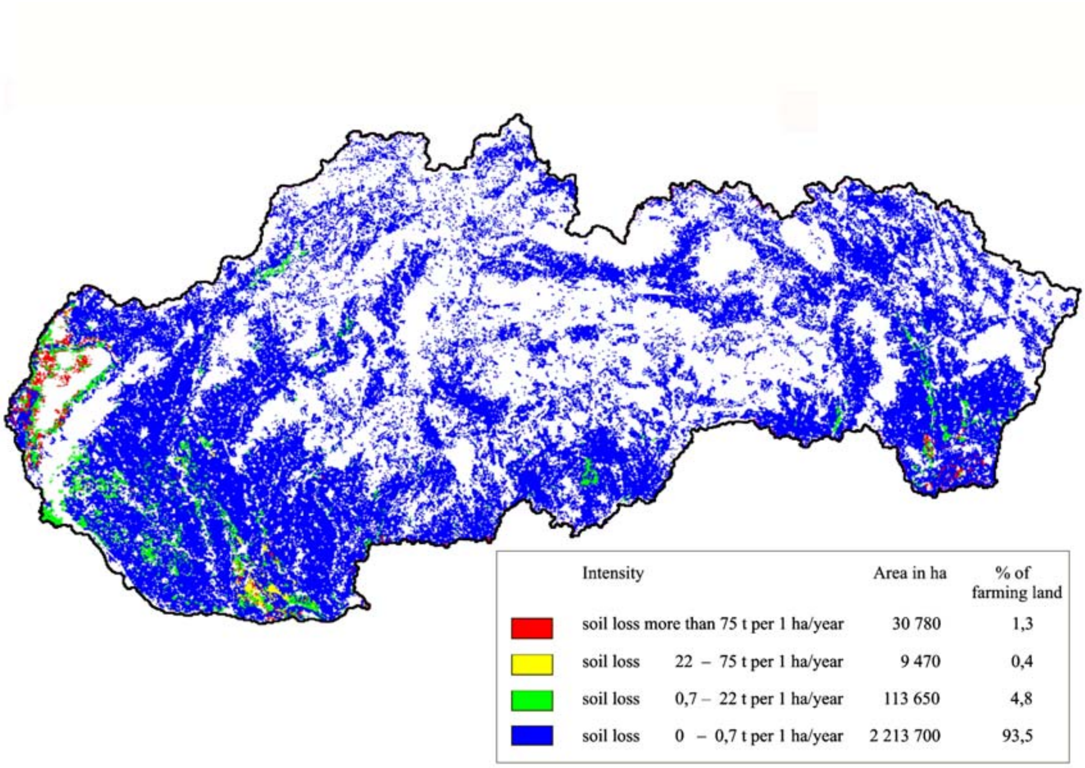

Figure 5: Potential wind erosion risk on Slovakian agricultural soils

According to Resolution number 7 of the Slovak Government, 12th January 2000, the next episode of soil monitoring in the framework of the monitoring of environment, and its compatibility with EU countries, was agreed. Global soil changes depend on composition of soil cover and on anthropogenic impact as well as on global climate change. These factors are often significant and therefore it will be necessary to permanently monitor all soil cover in Slovakia, in the same way as in other EU countries.

Monitoring the impact of the Gabčíkovo hydropower plant

The effect on the natural environment of the construction and operation of the waterworks structure Gabčíkovo is being assessed by a complex monitoring project. The study area is the Žitný ostrov (the Rye Island), situated between Bratislava and Komárno and surrounded by the River Danube and the branch of the Small Danube. The character of the soilscape of Žitný ostrov has been determined by the height and duration of the groundwater table in soil profile and according to its hydromorphic or automorphic influence as well as its soil texture.
The most widespread soils in the Žitný ostrov are semi-hydromorphic and hydromorphic soils with mollic A horizon. The second most widespread group of soils are automorphic soils of chernozemic type. Small areas of salt affected soils occur in the lower Žitný ostrov, where moderate to strong mineralisation of groundwaters is found.

The following items have been monitored within this project:

- Hydrological regime of the groundwater and surface water;
- Quality of surface water and groundwater;
- Climate and chemistry of atmosphere;
- Soils and agriculture;
- Forest and forestry;
- Waste, dumping sites and other sources of pollution.

Monitoring of soils and agriculture

Monitoring of soils and agriculture, as a constituent part of the comprehensive monitoring scheme, has been carried out since 1989 (Figure 6). Its aim in the long-term is observation to establish changes in soil properties and soil processes in relation to changes in the hydrological and hydrochemical regime of the groundwater, caused by the construction of the Gabčíkovo hydropower project.

The monitoring is divided into two stages. The first stage, from 1989 to 1992, characterised the so-called initial condition of soil properties and soil processes, i.e. the situation within the last four years before putting the hydropower plant into operation. This stage assessed a wide range of physical and chemical properties of soils, the present pedogenic processes, chemistry of the groundwater and the results of plant production achieved by agricultural companies during 1984-1991.

The second stage of the monitoring scheme after 1992, characterised the situation after the power plant came into operation. It was set up to gauge the effect of the changed hydrological regime of groundwater on the selected set of soil properties. This set includes: soil moisture, soil water regime, humus content and its quality, salinisation and alkalisation of soil in relation to chemical composition of the groundwater and yields of cultivated plants in relation to soil water regime.

Network of monitoring sites and collection of data

Collecting data for monitoring of soils, groundwater and crop yields has been carried out within a network of stationary monitoring sites. The network consists of a set of locations on arable land from which to take soil samples, to measure soil moisture and rainfall, to take samples of groundwater, and to measure its level as well to measure yields.

Each monitoring site contains the following items: soil pit, moisture pit, hydrogeological well and rainfall gauge. In terms of the scope and frequency of data collection of soil and groundwater properties, the monitoring involves one-off as well as periodic measurements. The one-off determinations include soil texture and basic physical and chemical properties. The periodical determinations include soil moisture, humus content and quality, salinisation, and alkalisation and chemical composition of groundwater.

In terms of establishment and assessment of the influence of the waterworks upon soils and agriculture, soil moisture is the most significant soil characteristic. Its long-term changes can result in a change in moisture regime of soils and thus also changes in quality of soil properties and processes. Soil moisture is, therefore, monitored by 10cm layers to the groundwater in 10-15 day intervals. Other soil properties are monitored once a year, chemical composition of groundwater twice a year.

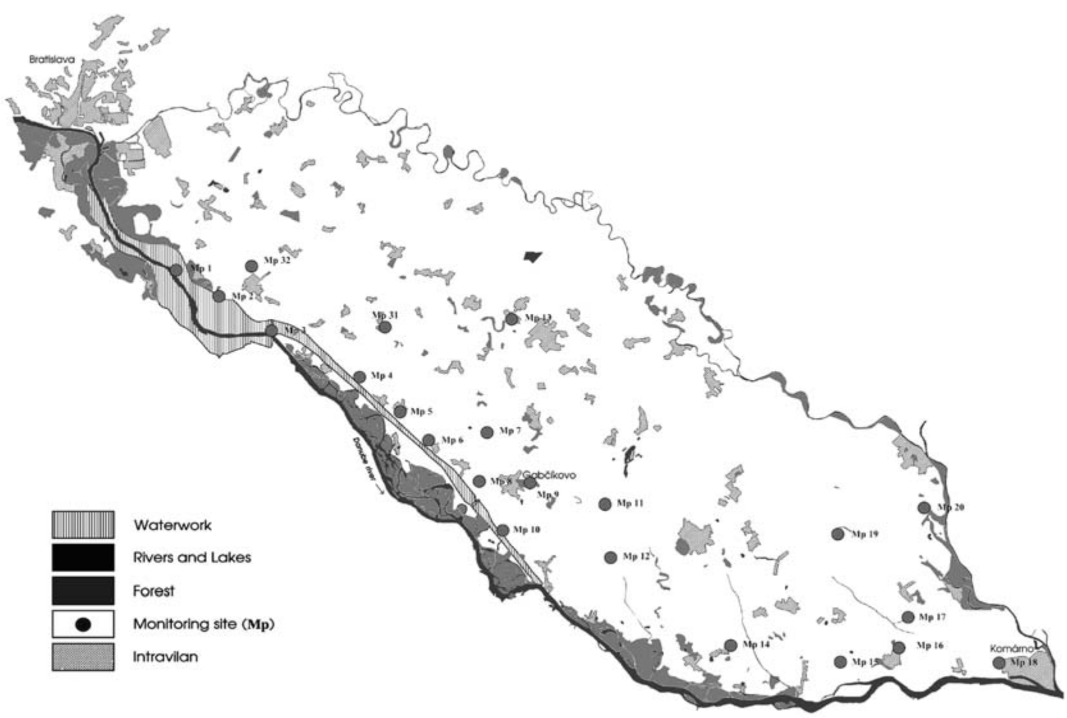

Figure 6: Monitoring sites of Zitny ostrov

The analysis of soil monitoring data has confirmed that the Gabčíkovo hydropower plant affects soils and agriculture primarily by changing the hydrological regime of groundwater. Putting the structure into operation, i.e. filling up the water reservoir, by-pass and tailrace canals with water, the adverse trend of groundwater table decline was not only stopped, but also positively changed. In the area adjacent to the reservoir, the groundwater table rose from the original depth of 5-7m to a depth of 3-2m below the surface. Above this groundwater table, a thick capillary zone with high moisture content (30-40%) was established. The capillary rise of the ground water into the root zone has positively changed the soil water regime of the area close to the reservoir.

Soil Geochemical Mapping

Soil geochemical mapping in the Slovak Republic (SR) which may be considered as basis for the soil monitoring was conducted in two stages:

The Geochemical atlas of the Slovak Republic, at a scale of 1:1,000,000. was started in 1991. The primary reference network soils is 10km^2 grid cells distributed over all country. In these cells, the soil samples were taken at random. Within this project, agricultural and forest soils were sampled over all territory (1 sample/10km^2) from the A and C horizons. At each site 3-5 sub samples were collected and one composite sample was prepared for each horizon. The samples were prepared by dry sieving. The fraction <0.125mm was then used for chemical analysis and the fraction <2mm was used for the soil analysis. The assemblage of 36 elements: Al, As, B, Ba, Be, Bi, Ca, Cd, Ce, Co, Cr, Cs, Cu, F, Fe, Ga, Hg, La, K, Li, Mg, Mn, Mo, Na, Ni, P, Pb, Rb, Sb, Se, Sn, Sr, V, W, Y and Zn, was analysed.

This project is finished and the results have been published (Čurlík and Šefčík: Geochemical atlas of Slovak Republic, Part V - Soil, 1999).

These data form a good basis for detailed studies and can contribute to a general awareness about soil degradation and its adverse effect on all other environmental components. This mapping in Slovakia was performed in the framework of a large national programme 'Geochemical atlas of Slovakia' in which different media were sampled (rocks, stream sediments, soils, water and biota) and analysed. The atlas should be helpful in the creation of an integrated view of the spatial distribution of chemical elements, whether geogenic or influenced by man.

The data obtained need to support environmental soil quality assessments also in a European context. They also enable the provision of an interdisciplinary linkage, when solving environmental problems.

The results presented in maps and in the database of the Ministry of the Environment of the Slovak Republic enable better assessment of regional soil pollution problems and form the basis from which improvements can be made.

Regional geochemical mapping at semi-detailed scale (1:50,000) is conducted within the projects. It gives particular emphasis to the preparation of sets of regional geofactor maps for hot spot regions. In this stage only soil samples from A horizons were collected and analysed for the following risk elements: As, Ba, Be, Cd, Co, Cr, Cu, Hg, Ni, Pb, Sb, Se, Sn, V and Zn.

The analytical measurements are compatible with international standards, and accuracy of the results has been tested. The same methodology of sampling, sample preparation and analytical procedures have been applied in both stages. In this way an understanding of the distribution of chemical elements in Slovakian soils is being established.

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Soil Information and Soil Data Use in Slovenia

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Introduction

Systematic soil mapping in Slovenia started in the 1960s, while collection of soil data started in 1930s (B. Vovk). In the late 1980s the Centre for Soil Science and Environment (CSES) started to establish the digital soil map of Slovenia. The work on soil mapping continued with several interruptions until the end of January 1999, when all the territory of Slovenia was included in an operative digital soil map at the scale 1:25,000 (DSM25). DSM25 represents the core of digital soil data brought together into the Soil Information System (SIS), providing a wealth of information on Slovenian soils. Beside DSM25 two important soil information layers associated with DSM25 are included in SIS: measured data on ~1,700 soil profiles (SP) and the soil pollution point data layer (SPP).

Available Soil Data and Soil Protection Measures

Most of the older soil maps have been classified according to the modified Yugoslav classification system (Škorić, Čirić, Filipovski; cit. in Škorić, 1986). Several names of the soil systematic units have been introduced according to Stepančič & Ažnik (1976). Stritar (1990) presented soil associations for the needs of urban planning in the early 1980s as an approach based on natural regions, landscape appearance and soil. In that system, soil sequences or pedosequences, determined on the basis of parent material, have been mapped at the scale 1:5,000 together with land categories, developed according to the land capability classification of Klingebiel and Montgomery (1961) with certain modifications necessary for Slovenian conditions (Stritar, 1990.

These maps were very important for protection of agricultural (specially arable) land.

Class 1 and 2 agricultural land are included in a special planning zone called ‘best agricultural land’, with very limited possibilities for non-agricultural land use change, defined also in the latest law on agricultural land (Official Gazette RS No.59, 1999). Land categories were introduced into the system of agricultural land protection at the time when soil information was not sufficient and large-scale soil maps were not available for the whole Slovenian territory.

Therefore, land categories were not founded on ‘concrete’ soil data; consequently certain discrepancies in the land use planning process appeared. A new categorisation based on soil data is necessary, and preliminary tests on using digital soil information for elaboration of new categorisation have already been undertaken.

The Slovenian Soil Classification

The Yugoslav classification system was officially used in Slovenia until 1991. However in practice, this system has been modified in many cases, as mentioned before. The need for a comprehensive classification system has been recognised with the start of systematic digitisation and preparation of the attribute tables To accommodate this, the solution was a provisional Slovenian soil classification system, which has been upgraded several times during the process of digitisation. A parallel conversion of soil systematic units according to the revised legend of the Soil Map of the World, 1988, has been applied in this system.

Soil types and their distribution

The system is basically genetic, hierarchical and mostly influenced by the ideas of Kubiena. Four major groups are distinguished on the basis of presence of water, soil permeability and salt presence.

They are Terrestrial (automorphic) soils, Hydromorphic soils, Salt affected soils and Submerged soils. The two latter groups are present due to the marine coast and several larger lakes but no soil profile has been described yet.

The less developed soils are raw soils such as Lithosols (Lithic Leptosols), Regosols and Colluvial (deluvial) soils. Rendzinas (Rendzic Leptosols), thin soils with A-C or A-R profiles, are the most widespread soil type in Slovenia covering about 24% of the mapped territory. They form on limestone and dolomites, which cover almost half of Slovenia (44%), and on other rock derived parent materials. Rendzinas are classified in much detail and Rankers (Dystric Leptosols) are relatively rare (4%).

Soils with a developed cambic B-horizon are included in the class of Cambic soils. Further division is made on the basis of parent material. In a word-for-word translation from the Slovenian language, they are called brown soils overlying hard carbonate rocks and terra rossa (both Chromic Cambisols), which cover 14% of the Slovenian territory, eutric brown soils (Eutric Cambisols, 14%), and dystric brown soils (Dystric Cambisols, 16%).

Eutric Cambisols, often found on the bottom of basins and valleys or in terraced hilly regions, make the most fertile Slovenian agricultural land. Leached varieties of Chromic Cambisols and Luvisols are less widespread, but can be found on limestone and dolomite as well. On siliceous parent materials, Podzols are an extremely rare soil type. The group of terrestrial soils has also one class containing arable man-modified soils with the soil types, Rigosol and Hortisol (Aric and Fimic Anthrosols, and deposited man-made soils, such as, for example, on municipal deposits (Urbic Anthrosols), cover 1.6% of Slovenian territory.

Hydromorphic soils can be found in tectonic basins and flat areas. Eutric, Dystric and Calcaric Fluvisols are common along the rivers and cover more than 5% of Slovenian territory. Other Hydromorphic soils are also common in these areas, covering almost 9% of Slovenia. Eutric and Dystric Pseudogleys (Planosols) are soils with periodical surplus of surface water originating directly from the atmosphere. Gley soils (Gleysols) are characterised by seasonal water surplus originating from the shallow groundwater table. If floodwater or water collected in a local catchment is added to that soil surface, an amphigley soil is developed.

Peat or organic soils (Histosols) are distinguished as lowland peat soils, upland peat soils and transitional peat soils. The group of Hydromorphic soils is also includes the class of man-modified soils. Ameliorated soils to which a drainage system is applied are the only representative.

Soil Survey in Slovenia

Systematic soil mapping at the scale 1:25,000 began in Slovenia in 1963 when Slovenia was a republic of the Federal Republic of Yugoslavia. Numerous soil profile data were collected and several soil maps were published in paper form. In 1981, the initial mapping scale at 1:50,000 was changed to 1:25,000. By the end of 1986, about 50% of Slovenian territory had been covered with soil maps, partly at scale 1:50,000 and partly at scale 1:25,000.

Only a few map sheets were published on old military topographic base maps, others existed as manuscripts and soil profile data as typescripts. Three soil maps on new, 1:50,000 scale topography were published between 1984 and 1986: parts of Ljubljana, Murska Sobota and Ptuj. Each of them was accompanied by a booklet containing soil descriptions, information on basic soil properties, representative soil profile, measured data and land use information.

The first digital soil data in Slovenia were captured by CSES in the early 1970s. The design of databases and the definitions of attributes were standardised as a part of the federal project, ‘Pedological Information System of Yugoslavia’ (PIS, 1978). The data were centrally maintained in a computer centre in Sarajevo. The PIS did not include maps; the computer systems were not capable of storing digital maps so the maps were stored in paper form.

The fate of this information base is not known, but it is very likely that the digital and papers records were lost during the war in Bosnia and Herzegovina. The majority of information input to PIS by CSES remained preserved in archives, though later this information was revised and stored in electronic form. Rapid development of geoinformatics in the 1980s enabled the project 'Digital Soil map of Slovenia at the scale of 1:25,000' to begin in 1987.

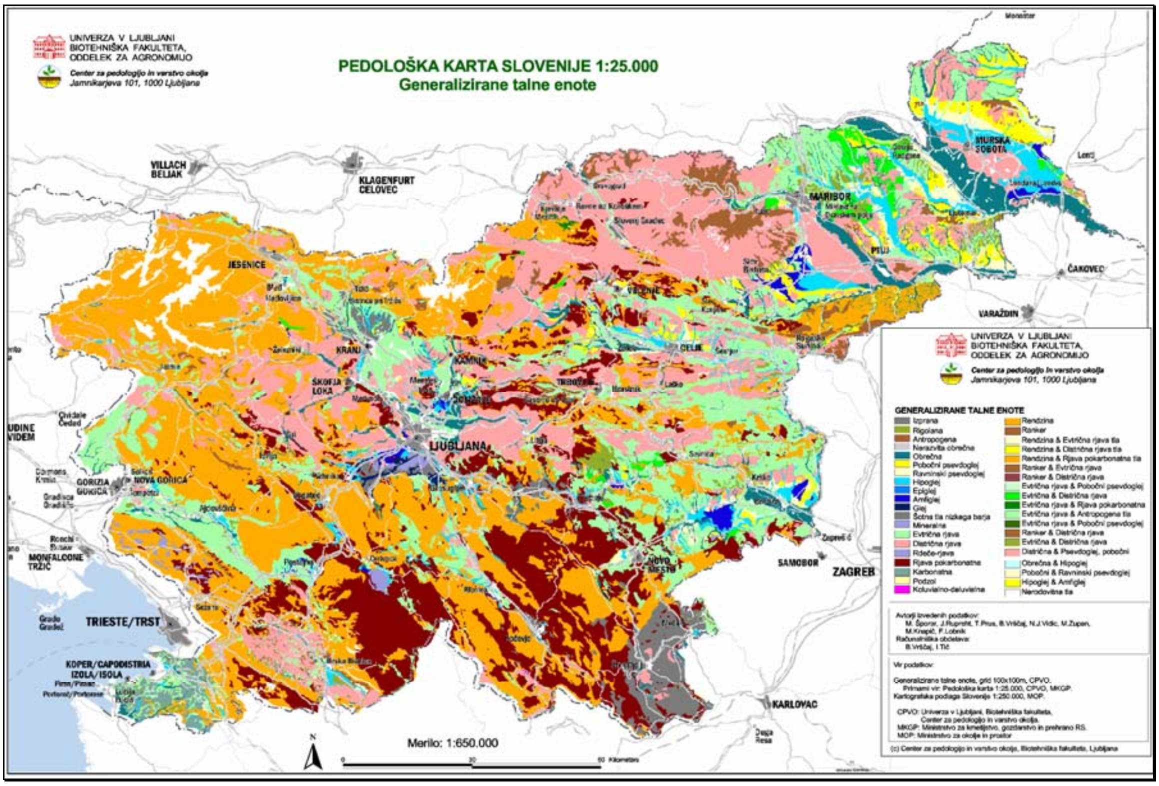


Figure 1: Digital soil map of Slovenia at 1:25,000 scale, generalised according to the FAO classification.

The project was initiated by CSES (Lobnik, Vrščaj, Prus) and financed through various research works by the Ministry of Science and Technology. The core of the project was digitisation of soil maps and associated information into a GIS system.

After achieving independence in 1992, it was decided in Slovenia that the work on mapping soils, digitisation of soil data and the establishment of digital soil databases should be accelerated. In 1992, a new contract was made between the Ministry of Agriculture, Food and Forestry of Slovenia (MAFFS) and CSES. The project had the following major goals:

- Complete soil mapping in the scale 1:25,000;
- Design digital soil map as a contemporary GIS layer;
- Elaborate digital soil map;
- Collect, verify and enter soil profile data into the databases.

Soil mapping was divided into 200 sheets based on 1:25,000 scale topographic maps (TM25). Each TM25 map covers approx. 13,000ha. Between 1992 and 1998, the additional soil survey fieldwork was carried out simultaneously with computerisation of the data.

The project was completed in January 1999, when a unified, seamless Digital Soil Map at scale 1:25,000 (DSM25) for the whole of Slovenia was available (Figure 1).

Soil Information System

Besides soil mapping, many different research projects concerning soil and soil pollution have been accomplished in Slovenia. Altogether these have resulted in a large amount of data that has to be organised and used in the most effective way. The data have to be stored in an adequate geographic information system. At the present time, the soil data available in digital form are brought together into the Soil Information System of Slovenia (SIS), initiated, developed and maintained at CSES (Vrščaj and Prus 1994; Vrščaj 1996, Vrščaj,*et al.*, 1998).

The SIS is not directly financed by the state but is operated through ongoing research projects. The basic goal of SIS is to unite this geographically defined soil data into an easy-to-serach and, through computer communications, easy-to-access entity. It is a comprehensive source of soil data, verified and comparable with respect to laboratory analyses, procedures and spatial accuracy. SIS represents a basis for further investigation in soil, environmental, and soil-related sciences using GIS tools and methods.

SIS unites the following main layers into a logical whole:

- Digital Soil Map at scale 1:25,000 (DSM25) and associated soil attribute databases:
- Soil Profiles (SP);
- Soil Pollution Monitoring (SPM).

Following recent soil survey and soil monitoring, new data, new software and users needs ensure that SIS development is ongoing.

The applicability of DSM25

The Digital Soil Map, at scale 25,000, was designed as the basic reference base of Slovenian soils as a natural resource. The resolution of databases enables spatial analyses and their use at state, regional and sometimes even at county scale. It was designed for use at the scales 1:50,000 to 1:20,000. Scales of 1:100,000 and smaller (state level) require the generalisation of DSM25. When used at a scale larger than 1:10,000 or 1:5,000, the data are used as a rough (but still useful) approximation and are supplemented with additional data.

The attribute component of the DSM25 database is constantly being improved in various research projects. The pedologists/field soil surveyors, who work on soil mapping, are enriching the DSM25 attribute dataset with expert knowledge about basic soil properties. Yet in the future, it is intended to improve the sometimes subjective expert opinion using statistical and geostatistical approaches.

Currently, the DSM25 graphical and attribute information are repeatedly used in different projects at CSES, mostly financed by state institutions. Recently, the increasing use of GIS tools and procedures by land use planners, civil engineers, scientists, local communities, and students, has increased the demand for DSM25 data.

The DSM25 structure

DSM25 incorporates spatial and attribute information; thus it is truly a GIS information layer. Graphic information is represented by soil mapping unit (SMU) polygons with the properties described in attribute tables. From a technical point of view, DSM25 is organised into a computer map library of 200 sheets. The basic objects of the maps are the SMU polygons**.**

Each SMU is composed of up to three different soil types named soil-systematic units (SSU), which cannot be shown separately because of the scale or because they appear in the same soil series. In addition to the three main SSUs, another SSU can be entered into the SMU attribute table. This is described as an inclusion.

The total area of the inclusion soil type does not exceed 10% of SMU area. The SSU is a soil type with typical characteristics that are fundamentally different from characteristics of other soil types (other pedo-systematic units). SSU properties are described in attribute tables maintained by a computer relational data base management system (RDBMS) (Figure 2).

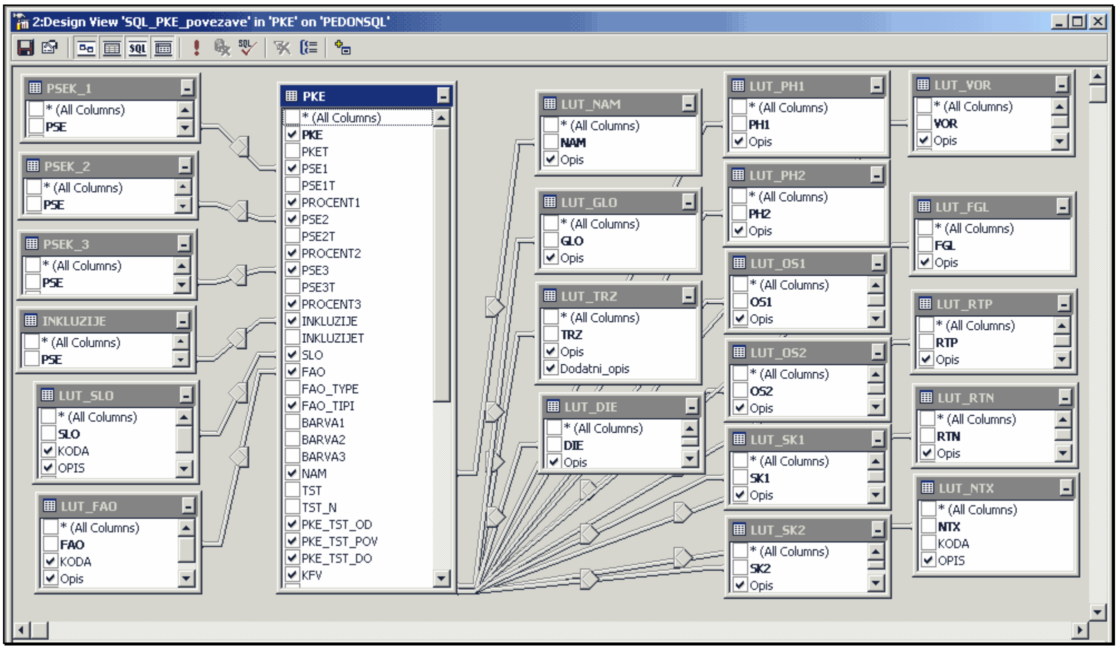


Figure 2: DSM25 attribute data; the design of SQL query, MS SQL 2000 environment.

For modeling purposes, the DSM25 information is rasterised into separate grids, on the basis of attribute data, for use in raster GIS systems. Raster grid modeling enables the use of unlimited additional soil and non-soil spatial information in raster form. Inside the DSM25 GIS layer, two major attribute datasheets are linked using the relations between SMU and SSU databases. The first one is closely connected to the graphic SMU polygon data. The SSU database contains the data on soil type (SSU) properties and the SMU soil properties can be calculated from individual SSU properties using different models.

Supplementing spatial databases

The structure of the DMS25 is adapted to the relatively rich GIS data sources available in Slovenia, which are constantly improved. The separate soil-related spatial information allows its flexible use in a GIS environment. The most important or most frequently used spatial information at CSES is the following:

Digital elevation models. Data on terrain are not a part of the DSM25 attribute data set. The relief information (elevation, slope, aspect) originates from three different available digital elevation models (DEM) at resolutions 100m, 25m and 20m; all of them covering the whole of Slovenia.

Land use information in Slovenia is available at two scales: CORINE Land Cover for Slovenia 1:100,000 vector database, EC-Phare project (Kobler and Vrščaj, 1998) and the recently completed vector database Land use 5,000, a GIS database at the scale 1:5,000 financed by MAFF.

Information on *parent material* is available from a rectified scanned map of 1:1,000,000 scale (Institute for Geology and Geotechnics, Ljubljana). The new geological vector database is being prepared. Until now, the 30-year average *precipitation data* (Kastelec, 2000) in 100m GIS grid format, the *potential evapotranspiration* (Kastelec, 2002) and *estimated water surplus* on the soil surface (Kastelec, 2002) have been available to the CSES. In the models some data for microclimatic conditions are derived using DTM.

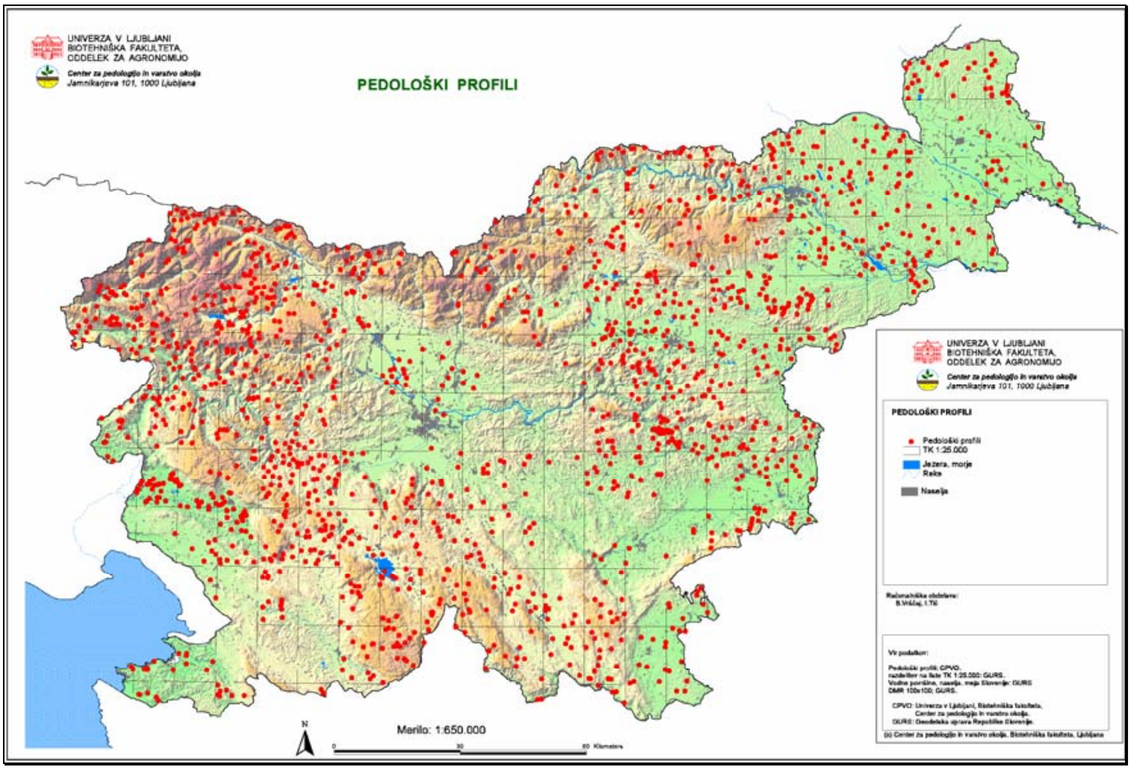
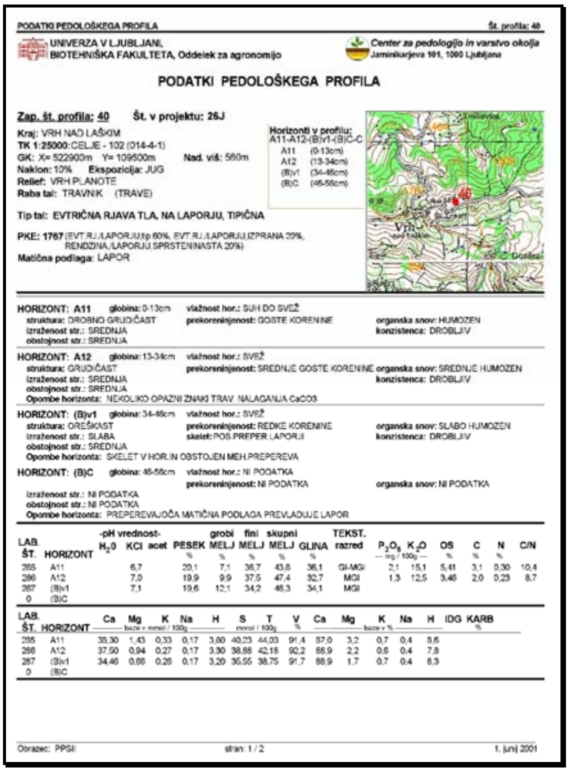


Figure 3: Locations of soil profiles.



PODATKI PEDOLOŠKEGA PROFILA | Št. profila: 40

UNIVERZA V LJUBLJANI, BIOTEHNIŠKA FAKULTETA, Oddelek za agronomijo

Center za pedologijo in varstvo okolja, Jamnikarjeva 101, 1000 Ljubljana

PODATKI PEDOLOŠKEGA PROFILA

Zap. št. profila: 40 Št. v projektu: 26J
Kraj: VRH NAD LAŠKIM
TK 1:25000: CELJE - 102 (014-4-1)
GK: X= 522900m Y= 109500m Nad. viš: 560m
Nakion: 10% Ekspozicija: JUG
Relief: VRH PLANOTE
Raba tal: TRAVNIK (TRAVE)

Horizonti v profilu: A11-A12-(B)v1-(B)C-C
A11 (0-13cm)
A12 (13-34cm)
(B)v1 (34-46cm)
(B)C (46-56cm)

Tip tal: EVTRIČNA RJAVA TLA, NA LAPORJU, TIPIČNA

PKE: 1767 (EVT.RJ./LAPORJU,tip 60%, EVT.RJ./LAPORJU,IZPRANA 20%, RENDZINA,/LAPORJU,SPRSTENINASTA 20%)

Matična podlaga: LAPOR

HORIZONT: A11 globina: 0-13cm vlažnost hor.: SUH DO SVEŽ
struktura: DROBNO GRUDIČAST prekoreninjenost: GOSTE KORENINE organska snov: HUMOZEN
izraženost str.: SREDNJA konzistenca: DROBLJIV
obstojnost str.: SREDNJA

HORIZONT: A12 globina: 13-34cm vlažnost hor.: SVEŽ
struktura: GRUDIČAST prekoreninjenost: SREDNJE GOSTE KORENINE organska snov: SREDNJE HUMOZEN
izraženost str.: SREDNJA konzistenca: DROBLJIV
obstojnost str.: SREDNJA
Opombe horizonta: NEKOLIKO OPAZNI ZNAKI TRAV. NALAGANJA CaCO3

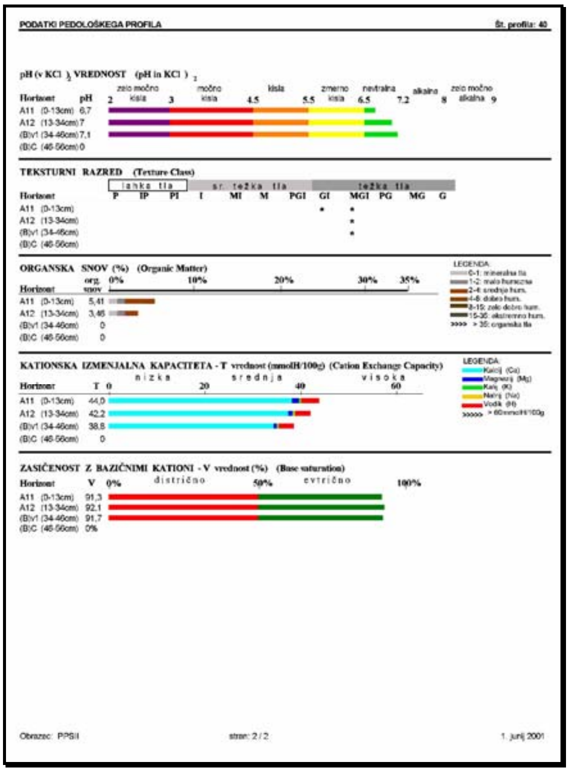
HORIZONT: (B)v1 globina: 34-46cm vlažnost hor.: SVEŽ
struktura: OREŠKAST prekoreninjenost: REDKE KORENINE organska snov: SLABO HUMOZEN
izraženost str.: SLABA skelet: POS.PREPER.LAPORJI konzistenca: DROBLJIV
obstojnost str.: SREDNJA
Opombe horizonta: SKELET V HOR.IN OBSTOJEN MEH.PREPEREVA

HORIZONT: (B)C globina: 46-56cm vlažnost hor.: NI PODATKA
prekoreninjenost: NI PODATKA organska snov: NI PODATKA
izraženost str.: NI PODATKA
obstojnost str.: NI PODATKA
Opombe horizonta: PREPEREVAJOČA MATIČNA PODLAGA PREVLADUJE LAPOR

LAB. ŠT.	HORIZONT	pH vrednost H_2O	KCl	acet	PESEK %	grobi MELJ %	fini MELJ %	skupni MELJ %	GLINA %	TEKST. razred	P_2O_5 mg/100g	K_2O mg/100g	OS %	C %	N %	C/N
285	A11		6,7		20,1	7,1	36,7	43,8	36,1	GI-MGI	2,1	15,1	5,41	3,1	0,30	10,4
286	A12		7,0		19,9	9,9	37,5	47,4	32,7	MGI	1,3	12,5	3,46	2,0	0,23	8,7
287	(B)v1		7,1		19,6	12,1	34,2	46,3	34,1	MGI						
0	(B)C															

LAB. ŠT.	HORIZONT	Ca (baze v mmol/100g)	Mg	K	Na	H	S (mmol/100g)	T	V %	Ca (baze v %)	Mg	K	Na	H	IDG	KARB %
285	A11	38,30	1,43	0,33	0,17	3,80	40,23	44,03	91,4	87,0	3,2	0,7	0,4	8,6		
286	A12	37,50	0,94	0,27	0,17	3,30	38,88	42,18	92,2	88,9	2,2	0,6	0,4	7,8		
287	(B)v1	34,46	0,86	0,26	0,17	3,20	35,55	38,75	91,7	88,9	1,7	0,7	0,4	8,3		
0	(B)C															

Obrazec: PPSII stran: 1 / 2 1. junij 2001



PODATKI PEDOLOŠKEGA PROFILA | Št. profila: 40

pH (v KCl) VREDNOST (pH in KCl)

zelo močno kisla | močno kisla | kisla | zmerno kisla | nevtralna | alkalna | zelo močno alkalna

Horizont	pH
A11 (0-13cm)	6,7
A12 (13-34cm)	7
(B)v1 (34-46cm)	7,1
(B)C (46-56cm)	0

TEKSTURNI RAZRED (Texture Class)

lahka tla | sr. težka tla | težka tla

P IP PI I MI M PGI GI MGI PG MG G

Horizont	GI	MGI
A11 (0-13cm)	•	•
A12 (13-34cm)		•
(B)v1 (34-46cm)		•
(B)C (46-56cm)		

ORGANSKA SNOV (%) (Organic Matter)

Horizont	org. snov
A11 (0-13cm)	5,41
A12 (13-34cm)	3,46
(B)v1 (34-46cm)	0
(B)C (46-56cm)	0

LEGENDA: 0-1: mineralna tla; 1-2: malo humozna; 2-4: srednje hum.; 4-8: dobro hum.; 8-15: zelo dobro hum.; 15-35: ekstremno hum.; > 35: organska tla

KATIONSKA IZMENJALNA KAPACITETA - T vrednost (mmolH/100g) (Cation Exchange Capacity)

nizka | srednja | visoka

Horizont	T
A11 (0-13cm)	44,0
A12 (13-34cm)	42,2
(B)v1 (34-46cm)	38,8
(B)C (46-56cm)	0

LEGENDA: Kalcij (Ca); Magnezij (Mg); Kalij (K); Natrij (Na); Vodik (H); > 60mmolH/100g

ZASIČENOST Z BAZIČNIMI KATIONI - V vrednost (%) (Base saturation)

distrično | evtrično

Horizont	V
A11 (0-13cm)	91,3
A12 (13-34cm)	92,1
(B)v1 (34-46cm)	91,7
(B)C (46-56cm)	0%

Obrazec: PPSII stran: 2 / 2 1. junij 2001

Figure 4: Standardised SIS report: Page 1: soil profile description; Page 2: brief interpretation for non-soil scientists

Measured Parameters: Soil Profile data

A soil profile is a vertical cross-section of a soil type from the surface to the parent material. It is representative of a soil type (SSU), and it is geographically oriented by x, y and z co-ordinates. A soil profile point layer contains data on physical and chemical soil properties obtained by standard soil analyses. Thus, SP/PP contains the attribute data for a SSU in a certain location. By the end of January 1999, the data from approximately 1,700 soil profiles had been compiled. The work is not finished yet, as apparent from Figure 3, and there are still some areas for which measured soil data are not available

The soil profile point layer is related to the attribute databases containing:

- The description of the profile site;
- Field descriptions of soil profile horizons (Figure 4);
- The standard soil laboratory analyses of soil profile horizon samples.

Soil Pollution Monitoring

The Soil Pollution (SP) layer contains the point data of concentrations of several organic and inorganic pollutants in soils. The soil sampling pattern performed on predefined sampling locations is standardised and defined by legislation (Official Gazette RS, 1997). One sampling point represents the centre of the 100m circle with six sub-sampling locations. From each, samples are taken at three different depths (0-5cm, 5-20cm and 20-30cm) and combined into three representative samples.

In addition to soil samples, the tissues of the test plant (Plantago lanceolata - narrow leaf plantain) are sampled in and around the circle and analysed (Hudnik *et al.*, 1994). Predefined sampling in regular grid covers the complete state territory. The density of sampling points is 2km x 2km in agricultural areas while forests and high-elevated areas are covered with a 4km x 4km grid.

In areas where there was anticipated to be contamination of the soil by heavy metals and pesticides, denser sampling was performed on a 1km x 1km grid in the late 1980s and early 1990s (Celje County, parts of the Ljubljana, Jesenice, Dravsko - Ptujsko Polje, Krško Polje and Region of Koper - Figure 5). Since July 2002, soil pollution data on 367 sampling have been stored in the SIS and available, interpreted according the legislation (Official Gazette RS, 1996).

In 1998, a new project financed by the Ministry of Environment and Physical Planning started. The aim of the project is to establish monitoring of soil pollution on selected predefined points for the whole of Slovenia.

Sampling location point attribute data consist of:

- Co-ordinates of the point and site description data;
- The concentrations of inorganic substances in soil samples (heavy metals);
- The concentrations of organic substances in soil samples (pesticides, PCB...).

The concentrations of heavy metals are determined in the test plant Plantago lanceolata - narrow leaf plantain.

Applications of SIS data

Because of the increasing availability of GIS tools, the demand for soil data is growing among land use planners, state institutions, civil engineers and students. The main projects through which the applicability and the advantages of the digital soil map data set were tested are described in the following sections.

Land suitability for agriculture

The results of this project are six raster databases at 100m resolution. Each of them represents the spatial information on suitability for certain agricultural use: arable land, vineyards, orchards, hops, grassland, and olive growing. A computer model was made for each database. The elaborated maps show the suitability of the land for the particular agricultural use. They were used in land use planning on at the state level.

Areas affected by drought in 2000.

A GIS raster model was designed to elaborate the raster (100m resolution) database of soils affected by severe drought in the year 2000. Beside DSM25 polygons, basic model input information was: soil parameters (water retention capacity), expert classification of soil systematic units and precipitation data, DEM 100m.

Soil pollution

Monitoring of soil pollution in Slovenia is described in (Lobnik *et al*., 1992, 1994; Zupan *et al*., 1995. A case study of soil and plant pollution in industrial areas in Slovenia is described in (Hudnik *et al*., 1994, Prus and Vrščaj 1994, Lobnik *et al*., 1994). An SIS report is shown in Figure 6.

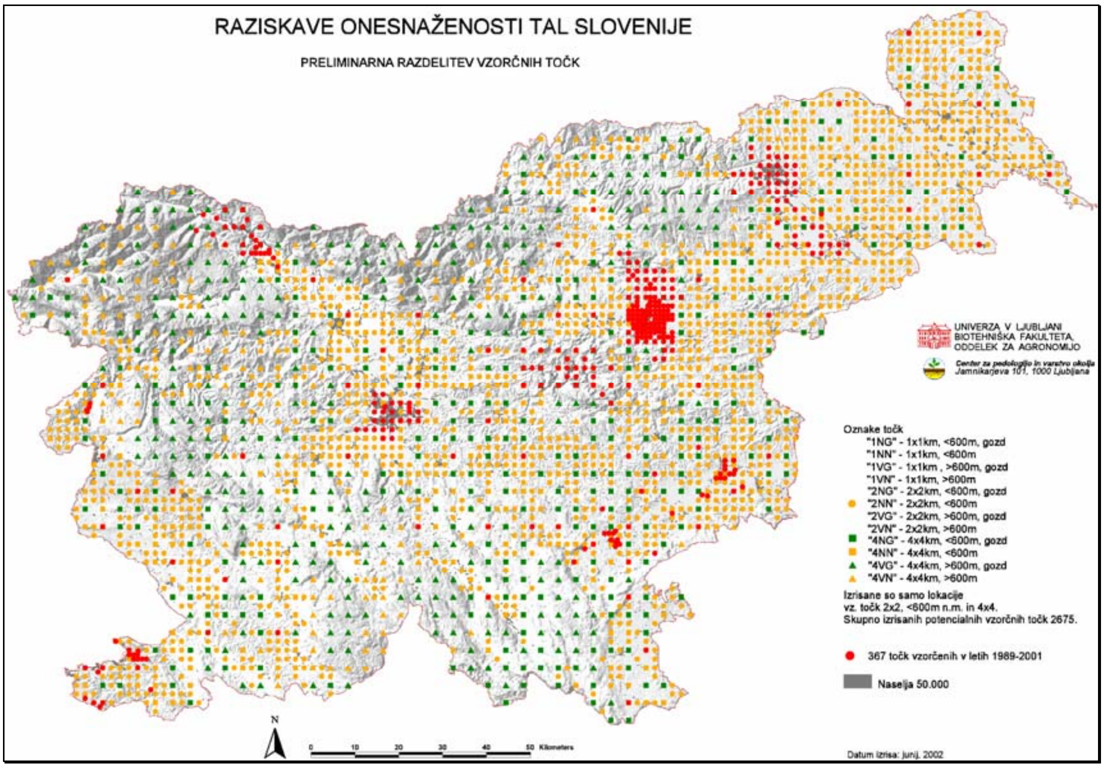
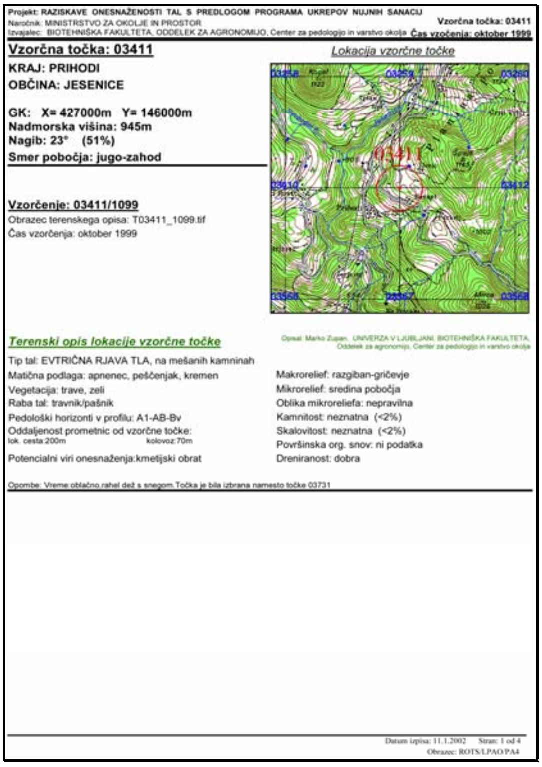
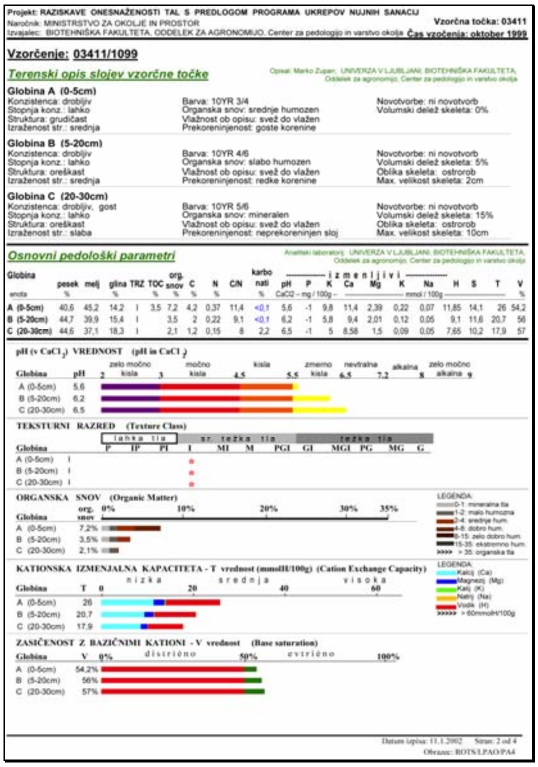


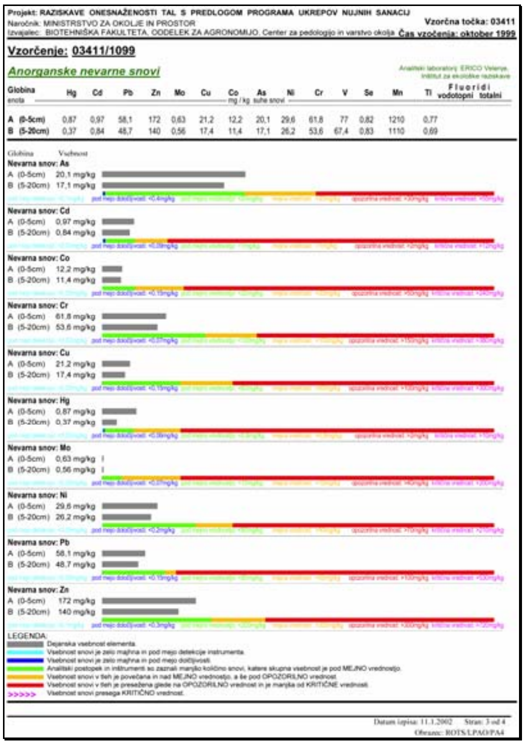
Figure 5: Predefined sampling locations according to the land use and elevation.
Red dots: locations of 367 sampling points with data available in SIS.


Projekt: RAZISKAVE ONESNAŽENOSTI TAL S PREDLOGOM PROGRAMA UKREPOV NUJNIH SANACIJ
Naročnik: MINISTRSTVO ZA OKOLJE IN PROSTOR
Vzorčna točka: 03411
Vzorčna točka: 03411
KRAJ: PRIHODI
OBČINA: JESENICE
GK: X= 427000m Y= 146000m
Nadmorska višina: 945m
Nagib: 23° (51%)
Smer pobočja: jugo-zahod
Vzorčenje: 03411/1099
Obrazec terenskega opisa: T03411_1099.tif
Čas vzorčenja: oktober 1999
Lokacija vzorčne točke
Terenski opis lokacije vzorčne točke
Tip tal: EVTRIČNA RJAVA TLA, na mešanih kamninah
Matična podlaga: apnenec, peščenjak, kremen
Vegetacija: trave, zeli
Raba tal: travnik/pašnik
Pedološki horizonti v profilu: A1-AB-Bv
Potencialni viri onesnaženja:kmetijski obrat
Makrorelief: razgiban-gričevje
Mikrorelief: sredina pobočja
Oblika mikroreliefa: nepravilna
Kamnitost: neznatna (<2%)
Skalovitost: neznatna (<2%)
Površinska org. snov: ni podatka
Dreniranost: dobra

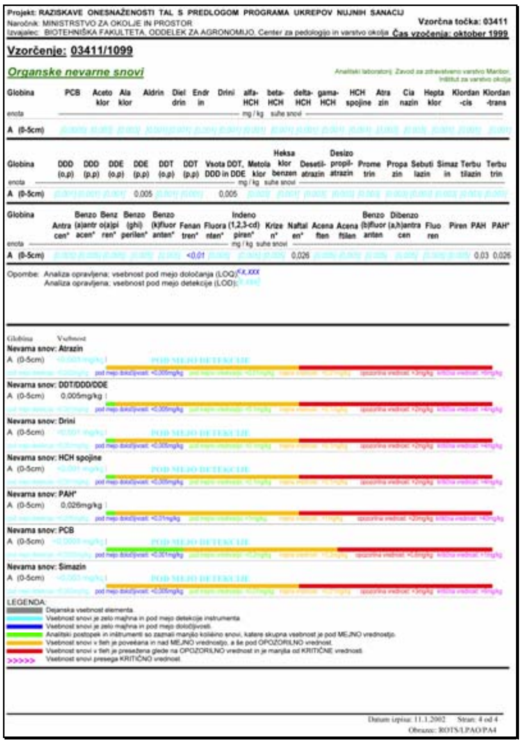
Page 1: data on sampling location


Vzorčenje: 03411/1099
Terenski opis slojev vzorčne točke
Globina A (0-5cm)
Globina B (5-20cm)
Globina C (20-30cm)
Osnovni pedološki parametri
pH (v CaCl2) VREDNOST
TEKSTURNI RAZRED (Texture Class)
ORGANSKA SNOV (Organic Matter)
KATIONSKA IZMENJALNA KAPACITETA - T vrednost (mmol/100g) (Cation Exchange Capacity)
ZASIČENOST Z BAZIČNIMI KATIONI - V vrednost (Base saturation)

Page 2: soil description, short interpretation


Vzorčenje: 03411/1099
Anorganske nevarne snovi

Page 3: Heavy metal concentrations interpreted according to the national legislation


Vzorčenje: 03411/1099
Organske nevarne snovi

Page 4: Organic substances, some of them interpreted according to the national legislation

Figure 6: Standard SIS four-page report on soil pollution at certain sampling points

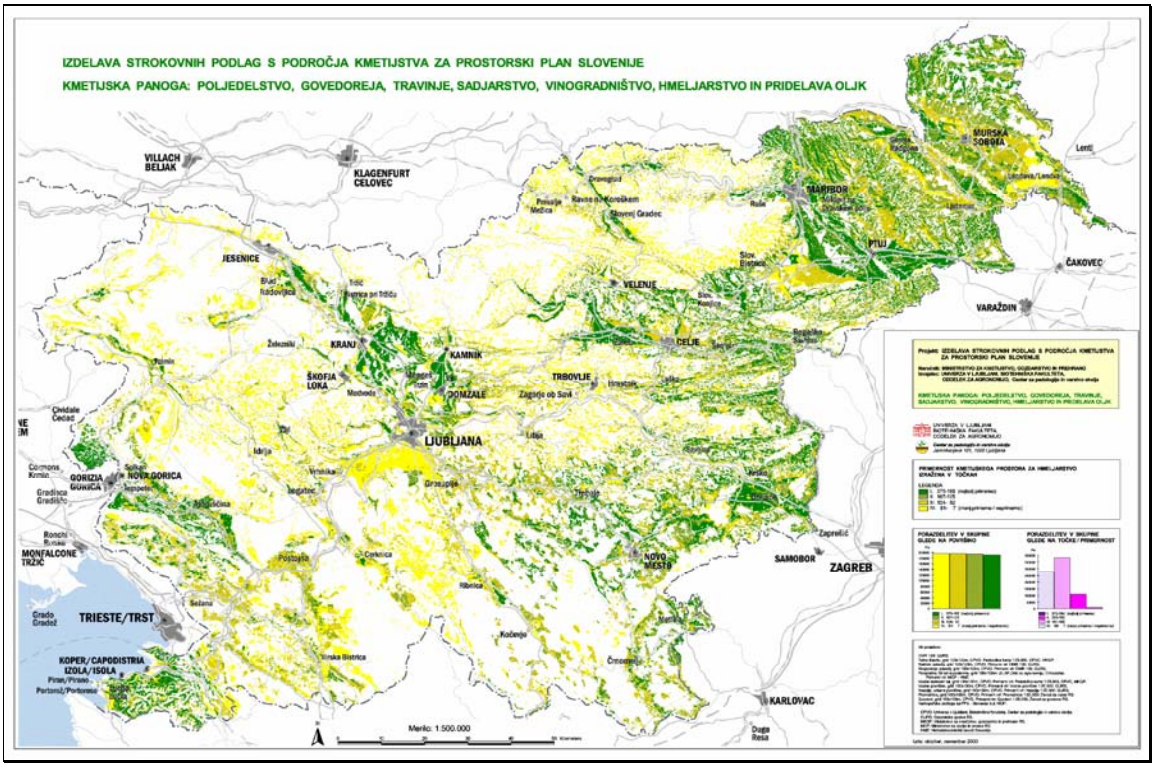


Figure 7: Suitability of land for agricultural production.
Dark green - very suitable; pale yellow - marginal agricultural land.

Natural limitations for agriculture

The raster database at 100m resolution shows the areas with limited capability for agricultural production. A GIS raster computer model was developed, with the basic input data being DSM25 polygons, DSM25 attribute data, soil-type suitability for agriculture (expert classification attribute data), DEM at 100m resolution (slope, aspect) and 30-year average precipitation data (see Figures 7 & 8).

Nitrate leaching

The problem of nitrate leaching in Slovenia is being evaluated in an ongoing project financed by Ministry of Environment and Spatial Planning. DSM25 with derivatives and data on actual agricultural practice are used as most important input data. Preliminary results (Figure 9) show that potential ground water pollution is high in places with permeable soils and where the good agricultural practice is not respected.

National Irrigation Programme

The proposed irrigation areas in Slovenia were analysed and classified according to 6 soil properties. As a result, 65 maps were plotted in which the soil suitability for irrigation was shown in 5 categories. A map of water holding capacity is shown in Figure 10.

Highway construction

The proposed routes for several highway sections were evaluated: Arja vas - Vransko, Blagovica - Šentjakob, Cogetinci - Radmožanci, and Vipava Valley. The loss of soils in the intensive agricultural areas and environmental impact on agricultural production have been estimated (Šporar *et al,* 1990, 1991; Prus, 1996; Rupreht *et al.*, 1994, 1995).

Important Digital Maps

At CSES several different soil and soil/land related digital maps have been completed with the help of DSM25:

- Soil map of Slovenia at the scale of 1: 400,000;
- Soil Map of Europe 1:1,000,000 - Slovenia;
- Soil map, 1:5,000 -areas of detailed projects;
- Land Cover /Land Use - Phare, Corine projects;

Work in Future vs. Needs

The future work is extensive and must focus on multi-functionality and applicability of data with the emphasis on the needs of the end-user who is often not a soil scientist. In reality much will depend on appropriate financial support but existing soil information should be adapted/enhanced to:

- Answer the national and European needs to protect landscapes;
- Reduce any kind of land degradation;
- Maintain soil quality and sustainability of soil and land;
- Serve the end-users better.

The following work is needed in the future:

- Improve and adapt existing soil information - soil maps to enhance the applicability and multifunctionality of data;
- Derive important basic soil parameters as separate datasets at a resolution suitable to be used at the county / watershed / landscape scale;
- Develop a set of pedotransfer functions to cover air and water related soil properties and to implement them in GIS modelling;
- Improve the spatial resolution and accuracy of DSM25 using high resolution DTM and EO data and new modelling techniques;
- Enrich the soil datasets with new data;
- Establish a very detailed national soil classification system, which is necessary for land use planning;
- Study, in detail, forest ecosystems as well as certain studies in the field of agronomy;
- Develop the possibility of converting national classification into world-wide systems;
- Explain certain phenomena in soil genesis which do not fit with known environmental conditions;
- Popularise and enhance knowledge about the significance of the soil as a natural phenomena and the dependence of humans on soil.

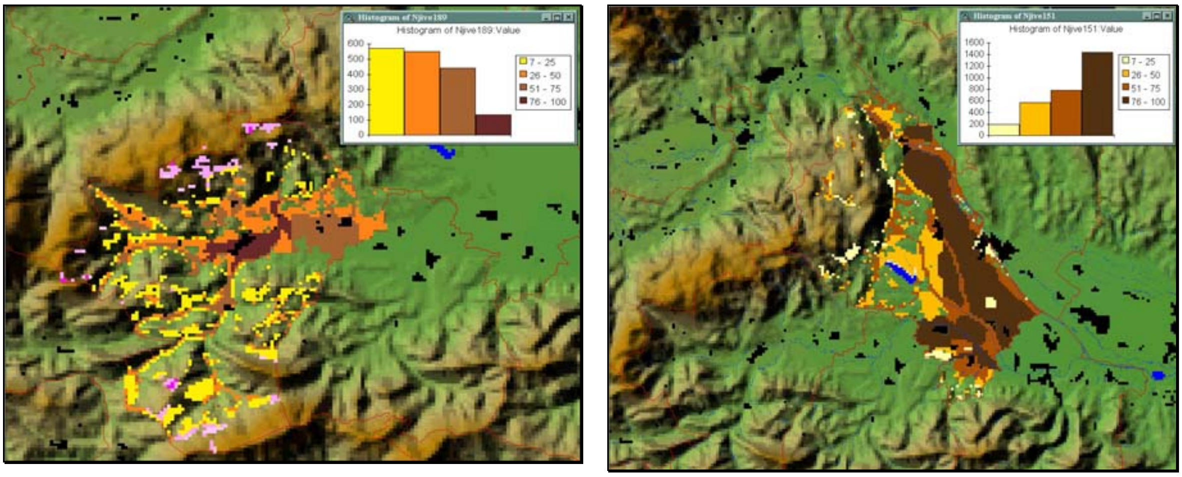


Figure 8. Evaluation of agricultural land according to the suitability for arable land - for two neighbouring counties.
The histograms show the hectares of best arable land (dark brown) and less suitable agricultural land (pale yellow).

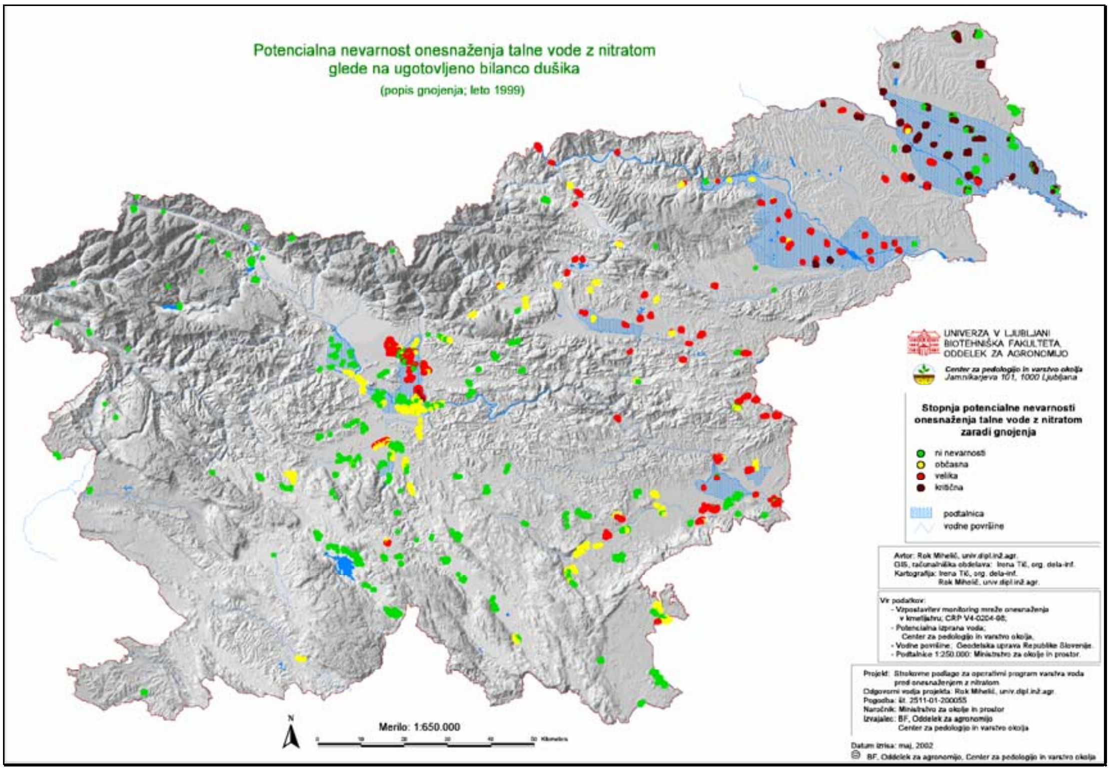


Figure 9: Preliminary results of potential pollution of ground water with nitrates

Green - no risk   Brown - very high risk.

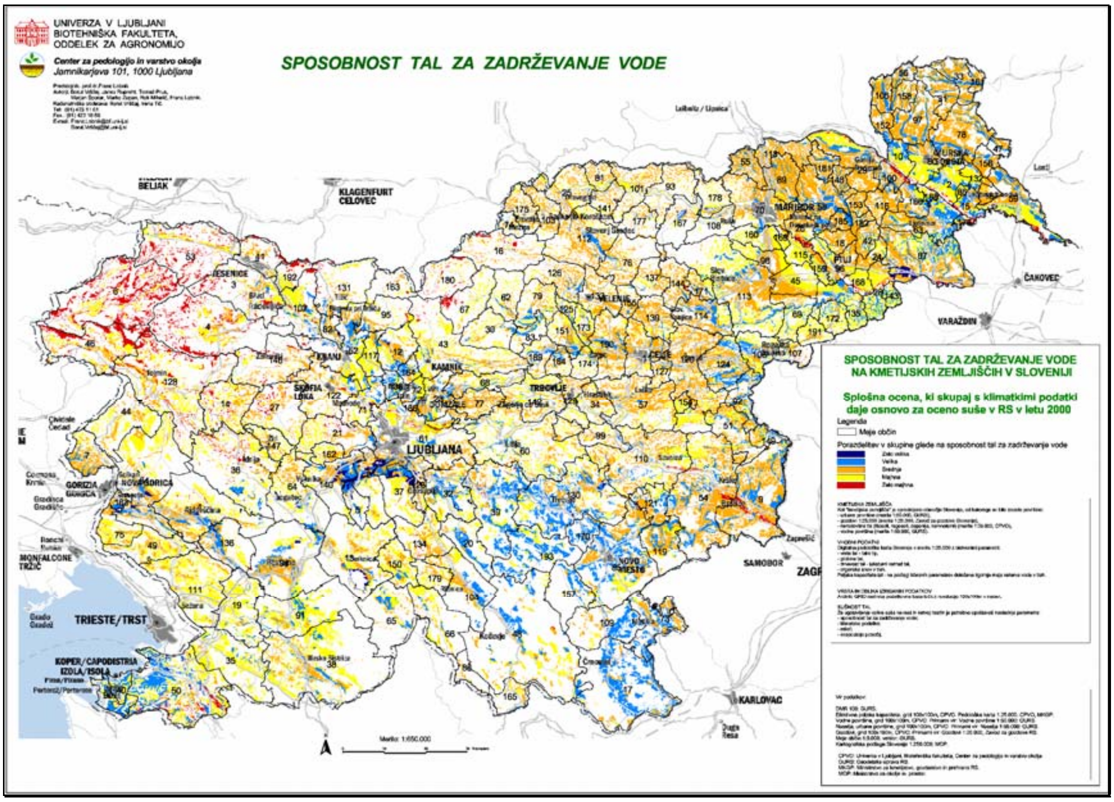


Figure 10: Water holding capacity of soil of agricultural land in Slovenia.
The printout from the raster database

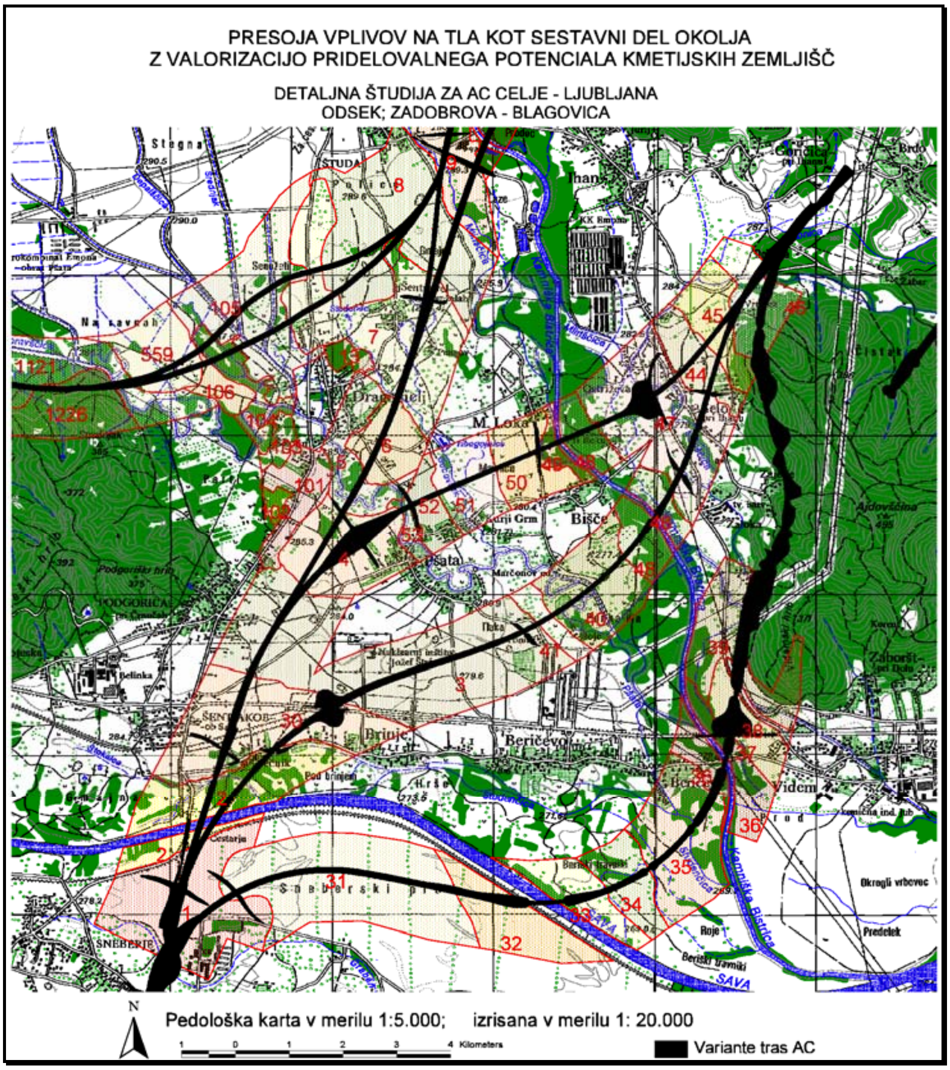
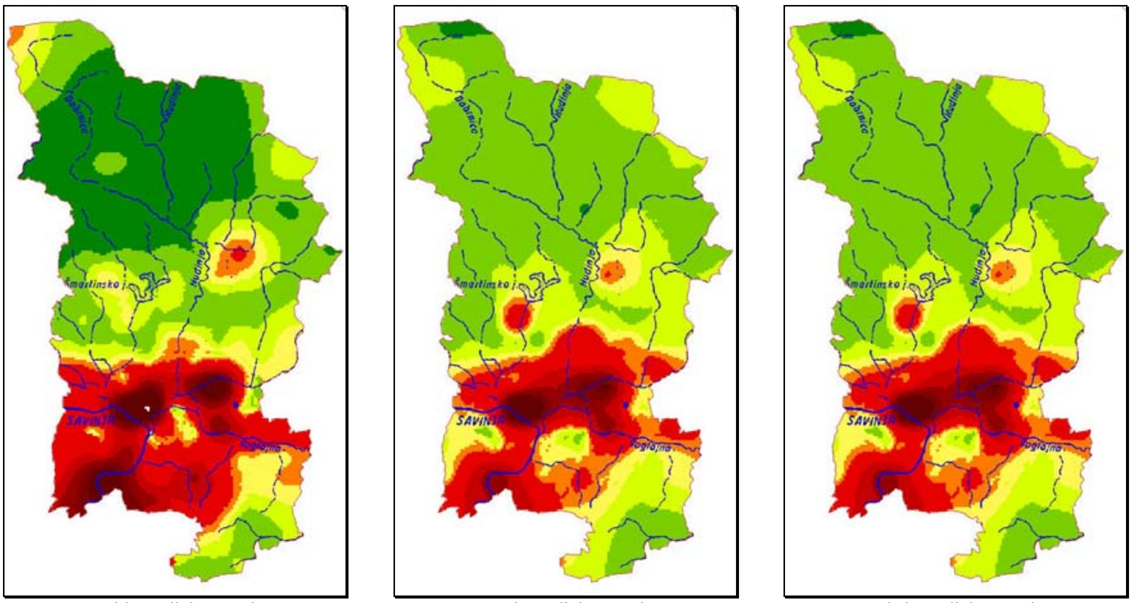


Figure 10: Evaluation of proposed highway routes; section Zadobrova-Blagovica.



Cd in soil (0-5cm) Zn in soil (0-5cm) Pb in soil (0-5cm)

Figure 11: Celje County case study. Soils polluted with Cd, Zn and Pb according to the national legislation.

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Collection of Soil Information in Spain: A review in 2003

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Introduction

Meetings of European Union Heads of Soil Survey Organisations were held in 1989, 1994 and 1998 respectively. All were followed by the publication of monographs describing the state-of-the-art in each of the member countries (Hodgson 1991; Le Bas and Jamagne, 1996; Bullock *et al.* 1999). Limited progress has been made in Spain since the last of these meetings, except for the launching for an ambitious macroproject (Plan Nacional de Cartografia Tematica Ambiental, PNCTA), that was abruptly interrupted in 1998. Readers interested in historical aspects of Spanish pedology and/or soil mapping can refer to Díaz Fierros (1979 and 1997) Mudarra (1989 and 1994); Sunyer (1996), Ibáñez *et al.* (1991, 1997, 1999), Boixadera and Ibáñez, (1996), Guerra, (1997), Porta *et al.* (1994) and Donezar (2003).

This paper describes progress in soil survey from 1998 to 2003 and provides additional information on soil mapping, soil monitoring and soil databases in Spain in the period 1994-2003. Nevertheless, some Spanish soil databases coming from initiatives in Pan-European programmes are not included in the discussion here due to their particular scope.

The Spanish contribution to the ICP Forest programme, published on a CD-ROM that holds morphological, taxonomic and analytical information corresponding to 453 soil profiles, is a case in point (Montoya and López-Árias, 1998).

Changing the perception of the soils role in Europe

As in all developed societies, Europe is living the 'era of environmentalism'. We all know well that this has changed the type of demands for soil information in the EU's 6th Framework Programme of Research and Development. In addition, the United Nations as well as the European Union, among other international institutions, has begun to acknowledge that soil resources are at risk of further degradation.

Over the past years, the awareness of pedosphere deterioration as a consequence of anthropic activities has been growing. As a corollary, there have been emergency calls to rationalise its use. Thus, the United Nations Environment Programme (UNEP), published the report 'Down to earth: Soil degradation and sustainable development in Europe: A challenge for the 21st century'. This report outlines and assesses the threats to Europe's soils and suggests some solutions. Likewise, the European Environment Agency (e.g. EEA 1995, 1999), has repeatedly drawn attention to the fact that European soils are one of the most degraded components of the natural environment. Furthermore, legislation on soil protection is either weakly defined or non-existent in many parts of the continent. This may become, in particular, an important challenge for sustainability and will require a common approach. In similar terms, the UNEP's executive director stated: "The sustainable use of soils is one of Europe's greatest environmental, social and economic challenges; although often overlooked, soil is a natural resource that is no less important to human well-being and the environment than clean water and clean air" (see http://www.eea.eu.int, http://www.unep.ch and CORDIS RTD-NEWS/EU,).

Furthermore, in the 16th World Congress of Soil Science (Montpellier, 1998), the International Union of Soil Sciences (IUSS), through its Secretary General, launched an initiative in order that the United Nations support a 'Soil Convention', like others (climatic change, desertification and biodiversity). For these reasons and during Spain's Presidency of the EU in 2002, an official Communication from the Commission to the Council, The European Parliament, The Economic and Social Committee and The Committee of the Regions, entitled 'Towards a Thematic Strategy for Soil Protection', was launched. The authorities of the European Union approved this document (June 25, 2002), coinciding with the end of the Spanish Presidency.

On 18 July 2002, the Council of the European Union, ratified the Communication and published the 'Council Conclusions on Integrated Soil Protection' (Council of the EU, 2002). In 2003, the DG Environment initiated a consultation with stakeholders preparatory to developing the Thematic Strategy for Soil Protection in Europe.

As a consequence of the agronomic bias of the activities related to the collection and use of soil information (Ibáñez and Boixadera, 2002), the potential role of pedology in solving environmental deterioration is not yet fully appreciated by politicians, environmentalists and citizens alike.

Meanwhile attention has been drawn to the decline in soil science and the lack public support for the subject (Boixadera e Ibáñez, 1996; Ibáñez *et al.* 1997, 1999; Ibáñez and Boixadera, 2002). It is clear that in most European countries the number of soil scientists and funding for the study of soils has decreased significantly since the 1970s (Ibáñez and Boixadera, 2002)

Reaction of Spain to Soil Protection

The Spanish Government initiative at EU level marks a turning point for European soil protection. The Spanish Ministry of Environment (MIMAN) has consulted national experts and agreed the formation of technical working groups (TWG) that parallel those set up at European Level. The IGME (the EIONET Spanish Focal Point on Soil), in co-operation with MIMAN, have the responsibility for co-ordinating the Spanish TWGs.

In summary, although the Spanish Government was instrumental in launching the EU initiative on soil protection, the position regarding soil protection at national level has not changed significantly from that previously described by Ibáñez *et al*. (1991), Boixadera and Ibáñez (1996) and Ibáñez *et al*. (1999).

Problems of Pedology and Soil Information

Through its National Pedology Institute (Instituto de Edafología y Biología Vegetal, now known as *Centro de Ciencias Medioambientales* - Environmental Sciences Centre), and its twelve regional centres (currently under autonomous status), the Consejo Superior de Investigaciones Científicas (CSIC or Spanish National Research Council), was an active Institution (in co-operation with the Universities and INIA) in the field of pedology and soil surveying during the 1960s and 1970s. Whilst the outputs from this period had certain shortcomings, such as the fact that most soil maps were made at a small scale (1:200,000) (Donezar, 1981; Mudarra, 1989; Boixadera and Porta, 1991, there is no doubt about their significant contribution to the improvement in the knowledge of the Spanish soil resources.

However, the application of a new scientific policy in Spain during the 1980s created a situation that affected profoundly (both positively and negatively) some disciplines such as soil survey (Rey *et al.* 1998). According to Ibáñez *et al.* (1997) this led to a decline in the funding for soil surveys and a transfer of responsibility for soil survey to the Regional Autonomous Institutions. These activities suffered from a lack of coordination, and an over-emphasis on environmental problems. The outputs tended to be interpretations of existing information, using Geographical Information Systems (GIS), rather than basic information about the soil resources of Spain.

During the 1980s, CSIC lost its role as the institution responsible for the coordination of the national soil survey activity and no other institution took its place. This had a significant impact on the development of soil science in the country and led to the decline of pedology as an integrating discipline not only within CSIC but also at national level.

In 1998, the Ministry of the Environment (MIMAN) assigned to the Technological and Geomining Institute of Spain (IGME) the responsibility for being the National Reference Centre on Soils.

Currently there are some Autonomous Regions that have made soil inventories, whilst in others no inventories have been or are being made. It is also unfortunate that different methodologies and soil classifications are used in different regions. Furthermore, there is a serious lack of information on soil physical properties.

By contrast during the past few years, research on soil quality has been growing, but to date there is competition between CSIC and University departments on soil monitoring work, whilst, at the same time, the Spanish task force on soil survey has been declining.

Main Projects 1994-2003

Four national programmes and one regional programme of research, related to the collection and management of soil information, were ongoing between 1994 and 1998 (Ibáñez *et al*., 1999).

IRNAS Soil Database (SEISNET)

Over the last 15 years the IRNAS centre has placed particular emphasis on getting previously collected soil information into a useable format. Interpretative procedures, to facilitate practical use of such basic information and dynamic quantitative modelling, have been developed to predict soil productivity potential, the susceptibility of soils to degradation and the impact of climate changes on the pedosphere.

At first, a geo-referenced soil database (SEISNET) was developed in collaboration with FAO/AGLS and ISRIC (FAO-ISRIC-CSIC, 1995). A major part of this database consisted of morphological and analytical descriptions of soil profiles produced by IRNAS throughout more than 40 years, mainly in Western Andalusia and Valencia. The long-term objective was the development of a national soil database but interest from MIMAN waned and, at the present time, IRNAS merely maintain SEISNET on a web site. The system has not met with universal approval by Spanish pedologists and it can be considered a non-official regional database. In fact, the Andalusia Regional Government have an active Institutional database (SINAMBA), that is not available to public.

SEISNET does not follow the Manual of procedures on the development of georeferenced soil databases according to European guidelines, published by the European Soil Bureau (Finke *et al*. 1998). However, additional technical information is available in Ibáñez *et al*. (1999) and de la Rosa *et al*. (2002, 2003).

CIEMAT Soil Database

CIEMAT assembled a soil database to support the study of critical loads on Spanish soils. It is understood that computerised morphological and analytical data from more than 2,000 soil profiles were compiled, though the technical details of this initiative are not readily available.

CCMA Digitised Map Library

In response to the requirements of the European Soil Bureau, the Environmental Science Centre (CCMA) produced a digitised map library of pedotaxa and soil forming factors in order to respond to national and international requests for soil information (J.J. Ibáñez pers comm.). The initial aim of this map library was to act as a basis for the subsequent establishment of a nationwide Soil Information System (SIS) at small scales (e.g. 1:1,000,000). A collaboration contract between CSIC and the Spanish Society of Soil Science is near agreement and will result in publication of data on a CD Rom (Carrera, 1998; Ibáñez *et al*., 1999).

Expected developments include linking with a soil database and additional modelling routines, and finally, to develop an SIS with capability to respond to demands for pedological information (e.g., soil erosion risk, vulnerability of soils to contamination, likely effects of climate change, etc.) at broad scales for the whole of Spain. However, to date, funds for further expansion of these activities have not been made available.

National Environmental Cartography Theme Plan

General aspects

The National Environmental Cartography Theme Plan (PNCTA) was initiated in 1995 by the Ministry of Public Works, Transport and the Environment with development in compliance with the Royal Decree no. 1056/95 of 23 July ('Design and Implementation of an Environmental Cartography System in cooperation with the National Geographical Institute'). The proposal for, and establishment of, the Plan was jointly agreed with the Autonomous Communities.

The Plan was concerned with the nationwide drafting of different thematic maps: plant communities, land use, lithology, geomorphology and surface processes, soil types and natural heritage (sites of special geological and biological interest). The mapping scale proposed was 1:50,000 and the Technological and Geo-mining Institute of Spain (ITGE) was nominated to manage the Plan.

Soil Mapping

In the design (pilot) stage of the PNCTA, the task was to map the soils at 1:50,000 scale, using a common methodology for the whole of Spain. It was planned that the product format would be standardised, and digitised by implementing a user-friendly GIS environment, capable of being accessed from any part of the country. Both the soil maps and GIS outputs were expected to contain information to be used for land and environmental planning, and be a source of basic documentation for environmental impact studies. The soil mapping units were defined on the basis of types of cartographic units.

Soil Classification. The classification reference systems are: (a) the Soil Taxonomy (Soil Survey Staff, 1995) at a Subgroup level and (b) the third level of the FAO units (FAO-UNESCO, 1988).

Capacity Indicator. This was defined as the set of soil and environmental parameters and attributes reflecting the intrinsic capability for agricultural use.

Vulnerability Indicator. This was defined as the set of limitations restricting the possibilities of using the soil in a particular place. The parameters that shape the indicator reflecting soil vulnerability to degradation are: (i) potential water erosion risk, (ii) risk of salinisation and/or alkalisation, and (iii) contamination risk. Additional technical information can be found in Ibáñez *et al.* (1999).

Seven soil maps for the eleven areas, representative of the different climatic regions of the country, were made in the pilot stage. The pilot areas were distributed among different Autonomous Communities. A Technical Standard was drafted for drawing up the soil maps (Sánchez, Colomer and Nieves, 1996, unpublished). An *ad hoc* Committee of the Spanish Society of Soil Science subsequently discussed this Draft. The final document included a description of the overall methods, soil database design used from FAO-ISRIC-CSIC (1995), and format and legend of the map. The maps for the aforesaid pilot areas were drawn up and presented during 1997 (e.g. ITGE, 1997) and the general plan was to have been implemented from 1998.

RESEL Monitoring Network

Unfortunately, this is the only national programme that remains active of those described by Ibáñez *et al*. (1999). The Experimental Erosion Monitoring and Evaluation Station Network -RESEL- in the LUCDEME Project (Combatting Desertification in the Mediterranean) started in its pilot stage in 1995. Currently, with other complementary initiatives, the RESEL Network is a keystone of the recently approved Spain Desertification Programme. The RESEL Network was an initiative of the Directorate General for Nature Conservation (Spanish Ministry of the Environment). The main aims of RESEL are:

- Coordinating and integrating the catchment basins of the Network's stations and plots representative of the major erosion landscapes in Spain;
- Standardising instrumentation and field methods used at all stations for acquiring data and procedures for processing and storing the information obtained;
- Testing erosion, soil and water management systems, and erosion techniques;
- Coordinating and integrating the Network's stations.

RESEL currently involves 21 associated research centres belonging to various Universities and CSIC. There are a total of 41 experimental stations, distributed over 12 Autonomous Communities (Figure 1): Andalusia (5), Aragón (7), Balearic Islands (1), Canary Islands (2), Castilla-La Mancha (3), Catalonia (6), Extremadura (1), Galicia (5), Madrid (2), Murcia (4), Navarra (1), and Valencia (3).

Within the RESEL framework, it is intended to establish a nationwide database to cover erosion processes, hydrological cycles and water quality. The aim is for field and derived data to be used to design preventative actions and use and management plans in the areas most vulnerable to desertification.

The RESEL-1996 Stations Handbook gives a detailed description of the different experimental facilities in the plots and catchments at the time of starting the Network (Rojo-Serrano and Sánchez-Fuster, 1997).

It includes an ecosystem characterisation for each station as well as an itemised description of the facilities, instruments used and the variables recorded. Currently in 2003, the stations comprise experimental areas with a total of 139 plots presenting facilities for monitoring water erosion (at 29 of the 41 stations) and others where small drainage basins are monitored (at 17 of the 41 stations).

The size of the experimental plots ranges between 0.003 and 0.2 hectares and the area of the experimental basins ranges between 2 and 72,600 hectares. A total of 21 stations are located in humid to sub-humid environments with mean annual precipitation over 600mm, 19 stations represent semi-arid environments and the remaining station (Canary Islands) an arid environment with a mean annual precipitation of 130mm.

Table 1 gives a synthesis of the ecosystems and land uses represented in the different stations updated in 2003. One station can support more than one kind of land use or vegetation. The land use of shrubs and/or brush is the most studied, being monitored in 32% (19) of all stations. Abandoned fields in the 17% (10) of the stations and forest in the 15% (9) of the stations are the next two most studied land uses, while in contrast there is only one station monitoring the erosive responses of horticultural crops and two stations including ecosystems affected by fire.

INES Programme: Spanish Inventory of Soil Erosion

This is the second keystone of the Spanish Plan against the desertification in Spain. The National Inventory of Soil Erosion (INES) is based on previous work done by the National Institute for the Conservation of Nature (ICONA), which applied a methodology based on the Universal Soil Loss Equation (USLE) to generate Maps of Erosive States for each of the main catchments in the country (1987-2002). INES intends to improve and update these maps, with the general objective of getting a better and more detailed vision of soil erosion by water and wind.

The final aim of the project is to define, as precisely as possible, the priority areas where actions to fight against soil erosion need to be taken, and to design and evaluate these actions. More specific objectives (Donezar, 2003) are:

- To detect, quantify and map the main processes of soil erosion within the Spanish territory, both in digital and graphic formats;
- To analyse the evolution of soil erosion in Spain through comparisons between inventories from different years, including a monitoring framework; To serve as a tool for the coordination of policies regarding soil conservation at regional, national and European levels;
- To produce an easily accessible data system which can be used for educational and participatory purposes;
- To develop a key element for the European network of environmental information and communication;
- To provide some Pan-European indicators of sustainable management of forests, in a quantitative context.

The project was initiated in 2001 and should be concluded in 2012. The results will be especially useful for planning purposes, with many applications in fields such as hydrology, forestry, fight against desertification, soil conservation, land resource management or agrarian and urban planning.

The inventory is structured into five modules that cover different forms of erosion (Donezar, 2003):

- *Module 1: sheet and rill erosion:* This module involves a large amount of fieldwork. The Revised Universal Soil Loss Equation (RUSLE) is applied in previously defined plots. The R factor is obtained from rainfall data from a network of weather stations. A DEM is used to derive the LS factor. K, C and P factors are obtained from fieldwork, which includes sampling and laboratory analysis;
- *Module 2: gully erosion:* The aim of this module is to identify this type of erosion. The areas affected by this type of erosion are mapped by photo-interpretation of recent aerial photographs and the results are digitised;
- *Module 3: mass movements:* The territory is divided into different zones according to the different degree of potentiality to suffer mass movements and to the dominant typology. Existing information about basic risk, seismic activity and occurrence of these phenomena is used for this purpose;

Figure 1: Location of the RESEL experimental stations
(Source: Rojo-Serrano and Sánchez Fuster, 1997)

Table 1: Summary of land uses at the RESEL Stations.

Land Use	RESEL Stations	% of total
Forest	9	15
Dehesa (forested grassland)	1	2
Shrub and brush	19	32
Grasslands	2	3
Abandoned fields	10	16
Herbaceous crops (drylands)	7	12
Horticultural crops	1	2
Badlands and gullies	5	8
Burnt lands	2	3
Mixed land uses	4	7
Total	60	100

- *Module 4: riverbed erosion:* This module sets out to make a qualitative classification of the land units that compose the territory, based on the degree of susceptibility to devastating forms of erosion over the drainage basin. The value of potential riverbed erosion risk in each hydrologic unit is calculated from different factors such as slope, parent material, rainfall intensity, sheet erosion and mass movements;
- *Module 5: wind erosion:* Areas susceptible to suffer this form of erosion are mapped by identifying areas of deflation (areas with slopes less than 10% and a minimum surface of 2,500ha), and analysing the relevant factors in these areas (wind, vegetation cover and soil). Regarding the soil factor, both the textural erodibility (clay, loam and gravel percentage) and the analytical erodibility (carbonates and organic matter) are considered.

Some other aspects concerning the national inventory are worth mentioning:

- Homogeneous and available information for the whole of Spain is used. The information, in digital format, is being integrated into a GIS;
- The different themes (covers) can be consulted and the results can be viewed at the more detailed scale of 1:50,000;
- The work will be carried out in a continuous cycle, with a 10-year frequency. The first cycle

(inventory) will be carried out between 2002 and 2012. Comparisons over time will be possible when the base maps and the field data are updated (monitoring);

- The work will be structured by province in order to be consistent with the preparation of other inventories, specially the National Forest Inventory and the Spanish Forest Map at scale 1:50,000. The area occupied by agricultural land has been classified using the Map of Crops and Land Uses of the Ministry of Agriculture, Fisheries and Food at scale 1:50,000;
- The regional inventories will be disseminated by means of publications, which include texts, tables and maps on paper format and also a CD with a large amount of alphanumerical and graphical information.

Up to the end of 2003, INES has completed and published the work for two Spanish provinces (Madrid and Murcia) and the results for other two provinces (Lugo and A Coruña) will soon be available (currently in press). The fieldwork for the provinces of Baleares, Rioja, Navarra and Asturias has also been completed and the information gathered is being processed. Fieldwork for the provinces of Pontevedra, Ourense, Tarragona, Girona and Cantabria is already planned and should last until June 2004.

Thus, due to its structure and development, INES constitutes an indirect instrument for the Soil Monitoring System in Spain (Donezar, 2003). The density of sampling used to estimate sheet and rill erosion is one observation every 2,500ha, which makes a total of 20,000 sampling points for the whole of Spain. Proposals for a future soil monitoring system at EU level include a sampling density of one per 16km x 16km which, for the whole of Spain, would total 2,000 to 2,500 observation points.

MIMAN Inventory of Contaminated sites

The MIMAN contains an inventory of all potentially contaminating activities and contaminated sites throughout Spain. However, at the present time, the precise characterisation of such places is far from complete. The Instituto Nacional de Investigaciones **A**grarias (National Institute of Agricultural Research) - INIA, through its Forest Ecosystems and Agro-biosystems Laboratory, is carrying out several tasks related to soils.

The first example is the creation of a map of heavy metal and organic matter contents in Spanish soils, carried out during 2002 and 2003, through an agreement between the Ministry of Agriculture and the Ministry of the Environment. The project is based on the systematic sampling of arable and pasture soils following a 8km x 8km grid. Composite samples, made up from 21 sub-samples obtained within a radius of 25m around each sampling point, following a random scheme and sampling the first 25cm of soil, are taken.

The samples are being analysed in the laboratory for content of coarse fragments, particle-size (sand, loam, clay), Ca, Mg, soil pH, electrical conductivity, carbonate, organic matter, and heavy metals - Cr, Ni, Pb, Cu, Zn, and Cd. A total of 3,670 samples were collected during the sampling campaign. Of these, 1,200 samples come from pasture soils and the remainder from agricultural (arable) soils. A total of 2,600 samples have been analysed up to December 2003.

The second project is aimed at studying the nitrogen extraction rate in pasture soils, by assessing the mean production of dry matter on the different types of pastures and modeling the variability of their potential productivity against the yearly weather variables. Samples from previous studies, as well as results from other studies reported in the literature, are used in order to determine the soil water retention properties. The work is being funded through an agreement with the Ministry of Agriculture, which, at the time this report was in preparation, will be operative till the end of 2003.

Finally, the effects of atmospheric pollution and other stress factors on the Spanish forest ecosystems are being analysed within the framework of the Pan-European ICP Forest programme (Effects task group). Further details, are given by Montoya and López Arias (1998).

Autonomous Communities and other projects

It is very difficult to carry out an inventory of all activities related, directly or indirectly, with the gathering of basic spatial and temporal soil information is Spain. As far as is known, Andalusia maintains soil survey activities in order to finalise as soon as possible its soil mapping programme at 1:50,000 scale. In addition, this Autonomous Community is preparing a soil map, at the scale 1:50,000, of all protected areas in the region, the purpose of which is to provide a better understanding and management of the regional natural heritage.

On the other hand, two years ago, Galicia Autonomous Region began a full inventory and soil mapping at the scale 1:50,000, using the World Reference Base classification (FAO, 1998). Finally, Asturias Autonomous Region has recently begun a pilot project with the same aim and approach to that adopted by Galicia. Other Regions (Valencia, Catalonia, etc.) continue to follow the activities described in the previous report (Ibanez *et al*,. 1999). However, this section cannot provide an exhaustive list of such activities.

Among the soil surveys being digitised or published it is worth mentioning the soil maps from LUCDEME project - Fight Against Desertification in the Mediterranean. One of the main outputs of this project will be the soil maps, which cover most of the project's study area (SE Spain). These are a very important tool for the design of specific remediation actions in the affected areas and 138 sheets of the Soil Map have been generated.

The following universities and research centres have participated in the LUCDEME project: University of Murcia, University of Granada, University of Sevilla, University of Almería, University of Valencia, the Zaidín Experimental Station (Granada) and the Desertification Research Centre-CIDE (these last two centres belonging to the Spanish Research Council).

The soil maps are made by establishing cartographic units, which describe the dominant soil associations (those which occupy more than 20% of the unit area) and inclusions (soils occupying 5 to 20% of the unit area). Each map comes with a report that describes the main characteristics of the area covered by the corresponding sheet. The maps are presented at scale 1:100,000. Also Galicia (Xunta de Galicia) is now publishing soil maps at scale 1:50,000 and several sheets are already available.

Soil Inventory, Soil Monitoring and a New Research Framework

After many decades during which the importance of soils in agricultural production was predominant, and the need for research into soils for this purpose met, the focus has now shifted to environmental problems (Ibáñez *et al.*, 1993; Yaalon, 1996). The EU Common Agricultural Policy (CAP) directives, for example, give priority to reducing agricultural production, with a view to reducing surpluses and reducing or preventing environmental pollution from agrochemical products.

With respect to the environment, soil degradation problems (e.g. contamination and erosion) are of high priority. The European Environmental Agency (EEA, 1999) has reported that these major environmental problems were amongst the ones showing little or no improvement as a result of national policies. There is also concern about the sustainability of some land use practices, as highlighted by the initiative promoting a global 'Soil Convention on the Sustainable Use of Soils' (Catizzone, 1998).

The current trend in policy making and reporting on the state of the environment (e.g. Huber, 2001, 2002) places emphasis on monitoring the loss and degradation of the natural resources at the expense of making or continuing basic inventories. Yet good quality detailed spatial information on soils is vital for implementing adequate soil protection measures. One of the lessons to be learned from some other monitoring programmes is that the practitioners did not have sufficient knowledge of the resource to be monitored and, as a result, adopted in appropriate sampling designs.

The proposal for site stratification of key national sites, benchmark sites and specialist sites of EuroSoilNet (Huber, 2001, 2002) is compatible with the ESB framework to implement a future Soil Database of EUSIS at scale 1:250,000 with reference to areas at the scale 1:50,000 or 1:25,000. Furthermore these approaches are also compatible with the proposal made by Ibáñez *et al*. (2004a) for the design of a network of soil reserves for conserving soilscapes and taxonomic pedodiversity.

These reserves (Ibáñez *et al*,. 2003 and Ibáñez *et al*., 2004b) could be used to:

1. Conserve soilscapes diversity (pedologic functional units);
2. Conserve taxonomic pedodiversity;
3. Conserve soil biodiversity; Conserve benchmark soils to soil quality and monitoring studies;
4. Detect hotspots of soil pedodiversity (and as we have written above, also of soil biodiversity);
5. Detect hotspots of soil degradation;
6. Detect hotspots of natural heritage interest (e.g. paleosoil scapes).

The so-called 'minimum data sets' for soil quality studies is a matter of concern. Do we really have the sufficient scientific knowledge to be precise about which variables should be included in these minimum datasets? Furthermore, minimum data sets may not be universal but geographically constrained? (Lobo and Ibáñez, 2002; Ibáñez *et al*., 2004c). Support for basic soil science should not follow environmental fashion, thus running the risk of being replaced by other fashions.

Therefore, it seems important that pedology and soil survey develop a new paradigm and evaluate new conceptual, methodological and technological tools. Since a detailed description of these topics is beyond the scope of this paper, readers interested in them are referred to the reviews made by Zinck (1990, 1993), Ibáñez *et al.* (1993, 1994) Ibáñez and Boixadera (2002) and Basher (1997), as well as the monographs published by Mausbach and Wilding (1991) and Bryant and Arnold (1994). However, a provisional but non-exhaustive list of new requirements is given below.

For the collection of soil information, this new approach would require the following:

- Better understanding of the spatial variability of soil properties and pedodiversity of soil taxa;
- Better understanding of temporal changes in soil properties (research on soil monitoring methods);
- Improvements in cartographic representation of the pedosphere;
- Mapping of soil bodies and soilscape functional units;
- Better techniques for designing sampling schemes for soil mapping and spatial analysis of the pedosphere;
- Better characterisation of regoliths to depths below those traditionally considered in the soil survey;
- Improvements in mathematical tools for scaling soil data from site-specific to regional and global territories.

Conclusions: Problems Collecting Soil Data

Spain has experienced a serious decline in resources, both human and capital, for soil survey and pedology in the recent past. The absence of a National Soil Survey organisation and the temporal discontinuity of survey programmes have aggravated this decline.

Policies of decentralisation in matters of agriculture and natural resources and environment have given rise to very different situations between regions and, at state level, have led to products (e.g. soil maps, soil databases) drawn up using different approaches. Consequently, as Boixadera and Ibáñez (1996) and Ibáñez *et al*. (1999) pointed out, many of the old problems remain, such as lack of coordination, different standards and methods between regions, uneven correlation, different scales of mapping, difficulty with the availability of information, different length of the various programmes, etc.

However, it should be welcomed that soil protection now has a heightened profile at European level, as a result of the Spanish Presidency of the EU.

The PNCTA programme, described by Ibáñez *et al.* (1999), could have solved some of the severe problems affecting the collection of basic standard soil information in Spain. However, suspension of this Programme after the pilot stage had been completed, raises serious concerns amongst pedologists and returns Spanish pedology to the situation of decades ago.

From previous reviews, it is clear that the developments taking place with respect to soil in Spain are mostly in the area of monitoring, in line with the emphasis of EU policy. At a time when human capital in public institutions with expert knowledge of pedology and soils survey is rapidly declining, it is disappointing that the soil monitoring effort is not being used to reinforce them.

Spain urgently needs a national institution in charge of collecting, compiling and maintaining the spatial and temporal information on soil at state level, with the participation of the Autonomous Communities and the most reputed Spanish experts. The problem in Spain is not the lack of a task force to respond to the current challenges to collect spatial and temporal soil information. The problem is that attention is focused: on short-term demands at the expense of long-term issues such as collection of basic data and provision of sufficient soil expertise.

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Soil Survey in Sweden

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Introduction

The first systematic surveys and mapping undertaken in Sweden with some relevance for soil conditions were undertaken by the Geological Survey of Sweden in the middle of the last century. They were focussed mainly on geological parameters of the parent material (C horizon) and on this basis cannot be classed as real soil surveys.

However, they played an important role in the understanding of soil properties and land use planning, and came later to provide a useful basis for national soil mapping. The geological surveys gave rise to the so-called Quaternary and Petrological Maps, the first one being published 1857. The maps show mineralogy and texture and genesis of the parent material, e.g. texture of glacial till and water or wind deposited sediments, and occurrence of peat and gyttja.

Between 1947 and 1966 the most southerly part of the country was surveyed and mapped in a similar way by the Geological Survey of Sweden, but at a more detailed scale, 1:20,000, and limited to small important agricultural regions. These so called Agrogeological Maps include, in addition to texture and mineralogy of parent material, some characterisation of the plough layer (Ap horizon) and an estimate of the market value of land (based on expected production capacities). They may, therefore, justify being designated as the first systematic soil surveys in Sweden, though not national, in view of the relatively small area covered.

Real national soil surveys did not start until the National Survey of Forest Soils was initiated in 1961 by the Department of Forest Soils at the Royal College of Forestry. The organisation was later changed and is now part of the Swedish University of Agricultural Sciences (SLU).

The soil survey was combined with the Swedish National Forest Inventory (ongoing since 1923) in such a way that both forest and soil parameters were recorded on the same plots, thus enabling a better understanding of forest-soil interactions.

These surveys, however, are limited to productive forestland, defined by a stem production exceeding $1m^3$ per ha per year. There is some justification for this in that productive forestry is the single most widespread land use in Sweden. Of a total land area of ca. 41 million ha, about 23.5 million ha is presently under productive forestry. Other main land categories are peat land, mountainous land without forests, and arable land. As a special task in the inventories, soil samples are collected for chemical analyses and are held in a soil bank for use in future studies.

The nationwide surveys and samplings of forest land were carried out during the periods 1963-1972, 1973-1975 and 1983-1987, and are presently ongoing in the period 1993-2002. The methodology of the inventories has changed slightly with time. The present survey is called the Swedish National Survey of Forest Soils and Vegetation. The aim is, by repeated inventories, to form a base for studies of conditions and changes in soil properties and in vegetation with time.

The first national systematic survey of Swedish arable land was carried out between 1988 and 1995 with random sampling of 3,100 plough-layer horizons (Ap) and 1,700 subsoil samples throughout the agricultural areas in Sweden. The survey was carried out by the Department of Soil Science at SLU and focussed on humus content and the most important soil chemical properties. Reports and maps of arable soil properties have been produced.

Plans for a national mapping of soil units had been drawn up in 1958. Manuscripts were produced for the European Commission at the scale 1:1,000,000 but were never printed, except for being included in the 1:5,000,000 World Soil Map published by FAO-UNESCO. However, new mapping was carried out and eventually published in Sweden.

Soil Mapping

Quaternary and Petrological Maps

Quaternary and Petrological Maps and associated legends have been compiled in a systematic way by the Geological Survey of Sweden since the middle of the 19th century. They were based on topographic reconnaissance maps produced at a scale of 1:50,000 and published in a series from 1862-1974. Outcrops were differentiated on rock types, and the Quaternary deposits according to their genetic origin and textural composition. The mapping relates to a depth of 50cm.

In a more modern series, started in the early 1960s, both methods and mapping were improved. The improvements include interpretation of air photography, both infrared and ortho photos at scales from 1:10,000 to 1:30,000, followed up by field controls and sampling for texture analyses. The maps are generalised regarding both grouping in geological map units and unit contours.

Quaternary and Petrological Maps from the different series are available at a scale of 1:50,000 for approximately 20% of the total area, mainly in the southern part of Sweden. However, these maps are of variable quality because the methodology has changed with time and because some of them, mainly in less densely populated regions in Northern Sweden, are made to give an overview of the geology.

There are also Quaternary and Petrological Maps at scales of 1:100,000 to 1:400,000. In total, the whole country is covered by these geological maps, but with varying degree of precision.

Geochemical Maps of Soil Parent Material

Soil Geochemical maps at a scale of 1:250,000 and 1:1,000,000 have been made by the Geological Survey of Sweden and relate to the aqua-regia soluble content of ca. 30 major and trace elements at a depth of 80cm in the soil parent material (C horizon), mainly glacial till. The maps are based on ca. 32,000 plots with each geographical position set within a precision of better than 50m. About 30% of the land area is presently covered.

Forest Land Mapping

National maps of site and soil properties of forestland have been compiled based on the national survey by the Swedish National Survey of Forest Soils at the Department of Forest Soils, SLU (the Swedish University of Agricultural Sciences). Most maps are based on the inventory period 1983 to 1987, involving 23,100 plots. The soil samples are from the O or A, E, B, B/C and C horizons. The methodology is described below (see Soil Monitoring).

National or regional maps are made at a scale of ca. 1:10 million by interpolation using mainly ordinary kriging (Davis 1986). They are available for a large number of site conditions such as vegetation type, soil unit, groundwater level, humus form, humus-layer thickness, pH, content of C, N and exchangeable ions in O, E, B and C horizons and total elemental composition of C horizons.

Total concentration and amount of heavy metals in humus layers were analysed and mapped by Andersson *et al*. (1989), using samples collected by the Swedish National Survey of Forest Soils and Vegetation.

Mapping of Arable Land

Agrogeological Maps, prepared by the Geological Survey during 1947-1966, are available for the most southerly part of the country (e.g. Ekström, 1953a). It was intended that the maps should be used for the management of arable land. This kind of mapping was restricted to the most productive agricultural districts in Sweden, particularly on carbonate-rich boulder clay.

The maps include information on the texture at a depth of 35cm, i.e. the texture below the Ap horizon, and humus content of the Ap horizon. Each map also includes a description of the general geology and profile data including a classification of site capacity and estimated market value. Maps are at a scale of 1:20,000 but they cover together not more than ca. 0.1 million ha, i.e. about 3% of the present arable land area or 0.25% of the total land area in Sweden.

An overview soil map for arable land for the whole of Sweden focussing on plough layer (Ap) conditions was compiled at the beginning of the 1950s at a scale of 1:5 million by Ekström

(1953b), based on geological maps and the author's observations.

Swedish arable soils were also mapped at a scale of ca. 1:10 million by Eriksson *et al*. (1997), based on a systematic sampling of arable land from 1988 to 1995. Properties taken into account include humus content and the most important soil chemical properties: pH, total content of C, N and S, carbonate, cation exchange capacity and exchangeable bases, and various trace elements. The methodology is described below (see Soil Monitoring).

Soil Maps

A national soil map at a scale of 1:1,000,000 was made by Troedsson and Wiberg (1986). The map is based on data from the Swedish National Survey of Forest Soils collected in the period 1963-1978. In addition, data from investigations by the authors have been used, together with information from other maps such as Quaternary and Petrological Maps, Agrogeological Maps and topographical maps.

The soils are classified in the Swedish system but translated into the FAO-UNESCO legend and into the Soil Taxonomy system. Podzols are the most dominant soil unit in Sweden, but they are defined differently in the Swedish system compared to the FAO-UNESCO legend. In Sweden, the main criteria for their delimitation is the occurrence of an E horizon. The sub-types are defined by the E horizon thickness, i.e. 0-3cm, 3-6cm and >6cm.

The delineation of map units in Podzol regions of Sweden is mainly based on the occurrence of sub types, i.e. the E horizon thickness. This is particularly the case for the northern part of the country. However, in the FAO-UNESCO system most of these sub types would be classed as Haplic Podzols and they would be considered as more or less one and the same map unit. Therefore, the translation to the FAO-UNESCO legend will result in a loss of important information.

Histosols, Gleysols, Arenosols and Regosols occur in addition to Podzols. In Southern Sweden the pattern is more complex and additional map units are Cambisols and Leptosols.

Soil forming factors and Spodosol properties and occurrence in Sweden were described by Olsson and Troedsson (1990) at a Soil Correlation Meeting (ISCOM) in USA and Canada 1987 concerning characterisation, classification, and utilisation of Spodosols.

A Nordic soil map at a scale of 1:2,000,000 together with a description of units was compiled by Rasmussen *et al*. (1991) as a joint venture between Denmark, Finland, Norway and Sweden. In the case of Sweden, the map is based on the 1:1,000,000 map by Troedsson and Wiberg (1986). The classification scheme used relates to that of the FAO-UNESCO World Soil Map.

However, exceptions occur, e.g. the separation of podzol types is based mainly on E-horizon thickness as previously followed in the Nordic countries. In accordance with definitions of peatland, the Histosols are classified as soils with a peat layer thicker than 30cm.

Some Quaternary and Petrological Maps, since 1991, have been supplemented by a soil-unit map based on the FAO-UNESCO system at a scale of 1:250,000. Though the maps are published by the Geological Survey of Sweden, the soil map supplement is a cooperative effort with the Swedish University of Agricultural Sciences (T. Troedsson). The delineation of map units is based on the description of the Quaternary geology, the 1:1,000,000 soil map and field observations. The total area presently covered by these soil maps, however, is still only about 0.15% of the total land area.

Soil Monitoring

Systematic soil monitoring in Sweden, at national level, is carried out mainly by:

- The Swedish National Survey of Forest Soils and Vegetation at the Department of Forest Soils, SLU;
- Integrated Monitoring (IM) through the Department of Environmental Assessment, SLU;
- Intensive Monitoring Plots (ICP Forest, Level 2) through the National Board of Forestry;
- Monitoring of Arable Land, carried out by the Department of Soil Science, SLU.

In addition, soil monitoring is also performed on a regional scale under the responsibility of County Boards but with a common protocol.

The Swedish National Survey of Forest Soils and Vegetation

The survey methods since 1963, when the first survey started, have changed but can generally be described as a stratified random sampling with higher densities in southern Sweden and lower densities in northern Sweden.

The first inventory, during the 10-year period 1963-1972, comprised recording of, e.g. parent material, soil unit, topographical and hydrological conditions, and ground- and field vegetation, in random sampling on almost 76,800 plots.

The country was re-sampled during the 3-year period 1973-1975, with around 23,100 plots and with several investigational pits per plot. The inventory during the 5-year period 1983 to 1987 comprised a total of 23,100 plots on forestland. A new method was implemented for this survey with defined permanent circular plots of a radius between 7 and 10m. The intention is that the use of permanent plots will improve possibilities for following changes over time. The plots are clustered into "tracts". These are quadratic or rectangular with a side, depending on location in the country, within a range of 300-1,800m.

The tracts are located in a ca. 5km x 5km to 15km x 15km grid, depending on location in Sweden (denser in the south). In general, soil pits and soil and site descriptions are made at one to two circular plots per tract. At each circular plot, general site properties such as vegetation type and occurrences of different species, type of soil parent material and hydrological conditions are described. Specific variables include thickness of humus layer, humus form and thickness of E horizon. The inventory also records soil type according to the Swedish system and the FAO-UNESCO legend (Figure 1).

The soil is sampled according to O or A, E, B, B/C and C horizons. Samples are stored in a soil bank and analyses include: pH (Figure 2), contents of C, N, exchangeable base cations and aluminium. Parent material (C horizon) from selected plots (ca. 3,000) has been analysed for the total elemental composition of major and trace elements. Some plots are included in CCP Forest, level 1 programme. This survey is followed by a new, still ongoing one, covering the 10-year period 1993- 2002.

The results of the measured parameters from The Swedish National Survey of Forest Soils and Vegetation can be related to natural site conditions such as geology and climate and to man-made impacts such as pollution. Using the data, critical loads for acidity and N deposition have been developed.

The geochemical surveys have led not only to a geochemical map but also to assessment of weathering rates in Sweden. The repeated surveys have enabled trends over time to be established, e.g. for acidity and base saturation. It has also been possible to verify that the accumulation of carbon is increasing in humus layers, a fact that is relevant to global climate change and management strategies to reduce net emissions of CO_2.

Most of the material is being presented and free to use as maps or as an interactive database on the world-wide-web (http://www-markinfo.slu.se). Unfortunately the web-material is still in Swedish but a translation to English is being undertaken.

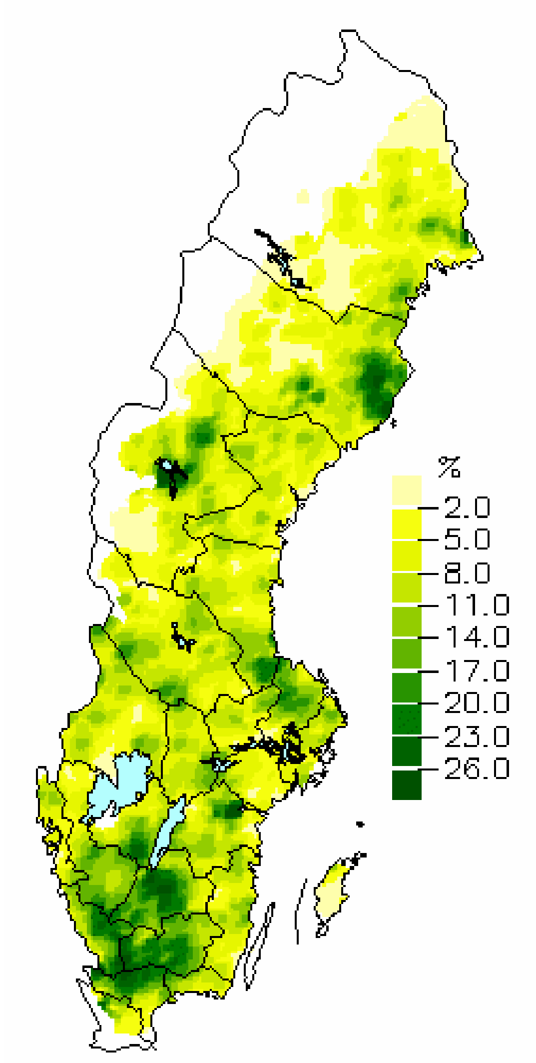

Figure 1: Distribution of Histosols (peatlayer > 30cm) in % of land area.

[Based on data from the Swedish National Survey of Forest Soils and Vegetation.]

Integrated Monitoring (IM)

Integrated Monitoring is presently carried out at four locations in Sweden where there is no or only minor impact from forest management. These sites are: Gårdsjön (F1)-SE04, Aneboda-SE 14, Kindla-SE 15, and Gammtratten-SE 16. The monitoring is carried out in accordance with the UN/ECE LRTAP convention and is part of European-Canadian network. The monitoring includes water and nutrient budgets for small catchments (50-100ha) and measurements of climate, hydrology, soil physical and chemical properties, soil unit, soil-water and ground-water chemistry, deposition of e.g. N and acidity, vegetation species, soil respiration, litter decomposition and arginin in needles.

Measurements were initially made in a 50m x 50m grid for each of the catchments. Four horizons of the soils were sampled and analysed. Within each catchment there is a sub-plot for intensive monitoring with renewed sampling and analyses at 5-year intervals.

Thirty six samples are collected and put together to form 6 composite samples for each one of the layers: humus layer, 0-5, 5-10, 10-15 and 15-20cm. In addition three separate samples are collected from 70cm depth. Chemical analyses include major and trace elements. The IM activities are described on the world wide web: http://info1.ma.slu.se/IM/.

Intensive Monitoring Plots

The Intensive Monitoring is a national network for managed forests consisting since 1995 of 223 plots of which about 100 plots are part of an international network (ICP Forest, level 2). Of the total number of plots, almost 200 are located in conifer stands, and 30 in deciduous stands. The main aim is to investigate forest vitality and its changes over time. To this end, the measurements on each plot include, apart from a number of tree parameters, soil chemistry and soil-water chemistry.

This monitoring is thus relevant with respect to the soil survey activities carried out in Sweden. The plots are not randomly located but placed in order to cover a range of deposition conditions and to represent commonly occurring site types. The soil measurement programme comprises: initial (just once) determination of contents of N, organic matter and acidity and exchangeable base cations in different horizons. General site characteristics such as type of parent material, soil unit and hydrological conditions are described.

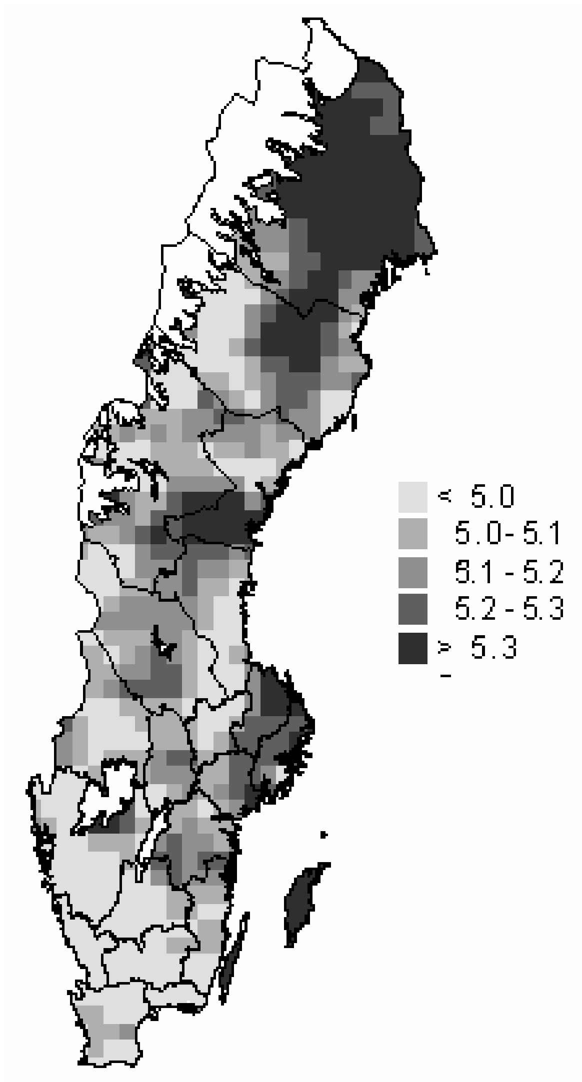

Figure 2: pH(H_2O in B horizon in forest soils.

[Data from The Swedish National Survey of Forest Soils and Vegetation 1983-1987.]

Monitoring of Arable Land

The current status of Swedish arable soils was monitored from 1988 to 1995 by the Department of Soil Science at SLU (Eriksson *et al.* 1997), with respect to humus content and the most important soil chemical properties. The data set includes 3,100 plough layer (0-20cm) samples and 1,700 subsoil samples (40-60cm) from sites randomly distributed throughout the country.

Chemical variables include: pH, total concentration of C, N and S, carbonate, cation exchange capacity and exchangeable base cations, and various trace elements. At each sampling site the 0-20cm sample was composed of 6-20 subsamples, and the 40-60cm sample of 6 subsamples. The area of the sampling site varied between 2 and 20m^2.

Profiles were analysed in a 100m grid net, with regard to texture, water retention capacity, pH, humus and calcium carbonate contents and plant available P and K.

The results from the monitoring of arable land identify the link between the investigated variables and general site conditions such as climate and parent material. One example is the distribution of trace elements in the plough layer (Ap), which can be explained mainly by parent material composition, a regional pattern due to influence of the parent materials being clearly visible.

However, anthropogenic depositions also affect the pattern to some extent, particularly with respect to Hg, Cd and Pb. Most of the information is presented and free to use as maps or as an interactive database on the world-wide-web (http://www-umea.slu.se/miljodata/akermark/index.htm). Regretfully the web-material still is in Swedish.

Soil Databases

Soil databases are generally available by the following means:

- Directly and interactively on the world wide web;
- By order through the web;
- By contacting the responsible authority.

Applications of Soil Data

Forestry plays an essential role in the Swedish economy, and forestry adaptation to site conditions is important both from a timber production and environmental point of view. The database from the National Survey of Forest Soils and Vegetation has facilitated the development of a method for determining site capacity based on-site characteristics (Hägglund and Lundmark, 1976).

This system is generally practised now in Sweden and is particularly useful where site capacities cannot be estimated from stand properties, e.g. damaged stands, clear cut areas and shift in tree species. The database has also been used to estimate acidification (Troedsson, 1985), critical loads for acidity (Sverdrup *et al*., 1992) and for nitrogen (Rosén *et al*., 1992), and for the determination of base cation balances (Olsson *et al*., 1993 and Olsson, 1993).
National strategies for forestry management and environmental protection have been developed by the National Board of Forestry and the Swedish Environmental Protection Agency. These strategies are based on the soil databases described above as well as on soil maps. They deal with measures like site preparation, fertilisation, and lime or ash application to counteract acidification. Several provinces in Sweden have based their selection of relevant or type sites for environmental monitoring on data from databases such as the National Survey of Forest Soils and Vegetation.

Currently a programme has started aimed at developing land use strategies for reducing net greenhouse gas emissions (LUSTRA) in Sweden. A prerequisite for the modelling and upscaling of greenhouse gases to national level is access to a national soil database.

Outlook

It is obvious that access to soil databases is increasingly important in order to understand ongoing changes and to develop guidelines for land use and management. Currently environmental surveys are carried out by different authorities but are partly co-ordinated by the Environmental Data Centre at SLU and the Swedish EnviroNet at the Swedish Environmental Protection Agency. The effectiveness should, however, benefit from a higher degree of co-ordination, e.g. between the surveys carried out the Geological Survey of Sweden (SGU) and the Swedish University of Agricultural Sciences (SLU).

It is worthy of note that soil analyses within forestry and agriculture are carried out on < 2mm fine material, whereas geochemical or mineralogical investigations within the geological discipline are often carried out on the < 0.06mm fraction. This inconsistency restricts the ability to compare results.

It can be foreseen that more emphasis needs to be placed on the rather slow processes but often large pools in B horizons in managed forests, e.g. changes in C pools, acidity, nutrient conditions, etc. The present survey methods are not always sufficient to follow up these new environmental concerns, e.g. slow changes in the soil C-pool relative to the high degree of variability. Supplementary survey systems need, therefore, to be employed.

Following the recognition of benefits from different land-use forms there is a shift of emphasis from biomass production to water and air quality. This may lead to a more intensive survey of certain critical site types like wet soils with high contents of C and N and with great impact on greenhouse-gas emissions and surrounding waters.

For the same reason the mountainous areas in north-west Sweden should be more intensively surveyed. They have previously been partly forgotten perhaps because of their insignificance for agriculture and forestry. We can also foresee that new parameters in the surveys will successively be introduced, e.g. biological activity, mycorrhiza, soil water in the unsaturated zone, biodiversity.

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Soil Survey in Switzerland

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History and Development

The specific interest in soil survey in Switzerland began in the early 1950s in connection with academic training and teaching in agricultural chemistry at the Department of Agriculture of the Federal Institute of Technology, Zurich. It also originated from the agronomic research performed in various Experimental Stations and Schools of Agriculture. No soil survey as such had previously been carried out in Switzerland.

Various studies relating to nutritional elements, soil water, mineral and organic fractions were ongoing, and the need to study the soil as an entity *per se*, and no longer only as the existing physical framework supporting and feeding plants, came to be recognised. As part of this new interest, studies of the morphological, chemical and physical properties of soil profiles developed along with those on the spatial variability of soils within the landscape. Thus soil cartography in Switzerland was born (Frei and Juhasz, 1963).

The promotion of soil cartography as a basis for agricultural planning (Frei, 1959; Frei *et al.*, 1969; Bonnard, 1972; Bonnard *et al.*, 1988) was mainly by the Swiss Federal Research Station for Agronomy (FAP), along with other institutions (Alther, 1976; BGS/SSP, 1985a). Initially interest was local (Bonnard, 1982) but this gradually extended to regional (Frei and Juhasz, 1965, 1967); Frei and Guyer, 1968; Dietl and Jäggli, 1972), and national levels by demand.

The nomenclature and classification of soils became an important issue. The taxonomic system developed by Pallmann (1947) was adopted. In it water regime and the physical soil composition were rated as primary factors (Peyer and Frei, 1992).

Soil surveys have been undertaken since the beginning of the 1960s to evaluate the quality and potential of agricultural soils, mainly at the time of ongoing land improvement such as the redistribution of real estate, land drainage or irrigation works (Peyer *et al.*, 1976).

It was considered important to establish and develop a rating system (Frei, 1961) which could be applied to the various topo-climatic regions of Switzerland (FAL, 1997). Other issues that currently require a knowledge of soils and their distribution include among many: the storage of sewage sludges and the safeguarding of cultivable land for food security.

In 1977 a long-term project to survey the soils of the whole of the country at a scale of 1:25,000 was initiated, with priority being given to the agricultural Midlands.

Soil Maps

Numerous soil maps have been prepared over the last 30 years, most of which were by staff of FAP. Many are in the form of unpublished manuscripts, with issues of 1 to 5 copies. Some are of several tens to hundreds of hectares, others represent whole regions. Others cover the whole country apart from the highest mountains but at a coarser scale.

The scales of the maps vary from 1:1,000 to 1:1,000,000, with the detail of the information provided varying accordingly (Frei *et al.*, 1966; Peyer, 1983) (Table 1).

Most of the maps are biassed towards agriculture (Gratier, 1986), and are capable of being used to indicate the suitability of soils for drainage or irrigation, for different crop rotations, or the

Table 1 Main published soil maps of Switzerland

Maps	Date	Publisher	Scale	Area
Soil map of Switzerland (Annex to Geotechnical map of Switzerland)	1934 1st Ed 1964 2nd Ed	Geological Commission of the Swiss Academy of Sciences	1:1,000,000	35,000 km^2
Map of Soil Capacity for Agriculture in Switzerland	1973	Federal Offices for Agriculture forestry and land planning	1:300,000	35,000 km^2
Map of Soil Capacity for Agriculture in Switzerland 3 folios (Solothurn, Zurich, Geneva)	1976		1:50,000	Each 840km^2 Total: 2,520km^2
Map of Soil Capacity of Switzerland	1980	Federal Offices for Agriculture forestry and land planning.	1:200,000	35,000km^2
Soils Overview. (in Atlas of Switzerland)	1984	Federal Office of Topography	1:500,000	35,000km^2
Soil maps at 1:25.000 scale	Since 1981	Swiss Federal Research for Agronomy	1:25,000	Each 210 km^2 Total: 2,730km^2
Diverse soil maps	Since 1970	Various Cantons (Zurich, Basel, St-Gall, Jura, etc.)	1:5,000 to 1:10,000	Hundreds to thousands of hectares

capacity of soils to absorb liquid manures, especially sewage sludge (Peyer *et al.*, 1977).

Thematic maps are derived from basic pedological surveys to indicate crop suitability, agricultural land values, hydrology, amongst others. Forest soils, because of their specific nature, were mapped separately and their evaluation took into account tree density (BUWAL, 1996).

In addition to maps made on request, the FAP undertook a systematic survey of the national territory at a scale of 1:25,000 from 1977 onwards. So far 13 folios have been published (Figure 1) covering some 2,730 square kilometres.

The mapping has been carried out according to the procedures outlined in Figure 2. Field information has been obtained from soil trenches, specially dug soil profiles and through a network of manually or hydraulically excavated 1-2 metre deep boreholes, the density of which relates to the needs and scale of the survey.
Boundaries on maps were delineated by geomorphological analysis (interpretations in the field and on aerial photographs of topography, geology and position in the landscape). Additionally, soil analysis (granulometry of the fine fraction, pH, lime content and organic matter) is used to support delineations in the field.

The legend of most maps, particularly large scale ones, are set up to provide information on both pedological classification and agricultural applications. Broad categories are established which include information on 'water regime' and soil depth (suitability for plants).

Soil Monitoring

Given the political organisation of Switzerland on the basis of a strict federal system, and consequently the power of the twenty three Cantons to settle territorial issues, there is no national office in charge of the study and survey of soils. It was only in 1986 that, as a result of a federal law on environmental protection, the central state established a control network to monitor the diffusion of pollutants in the soils of Switzerland (NABO).

Massstab / *Echelle*	Karten / *Cartes*	Preis inkl. Mwst. Prix incl. TVA	Vertrieb, Auskunft / *Vente, informations*
1:500'000	Bodenkarte der Schweiz (Atlas der Schweiz, Tafel 7a) *Carte des sols de la Suisse (Atlas de la Suisse, feuille 7a)*	auf Anfrage sur demande	Bundesamt für Landestopographie, 3084 Wabern *Office fédéral de topographie, CH-3084 Wabern*
1:300'000	Landwirtschaftliche Bodeneignungskarte der Schweiz *Carte des aptitudes culturales des sols de la Suisse*	Fr. 5.--	Eidgenössische Forschungsanstalt für Agrarökologie und Landbau, CH-8046 Zürich-Reckenholz *Station fédérale de recherches en agroécologie et agriculture, CH-8046 Zurich-Reckenholz*
1:200'000	Bodeneignungskarte der Schweiz (inkl. 1:50'000 Genève, Solothurn, Zürich) *Carte des aptitudes des sols de la Suisse*	Fr. 10.--	
1:25'000	**Bodenkarte der Schweiz (siehe unten)** **Carte des sols de la Suisse (voir ci-dessous)**	**Fr. 25.--**	Telefon 01 377 71 11, Telefax 01 37772 01
1:10'000 1: 5'000	Bodenkarten von diversen Gemeinden und Regionen *Cartes des sols de communes et régions diverses*	auf Anfrage sur demande	

Die **Bodenkarte 1:25'000** ist benutzerfreundlich und auswertbar.
Sie ist die Grundlage für
- **Raumplanerische Tätigkeiten**
  Ausscheidung von Landwirtschaftszonen
  Erhaltung unserer fruchtbarsten Böden
  Ausscheidung von Naturschutzgebieten
- **Beurteilung der landwirtschaftlichen Eignung**
  Anbaueignung, Ausscheiden von Fruchtfolgeflächen
  Landwirtschaftliche Betriebsberatung
- **Beurteilung der forstwirtschaftlichen Eignung**
  Baumartenwahl
  Produktionsfähigkeit
  Holzernte / Erschliessung
- **Umweltschutz / Bodenschutz**
  Risiko von Nährstoffverlusten durch Auswaschung und Abschwemmung
  Erosions- und Verdichtungsgefahr des Bodens
- **Wissenschaftliche Erforschung von Naturräumen**

*La **carte des sols au 1:25'000** est d'un emploi facile et a diverses applications:*
- ***planifications***
  dégagement de zones agricoles
  préservation des terres les plus fertiles
  création des aires naturelles protégées
- ***estimation de l'aptitude agricole***
  aptitude culturale, dégagement des surfaces d'assolement
  conseils agricoles
- ***estimation de l'aptitude sylvicole***
  choix des essences
  capacité de production
  récolte / débardage
- ***protection de l'environnement et du sol***
  risque de lessivage des substances nutritives
  danger d'érosion et de tassement des sols
- ***étude scientifique des espaces naturels***

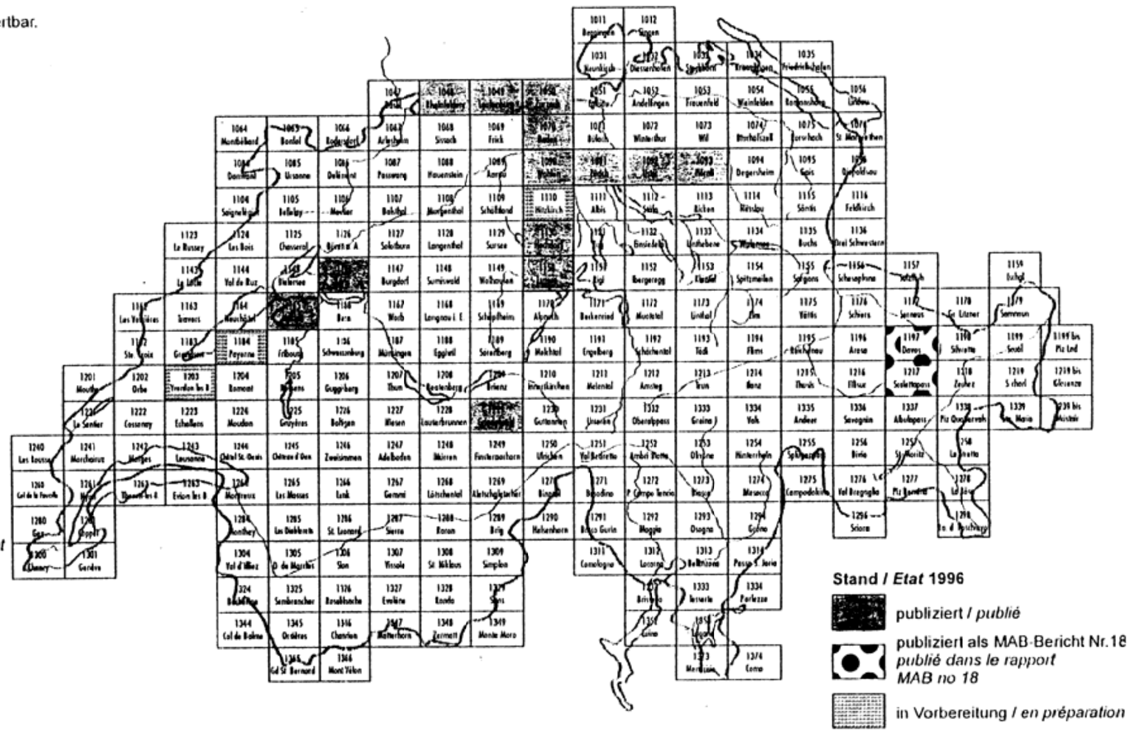

Figure 1: Overview of the maps at scale 1:25,000 published nowadays

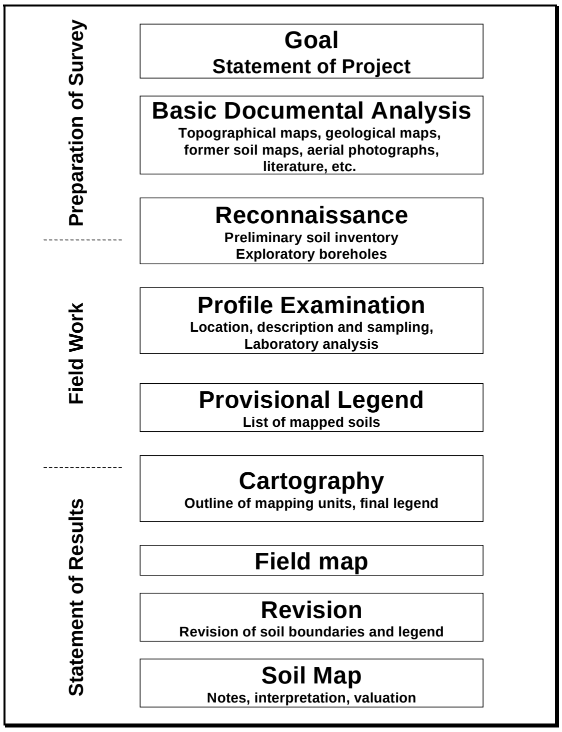

Figure 2: Scheme for Preparation of Soil Maps

This network follows an existing programme designed and run by the individual Cantons to detect chemical, biological and physical degradation in the soils. Apart from some localised problems of heavy metal contamination, the first results of the national programme gave no major cause for concern. The results are as yet incomplete with respect to organic pollutants.

The extension of the built environment in a country with limited space for agricultural production, with overpopulation and a high level of industrialisation, has become a major issue of concern over the past 20 years (BGS/SSP, 1985b).

Food autonomy is far from being achieved in spite of increased agricultural yields associated with crop selection, improved methods of cultivation and land improvement. The reduction in the size and amount of 'natural zones' and the extension of the area of built structures in the landscape have provided an incentive to survey the remaining 'green' areas as a basis for a preservation plan.

Some of the Cantons, challenged to undertake such surveys, drew up thematic soil maps indicating the possible areas for different crop rotations. In addition to these measures a national soil research programme was set up between 1985 and 1991 (Häberli, 1991) aimed at promoting a more cautious, more conservational approach to the Swiss soil resources. The intention was to reduce losses to the construction industry, maintain soil fertility, safeguard natural sites and encourage the adoption of more sustainable ways of managing the soil resource.

Soil Databases

Thousands of profile descriptions and analyses are stored at the FAP, following numerous research studies. Further data is kept in various archives in the institutions of the Polytechnical Schools (forestry, agronomy, land engineering, earth sciences, ecology) and at the Higher Technical Schools, among others. A computerised database is foreseen to improve the organisation and availability of these data. Future soil maps, especially those at 1:25,000 scale, will be digitised.

Applications of Soil Data

As most of the large and medium scale maps were requested by official agencies to evaluate land fertility, crop rotation, capacity to retain liquid fertilisers, among many applications, use has generally been made of the maps. Maps at a scale of 1:25,000 are intended to support agricultural planning and teaching. Their use is mainly at the level of the Canton because of their scale (Muller and Zihlmann, 1987; Peyer, 1982).

Maps at a scale of 1:200,000 are a reference for all federal officers working in agriculture, forestry and the environment. Maps, soil descriptions and analyses support investigations of environmental issues. Studies of soil erosion and compaction, both problems accentuated by modern farming techniques such as enlargement of field size and increasing weight of cultivation and harvesting machinery, benefit from soil data.

Another recentexample of the application of soil data is the status of organic carbon in soils (SOC). Most SOC in Swiss agriculture is stored in permanent grasslands, which account for more than 70% of the total agricultural area (Leifeld *et al.,* 2003). Leifeld *et al.* (in press) have calculated carbon stocks in Swiss agricultural soils by combining georeferenced data for land use, topography and soil profiles (544). The mean soil organic carbon content of the 0-20cm layer ranged from 41 t ha^{-1} for arable land to 63–117 t ha^{-1} for grassland. Organic soils account for <3% of the total area but store about 28% (47Mt) of the total SOC stock of 170Mt.

Land-use type, clay content and altitude were identified by Leifeld *et al.* (in press) as the main SOC predictors in mineral soils. Clay content explained 44% of the variability in SOC and it has been estimated that about 16% of the national SOC stock has been lost historically due to peatland cultivation, urbanisation and deforestation.

Outlook

It is expected that soil surveys will have an increasing part to play in maintaining a sound, sustainable environment. In the future, soil mapping contracts are likely to be awarded to the private sector, with the companies using methods suggested by the FAP or similar organisation. Despite this, divergent methods of soil mapping are likely to make it difficult to compare soil data from one study to another.

To try to limit these likely problems, the Swiss Pedological Society, founded in 1975, has set up a Working Group, the aim of which is to maintain a level of consistency in cartographic methods, terminology used and interpretation of results.

In the past, soil maps have proved their usefulness and have been widely accepted as important references. The increasing care for the study, control and maintenance of the environment, as well as the requirements of food production that is more respectful of land and water supplies, confirm the need for future extensive use of soil surveys and the information they generate.

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Soil Survey and Soil Database of Turkey

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Introduction

Turkey has a total land area of 78 million ha. About 28 million ha are devoted to cultivation. Thus, over the last five decades soil surveys have received particular attention for land use planning and the sustainable management of natural resources that have been carried out by the responsible body of the General Directorate of Rural Services (GDRS).

Unfortunately, farmland is threatened by a rapidly growing, huge transportation and construction industry in need of large spaces that have mainly occupied prime soils with access to marketing centres and metropolitan areas since the early 1960s. Hence, the country's primary necessity has been to consider the re-establishment and renovation of the previously functioning soil survey service of the General Directorate of Soil and Water (TOPRAKSU-Turkish acronym) transformed as the GDRS.

The major emphasis is on the development of interdisciplinary management plans for the numerous agro-ecosystems of the country. The renovation of the soil survey activities, the responsibility of the Ministries of Agriculture, Forestry and Environment in Turkey, follows earlier examples of development elsewhere, such as that of the Macaulay Soil Research Institute of Scotland in Aberdeen into its contemporary version, the Macaulay Land Use Research Institute (MLURI).

Countrywide Soil Surveys conducted by the GDRS

In the early 1960s, the task of classifying and mapping of soils in Turkey in more detail than in the past soil surveys (Caglar, 1958; Oakes, 1958) was given to the former TOPRAKSU or the present GDRS. These studies were meant to be part of the small-scale reconnaissance soil maps of Europe, which were prepared from 1966 to 1971, using topographic maps at 1:25,000 scales. The preparation of further maps at provincial (1:100,000 scale) and basin level (twenty six maps at 1:200,000 scale), (Figure 1) for use in land management and planning, was undertaken using the Great Soil Group system of Baldwin *et al.*, (1938), together with essential phases.

The pioneering soil studies using the earlier version of Soil Taxonomy of the Soil Survey Staff (USDA, 1960) were accomplished by Groneman (1968) in Karapinar (Central Anatolia), de Meester (1970) on the Konya Plain (Central Anatolia) and Boxem and Wielemaker (1972) in the Kucuk Menederes Valley (Western Anatolia). From 1973 to 1984, numerous soil survey reports of the GDRS enabled planners to develop the strategies needed for solving problems related to land use planning and accomplishing well based legislation (State Planning Office-SPO, 1973, 1979, 1984; Official Gazette, 1995).

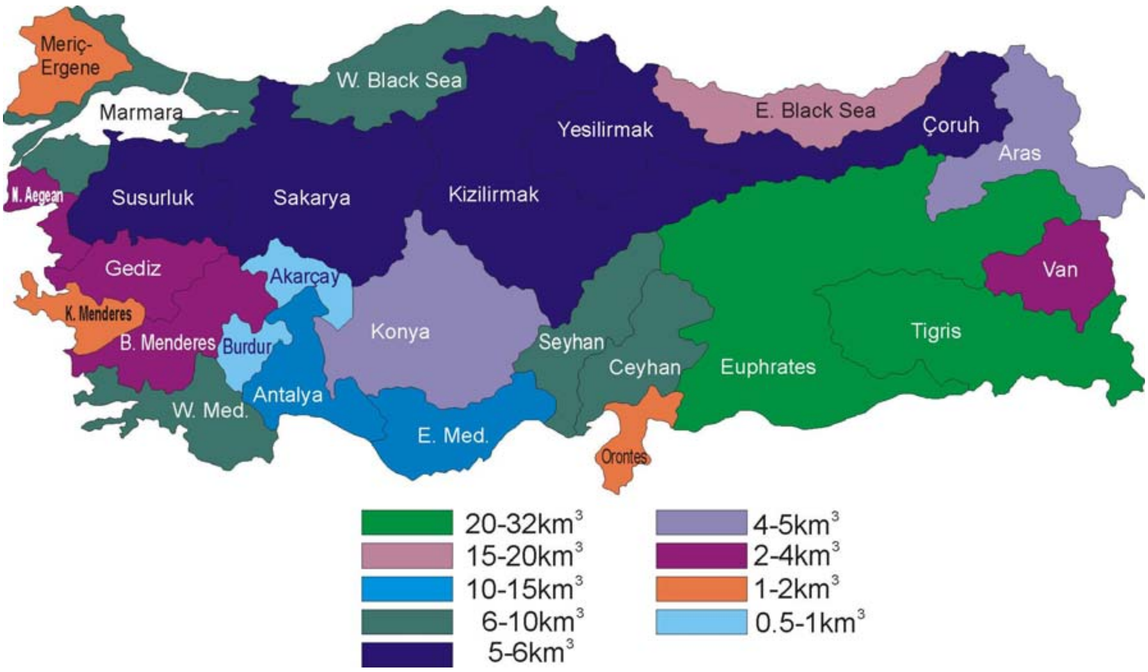

Figure 1: The water basins of Turkey

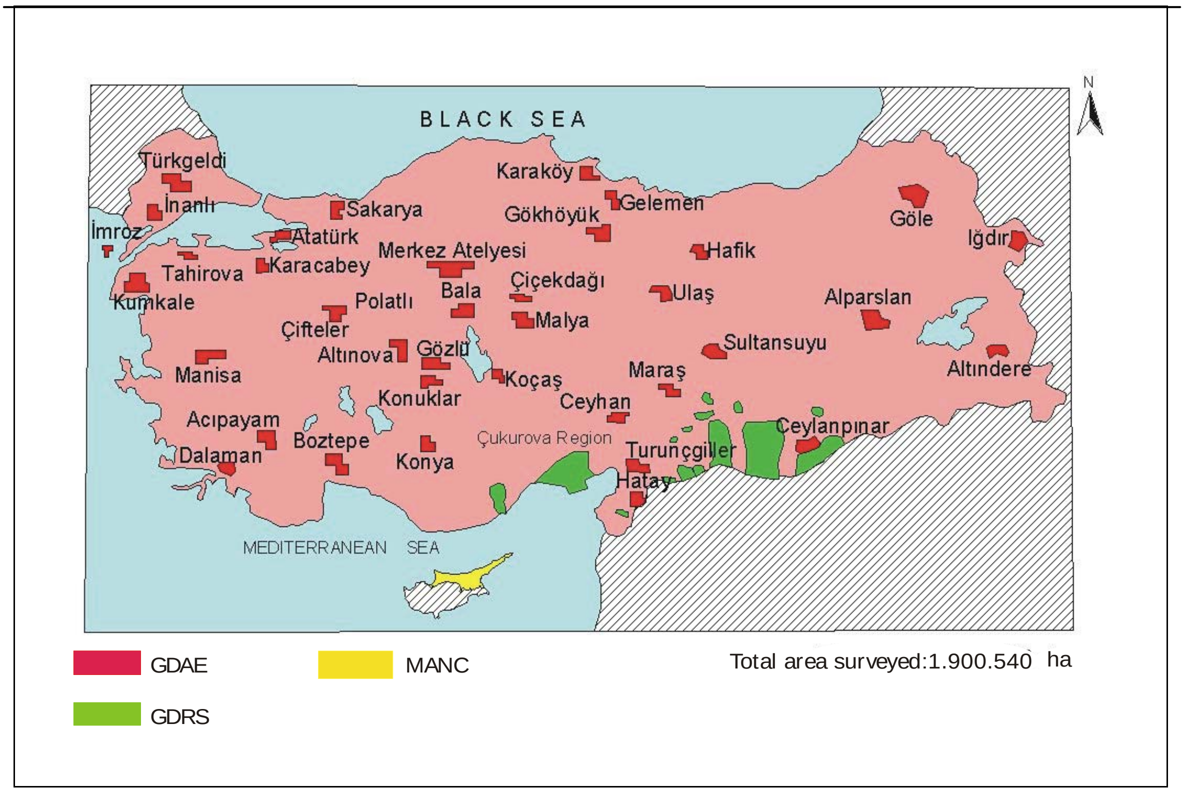

Figure 2: Soil Surveys undertaken by The University of Çukurova in collaboration with the GDAE, GDRS and MANC

However, these land use legislations were rarely applied in reality, due to uncoordinated actions by government agencies and local administrations pursuing different approaches in developing land use policies. Ultimately, this caused the expected mismatch between land quality and land use, resulting in land resource consumption (Cangir *et al*., 2000) and land degradation.

The present GDRS activities and responsibilities in the area of soils are to sustain soil and water management, monitor soil fertility of cultivated soils, conduct environmental impact assessments and create the national soil database. To address these activities, the National Information Centre of Soil and Water Resources (NIC) was established in 1999.

The NIC has recently completed the digitisation of the available soil maps at the scale of 1:25,000 and has set up the national data base. Thus, thematic maps, such as those relating to present land use, erosion risk and land use capability, are made available on request by NIC for governmental and public use. In addition, a network of organisations is under construction to cover many aspects of the natural resources of the country.

Soil Surveys, Monitoring of Land Degradation and Desertification of Agro-ecosystems

Soil surveys supporting agro-ecosystem management have mostly been conducted by the departments of Soil Science of several universities in the country, for example, by the University of Cukurova in Adana, Southern Turkey (Figure 2).

The Soil Survey and Remote Sensing Research Group of this university, equipped with contemporary soft- and hardware technology, led by the principal author of this article, has accomplished the soil survey of a land area of 337,000ha in the south of Turkey, Cukurova region (Figure 3) and 32,000ha in Northern Cyprus at a scale of 1:25,000, with funds from the Ministry of Agriculture of the Turkish Republic of Northern Cyprus (MANC).

Other large scale soil survey work undertaken by the research group of the department has included the mapping of the land use and land capability of a total of 27 State Farms of the General Directorate of Agricultural Establishments (GDAE) at a scale of 1:25,000, covering a land area of 361,980ha (Figure 4). The largest project undertaken by the department has been the detailed soil survey and land use planning of the 14 basins (853,188ha) of the South Eastern Anatolian Irrigation Project area (The GAP, Turkish acronym), funded by the GDRS (Figure 5).

Maps are available at the NIC in digitised format at 1:25,000 scales for all of the cultivated soils of Turkey. The soil map and the database of 1:1 million scale is also being prepared in collaboration with the GDRS using the system of the World Reference Base (WRB), and is available on the website of the NIC. Furthermore, soil studies related to environmental management and monitoring of the Agroscapes (term coined by Akça *et al.*, 2004 to complement the Soilscape concept of the WRB designating particular landscapes of soils with indigenous plant cover) have been conducted in the department in collaboration with the Mediterranean Agronomic Institute in Bari, Italy, funded by the EU.

New projects focussing on man-made Agroscapes are under preparation, covering the riparian countries of the Mediterranean basin. These are led by the European Soils Bureau of the Instıtute of Environment and Sustainability in Ispra-Milan, Italy. The Departments of Soil Science of the Universities of Ankara, Atatürk in Erzurum-Eastern Turkey, Ege in Izmir-Western Turkey and Thrace in Tekirdağ, Thrace have conducted numerous soil surveys concerning the sustainable land management of particular areas at risk from improper land use.

A special study of the soils of Thrace has been undertaken by the Research Group of Land Evaluation of the Department of Soil Science of the University of Thrace, with emphasis on pollution caused by the increasing industrial sprawl. This has involved the preparation of land use maps, together with environmental risk assessments and land use capability classifications, and these form a basis for recommendations for the most appropriate land use.

Soil Surveys and Land Use Planning for the Sustainable Use of Water

The General Directorate of the State Hydraulic Works (SHW) has completed maps at the scale of 1:25,000 showing soil suitability for irrigation in the large basins in Turkey. The maps have been used for the sustainable water management of the basins in collaboration with the GDRS.

Since the early 1960's the SHW has been monitoring water availability in basins using data obtained from numerous observation wells, meteorological records and records of the amounts of water used in irrigation. Further studies on the determination of sustainable water management proceeds via bilateral international projects and the collaboration of the Department of Agricultural Constructions and Irrigation of the University Cukurova. The main concern of these studies is irrigation and related agricultural practices such as tillage and their effects on regional climate change especially in the Mediterranean part of Turkey.

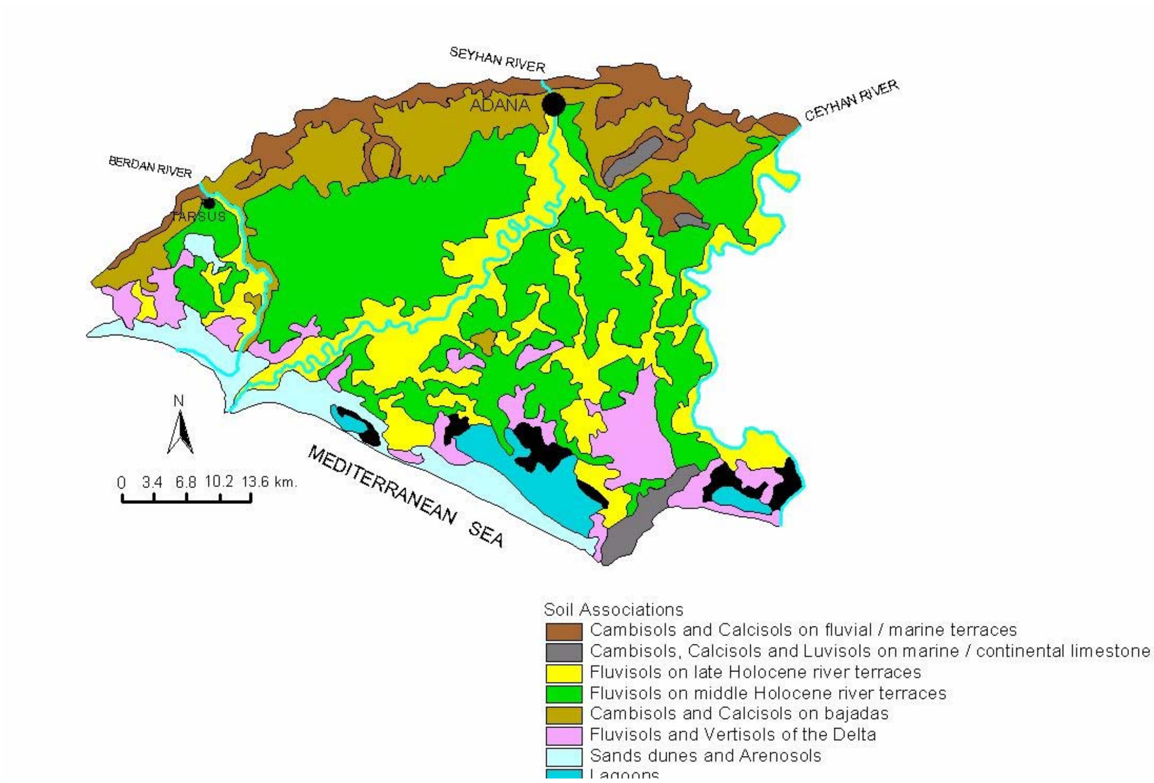

Figure 3: Soil association map of the Cukurova Region in the WRB system

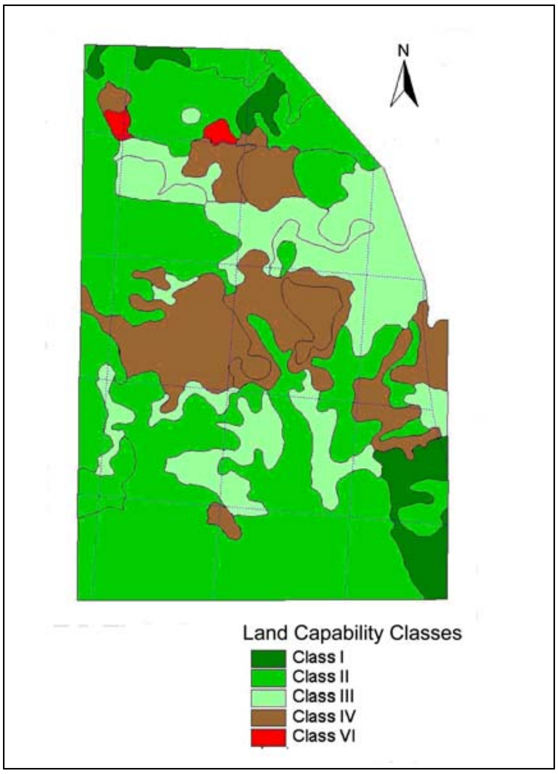

Figure 4: Land Capability Classes of the Altınova State Farm

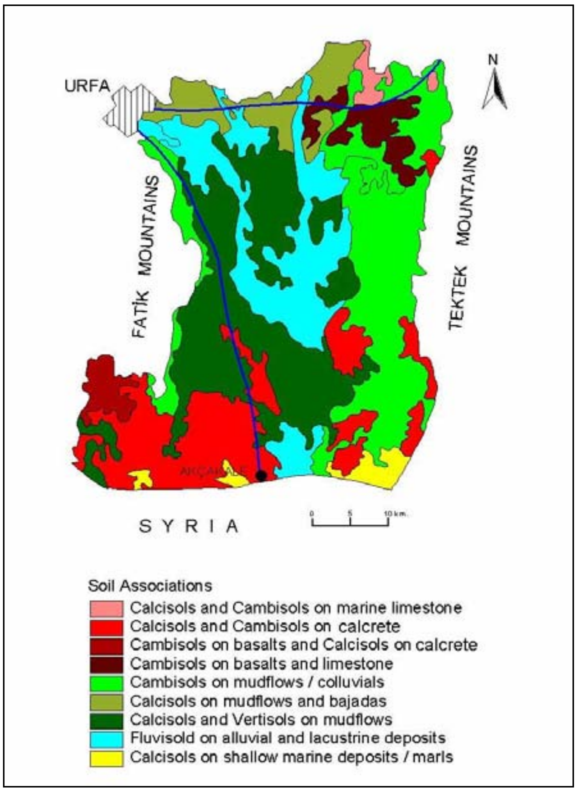

Figure 5: Soil association map of the Harran Plain- the largest plain in South Eastern Anatolia

Participation of the irrigation management unions is also sought for the development of a bottom to top approach for the determination of sustainable water management in the basin.

Future Prospects for Soil Survey in Turkey

There is an increasing demand for available as well as new reconnaissance and detailed soil surveys in Turkey by scientists and technicians working on projects of sustainable soil and water management, urban development, renovation of cadastral plans and construction of infra and ultra structures such as the petroleum pipelines crossing the country. Raw material / soil extraction for roads, buildings and brick manufacturing along with the highly developed ceramic industries of the country are the other prospective fields that require ample technical input from soil survey reports.

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Soil information and its application in the United Kingdom: an update

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Introduction

Appreciation of the significance of soil resources in the United Kingdom for sustainable land management, and for care of the environment through the integrated management of land, water and air, is increasing. Policy statements and/or action plans for England and Wales separately and a strategy statement by the Environment Agency for England and Wales have been produced. These initiatives follow the recommendations of an enquiry by the independent Royal Commission on Environmental Pollution (RCEP, 1996) but are also being influenced by activity in Europe.

Loveland and Thompson (2001), after considering the role and needs for indicators of soil quality, recommended a set of indicators including a short set of headline indicators that could be adopted immediately.

History and Development of Soil Survey

The development of soil survey in Britain has been summarised by Muir (1960) and Hollis and Avery (1997). Muir makes reference to early suggestions about the collection of information on British soils as far back as 1665. In the 18th century a series of reports entitled "General Views on Agriculture" were the first to incorporate soil maps and descriptions, some of which give a good indication of the range of soil types and their spatial distribution within the counties. Notable examples are the reports for Hertfordshire, Cambridgeshire, Essex, Sussex, Devon and Hampshire. In the early 20th century a number of projects looked at the nature and distribution of soils mainly in England and Wales. The basis for mapping the soils was almost always the supposed link and correlation between soils and geology and at this time none of the researchers seemed to appreciate the significance of soil morphology for this purpose. Study of the soil profile as the basic unit in making soil maps began in the 1920s and a Soil Survey conference was instituted in 1926 when this novel approach was demonstrated.

Further meetings established a standard system of soil description and methods for recording soil series and types on the maps, the whole being crystallised in the Soil Survey Handbook (Clarke, 1940). By 1930, surveys were being undertaken in southeast England, Oxfordshire, around Bristol, Shropshire, south Wales, in the Lothians of Scotland and in Aberdeenshire. A Soils Correlation Committee was set up in 1930 to promote uniformity of methods classification and nomenclature.

The Soil Survey of England and Wales was formally set up in 1939. Soil survey in Scotland was based in the Macaulay Institute for Soil Research, founded in 1930, and in the early years most work was done from Aberdeen. In 1946, the Soil Survey of England and Wales was transferred to Rothamsted Experimental Station, Harpenden Herts., and a truly national soil survey programme began. In Scotland, the first national survey was started in 1948.

The principal products of the national systematic soil survey programmes in Scotland, England and Wales are described in Hodgson (1991) and Jarvis (1999). These programmes had effectively ceased to function by 1987. In summary, the output comprised a range of general purpose detailed maps at scales ranging from 1:25,000 to 1:63,360 together with explanatory reports incorporating information about the soils and their associated landscapes and environments. In many, soil data are interpreted to provide guidance about specific land use, mainly for agriculture and forestry. About 24 percent of England and Wales is covered by such maps and in Scotland most of the arable land has similar cover. Together with other special purpose surveys, remote sensing, geological data and further limited field work, these maps formed the basis for the production of the National Soil Maps at the 1:250,000 scale.

In Northern Ireland, systematic soil survey did not begin until 1987 (Cruickshank and Jordan 1996). The full 1:50,000 programme is now finished and, for the first time a complete cover of soil maps at the 1:250,000 scale exists for the whole of the United Kingdom (Figure 1).

Developments in England and Wales

Soil mapping

The coverage of detailed soil mapping is described by Bullock (1991), Bullock and Jones (1996) and Jarvis (1999). To date there has been no resumption of a strategic national mapping programme.

However, some small amounts of special purpose soil mapping have been undertaken, for example:

A project to collect detailed information and prepare maps of soil series, pH and land use around nuclear power stations has produced approximately 500km^2 of new and revised detailed soil survey.

A request from a commercial company requiring detailed soil (series) information for an area around Bristol, in south-west England, where there was only partial detailed map cover, was met by means of a desk study. This was undertaken by an experienced soil scientist who knew the area well and who, with the aid of aerial photographs and his detailed knowledge of local landscapes and soil patterns, prepared a soil series map. This map formed the basis of a spatial application for the company concerned. The approach demonstrated what could be achieved with little or no additional fieldwork by using the accumulated knowledge of landscapes acquired by experienced field scientists.

Isle of Man: Groundwater vulnerability mapping has formed a major project for the Isle of Man government. The existing soil maps were not sufficiently detailed and so an intensive survey was made to produce a 1:50,000 scale map of the 560km^2 island. From these data and existing geological information a robust groundwater vulnerability map was provided. The maps have subsequently been invaluable in identifying sites with specific soil and hydrological properties; allowing suitability assessments to be made for septic tank drainage associated with new development sites.

Mapping of the soils on the Salisbury Plain military training area has been carried out with a view to predicting trafficability for wheeled and tracked vehicles. A soil map data set will be produced by environmental modelling based on existing large (1:25,000) and small-scale soil information (1:250,000 National Soil Map), parent material derived from drift and solid geology and landscape analysis and classification (Digital Terrain Models). Ground truthing will be undertaken using a grid survey in order to quantify map accuracy.

Soil Monitoring

National Soil Inventory

As reported by Jarvis (1999), the National Soil Inventory (NSI) was a programme of sampling and describing the soils of England and Wales on a regular 5km x 5km grid across the two countries. It was undertaken during the National Soil Map programme (1979-1984). The analysis of the 5,692 samples taken from the upper 0-15cm give a national picture of soil quality in that period (McGrath and Loveland, 1992). Subsequently 900 arable and ley grass sites and 750 permanent grassland sites have been revisited (1995-1996) and samples analysed for pH, organic carbon, P, K, Mg and heavy metals to discover if changes have occurred since the first inventory of 1979-84. In 2002-3 a subset (580) of the non-agricultural sites were re-sampled to complete the exercise.

Analysis of the results suggests that for arable and rotational grass soils there is a slight decrease in the median OC in topsoils with less than 18% clay soils (1.7 to 1.6%) and a decrease in the median for topsoils with more than 18% clay (2.6 to 2.4%) (Figure 2). Permanent grass soils show increases in the median OC content (3.7 to 4.2%). The results for some of the other properties measured are given in Table 1.

There are significant decreases in OC in all categories of non-agricultural soils from the OC measured in the 1980's. Within the land use types, bogs, coniferous woodland, rough grazing, upland grazing and upland heath all show significant decreases, and deciduous woodland, lowland heath and scrub show no change. Only brown soils show an increase in OC between the two sampling dates. Soils with wetness classes 1 (well drained), 4 (poorly drained), 5 (very poorly drained) and 6 (wet soils) show significant losses (Bradley 2004a).

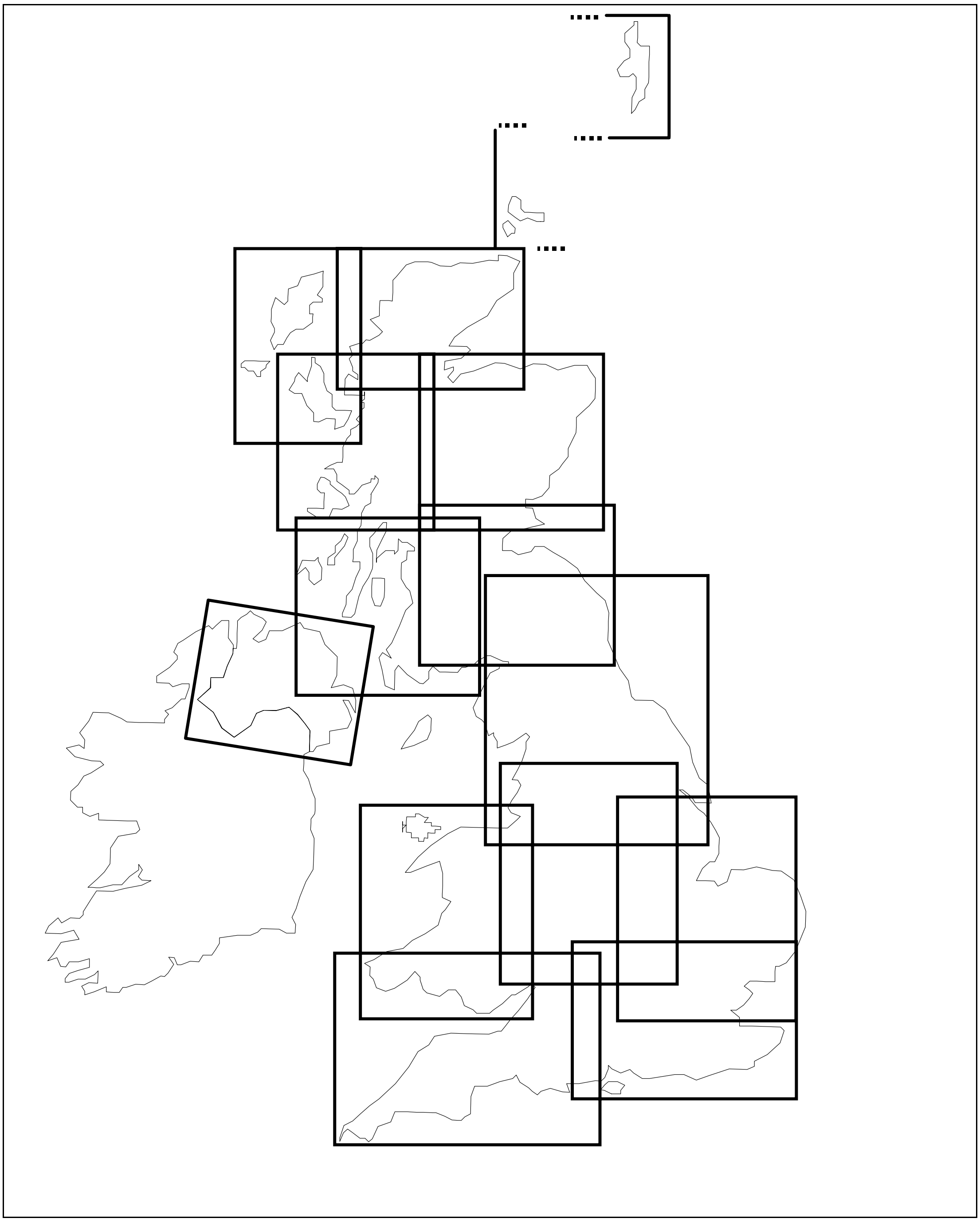
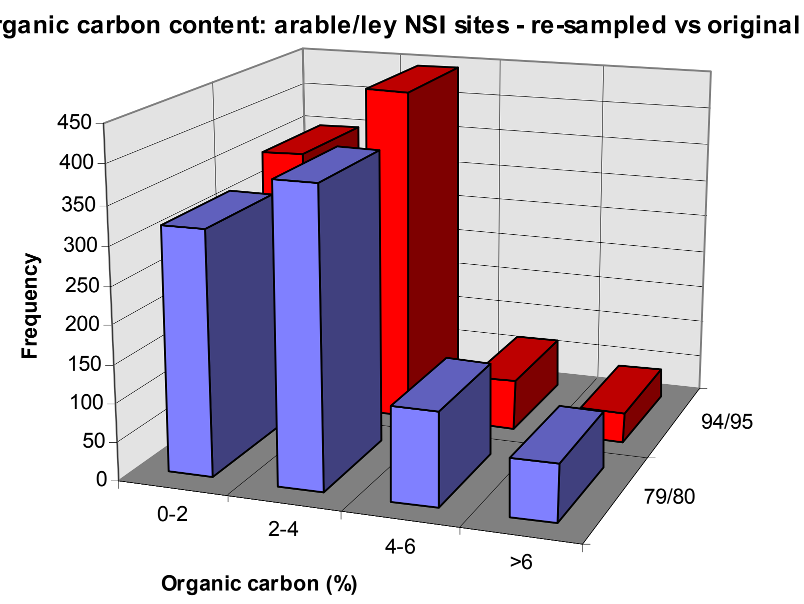


Figure 1: Soil maps published at 1:250,000 scale for the UK



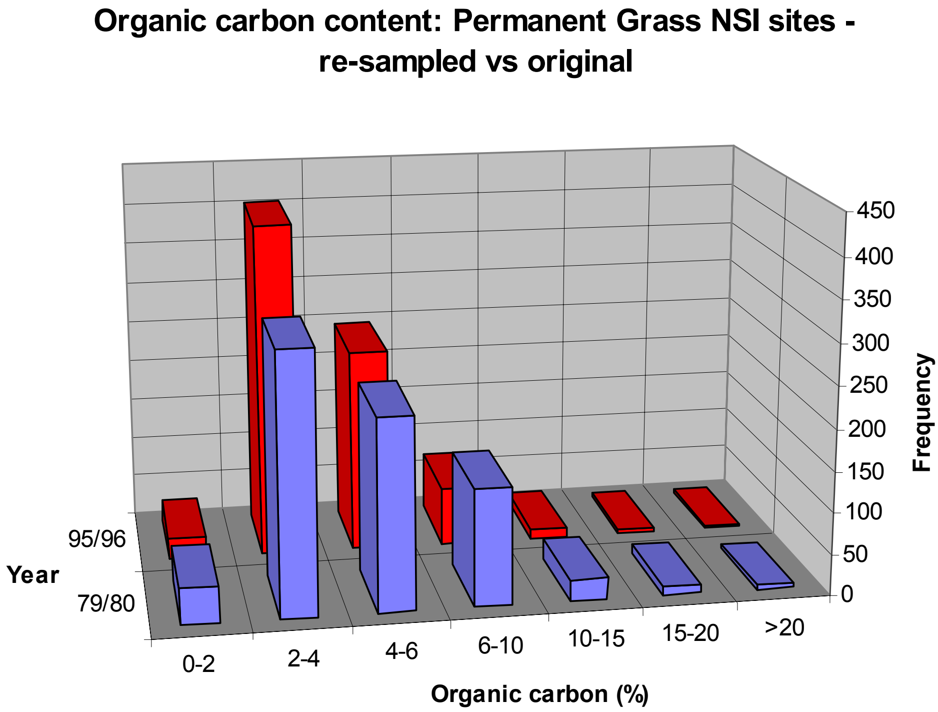


Figure 2: Monitoring Organic Carbon contents under different land uses

Table 1. Summary Statistics for NSI resampled sites and the original data for the same sites

	Arable Re-sample 1994/95 (n = 904)						Arable original 1979/80 (n = 883 - 904)					
Var.	Min	25%	Med	75%	Max	Mean	Min	25%	Med	75%	Max	Mean
pH	4.01	6.56	7.22	7.78	8.57	7.12	4.20	6.10	7.00	7.70	8.40	6.90
OC%	0.43	1.66	2.29	3.14	46.80	2.78	0.40	1.80	2.40	3.80	30.20	3.30
Ptot	51	451	595	783	8,150	661	170	611	785	1,034	3,728	875
Pav	0.2	21	33	53	2,329	44	1	16	25	41	274	32
Kav*	6	129	198	289	2,000	236	12	105	160	249	960	199
Mgav*	1	46	81	180	1,060	143	9	59	98	171	981	141
Cd	0.05	0.18	0.23	0.31	3.50	0.32	0.05	0.60	0.80	1.10	11.70	0.82
Cr	0.05	19	28	40	2,340	40	2	31	42	55	285	44
Cu	0.05	12.0	16.7	21.0	223.0	18.5	2.6	13.3	18.1	23.1	189.0	20.2
Pb	0.05	22.3	28.7	40.3	1,287.0	38.5	3.0	24.0	32.0	44.0	3,461.0	45.0
Ni	0.05	14.7	22.0	31.7	1,350.0	28.0	0.9	18.0	25.0	34.0	299.0	27.0
Zn	0.05	49	67	87	1,427	70	10	64	83	105	1,850	91
Co	0.4	7.0	10.3	13.7	59.3	10.9	0.2	7.5	11.0	14.5	4.76	11.6
Mo	0.05	0.05	0.37	0.83	33.00	0.71						
V	0.05	26.0	40.8	57.0	330.0	44.1						
As	0.05	1.9	3.2	6.0	110.0	5.4						
Hg	0.05	0.05	0.10	0.10	2.20	0.14						
Se	0.04	0.16	0.40	0.44	4.40	0.41						
Permanent Grass Re-sample 1995/96 (n = 768)							Permanent Grass Original 1979/80 (n = 768)					
pH	3.72	5.23	5.64	6.40	8.29	5.88	3.40	5.10	5.60	6.40	8.00	5.70
OC%	1.0	2.9	3.7	4.7	33.4	4.2	0.6	3.2	4.2	6.0	49.3	5.0

*n = 903

To account for the varying time interval between samplings, annual rates of change averaged over sampling intervals were calculated (Figure 3) by Bellamy *et al.* (2004). This assumes that the process of change is linear over the sampling interval. An analysis of known rates of change in soil carbon under different conditions showed this to be reasonable, except where carbon is being lost very rapidly as for example where long-term manuring has recently been discontinued.

There is an overall increase in pH, i.e. topsoils are becoming less acid. When considering the land use types, there are significant increases under deciduous woodland, rough grazing and upland heath with significant decreases only under upland grass (Figure 4).

These projects will enable further work to be instigated to model changes in soil parameters across all land use types in England and Wales. They form the basis of any on-going soil monitoring to satisfy the requirements of the proposed EU Soil Monitoring Directive.

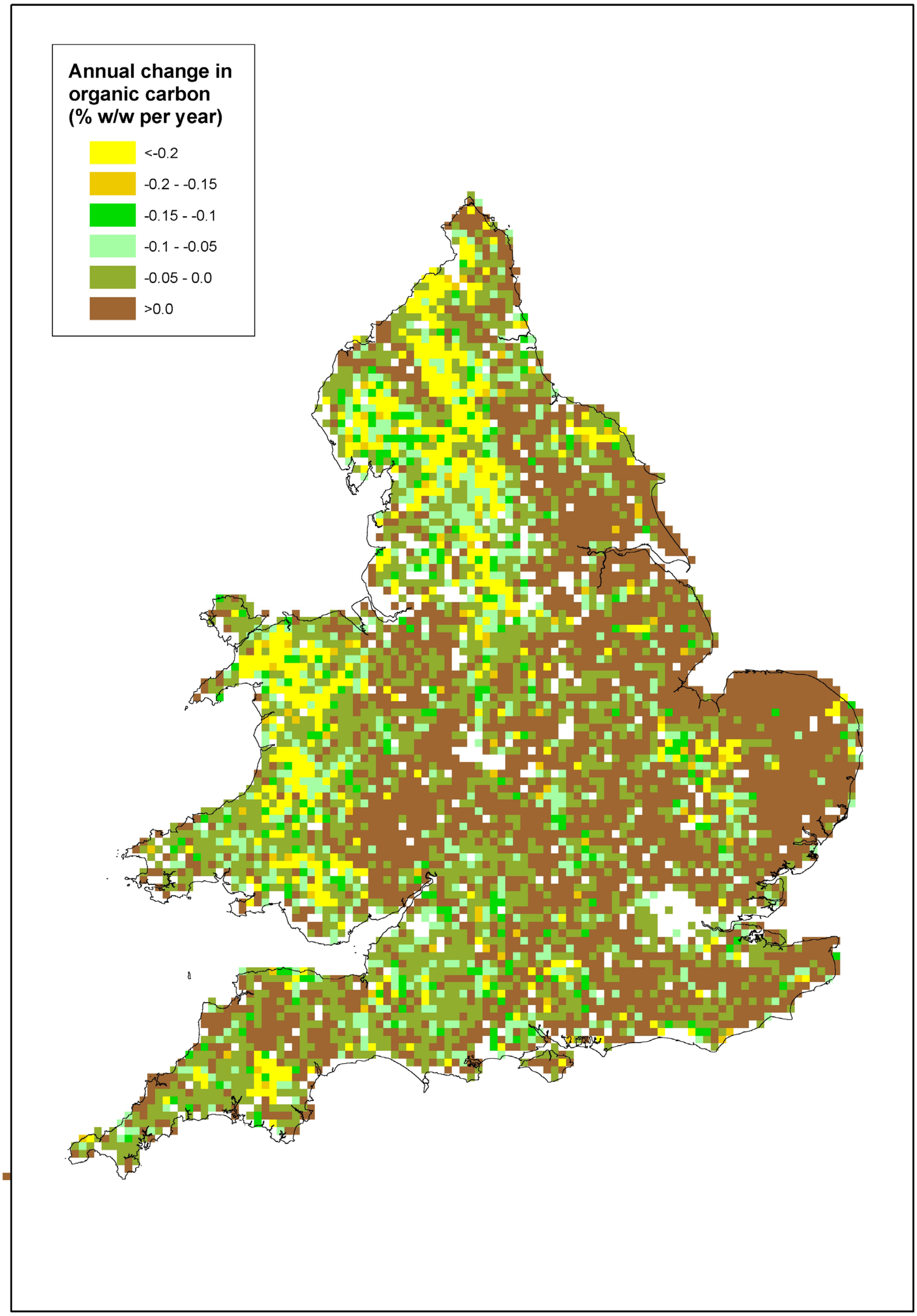


Figure 3: Annual changes in organic carbon normalised for differences in sampling intervals

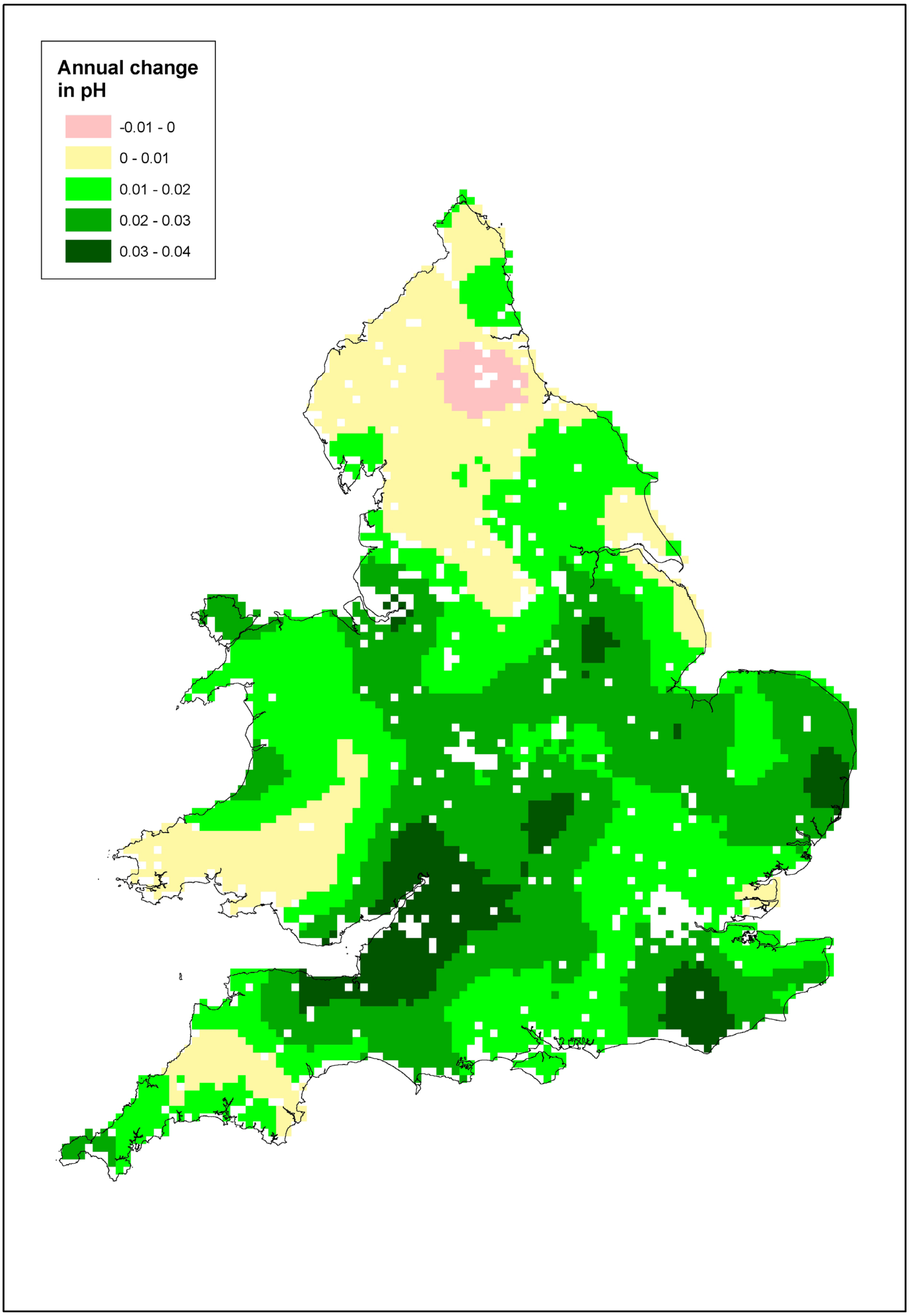


Figure 4: Annual changes in pH normalised for differences in sampling intervals

Environmental Change Network

A series of terrestrial sites to monitor changes with time of a wide range of environmental parameters has been established across the United Kingdom. These sites are mainly located in places where there was already a good historic record of environmental measurements. The soils of each site have been mapped and within a target sampling area, the soil described in detail according to a standard protocol. Samples have been taken and analysed for particle-size distribution, pH, organic carbon, nutrients and heavy metals.

The intention is to monitor these sites in the long-term and five-year and twenty-year soil sampling cycles are planned. The first and second sampling and analysis has been completed and the third of the five-year cycle samplings is now under way.

Representative Soil Sampling Scheme (RSSS)

The RSSS was initiated in 1969 to keep the Ministry of Agriculture (MAFF) informed of the status of agricultural soils in England and Wales by obtaining truly representative soil pH and nutrient data across the range of farming types. It is managed by ADAS with Rothamsted Research responsible for storing the digital data. To minimise costs and to spread the work load evenly over the years, the strategy was adopted of sampling a relatively small number (120 to 180) of farms in each year. The results are bulked from 5 year periods to obtain enough data for statistical analysis with temporal changes assessed between these 5 year periods.

The latest report (2003): (http://www2.defra.gov.uk/research/project_data/Default.asp) suggests that between 22 and 30% of the sites sampled have never been limed and over 40% have not been limed for at least 5 years. About a third of all fields sampled have been limed within the last 4 years. More arable (between 30 and 36%) than grass (16-25%) fields have never been limed. Mown grass is more likely to have been limed (79-87%) than other grass (62-79%) with 26-32% of those applications in the last 4 years compared with 16-25% for other grass.

For arable crops the results show differences in liming policy which reflect the known variation in susceptibility to acidity of these crops. Sugar beet and winter barley are susceptible to acidity and 43-56% of sugar beet and 38-45% of winter barley fields had been limed within the last 4 years, with 17-27% (sugar beet) and 8-15% (winter barley) in the previous year. Only 6-7% of fields had been limed in the year prior to potatoes. This is consistent with the fact that potatoes can tolerate acid soils and recent lime application can increase levels of potato scab.

Between 66 and 70% of the fields sampled have received a dressing of organic manures at some time and about a third of fields had received organic manures in the previous year. Farmers reported that 55-59% of arable fields had received a dressing of manure at some time. For ley/arable rotations the proportion of fields receiving manures was much greater at 81-97%, whilst for all-grass rotations 73-76% of fields received manures.

Between 60-68% of mown grass fields had had manure in the previous year, while for other grass types the proportion of fields was less at 25-31%. For arable fields, spring-sown crops provide farmers with a 'window of opportunity' for manure spreading, this is reflected in the greater proportion of applications in the year prior to planting sugar beet (about a third) and potatoes (37-65%) compared with 7-20% of winter wheat/barley and oilseed rape crops.

Countryside Survey

The CS is a research programme jointly funded, as a partnership, by several Government departments and Agencies, and the Natural Environment Research Council (NERC). It provides a national network of sites across Great Britain and is used to obtain information necessary for reporting on biodiversity in the wider countrywide, measuring progress towards sustainable development and detecting the impacts of human activities and global environmental change

The first survey was carried out in 1978 with subsequent surveys in 1984, 1990 and the most recent in 1998/99, which is known as Countryside Survey 2000 (CS2000). Soils were sampled during 1978 and again in CS2000 with soil mapping in 1994 by SSLRC (formerly the Soil Survey of England and Wales now National Soil Resources Institute) and MLURI (now The Macaulay Institute). Soils were sampled in CS2000 for a baseline assessment of soil biological properties and to examine long-term change in soil pH and organic matter. Soil data are also used to investigate associations between soils and vegetation, for example, eutrophication in British habitats.

Analysis of the information on soil acidity suggests that, since 1978 when the data were first collected, soils have become slightly less acid overall (Figure 5). (http://www.cs2000.org.uk). However, the change is most marked for the soils that were most acid in 1978, while neutral and base-rich soils show a slight increase in acidity. Although falling acidity would be in line with the recent success in reducing levels of acid deposition in the environment, the full analysis of soils has not yet been completed and it is too early to draw firm conclusions.

Although we can infer some of the possible causes of vegetation change from the analysis of CS2000 data alone, it is also necessary to consider the results in relation to other scientific work, so that ideas and hypotheses about the drivers of change can be tested critically. An important issue, for example, is the extent to which the changes in vegetation condition between 1998 and the earlier Countryside Surveys are due to random differences in weather conditions at the time of the survey, changes in land management or global climate change.

Soil Databases

The Land Information System - LandIS.

The structure of LandIS and its key databases has been described by Bullock and Jones (1996), Proctor *et al.* (1998) and Jarvis (1999). The system is a relational database management system running under ORACLE. Stand-alone (off-line) packages have been developed to provide querying, analysis and reporting of a number of LandIS datasets (Dufour *et al.*, 1998; Hallett *et al.*, 1994, 1995).

Spatial representation of data held in the Oracle system and manipulation of vector data is now possible using GIS software such as ArcGIS. Graphical user interfaces have been developed to allow on-line data query and reporting. Remote on-line access to these interfaces is currently under investigation.

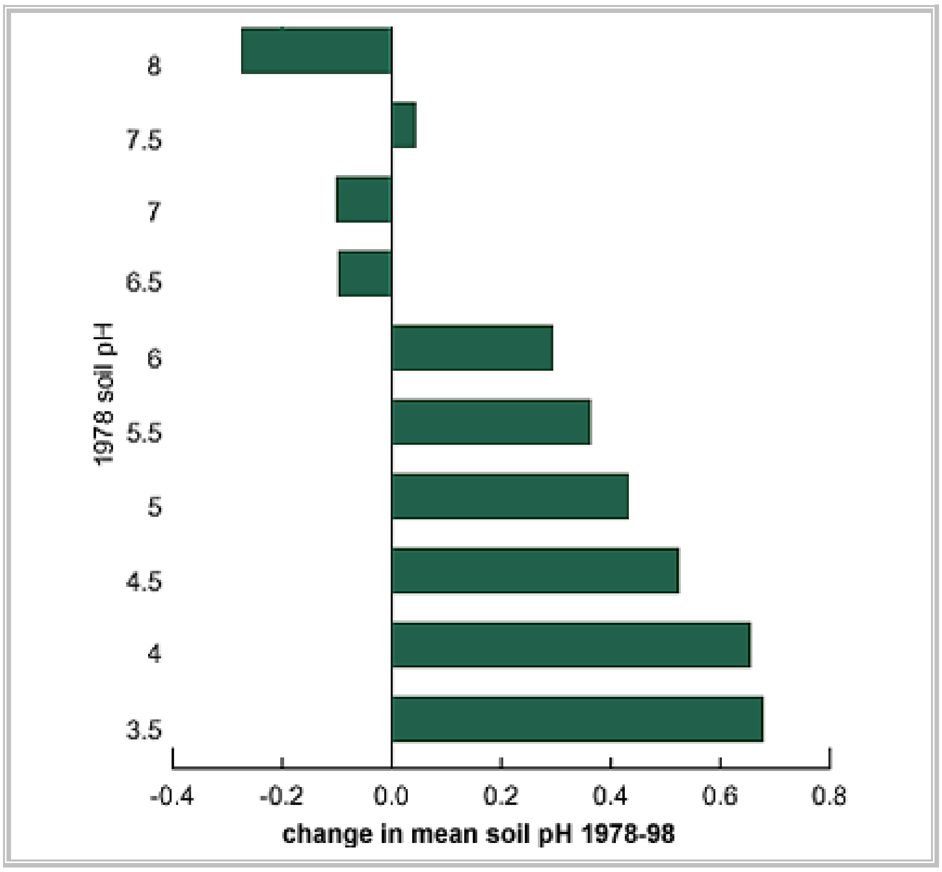


Figure 5: Changes in mean soil pH between 1978 and 1998.

Each bar gives the mean change in pH for soil samples grouped according to their pH in 1978. There was an overall statistically significant increase in mean pH between 1978 and 1998 ($P<0.05$, $n=573$).

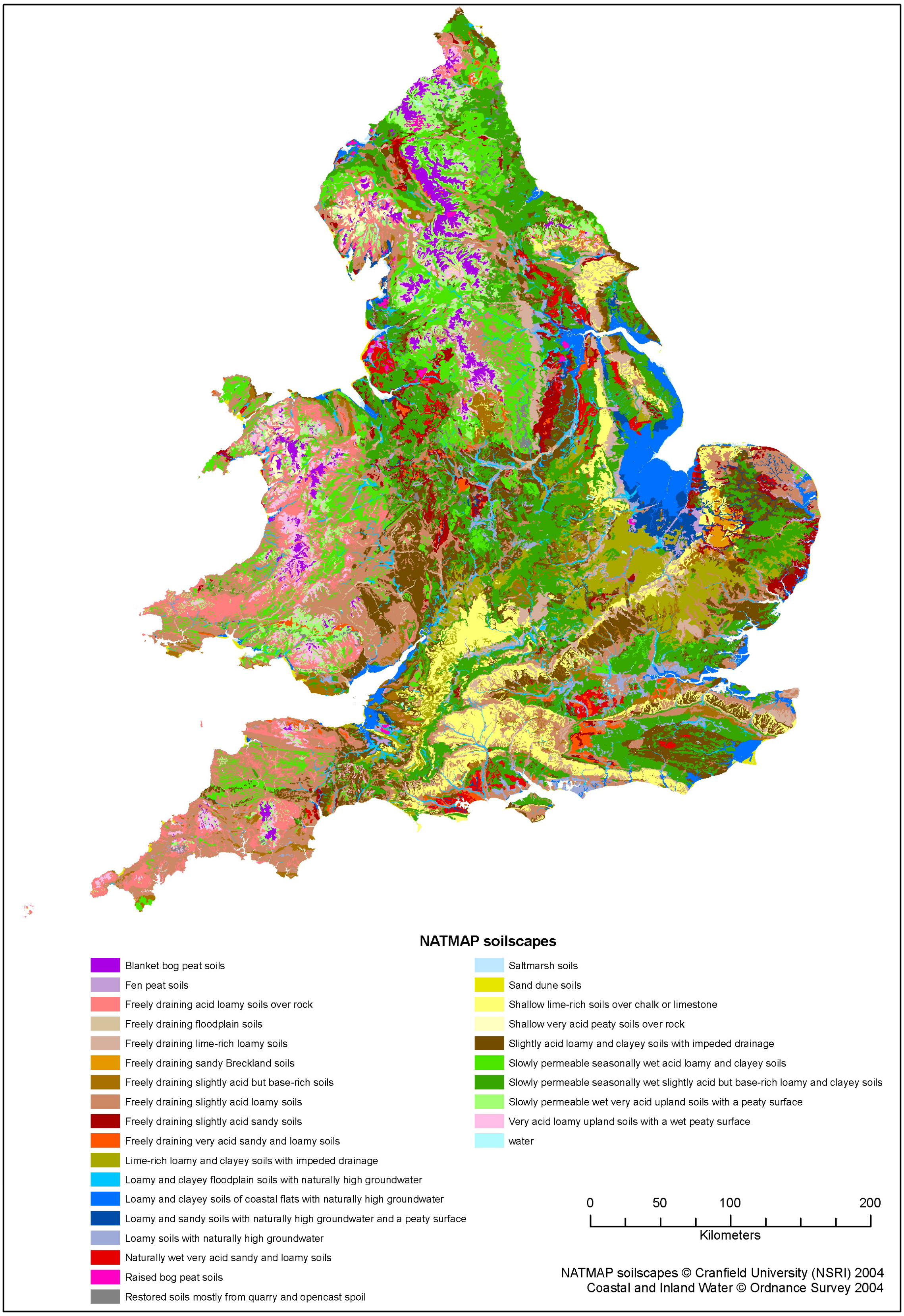


Figure 6: Soilscape map for England and Wales

The soil map unit boundaries of the National Soil Map were comprehensively reviewed in 1999 - 2001 and a new digital vector data set created by digitisation of the original 1:50,000 scale film compilation map sheets, from which the 1:250,000 scale National Soil Map was constructed. Cartographic errors and inaccuracies, caused in part by the manual transfer of information from the 1:50,000 to 1:250,000 scale, were removed during this process. In addition, soil map unit boundaries were introduced for all urban areas of England and Wales giving complete national coverage. A new set of raster data sets has been generated from this vector map with pixel sizes of 1km, 2km and 5km.

In 2003, a national map of Soilscapes was generated by the amalgamation of soil associations into 27 map units with similar texture, base status and water regime (Figure 6). The part of this map covering England is available on a Government-supported web site, www.magic.gov.uk. An A2-size paper map was published in Spring 2004 by the Environment Agency for England and Wales as an insert to its state of the soil environment report (Environment Agency, 2004a).

Applications and use of soil data

Since 1987, much of the work undertaken by the National Soil Resources Institute has been to use the accumulated soil information and other environmental data to provide solutions to specific issues of concern. Some of these applications are listed by Bullock and Jones (1996). Further information on the principal developments are given in the sections below.

Hydrology of Soil Types (HOST)

The HOST classification is based on a number of conceptual models that describe dominant pathways of water movement through the soil and, where appropriate, the substrate (Boorman *et al.*, 1995). The most important soil properties that influence the hydrological response of a catchment are hydraulic conductivity, soil moisture retention and pathways of water movement. Such properties are both difficult and expensive to measure.

To develop the HOST classification, soil types from the whole of the United Kingdom were characterised in terms of surrogates for direct measurement of soil hydraulic properties, e.g. depth to gleying, depth to a slowly permeable layer, integrated air capacity and the presence of a peaty surface layer. HOST has been used to estimate low flow indices and standard percentage runoff from stream and river catchments.

Groundwater Vulnerability

The risk that groundwater will be polluted by substances applied to or spilled upon the land surface, depends on the natural characteristics of a site and relates to the ease of vertical movement of pollutants. Assessments of soil leaching potential were combined with aquifer type and distribution, and the occurrence of low permeability drift, to gauge the risk of groundwater pollution (Palmer *et al.*, 1995). A series of 53 maps at the 1:100,000 scale have been produced covering England and Wales. These maps are intended for use by planners, developers and regulatory bodies to help implement the Groundwater Protection Policy. Maps at the 1:250,000 scale have also been produced for Scotland and Northern Ireland.

CatchIS

The Catchment Information System – CatchIS – is a spatial computer based system developed by the National Soil Resources Institute in collaboration with Severn Trent Water Ltd and is a decision support tool to help manage water quality in midland England. The system presents an overview of the water resources, soil and climate together with cadastral and catchment features. It combines environmental datasets with simulation models of contaminant movement, so that the user can assess the vulnerability of water resources to diffuse pollution. Use of CatchIS is described in more detail by Hollis *et al.* (1995 and 1997) and the system is currently being ported onto ArcGIS.

SEISMIC

The Spatial Environmental Information System to Model the Impact of Chemicals – SEISMIC – (Hallett *et al.*, 1995; Hollis 2000) brings together spatial and parameter soil, groundwater resource, spatial cropping, computed agroclimatic, daily weather data and crop suitability assessments to aid the assessment of the fate and behaviour of potential environmental contaminates. The system uses data from LandIS and processes them for use in other software packages such as simulation models.

NATURAL PERILS DIRECTORY

NPD has been developed to identify areas of England, Wales and Scotland where low buildings and domestic houses are susceptible to subsidence and/or flood damage because of soil shrinkage and swelling. The subsidence vulnerability assessment model (Hallett *et al.*, 1994; Jones *et al.*, 1995) is based on soil shrink-swell potential and potential soil moisture deficit (Jones and Thomasson, 1985). The flood predictions are based on the extent of soils developed in alluvium.

LEACS

The LEACS is a Land Evaluation for Assessing Corrosivity and Shrinkage package. Failures in the potable water pipe distribution network are a major cost to water supply companies. The chemical aggressiveness of soils and their capacity to shrink and swell as they dry and re-wet are significant natural factors leading to bursts. Soil data are used in LEACS to identify where aggressive and shrinkable soils are found and therefore where damage might occur (Jarvis and Hedges, 1994; Dufour *et al.*, 1998).

Developments in Scotland

The full extent of soil survey in Scotland is described by Bibby (1991) and Gauld and Paterson (1996).

Soil mapping

Most arable areas are covered at the 1:63,360 scale with surveyor's field maps available in many cases at 1:25,000 scale. There are also numerous unpublished farm, estate and other local soil maps often covering areas of high ecological value at the 1:10,000 scale. The National Soil Map at 1:250,000 covers the whole of the country (Figure 1).

Soil monitoring

National Soil Inventory

Coincident with the preparation of the National Soil Map, soils were described at 5km intervals (3,200 profiles) in a similar way to the NSI in England and Wales, except that samples were taken and analysed only at every 10km intervals (810 profiles). No further re-sampling has been undertaken.

Environmental Change Network

Two of the sites in the Network are located in Scotland, one at Glensaugh near Aberdeen, the other at Sourhope in the Borders. The soils are mapped and sampled to the same protocols as elsewhere in the United Kingdom.

Soil databases

The principal datasets held in the Macaulay Land Use Research Institute (MLURI) soils database have been described by Gauld and Paterson (1996). The database now incorporates digital images of all detailed soil maps.

Application and use of soil data

The following are examples of the ways soil data are being applied:
Soil acidification and critical load assessment;
Assessment of environmental and experimental sites;
Review of sites intended for opencast coal mining;
Appraisal of land proposed for gravel extraction;
Assessment of the agricultural potential of development land;
Selection of suitable sites for forest nurseries, vegetables etc.;
Predicting risk of soil related subsidence (see INSURE above);
Estimates of the soil carbon pool.

It is officially recognised that soil data are needed for the prevention of environmental pollution from agricultural activities (SOAFD, 1992). In 2001, the Scottish Environmental Protection Agency (SEPA, 2001) published a *State of the Environment – Soil Quality Report*) while the Scottish Executive Environment and Rural Affairs Department commissioned a study of soil protection issues (Adderley *et al,* 2001).

Soil data are also being incorporated into models being developed at Macaulay that predict the behaviour of deer and the restoration of native woodland.

Developments in Northern Ireland

Soil mapping

Cruickshank and Jordan (1996) reported that detailed mapping had been completed in Northern Ireland (13,550km^2). In total, 17 map sheets covering the whole area at 1:50,000 scale (Figure 7) and a single 1:250,000 map have now been published together with an explanatory text (Cruickshank, 1997).

Soil monitoring

Soil geochemical survey

Coincident with the fieldwork for the soil mapping project, soils were sampled to 15cm depth at a site in each 1km x 1km in the agricultural lowlands and analysed for total concentrations of 15 elements (calcium, cadmium, cobalt, chromium, copper, iron, lead, magnesium, manganese, molybdenum, nickel, phosphorus, potassium, sodium and zinc) to constitute a geochemical database. The results have also been published as an atlas (Jordan *et al.*, 1997). Available concentrations of these elements have also been measured.

Environmental Change Network

One of sites in this national network is located at Hillsborough, Co. Down. It is representative of grassland in much of the north-western United Kingdom.

Soil databases

Soil maps.

The 17 soil maps at 1:50,000 and the 1:250,000 soil map are available in digital form.

Soil attribute database

This is a comprehensive compilation of information on the observed physical and chemical nature of all soil horizons at inspection pits, sampled on a 5km x 5km grid, as part of the soil survey (Cruickshank, 1997).

The database is held as a number of ORACLE tables linked by the grid reference of the actual site. It is distributed on CD-ROM.

Environmental database

This is a database storing data on dominant soil series, HOST class, solid and drift geology, and various climate data for every 1km^2.

Application and use of soil data

Cruickshank (1997) cites a range of applications. The following is a selected list:

- Estimations of the soil carbon pool;
- Soil acidification and critical load assessment;
- Soil hydrology classification (see above);
- Agricultural land classification;
- Groundwater vulnerability (see above);
- Assessment of pipeline corrosion risk (see above).

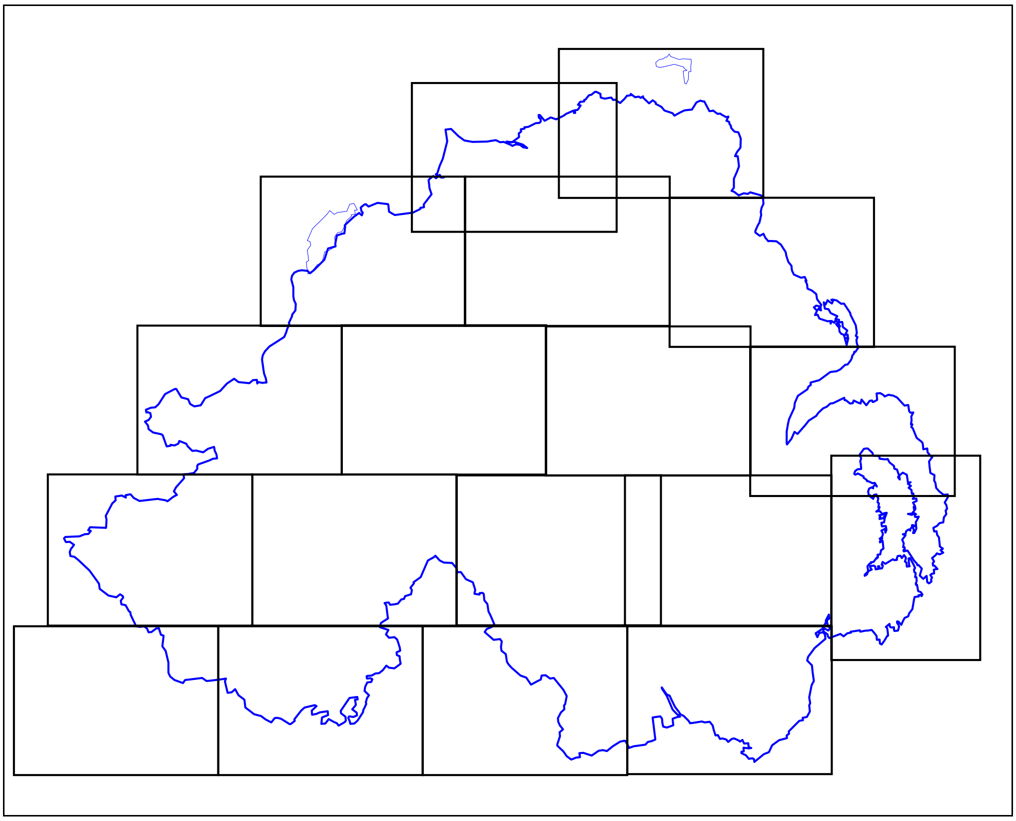


Figure 7: Soil maps at 1:50,000 for Northern Ireland

UK soil organisations are also applying soil data to:

- Climate change impact studies;
- Integrated soil and water management;
- Salmonid fisheries management;

- Water supply and sewerage network management;
- Waste management;
- Management of biodiversity in the wider landscape;
- Prediction of foundation conditions and vulnerability of property to subsidence and flood damage.

Outlook

Soil protection policy initiatives received considerable impetus following the publication of the Royal Commission's report on *The Sustainable Use of Soil* (RCEP, 1996). Among its key recommendations were:

- A soil protection policy should be implemented for the UK:
- Planning policies should be reviewed to give greater weight to the appropriate use of soil resources;
- A national soil quality-monitoring scheme should be established;
- Legislation governing the spread of wastes on land should be reviewed.

There is now a Soil Action Plan for England (Defra 2004) and a State of Soils Report (Environment Agency 2004a) A Soil Strategy for Wales and a Soil Strategy for the Environment Agency for England and Wales (Environment Agency 2004b) are in preparation in 2004.

Soil information and data are beginning to feed into thinking about the implementation of the Water Framework Directive and revised Agri-Environment Schemes for farmers where natural resource protection will constitute certain of the options for adoption.

The likelihood of a soil monitoring requirement under the European Thematic Strategy on Soil is prompting attention to be given to the structure and focus of soil monitoring networks for the devolved Governments of the UK. A fundamental review of the issue associated with soil quality indicators is reported by Loveland and Thompson (2001). At present there is no well-developed or widely agreed means of comparing the performance of different possible soil monitoring designs for use at regional, national and continental scales. Bellamy and Kibblewhite (2004) have described a set of generic performance criteria, which assess the fitness-for-purpose, and comparability based on geostatistical analysis of spatial and temporal criteria.

While all these initiatives are expected to result in more interest in soil protection and management and therefore create more demand for soil information, the shortcomings in data availability have been highlighted by Loveland and Thompson (2001) and by Stevens *et al* (2002). No significant survey activity has been undertaken since 1986. While there is considerable demand for more detailed mapping than the National Soil Maps at 1:250,000 scale, no funding exists for strategic approaches to the production of more detailed mapping information.

In order that the true significance of soil can be incorporated into environmental assessments and environmental models, national 1:50,000 scale map coverage of soils is required. This is unlikely to happen in short- or medium-term timescales because, using conventional techniques, field survey is intensive labour and hence expensive. The necessary skill-base is also rapidly disappearing as soil surveyors retire.

A new, rapid and cost effective method of soil map preparation is therefore urgently required. Promising results have been obtained for the application of mathematical techniques, in the form of a predictive soil-mapping model, to a range of existing environmental and remotely sensed data.

A model has been developed in trial areas in Derbyshire and Essex. The areas were selected to make use of relevant, but not necessarily universally available data, in a wide range of soilscapes. Once developed the model was used as a predictive tool to generate soil maps in nearby test areas where soilscapes were broadly similar to those of the trial areas.

It is hoped to extend the system over all England and Wales. Initially, a hierarchical landscape classification will classify the whole of England and Wales into landscape regions (1:1M to 1:5M), systems (1:200,000 to 1:1M), catenas (1:80,000 to 1:200,000) and facets (1:10,000 to 1:80,000). This will be achieved by processing a digital elevation model consecutively at 1,000m, 500m, 250m, 100m, 50m and 10m grid size. These will be more precisely defined and delineated using surface lithology from geological maps, drainage patterns, climatic data and land-use information to establish distinct physiographic units.
The resulting physiographic units will provide a spatial context, into which each of the existing large-scale soil maps can be placed. These regions will largely define the spatial extent to which each soil map can be used for extrapolation, i.e. extrapolation is only possible to areas of the same

physiographic unit. The map of physiographic units will also highlight the limited number of soilscapes, which are currently not covered by detailed soil mapping.

The physiographic units will be defined as precisely as possible both in terms of how individual soil series are distributed within the association and the relationship of the association to its neighbours. These definitions will be derived from published material and more importantly from 'workshops' involving appropriately experienced surveyors.

Until 2003 there was no reliable inventory of soil organic carbon for the UK as required by the Kyoto Protocol. A project has now been completed to produce such a database for UK topsoils and subsoils to an agreed set of protocols and compatible with GIS and numerical modelling requirements. Protocols have been agreed between the collaborators and with OC modellers leading to the compilation of a profile-based core dataset. The derived database gives the organic carbon, sand, silt and clay and bulk density weighted to reference layers from 0 to 30 and from 30 to 100cm depth (Bradley 2004b).

The data will be used initially to model OC change from a baseline of 1990 to 2050 (Falloon *et al.* 2004). The database should not be an end in itself, its value lies in the way it is used to help understand carbon dynamics in the UK. The project has demonstrated how the national soil institutes can collaborate together to create a unified UK database to agreed protocols. It augers well for future collaborations to extend the range of parameters included.

Acknowledgements

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Section 3: Conclusions

Soil Information: Uses and Needs in Europe

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Introduction

There is now abundant evidence of the need for soil surveys, monitoring of soil conditions and information systems to meet the demands for soil data at all scales. In the 1950s and 1960s, the use of soil 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, its contribution to such issues as food production for an ever-growing population, biodiversity, urban and rural infrastructures, and environmnetal protection in general, is now required at all of the following levels:

GLOBAL
↓
EUROPEAN
↓
NATIONAL
↓
REGIONAL
↓
WATERSHED/LANDSCAPE
↓
FOREST – FARM/FIELD – URBAN PERIMETER – ANY PARCEL OF LAND

Global Requirements

There has been an exponential increase in the need for soil information at the 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 United Nations Conference on Environment and Development, known as the Earth Summit.

Important outcomes have been a number of initiatives at a global scale, 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. Biodiversity (CBD).

The need to make changes on a global scale and to develop long–term environmental strategies for sustainable development have been added to the agenda of most nations. 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.

All of these initatives require soil information. The UNFCCC is an interesting example of a global scale environmental agreement involving the need for information about soil properties on a national basis and requiring such information rapidly. Countries signing up to the Convention are encouraged 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 have been, able to obtain this information from their Soil Information Systems (Cannell *et al.*, 1999).

Because several EU, former EFTA and neighbouring (bordering) countries lack comprehensive national soil databases, they are unable to meet fully the requirements of the UNFCCC. 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.

Thus 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

Soil protection has not been accorded high ranking amongst the priorities for environmental protection in Europe. The majority of the population in Europe lives in urban areas and has only scant appreciation for the features and functions of soils. Direct contact with soil and the rural environment has been lost. The most common perception of soil is that it is: material covering the garden that supports plants and vegetables, a medium for burial or dumping waste and a surface on which to build houses and other infrastructures, such as roads and industrial premises.

Only during the last 3 years has the need for a coherent approach to soil protection become a political issue in Europe and, as a result, has been introduced as one of the thematic strategies to be developed within the Community's 6th Environment Action Programme (6th EAP). The rationale behind the development of a coherent approach to soil protection is based on the recognition of the multi-functionality of soils.

Soils are increasingly seen as a fundamental compartment of the environment performing vital ecological, social and economic services for European citizens, e.g.: filtering and buffering of contaminants allowing us to have clean drinking water, pool of biodiversity, source of raw materials, sink for atmospheric carbon dioxide, archive of cultural heritage etc. These functions are now recognised to be of equal importance to the traditional soil functions: production of food and fibre (agriculture and forestry) and surface for housing and infrastructure (spatial development).

In order to develop a soil protection strategy it is important to recognise that soils have distinctive features that make them quite different from air and water. Soils are first of all highly diverse both in space and time. Soil properties can change completely over the distance of a few metres. The development of a harmonised soil map of Europe (CEC, 1985) has highlighted the very great spatial variability of soils across the European continent (Figure 1).

The timescale for soil formation and subsequent changes is usually very long, often hundreds or even thousands of years. For policy making purposes, soils must be considered as a non renewable resource. This is at least the case in terms of the human lifespan. The great variability of soils demands that any protection strategy must contain a strong local element. It is at local level that we can act effectively in specific ways that are appropriate to the features of particular soil types.

For any soil protection strategy to succeed, it will be vitally important to identify the services that must develop and implement the protection measures. Off-site effects of soil degradation, that justify an European or even global approach to soil protection, must be clkearly identified. These include: silting-up of hydro-electric power generating schemes, increase in atmospheric carbon dioxide, contamination of drinking and bathing waters, contamination of food, increased frequency of flooding and landslides, etc. All these off-site effects can seriously threaten human health and have substantial economic implications.

A key feature for developing a soil protection strategy is the recognition that soils in Europe are commonly submitted to property rights and that the majority of soils are in private ownership. This ownership of soil makes it completely different from air and water, and brings with it a series of environmental liability implications.

The EU Soil Thematic Strategy builds upon the recognition that many important functions of soils are threatened by severe degradation processes. The major threats identified so far are: soil erosion, decline in organic matter content, loss of soil biodiversity, soil contamination, salinization, soil compaction, soil sealing and major hydro-geological risks (floods and landslides).

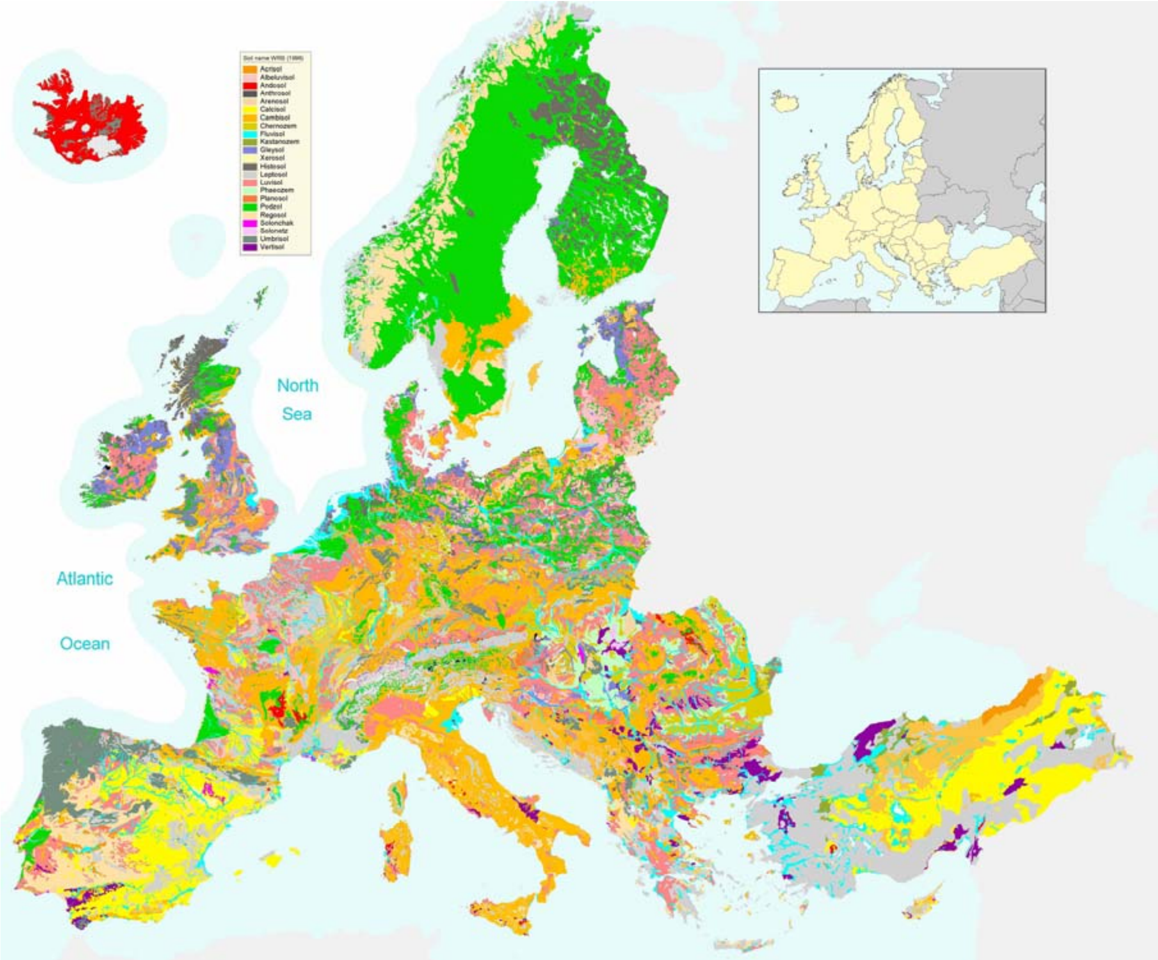


Figure 1: Soil map derived from the European Soil Database at scale 1:1,000,000.

Although much is known about the soils in Europe, this information is often scattered in different institutions both at National and at European level. Many data were collected a long time ago and need updating. A proposal for a common approach to soil monitoring will be put forward by the Commission in 2005 to address this problem. Existing soil information systems in Member States will be taken into account and a framework allowing for the interchange of data in an harmonized way across the EU will be included. In the longer term, the availability of policy relevant soil information will allow efficient implementation of the necessary measures to protect soils as the basis for sustainable development in Europe.

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.

The 6th Environmental Action Programme, published by the Commission in 2001, established the objective to protect soils against erosion and pollution while the Sustainable Development Strategy, also published in 2001, noted that soil loss and declining fertility are eroding the viability of agricultural land.

A coherent approach to soil protection in Europe is just beginning. The Communication 'Towards a thematic strategy for soil protection' (EC, 2002) outlines the steps needed to protect soil within the EU. It will take time to put these in place and further steps, as outlined in the final conclusions of the Council on the Soil Thematic Strategy, will be needed. An efficient soil information system, capable of answering the questions raised by policy makers, is a key requirement that must be implemented before further action can be undertaken effectively (see Van-Camp *et al.*, 2004a).

Directives Relating to Soils

During the last 20-30 years, the European Commission has produced a number of Directives aimed at protecting the European environment, that cover some aspects of soil protection. 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 directives 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 the Directive after swift recognition of a widespread problem.

The aim of the Nitrate Directive is to reduce 'water pollution caused by nitrates leaking 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, for example 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.

The Communication on the Soil Thematic Strategy (EC, 2002) has explicitly emphasised the need for improved information, both in space and time, on soils in the EU. The actions to be taken in the near future to address soil protection will be based on existing information, which is recognised as incomplete (see Van Camp *et al.*, 2004a). For the long-term protection of soils, it will be necessary to ensure the development of a more complete information base, monitoring systems and indicators to establish the prevailing soil conditions, and to evaluate the impact of diverse policies and practices.

The specifications of a Community information and monitoring system on soil threats will be the subject of an appropriate proposal for soil monitoring legislation. It will aim to ensure that a number of measurements on the identified threats in the relevant areas are carried out in a harmonised and coherent way and that its results are relevant to and accessible for policy makers and for early warning purposes. As regards contaminants, the monitoring will give priority to those substances that can be transferred from soil to food or have potential health implications in any other way.

The monitoring system to be established should, so far as possible, be based on existing information systems, databases and 'know-how' (see Van-Camp *et al.*, 2004e). The principle of cost-effectiveness will be taken into account. Systems should be designed in such a way that the data can be integrated into more comprehensive/multi-layered monitoring and reporting programmes, for example the Commission's INfrastructure for SPatial InfoRmation in Europe – INSPIRE – initiative (http://inspire.jrc.it) *last accessed 21/03/2005*). The consultation process should be completed to allow a formal proposal to be made by mid 2005.

The need for policy relevant soil information and databases was further reinforced by the Council, the Committee of the Regions and the Parliament.

The European Parliament supports the Commission in collating and perfecting the existing soil databases and completing the maps in order to obtain a georeferenced system; likewise, it approves the creation of a digital Geographical Information System, that would gather the currently fragmented information at appropriate levels for public access. The Council of Environment Ministers recognises that, in the absence of comparable policy relevant data, and in-line with the knowledge based approach, there is a need to set up a Community framework, including legislation, to develop a soil monitoring system based, as far as possible, on already existing systems and capable, where appropriate, of being integrated into more comprehensive multi-layered monitoring and reporting systems.

Trans-national 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. Monitoring programmes were 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 several Europe-wide research and monitoring programmes 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, particularly in the north. 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 is the Algarve-Andalucia project which was part of the CORINE programme. Under the EU Research Framework Programme VI, soil features more overtly as a key topic than in the previous Framework programmes. Recent examples of trans-national initiatives are the 1:250,000 scale georeferenced soil database projects organised by the European Soil Bureau (JRC) in the Oder, Meuse and Danube river basins – see the first chapter (Montanarella and Jones, 2005) in Section 1 of this book.

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 Network (ESBN) 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 detailed, accurate soil information Europe-wide.

Therefore, it is of paramount importance for the EU Member States to strengthen the ESBN as well as augment national soil databases to deal with these issues. Support for the Europe-wide initiatives of ESBN, the European Environment Agency and the Services of the European Commission are also needed urgently.

The countries of the enlarged EU, the former EFTA and Neighbouring (bordering) countries will need to assess whether they have an adequate information base on soil resources to support effective soil protection policies. On the evidence presented in this book, there appear to be very few countries with adequate detailed soil data to address even some of these issues.

There was a good response from soil experts from all over Europe to requests from the Commission for help in producing the 1:1,000,000 scale soil map and database. However, the minimum level of soil information in spatial terms for supporting present and future requirements would be a 1:250,000 scale georeferenced soil database for the whole of the Europe. The European Soil Bureau Network has already been actively involved with experts from the Member States in creating the framework for such a database (ESB 1998). The resulting manual of procedures has been translated into the several European languages (ESB, 1999a, 1999b, 2001).

National Needs

The fact that protecting 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 (Oldeman *et al.*, 1991). In the 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. Contamination;
3. Soil compaction;
4. Salinisation/alkalisation;
5. Loss of biodiversity;
6. Soil sealing - loss of land to urbanisation.

Soil Erosion

Soil erosion is a natural process, occurring over geological time, and indeed it is a process that is essential for soil formation in the first place. With respect to soil degradation, most concerns about erosion are related to accelerated erosion, where the natural rate has been significantly increased, mostly by human activity. Soil erosion by water is a widespread problem throughout Europe.

Soil erosion is regarded as one of the major and most widespread forms of land degradation, and bout 17 per cent of the total land area in Europe (excluding Russia) is affected to some degree. Water erosion is the most more common form of erosion though wind erosion is also prevalent in some parts of western, central and eastern Europe, and requires separate indicators from water erosion.

Three zones of erosion can be distinguished in Europe:

1. Southern zone characterised by severe water erosion;
2. Northern loess zone with moderate rates of water erosion;
3. Eastern zone where the two zones overlap and where former intensive agricultural practices caused significant erosion problems.

Within all three zones, there are areas where erosion is more serious, the so-called 'hot spots'.
The largest area with a high erosion risk is southern and western Spain (covering 44 per cent of the country's territory), with local erosion hotspots on the southern coast. Portugal, one-third of the country is at a high risk of erosion. In France, Italy and Greece, the areas with a high erosion risk cover from 1 to 20 per cent of the land surface respectively. In central and eastern Europe, Bulgaria and Slovakia are mostly affected by soil erosion, where around 40 per cent of land is affected.

By removing the most fertile topsoil, erosion reduces soil productivity and, where soils are shallow, may lead to an irreversible loss of natural farmland. Even where soil depth is good, loss of the topsoil is often not conspicuous but nevertheless potentially very damaging.

Severe erosion is commonly associated with the development of temporary or permanently eroded channels or gullies that can fragment farmland. The soil removed by runoff from the land, for example during a large storm, accumulates below the eroded areas, in severe cases blocking roadways or drainage channels and inundating buildings.

Erosion rate is very sensitive to both climate and land use, as well as to detailed conservation practice at farm level. The Mediterranean region is particularly prone to erosion because it is subject to long dry periods followed by heavy bursts of erosive rain, falling on steep slopes with fragile soils. This contrasts with north-west Europe where soil erosion is less because rain, falling on mainly gentle slopes, is evenly distributed throughout the year and consequently, the area affected by erosion is less extensive than in southern Europe.

However, erosion is still a serious problem in north-west and central Europe, and is on the increase. In parts of the Mediterranean region, erosion has reached a stage of irreversibility and in some places has practically ceased because there is no more soil left.

With a very slow rate of soil formation, any soil loss of more than $1t.ha^{-1}.yr^{-1}$ can be considered as irreversible within a time span of 50-100 years. Losses of 20 to $40t.ha^{-1}.yr^{-1}$ in individual storms, that may happen once every two or three years, are measured regularly in Europe, with losses of more than $100t.ha^{-1}.yr^{-1}$ in extreme events. The main causes of soil erosion are still inappropriate agricultural practices, deforestation, overgrazing, forest fires and construction activities.

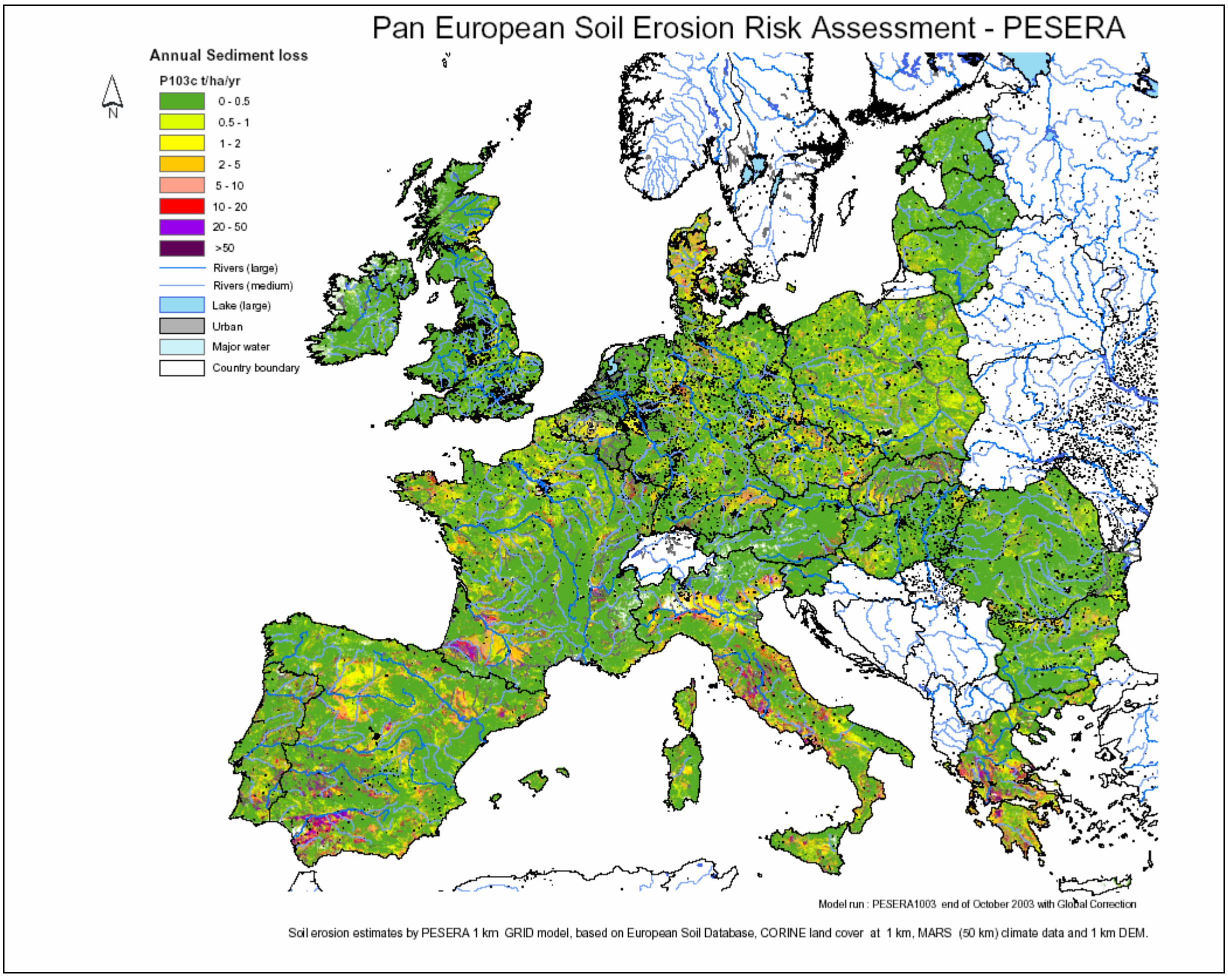


Figure 2: Annual soil erosion risk by water (S.P.I.04.73, Kirkby *et al.*, 2004).

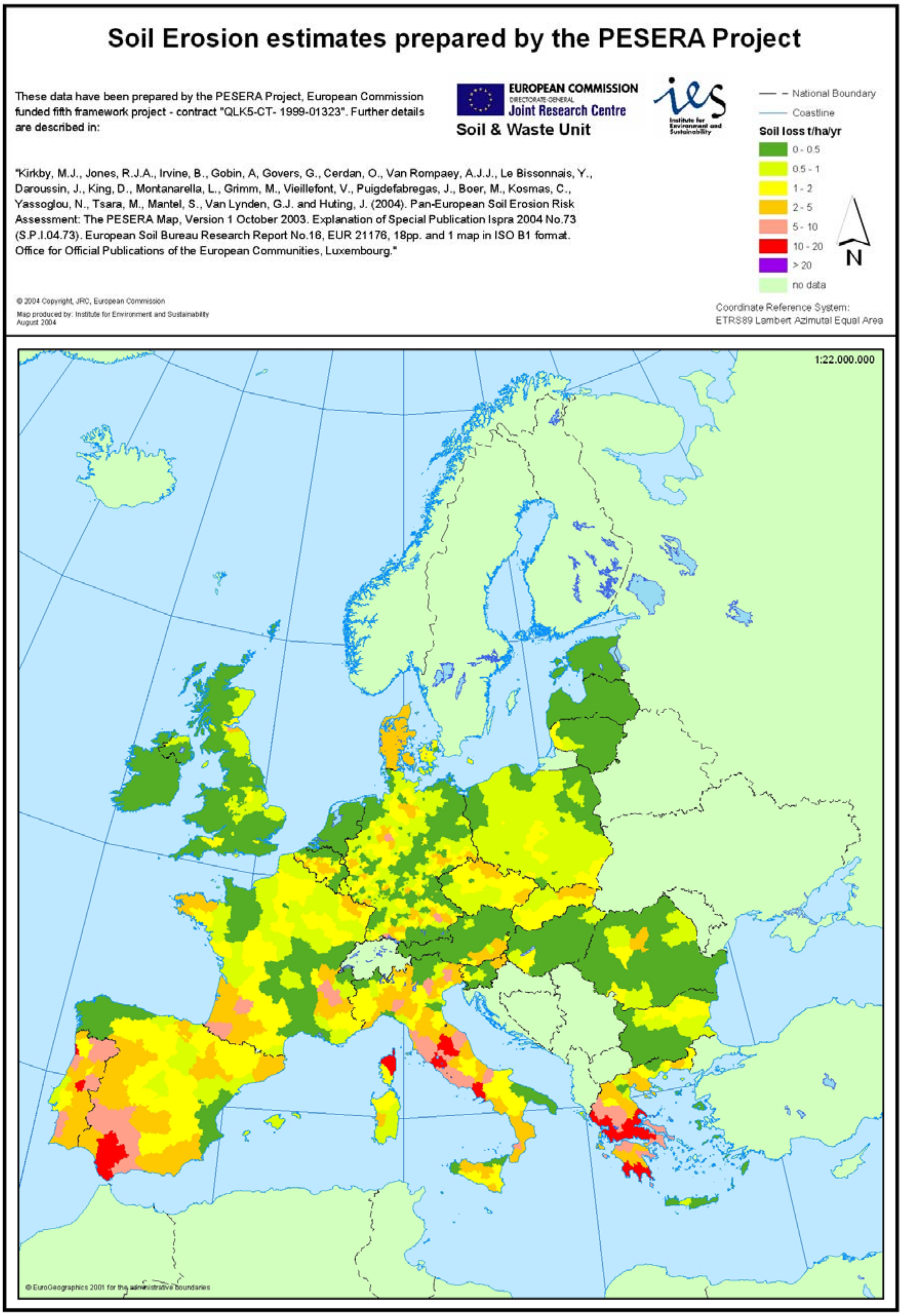
In a period of rapid change in both climate and land use, due to global change, revised agricultural policies and changing international market forces, it is vitally important to be able to assess the state of soil erosion at a European level, using an objective methodology. This methodology must also allow the assessment of erosion to be repeated as conditions change, or to explore the broad scale implications of prospective global or European-wide changes in land utilisation.

The results of applying such a methodology can provide estimates of the overall costs attributable to erosion under present and changed conditions, and objectively identify areas where more detailed study is needed and possible remedial action.

The Pan-European Soil Erosion Risk Assessment - PESERA - approach (Gobin *et al.*, 1999) uses a process-based and spatially distributed model to quantify soil erosion by water and assess its risk across Europe (http://eusoils.jrc.it/ last accessed 21/03/2005). The resulting 1km x 1km annual soil erosion risk map (Figure 2) reports estimated soil losses in t/ha/year. The background to these spatial calculations is described by Kirkby *et al.* (2004).

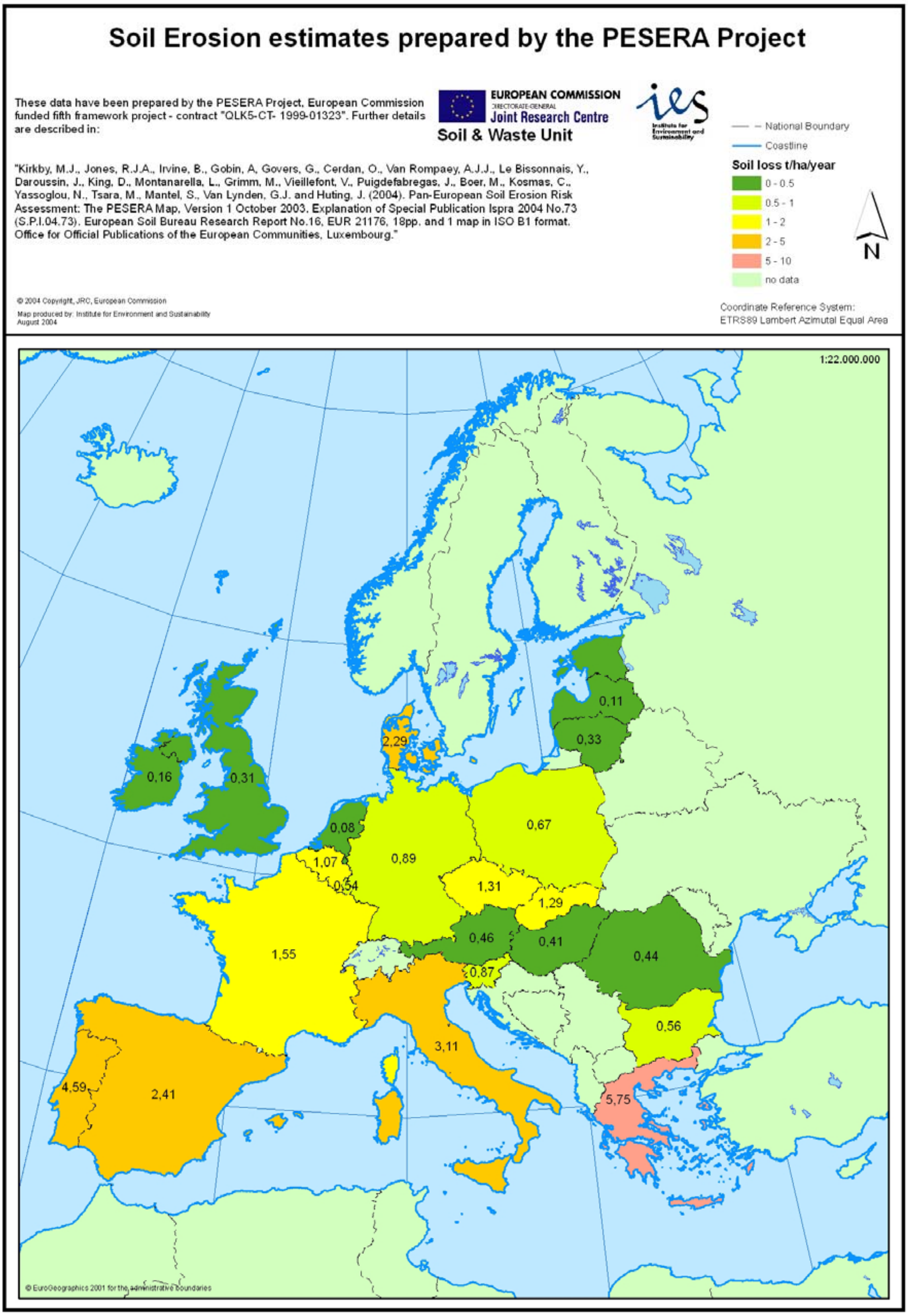
Aggregated results at NUTS3 level (Figure 3) allow more policy relevant information to be derived from this indicator. Areas with very high erosion rates are located in the Mediterranean. Most affected are zones in Andalusia, Corsica, southwest France, central Italy and Greece.

Mean annual soil erosion rates at country level (Figure 4) clearly identify Greece, Portugal, Italy and Spain as the most affected. As described above, soil erosion has been identified by the Commission, in its Thematic Strategy for Soil protection (EC, 2002), as one of the priority areas where immediate action is needed. The importance of soil erosion was also recognised by the Council and the European Parliament in their position papers following the above communication. More information about the current status of soil erosion at European level is given in Van-Camp *et al.* (2004b, p.145-185).



Map production by Jean Dusart

Figure 3: Annual soil erosion risk by water (aggregated results at NUTS3 level).



Map production by Jean Dusart

Figure 4: Annual soil erosion risk by water (mean erosion rates (t/ha/yr) at National level).

Council Regulation (EC) No. 1782/2003 of 29 September 2003 has recognised, under article 5, the main issues that should be addressed by Good Agricultural Practices: soil erosion, decline of soil organic matter and physical soil degradation.

It will be necessary to further develop the indicator – estimated soil loss – with a time component (soil monitoring) in order to detect impacts of soil protection measures. The need for a comprehensive approach for soil monitoring has been well recognised by the Commission in its communication and will be one of the main elements of the forthcoming EU Thematic Strategy for Soil Protection.

The OECD expert meeting on soil erosion (Rome, March 2003) has fully endorsed the modelling approach for the development of soil erosion indicators. Crucial for the successful implementation of such models remains the availability of the necessary high quality input data. In the same context, it seems necessary to identify a more aggregated indicator of 'Soil quality', defined on the basis of the basic soil indicators, such as soil erosion, soil organic matter content, soil compaction, etc.

The current indicator allows identification of the areas at high risk of soil erosion, where adequate protection measures should be implemented. For the detection of impacts of such measures, a soil monitoring system is needed that is currently still in the definition phase (see Van Camp *et al.*, 2004e).

Contamination

Like soil erosion and desertification, contamination of soils has also has 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 mapping of the locations of all contaminated sites but it is estimated that there are over 300,000 such 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 'sphere of influence'. Here, 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, Czech Republic, Denmark, France, Finland, Germany, Ireland, Netherlands, Serbia and Montenegro, Sweden and the UK, which have helped to identify contaminated sites and the nature of the contaminants. Several other countries of the enlarged 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.

More information on soil contamination at European level can be found in the Soil Thematic Strategy (STS) Technical Working Group Report on Contamination (Van-Camp *et al.*, 2004d).

Salinisation/Alkalisation.

Concern about salinisation/alkalisation 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. More details of salinisation in Europe are given in Van-Camp *et al.* (2004b).

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 in this volume identify this as one of the most important areas for future research and one that is fundamental to the sustainable development of soil resources. The recent report of the Soil Thematic Strategy Technical Working Group on Organic Matter and Biodiversity (Van-Camp *et al.*, 2004c) contains more information on biodiversity.

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 traditional uses such as agriculture. Rates of loss of land in this way, given in a recent EU Report (Montanarella, 1999), are: Netherlands 36ha. per day, Germany 120ha per day, Austria 35ha per day and Switzerland 10ha per day. In the UK over a ten year period about 1% of the land area has been 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 taken for building, 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 as much as possible.

The use of land capability classifications and land evaluations, based on a sound knowledge of the quality of soils, should be an essential stage in reaching decisions about whether or not to take land out of agriculture or natural habitat. Such information should be part of every country's land use strategy. The recent report of the STS Techical Working Group on Research and Soil Sealing examines in more detail the loss of land to urbanisation in Europe (Van-Camp *et al.*, 2004f, p.771-817).

Soil Quality and Sustainability

A measure of Soil Quality is how well does the soil perform its key functions in the environment. More specifically, soil quality is the capacity of a specific kind of soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation (USDA, http://soils.usda.gov/sqi/soil_quality/what_is/ last accessed 21/03/2005).

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 application of the DPSIR framework (OECD 1993):

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.

Currently, much attention is focused on the identification of indicators. Indicators are a suite of key components that can be measured and point to change in the environment. Given the cost of regular measurement of an indicator, attempts have been made to keep the list as short as possible. 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 Europe are declining organic matter levels under intensive agriculture, increasing soil erosion, 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.

An unambiguous definition of soil quality for the purposes of the EU is currently lacking. Nevertheless, in its Communication – COM179 final (EC, 2002), the Commission has put forward a number of criteria for defining well functioning soils from the European perspective. Four out of five functions are directly linked to soil organic carbon content: food and biomass production, filtering and buffering capacity, pool of biodiversity and source of raw materials (peat). Furthermore, the Communication identifies declining organic matter as an ongoing process of soil degradation.

A new and important aspect related to soil organic carbon is the recognition of the significance of the soil organic carbon pool in the context of the European Climate Change Programme (http://www.europa.eu.int/comm/environment/climat/agriculturalsoils.htm last accessed 21/03/2005).

Soil quality cannot be measured directly. However for the EU, soil organic carbon content in topsoil has been identified as the most appropriate indicator for soil quality. High organic carbon content generally corresponds to good soil conditions from an agro-environmental point of view offering limited soil erosion, high buffering and filtration capacity, rich habitat for soil organisms, enhanced sink for atmospheric carbon dioxide, etc. Soils with organic carbon (OC) content between 2 and 10% can also be considered of medium to high agricultural value, while soils with less the 1% OC can be considered as degraded (desertification). Peat and peaty soils should be considered separately in this context.

The decline of soil organic carbon content has been identified in the Soil Thematic Strategy as another of the priority areas where immediate action may be needed. The importance of organic carbon was as well recognised by the Council and the European Parliament in their position papers following the above communication (see also Council Regulation (EC) No. 1782/2003 of 29 September 2003).

Monitoring changes in Soil OC content will be particularly relevant in the context of potential contribution of soils to the achievement of the Kyoto target. A mitigation potential of 60-70 $MtCO_2$-eq has been estimated (ECCP, 2003) provided by conservation and enhancement of carbon stocks by extensification (e.g. organic farming, conservation agriculture) and other Good Agricultural Practices.

Figure. 5 displays organic carbon contents in topsoils (OC_TOP) in Europe, grouped into 7 classes (Jones *et al.* 2004, In press). The distribution has been validated against national data with good agreement. Areas in southern Europe with OC_TOP content between 0 and 1% appear in the expected places and often correspond with areas where soil erosion rates are estimated to be high. The organic soils (peat) in northern Europe are clearly highlighted.

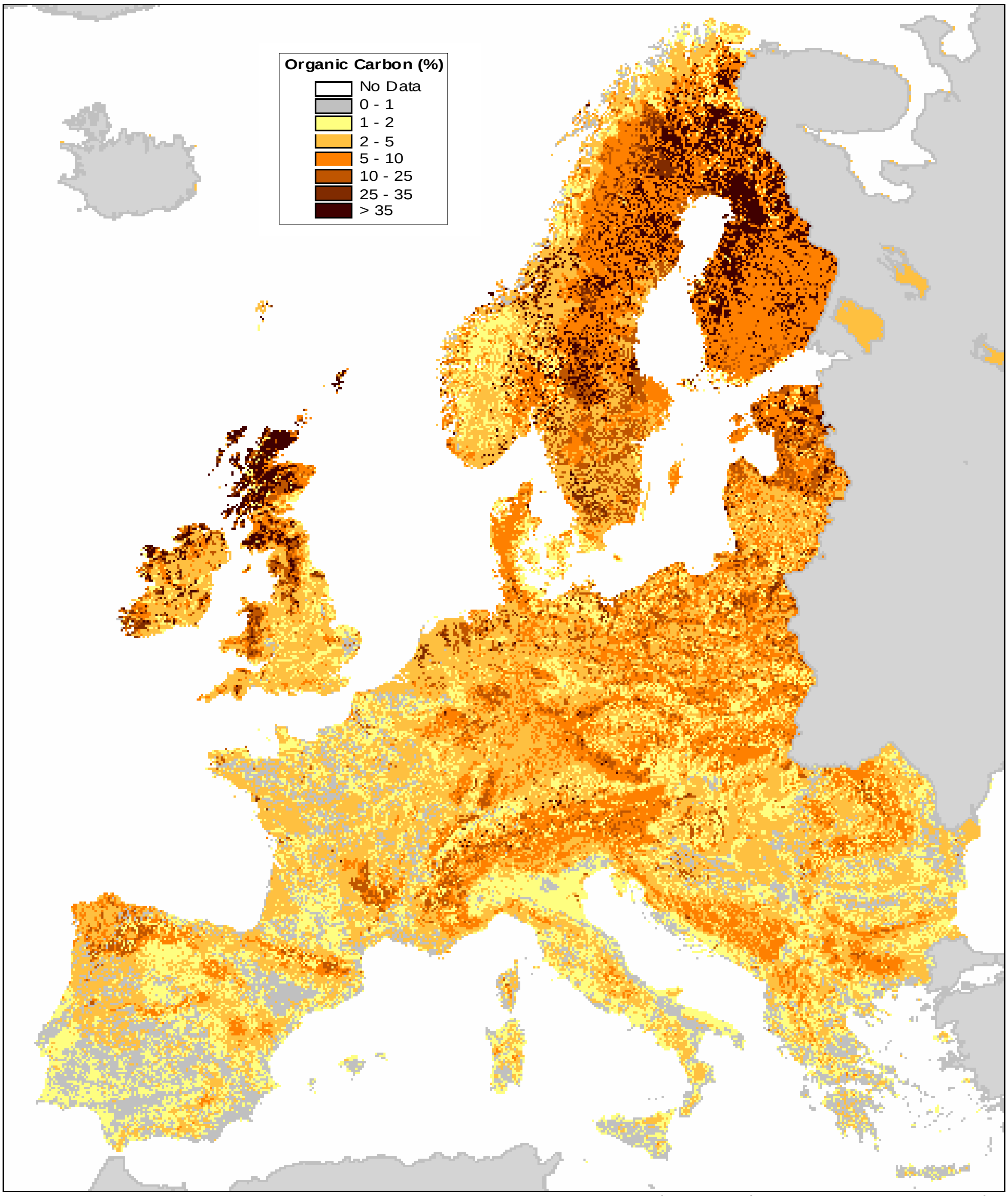
An estimated distribution of organic carbon in topsoil in Europe shows that 45% of the area has medium organic carbon content (good condition). Soils with low and very low organic carbon content account for ca. 45% and the remained are mainly organic soils (peat and peaty soils).

A clear humidity and temperature trend is present, with soils in the dry and warm Mediterranean area suffering low to very low organic carbon content. This corresponds to areas that have been recognised in other assessments related to indicators for desertification in the Mediterranean (http://dismed.eionet.eu.int/index_html last

accessed 21/03/2005) as areas highly sensitive to desertification processes.
Of particular importance for assessing the potential of soils for mitigation strategies towards the Kyoto target are the aggregated national carbon stocks (Figure 6). These stocks have been computed for a soil layer 0-30cm using accurate bulk density data derived from the European Soil Database (Jones *et al.*, 2004, In press), thus providing good estimates of the current carbon pools in European soils.

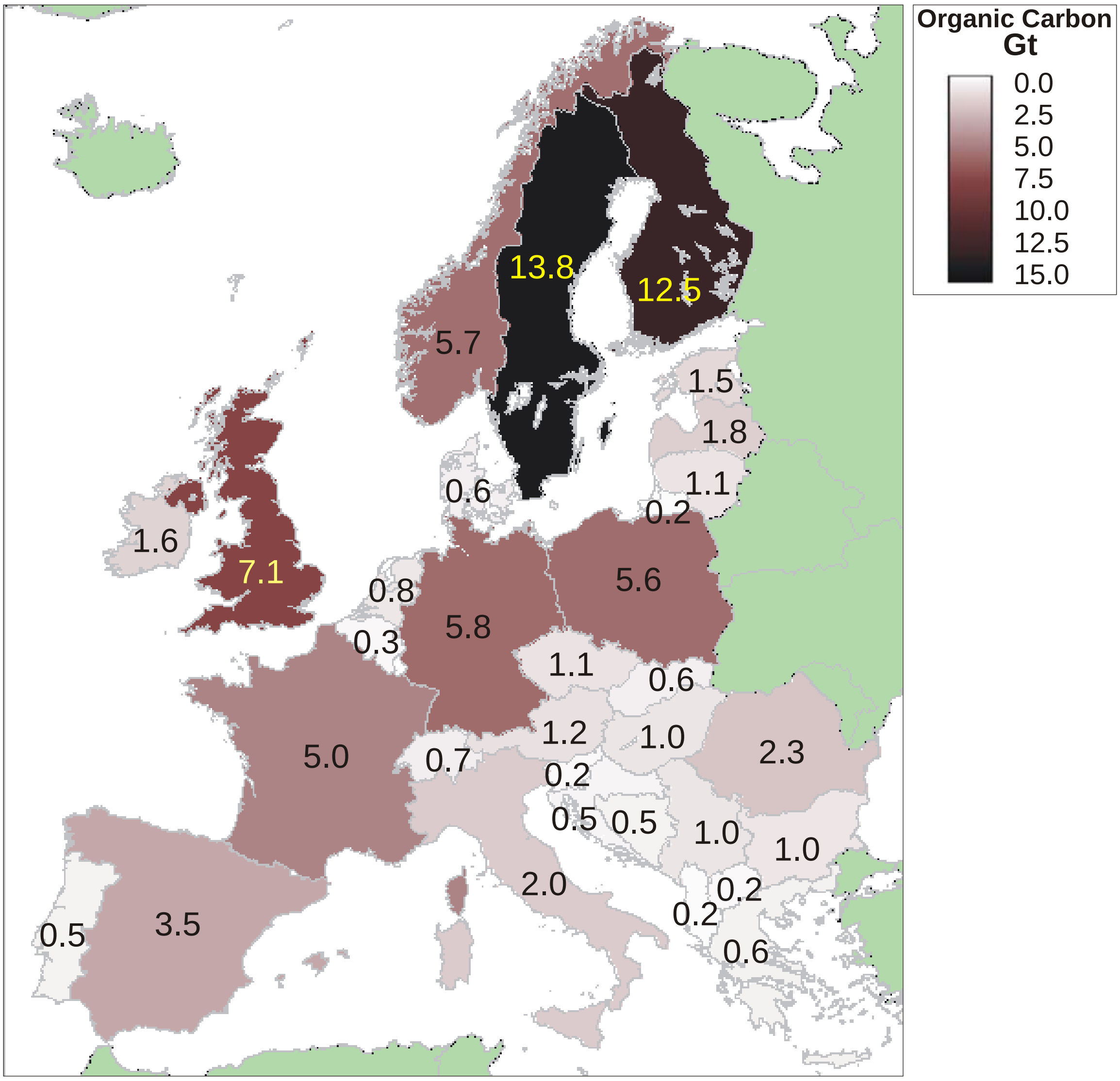
Land use has a significant effect on soil organic carbon content. The new CORINE Land Cover for 2000 (CLC2000) (http://www.ec-gis.org/clc/ last accessed 21/03/2005), and land use data available from the LUCAS survey (Gallego, 2002), will allow more accurate monitoring of soil organic carbon changes in the future.

More information on the current status of organic carbon in Europe's soils can be found in Van-Camp *et al.*, 2004c, p.329-352).



(Jones *et al.*, 2004; In press; S.P.I.04.72).

Figure 5: Organic carbon content (%) in the surface horizon (0-30cm) of soils in Europe



(S.P.I.04.72)

Figure 6: National Soil Organic Carbon stocks (0-30cm) in Gt (Pg)

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 H_2O 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 industrialization 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 been regulated but, with the EU ban on dumping of sewage sludge at sea in 1998, the land (and hence soil) is now again seen as major means of 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 is growing and so will the pressures on the land to receive 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 Europe. 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 < 4.5 when 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 non-experts. 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 European countries produced general purpose land capability classification maps, based on the methodology of Klingebiel and Montgomery (1961). Thus the maps did not indicate capability for one specific use, they merely indicated the overall quality of land for a number of perceived uses. These general-purpose maps were often used to protect the better quality of land for future agricultural production.

With improvements in soil databases, their links to other data and the development of modelling, it became possible to evaluate the suitability of land for specific uses, such as cereal or grass production, forest production (e.g for specific species), new crops and ecological habitats.

It is possible to produce land evaluations for a given region provided there is an adequate soil and climatic data, a knowledge of the particular requirements of land use and land management, simple or complex models, and a land information system capable of integrating the different types of data and producing 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 Surveys 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 Europe.

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, significant quantities of iron were produced and released into the drainage systems, 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 1cm 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 has been lost. After drainage the organic matter has merely oxidised and disappeared into the atmosphere.

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 countries in Europe and several of these 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 trans-boundary 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 Trans-boundary 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, 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 civilisations 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. soil degradation
2. food safety and security;
3. loss of biodiversity;
4. climate change impacts;
5. sustainability of land use systems in soutern Europe, particularly in the Mediterranean zone;
6. sustainable development of soil resources;
7. management of the water resources;
8. environmental protection.

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 conditions, 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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