Scientific Basis for the Management of European Soil Resources

Research Agenda

Scientific-technical questions related to the content of this brochure will be answered by the
European Confederation of Soil Science Societies (ECSSS)
Secretariat: Institute of Soil Research, Department of Forest and Soil Sciences
University of Natural Resources and Applied Life Sciences (BOKU), Vienna
Peter Jordan-Straße 82, 1190 Vienna, Austria
Tel.: (+43-1)47654-3101; Fax: (+43-1)47654-3130
E-mail: winfried.blum@boku.ac.at

Guthmann-Peterson
Büchermacher und Verleger
A-1130 Wien, Elßlergasse 17
Tel. +43 (0)1 877 04 26
Fax +43 (0)1 876 40 04
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Content

Organising Institutions and Projects

European Commission, Directorate General RTD
JOINT – Joint Technical Approach for Decontamination of Soil and Groundwater
SCAPE – Soil Conservation and Protection for Europe
BOKU – University of Natural Resources and Applied Life Sciences, Vienna
ECSSS – European Confederation of Soil Science Societies

Dedicated

to the memory of
Prof. Dr. Michel Robert
who passed away on
28 October 2004

1 Foreword

Soils are fundamental to society. They provide numerous services. Their health is a key asset for the competitive advantages of Europe in the world. Without a sustainable use of soil, risks and insecurity will increase and economic opportunities will decrease.

Threats to soil as described in the EU-Communication „Towards a Thematic Strategy for Soil Protection“ (COM [2002] 179 final) are causing social and economic damage in Europe amounting to billions of Euros each year, not only reducing the quality of life and the wellbeing of citizens, but also challenging the social and economic development in Europe at large.

This underlines the importance of protection and sustainable use of soils which is now widely recognised, both nationally and within the EU. The ultimate goal is to achieve a more eco-efficient European economy based on a sustainable use of soil resources. Basic and targeted research is needed on a national, international and European level to achieve this goal. Research needs to create the sound scientific basis for the development of new policies, to support the implementation of national and European policy objectives, and is necessary for maintaining international competitiveness. In view of the strong European potential for excellent research. Europe has a realistic basis for becoming an international leader in soil protection and sustainable soil management including related fields of technology development. This will in turn lead to wider benefits from this research, and guarantee win-win situations in the European environmental, social and economic development.

Therefore, a group of scientists, under the guidance of the European Commission, DG Research, decided to analyse and evaluate the actual knowledge basis with regard to soil in order to determine future research needs, aimed at soil protection and the sustainable management of Europe's natural soil resources.

The present booklet will outline the procedural advances and list the research targets that will help to define research needs on the national and European level based on importance, urgency and cost-effectiveness.

Winfried E.H. Blum, Damia Barcelo, Jürgen Büsing,
Thomas Ertel, Anton Imeson, Joop Vegter

Participants of the
EU-workshop in Vienna
28–29 Oct. 2004

2 Introduction

Soil is one of the most important ecosystems and largely non-renewable. Worldwide, all economies depend on the goods and services provided by their natural environment.

Soils as a natural resource perform a number of key environmental, social and economic functions. Agriculture and forestry depend on soil for the supply of water and nutrients and for root fixation. Soils perform storage, filtering, buffering and transformation functions, thus playing a central role in the protection of water and the food chain and the exchange of gases with the atmosphere. Moreover, soil is a biological habitat, a gene pool, an element of the landscape and a cultural heritage as well as a provider of raw materials (see Fig. 1).

Fig 1: European soil resources. Soils and their different natural qualities are fundamental to land uses and functions in providing ecological services. European soils are under pressure by non-sustainable landuse practices. Understanding the varying properties of the soil (and water) systems in space and time that determine the opportunities for more eco-efficient land uses is essential for future integrated resource management policies.

Growing population and increasing energy consumption, transport and agricultural activities, linked to pressures such as global climate variability and warming are adding increasing pressure on the reserve of natural resources in general and especially on the soil environment.

The most important threats to soil as described in the EU Communication „Towards a Thematic Strategy of Soil Protection" (COM [2002] 179 final) are listed in the following box:

- erosion
- contamination (local and diffuse)
- loss or organic matter
- loss of biodiversity
- compaction and other physical soil deterioration
- salinisation
- floods and landslides
- sealing

Through sealing alone, Europe loses several square kilometres of fertile land every year (see Fig. 2). These soil losses and soil degradation processes are impairing the quality of air, the quality of water resources (surface and ground water) the production of biomass (including the food chain), the biodiversity and indirectly also human health.

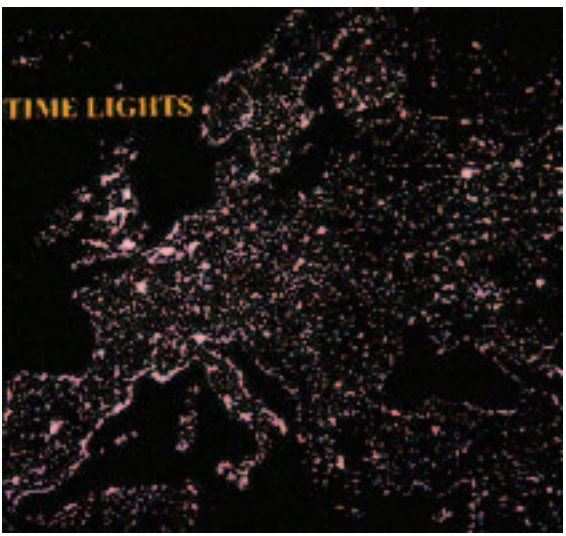

Fig. 2: Europe's built environment is expanding, blocking water- and geochemical cycles and increasing the pressure on the ecological services of the remaining land, already under pressure from intensive agriculture. This result of the current management of soil resources is not easy to reverse. To enhance the economic competitiveness in Europe while maintaining a high quality of life and well-being in a healthy environment, land management has to exploit the natural capacities and ecological services of the soil and water system in a more sustainable way. Research is essential to explore options for sustainable management.

As a follow-up to the EU Communication, the European Commission, DG Environment decided to formulate a Thematic Strategy for Soil Protection and installed in 2002 five

‚Technical Working Groups' (TWGs) and an Advisory Forum. These 5 TWGs addressed ‚Monitoring', ‚Erosion', ‚Organic Matter', ‚Contamination' and ‚Research'.

The ‚TWG Research' (TWG RTD) had 3 specific mandates:

- to identify and to structure the existing information on soil in Europe;
- to identify barriers that prevent the full use of existing information for policies and to make recommendations how to improve the transfer of information;
- to identify research gaps and needs, indicating, in which time spans these can be closed (short-, medium-, and long-term activities).

Fig. 3 (next page) shows the basic approach, used for the identification of research gaps and needs.

Moreover, a concept for integrated research in soil protection and soil resource management, was developed (see Tab. page 9). From this table, it becomes clear that only collaborative research, including the co-ordination of national programmes and the development of new research infrastructures, using all available human resources, and installing a European technology initiative, is able to do the needed basic and targeted research for addressing the challenges of the future. Based on this, priority research areas for soil protection and the management of Europe's natural resources, were developed*.

A European Workshop held in Vienna on October 28 and 29, 2004, analysed this document in line with the requirements set by the five Research Clusters (see Fig. 3), and grouped the most important, urgent and cost-effective soil research issues accordingly, which are presented in the following chapter, under the title: „Priority Research Areas".

* (see document „European Union Soil Thematic Strategy, Working Group Research, Summary Report, June 2004" – Co-chairs: Winfried E.H. Blum, Jürgen Büsing, Thierry de l'Escaille, electronic address: env-soil@cec.eu.int)

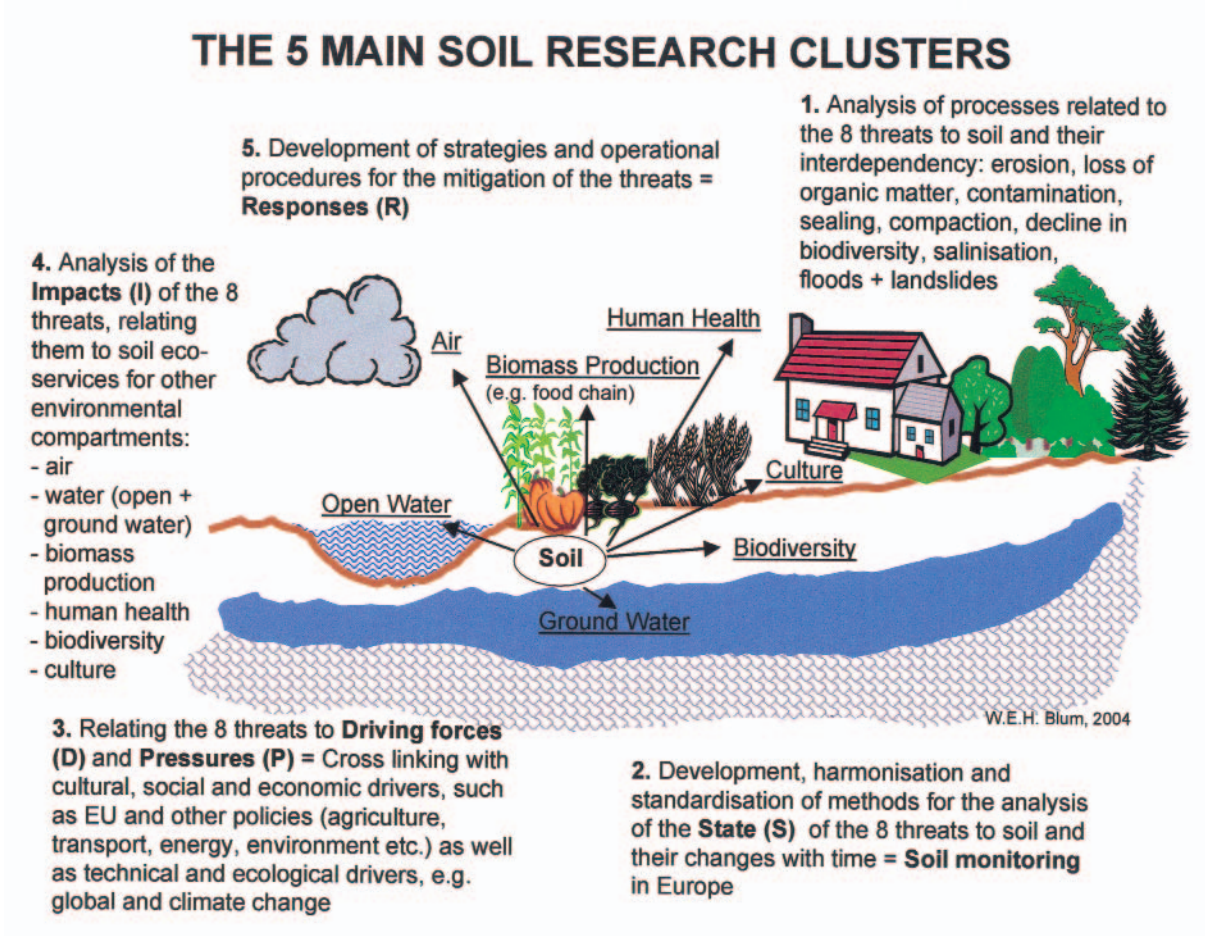

Fig. 3: The 5 main soil research clusters

Concept for integrated research in soil protection and soil resource management

	Main research goals	Research clusters	Sciences involved
1	To understand the main processes in the eco-subsystem soil underlying soil quality and soil functions, in relation to land uses and soil threats	Analysis of processes related to the threats to soil and their interdependency: erosion, loss of organic matter, contamination, sealing, compaction, decline in biodiversity, salinisation, floods and landslides	Inter-disciplinary research through cooperation of soil physics, soil chemistry, soil mineralogy, and soil biology
2	To know where these processes occur and how they develop with time	Development, harmonisation and standardisation of methods for the analysis of the **State (S)** of the threats to soil and their changes with time = **soil monitoring**	Multi-disciplinary research through cooperation of soil sciences with – geographical sciences, – geo-statistics, – geo-information sciences (e.g. GIS)
3	To know the driving forces and pressures behind these processes, as related to policy and decision making on a local and regional basis	Relating the threats to **Driving forces (D)** and **Pressures (P)** = cross-linking with cultural, social and economic drivers, such as policies (agriculture, transport, energy, environment etc.) as well as with technical and ecological drivers, e.g. global and climate change.	Multi-disciplinary research through cooperation of soil sciences with political sciences, social sciences, economic sciences, historical sciences, philosophical sciences, and others
4	To know the impacts on the eco-services provided by the sub-system soil to other environmental compartments (eco-subsystems)	Analysis of the **Impacts (I)** of the threats, relating them to soil eco-services for other environmental compartments: air, water (surface and ground water), biomass production, human health, biodiversity, culture	Multi-disciplinary research through cooperation of soil sciences with geological sciences, biological sciences, toxicological sciences, hydrological sciences, physio-geographical sciences, sedimentological sciences, and others
5	To have strategies and operational tools (technologies) at one's disposal for the mitigation of threats and impacts	Development of strategies and operational procedures for the mitigation of the threats = **Responses (R)**	Multi-disciplinary research through cooperation of natural sciences with engineering sciences, technical sciences, physical sciences, mathematical sciences, and others

W.E.H. Blum and J. Büsing, 2004

3 Priority research areas for soil protection and the management of Europe's natural resources

Cross-cutting and over-arching issues

Common fundamental research needs are:

- understanding of the dynamic soil architecture (spatial arrangement of physical, chemical and biological soil properties) and its relation to functional processes
- understanding and quantification of soil resistance and soil resilience
- knowledge of interactions between the physical, chemical and biological processes as a basis of multi-process models
- information and integration of different spatial and temporal scales
- assessment of site-specific soil processes responding to climate and land use change
- organic-inorganic interactions, as basic features of soil functions
- linkages between the behaviour of soil properties under experimental conditions to their behaviour under field conditions
- linkage between soil reactions on threats and broader social and economic assets related to land use and society

Cluster 1: Processes underlying soil functions and quality

Analysis of processes related to the 8 threats to soil and their interdependency: erosion, loss of soil organic matter (SOM), contamination, sealing, compaction, decline in biodiversity, salinisation, floods and landslides, cross-cutting issues.

Erosion

- Ecological and socio-economic impact of water and wind erosion
- Influence on sedimentation

Compaction

- Modelling and quantification of soil compaction

Floods and Landslides

- Assessment of the water transport and storage capacity
- Impact of land use changes

Contamination

- Sources, fate and behaviour of pollutants

SOM and biodiversity

- Dynamics and soil biology
- Soil biodiversity under different land use practices
- Influence on the resilience under different land use practices

Salinisation

- Relationship between soil material, functional properties and salinisation/sodication
- Soil resilience and related indicators
- Desertification

Sealing
- Definitions
- Survey methods
- Impact assessment
- Threshold values, including socio-economic relevance

Monitoring
- Recovery, evaluation, upgrading and accessibility of existing data
- Definition of soil quality indicators

Cluster 2: Spatial and temporal changes of soil processes and parameters (State – „S“)

Development, harmonisation and standardisation of methods for the analysis of the state (S) of the 8 threats to soil and their changes with time = soil monitoring in Europe.

Erosion
- Installation of long-term monitoring sites
- Calibration and validation of models with the definition of risk-based indicators
- Behavioural responses to erosion events;

Compaction
- Assessment and monitoring of existing soil compaction levels

Floods and landslides
- Flood risk assessment, including sedimentation risks
- Assessment of landslide-risks, based on soil stability
- Water regulating functions of soil indicating risks for flooding and landslides

Contamination
- Development of fast and cost effective screening methods
- Identification and quantification of new hazardous substances in soils
- Early warning systems for soil pollution, including bioindicators
- Definition of indicators for the assessment of soil quality
- Mobility and availability of contaminants to other environmental compartments

SOM and biodiversity
- Development of comparable, compatible and standardised methods for the characterisation of SOM and biodiversity across Europe
- Definition of indicator organisms
- Definition of spatial and temporal scales for the monitoring of SOM pools and biodiversity

Salinisation
- Identification of new indicators
- Monitoring of effects on soil functional parameters
- Harmonisation of monitoring techniques across Europe

Sealing
- Development and harmonisation of sealing survey and monitoring methods across Europe
- Standardisation of sealing quality assessment
- Development of methods for survey and monitoring of urban soils and soil substrates

– Development of temporal and spatial scales for sealing and urban soil monitoring
– Development of integrative monitoring systems, including technical, ecological, social and economic parameters

Cluster 3: Ecological, economic and social drivers of soil threats (Driving forces and pressures – „D“ and „P“)

Relating qualitatively and quantitatively the 8 threats to Driving Forces (D) and Pressures (P) = cross-linking with social and economic drivers, such as EU and other policies, e. g. agriculture, transport, energy, environment etc., as well as with ecological drivers, e.g. global and climate change.

Erosion
– Assessment of erosion risk through land management within different land uses and through land use change
– Better understanding of the impact of land management within different land uses
– Assessement of erosion risks in relation to climate change

Compaction
– Assessment of technical, industrial developments in the production of agricultural machinery, causing deep reaching compaction
– Quantification of soil conditions sensitive to compaction

Floods and Landslides
– Effects of climate and climate change on flooding events, soil hydrology, ground water systems and soil stability

Contamination
– Harmonisation of methodologies for the identification and quantification of potentially dangerous chemicals
– Identification and quantification of social and economic driving forces on local and diffuse soil pollution and their impacts

SOM and biodiversity
– Effects of climate change and related land use changes on SOM-pools and biodiversity
– Effects of land management practices on SOM-pools and biodiversity
– Role and functional impacts of contaminants on SOM-pools and biodiversity
– Potential of soils to sequester carbon across Europe
– Analysis of models used in policy and guidance frameworks

Salinisation
– Influence of different drivers on the processes of salinisation and sodication under contrasting ecological conditions across Europe
– Development of integrated regional and world wide policies and actions for the prevention of salinisation and sodication

Sealing
– Social and economic parameters leading to sealing
– Determination of minimum soil surfaces and their spatial distribution in areas with a high degree of sealing
– Implementation of a European spatial planning observatory network (EPON) with links to already existing structures

Cluster 4: Factors (threats) influencing soil eco-services (Impacts – „I“)

Analysis of the Impacts (I) of the 8 threats, relating them to soil eco-services for other environmental compartments: air, water (surface and groundwater), biomass production, human health, biodiversity.

Erosion

- Relationship between upland erosion and catchment transport/sedimentation
- Relationship between soil erosion and biodiversity
- Relationship between soil erosion and water/sediment quality

Compaction

- Quantification of compaction effects on soil functions

Floods and Landslides

- Impacts on other soil threats
- Ecological, social and economic impacts of floods and landslides
- Monitoring and modelling

Contamination

- Improvement and harmonisation of concepts and models for the transport of contaminants in soils and their transfer to other environmental compartments (water, air, biomass)
- Development of concepts and models for the direct and indirect transfer of contaminants from soil to humans
- Improvement of risk assessment methodologies for remediation activities, with the final aim of developing a „Fit-for-use“ toolbox for risk-modelling, including the re-use of decontaminated soil
- Development of harmonised methods for defining „tolerable“ loading on soil and groundwater systems

SOM and biodiversity

- Role of the SOM pools in relation to soil functions, including soil biodiversity
- Understanding of soil resilience regarding changes in soil functions, based on *SOM*
- Influence of GMOs on soil functions

Salinisation

- Risk assessment of salinity and salinisation on soil eco-services
- Economic impacts of salinity and salinisation
- Impact on soil functional parameters, with special regard to hydraulic soil characteristics and biodiversity

Sealing

- Risk assessment of sealing on soil eco-services
- Analysis of social and economic impacts of sealing
- Impact of sealing on the water, mass and energy flow in urban, peri-urban and rural areas

Cluster 5: Strategies and operational procedures for soil protection (Responses – „R“)

Development of operational procedures for the mitigation of the threats = Responses (R).

Erosion

- Development of new conservation and remediation methods for agriculture, based on education and raising of awareness

Compaction

- Development of management tools for reducing sub-soil compaction

Floods and Landslides

- Development of new approaches in land use planning (giving more space to the rivers)
- Development of early warning systems and technical prevention measures, including land use change
- Development of legal instruments

Contamination

- Improvement of soil functions, contributing to natural attenuation
- Quantification and improvement of natural rehabilitation processes
- Improvement of methods for alternative management options, taking into account environmental, social and economic conditions
- Development of techniques, e.g. containment devices for safe storage, handling and transport of harmful substances
- Sustainability/persistence of remediation technologies and their environmental impacts
- Economic models for assessing the cost-benefit relationship for cleaning-up methods of contaminated soils

SOM and biodiversity

- Management of SOM pools for different agricultural land use practices
- Effects of exogenous organic materials on SOM pools and their functions
- Management of SOM pools for raising soil resilience and soil biodiversity as influenced by changing environmental conditions

Salinisation

- Improvement of information on the status of salinisation and sodication in Europe
- Validation and calibration of models predicting salinisation based on different land use practices and indicators, including their social and economic consequences
- Integration of policies and actions into European programmes preventing salinisation and sodication

Sealing

- Establishment of legal binding instruments for the restriction of soil consumption at a local, regional or European level
- Establishment of local and regional threshold values for sealing
- Mitigation of sealing problems by changes in land use or of social and economic conditions
- Development of a new legal basis for economic, fiscal and planning instruments to reduce sealing and sealing effects
- Development of a soil conservation service for urban, industrial and traffic areas, strongly focussing on sealing problems

4 Steps to implementation

The priority RTD needs and gaps presented in the present brochure should create the basis for a coherent planning of national, international and also European RTD programmes. Depending on their nature, these RTD tasks reflect long-, medium-, or short-term activities and require tailor-made tools for implementation such as longterm RTD projects, targeted projects of applied research, networking activities, provision of infrastructure, co-ordination of national programmes, short-term studies as well as specific actions for policy support.

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Peter Jordan-Straße 82, 1190 Vienna, Austria
Tel.: (+43-1)47654-3101, Fax: (+43-1)47654-3130
E-mail: winfried.blum@boku.ac.at

The authors and editors of this brochure do hope that it finds a broad distribution amongst the European scientific community, including soil sciences, as well as in different European Countries and the European Commission.

The authors do hope that part of this research agenda can be realised within the 7th framework programme of DG Research of the European Commission and national research programmes in the years to come. – The ECSSS will take the lead in the future updating of this research agenda.

Scientific basis for the management of European soil resources – The 5 key messages

1 Soil is one of the most important ecosystems and a largely non-renewable resource. A vital soil provides numerous services fundamental to the welfare of society and the competitive advantages of Europe in the world. Without a sustainable use of soil, risks and insecurity will increase and economic opportunities will decrease.

2 Threats to soil are causing serious social and economic damage in Europe, amounting to billions of Euros every year. Erosion, contamination, loss of organic matter and biodiversity, compaction, floods and landslides, salinisation and sealing reduce the quality of life and the wellbeing of citizens and challenge the social and economic development in Europe at large.

3 Research is needed to alleviate the negative impacts on soil, air and water, on the production of biomass and food, and on biodiversity and human health. Research should also lead the way to a more eco-efficient and sustainable use of soil and water resources. This requires collaborative research, developing new research infrastructures and starting new European technology initiatives. National and European programmes need to join forces to provide the basic and targeted research in this area.

4 The five priority research areas for soil protection and the management of Europe's natural resources identified by the research community and listed in this brochure, clearly indicate that the raising of funds for actions at the national and the European level is highly necessary and urgent.

5 The five priority research areas will lead to a better understanding of soil and its interactions with other environmental compartments. Understanding the natural capacities and restrictions of this system is essential for the development and implementation of integrated resource management policies in the near future.

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