Northern latitudes

A Cryosol from northern Russia. The wet base of the section is the continuously frozen ground known as permafrost. The bluish-grey zone is known as an active layer where cycles of freezing and thawing cause cryoturbation and mix organic matter into the soil (EM).

A striking example of a Podzol. The pale leached topsoil indicates a loss of iron oxide coatings which subsequently accumulate in the reddish-brown"iron pan" horizon lower down the profile (EM).

Northern latitudes

Europe is part of the circumpolar segment of the global soil coverage. This part of the atlas describes the pattern of soil distribution around the Arctic, a pole of snow and ice. The harsh continental climate with a low amount of solar radiation, intense cold during long winter and limited heating during the short summer provide a negative heat balance on these lands. The cold affects the surrounding landscape and leads to the formation of permanently frozen ground known as permafrost (soil having an annual temperature within the upper one meter layer of below 0^{o}C).

Cryosol is the most characteristic soil type of the northern latitudes and is often found in association with Histosols and Gleysols. Cryosols form from coarse-textured deposits and from fresh alluvial or aeolian parent material associated with Podzols, Planosols and/or Cambisols.

Cryosols have a number of specific soil-forming processes that distinguish them from other soil. Most of these processes are driven by a soil water regime that migrates along a thermal gradient from warm to cold sites. This move has different directions due to the seasonal freeze-thaw cycle and may cause cryoturbation, frost heave, cryogenic sorting, thermal cracking and ice segregation.

Repeated freezing and thawing of water in the soil results in lifting of coarse rock fragments, cryoturbation (i.e. is the churning of minerals by hard frost) and mechanical crashing (physical weathering) of rocks. During freeze-back (the freezing portion of the cycle), freezing fronts move both from the soil surface downward and from the permafrost table upward. As this happens, moisture is removed from the unfrozen soil material between the two fronts (frost desiccation). Desiccation is responsible for the development of blocky structures in these soils; the combination of cryoturbation and desiccation causes the granular structure of many fine-textured Cryosols. The cryostatic pressure that develops as the freezing fronts merge results in a higher bulk density of the soil.

Cryoturbation (frost churning) mixes the soil materials and results in irregular or broken soil horizons, involutions, organic intrusions, organic matter occurrence in the subsoil, oriented rock fragments, silt-enriched layers, silt caps and oriented micro-fabrics. Two models have been suggested to explain the cryoturbation process:

- in the cryostatic model, freezing fronts moving downward from the surface and upward from the permafrost table cause pressure on the unfrozen material between the fronts;

- in the convective cell equilibrium model, heave-subsidence cycles at the bottom move upward and inward. This results in a slow upward cell-type circulation.

Frost heave is caused by an expansion of soil volume due to freezing either because of the change in volume that takes place when water is converted to ice or because ice build-up in the subsoil causes cracks to form in the soil.

Re-freezing causes coarse fragments in the soil to be heaved and sorted resulting in oriented features in the soil and micro-topography of patterned ground. These include circles (including earth hammocks), nets, polygons, stripes and steps.

Thermal cracking is formed when frozen materials contract under rapid cooling. The resulting cracks are typically several centimetres wide. They might become filled in with water or sand later to form ice or sand wedges. Since old thermal cracks are zones of weakness, cracking recurs at the same place.

Ice segregation refers to the accumulation of ice in cavities and hollows in the soil mass and manifests itself in a variety of phenomena. Features include ice lenses, vein ice, ice crystals and some types of ground ice. The characteristic platy and blocky macro-structures of Cryosols result from vein ice development.

Cryosols can have Gleyic properties that develop from prolonged saturation with water during the thaw period. Cryosols might also manifest features of podzolization if derived from coarse-textural deposits. In the cold deserts, Cryosols might have alkaline properties and salts or show signs of reddening (Rubefaction).

A Cryosol from northern Russia. Below 40 cm, one can clearly see the frozen ice of the permafrost. The upper portion of the profile thaws during the summer months. The maximum thaw depth of the seasonally frozen layer is known as the active layer and varies according to the physical characteristics of the soil and prevailing weather condition (EM).

While the subsoil of Cryosols remains permanently frozen (the permafrost layer), the upper portion thaws in summer. The maximum thaw depth of the seasonally frozen layer represents the depth of the active layer. The latter is highly dynamic and depends on climate and environmental changes. The active layer in Cryosols can extends up to 80 cm below the soil surface and depends on the physical environment of the soil and the soil texture, soil moisture regime and thickness of organic topsoil. When the temperature drops, freeze-back occurs from the frost table upwards and from the soil surface downwards. The soil material between these freezing fronts comes under cryostatic pressure and, as a result, unfrozen materials are displaced and soil horizons are contorted and broken. This causes the characteristic cryogenic structure and cryoturbated soil horizons.

Weak leaching and translocation of materials occur in permafrost soil giving rise to leached horizons. However, the evidence of the transformation of soil material is often partially or completely destroyed by cryoturbation, which mixes the soil materials in the active layer.

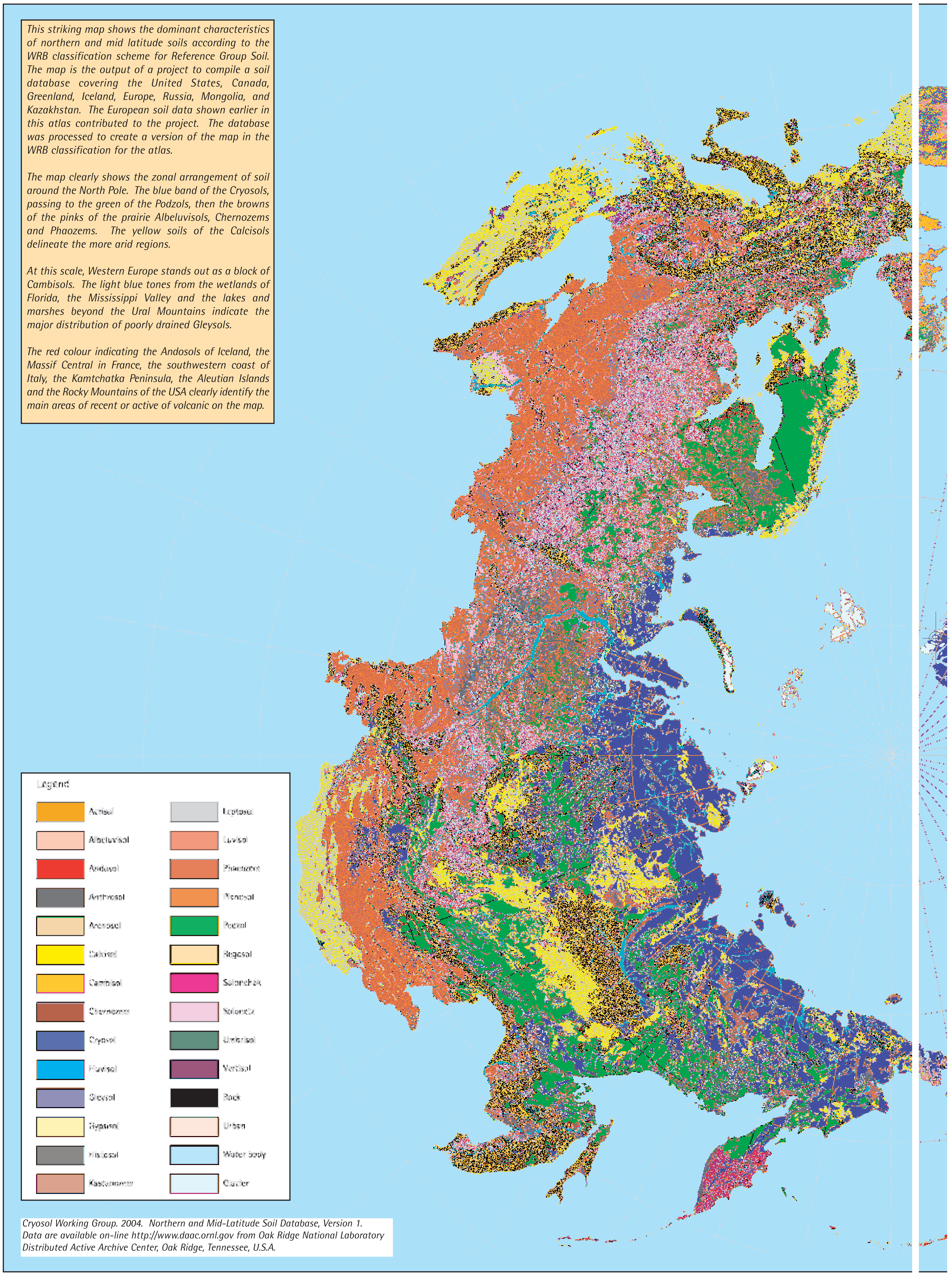
Cryosols with a high silt content are thixotropic, such that viscosity decreases when stirred or shaken, to become liquified gel but returns to the hardened state upon standing.

The active soil layer in Cryosols supports biological activity and protects the underlying permafrost. Soil texture, moisture regime, thickness of organic surface layer, vegetation cover, aspect and latitude are among the factors that control the thickness of the active layer.

Salt crusts are common on soil surfaces on the high arctic islands of Canada and Russia. These salt crusts develop during dry periods in the summer because of increased evaporation from the soil surface.

The pH of Cryosols varies greatly and depends on the composition of the parent material: Cryosols developed in calcareous parent material have a higher soil-pH than soils in non-calcareous material. The similarity of the soil-pH to that of the parent material is also caused, in part, by cryoturbation, which mixes soil materials not only between horizons but also with the parent materials.

The cracking of frozen soil leads to the formation of patterned and sorted ground on Cryosols (EM).



This striking map shows the dominant characteristics of northern and mid latitude soils according to the WRB classification scheme for Reference Group Soil. The map is the output of a project to compile a soil database covering the United States, Canada, Greenland, Iceland, Europe, Russia, Mongolia, and Kazakhstan. The European soil data shown earlier in this atlas contributed to the project. The database was processed to create a version of the map in the WRB classification for the atlas.

The map clearly shows the zonal arrangement of soil around the North Pole. The blue band of the Cryosols, passing to the green of the Podzols, then the browns of the pinks of the prairie Albeluvisols, Chernozems and Phaozems. The yellow soils of the Calcisols delineate the more arid regions.

At this scale, Western Europe stands out as a block of Cambisols. The light blue tones from the wetlands of Florida, the Mississippi Valley and the lakes and marshes beyond the Ural Mountains indicate the major distribution of poorly drained Gleysols.

The red colour indicating the Andosols of Iceland, the Massif Central in France, the southwestern coast of Italy, the Kamtchatka Peninsula, the Aleutian Islands and the Rocky Mountains of the USA clearly identify the main areas of recent or active of volcanic on the map.

Cryosol Working Group. 2004. Northern and Mid-Latitude Soil Database, Version 1. Data are available on-line http://www.daac.ornl.gov from Oak Ridge National Laboratory Distributed Active Archive Center, Oak Ridge, Tennessee, U.S.A.

The distribution of permafrost-affected soil is a specific feature of the circumpolar soil map. The southern boundary of the permafrost reaches between 45° to 50° North on the Eurasian Continent, 55° latitude in North America while it is shifted northwards to about 70° North in Europe due to the warming effect of the Gulf Stream. The decrease in temperature with elevation also causes permafrost to occur in mountains areas, usually above the snow-line, the altitude at which snow occurs all year around. Exposure to sunshine can cause a different pattern of permafrost on north-facing slopes compared to the sunnier, south-facing slopes.

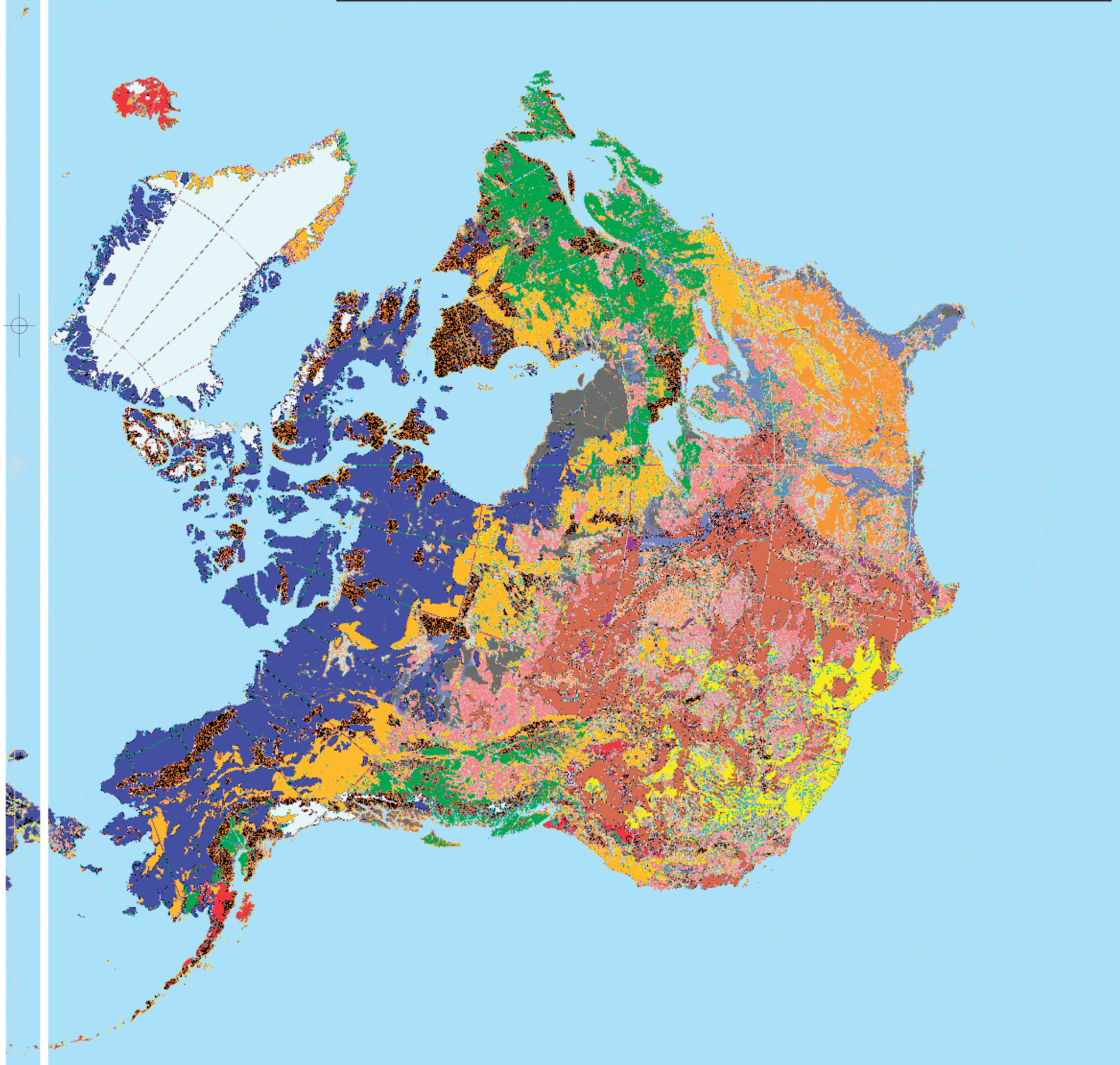
Major areas with permafrost-affected soils are found in Russia (10 million km²), Canada (2.5 million km²), China (1.9 million km²) and Alaska (1.1 million km²) and parts of Mongolia. Continuous permafrost is observed in the Arctic and sub-arctic zones. Discontinuous permafrost is common in the boreal zone and sporadic in more temperate mountainous regions.

Natural and man-induced biological activities in Cryosols are confined to the active surface layer that protects the underlying permafrost. Removal of the upper peat layer or of the vegetation and/or disturbance of the surface soil often induces rapid environmental change, with possible damage to man-made structures.

Most areas of Cryosols in Eurasia are in a natural state and support sufficient vegetation for grazing animals such as reindeer (herding of reindeer is an important industry in the northern areas of Europe). Overgrazing leads rapidly to erosion and other environmental damage.

Human activities, mainly relating to oil and gas production and mining have had a major impact on Cryosols. Severe "thermokarsting" has occurred on land cleared for traffic. Improper management of pipelines and mining can cause oil spills and chemical pollution that affect large areas.

Global warming studies predict significant temperature increases in northern areas. Cryosols contain a lot of peat and act as a carbon sink under the present climate. However, warming of the circumpolar regions would alter the thermal regime of the soils and increase the depth of the active layer. This would strongly enhance the decomposition of soil organic matter; previously "fixed" carbon would be released to the atmosphere as carbon dioxide and methane and accelerate global warming even more.



A Soil Database of Europe

A catena is a repeated sequence of soils that are associated with a change in landscape along river valleys. The term is derived from the Latin word for chain since all the soils from the skyline to the valley floor are linked together, or chained, when traced down the slope. The characteristics of the soils vary with changing slope angle and drainage conditions so that different degrees of leaching and translocation of clays are found (EM).

Looking at soils from the air provides a graphic view of their variability in the landscape. The darker, freely draining soils along the gullies in this field are clearly apparent. Aerial photographs are widely used in soil survey and archaeology. The remains of buried structures or even wooden buildings that have completely rotted away can often be seen through variations in soil colour or other physical characteristics (EM).

Geographical Information Systems

What is a Geographic Information Systems?

All the maps contained in this Atlas, have been produced using a technology known as Geographic Information Systems or GIS for short.

A GIS can be defined as a specialised computer system (both hardware and software) for capturing, storing, checking, merging, manipulating, analysing and displaying data which can be located somehow on the surface of the Earth. In geography, the term "spatial" is used when referring to such data. Latitude and longitude coordinates, map references, administrative regions, water bodies and settlements are some of the means of relating information to a particular location. In this respect, a GIS is different from a Computer Aided Design programme (CAD) that stores information on features in an abstract space.

Real world features such as roads, rivers, soil types, or water quality sampling sites are represented in a GIS in digital form as points, lines (arcs), polygons (areas) or as cells (a grid).

Descriptive information or attributes about objects (e.g. names, ownership, depth, soil type) can be associated with the geographical data. This "descriptive" information is normally stored in the form of tables in a database and is linked to the geographic or map data by a common identifier.

For the most part, spatial data can be "re-projected" from one coordinate system into another, thus data from various sources can be brought together into a common database and integrated using GIS software. In this way, a global database on rare birds using latitude and longitude to mark sightings of particular species could be combined with data on river networks compiled on the basis of maps using the Spanish national coordinate system. Spatial data and associated attributes in the same coordinate system can viewed together and layered on top of each other to create maps.

Another property of a GIS database is that it has "topology". This term defines the spatial relationships between different features. When topological relationships exist, analyses such as modelling the flow through connecting lines in a network, combining adjacent polygons that have similar characteristics and overlaying geographic features can be performed.

Higher level analysis can also be carried out on data. Questions such as "What would happen if…pollution accidentally leaked into a river?", "Where does…a Podzol occur next to arable land?" or "Is there a pattern to…burglaries in a city?" are only feasible on large volumes of information by using a GIS.

Other examples of analysis that have been carried out using GIS software range from identifying houses on flat land that are within 200m of rivers for flood predictions to locating groundwater regions under permeable soils to limit pesticide applications.

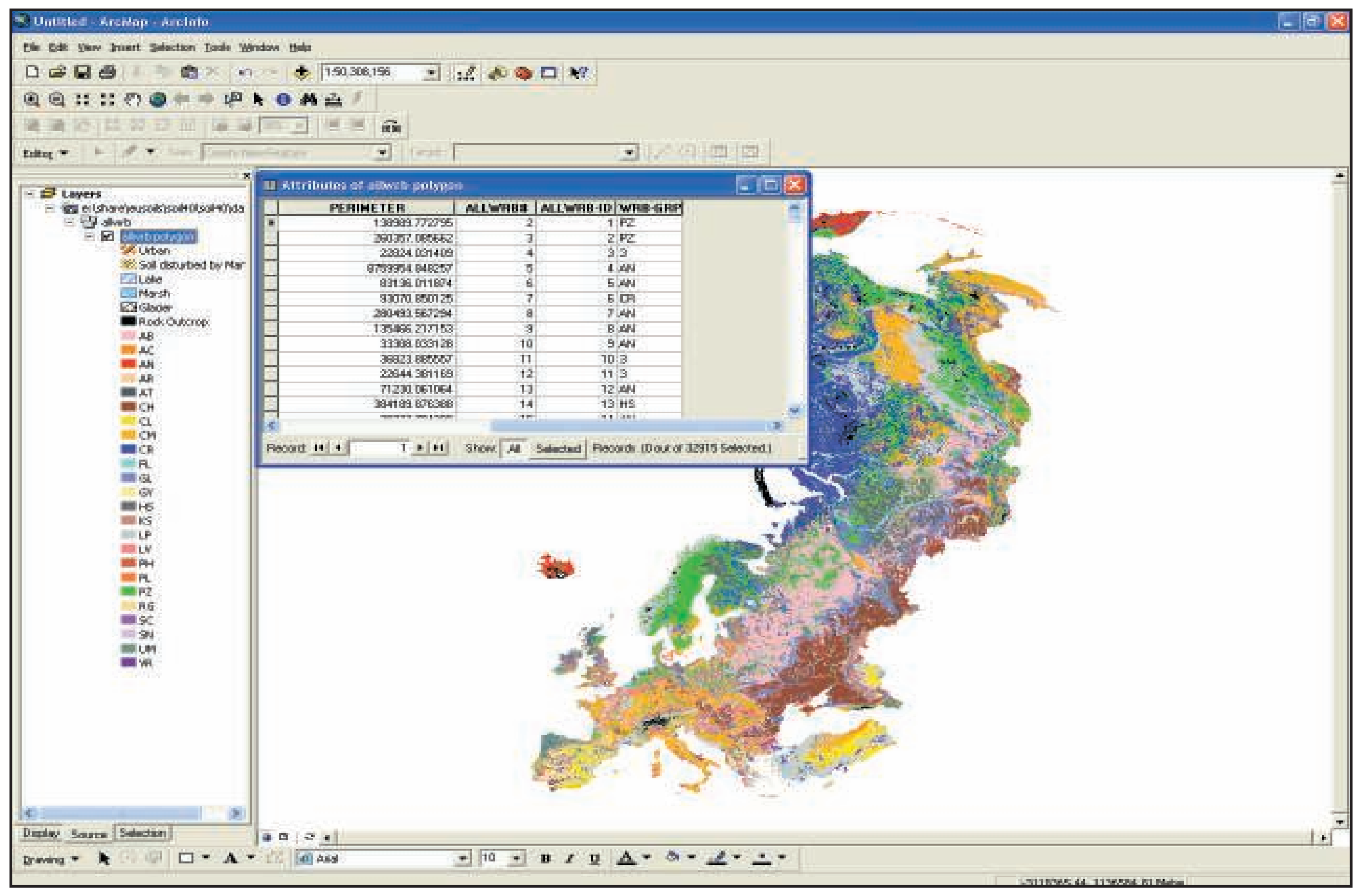
The last, but by no means least, component of a GIS is the human element! Well-trained people, knowledgeable in spatial analysis and skilled in using GIS software are essential to the GIS process.

Increasingly, GIS are being used by more and more organisations. Originally developed primarily as a research tool for Geography departments of universities, now GIS is widespread in facilities management (e.g. water pipes, electricity cables), marketing and retailing (e.g. optimising store location with respect to customer needs), military (e.g. battlefield maps, terrain evaluation), environmental (e.g. predicting floods, erosion risk, forest fires), transport (e.g. vehicle routing, noise surveys), health (e.g. relationship between illnesses and social or environmental factors) and many, many more cases.

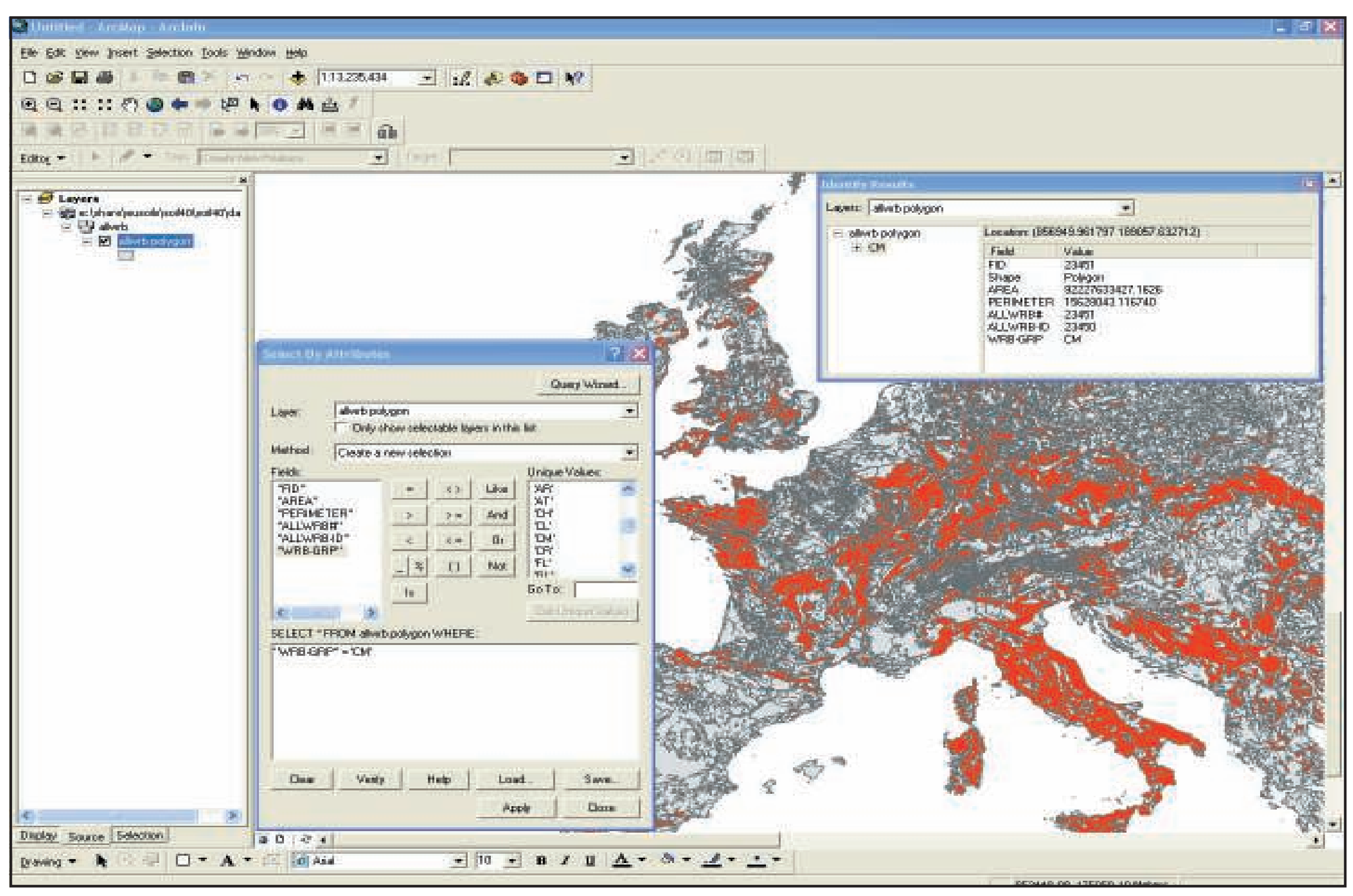
The GIS software used in the production of the maps in this book was a product called ArcGIS developed by ESRI Inc. from Redlands, California.

If you would like to learn more about spatial data and Geographic Information Systems then have a look at the following sites on the World Wide Web;

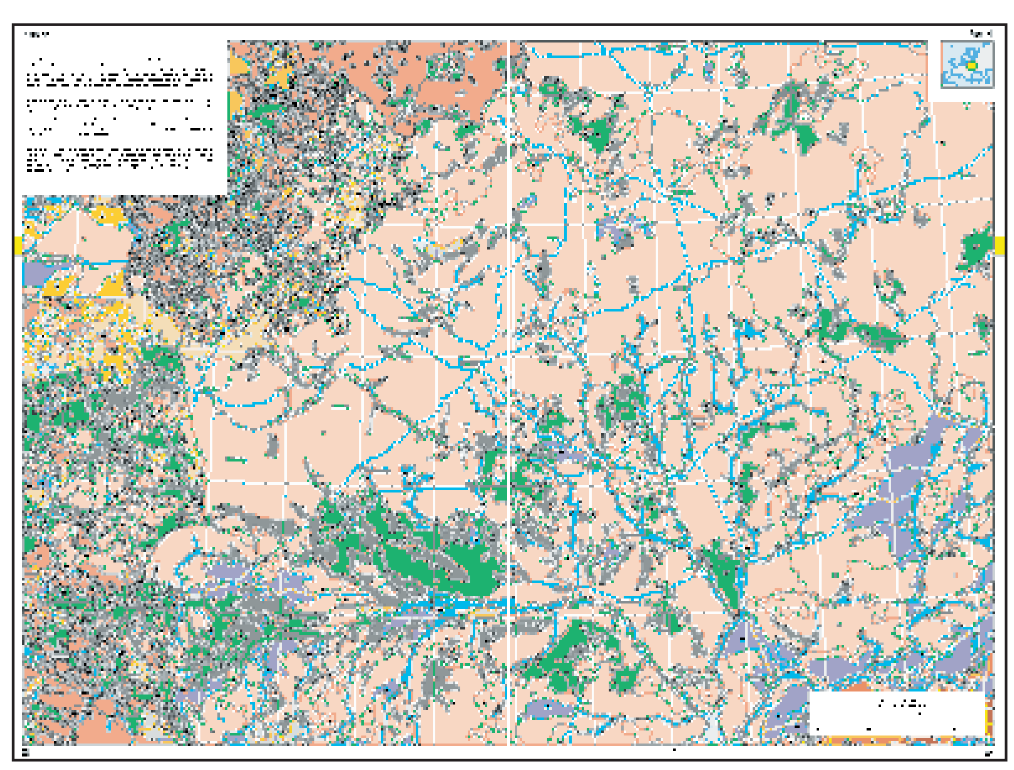
- http://www.ec-gis.org/inspire/
- http://www.eurogi.org/
- http://www.gis.com
- http://www.geo.ed.ac.uk/home/giswww.html
- http://www.usgs.gov



The above picture shows the interface to the GIS software used to produce the maps in the atlas. The digital cartographic data (map) have been coloured using a legend based on codes indicating the WRB Reference Group. The small window displays the attribute table for the map data. Each polygon or area has been coded with the appropriate WRB code and a unique identifier (ID) to link the attribute data to the graphics (AJ) (ESRI ®).



The above picture shows the GIS software can be used to query or search spatial data and display the results. The picture shows the location of all polygons containing the code CM in the WRB-GRP column of the attribute table. In effect, the map shows the distribution of Cambisols (AJ) (ESRI ®).



GIS are often regarded as mapping software. However, GIS are powerful tools to visualise different sources of data in many ways. The figure on the right is an extract from the atlas showing how soil data from six countries were combined to produce a single map (AJ).

Soil Geographical Databases of Europe

Introduction

The soil maps of Europe contained in this Atlas are based on a collection of knowledge contained in a databank known as the Soil Geographical Database of Eurasia. The database contains a range of information on soil which is stored in several databases, referred to as the:

- Soil Geographical Database of Eurasia at a scale 1:1 million (SGDBE);
- Soil Profile Analytical Database of Europe (SPADE);
- Hydraulic Properties of European Soils (HYPRES) Database;
- Pedotransfer Rules Knowledge Base (PTR).

These linked databases represent a first step in the development of a fully integrated European Soil Information System (EUSIS), the concept of which is described on Page 105 of the Atlas.

The information used to create the maps of Europe depicted in this Atlas resides in the Soil Geographical Database of Eurasia. This database is the result of a collaborative project involving all the European Union Member States and neighbouring countries through participation in the European Soil Bureau Network (see Page 104).

How does the database work?

The Soil Geographical Database of Eurasia is a simplified representation of the diversity and geographical variability of the soil coverage at a European level. It is based on Geographical Information System concepts (see Page 97).

The database is composed of a digitised soil map (digital or computerised representation) that is made up of closed contours called polygons. The soil map is at a scale of 1:1,000,000 where 1 centimetre on the map represents 1 kilometre on the ground. At this scale, it is not possible to draw very small polygons, so it is not possible to draw directly the delineation of individual soil types. Thus, the soil map represents the delineation of groups of soil types that are called Soil Mapping Units or SMU for short. Soil Mapping Units correspond to the polygons that are defined by the same group of soil types. The groups of soil types are generally defined as areas in the landscape where the same soils are present, in the same position and which have functioning relations between them.

Each SMU contains one or more Soil Typological Units (STU) which are individual soil units that can be described by parameters (or attributes) specifying the nature and properties of the particular soil (for example the texture, the water regime, the stoniness, WRB code, etc.). This information is stored as a separate table called STU Attributes.

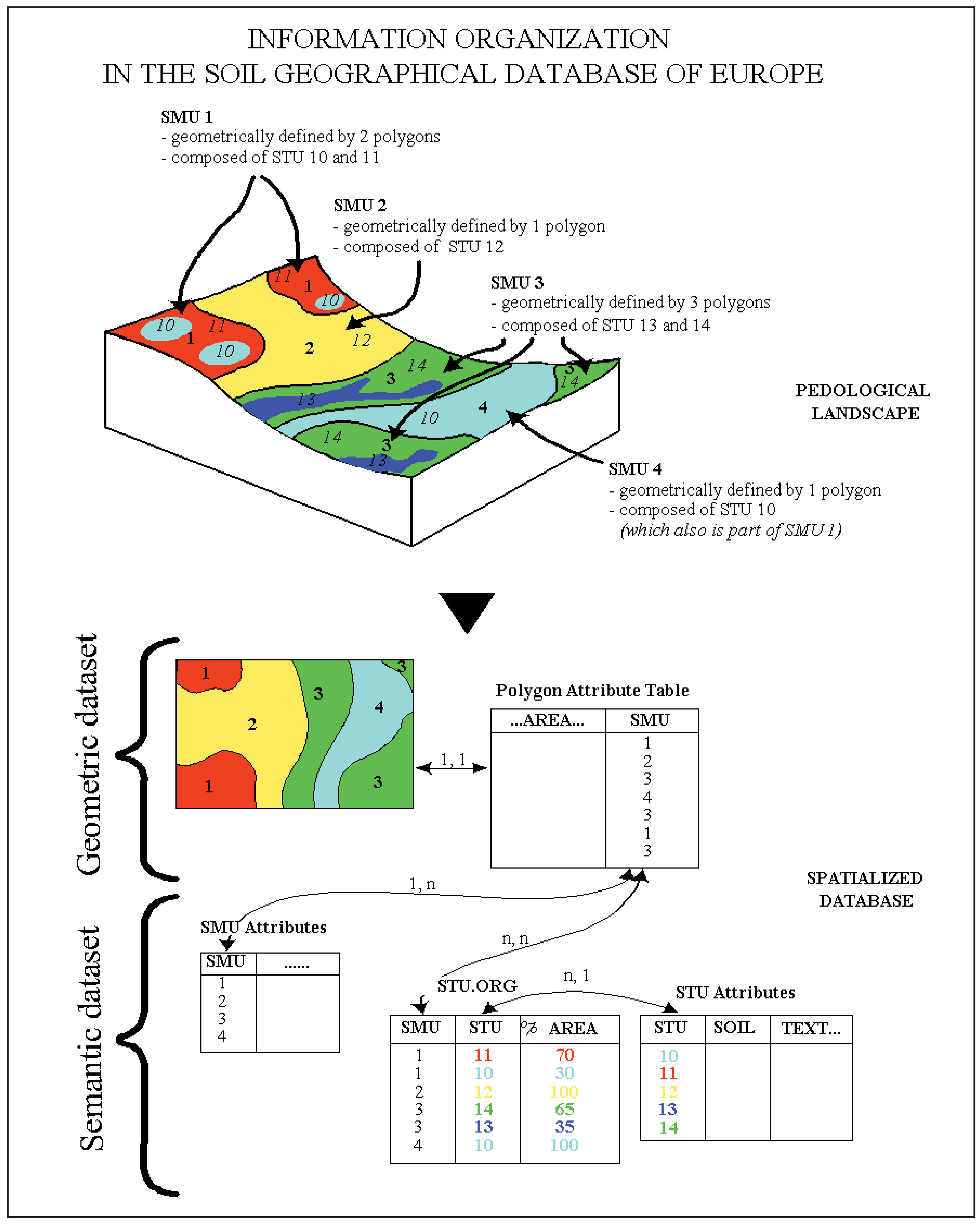
To describe the properties of the soil types, several tables are available forming the semantic dataset. The first table, called SMU, contains variables (named also as attributes) that give information about the SMU. The second table, called STU, contains the information describing the soil types, named in the database Soil Typological Units (STU). These variables give information about the nature and the properties of the soil like its texture, its name in WRB classification, its parent material and so on.

A third table, called STU.ORG, gives the list of the STUs that belong to each SMU with the percentage of area they represent within the SMU. When the SMU is composed of only one STU, this percentage is equal to 100. When the SMU is composed of several STUs, then the sum of the percentages is equal to 100% (for example in the figure on this page, the SMU 1 is composed of the STU 11 representing 70% and of the STU 10 representing the remaining 30%).

The data are stored in a relational database management system that enables to define relations between the polygons, the SMU table, the STU.ORG table and the STU table and which are symbolised on the figure by arrows. These relations enable the transfer of information from one object to another and are very useful to make maps from the Soil Geographical Database.

How do you deal with more than one STU?

By now, you will have realised that, in many cases, there will be several SMUs with more than one STU. But, soil properties are described for the STUs, not for the SMUs and generally, the STUs that belong to the same SMU have different properties.



The Soil Geographical Database of Europe at a scale 1:1 million consists of a geometrical dataset (digital map) and a semantic dataset (set of attribute files) that link attribute values to the polygons of the geometrical dataset. The above diagram illustrates how map polygons, SMU's and STU's are linked together. Try and follow the diagram to understand that polygon 1 from the digital map (the red area), corresponds to SMU 1, which consists of two STU (10 and 11) that occupy 30% and 70% of SMU1 respectively. In this example, analysis of the STU.ORG and the STU Attribute table would show that the dominant soil of SMU1 would be STU 11, an Andosol (AN) (JDN).

So, how is it possible to draw a map for a soil property? This is possible using the relations between tables and polygons.

The most common way to make a map of a soil property is to determine a dominant STU within each SMU. This can be done using the STU.ORG table where the percentage of area of each STU within a SMU is given. Then, the dominant STU within a SMU is the STU having the higher percentage of area. Then, you just have to take the value of the dominant STU for the soil property you want to map and to assign this value to all the polygons that form the SMU.

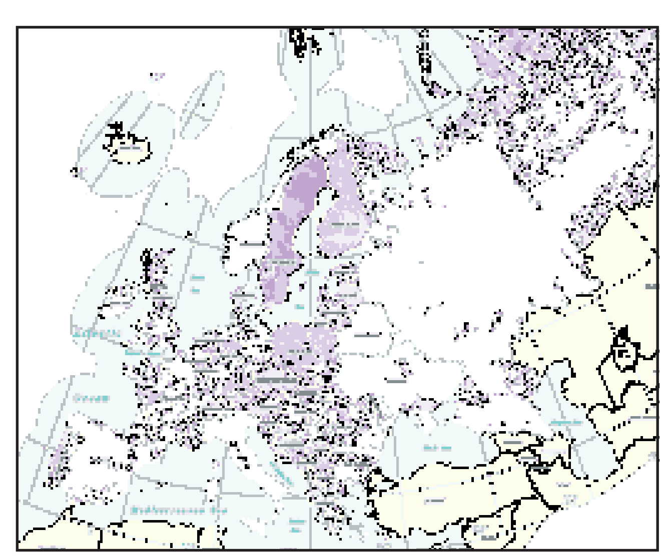
It is important to keep the indication of the percentage of area corresponding to the value drawn on a map. In the above method, it is the percentage of area of the dominant STU. This percentage can also be drawn on a map. Such maps are called purity maps and give important information about the variability of the soil property within the SMUs (see the figure of the bottom of the page). The higher the percentage, the lower is the variability inside the SMU.

Producing the maps for the Atlas

To produce the maps shown in the Atlas, a procedure was carried out to take the dominant value per SMU using an automatic procedure developed in the GIS.

Be careful in using these maps?

The Soil Geographical Database of Eurasia results from a synthesis work done by national soil scientists in each country by expert judgment. Thus, the accuracy of this work is depending on the state of knowledge of soils and the availability of more detailed soil information in each country. Thus, quality indices of the information are important to look at, like the purity maps or confidence level for estimated data (see Page 99).



An example of a confidence index for the soil data. The above figure is a purity map that shows the proportion of the area of the SMU that is effectively covered with the corresponding thematic value shown on a corresponding thematic map; darker hues indicate purer areas (JDN).

Soil Geographical Databases of Europe

As explained in the previous page, the soil maps in this Atlas are based on a databank known as the Soil Geographical Database of Eurasia. In addition to the 1:1 million scale Soil Geographical Database of Eurasia (described in detail on Page 98), the databank contains a series of additional databases.

- Soil Profile Analytical Database of Europe (SPADE);
- Hydraulic Properties of European Soils (HYPRES);
- Pedotransfer Rules Knowledge Base (PTR).

This page will briefly explain the significance of the information contained in these three databases.

Soil Profile Analytical Database of Europe

The Soil Profile Analytical Database of Europe (SPADE) was developed to link to the Soil Typological Units (STU) of the Soil Geographical Database of Europe with chemical and physical soil profile data that would be representative of these STUs. The driving force of this database was a need of data about the soil available water for plants for a project called MARS (Monitoring Agriculture by Remote Sensing) which develop a tool for predicting crop yield across Europe.

SPADE was compiled through the collaboration of national experts from the 12 European Union member countries in the 1980s. The main problem encountered when compiling this database was the availability of data. Many countries were not able to give a representative measured soil profile for each STU of the Soil Geographical Database of Europe due to the lack of more detailed soil information in some areas.

The second problem is the availability of data concerning some particular measurements, especially those concerning the hydraulic properties of soils. These measurements are very expensive and are thus generally not performed. To alleviate this problem, estimated profiles were compiled. When real measurements are lacking, the national expert gave an estimation of the corresponding soil property.

The database includes analytical information for the key soil horizons on parameters such as:

- Texture (& particle size grades)
- Electric conductivity
- Organic matter content (C, N)
- CEC and exchangeable bases
- Structure
- Soil water retention
- Total nitrogen content
- Bulk density
- pH
- Root depth
- ESP or SAR
- Groundwater level
- Calcium carbonate content
- Parent material
- Calcium sulphate content

The quality and the reliability of the information in SPADE is an important matter for users.

Firstly, when the SPADE initiative began, the database was referring to a certain version of the Soil Geographical Database of Europe. When countries provided new versions of their soil map, they did not always update the data stored in SPADE, making the link between soil profiles and STUs difficult.

Secondly, the soil data in each country are generally linked to soil units defined in the national soil classification. In most countries, these classifications differ significantly from the classification system used for the European databases. This difference leads to gaps in the database especially when trying to find representative profiles.

Thirdly, the determination of a unique and representative profile for STUs, which are defined at a global level due to the high variability of their properties, is a difficult procedure.

During recent years, a major initiative has been underway supported by the European Crop Protection Association to update the database. A revised version, SPADE2, is foreseen to be available for 2005.

The soil of woodlands. The soils on steep slopes in wooded areas are well protected from erosion by the thick litter layer produced by falling leaves and the tree root system that helps bind the soil (EM).

Hydraulic Properties of European Soils Database (HYPRES)

In SPADE, measurements about hydraulic properties of soils are often not available. But, unfortunately, these soil properties are essential to answer to many agricultural or environmental problems. Many researchers throughout the world have worked to develop tools that provide accurate estimations of these properties. These tools are developed through the generic term of pedotransfer functions.

What is a pedotransfer function? A pedotransfer function is a tool that allows the use of available soil information (*pedo-*) to estimate (*-transfer*) another soil information. They are generally developed using a set of profile information where measurements of the hydraulic properties are available and are compared to more common soil information like particle size distribution, organic matter content, etc. This leads to the determination of statistical relations giving a mathematical *function* to estimate the hydraulic property by using other soil information.

Many pedotransfer functions were developed but the main problem in using it is their domain of application. Does a function developed on soil profiles from the United States or from Germany be valid to estimate hydraulic properties of European soils?

To overcome this issue, 20 institutions from 12 European countries collaborated to establish a database about hydraulic properties of European soils (HYPRES). Data for 5521 horizons were collected and analysed to define pedotransfer functions for estimating soil water retention and hydraulic conductivity for topsoil and subsoil using the texture class of the Soil Geographical Database of Europe. These pedotransfer functions applied to the STUs of the Soil Geographical Database of Europe allows the mapping of hydraulic properties of European soils.

Pedotransfer Rules (PTR) Database

Some properties of soils are not described specifically in the Soil Geographical Database of Eurasia but are essential to be known to answer to specific demands. As we saw it for the HYPRES database, tools were developed to estimate some soil properties using available soil information: the pedotransfer functions. But, to develop pedotransfer functions, a set of soil profiles with measurements of the needed soil property is necessary. When the Soil Geographical Database was first used, such a set was not available. Thus, to use the database, it was decided to develop pedotransfer rules. As for pedotransfer functions, a pedotransfer rule is a tool that enables the estimation of a soil property using available information. But, the estimation is not based on a mathematical relation but on an expert judgment (it is why we used the term *rule* instead of *function*).

The innovative work done within this project of pedotransfer rules development was to formalized the expert judgment and to develop a specific database to store the pedotransfer rules: the knowledge base. Each rule is developed in the form of:

IF <condition> AND <condition> THEN <estimated variable> = <this value>

A confidence level (high, medium, low) is given by the author of the rule to the estimation that enables to give information to users about the quality of the estimated data.

The knowledge base enables also the development of trees of rules, where a rule uses as input data results coming from another rule. The soil properties estimated by the pedotransfer rules concern biological, chemical, mechanical and hydrological properties of European soils. They permit the use of the Soil Geographical Database as input for modelling in many domains such as yield forecasting, climate change impacts, erosion risk assessment and many others.

The output attributes were grouped into four classes that correspond to biological, chemical, mechanical and hydrological properties of soils. These include:

- Topsoil organic carbon content
- Presence of a raw peaty topsoil horizon
- Soil profile differentiation
- Profile mineralogy
- Topsoil and subsoil mineralogy
- Topsoil and subsoil cation exchange capacity
- Topsoil and subsoil base saturation
- Depth to rock
- Volume of stones
- Subsoil textural class
- Topsoil and subsoil structure
- Topsoil and subsoil packing density
- Parent material hydrogeological type
- Depth to a gleyed horizon
- Depth to impermeable layer
- Hydrological class
- Topsoil and subsoil available water capacity
- Topsoil and subsoil easily available water capacity

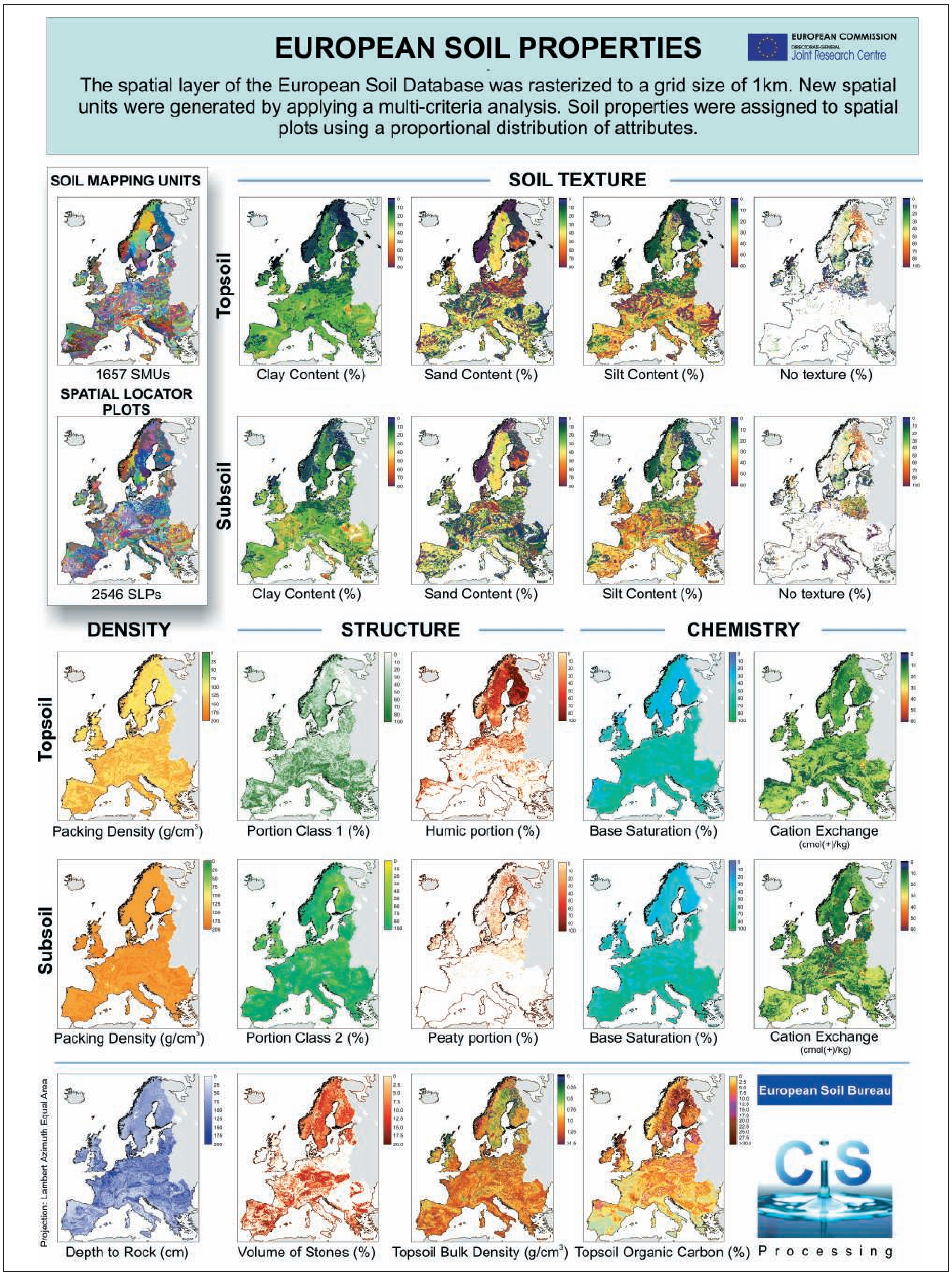
An example of a PedoTransfer Rule

IF <soil name is "eutric Cambisol" and parent material is "calcareous regional metamorphic rocks">

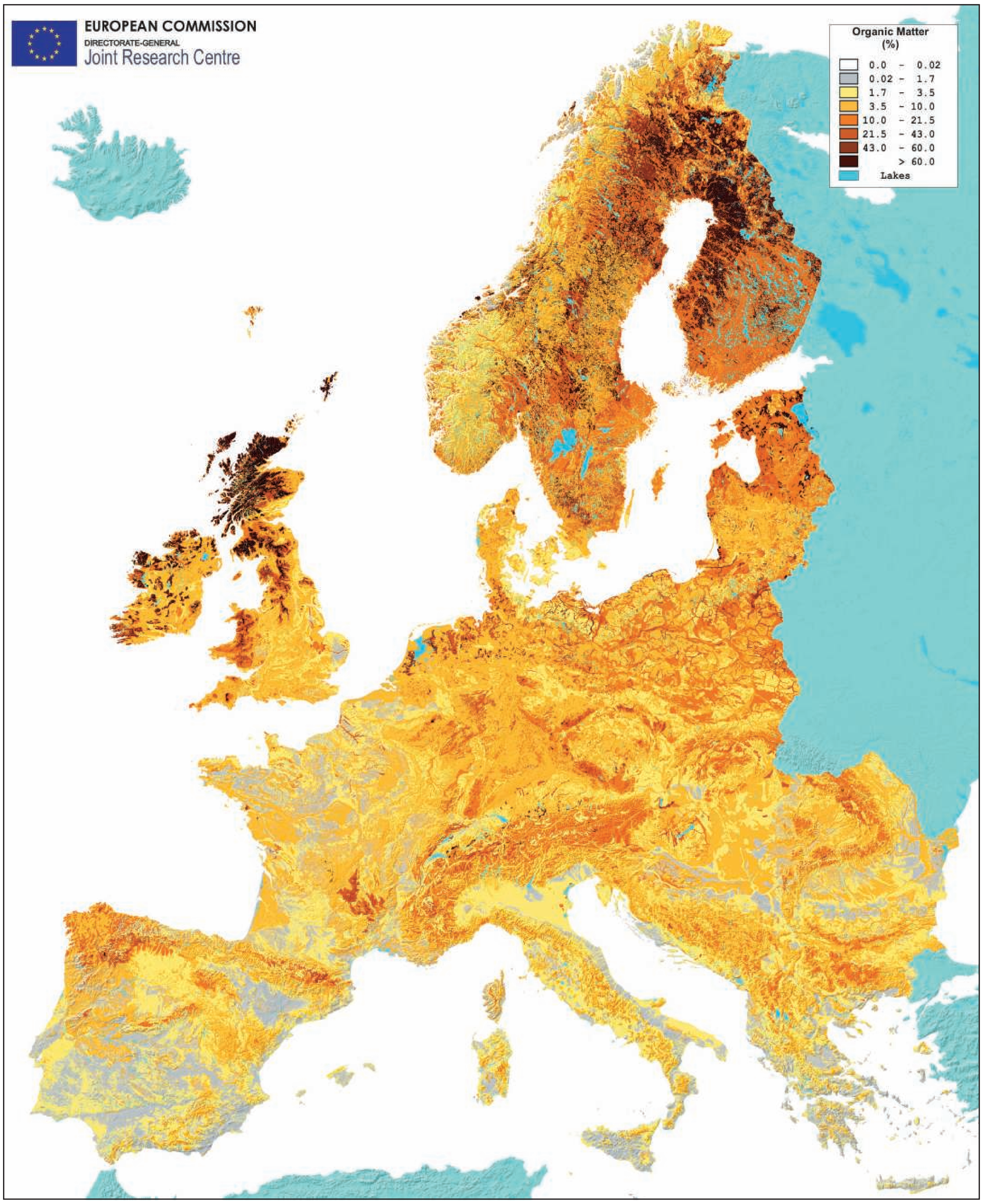
THEN <soil depth is "Medium">

ELSE IF <soil name is "eutric Cambisol" and parent material is "any other parent material">

THEN <soil depth is "Deep">



The maps shown on this page illustrate how the various databases described in the preceding pages can be used to provide information on the characteristics and properties of soils in a harmonised manner across Europe. In this instance, the data for Belarus, Cyprus, Iceland, Russia, Turkey and Ukraine were not processed. For an explanation of the properties displayed by the individual maps, please consult the Glossary on Page 126 of the Atlas (RH, RJ & LM).



Organic material in the soil is essentially derived from residual plant and animal material, broken down by microbes and decomposed under the influence of temperature, moisture and local soil conditions. Organic matter is extremely important in all soil processes by acting as a storehouse for nutrients, contributing to soil aeration and ensuring good structure. Soil which is dark-brown or black in colour usually contains significant amount of organic matter (>15%).

The map above shows the distribution of organic matter in the topsoil (0-30 cm depth) across Europe at a resolution of 1 km based on land cover, temperature and soil data for the 1980s and early 1990s. The dark brown and blackish tones on the map clearly show the extent of organic rich Histosols in Scotland, western Ireland and Scandinavia. These areas are in marked contrast to greyish and yellowish areas occupied by Calcisols and Cambisols in southern Europe, where organic matter contents are much lower than in the north. There are many factors affecting the amount of organic matter in soil and these are described in more detail on Page 112.

Since carbon, in the form of organic matter, may be sequestered by vegetation and soil in sufficient quantities to mitigate some detrimental effects of Global Change, the map attempts to define the status of organic matter content in European topsoils for 1990, in-line with the Kyoto Protocol.

This map was produced by the Institute of Environment and Sustainability, Joint Research Centre (RH).

Using the soil database

Interpretation of soil resources

The soil classes shown in the Atlas have a fundamental meaning. These principal classes can be exploited to specify a quality of soil resources in relation to their current use and potential. Generally, quality is a relative term that shows the suitability of a particular soil type to meet a specific practical purpose. For example, different crops have varying demands on soil characteristics such as texture, rooting depth, acidity and so on. Consequently, soil quality is often regarded as a crop specific measure. Similar examples can be given for the suitability of soils to any other uses (e.g. engineering, waste, recreational activities, etc.). In this text, an evaluation of the natural quality of European soil regarding their agricultural use is provided allowing the reader to make their personal assessment of the soil quality across any territory.

Natural soil fertility is expressed by three levels that are derived from an evaluation of a combination of many soil characteristics including organic matter content, clay content, clay mineralogy, presence of weatherable minerals, pH, base saturation and biological activity.

Natural soil fertility levels for Reference Soil Groups of Europe

Low	Moderate	High
Acrisols Planosols Alisols Podzols	Regosols Andosols Calcisols Umbrisols Luvisols Albeluvisols Histosols	Fluvisols Gleysols Vertisols Kastanozems Chernozems Phaeozems

Soil toxicity interprets the level of certain soluble compounds in soil. These substances are toxic to many crops and affect their productivity. A general evaluation of the Reference Soil Groups showing one or more of these toxic characteristics is given in the table below.

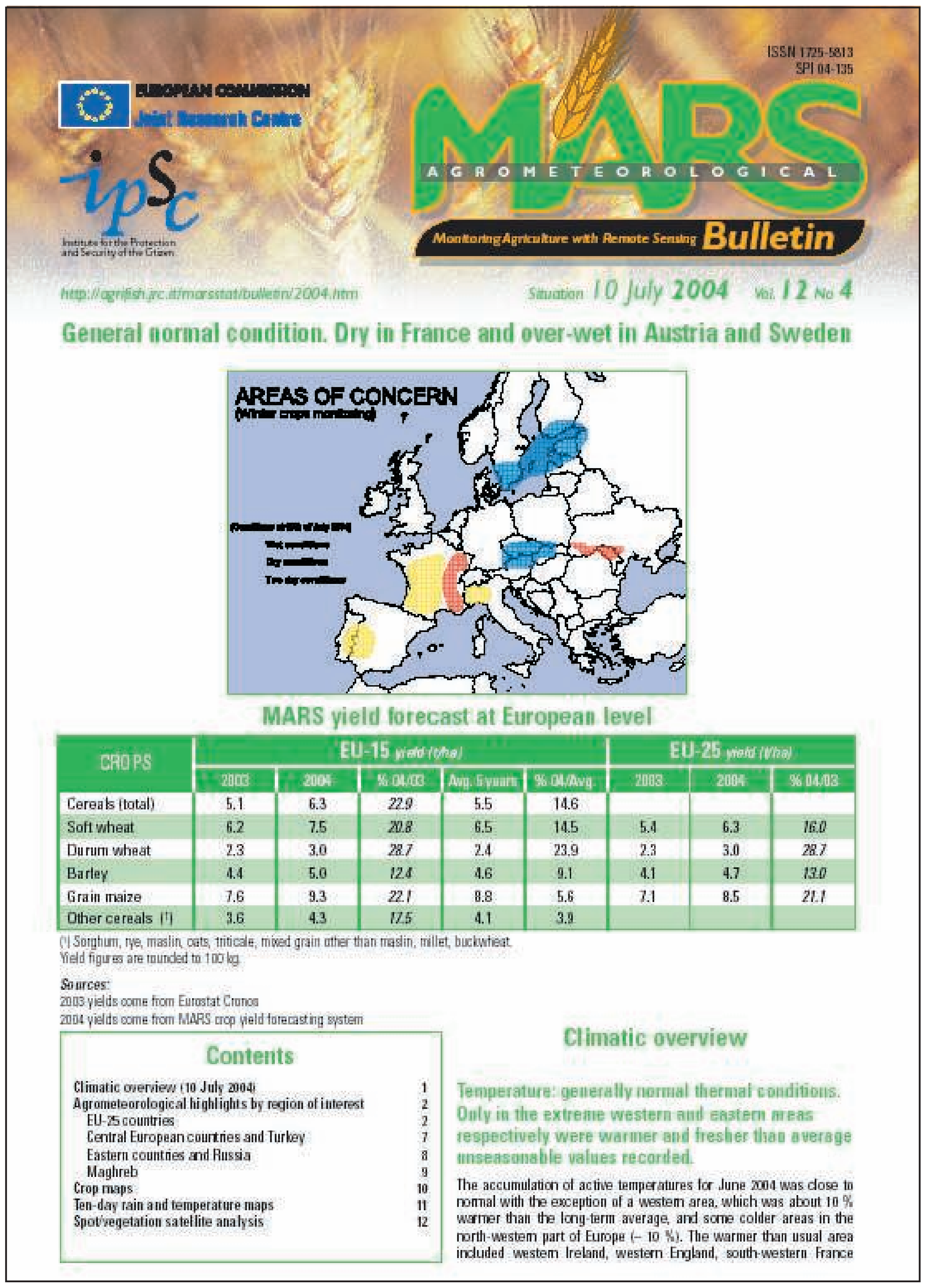
Soil chemical constraints in Reference Soil Groups of Europe

Salinity	Sodicity	Al-toxicity	$CaCO_3$	Gypsum
Solonchaks Solonetz	Solonetz Kastanozems	Andosols Acrisols	Calcisols Gypsisols	Gypsisols

Soil that requires protection, conservation and particular attention is often formed in specific environmental conditions that strongly limit their use. A Cryosol is the soil of severe cold climate and is extremely sensitive to human impacts. Anthropogenic intervention on these soils affects very fragile tundra ecosystems. Histosols are often formed under waterlogged conditions and play a regulatory role of hydrological balance of the landscape. In addition, Histosols accumulate an enormous mass of partly decomposed organic residues, which will decay if the land is drained and thus contributing to an increase in the concentration of carbon dioxide in the atmosphere (the most important greenhouse gas). There is widespread agreement that this soil type should be protected. Fluvisols and, to some extent, Gleysols indicate land with a high risk of flooding. The increasing evidence of this hazard in Europe makes it important to account for the geographical distribution of these soil types when planting crops, establishing infrastructure and settlements.

Monitoring of Agriculture with Remote Sensing

The figures on the **right** illustrate one of the main driving forces behind the creation of the European Soil Databases. The Monitoring of Agriculture with Remote Sensing, (MARS), project, started in 1988, was designed initially to apply emerging space technologies for providing independent and timely information on crop areas and yields through the use of agro-meteorological models. The soil parameters from the soil databases described previously are used as inputs to a Crop Growth Model to define the hydrological characteristics of the soil and the ease by which the root systems of crops can develop. MARS bulletins, produced by the MARS-STAT Project of the Joint Research Centre's AgriFish Unit, are published 6 to 8 times a year to provide a forecast of crop yields throughout the European Union (GG).



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EUROPEAN COMMISSION
Joint Research Centre

ipsc
Institute for the Protection and Security of the Citizen

MARS
AGROMETEOROLOGICAL
Monitoring Agriculture with Remote Sensing Bulletin

http://agrifish.jrc.it/marsstat/bulletin/2004.htm
Situation 10 July 2004 Vol. 12 No 4

General normal condition. Dry in France and over-wet in Austria and Sweden

AREAS OF CONCERN
(Winter crops monitoring)

MARS yield forecast at European level

CROPS	EU-15 yield (t/ha)					EU-25 yield (t/ha)		
	2003	2004	% 04/03	Avg. 5 years	% 04/Avg.	2003	2004	% 04/03
Cereals (total)	5.1	6.3	*22.9*	5.5	14.6			
Soft wheat	6.2	7.5	*20.8*	6.5	14.5	5.4	6.3	*16.0*
Durum wheat	2.3	3.0	*28.7*	2.4	23.9	2.3	3.0	*28.7*
Barley	4.4	5.0	*12.4*	4.6	9.1	4.1	4.7	*13.0*
Grain maize	7.6	9.3	*22.1*	8.8	5.6	7.1	8.5	*21.1*
Other cereals (¹)	3.6	4.3	*17.5*	4.1	3.9			

(¹) Sorghum, rye, maslin, oats, triticale, mixed grain other than maslin, millet, buckwheat.
Yield figures are rounded to 100 kg.

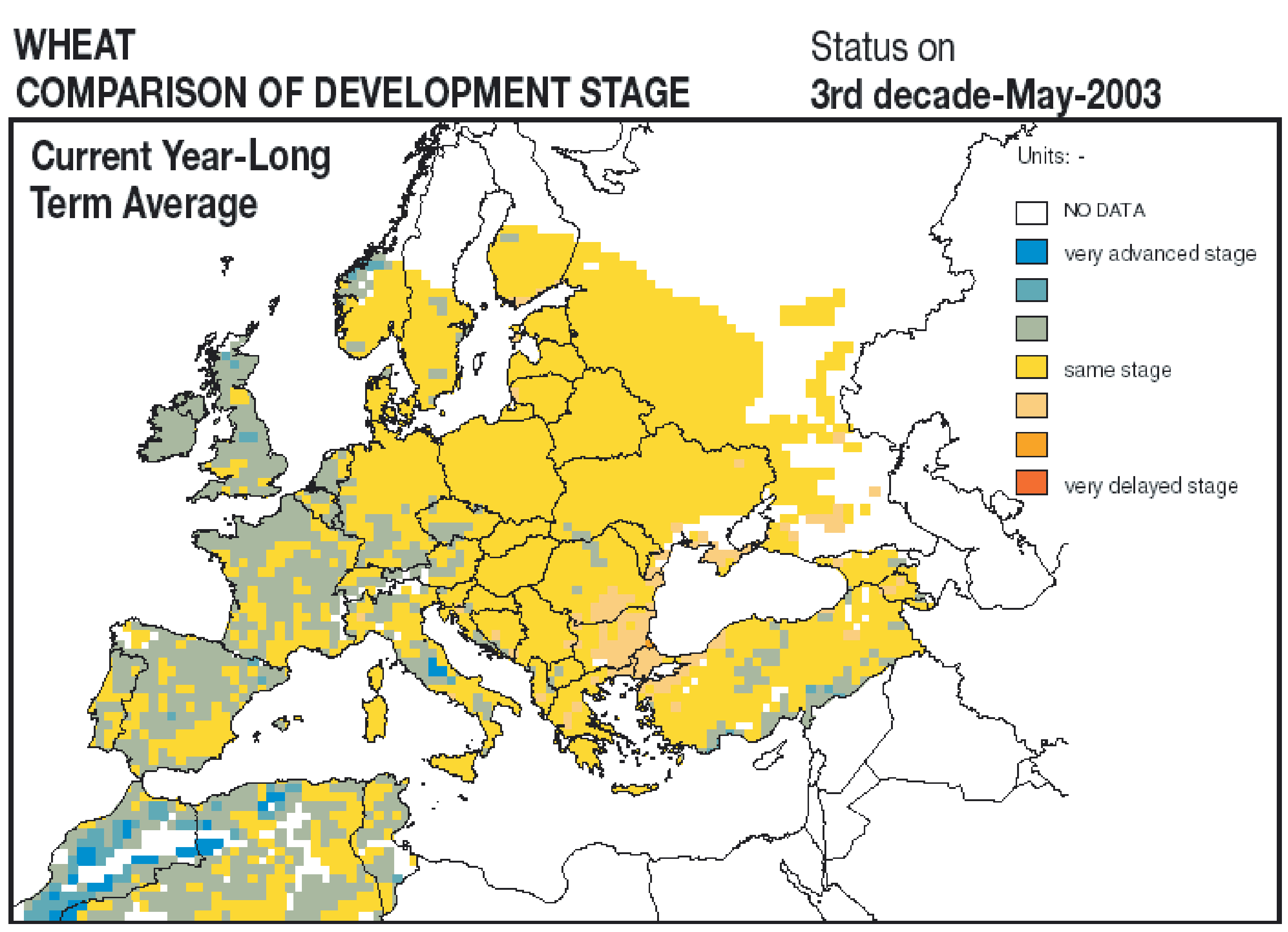
Sources:
2003 yields come from Eurostat Cronos
2004 yields come from MARS crop yield forecasting system

Contents

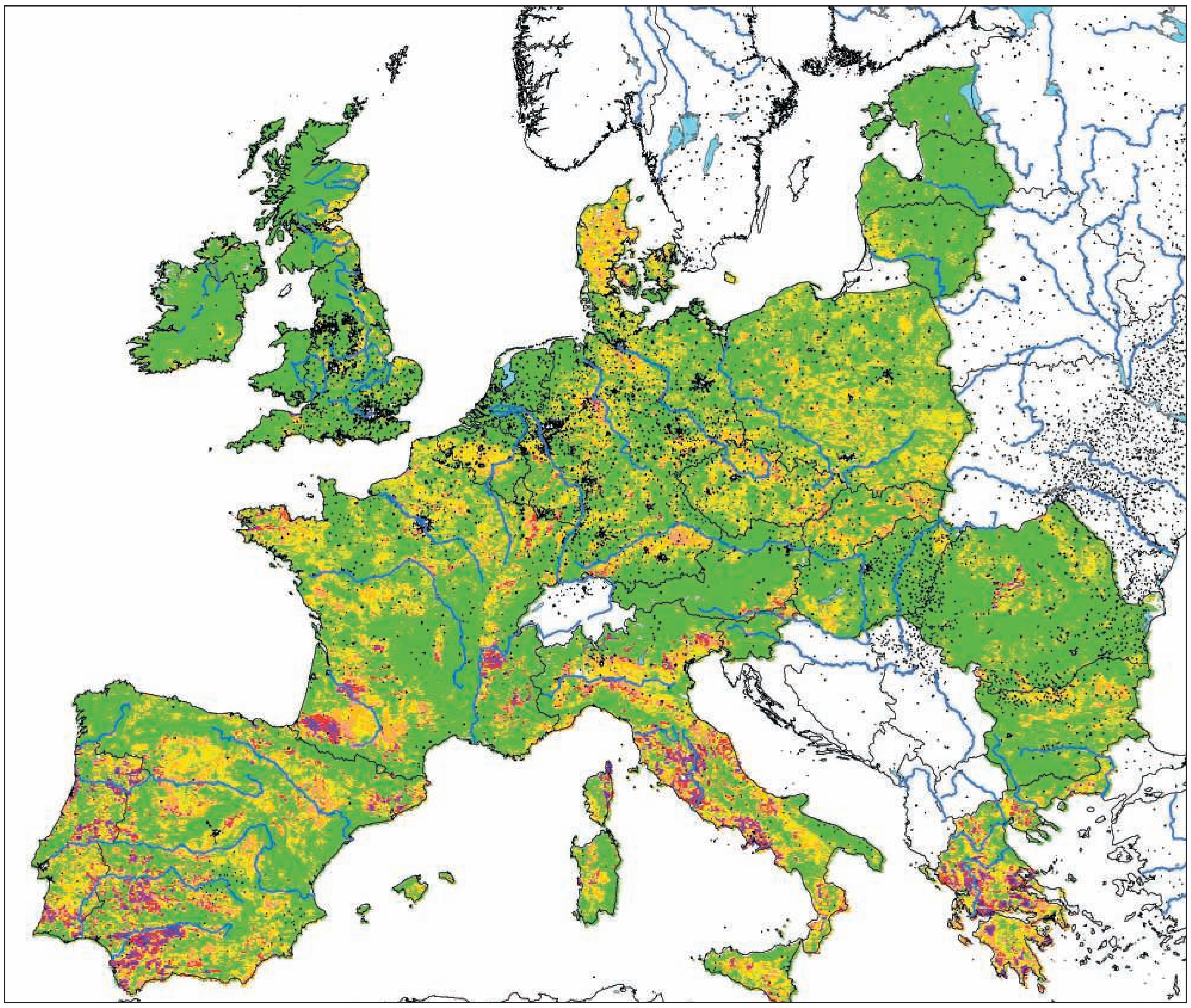
Climatic overview

Temperature: generally normal thermal conditions. Only in the extreme western and eastern areas respectively were warmer and fresher than average unseasonable values recorded.

The accumulation of active temperatures for June 2004 was close to normal with the exception of a western area, which was about 10 % warmer than the long-term average, and some colder areas in the north-western part of Europe (– 10 %). The warmer than usual area included western Ireland, western England, south-western France



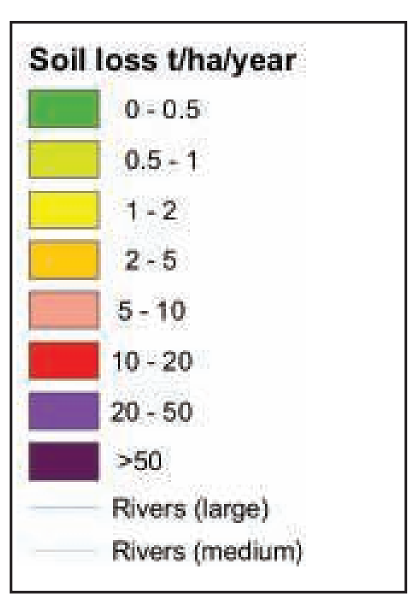
Using the soil database



The above map is taken from a EU research project to develop a Pan-European Soil Erosion Risk Assessment (PESERA). The map shows the estimated sediment loss from soil erosion by water based on a model that combines soil property data with information on climate, land cover and topography (altitude, slope angle, etc.) for river basins across Europe (RJ).

The legend shows areas with very low estimated sediment loss (green) to high estimated sediment loss (red/purple). The map clearly highlights the problems of soil erosion in the Mediterranean regions (e.g. central Italy, southern Spain and Greece) and in southwest France.

Sheet wash erosion on a Chernozem in Hungary. Sheet erosion is the removal of soil by overland flow on low gradient slopes. Soil particles loosed by the impact of raindrops are carried away by unchannelled flow of water during intense rainfall when the infiltration rate of the soil has been exceeded (ED).

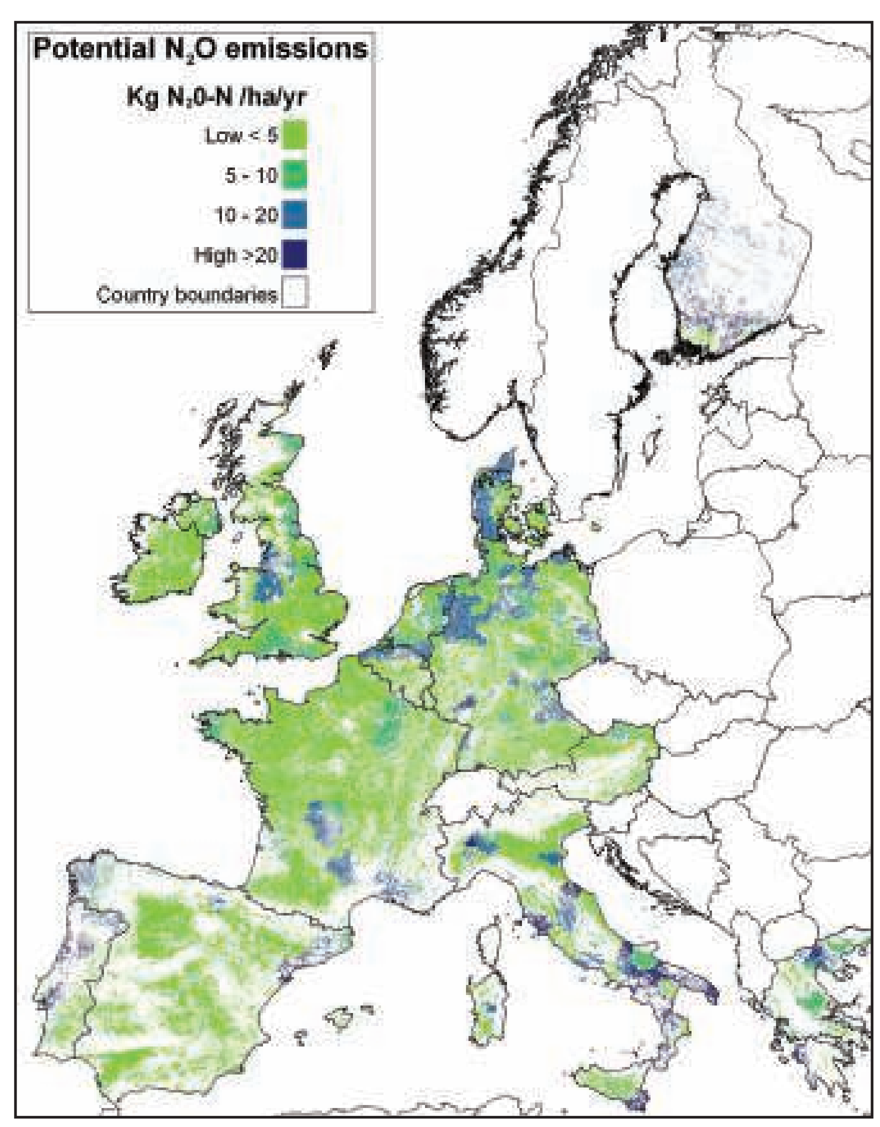


Estimated Soil Loss (t/ha/yr)

The image on the right (DM) is the output of a study carried out by the JRC that used information from the soil database to estimate direct N_2O emissions from agricultural soils. N_2O has a high global warming potential and due it's long atmospheric lifetime can also affect stratospheric ozone levels.

Soil characteristics (i.e. soil organic carbon and texture) along with fertilisation and climate are some of the key factors determining N_2O formation and losses from agricultural soils.

Regional 'hot-spots' were identified where agricultural soils with high organic carbon content and moisture content combined with high fertilisation rates produce the potential for high N_2O emissions.



European Soil Bureau Network

The European Soil Bureau Network provides policy makers with information on soil processes and related issues in Europe. The network is made up of representatives from the European Commission's Joint Research Centre, all EU Member States, Candidate and Neighbouring Countries. Details on how to contact the ESBN member in your country are given at the end of the Atlas (AK).

European Soil Bureau Network

The maps in this Atlas are an output from the European Soil Bureau Network (ESBN), which is a network supporting the soil bureau of the Joint Research Centre (JRC). It includes soil scientists from more than 40 soil science institutions covering the entire European continent. It is a scientific expert group providing advice to the JRC on soil information, as well as on technical options for soil management and their implementation. ESBN has a specific role as a facilitator and provider of soil information that is relevant to European Union and national policies.

History of the ESBN

The ESBN was established formally in 1996 but its origins as a network of soil science experts go back more than three decades. Its major achievement to date has been the successful compilation of a Soil Information System for Europe (EUSIS).

One of the key goals of the ESBN was the development of a harmonized soil geographical database for Europe, based primarily on the soil map of the European Communities (see Page 37 on the history of these soil maps). The further development of this database remains a primary objective of the ESBN.

The 'digital age' for European soil information began in 1982 when a 'Computerisation of Land Data Group' (CLDG) was established by the European Commission, comprising representatives of the main centres of expertise within the EEC at that time. The main result of this group was the publication of the Soil Map of the European Communities in 1985. The group continued to meet annually until 1988 and was responsible for a number of initiatives that relate to the maps in this Atlas, of which the digitisation of the EC Soil Map is the most important.

Progress slowed in the 1980's due to difficulties in funding. However, in 1990 the strategic need for soil information became clearer when a Monitoring of Agriculture by Remote Sensing (MARS) project at the JRC required information on the water holding capacities of European soils, as an input to a crop growth model supporting yield forecasting for main agricultural crops throughout the continent.

In response, a Soil and GIS Support Group was funded by the JRC and it began new work on a number of fundamental database projects, including

- a major update of the EC Soil Geographical Database (the digital version of the published EC Soil Map)
- the compilation of a soil profile analytical database
- development of a "pedotransfer" rules database (to allow the characteristics of soils to be derived from a series of other, known parameters, e.g. slope, soil name, land cover, etc.).

From the early 1990's and continuing up to the present, representatives within the ESBN of the national soil surveys of Europe have been concerned about a general decline in soil survey and monitoring in many EU member states. Among the initiatives to revive soil monitoring as an important research activity, was the creation of network of centres of excellence in soil hydrology under the EU Human Capital and Mobility Programme. One of the first products of this network was computation of pedotransfer functions for estimating the hydraulic properties of European soils.

In 1992, the Soil and GIS Support Group was renamed and became the Soils Information Focal Point (SIFP) with a work programme devised by a Soil Information System Development (SISD) Committee, under the chairmanship of the Institut National de la Recherche Agronomique (INRA) of Orleans, France.

At a meeting of the SIFP, held in Athens in 1996, the ESBN came into existence and the SISD evolved into the ESBN Scientific Committee. Starting in 2003 and in response to a new, European-level appreciation of the importance of soil resources, the ESBN has re-defined its aims and objectives so that it can make a full contribution to the development and implementation of the complete scope of soil management and protection within Europe. The ESBN has confirmed that as a network of the JRC it is a European organisation with a membership that does not represent single countries or national interests and whose principal interest is in the application of soil science in support of sustainable development throughout Europe. It is seeking to produce soil information for policy making in a reactive but also pro-active way, linking policy makers and soil scientists to improve reporting about soils in Europe. To support this aim it is developing close-working relationships with the European Environment Agency (EEA), in partnership with the JRC.

Soil Information Needs in Europe

The demand for soil information has been increasing rapidly in the last few years and continues to do so. This is driven by several factors that reflect the growing strategic importance that is attached to soil information. Some of the factors are

- the establishment of the EEA, and its European Topic Centre (ETC) on Soils, which has generated a need for a large amount of soil-related information
- a growing concern about the impacts of agriculture and other human activities on soils, and of associated economic costs, which has triggered a number of policies and regulations that need soil information for their implementation
- specific EU policies, including the Common Agricultural Policy, the Sixth Environmental Action Plan, the European Thematic Strategy for Soil Protection
- internationally binding agreements, such as the UN Convention to Combat Desertification (UNCCD), which calls for detailed soil information at a regional scale and specifically requests comparable soil information for the countries of the Mediterranean basin
- environmental disasters, such as landslides and flooding, which have highlighted the need for adequate soil information for disaster prevention.

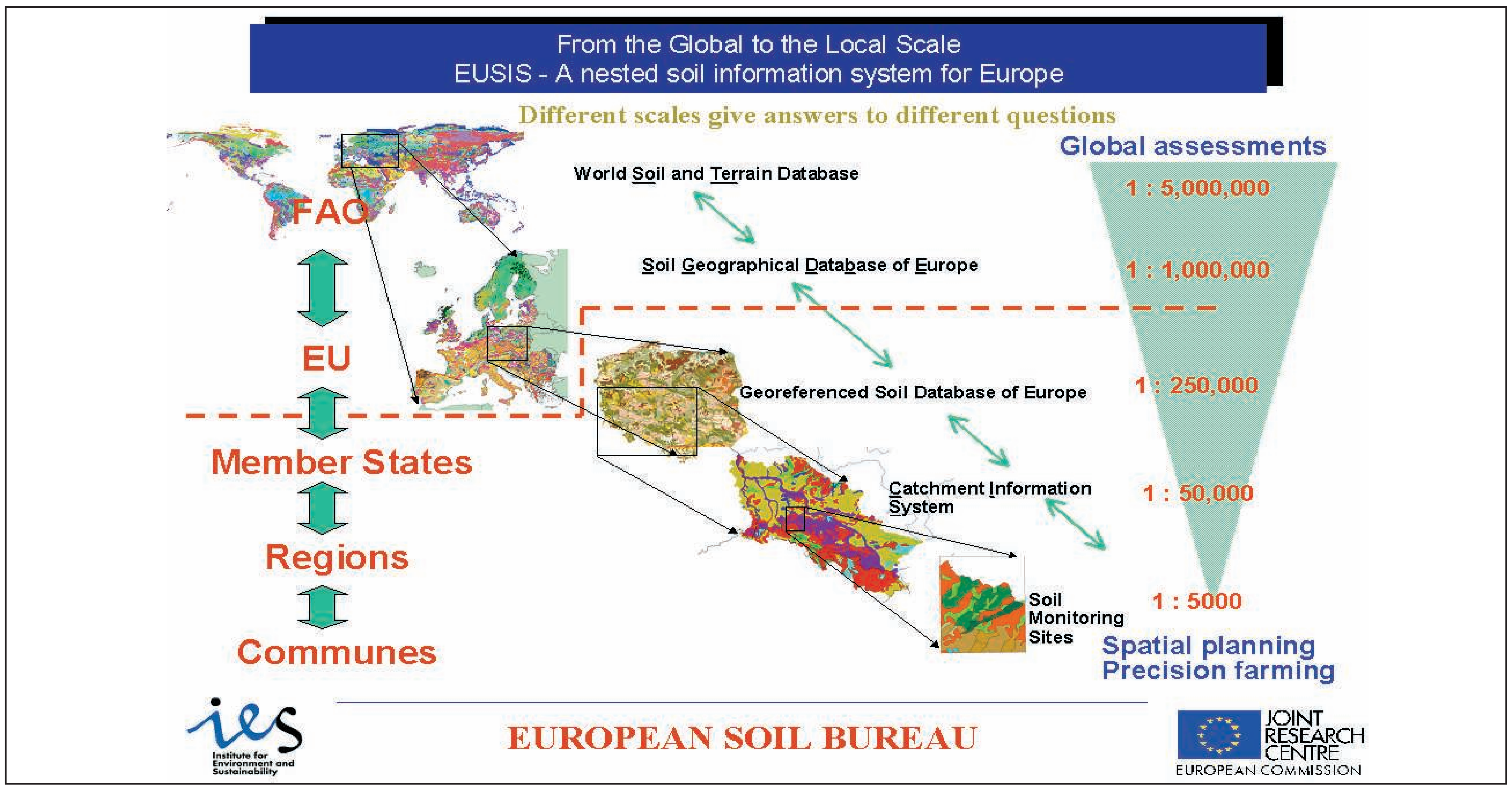
A meeting on 'Soil Protection Policies within the European Union' (Bonn, 9-11 December 1998) led to the so-called 'Bonn Memorandum', which called for a European Soil Forum of high-level officials and decision-makers to establish a 'common ground' for soil protection policies in Europe.

The publication in 2002 of the Communication 'Towards a thematic strategy for soil protection in Europe' marked a new phase in the development of soil policy for Europe. The European Commission initiated a major consultation process supported by an Advisory Forum and technical working groups, including one for soil monitoring. The ESBN and its membership contributed strongly to these initiatives and to the reports that were concluded in 2004.

Among the many, important conclusions of this extensive consultation process was an underlining of the need for better spatial information about soil properties and condition, based on a full appreciation of the great diversity and high variability of soils within Europe. To support tailored rather than "one size fits all" approaches to soil resource management within an integrated approach to natural resource protection, it is essential to have better spatial information about soils than is available currently at the European level, as well improved, finer-scale national-level information for management of soils within river-basins and smaller landscape units. ESBN is supporting initiatives by the JRC and the EEA to meet these strategic requirements.

Crops growing on a fertile Chernozem soil (EM).

European Soil Information System



A conceptual illustration of the nested European Soil Information System showing the inter-relationships between the different scales of soil data and needs (LM).

A European Soil Information System

Soil and land information systems vary across the countries. They range from essentially simple databases containing soil profile and analytical data to well developed and integrated computerised systems containing climate, land use and land ownership 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 the European Union countries are those of Austria, France, 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 digitized 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. 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.

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 least half of the EU and EFTA countries this is inadequate for decision making because less than 50 per cent of the area has sufficiently detailed soil maps.

EUSIS

The overall aim of the European Commission is that the soil database described and used in this Atlas will be fully integrated into a nested European Soil Information System (EUSIS), as portrayed in the above figure.

This nested system will be fully compatible with European soil data in the future and the World Soil and Terrain (SOTER) database of FAO, described earlier in the Atlas. At the same time, EUSIS will link up with the existing National and Regional soil information systems within the EU in order to address the needs of users of soil information at different scales. For example, estimating the impact of climate change will require generalised soil information at a global scale (e.g. 1:5,000,000 or smaller) while local planners utilise data at a much larger scale (e.g. 1:5,000 or 1:10,000) in order to have the detailed information required for spatial planning and precision farming applications.

INSPIRE

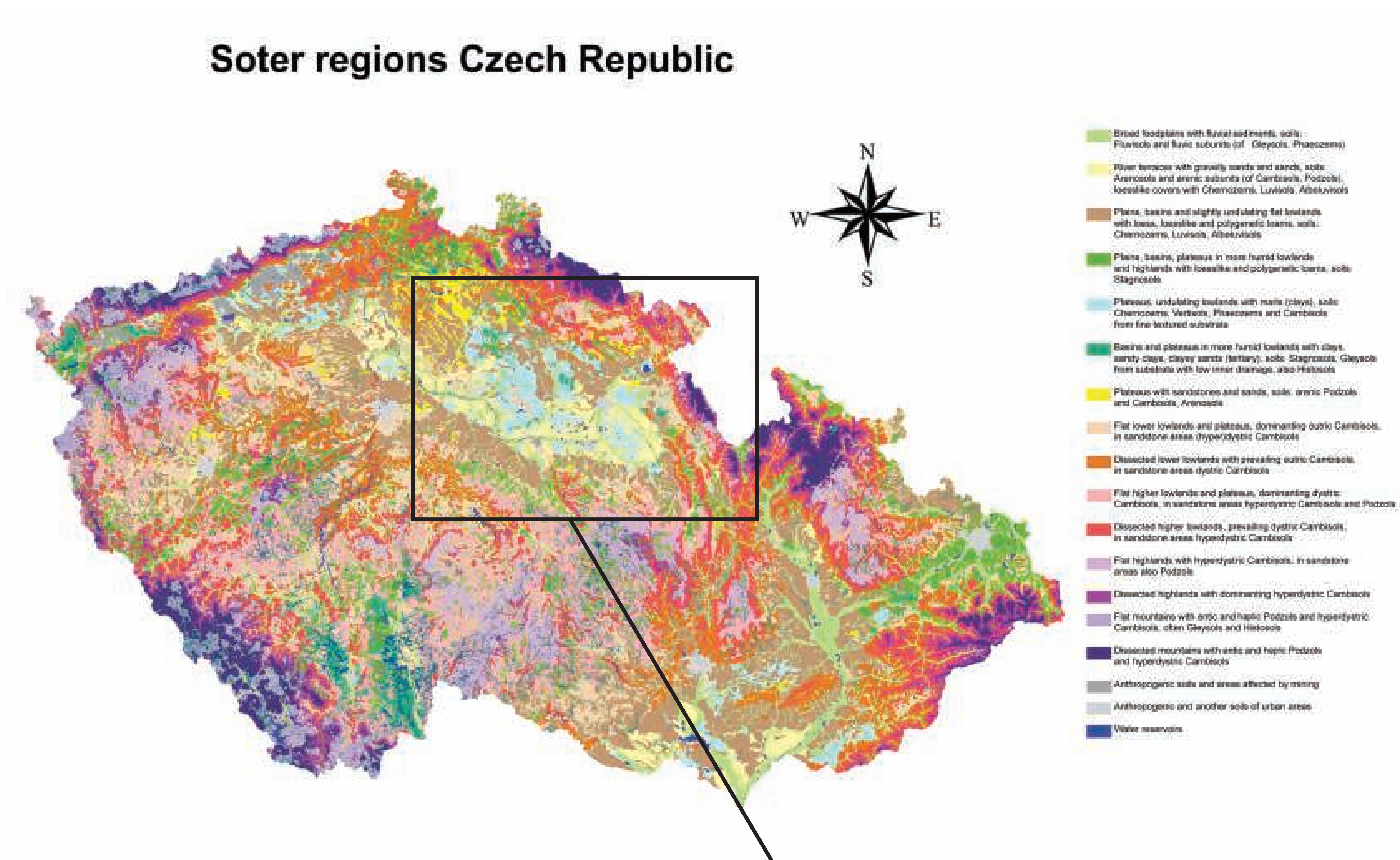
The general situation on spatial information in Europe is one of fragmentation of datasets and sources, gaps in availability, lack of harmonisation between datasets at different geographical scales and duplication of information collection. These problems make it difficult to identify, access and use data that is available. Fortunately, awareness is growing at national and at EU level about the need for quality geo-referenced information to support understanding of the complexity and interactions between human activities and environmental pressures and impacts

The EUSIS approach is designed to accommodate the guidelines set out by the European Commission to trigger the creation of a European spatial information infrastructure that delivers to the users integrated spatial information services. These services should allow the users to identify and access spatial or geographical information from a wide range of sources, from the local level to the global level, in an inter-operable way for a variety of uses.

This initiative is known as the INfrastructure for SPatial InfoRmation in Europe (INSPIRE). The INSPIRE initiative is therefore timely and relevant to soil data collection but also a major challenge given the general situation outlined above and the many stakeholder interests to be addressed. The key principles of INSPIRE are:

- Data should be collected once and maintained at the level where this can be done most effectively.
- Seamless spatial information from different sources across Europe should be combined and shared between many users and application.
- Information collected at one level should be available at different levels.
- Geographic information needed for good governance at all levels should be abundant under conditions that do not refrain its extensive use.
- Geographic information should be easily available
- Geographic data should become easy to understand and interpret.

Special attention is needed to ensure that land management or agricultural practices do not damage soils. This picture shows the unequal distribution of nitrogen fertilizer as illustrated by the dark and light green strips highlighting unequal crop growth and ploughing up and down the hill rather than across the slope to reduce erosion (EM).



(JK)

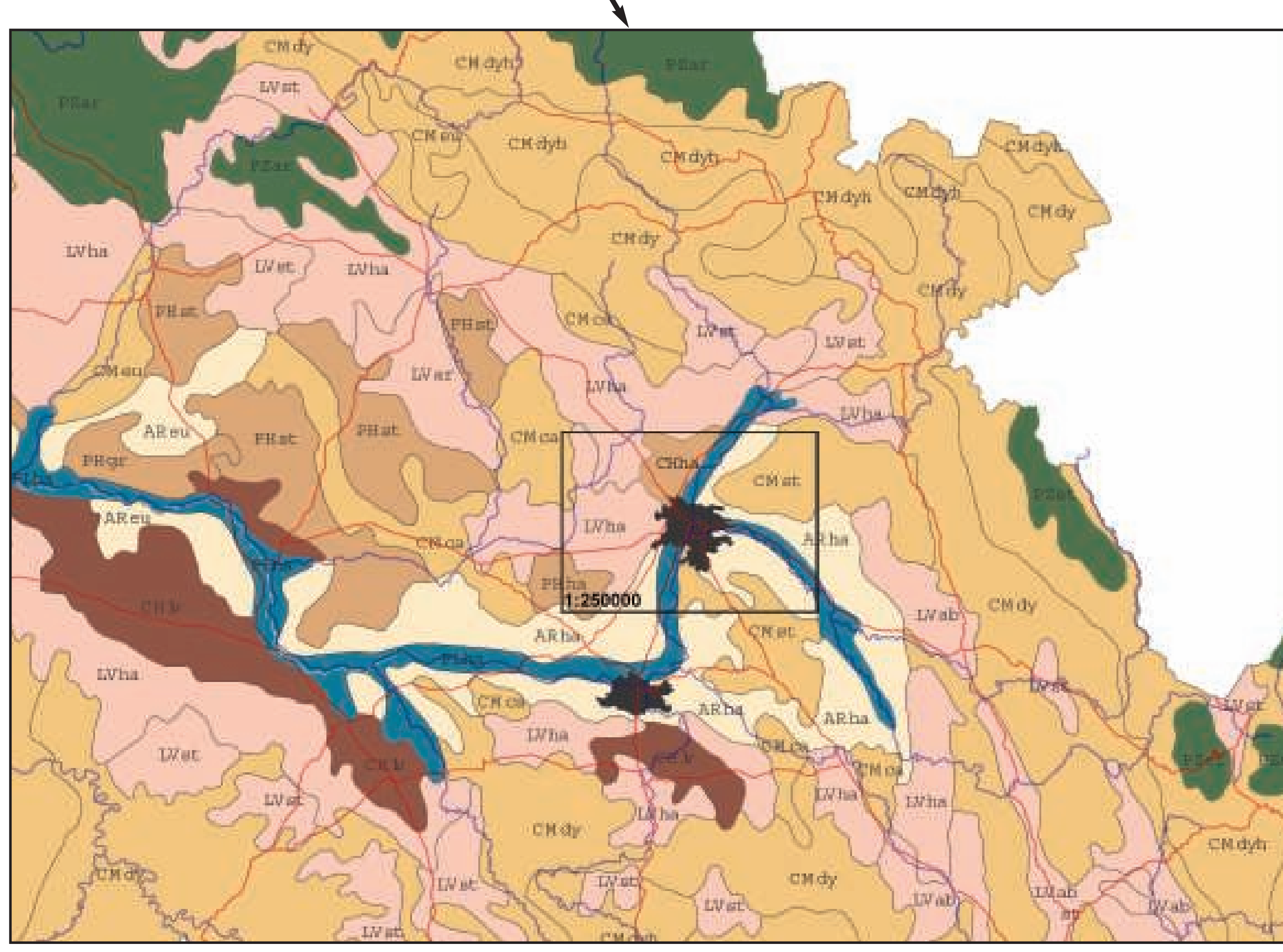
1 : 2 500 000

Examples of nested soil data

As explained in the previous pages, a key element of the European Soil Information System (EUSIS) within the INSPIRE initiative is concept of nested data. In simple terms this means that information at different map scales or resolution for the same location can be stored and accessed through EUSIS. One could imagine different map sheets laying one on top of the other.

The maps show soil units for the Czech Republic at a scale of 1:2,500,000 (**above**) with detail around the town of Haradec Králové at scales of 1:1,000,000 (**right**), 1:250,000 (**facing page top**) and 1:50,000 (**facing page bottom**).

By comparing the small-scale maps on this page with the more detailed maps on the facing page, the issue of cartographic generalisation of reality becomes strikingly obvious. Many of the patterns and soil types depicted on the 1:50,000 map cannot be identified at all on the 1:250,000 map. This means that the information collected at the base level or the largest scale must be simplified for displaying and use at regional or European level. Procedures must be developed to ensure that the boundaries between soil units can be redrawn accurately at different scales and that the smaller scale soil units are labelled or classified accurately in accordance with the information contained in the larger scale datasets (maps). One solution is to use a grid or cells to map the soil units at the larger scale. This grid can then be re-sized or resampled to generate coarser resolution data based on a statistical analysis of the finer cells that the larger cell occupies.



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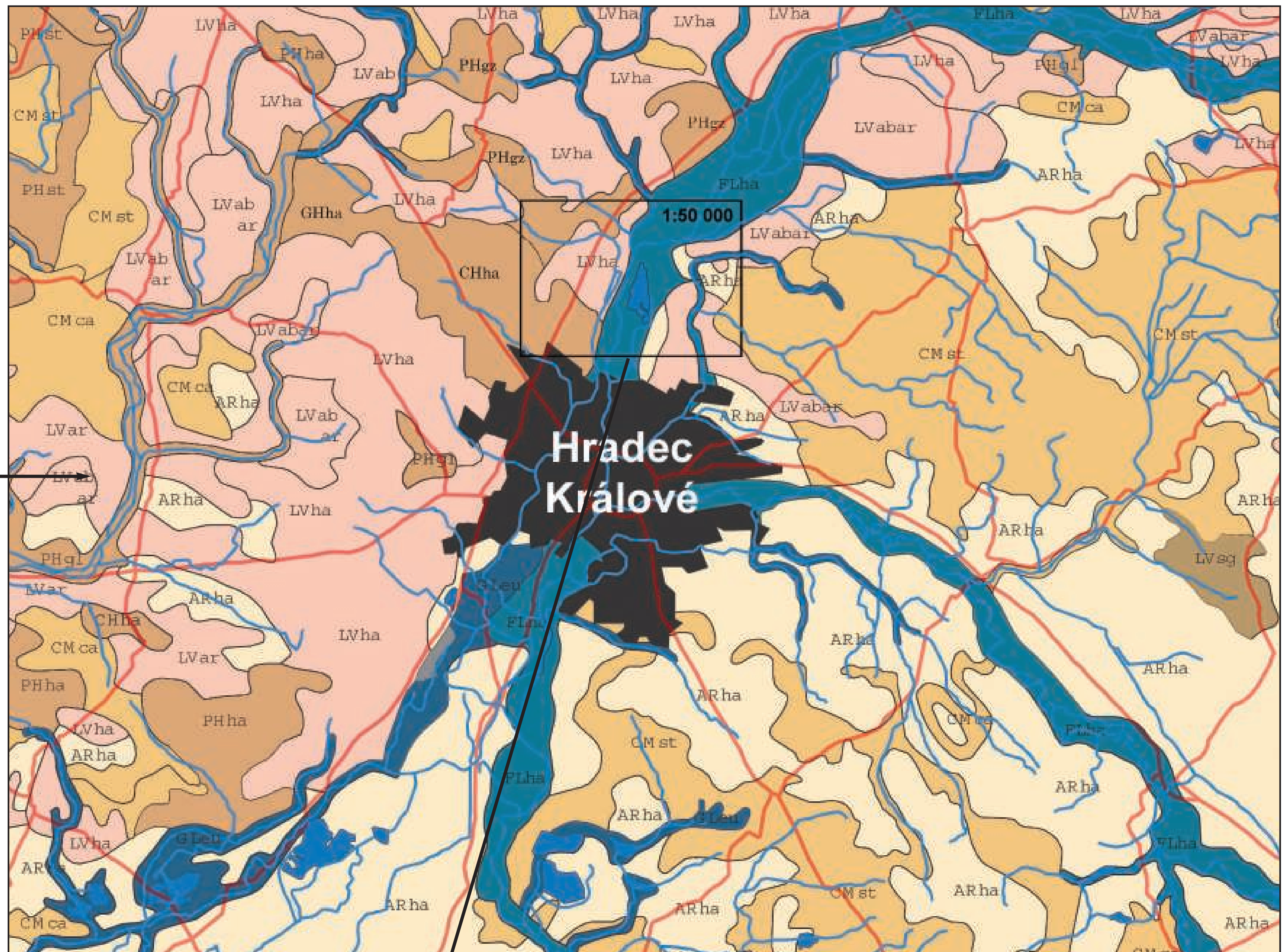
1 : 1 000 000

Nested soil data



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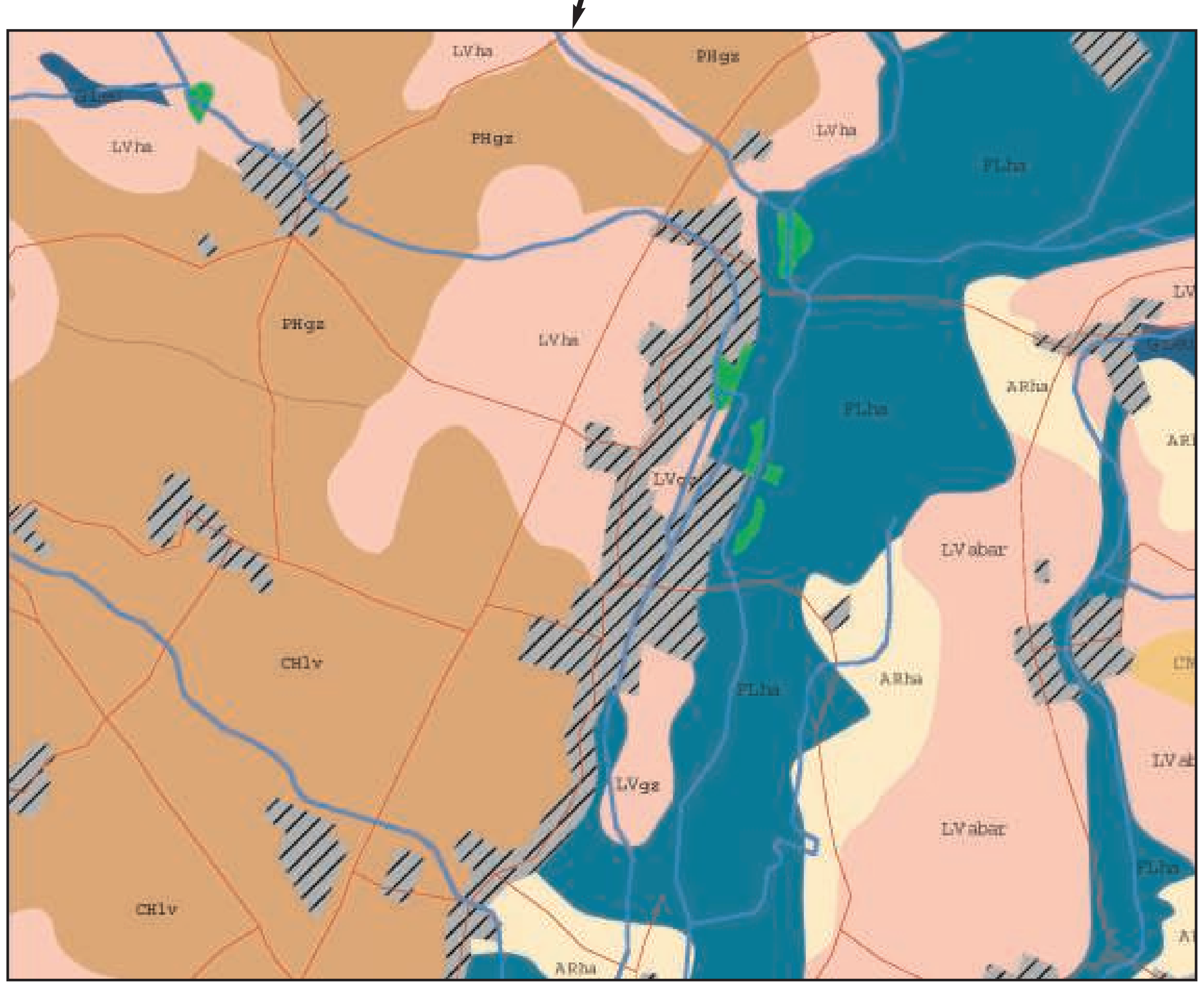

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1 : 50 000

Monitoring Changes in Soil Quality

Alongside soil maps and databases, monitoring the conditions of soil is now a vital component in the quest for information about the soils of a particular region or country. A monitoring programme 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.

Monitoring 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 the EU 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 by relating the monitored components to soil type. 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. It is particularly important that information collected is not isolated from all the other information about soils, their use and management.

Soil monitoring data will become a fundamental element of EUSIS.

Key threats to soil in Europe

Healthy soil is a fundamental and irreplaceable component of agricultural production. The demands of agriculture must be balanced by soil protection measures. This concept is known as sustainable agriculture. Good agricultural practices can maintain and even improve soil health, soil quality and soil biodiversity, combat soil erosion processes and protect human health (EM).

An example of poor land management practices. In this field, ploughing has been carried out up and down the slope rather than across the slope (a technique known as contour ploughing). As a result, the plough furrows act as rills or small gullies and facilitate the movement of soil down the slope when heavy rainfall occurs. The sediment is deposited as a fan-like feature at the end of the furrow (RJ).

Introduction

Key threats to soil in Europe

Maintaining soil condition is essential for ensuring the sustainability of society. However, soil is under increasing threat from a wide range of human activities. The threats are complex and although unevenly spread across Europe, their dimension is continental. For simplicity they are presented separately below. However, in reality they are frequently inter-linked. When many threats occur simultaneously, their combined effects tend to increase the problem. Ultimately, if not countered, soil will lose its capacity to carry out its functions. This process is known as soil degradation.

In the European Union, an estimated **52 million hectares, representing more than 16% of the total land area, are affected by some kind of degradation process.** In the new Member States this figure rises to 35%.

Soil degradation, when occurring in dry areas, is known as **desertification** which is caused by climatic conditions (droughts, aridity, irregular and intense precipitation regimes) and human activity (deforestation, overgrazing, soil structure deterioration). The affected land can no longer support vegetation. According to the UNEP World Atlas of Desertification areas under desertification risk include central and southeast Spain, central and southern Italy, southern France and Portugal and extensive areas of Greece. Worldwide desertification has extremely serious socio-economic consequences and can ultimately cause the destabilisation of societies and the migration of human populations.

Climate change presents an overarching but as yet uncertain factor linked to degradation processes.

In the communication of the European Commission to the Council and the European Parliament, entitled "Towards a Thematic Strategy for Soil Protection" (see Page 118), **eight main threats to soil** were defined.

- **Soil sealing** occurs mainly through the development of technical, social and economic infrastructures, especially in urban areas. In 1996, 43% of the area on the Italian coast, generally containing fertile soil, was completely built-up.
- **Erosion** is mainly due to the inadequate use of soil by agriculture and forestry, but also through building development and uncontrolled water runoff from roads and other sealed surfaces. In more than one third of the total land of the Mediterranean basin, average yearly soil losses can exceed 15 tons/ha.
- **Loss of organic matter** is mainly due to intensive use of the land by agriculture, especially when organic residues are not sufficiently produced or recycled to soil. Agronomists consider soil with less than 1.7% organic matter to be in pre-desertification stage.
- **Decline in biodiversity** is linked to the loss of organic matter, because biodiversity depends on organic matter, which means that all soil biota live on the basis of organic matter.
- **Contamination** can be diffuse (widespread) or localised and is due to many human activities, such as industrial production, traffic, etc., mainly through the use of fossil material, such as ores, oil, coal, salts and others, or due to agricultural activities.
- **Compaction** of soil is a rather new phenomenon caused mainly from high pressures on soil through heavy loads by vehicles in agricultural and forest land use. An estimated 4% of soil throughout Europe suffers from compaction.
- **Hydro-geological risks** are complex phenomena, resulting in floods and landslides deriving partly from uncontrolled soil and land uses (e.g. sealing, compaction and other adverse impacts) as well as uncontrolled mining activities.
- **Salinisation** is mainly a regional problem but in those areas where it occurs, such as the Mediterranean basin and Hungary, agricultural, forestry and the sustainable use of water resources are severely endangered. An estimated 1 million hectares in the EU are affected.

In a first approach, it is important to analyse these threats in two ways:

- to understand the driving forces behind them and the resulting pressures which lead to adverse effects on soil.
- to understand how the impacts of these threats negatively influencing the functions of soils for humankind and the environment.

Issues to consider include the protection of open water and ground water, control of air contamination and pollution, protection of the food chain through biomass production, protection of human health in the case of direct contact with soil and finally the maintenance of biodiversity of the soil, which is as important as the biodiversity on the earth surface.

The analysis of the impacts arising from the threats is an absolute prerequisite for the development of operational procedures or responses for the mitigation of these threats.

Regarding the state of the different threats in Europe, in many cases there is not enough information available about their spatial distribution and their changes with time. One of the important tasks facing soil scientists in Europe will be to create a soil monitoring system to provide detailed information about the development of these key threats in Europe.

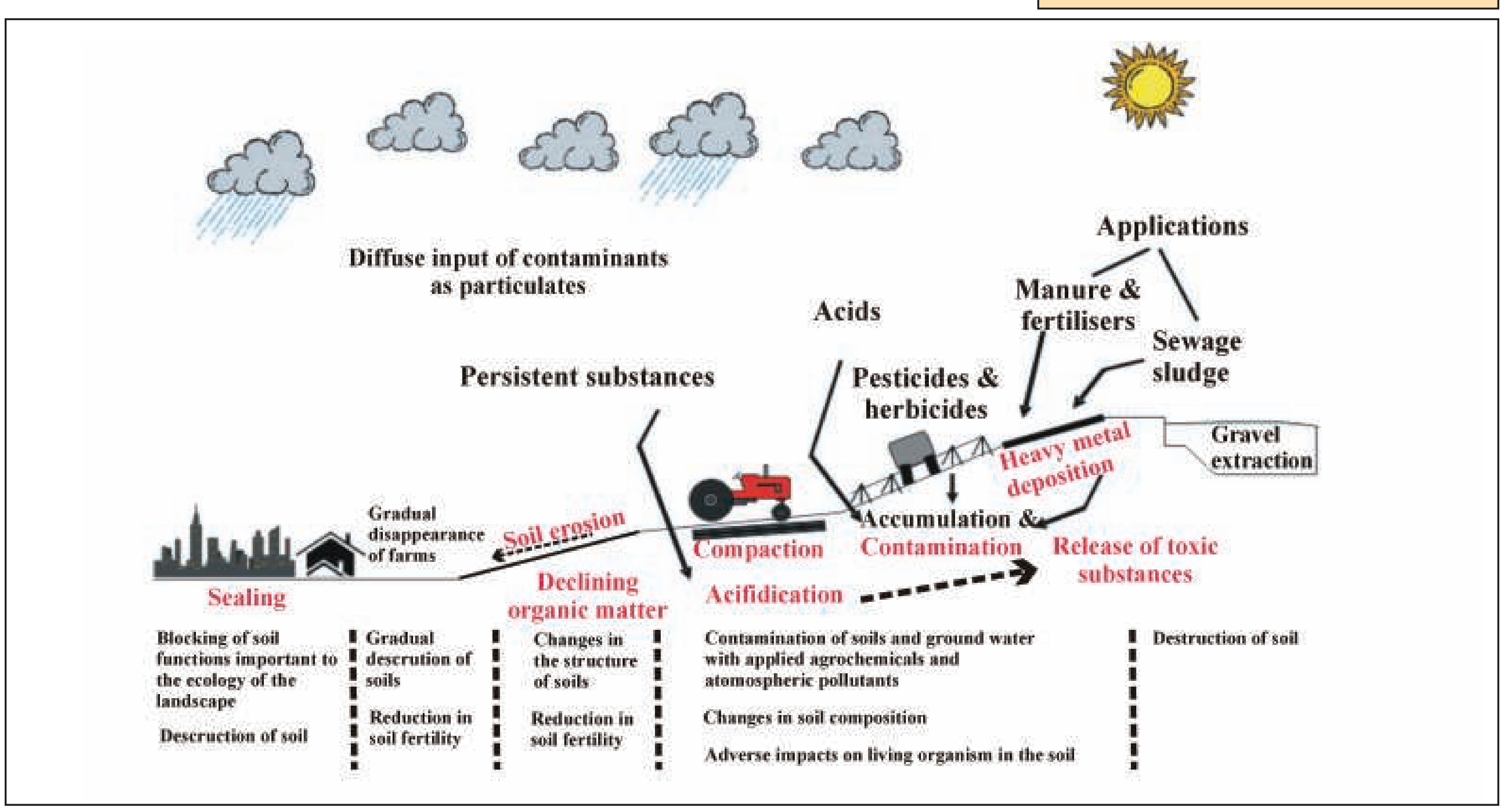
Relating the main threats to driving forces and pressures, through cross-linking with European and national strategies reveals that many agricultural, regional planning, environmental protection, transport, energy development, single market and other policies may have an important influence, because they are partly triggering or inducing threats.

Analysing the impacts of threats by relating them to important soil functions reveals that erosion can be correlated with air pollution, water pollution, decline in biomass production, endangering of human health and decline in biodiversity.

In the following pages, the cause and implications of the eight main threats are explained.

Threats to soil in the New Member States and Candidate Countries are essentially similar to those in the European Union.

- The average degree of soil sealing in parts of Germany between 1999 and 2001 was 5.3 hectares (seven football fields) per day. Analysis of the CORINE Land Cover 2000 dataset indicates that due to economic growth, soil sealing is a significant and increasing issue in the New Member States.
- The extensive floods that affected the Czech Republic in August 2002 caused more than 220 000 inhabitants to be evacuated and caused an estimated 2.7 billion Euros of damages (Ministry of Environment, Czech Republic).
- **Erosion** is a major environmental issue, although there are significant differences between countries regarding its extent and intensity. Areas affected range from 5% to 39% of the total surface.
- The European Environment Agency estimates the number of contaminated sites within the European Union to be between 300,000 and 1.5 Million depending on the definition taken. **Local contamination** associated with the 3000 former military facilities constitutes a major problem not yet fully evaluated.
- Several forms of **diffuse contamination** have been reported. Acidification is affecting about 35% of Poland, Hungary and Lithuania. Many parts of Lithuania have high levels of Barium but this may be strongly influenced by extremely high natural background concentrations.
- **Soil compaction** is widespread particularly in Bulgaria.
- In Hungary 8% of the territory is affected by **salinisation**, mostly of natural origin. In the other candidates countries it does not appear to be a major problem.



The process and inter-relationships of soil degradation. Decline in organic matter may cause erosion, facilitate compaction, decrease water infiltration and increase the danger of floods and landslides (RJ).

SOIL SEALING is the loss of soil resources due to the covering of land for housing, roads or other construction work.

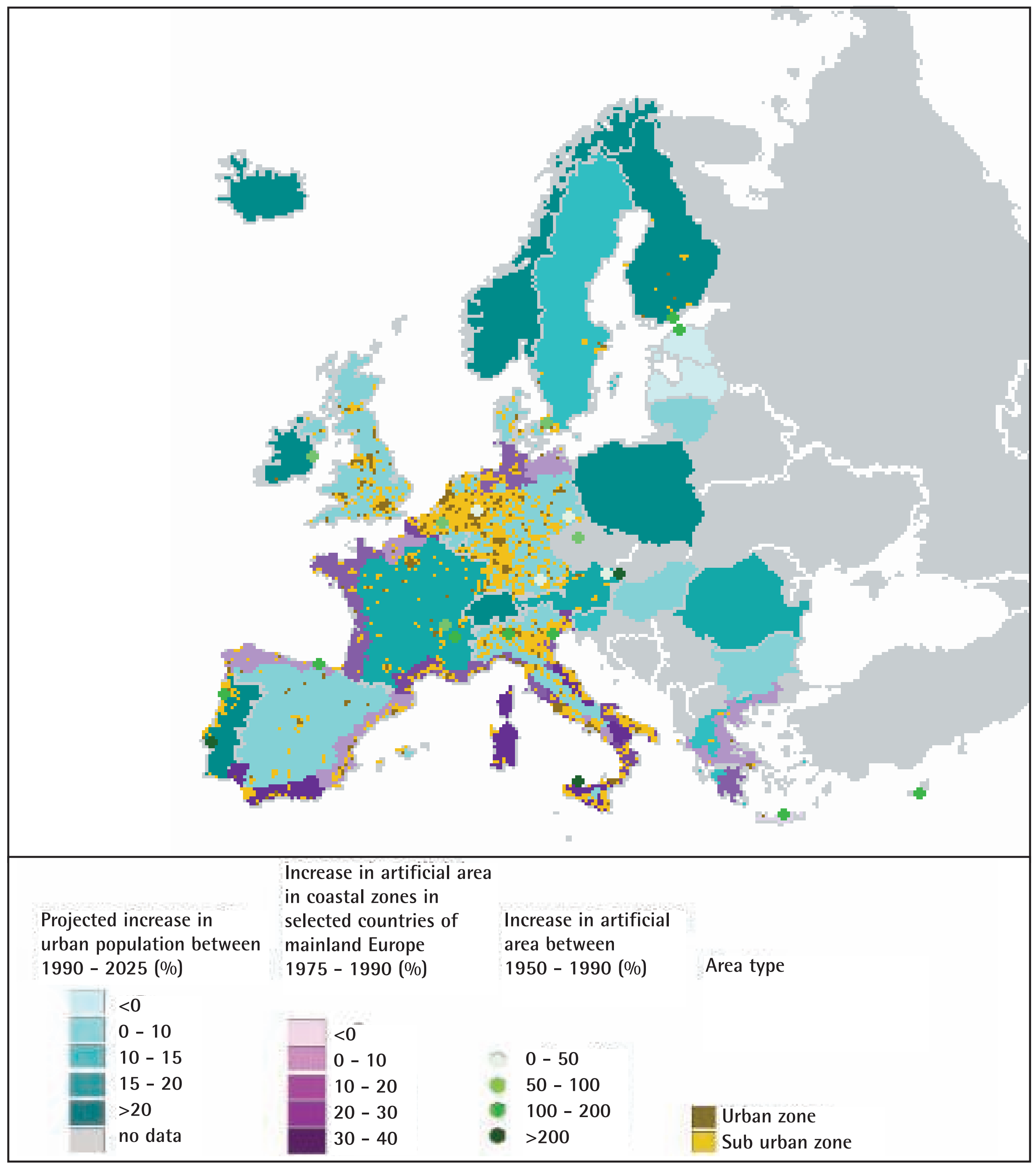
The building of new roads, houses, shops offices work seals off soil (ED).

The covering of the soil surface with impervious materials as a result of urban development and infrastructure construction is known as soil sealing. The term is also used to describe a change in the nature of the soil leading to impermeability (e.g. compaction by agricultural machinery). Sealed areas are lost to uses such as agriculture or forestry while the ecological soil functions are severely impaired or even prevented (e.g. soil working as a buffer and filter system or as a carbon sink). In addition, surrounding soils may be influenced by change in water flow patterns or the fragmentation of habitats. Current studies suggest that soil sealing is nearly irreversible.

The greatest impacts of soil sealing are observable in urban and metropolitan areas. The **Figures right** illustrate the areas in Europe where the rates of soil sealing are high and where the greatest pressures are likely to occur. In already intensively urbanised countries like Holland or Germany the rate of soil loss due to surface sealing is high. There is little space for further urbanisation. Most of the growth will presumably take place within or on the edge of the suburban areas. In the Mediterranean region, soil sealing is a particular problem along the coasts where rapid urbanisation is associated with the expansion of tourism. Very high rates of sealing are now predicted for countries like Portugal, Finland or Ireland where urbanisation levels are generally low.

In Central and Eastern Europe soil sealing has been comparatively modest in the past decades. An accelerated increase of built-up areas can be recorded as a consequence of the political and economic changes during the late 1980s. Rural populations migrated to the cities and new settlements were developed. Rising pressures on soil can be expected in the course of a strengthened economic growth in these countries. Generally the enlargement of the EU and the integration of new countries in the common market will lead to a heightened movement of people and transport of goods. More infrastructure will be built in order to ensure a good connection between peripheral regions and the centre.

Built-up areas have been mainly enlarged at the expense of agricultural land. Progressive soil sealing will take place especially for Western Europe where the area of built-up land increases at a faster rate than the population. Besides the influence of tourism, the rising demand for land resources can be mainly caused by changes in population behaviour such as people's preference for living outside the city centres, an increased demand for bigger houses or out-of-town developments such as supermarkets, leisure centres and associated development of transport infrastructure.



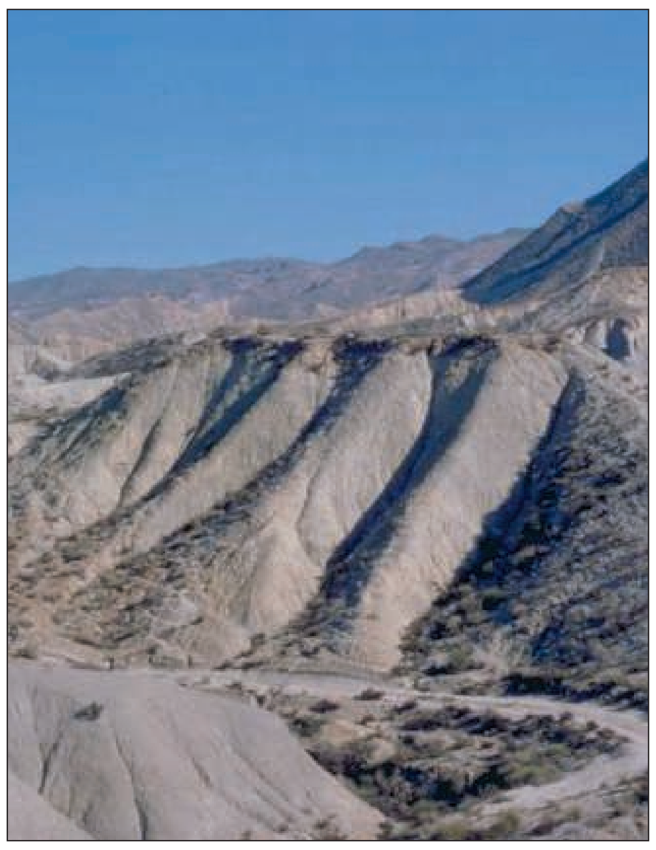
Probable problem areas of soil sealing in Europe (Source European Environment Agency)

Spatial planning strategies determine to a great extent the progression of soil sealing. Unfortunately neither the economical nor the ecological or the social effects of irreplaceable soil losses have been considered adequately so far. In the meantime the necessity to include environmental concerns and objectives in spatial planning, in order to reduce the effects of uncontrolled urban expansion, is widely recognised in the EU. A rational land-use planning to enable the sustainable management of soil resources and the limiting of sealing of open space is demanded. Possible measures include the redevelopment of brown-fields and the rehabilitation of old buildings.

This image was taken by the U.S. Air Force Defence Meteorological Satellite Program from about 800 km above the Earth's surface at approximately midnight local time. The detector in the satellite is sensitive to city lights. This picture clearly shows the extent of urbanisation throughout Europe and is a good indication where the pressures of soil sealing are at their greatest (NOAA).

Erosion

EROSION is a physical phenomenon that results in the removal of soil and rock particles by water, wind, ice and gravity.



Severe gully erosion in Spain (JI).

Erosion is a natural process, occurring over geological timescales, that has been largely responsible for shaping the physical landscape we see around us today. The action of rain, wind, ice (in the form of glaciers) and temperature (by freezing and thawing) wear down and shatter rock surfaces. Subsequently, geomorphic processes have distributed the weathered materials, produced by these agents, over the surface of the Earth. For millions of years, erosion has transformed the landscape, wearing down mountain and upland areas whilst sedimentation has filled in continental basins with the resulting debris. Thus erosion is a process that is essential for soil and landscape formation and has taken place since time began.

Most present-day concerns about soil erosion, leading to its perception as a process of degradation, are related to accelerated erosion, where the natural rate has been significantly increased by human activities. These activities include the stripping of natural vegetation especially clearing of forests for cultivation, changing land cover in other ways through cultivation, grazing, controlled burning or wildfires, levelling of the land surface, and varying the intensity of land management, for example through poor maintenance of terrace structures and cultivation of steep slopes. The resulting changes to the soil cover allow natural forces to remove soil particles much more rapidly than normal soil-forming processes can replace them, hence the term *accelerated erosion*. Soil losses > 2 t/ha/yr are considered by experts in many parts of the world to be irreversible within a timescale of 50-100 years.

Soil erosion is regarded as one of the most widespread forms of soil degradation, and as such, poses potentially severe limitations to sustainable land use in Europe. Soil can be eroded away by water and wind. Erosion by water occurs due to the energy of water when it falls to the earth and flows over its surface. Strong wind, depending on its strength and duration (persistence), can blow away loose soil from flat or undulating terrain. Soil erosion by water is a widespread problem throughout Europe and the main processes are rain-splash, rain-wash, rill-wash and sheet-wash. Whilst these processes are often localised they produce distinct features such as rills, gullies and, in extreme cases, badlands. There are other forms of water erosion, for example snowmelt erosion in northern Europe which can also produce surface features such as rills and gullies, and bank erosion where streams, rivers and lake waters wash bank material into suspension to be carried downstream, or away from the shore, until the velocity of flow or movement diminishes sufficiently for deposition to take place. Several other types of soil erosion have been recognised and studied by researchers. For example, wind erosion occurs in areas where soil is dominantly sandy or silty, dry and not stabilised by plant roots; cultivation, levelling of land for example to create terraces, trampling by animals destroying surface cover and soil removal by harvesting of root crops cause further losses of soil.

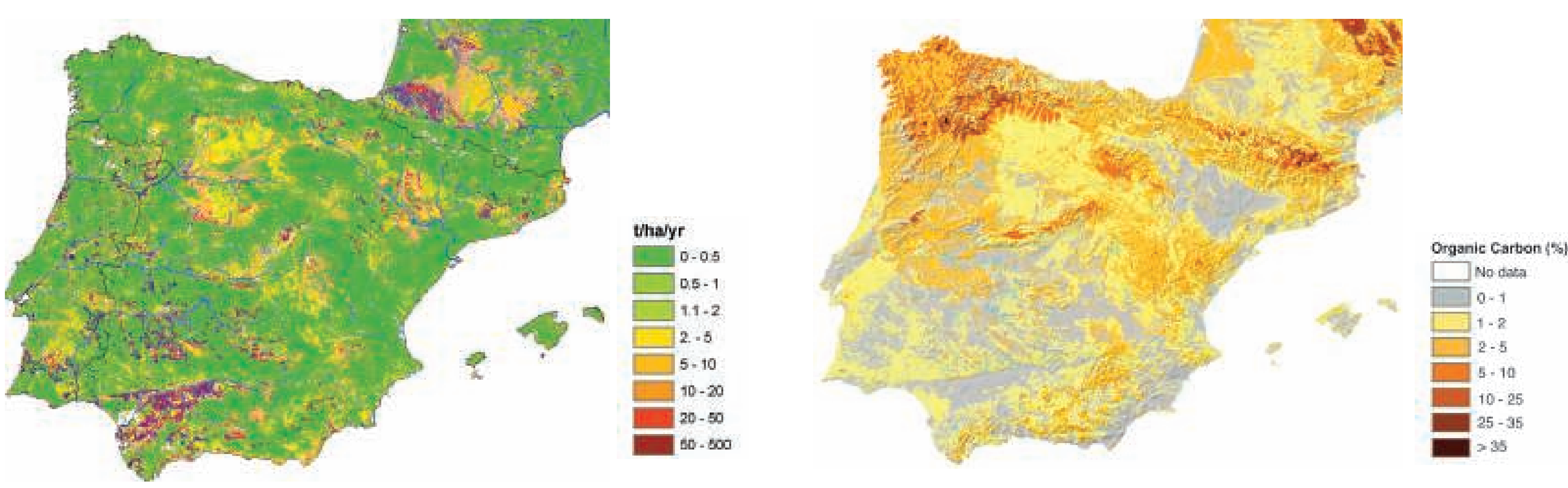
The most dominant effect is the loss of topsoil, which may not be conspicuous but nevertheless potentially very damaging. If soil loss by these various forms of accelerated erosion is to be reduced or eliminated, the amounts of soil removed must be quantified and this requires a different approach for each type of erosion. On-site measurements can quantify soil loss at the field scale and accumulation in reservoirs can reveal the amount of sediment removed within individual catchments or basins. Lakes and reservoirs act as large sediment traps and sedimentation rates can provide valuable comparisons between environments. However, complications arise because soil loss in one part of a catchment or basin can lead to deposition (sediment yield) in another part. Not all the material eroded on a hillslope will arrive at the outfall of the catchment or accumulates in reservoirs, a significant part may remain in intermediate storage on slopes, in alluvial fans, as colluvium along foot-slopes and as outwash on plains.

Climate, topography and soil characteristics are important physical factors affecting the amount of erosion. The Mediterranean region is particularly prone to accelerated soil erosion because it is subject to long dry periods, followed by heavy bursts of erosive rain, falling on steep slopes often with shallow soil low in organic matter. The introduction of agriculture and grazing during Neolithic times (6000-8000 years ago), in and around the Mediterranean Basin, marked the start of progressive forest clearance which has continued until the present day. A well known example of one of the effects of this is the Ebro Delta, the growth of which is linked to deforestation and expanding agricultural activities that took place between the Middle Ages and the 19th century. In parts of the Mediterranean region, erosion has reached a stage of irreversibility such that, in some places, erosion has practically ceased because there is no more soil left. This contrasts with NW Europe where there is less loss of soil, because rain falls mainly on gentle slopes and is more evenly distributed throughout the year than in the south. Consequently the area affected by erosion is less extensive than in southern Europe. However, erosion is still a serious problem, particularly off-site, in northwest and central Europe, and is on the increase largely as a result of sheet erosion on bare soil surfaces, the area of which has increased significantly in Europe since the Second World War.

Erosion causing a 1m deep rill in the Severn Valley UK, January 2001 (PNO).

There are very few sites in Europe where soil erosion has been or is still being monitored but the measurements of soil loss that do exist show average rates varying from less than 0.5 to more than 200t/ha/yr. The highest losses, sometimes as high as 500 t/ha/yr, have been measured following single storm events of short duration but with heavy rain falling on bare soil surfaces. Erosion literature commonly identifies 'tolerable' rates of soil erosion, but these usually exceed the rates that can be balanced by natural weathering of parent materials to form new soil particles.

Soil loss in some places may be considered acceptable from an economic standpoint but some modern cultivation methods are causing overall erosion rates that are becoming increasingly unacceptable from a long-term point of view. Two examples of this are the use of herbicides to kill the vegetation on the ground in olive groves and vineyards, thus reducing competition for water and nutrients, and cereal cultivation on hilly land previously in pasture for stock rearing. Both these systems currently receive financial support from the European Common Agricultural Policy yet are visibly degrading the land. It is clear that on some productive land there is an overall loss of soil material that is becoming irreversible. By contrast, there are some ancient farming systems that have proved to be sustainable over a long period, for example the dehesas in Spain, the *montados* in Portugal and the bocage in France. Unfortunately, these systems tend to be labour intensive and mainly practised by the older people in rural communities.



*The **above** maps show the relationship between erosion and organic matter levels in soil. The map on the **left** shows estimated soil erosion rates for Spain, Portugal and southwestern France **(see Page 102)**. Areas with very low erosion rates are indicated in green while high-risk zones are red or purple. The map clearly highlights the problems of soil erosion in Andalucia, along the Tajo Valley and just north of the Pyrenees. The map on the **right** shows the levels of organic carbon in the topsoil. Note the close correspondence between the areas of low organic carbon (shown in grey) and the high risk of erosion (RJ).*

LOSS OF ORGANIC MATTER. An imbalance between the build-up of soil organic matter and rates of decomposition is leading to a decline in soil organic matter contents in many parts of Europe.

A Histosol, a soil rich in organic matter. Most mineral soil contains less than 10% organic matter (6% organic carbon) in the topsoil (EM).

The presence of organic matter is extremely important in all soil processes, acting as a storehouse for nutrients and a source of soil fertility, contributing to soil aeration, thereby reducing soil compaction, and ensuring good structure. Other benefits are related to the improvement of infiltration rates and the increase in storage capacity for water. Furthermore, organic matter serves as a buffer against rapid changes in soil pH and it acts as an energy source for soil micro-organisms.

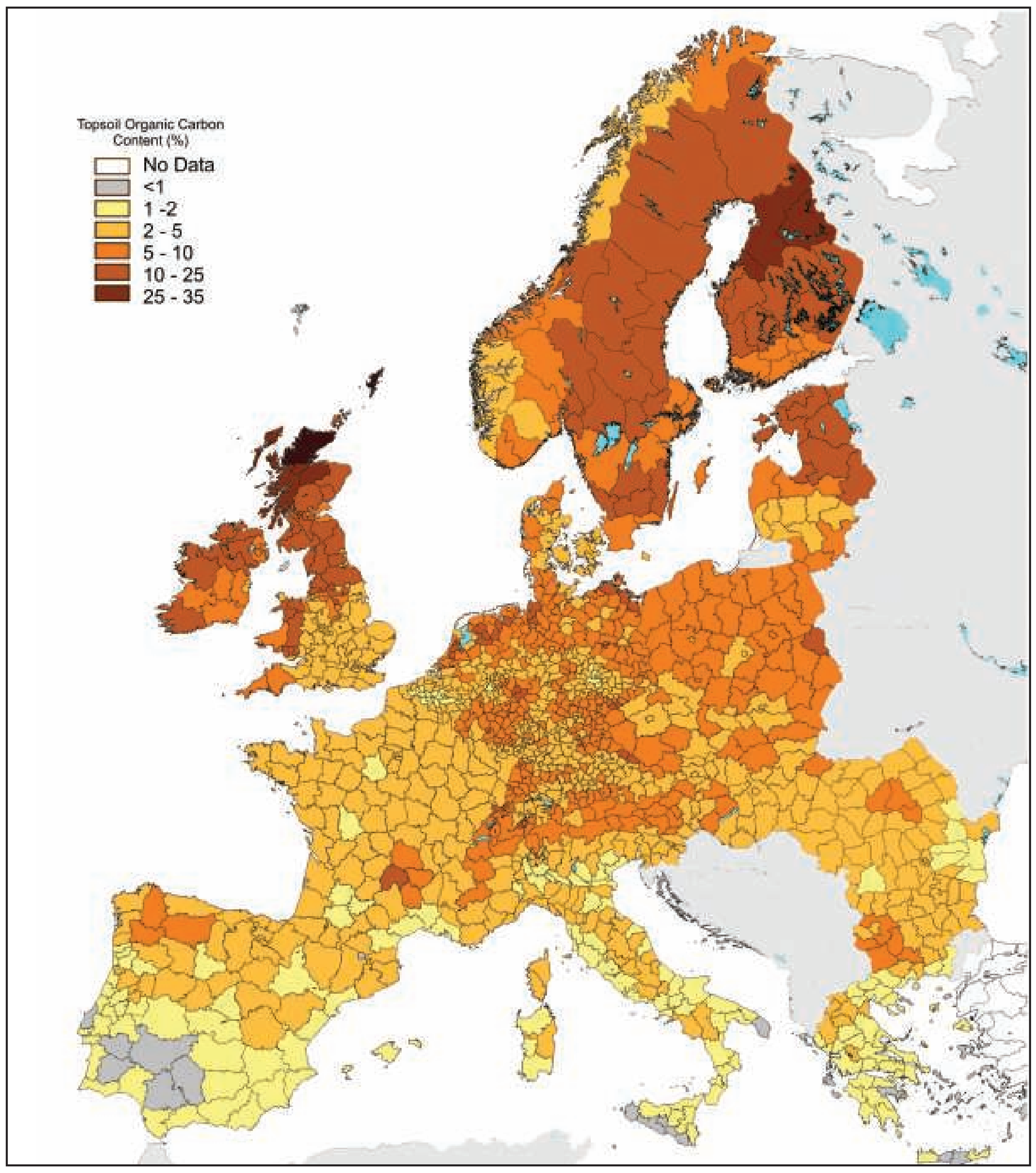
The amount of organic matter stored in soil is thus of great importance and, in the past few years, there has been increasing concern about declining levels leading to increased soil degradation (loss of structure and fertility), erosion and desertification. There are two groups of factors that influence the inherent levels of soil organic matter content: natural factors (climate, soil parent material, land cover and/or vegetation and topography) and anthropogenic or human-induced factors (land use, management and degradation).

Concerning climate, within belts of uniform moisture conditions and comparable vegetation, the average amount of organic matter increases by two to three times for each 10 deg C decrease in temperature, because decomposition rates reduce as temperatures decline. In general, organic matter increases as the effective soil moisture becomes greater, poorly drained soils generally having much higher organic matter contents than their better-drained equivalents. This is because decomposition of organic matter requires oxygen and this is in short supply in waterlogged soils.

A sandy soil usually contains less organic matter than a soil of finer texture, e.g. heavy loam or clay. This is because oxygen is required for decomposition of organic matter and poorly drained soils have low oxygen contents and fine textured soils are generally poorly aerated.

There are several factors responsible for the decline in soil organic matter and many of them stem from human activity:

- Conversion of grassland, forests and natural vegetation to arable land;
- Deep ploughing of arable soils causing rapid mineralisation of organic matter:
- Overgrazing;
- Soil erosion;
- Forest fires.



The map above shows the distribution of soil organic carbon, a major component of organic matter, according to administrative units; it emphasises the generally low levels in southern Europe compared to the north (RH).

In essentially warm and dry areas like Southern Europe, depletion of organic matter can be rapid because the processes of decomposition are accelerated by high temperatures. Some areas in southern Spain for example have experienced serious depletion of organic matter through changing land use and recently adopted management practices. It is clear that human occupation over the past 5000 years in this part of Europe gives us an idea of how other parts of the continent could be affected in the future.

This is an area east of Sevilla where olive cultivation has become almost a monoculture. The removal of soil and hence organic matter from the soil upslope is clearly visible (white area), the topsoil becoming browner lower down (RJ).

Degradation of peat soil in the Netherlands

There is evidence to suggest that the organic matter content of soils in Europe is decreasing, in some cases at an alarming rate.

- In Roman times, 45% of the Netherlands was covered by peat. Today, the figure is around 8%, most of which is used as pasture.
- In the 1970's the area of peat was about 290,000 ha. In recent years, water levels in ditches in the peat areas has been lowered to 60 cm – 120 cm below the surface (compared to originally 20-30 cm), which resulted in an increased oxidation of the peat and an average subsidence of the soil of 1 cm per year.
- Nowadays, the area of peat soil is about 220,000 ha. Thus, over the last thirty-five years, 70,000 ha of peat soil has degraded to an other soil type.
- A subsidence of 1 – 2 cm per year equals to 14 tons of peat per hectare (ha) per year. The oxidation of 1 cm per year results in a production of 22.6 tons/ha/year of CO_2.
- In the Netherlands the CO_2 emission of peat soil is about 3% of the national CO_2 production (in 1990). In a country like Norway the production of CO_2 from peat in agricultural use is higher than the production of CO_2 by the traffic.

Organic or mineral?

Soil scientists often use the term "*mineral soils*" to describe soils composed predominantly of mineral material which are low in organic matter or humus content. The soil profile below the A horizon is normally all mineral soil. A mineral is a natural crystalline inorganic substance. Silica is a mineral but coal is not because it is derived from organic material (i.e. plants).

DECLINE IN SOIL BIODIVERSITY is the reduction of forms of life living in soils, both in terms of quantity and in variety.

Soil contains a huge variety of life ranging from microbes, worms and insects to mammals. This picture illustrates the diversity within soil mites (DW).

The nature of soil biodiversity

Soil biodiversity is a term used to describe the variety of life below-ground. The concept is conventionally used in a genetic sense and denotes the number of distinct species (richness) and their proportional abundance (evenness) present in a system, but may be extended to encompass phenotypic (expressed), functional, structural or trophic diversity. The total biomass below-ground generally equals or exceeds that above-ground, whilst the biodiversity in the soil always exceeds that on the associated surface by orders of magnitude, particularly at the microbial scale. A handful of grassland soil will typically support tens of thousands of genetically distinct prokaryotes (bacteria, archaea) and hundreds of eukaryotic species across many taxonomic groups.

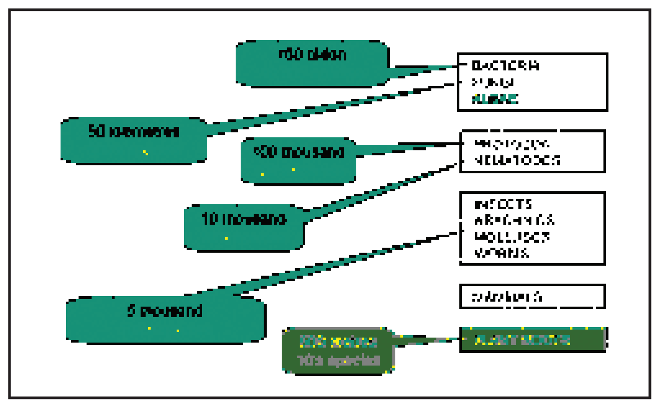
The soil biota plays many fundamental roles in delivering key ecosystem goods and services, and is both directly and indirectly responsible for carrying out many important functions (see Boxes).

> **Ecosystems goods and services provided by soil biota**
>
> Goods:
> - food production
> - fibre production
> - provision of secondary compounds (e.g. pharmaceuticals / agrochemicals)
>
> Services:
> - driving nutrient cycling
> - regulation of water flow and storage
> - regulation of soil and sediment movement
> - regulation of other biota (including pests and diseases)
> - detoxification of xenobiotics and pollutants
> - regulation of atmospheric composition

The value of soil biodiversity

Soil biodiversity carries a range of values that depend on the perspective from which they are being considered. These include:

- **Functional** value, relating to the natural services that the soil biota provides, the associated preservation of ecosystem structure and integrity, and ultimately the functioning of the planetary system via connections with the atmosphere and hydrosphere
- **Utilitarian** ("direct use") value, which covers the commercial and subsistence benefits of soil organisms to humankind.
- **Intrinsic** ("non-use") value, which comprises social, aesthetic, cultural and ethical benefits
- **Bequest** ("serependic") value, relating to future but as yet unknown value of biodiversity to future planetary function or generations of humankind.



Approximate number and diversity of organisms typically found in a handful of temperate grassland soil (KR & JJIM).

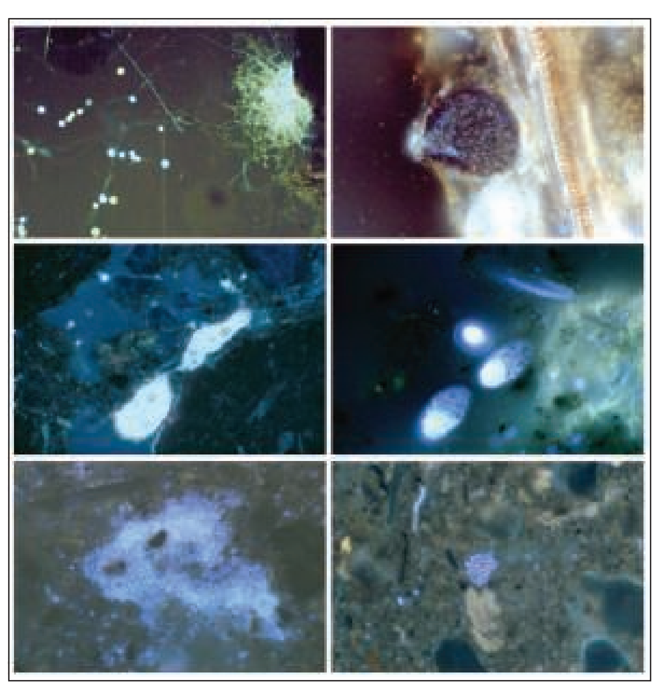
The ecological value of soil biodiversity is increasingly appreciated as we understand more about its origins and consequences. The monetary value of ecosystem goods and services provided by soils and their associated terrestrial systems, an entirely human construct which assists putting their significance into an economic context, was estimated in 1997 to be thirteen trillion US dollars ($13 x 1012). The soil biota underwrites much of this value.

Threats to soil biodiversity

A healthy soil biota needs an appropriate habitat. In soil, this is essentially the space denoted by the complex architecture of the pore network, and the associated supply and dynamics of gases, water, solutes and substrates that this framework supports. Hence threats to soil such as erosion, contamination, salinisation and sealing all serve to threaten soil biodiversity by compromising or destroying the habitat of the soil biota. Management practices that reduce the deposition or persistence of organic matter in soils, or bypass biologically-mediated nutrient cycling also tend to reduce the size and complexity of soil communities. It is however notable that even polluted or severely disturbed soils still support relatively high levels of microbial diversity at least. Specific groups may be more susceptible to certain pollutants or stresses than others, for example nitrogen-fixing bacteria that are symbiotic to legumes are particularly sensitive to copper; colonial ants tend not to prevail in frequently-tilled soils due to the repeated disruption of their nests; soil mites are a generally very robust group.

Consequences of soil biodiversity

The relationships between biodiversity and function are complex and somewhat poorly understood, even in above-ground situations. The exceptional complexity of below-ground communities further confounds our understanding of soil systems. Three important mechanisms underlying relationships between biodiversity and function are:



Some examples of the major groups of the microbial soil biota visualised in situ in arable soil. From top left: Fungus (filamentous hyphae and spores); fungus (spore-bearing perithecium in decomposing root); protozoa (naked amoeba); protozoa (testate amoebae); bacteria (large colony in vicinity of food source); bacteria (small colony isolated in soil matrix). As well as great species diversity, the physical form that soil organisms take is also extremely diverse, from long filaments, to naked cytoplasm, through silica-encased cells to minute single cells ñ the bacteria in the bottom image are 1 µm in diameter [KR].

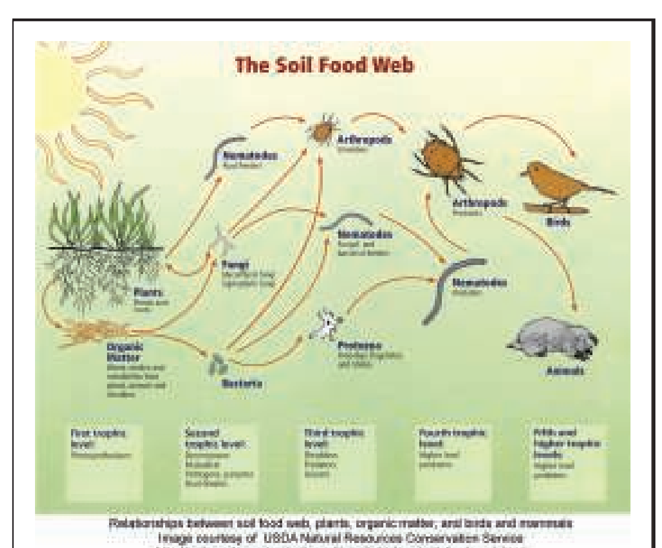
> **Key functions performed by soil biota**
>
> These map onto the 'goods and services' roles and are many and varied. Some of the most significant functions, and the main biotic groups that carry them out are:
> - Primary production [plants, cyanobacteria, algae]
> - Secondary production [herbivores]
> - Primary decomposition [bacteria, archaea, fungi, some fauna]
> - Secondary decomposition [some microbes, protozoa, nematodes, worms, insects, arachnids, molluscs]
> - Soil structural dynamics [bacteria, fungi, cyanobacteria; algae, worms, insects, mammals]
> - Suppression of pests and diseases [bacteria, actinomycetes, fungi, protozoa, nematodes, insects]
> - Symbioses [bacteria, actinomycetes, fungi (notably mycorrhizae)]
> - Soil organic matter formation, stabilisation and C sequestration [virtually all groups, directly or indirectly]
> - Atmospheric gas dynamics, including generation and sequestration of greenhouse gases [bacteria for nitrous oxides, methane; all biota for CO_2]
> - Soil formation [bacteria, fungi]

Repertoire: for a biologically-mediated process to occur, organisms that carry out that process must be present;
Interactions: most soil organisms have the capacity to directly or indirectly influence other organisms, either positively or negatively;
Redundancy: the more organisms there are that can carry out a function in a particular soil, the more likely it is that if some are incapacitated or removed the process will remain unaffected; those that remain fill the gap.

There is evidence that soil biotic communities are coupled to their associated vegetation, such that there is a mutual dependence between above-ground and below-ground communities, and hence that compromised soil communities may curtail particular plant assemblages from forming.

Consequences of decline in soil biodiversity

It is apparent that from a functional perspective, species richness *per se* is of little consequence; rather it is the functional repertoire of the soil biota that is critical. For processes such as decomposition, there is evidence that there is a high degree of redundancy at a microbial level. Other processes, such as nitrification (the oxidation of ammonium), are carried out by a narrower range of bacteria and there is less redundancy in this group, whereas for highly specific symbiotic associations, such as those between orchids and certain mycorrhizal fungi, there is total dependence and hence zero redundancy. A depletion of biodiversity will therefore have differing consequences in relation to different processes. In some circumstances it has been demonstrated that there are threshold levels of soil diversity below which processes are impaired, although these are usually related to narrow processes and are manifest under experimentally constructed systems of exceptionally low levels of diversity, as opposed to natural systems. From the intrinsic and bequest perspective, any loss of biodiversity is undesirable. Given our limited state of understanding of the consequences of soil biodiversity, it is common sense that a strong precautionary principle needs to be applied.



Simplified soil food web. Energy and nutrient elements are transferred from one trophic level to another. Note that there is also a continual movement of material from all trophic levels back to the detritus/organic matter pool and the base of the series (Tugel, A.J. & A.M. Lewandowski, eds., Soil Biology Primer. Available on-line from: http://soils.usda.gov/sqi/concepts/soil_biology/soil_food_web.htm

CONTAMINATION is the occurrence of a substance in soil above a certain level. Contamination can be diffuse or local and is due to many anthropogenic activities, such as industrial production, traffic, farming practices and waste disposal.

Pesticides, used to protect crops from insects and diseases, can in certain circumstances lead to diffuse pollution of soils (AJ).

Soil acts as a sink for almost all substances released into the environment by human activities. Therefore, many pollutants accumulate in the soil due to the specific filtering and buffering properties of the soil. On the other hand, many substances occur naturally in soil (e.g. heavy metals). If the concentration of these substances is above a defined background value or so high that it potentially causes a risk to human health, plants, animals, ecosystems or other media (e.g. water), the soil is regarded as "contaminated". Many parts of Europe are contaminated by a range of contaminants. They originate from either local or diffuse sources of human activity.

Contamination from localised sources

Soil contamination from localised sources is often related to industrial plants that are no longer in operation, accidents or improper waste disposals. At industrial plants that are still operating, soil contamination may have its origin in the past but current activities still have significant impacts.

Contaminated sites are the legacy of a long period of industrialisation involving uncontrolled production and handling of hazardous substances and unregulated dumping of wastes. The expansion of industry and subsequent increase in the amount of industrial wastes have led to considerable environmental problems. Mining activities and former military sites are also giving rise to severe contamination problems.

Contaminated sites considerably endanger human health and the environment. Pollution of drinking water, uptake of pollutants in plants, exposure to contaminated soil due to direct contact, inhalation and ingestion are major threats. Soil and groundwater contamination can be caused by losses during production, industrial accidents and leaching of hazardous substances at waste disposal sites. Major pollutants include organic contaminants such as chlorinated hydrocarbons, mineral oil and heavy metals.

Assuming that areas with a high probability for soil contamination from local sources are concentrated in densely populated and industrialised regions, the largest and probably most heavily affected areas are concentrated around the industries from the Nord-Pas de Calais in France to the Rhine-Ruhr region in Germany, across Belgium and the Netherlands and the large cities of the UK (see population density map on Page 123).

Other areas where the probability of local soil contamination is high include the Saar region in Germany; northern Italy, north of the river Po area, from Milan to Padua; the so-called Black Triangle region located at the corner of Poland, the Czech Republic and the Slovak Republic. However, contaminated areas exist around most major cities and some individual contaminated sites also exist in sparsely populated areas.

The management of contaminated sites is designed to remediate any adverse effects where impairment of the environment has been proved and to minimise potential threats. Provision of public and private money for remediation, as well as restrictions on land use and the use of groundwater and surface water, are particularly important responses to deal with the existing contaminated sites. Although the "polluter-pays" principle is generally applied, a huge sum of public money must be provided to fund necessary remediation activities. A problem can arise when the polluter is not financially liquid or the polluter can not be made liable! Even though a considerable amount of money has been spent on remediation activities already, the share compared to the total estimated remediation costs is relatively low (only around 8%).

Contamination from diffuse sources

Intensive agriculture, forestry, mining, transport, industrialization and urbanization in densely populated areas in Europe have led to inter-related problems of contamination and other forms of land degradation. Transport of acidifying and eutrophying components as well as potentially harmful elements by wind has led to soil degradation even in distant areas. Additionally, certain agricultural practices cause diffuse soil contamination by direct application of pesticides, sewage sludge, compost, fertilisers and manure.

Continued contamination can lead to an accumulation of hazardous substances in top soils. Soil functions most affected by contamination are buffering, filtering and transforming capacities. When the buffering capacity of soil with respect to a certain substance is exceeded, the substance is released to the environment, causing impairment of groundwater and/or surface water. Currently, the most important problems from diffuse sources are acidification, the effects of a surplus of nutrients and contamination by heavy metals.

Emissions of acidifying sulphur and nitrogen compounds from industry and transport have led to soil acidification and pose threats to forest health and the quality of surface and/or groundwater. Aluminium, cadmium and many other metals are more mobile in acid soils causing risk of damage to plant roots and contamination of drinking water. Sulphur emissions and deposition have declined substantially. Excesses of acidifying components in terrestrial ecosystems are at present dominated by nitrogen deposition, although the situation is not homogenous throughout Europe. Nitrogen and phosphorus are essential elements for plant growth and are added to soil by fertilization. However, if fertilizers are applied beyond what plants can use and soils

The application of new legislation at national and EU level (e.g. the Landfill Directive, Water Framework Directive, Environmental Liability Directive, Integrated Pollution and Prevention Control Directive) should result in better operational and technical requirements on waste and landfills (AJ).

can retain, the excess may be leached from the soil, eroded or washed off into ground waters and/or surface waters. Besides over-application of fertilizers, accumulation of nitrogen can be caused by wet and dry nitrogen deposition. Elevated nitrogen content in forest soils can negatively affect the vitality of European forests. According to estimations based on critical load data the excess deposition of nutrient nitrogen will be much lower by 2010 in comparison to 1990, but still in some areas of central and western Europe only less than 10% of the ecosystems will be protected against negative effects of eutrophication.

Deposition of heavy metals and other potentially harmful elements cause diffuse soil contamination throughout Europe. In forest soils, contamination is generally linked to atmospheric deposition. In agricultural soils, heavy metals and other contaminants enter ecosystems as a result of the application of fertilizers and animal manure, compost and pesticides. The application of contaminated sewage sludge has the potential to create a threat to soil ecosystems due to input of heavy metals, organic compounds and pathogens. In Eastern and Northern Europe, the fallout from Chernobyl can be still identified as a diffuse radioactive contamination of surface soil, but at a lower value than in the late 1980's. Much attention has been paid so far to diffuse contamination by cadmium, lead and mercury. Other potentially harmful elements include arsenic, chromium, copper, nickel, zinc and several persistent organic pollutants (POPs).

Reductions in heavy metal deposition can be expected throughout Europe as the result of the implementation of lead-free petrol and the application of industrial techniques of emission reduction. Concerning direct input of contaminants to agricultural soils, common Good Agricultural Practices and water protection legislation have to consider avoidance of soil contamination and related EU legislation.

The risk of soil contamination from mining activities is associated with the storage or disposal of tailings, acid mine drainage and the use of certain chemical reagents in the processing of metal ores. This striking photograph shows an old copper mine in the UK more than 100 years after the mine was abandoned. Notice the lack of vegetation on the soil heaps. The pH of some of the old tailing ponds can be as low as 2.5, strong sulphuric acid! (AJ).

SOIL COMPACTION is the term for the deterioration of soil structure (loss of soil features) by mechanistic pressure, predominantly from agricultural practices.

Driving heavy tractors on the subsoil during ploughing and harvesting is a major cause of subsoil compaction. The picture clearly shows how the wheels on one side of the tractor are driven in the plough furrow and press directly on the subsoil (JJHVDA).

Definition of the problem

Soil compaction is a form of physical degradation resulting in densification and distortion of the soil where biological activity, porosity and permeability are reduced, strength is increased and soil structure partly destroyed. Compaction can reduce water infiltration capacity and increase erosion risk by accelerating run-off. The compaction process can be initiated by wheels, tracks, rollers or by the passage of animals.

Some soils are naturally compacted, strongly cemented or have a thin topsoil layer on rock subsoil. Soils can vary from being sufficiently strong to resist all likely applied loads to being so weak that they are compacted by even light loads.

In arable land with annual ploughing, both topsoil and subsoil compaction is possible. A feature of compacted soils is the formation of a pan-layer, caused by the tractor tyres driving directly on the subsoil during ploughing (above). The pan-layer is less permeable for roots, water and oxygen than the soil below and is a bottleneck for the function of the subsoil. Unlike topsoil, the subsoil is not loosened annually, compaction becomes cumulative and over time, a homogeneous compacted layer is created.

The Impact

Large spaces in soils are known as macro pores and are created by plant roots, burrowing creatures and shrinkage caused by the drying of wet soil. These macro pores are usually continuous and form "highways" for air and water to travel deep into the soil. To an extent, continuous macro pores determine the soil's physical and soil biological quality. Macro pores are the most vulnerable pores to soil compaction.

The loss of macro porosity and pore continuity reduces strongly the ability of the soil to conduct water and air.

- Reduced infiltration capacity results in surface run-off, leading eventually to flooding, erosion and transport of nutrients and agrochemicals to open water.
- A poor aeration of the soil reduces plant growth and induces loss of soil nitrogen and production of greenhouse gases through denitrification in anaerobic sites.

Deformation of soil aggregates and higher bulk density increase the strength of the soil. This limits root growth which can result in a higher vulnerability of the crop to diseases. Subsoil compaction is a hidden form of soil degradation that can affect all the agricultural areas and results in gradually decreasing yields and gradually increasing problems with waterlogging.

The impact of subsoil compaction is most prominent in years with extreme dry or wet periods. Crop yield reductions of more than 35% have been measured. Subsoil compaction proves to be very persistent, even in subsoils with shrinkage and swelling or annual deep freezing. Reduced crop yields and reduced nitrogen content in crops were detected 17 years after a single compaction event with wheel loads of 50 kN or 5,000 kg.

A classic example of compacted topsoil. Note how the soil structure in the upper part of the profile has completely collapsed. This limits root growth and exploitation of soil water and nutrients by crops (JJHVDA).

Scale

All agricultural soils in developed countries display some degree of subsoil compaction. Estimates in 1991 suggest that the area of degradation attributable to soil compaction in Europe may equal or exceed 33 million hectares (ha). Recent research has showed that compaction is the most widespread kind of soil physical soil degradation in central and eastern Europe. About 25 million ha were deemed to be lightly compacted while a further 36 million ha were more severely affected.

Well-structured soils combine good physical soil properties with high strength. Sandy soils with a single grain structure and compacted massive soils can be very strong. However, rootability and soil physical properties are then often bad. Roots have a binding action and increase the elasticity and resistance of a soil to compaction.

Soil moisture has a dominant influence on soil compactibility. Dry structured soils are strong with low compactibilty. However, extremely dry sandy soils can be deformed and compacted rather easily. As the moisture content increases, compactibility increases until the moisture content is approximately at the field capacity point, when a condition known as the optimum moisture content for compaction is reached. At still higher moisture content, the soil becomes increasingly incompactible as water fills ever more pore space. Although the compaction of an overloaded wet soil may be minimal, plastic flow may result in the complete destruction of soil structure and macro-pores.

Increasing the organic matter content tends to reduce soil compactibility and to increase its elasticity.

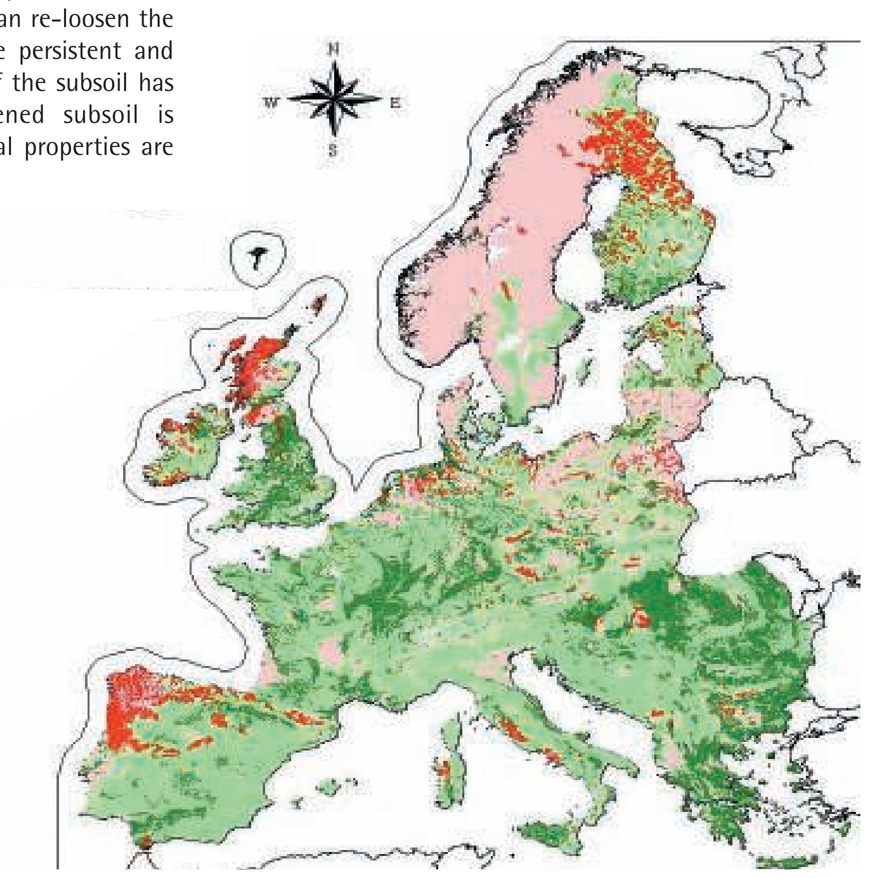
Solution

It is almost impossible to avoid topsoil compaction. On the other hand, tillage and natural processes can re-loosen the topsoil. Subsoil compaction is much more persistent and difficult to remove. Artificial loosening of the subsoil has proven to be disappointing. The loosened subsoil is recompacted very easily and many physical properties are strongly reduced.

Compaction leads to a deterioration in conditions for soil fauna (JJHVDA).

Areas degraded by soil compaction are increasing because wheel loads in agriculture are still increasing. Twenty years ago wheel loads of 50 kN (5000 kg) were considered very high. Nowadays wheel loads of up to 130 kN are used during the harvesting of sugar beet. Modern self-propelled slurry tankers with injection equipment with wheel loads of 90 – 120 kN are used in early spring on wet soils. Large tyres with an inflation pressure of about 200 kPa are needed to carry such high wheel loads. Even on moderate strong soil, compaction of up to 80 cm below the surface have been measured under such loads. The result is that the soil is increasingly compacted to ever-greater depth. The conclusion is that European soil is more threatened than ever (JJHVDA).

Subsoil compaction should be prevented instead of being repaired or compensated. Even on weak soils, relatively high wheel loads are possible by using large tyres with low inflation pressures or well-designed tracks. Subsoil compaction during ploughing can be prevented by using improved steering systems and adapted ploughs allowing the tractor to drive with all wheels on the untilled land. It is also possible to concentrate wheel loads on permanent traffic lanes and limit the compaction to these sacrificed wheel ways. By using gantries, the sacrificed area can be limited. However, these solutions are rarely used because of short-term economical constraints, lack of awareness, and negligence because the damage to the subsoil is not readily visible. Also the limited knowledge and data on soil strength under dynamic loading makes prevention of subsoil compaction difficult.



Provisional map of inherent susceptibility of subsoil in Europe to compaction, based on soil properties alone. Further input data are required on climate and land use before vulnerability to compaction of subsoil in Europe can be inferred from the susceptibilities shown here. Some of the very high areas (red) correspond to peat soils that are not subjected to "normal" agricultural practices. However, it is worth including the peat heaths and forests of Europe as they are often used for forestry and can be compacted by heavy timber harvesting machines and off-road vehicles (RJ).

HYDRO-GEOLOGICAL RISKS refer to floods and landslides related to soil and land management.

A landslide is the down slope movement of terrain due to a failure of the material composing the landscape. Landslides may be induced by physical processes such as earthquakes or caused by human interference on slope stability. Landslides, mudflows and other mass movement events are both erosional and depositional events (EM).

When river banks are overtopped through rising flood waters, the results can be devastating. In the last decade Europe has experienced a number of unusually long-lasting rainfall events that produced severe floods, For example, in the Netherlands, Belgium, France and Germany (1993, 1995), the Czech Republic, Poland and Germany (1997), in northern Italy (1994, 2000) and in the UK (1998, 2000, 2004). The trend seems to be continuing.

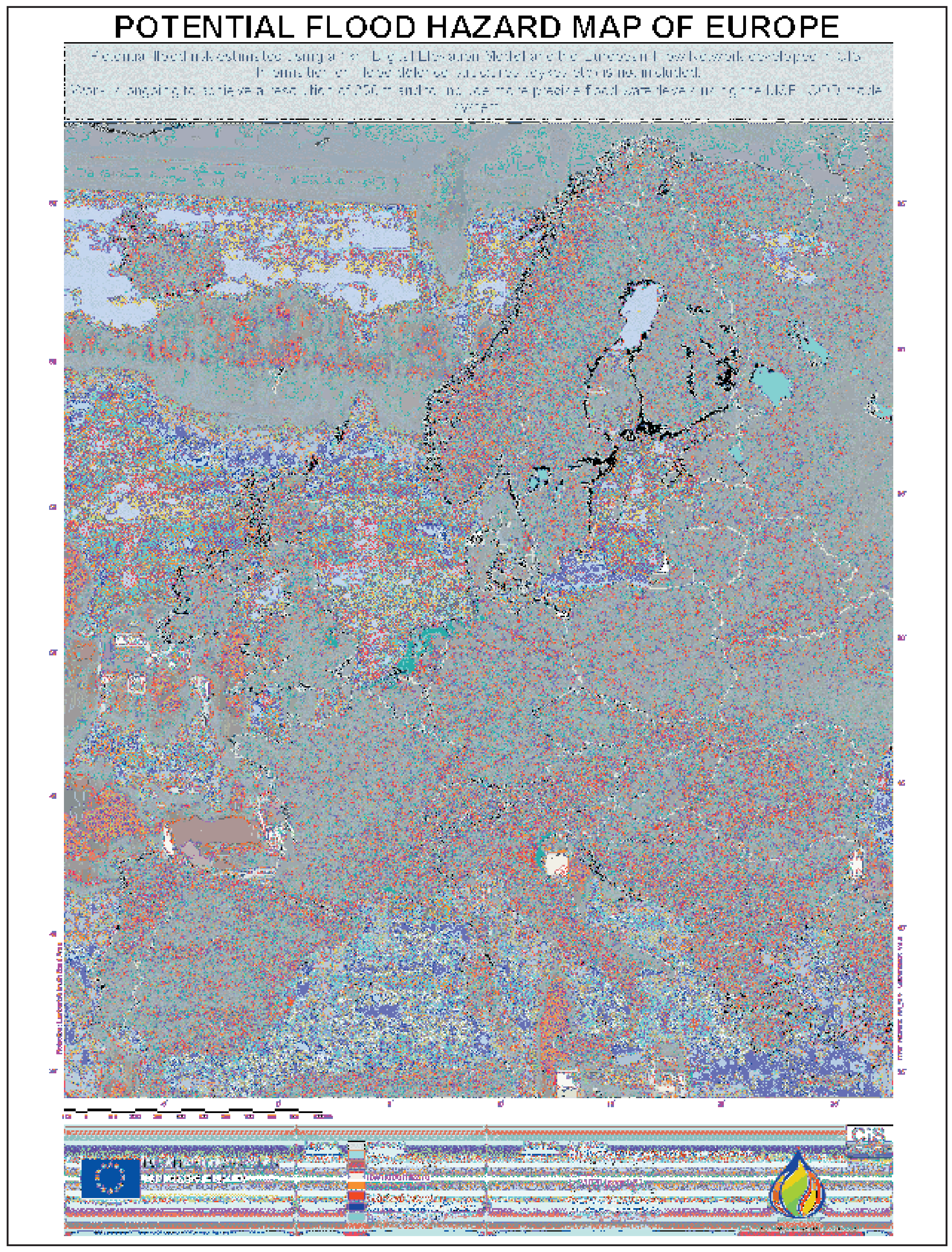
According to the World Meteorological Office review of the year 2001, the 24-months period ending in March 2001 was the wettest in the 236-year time series of precipitation in England and Wales. From October 2000 to March 2001, precipitation was also exceptional in the Bretagne (France), where the normal annual rainfall was exceeded by 20 to 40% in parts of the region. A third consecutive year of severe flooding occurred in Hungary and parts of Eastern Europe in March 2001 where the Tisza river reached its highest level since 1888 while two weeks of heavy rain during in June 2001 produced Poland's worst flood since 1997. In August 2002 devastating and costly floods in the Elbe and the Danube rivers were observed with further extreme precipitation and flooding in southern France, where almost half of the normal annual rainfall fell in just one day!

Prolonged periods of moderate rainfall can lead to "*plain floods*" that build up over days and can affect large areas, whereas short-lasting but very intense rainfalls cause "*flash floods*", that can develop within a few hours only, are very localised, and because of their sudden development and violence represent a particular problem for civil protection.

According to climate modellers, the probability, frequency, duration, intensity (seriousness) of extreme weather events (extreme temperatures and rainfall) are increasing and will be more common in the future. If these weather features are combined with hilly landscapes, a lack of permanent and dense vegetation cover, inefficient land management practices and soils with unfavourable physical properties, then increased extreme soil moisture situations, be it either waterlogging or drought, may develop. The former will lead to higher surface runoff and flood events while the latter will cause crop failure, reduced drinking water supplies and a breakdown of soil properties. The impact of such events depends greatly on the **physical and hydro-physical properties of soils.**

The **main factors affecting soil moisture** are:

- the depth, thickness and sequence of various soil horizons within the soil profile between the surface and the groundwater table;
- the hydro-physical characteristics of these soil layers;
- the quantity, status, energy, relations, chemical composition and vertical or horizontal movement of soil moisture.



(ADR)

The main hydro-physical characteristics of soils include particle-size distribution, saturation percentage, bulk density, aggregate state and stability, porosity, pore-size distribution, water storage capacity, field capacity, wilting percentage, available moisture range, infiltration rate, permeability, saturated and unsaturated hydraulic conductivity. The values of these parameters for a large number of European soils are stored in the HYPRES database (see Page 99).

Floods and landslides are natural hazards intimately related to soil and land management. Floods and mass movements of soil cause erosion, pollution and loss of soil resources with often catastrophic impacts for human activities and lives, damage to buildings and infrastructures and loss of agricultural land. Floods can, in some cases, result from soil not performing its role of controlling the water cycle due to compaction or sealing.

Such events are occurring more frequently in areas with highly erodable soil, steep slopes and intense precipitation, such as the Alpine and the Mediterranean regions. In Italy more than 50% of the territory has been classified as having a high or very high hydro-geological risk, affecting 60% of the population or 34 million inhabitants. More than 15% of the territory and 26% of the population are subjected to a very high risk. The impacts on population and the economic damage are relevant. In Italy over the last 20 years, floods and landslides had an impact on more than 70 000 people and caused economic damage of at least 11 billion euro.

This photograph shows the power of a large flood in the Ossola Valley of northwest Italy. A torrential and prolonged rain storm in 2000 completely destroyed one of the main highways between Italy and Switzerland (RJ).

The main objective of efficient **soil moisture control** is to *increase the water storage within the soil in a form that is available to plants* without any unfavourable environmental consequences. Such measures should:

- reduce evaporation, surface runoff and filtration losses of water (atmospheric precipitation and irrigation);
- increase the available moisture range of the soil (to help infiltration into the soil, increase the water storage capacity, reduce the immobile moisture content);
- improve drainage conditions of the soil profile (reduce over-saturation and waterlogging).

It is important to stress that most of these measures are also important elements of **water conservation and environment protection.** What is good for the soil is good for the land.

Salinisation

SALINISATION is the accumulation of soluble salts of sodium, magnesium and calcium in soil to the extent that soil fertility is severely reduced.

Salt affected soil often exhibits a white or grey salt crust on the ground. The pH of the soil is around 8.5 and the salt interferes with the growth of all but the most specially adapted plants (ED).

Salinisation, also known as alkalisation or sodification, is often associated with irrigated areas where low rainfall, high evapotranspiration rates or soil textural characteristics impede the washing out of the salts which subsequently build-up in the soil surface layers. Irrigation with high salt content waters dramatically worsens the problem.

In coastal areas, salinisation can be associated with the over exploitation of groundwater caused by the demands of growing urbanisation, industry and agriculture. Over extraction of groundwater can lower the normal water table and lead to the intrusion of marine water. Natural disasters in coastal areas, such as tsunamis, can cause severe salinisation problems with several years of low fertility of the affected soil before recovery.

In Nordic countries, the de-icing of roads with salts can lead to localised salinisation.

Salinity is one of the most widespread soil degradation processes on the Earth. According to some estimates, the total area of salt affected soil is about one billion hectares. They occur mainly in the arid-semiarid regions of Asia, Australia and South America. In Europe, salt affected soil occurs in the Caspian Basin, the Ukraine, the Carpathian Basin and the on the Iberian Peninsula. Soil salinity affects an estimated 1 million hectares in the European Union, mainly in the Mediterranean countries, and is a major cause of desertification. In Spain 3% of the 3.5 million hectares of irrigated land is severely affected, reducing markedly its agricultural potential while another 15 % is under serious risk.

Salt affected soil can be divided into five main groups:

- Saline soil (Solonchak) with high amount of water soluble soils.
- Alkaline soil (Solonetz), high alkalinity and high exchangeable sodium percentage (ESP).
- Magnesium soil: high magnesium content in the soil solution.
- Gypsiferous soil: strong gypsum or calcium sulphate ($CaSO_4$) accumulation.
- Acid sulphate soil: highly acidic iron or aluminium sulphate accumulation.

In Europe, the first two groups are the most significant (see Page 16 and the section in the Atlas on the major soil types of Europe for more details on saline soil).

The factors that determine the accumulation of salt in a soil are as follows:

- source of salt (local weathering, surface and subsurface waters, human activities);
- transporting agents accumulating salts from large areas to smaller deposits as well as from thick geological strata to thinner horizons (usually water, wind);
- limited vertical or horizontal drainage conditions;
- driving force for movement of solution, usually relief (surface runoff), hydraulic gradient (groundwater flow), suction (capillary transport) or concentration gradient (diffusion);
- negative water balance (evapotranspiration greater than precipitation).

Two main types of salt accumulation in soil can be distinguished in Europe:

- Continental salt accumulation due to intense weathering and arid climate or due to hydro-geological conditions (e.g. closed evaporative basins).
- Human induced salt accumulation due to improper land use (e.g. irrigation, fertilizer application).

The Carpathian Basin in Hungary is a good example of the first case. Surface runoff, seepage and groundwater transport soluble weathering products from a large water catchment area to the lowest part of the basin where subsurface waters, enriched with sodium, calcium and magnesium carbonate (salts), accumulate in a thick continuous aquifer. In poorly drained, low lying areas, capillary flow transports high amounts of water soluble salts from the shallow, stagnant groundwater to the overlying soil horizons. Due to the chemistry of the soil solution (strongly alkaline), the sodium is the dominant element in the migrating waters. High sodium saturation of heavy-textured soil with large amount of expanding clay minerals results in unfavourable soil properties and limits their fertility, productivity and agricultural utility.

Salinity as an environmental stress and limiting factor for agriculture.

The accumulation of salts, particularly sodium salts, are one the main *physiological* threats to ecosystems. Salt prevents, limits or disturbs the normal metabolism, water quality and nutrient uptake of plants and soil biota. When water containing a large amount of dissolved salt is brought into contact with a plant cell, the protoplasmic lining will shrink. This action, known as plasmolysis, increases with the concentration of the salt solution. The cell then collapses. In addition, sodium salts can be both caustic (corrosive) and toxic (poisonous) to organic tissue. The nature of the salt, the plant species and even the individuality of the plant (e.g. structure and depth of the root system) determine the concentration of soil-salt levels at which a crop or plants will succumb. Examples of plants and crops with a high tolerance to salt include bermuda grass, cotton, date palm, peas, rape and sugar beet while apples, lemons, oranges, potatoes and most clovers have a very low tolerance.

One of the main characteristics of salt affected soils is their temporal variability. Prolonged rainfall can lead to a temporary leaching of salt from the surface layers. In many salt affected areas, small ponds are dug to drain the saline water from the soil thus allowing limited agriculture on other parts of the land. The white deposits on the bank of the pond are evaporated salt crystals (EM).

Salinization processes are near to irreversible in the case of heavy-textured soils with high levels of swelling clay. Although a combination of efficient drainage and flushing of the soil by water is often used, the leaching of salts from the profile is rarely effective

Because the reclamation, improvement and management of salt affected soils necessitates complex and expensive technologies, all efforts must be taken for the efficient prevention of these harmful processes. Permanent care and proper control actions are required. Adequate soil and water conservation practices, based on a comprehensive soil or land degradation assessment, can provide an "*early warning system*" that provides possibilities for efficient salinity (or alkalinity) control, the prevention of these environmental stresses and their undesirable ecological, economical and social consequences.

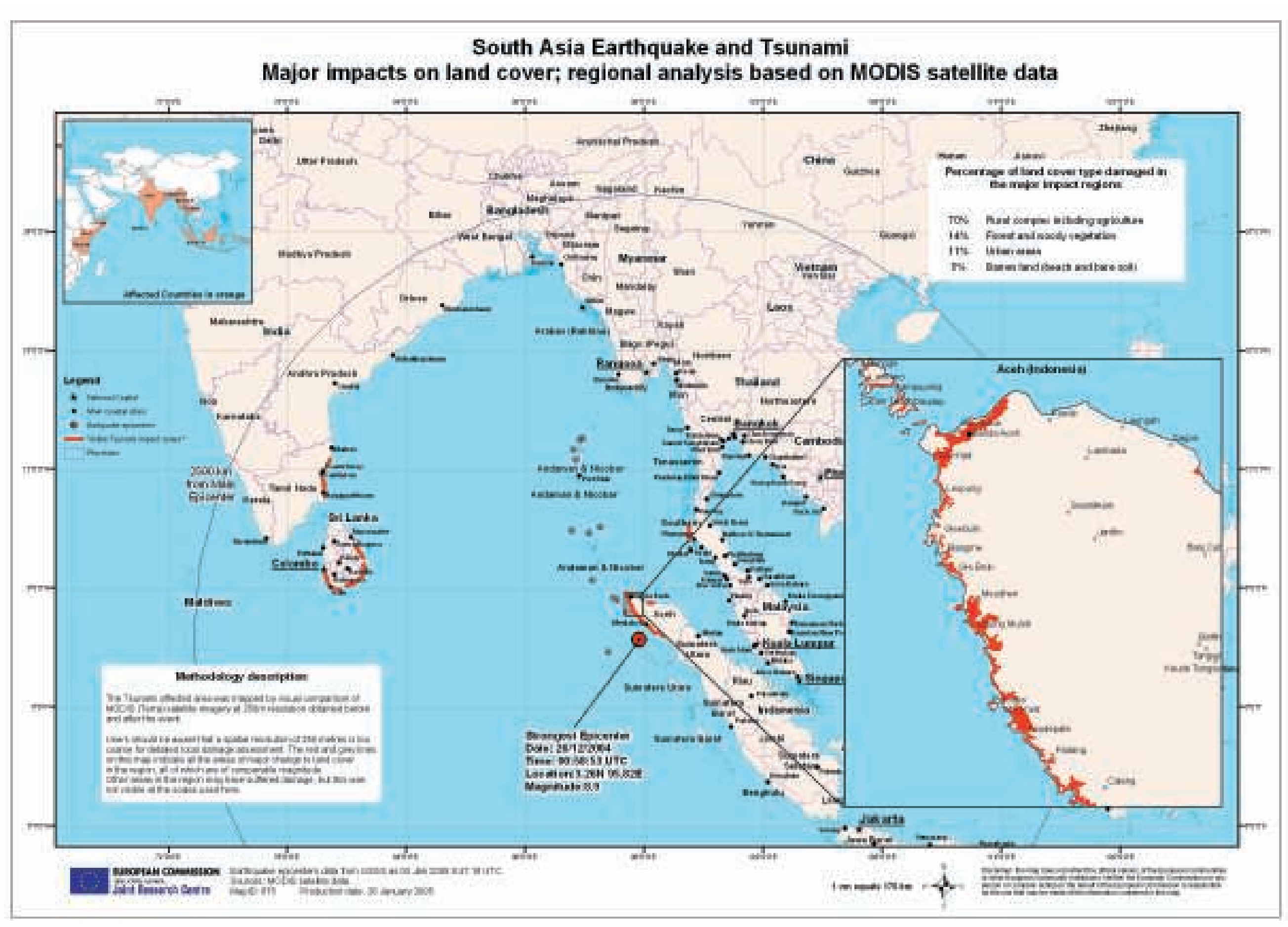
What is salinity?

Salinity is the degree to which water contains dissolved salts. Salinity is usually expressed in parts per thousand or grams per thousand grams. Normal seawater has a salinity of 33 parts per thousand. This rises to 40 parts per thousand in the Red Sea.

Soil salinisation in coastal areas affected by tsunami tidal waves

One of the long term effects of tsunami waves is the deposition of salty seawater on large flooded areas with consequent salinisation of soils. Depending on the climatic conditions, these effects can be temporary and the soils may recover rapidly by washing out the infiltrated salt deposits through heavy rainfall. In more arid or sub-humid areas the salinisation effects can on the other hand last for several years. Depending on the type of crops cultivated in the area and their resistance to salinisation there can be serious consequences on long term agricultural production and food security in the affected area.

The 9 magnitude earthquake that occurred at 00.58 UTC on 26th December 2004 at the interface between the India and Burma plates off the west coast of Northern Sumatra, Indonesia, triggered massive tsunamis that affected several countries throughout south and south east Asia (India, Bangladesh, Mynamar, Sri Lanka, Indonesia, Maldives and Thailand) as well as in East Africa (Somalia, Kenya, and Tanzania). The total inundated zone is estimated at ca. 60 000 sq. km. Soils of these areas have been affected by erosion and scouring that modifies the topography, land leveling and the elimination of bunds (for paddy fields), soil fertility losses when upper layer is washed away, deposition of salted sediment, salt infiltration and trash and debris accumulation. Recovery of the affected areas will require several years in some areas lacking sufficient rainfall for rapid outwash of accumulated salts and will be an additional burden to the local population.



The above picture shows the soil habitat at different scales: from left, field scale, ped scale, root scale, microbial scale. Each panel from left to right represents an approximate 10-fold magnification in scale (KR).

A reduction in the use of pesticides, as well as a phase-out of the use of certain dangerous substances in pesticides, is necessary to minimise the problems relating to the quality of agricultural soils. Soil protection policies include the decline in biodiversity, the processes of physical and chemical degradation triggered by erosion, desertification, pollution and the decline in organic matter (EM).

Conclusions

Above and below: An Umbrisol from Italy supporting a mixed woodland habitat (EM). Soil protection has both a national and community-wide dimension and requires that European Union Member States implement national and community relevant policy. Ensuring a soil protection dimension in all policies will benefit the whole of Europe and not only those regions facing severe environmental problems.

The Way Forward

Soil is considered to be a non renewable resource of common interest for the European Union. Indeed, it is recognised that the European Unionís sustainable development depends on many of the uses and functions of soil being preserved and managed carefully. In the 6th Environment Action Program, the European Union stressed the need to protect such a common resource putting forward actions to protect and improve soil quality.

It was decided do so through the development of a Thematic Strategy on soil protection and sustainable use of soil. In 2002, the European Commission adopted a Communication ìTowards a Thematic Strategy on Soil Protectionî identifying the main 8 threats to soil and recognising the importance of integrating soil protection aspects in other EU policies. This Communication was followed by a very broad consultation with stakeholders and experts, who produced a set of reports and recommendations.

Our improved knowledge of the environment, ecosystems and natural cycles has shown that many impacts on soil do have transboundary consequences. Thus issues related to soil are not as 'static' as we may have thought in the past.

Moreover, soil degradation or soil quality improvements have strong impacts on Europeís long term competitivity and on areas already considered of common interest such as water protection, human health, climate change, nature and biodiversity protection, food safety. The fact that there has not yet been specific EU legislation for soil protection does not mean that Member States have not tackled the issue at national level. Indeed some of them have very advanced soil protection policies.

Hence due to the importance of land use for almost all economic sectors, it has to be ensured through EU action that we establish a level playing field, where the differences in soil protection of national regimes do not create a distortion of competition for economic operators. All these arguments advocate for a comprehensive action at EU level. However, such action would have to identify the best level of intervention for the different measures that could be proposed. Indeed, many of the measures needed to achieve soil protection would better be taken at national, regional or local level due to the enormous specificity of soil.

The presentation of the Thematic Strategy on soil by the Commission towards the end of 2005 will not be the end of the process but rather another stage in the development of soil protection policy in the European Union. The goal is to set up a roadmap to preserve and restore soil, soil functions and to prevent the soil threats. To protect European soil quality is a long term objective which all Member States have to embrace wholeheartedly.

Conclusions

Soil supports human life. Being a natural, non-renewable resource with variable characteristics, such a statement means that soil must be managed in a sustainable manner throughout Europe.

Traditional users of the land had a clear view of the key role of the soil in their lives; many modern users of soil are often strong followers of short-term productive goals, ignoring the effects of their practices on the environment.

In developing the soil protection strategy, the Commission is placing soil alongside water and air as environmental media to be protected for the future. The strategy takes a pragmatic approach towards the adjustment of existing policies relevant to soil by taking both a preventative approach through the development of new environmental legislation and an integrational approach for sectoral policies of particular relevance for soil.

In addition the Commission has established the need to provide a more solid base through monitoring for actions in the future. These actions will be beneficial not only to soil, but will also contribute to reducing water and food contamination by hazardous pollutants and will therefore contribute to the limitation of environmental impact on human health.

We hope that this SOIL ATLAS will be a positive contribution to the process to protect soil in Europe.

Additional Information

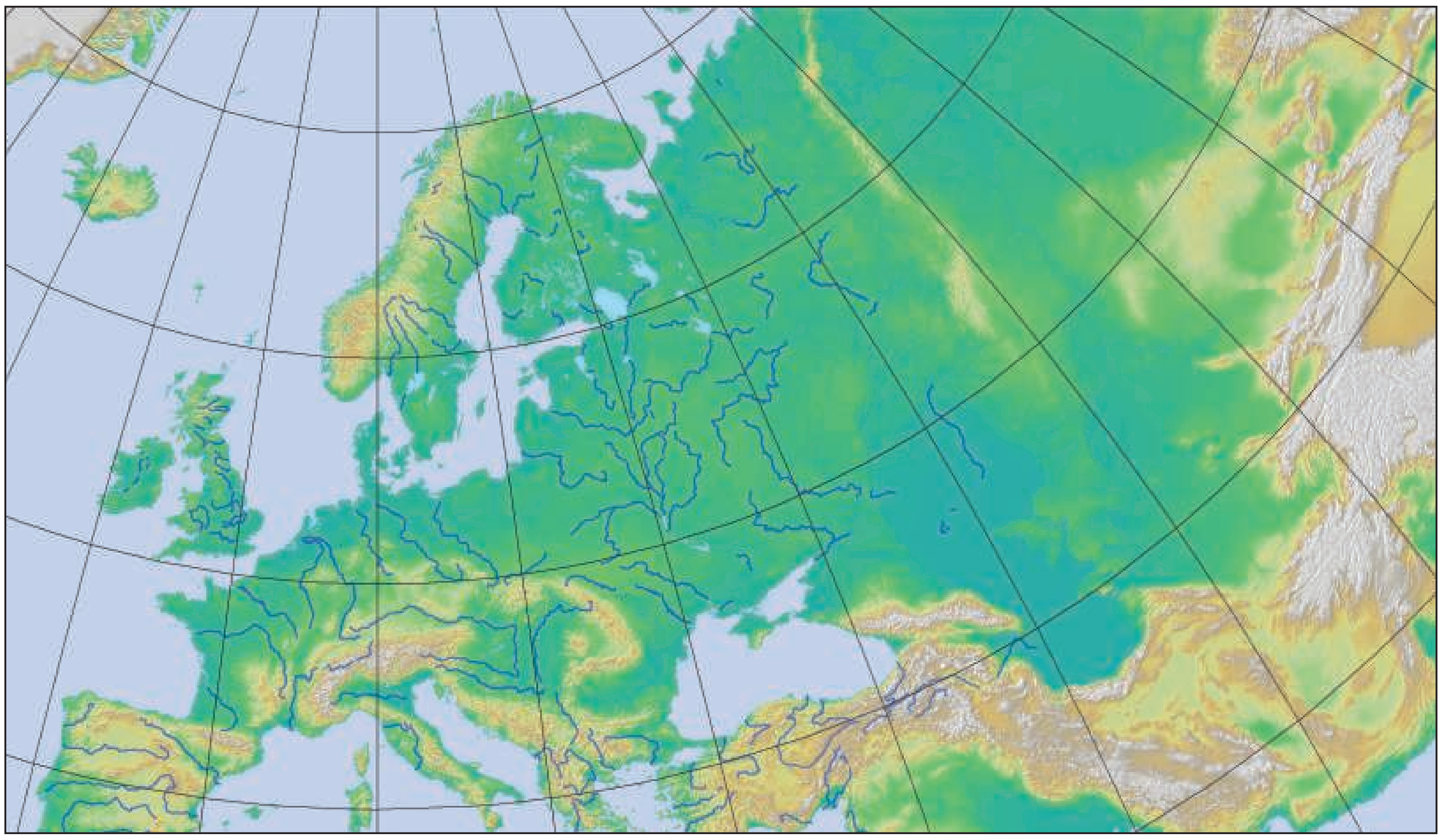
This section of the Atlas presents a series of thematic maps that aim to provide the reader with additional information to understand the factors affecting soil development and the threats to soil described over the previous pages.

The fascinating photographs (EM) on this page show clearly the close inter-relationships between biodiversity and soil formation.

The above picture and the one to the right show a nest made by Weaver Birds in Namibia. If you look closely, you can see that the ground underneath the nest has a different texture and colour from the surrounding soil. This is due to the bird droppings that fall out of the nest on to the ground.

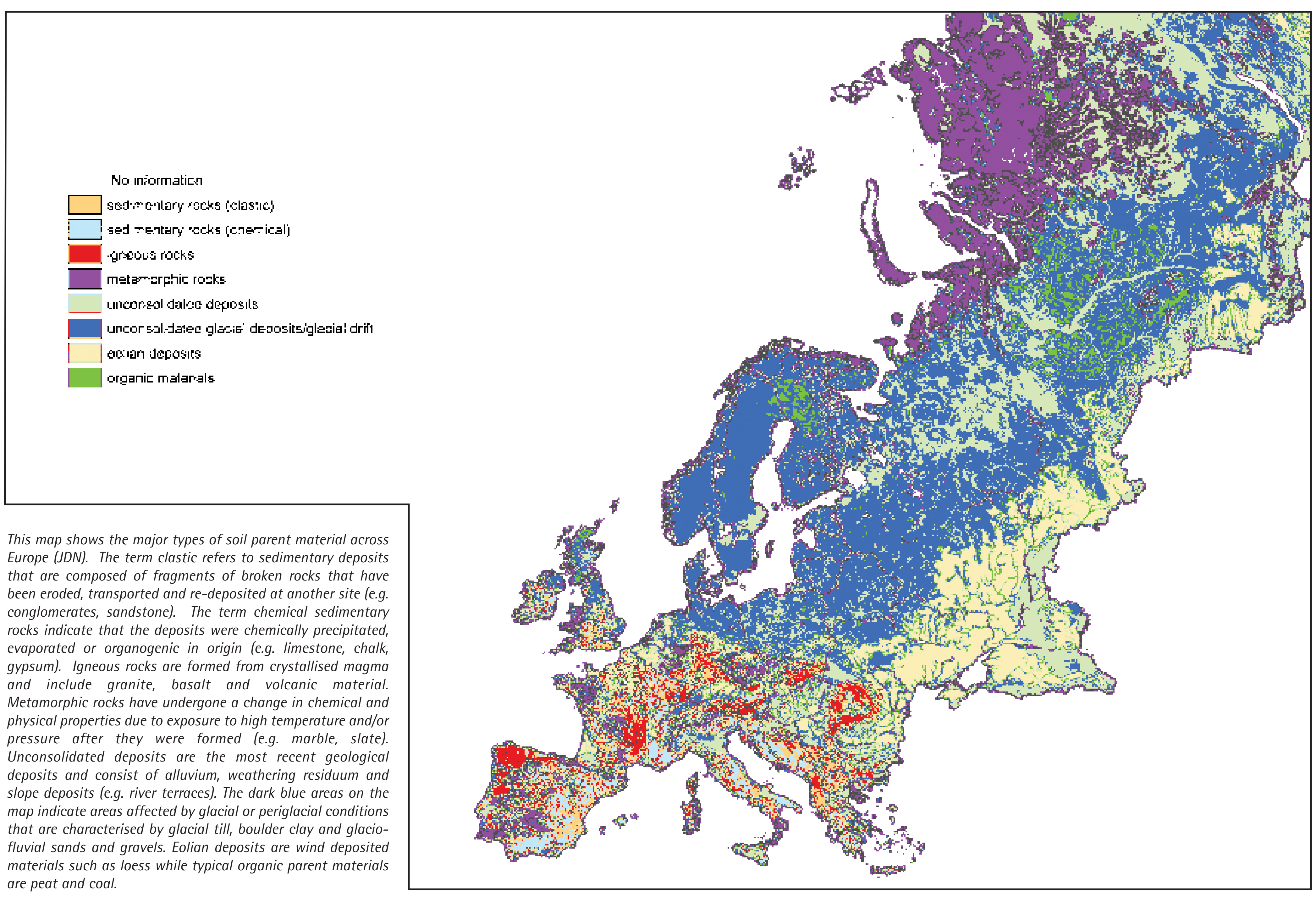
The picture below is a close up of the soil profile directly below the nest. The ground is covered by bird droppings (the white flakes). Over time, these droppings have accumulated to form a thin but highly organic layer on top of local soil. The darker patches above the gravel layer are the result of the mixing of the surface layer into the soil by burrowing animals.

Elevation

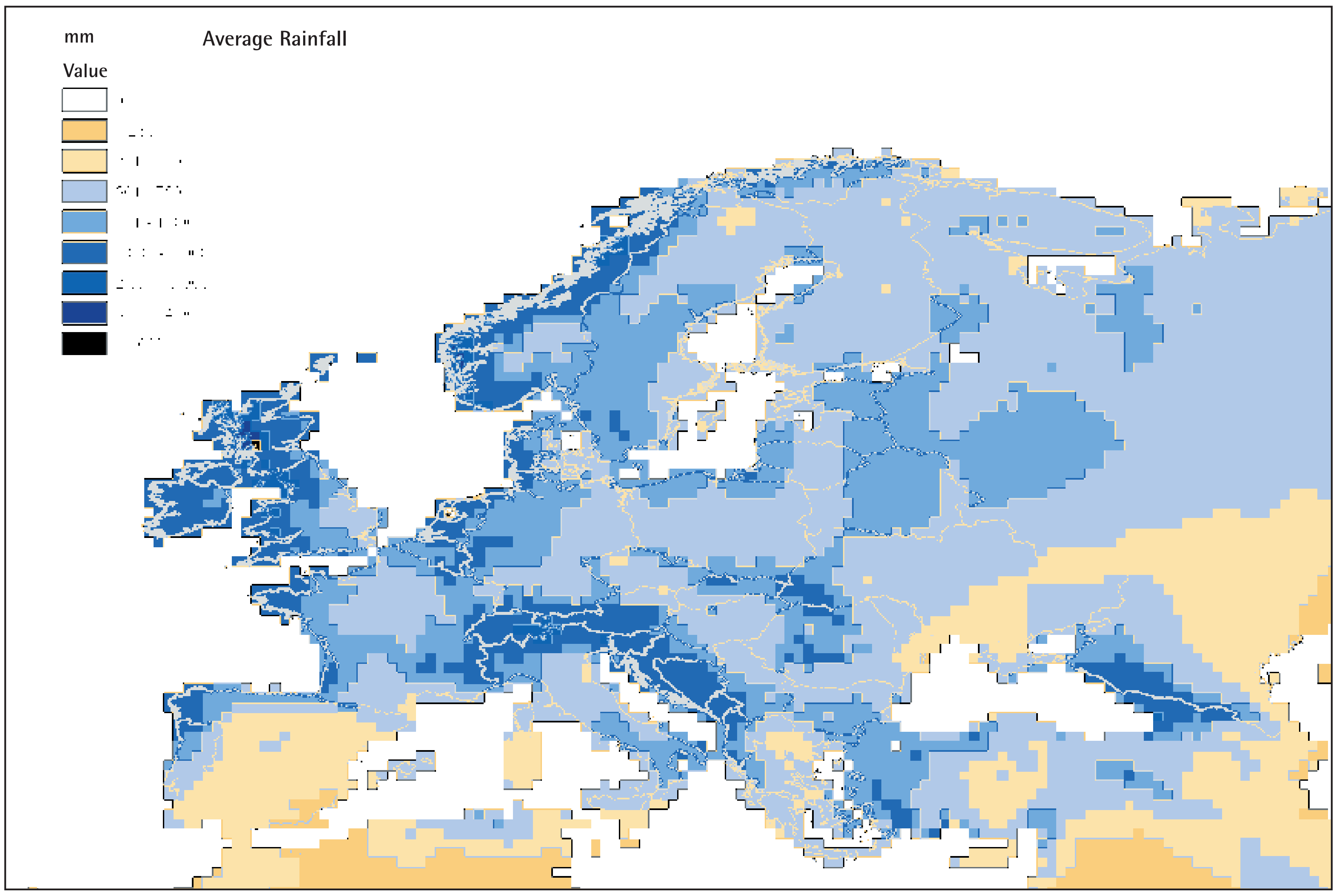


This map shows changes in elevation of land surface as depicted by a digital elevation model or DEM. A DEM is a digital representation of topography through a regular grid of cells that indicate the average altitude of the land surface within the area covered by the cell. The size of the cells used in the above DEM is 1 km. The green colours represent areas of low altitude while the brown colours highlight the mountainous regions of Europe (HR).

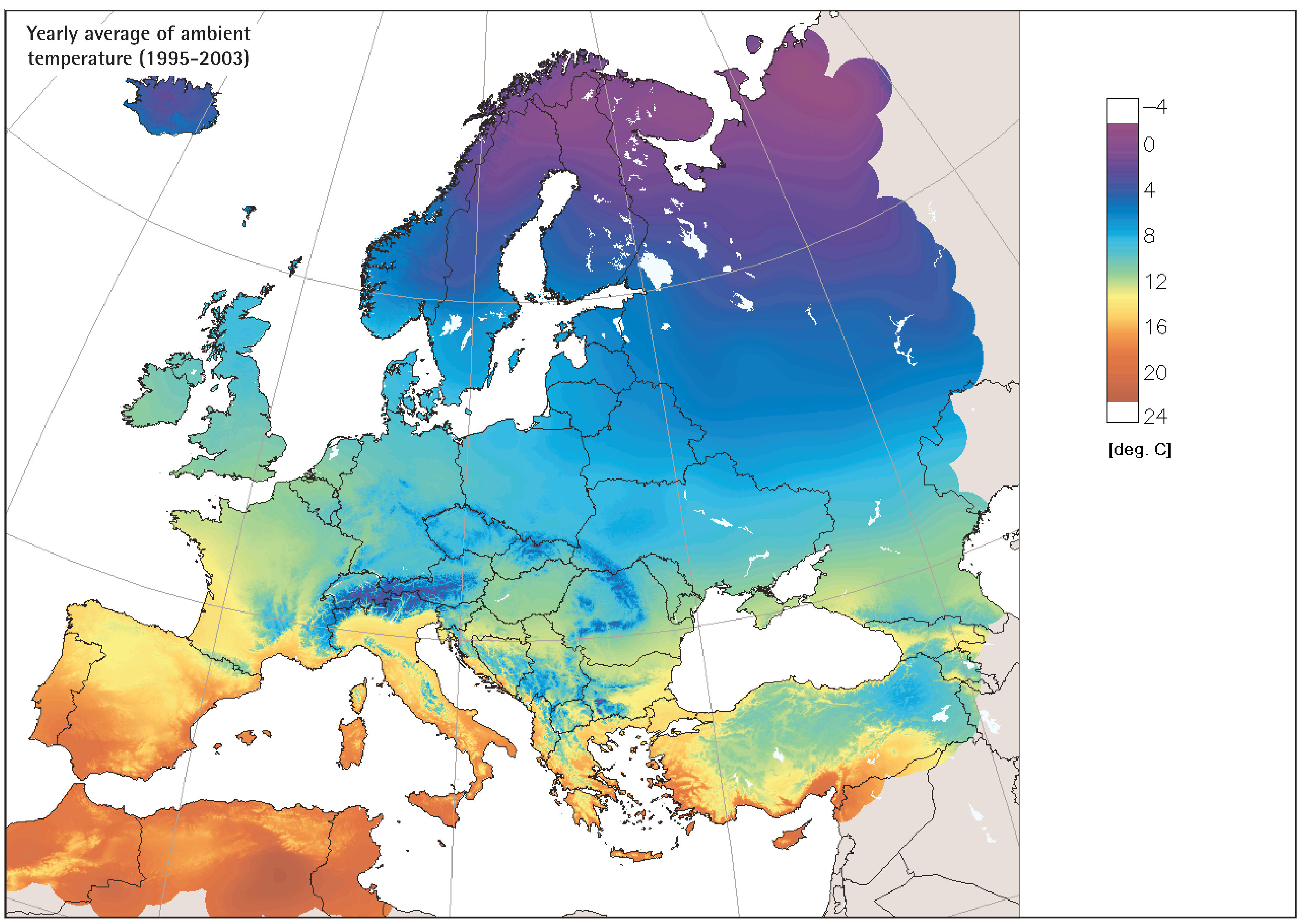
Major parent material of soil



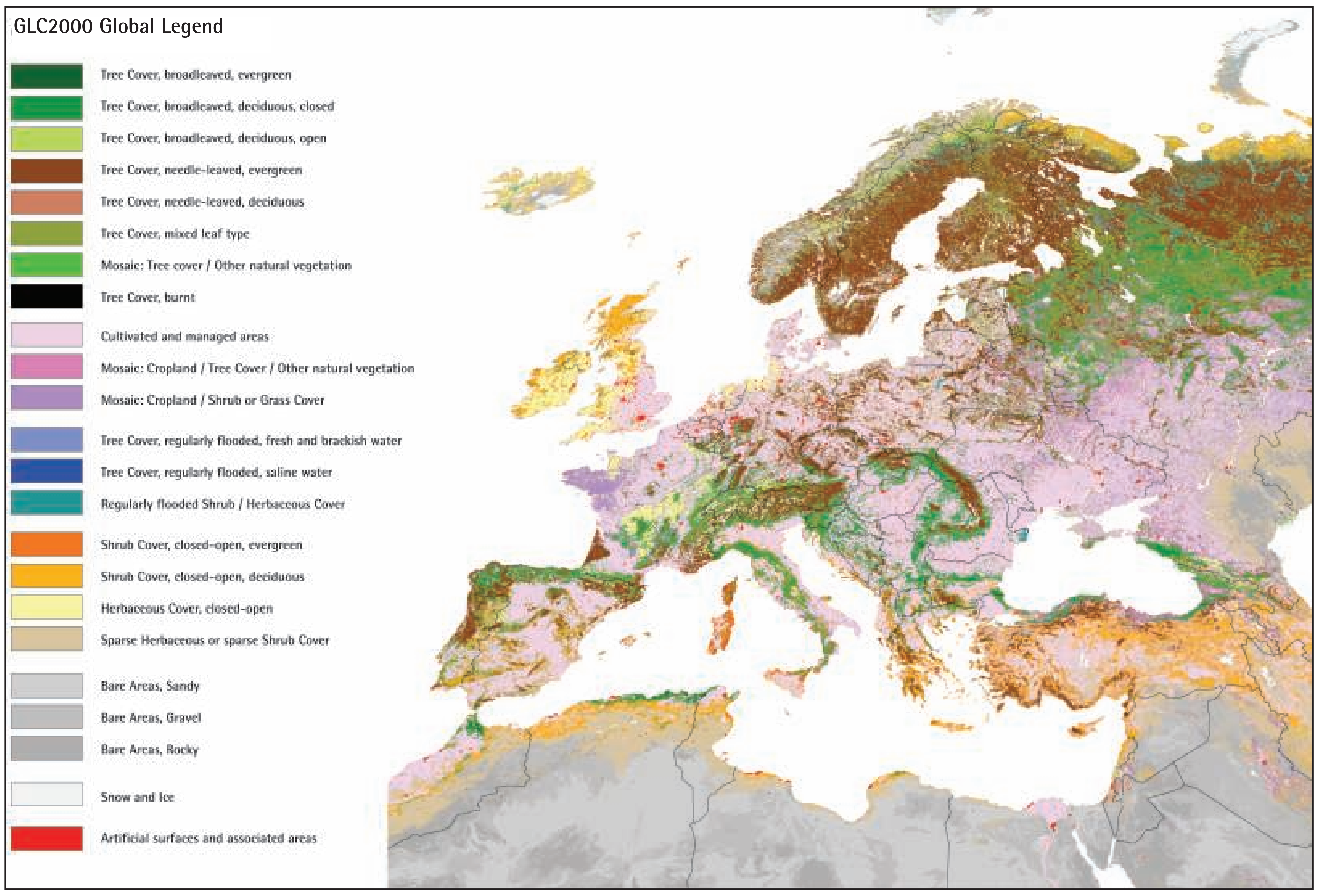
This map shows the major types of soil parent material across Europe (JDN). The term clastic refers to sedimentary deposits that are composed of fragments of broken rocks that have been eroded, transported and re-deposited at another site (e.g. conglomerates, sandstone). The term chemical sedimentary rocks indicate that the deposits were chemically precipitated, evaporated or organogenic in origin (e.g. limestone, chalk, gypsum). Igneous rocks are formed from crystallised magma and include granite, basalt and volcanic material. Metamorphic rocks have undergone a change in chemical and physical properties due to exposure to high temperature and/or pressure after they were formed (e.g. marble, slate). Unconsolidated deposits are the most recent geological deposits and consist of alluvium, weathering residuum and slope deposits (e.g. river terraces). The dark blue areas on the map indicate areas affected by glacial or periglacial conditions that are characterised by glacial till, boulder clay and glacio-fluvial sands and gravels. Eolian deposits are wind deposited materials such as loess while typical organic parent materials are peat and coal.



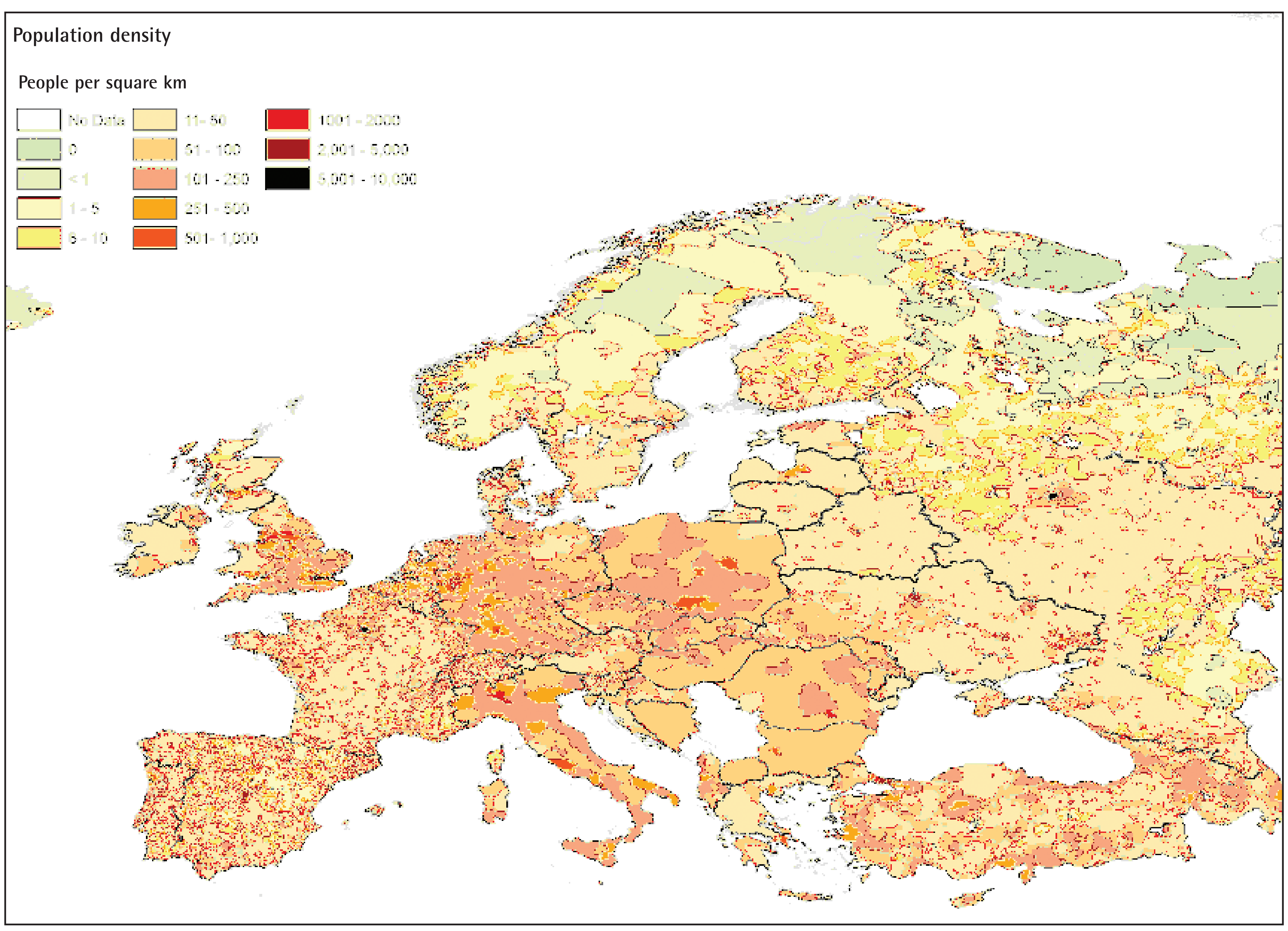
The dark blue tones indicate areas of high rainfall. There is a strong relationship between the amount of rainfall and the characteristics of the soil. The blocky nature of the map is due to the fact that the rainfall data are representative for 50 km cells (UNEP).



This map shows the yearly average of the ambient temperature for period 1995-2003 (degrees C) across Europe. The map represents interpolated data from the MARS database. Dark blue areas indicate cooler temperatures whilst the yellows and red of the Mediterranean region indicate warmer conditions (MS).

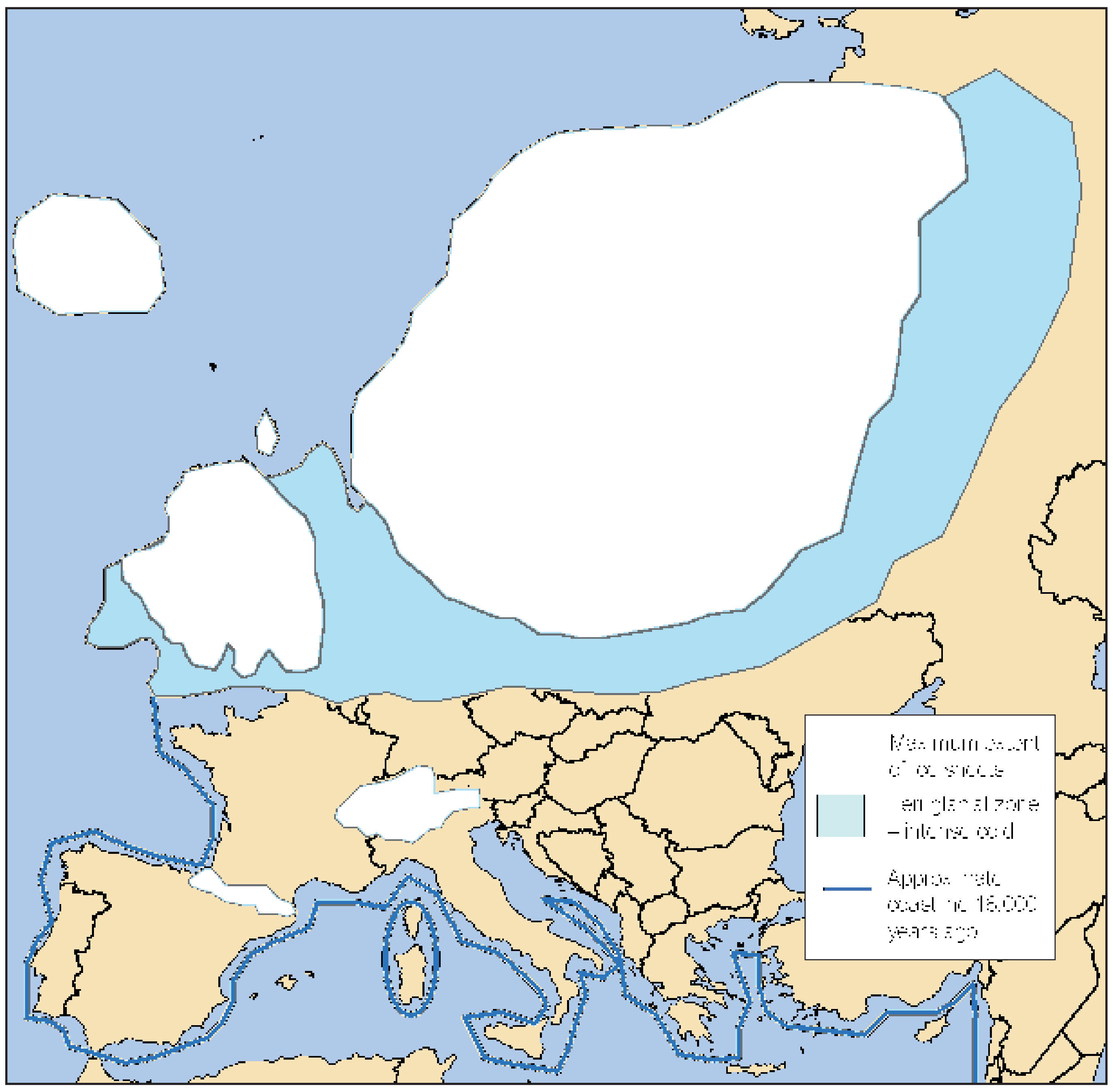


This map shows land cover of Europe from the GLOBAL LAND COVER 2000 Project. This map has been derived from data acquired by the VEGETATION sensor on board the SPOT 4 satellite. The map has a nominal resolution of 1 km (AB).



This map shows the population density of Europe in terms of people per square kilometre. The dark red areas on the map indicate the densely populated urban areas where soil sealing is an issue (UNEP).

Supporting maps



This map show the extent of the last ice age in Europe. A major factor that defines the parent material and characteristics of many soil types in northern and central Europe (SB).

Soil Education

This publication clearly sets out the importance of understanding our soil. Along with air and water , soil is a fundamental element of the world around us. If we are to manage the Earths resources in a responsible and sustainable manner then soil education must be introduced from an early age.

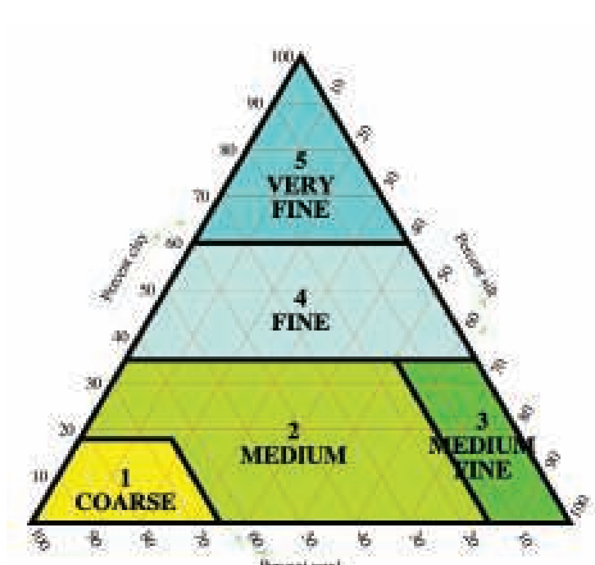
Several resources in particular set out to do this. The Soil-Net initiative, found at www.soil-net.com provides information and resources aimed at teachers and school students from 5 to 16 years old while the Soil Exhibition at Osnabruck in Germany, www.bgr.de/schoelerberg/start.htm, provides visitors with a unique insight in to the soil habitat.

Soil Texture

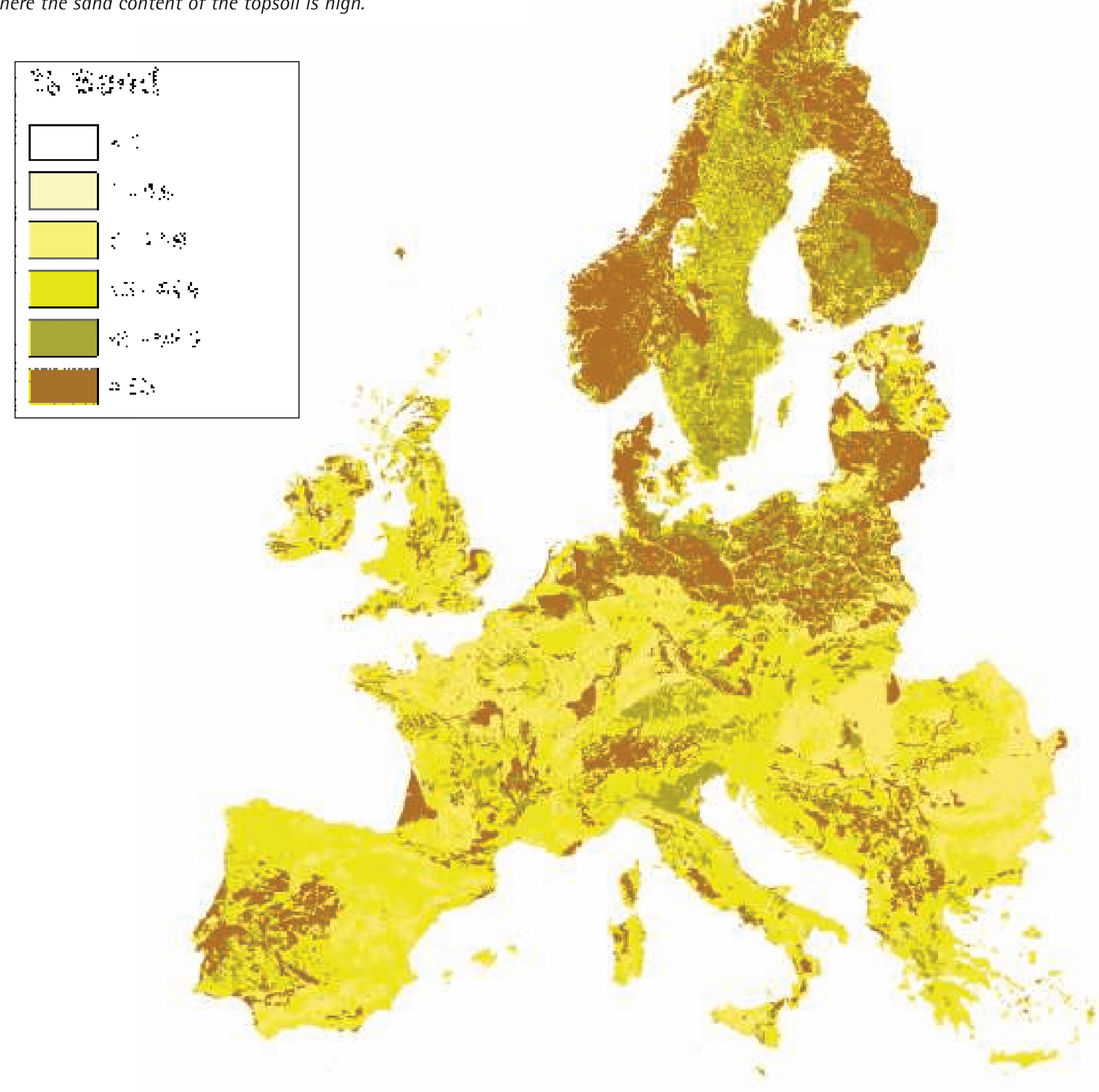
As described in the introduction to the Atlas, soil texture is an important parameter that can govern soil forming processes, soil structure and how the soil can be used. Soil texture is a measure of the size of the different mineral particles ñ the main size grades being sand, silt and clay. Silt and clay are determined by sedimentation by immersing air-dried soil in a column of distilled water, organic matter and carbonate being removed first. Sand is determined by using a stack of sieves that become finer towards the base. The sieves are vibrated allowing the smallest particles to fall to the bottom. The proportion of sand retained on each sieve is then weighed.

The particle size-grades most commonly used by soil scientists throughout the world are defined according to the equivalent spherical diameter as follows: gravel 2 mm-2 cm, coarse sand 0.5-2 mm, medium sand 0.2-0.5 mm, fine sand 0.2-0.05 mm, silt 0.05-0.002 mm, clay <0.002 mm.

The soil texture class can then be represented on a triangular diagram as percentages of sand, silt and clay. For example, a soil sample with 40% sand, 30% silt and 30% clay is described as medium texture according to the FAO texture triangle below, or a clay loam on a more detailed texture triangle in use by national soil surveys.



The map to the right shows the distribution of sandy topsoil across western Europe (RH). The dark red areas indicate regions where the sand content of the topsoil is high.



Further reading

This page contains references and web links to additional information on the soil resources of Europe. Some of these documents are in the language of the country and the research reports of the European Soil Bureau are available at: http://eusoils.jrc.it/

EUROPEAN SOIL BUREAU RESEARCH REPORTS

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Additional Information

Glossary of soil terms

absorption: Uptake of matter or energy by a substance

acid soil: Soil with a pH value less than 7.0.

acidification: Process whereby soil becomes acid (pH < 7) because acid parent material is present or in regions with high rainfall, where soil leaching occurs. Acidification can be accelerated by human activities (use of fertilisers, deposition of industrial and vehicular pollutants).

adsorption: Process by which atoms, molecules or ions are retained on the surfaces of solids by chemical or physical bonding.

aeration of soil: Amount of air-filled pores in the soil, expressed as the volume difference between total porosity and actual soil moisture. Optimum soil aeration is 30% but strongly depends on the structure and packing state of soil particles; 15–20% is normally satisfactory for the growth of grasses and cereals; below 10% is not good for plant growth.

aggregate: Soil aggregate consisting of two or more soil particles bound together by various forces.

aggregation: Process whereby primary soil particles (sand, silt, clay) are bound together, usually by natural forces and substances derived from **root exudates** and microbial activity. Soil aggregates are arranged to form soil peds, units of soil structure, classified by size, shape (platy, prismatic, columnar, angular, subangular, blocky, granular…) and grade (single-grain, massive, weak, moderate, strong). From an agronomical point of view, the most important soil aggregates are in range 3 – 1 mm.

anion: Particle with a negative charge. See also **ion, cation.**

anion exchange capacity: Sum of exchangeable anions that a soil can adsorb. Usually expressed as centimoles, or millimoles, of charge per kilogram of soil (or of other adsorbing material such as clay).

arable land: Agricultural land that is cultivated by ploughing, usually to 20 or 30 cm depth. More than 30 cm represents deep ploughing.

Black Earth: Term synonymous with Chernozem used (e.g. in Australia) to describe self-mulching black clays.

bog: Wetland that has no significant inflows or outflows, supports acidophilic mosses, particularly Sphagnum and in which peat is accumulating. Similar to: **fen, marsh, pocosin, swamp,** and **wetland.**

boulder clay: Unstratified glacial deposits laid down directly beneath the ice or dropped from the surface as the ice melted; boulder clay and till are synonymous terms for this unsorted material which ranges from rock flour to rocks and boulders of great size, according to the nature of the bedrock

calcification: Process whereby the soil is kept sufficiently supplied with calcium to saturate the soil cation exchange sites.

capillary water: Water in capillary pores influenced by forces that hold water in soils against a tension usually greater than 60cm. Capillary water can move upwards against gravity.

carbon cycle: Sequence of transformations whereby carbon dioxide is converted to organic forms by photosynthesis or chemosynthesis, recycled through the biosphere (with partial incorporation into sediments), and ultimately returned to its original state through respiration or combustion.

cation: Particle with positive charge; reactions between **anions** and cations create electrical forces.

cation exchange: Interchange between a cation in solution and another cation in the boundary layer between the solution and surface of negatively charged material such as clay or organic matter.

clay: Soil particle smaller than 0.002mm or 2µm, with high specific area mainly influencing soil **colloidal properties** (see also colloid) as well as stability of soil structure: high stability in both wet and dry conditions; also a soil texture class.

clay coating/film: Coatings of oriented clay on the surfaces of peds and mineral grains and lining pores, also called clay skins, clay flows, illuviation cutans, or argillans.

clay loam: Soil texture class. See also **soil texture.**

clay minerals: Clay-sized hydrous aluminium silicates having a large interlayer space that can hold significant amounts of water and other substances; they have large a surface area allowing **swelling** and **shrinking;** examples are montmorillonite or smectite and kaolinite.

coating: Layer of a substance completely or partly covering a surface of soil material; coatings can comprise clay, calcite, gypsum, iron, organic material, salt, etc.

colloid: Particle, which may be a molecular aggregate, with a diameter of 0.1 to 0.001 µm; clay and soil organic matter are often called soil colloids because they have particle sizes that are within, or approach, colloidal dimensions.

colluvial: Pertaining to material or processes associated with transportation and/or deposition by mass movement (direct gravitational action) and local, unconcentrated runoff on slopes and/or at the base of slopes.

colluvium: Unconsolidated, unsorted colluvial material.

decalcification: Removal of calcium carbonate or calcium ions from the soil by leaching.

diagnostic horizon: see **horizon.**

electrical conductivity (EC): Conduction of electricity through water or a solution of soil, commonly used to estimate the soluble salt content in solution, e.g. soil solution.

erosion: The wearing away of the land surface by water, wind, ice, gravity or other natural or anthropogenic agents that abrade, detach and remove soil particles or rock material from one point on the earth's surface, for deposition elsewhere, including gravitational creep and so-called tillage erosion.

feldspar: Group of hard crystalline minerals that consist of aluminum silicates of sodium or calcium or barium.

fen: Flat and swampy land, usually low in altitude and similar to a **bog** or **marsh.**

fertilization: Application of mainly mineral compounds, in order to increase soil fertility. In some cases, (e.g. liming) the purpose of fertilization is also to improve specific soil properties (pH, stability of soil structure).

field capacity: Field capacity has been defined as the soil moisture state when, 48 hours after saturation or heavy rain, all downward movement of water has ceased. It is the water content retained at low suctions (5-33kPa) depending on soil type, and is the upper limit of plant available water.

fine texture: (i) A broad group of textures consisting of, or containing, large quantities of fine fractions, particularly silt and clay. Includes sandy clay, silty clay, and clay texture classes. (ii) When used in reference to family particle-size classes in U.S. and FAO soil taxonomy, is specifically defined as having 35 to 60 percent clay. See also **soil texture.**

fluvioglacial deposits: Material moved from the margins of glaciers and subsequently sorted and deposited by streams flowing from the melting ice.

geomorphology: Science of landforms that studies the evolution of the Earth's surface and interprets landforms as records of geological history.

gibbsite: $Al(OH)_3$. Mineral with a platy structure, that occurs in highly weathered soils and in laterite.

glacial drift: Unstratified deposits laid down directly beneath the ice or dropped from the surface as the ice melted.

glaciers: Large masses of ice that form by the compaction and recrystallization of snow under freezing conditions; glaciers often move downslope or outward in all directions because of the stress of their own weight; they may be stagnant or retreating under warming conditions.

glaciofluvial deposits: Material moved by glaciers and subsequently sorted and deposited by streams flowing from the melting ice. The deposits are stratified and may occur in the form of outwash plains, deltas, kames, eskers, and kame terraces. See also **glacial drift** and **till.**

glaciolacustrine deposits: Material ranging from fine clay to sand derived from glaciers and deposited in glacial lakes by water originating mainly from the melting of glacial ice; many such deposits are bedded or laminated with varves.

gley soil: Soil formed under naturally wet or waterlogged conditions as evidenced by grey colours stemming from the reduction, under anaerobic conditions, of ferric iron to the ferrous state.

ground water: That portion of the water below the surface of the ground at a pressure equal to, or greater than, that of the atmosphere. See also **water table.**

gully: Channel resulting from erosion and caused by the concentrated but intermittent flow of water during and immediately following heavy rainfall; gullies are deep enough (usually >0.5 m) to interfere with, but not obliterated by, normal **tillage** operations.

horizon: Single layer in soil profile with similar properties or material but which differs at least in one property, e.g. colour or texture from adjacent horizons above or below in the profile; **diagnostic horizon:** Dominant soil property or material defines name of horizon, e.g. gypsic horizon having distinct calcium sulfate (gypsum: $CaSO_4$) enrichment; **genetic horizon** depending on the type of **pedogenesis.**

humification: Process whereby the carbon of organic residues is transformed and converted to **humic** substances through biochemical and abiotic processes.

humus: Organic compounds in soil, exclusive of undecayed plant and animal tissues, their partial decomposition products, and the soil biomass; a term often used synonymously with soil organic matter, its structure is amorphous, specific weight is low and surface area high. Humus is important for soil fertility, and helps to bind soil particles and aggregates together.

hydromorphic soils: Formed under conditions of poor drainage in marshes, swamps, seepage areas or flats.

ion: Electrically charged atom or group of atoms.

karst: Topography with sinkholes, caves and underground drainage that is formed in limestone, gypsum or other rocks by dissolution (dissolving).

landslide: A general term for a **mass movement** landform and a process characterized by moderately rapid to rapid (greater than 30 cm per year) downslope transport by means of gravitational stresses, of a mass of rock and regolith that may or may not be water saturated.

leaching: Removal of soluble materials from one zone in soil to another via water movement in the profile.

loess: Material transported and deposited by wind and consisting of predominantly silt-sized particles, forming important fertile soils.

map scale: Relationship between a certain distance on the map and the corresponding distance on the ground (e.g. 1:10,000, which means 1 cm on the map equals to 10,000 cm or 100 m on the ground); the scale is usually located in the legend box of a map.

marsh: A transition zone between water and land usually covered by grass.

mass movement: Dislodgement and downslope transport of soil and rock material as a unit under direct gravitational stress; includes slow displacements, such as creep and solifluction, and rapid movements such as landslides, rock slides, earthflows, debris flows and avalanches; water, ice and to a lesser extent air usually play an important role in the process.

moderately-fine textured: Texture group consisting of clay loam, sandy clay loam and silty clay loam textures; see also **soil texture.**

monolith: Representative vertical section taken from vertical face of a soil profile pit or section, which represents arrangement of soil horizons; there are various methods of how to take and conserve soil monoliths.

Munsell Color System: Colour designation system that specifies the relative degrees of the three simple variables of colour: hue (wavelength), value (degree of lightness or darkness), and chroma (purity or strength). For example: 10YR 6/4 is a colour (of soil) with a hue = 10YR, value = 6, and chroma = 4.

organic soil material: Consists of organic debris that accumulates at the surface under either wet or dry conditions and in which any mineral component present does not significantly affect the soil properties. Organic soil material must have organic carbon (organic matter) contents as follows: (1) if saturated with water for long periods (unless artificially drained), and excluding live roots, either: 18 % organic carbon (30 % organic matter) or more if the mineral fraction comprise 60 % or more clay; or 12 % organic carbon (20 % organic matter) or more if the mineral fraction has no clay; or a proportional lower limit of organic carbon content between 12 and 18 % if the clay content of the mineral fraction is between 0 and 60 %; or (2) if never saturated with water for more than a few days, 20 % or more organic carbon.

organic soil: A soil in which the sum of the thicknesses of layers comprising organic soil materials is generally greater than the sum of the thicknesses of mineral layers.

parent material: Mineral or rock material on and/or from which soils are formed during pedogenesis (soil formation process); parent material is one of the five major soil forming factors.

pasture: Grassland used for grazing of mainly domestic herbivores.

peat: Organic soil material with more than 50% of organic matter derived from plant residues with not fully destroyed structure. Peat forms in a wet soil environment or below the water table where mineralisation of organic matter comes close to zero; a peat horizon or layer is normally more than 30cm thick.

peatland: A generic term for any wetland where partially decayed plant matter accumulates; mire, moor and muskeg are terms used for peatlands in Europe and Canada; see also **bog** and **fen**.

pedogenesis: Process of soil formation and development by soil forming factors: climate (mainly temperature and precipitation), parent material, living organisms (plants and biota), topography, time, water and Man.

pedon: A three-dimensional body of soil with lateral dimensions (1 to 10 m^2) large enough to permit the study of horizon shapes and relations.

periglacial: Pertaining to processes, conditions, areas, climates and topographic features occurring at the immediate margins of glaciers and ice sheets and influenced by cold temperature of the ice.

permafrost: (i) permanently frozen subsurface material underlying the solum; (ii) perennially frozen soil horizon where temperature remains below 0°C throughout the year and in which Cryosols form.

permanent grassland: Natural (mainly steppe areas) or agricultural soils with grass cover not normally ploughed.

ploughing (tillage): mechanical cultivation of agricultural soils by the plough to different depths (20 – 30cm) deep, creating arable land.

pocosin: A bog formed in shallow depressions with poor drainage, supporting predominantly evergreen shrubs or small trees.

primary mineral: A mineral that has not been altered chemically since crystallization and deposition from molten lava. See also **secondary mineral.**

protection of soil: Conscious process necessary for soil and soil properties preservation realised at different levels (personal, local, national, continental) and using information obtained by soil research. Sustainability is the result of this process.

regolith: The unconsolidated mantle of weathered rock and soil material on the Earth's surface, sometimes considered to be loose earth materials above solid rock.

root exudates: Substances released from plant root system in drops or small quantities of carbohydrates, organic acids, vitamins and many other substances essential for life of **soil micro-organisms.**

saline soil: A non-**sodic soil** (see sodic soil) containing sufficient soluble salt to adversely affect the growth of most crop plants. The lower limit of electrical conductivity in the saturation extract of such soils is conventionally set at 4 dS m-1(at 25°C), though sensitive plants are affected at about half this salinity and highly tolerant ones at about twice this salinity.

saline-sodic soil: Salt-affected soils with a high exchangeable sodium percentage (ESP) greater than 15%, pH usually less than 8.5; in general these soils are not suitable for agriculture.

sand: Soil particles between 0.05 mm and 2 mm (in some countries 0.06 mm is the lower size limit), with low specific area and also used as a texture class name for coarse soil materials. Unlike clays, sandy soils do not shrink and swell on drying and wetting and, unless artificially compacted, are rapidly permeable.

salt-affected soil: Soil that has been adversely affected by the presence of soluble salts, with or without high amounts of exchangeable sodium. See also **saline soil, saline-sodic soil,** and **sodic soil.**

secondary mineral: A mineral resulting from the decomposition of a primary mineral or from the reprecipitation of the products of decomposition of a **primary mineral.**

silt: Soil particles between 0.002 mm and 0.05 mm (in some countries 0.06 mm is the upper size limit), with high or medium-high specific area influencing stability of soil structure; also used as a texture class name for medium and medium-fine soil materials.

sodic soil: Soil with excess of sodium, pH is higher than 7, usually in the range 8 - 10, exchangeable sodium percentage, ESP> 15 and very poor soil structure. These soils need special management and are not used for agriculture; non-**sodic soils** are without excess of sodium.

soil biology: A scientific discipline dealing with living components of soils, which are represented mainly by bacteria, fungi, protozoa, nematodes, arthropods and earthworms as well as by mammals.

soil chemistry: A scientific discipline dealing with chemical properties of soils and studies on the influence of fertilizers, pesticides and the other chemical substances applied on or into the soil on soil behaviour and fertility.

soil classification: Also termed soil taxonomy, is the scientific discipline dealing with grouping of soils into soil morphological units or soil types, according to similar or comparable soil forming properties. Many countries in the world have national soil classification systems but those of FAO, WRB and USDA are used internationally. For transnational comparisons, an international soil classification system, into which the majority of national systems can be translated, is needed. In future, this will be the WRB.

soil colour: soil colour is one of the indicators of soil status and depends on many factors, mainly on the amount and state of organic matter and iron oxide, as well as amount of air and water in soil pores; In general, dark soils have high organic matter content, grey soils are waterlogged or anaerobic, brown soils are well-drained and aerated soils. Soil colour is measured using **Munsell Soil Color charts.**

soil compaction: changing the nature of the soil such that there is a decrease in the volume of voids between soil particles or aggregates; it is manifest as an increase in bulk density and a severely compacted soil can become effectively impermeable. Some soils are naturally compacted, e.g. very heavy textured soils (fine textured). Man-made compaction is caused by the passage of heavy machinery and very intensive soil exploitation.

soil cracks: Openings in horizontal (mm or several cm) and vertical (cm or several m) orientation, mainly affecting soil hydraulic properties, arising from **swelling** and **shrinking** processes. Heavy clay soils are more susceptible to cracks formation than loamy soils whereas in sandy soils cracks do not form or they are very small and unstable. Soil cultivation destroys crack system, mainly by **tillage.**

soil degradation: Negative process often accelerated by human activities (improper soil use and cultivation practices, building areas) that leads to deterioration of soil properties and functions or destruction of soil as a whole, e.g. **compaction, erosion,** salinisation.

soil depth: depth of soil profile from the top to parent material or bedrock or to the layer of obstacles for roots. It differs significantly for different soil types. It is one of basic criterions used in soil classification. Soils can be very shallow (less than 25 cm), shallow (25 cm-50 cm), moderately deep (50 cm-90 cm), deep (90cm-150 cm) and very deep (more than 150 cm).

soil fertility: A measure of the ability of soil to provide plants with sufficient amount of nutrients and water, and a suitable medium for root development to assure proper plant growth and maturity.

soil geography: Scientific discipline dealing with distribution of soil types in landscapes, describing this distribution according to geographical rules.

soil micro-organisms: Represented by protozoa, viruses, bacteria, fungi and algae. The most prevalent are bacteria and fungi, and depending on conditions (water and nutrients content, temperature, etc.) they can be in an active or non-active state. According to nutrient (and oxygen) demand, micro-organisms are divided to *autotropic* and *heterotrophic*, (*aerobic* and *anaerobic*) groups. Micro-organisms are a good indicator of soil status and quality.

soil monitoring: Repeated observation and measurement of selected soil properties and functions, mainly for studying changes in soil conditions.

soil morphology: Form and arrangement of pedological features.

soil organic matter: The organic fraction of the soil exclusively comprising undecayed plant and animal residues. See also **humus.**

soil physics: Scientific discipline dealing with physical properties of soil (density, porosity, water retention and permeability, hydraulic conductivity etc.).

soil porosity: Volume of water and air that can be held in a soil; ratio of the volume of voids to the total volume of the soil.

soil profile: Vertical section of soil horizons from upper layer to the parent material, showing the arrangement (configuration) of soil horizons typical for single soil types and used as a basis for soil classification.

soil sorption: Selective process, which occurs on soil particles smaller than 0.002mm (<2µm); these small particles have colloidal properties, are able to hold and exchange ions, water or gases.

soil texture: Numerical proportion (% by wt.) of sand, silt and clay in a soil. Sand, silt and clay content are estimated in the field, and/or quantitatively in the laboratory, and then placed within the texture triangle to determine soil texture class. Texture can be coarse (sand particles predominate), medium (silt particles predominate), or fine (clay particles predominate).

stoniness: It is the relative proportion (vol %) of coarse particles (larger than 2 mm diameter) in the soil or on soil surface; 15% stones is a high value and can hinder cultivation and reduce water holding capacity.

surface soil: the layer of soil occurring on the surface, synonym **topsoil.**

swamp: Seasonally flooded low land. Similar to **marsh,** but with more woody plants and to **bog** but with better drainage.

swelling and shrinking: Two opposite processes of soil volume change. Swelling, increase of soil volume, shrinking, decrease of soil volume. These processes are influenced by actual water content and presence of clay minerals, which are able to take or to lose water in their interlayer spaces. Difference in volume can range from 5% to more than 100% depending on quality and quantity of clay minerals.

tidal flats: Nearly flat areas, periodically covered by **tidal** (periodical) waters, not suitable for agricultural use.

till: see **boulder clay**

tillage: see ploughing.

topsoil: (i) The surface soil horizon (A) which is modified when cultivated, and designated Ap. See also **surface soil.** (ii) Fertile soil material used to topdress roadbanks, gardens, and lawns.

vadose water: Water in the **vadose zone**.

vadose zone: The aerated region of soil above the permanent water table.

water retention: The ability of soil to hold water for a period that is longer than infiltration, normally 48h in a freely draining soil. It strongly depends on organic matter and bulk density. Soil texture also has an influence on water retention.

water table: The upper surface of ground water or that level in the ground where the water is at atmospheric pressure.

weathering: The breakdown and changes in rocks and sediments at or near the Earth's surface produced by biological, chemical, and physical agents or combinations of them.

wetland: A transitional area between aquatic and terrestrial ecosystems that is inundated or saturated with water for long enough periods to produce hydric soils and support hydrophytic vegetation. See also **bay, bog, fen, marsh, pocosin, swamp,** and **tidal flats.**

wilting point: Soil moisture content when the rate of absorption of water by plant roots is too slow to maintain plant turgidity and permanent wilting occurs. The average moisture tension at the outside surface of the moisture film around soil particles when permanent wilting occurs is 15 atmospheres or 1500kPa.

The Joint Research Centre

The mission of the JRC is to provide customer-driven scientific and technical support for the conception, development, implementation and monitoring of EU policies.

As a service of the European Commission, the JRC functions as a reference centre of science and technology for the Union. Close to the policy-making process, it serves the common interest of the Member States, while being independent of special interests, whether private or national.

The JRC

Europe faces public concern about complex issues such as food contamination, genetic modification, chemical hazards, global change, environment and health, and nuclear safety. The Joint Research Centre (JRC) supports EU policy makers in the conception, development, implementation and monitoring of policies to tackle such trans-national and global problems. In effect, the JRC is a research-based policy support organisation working for the EU policy-maker.

A research-based policy support organisation

More than 25% of EU legislation has a technical or scientific basis and this trend is likely to grow as increasingly policies cut across several disciplines. The JRC as the Commission's in-house research based policy support centre works to provide such support throughout the policy process, while maintaining a strong science base. The JRC's Multi-Annual Workprogramme for the Sixth Framework Programme, adopted in March 2003, reflects this user emphasis while also allowing the development of new scientific competence to meet emerging trends.

Examples of JRC support include the following:
Support to the new Chemicals policy, jointly led by the Commission's Environment and Enterprise DGs. JRC is helping to develop the guidance documents, software tools and infrastructure for REACH (Registration, Evaluation and Authorisation of Chemicals).

As the Community Reference Laboratory (CRL) for GMOs, JRC provides support to implementing EU policy on GM food and feed. JRC is assisted in this task by the European Network of GMO Laboratories.

With DG Environment, JRC has developed the European Forest Fire Information System (EFFIS), a coherent fire information system across Europe. A European flood forecasting system is also under development.

Contributing to ERA

The JRC is contributing to the goals of the European Research Area (ERA). This contribution is built around five major activities:

- common scientific reference systems,
- networking,
- training and mobility,
- access and use of research infrastructures,
- enlargement

These activities are embedded in the JRC's own workprogramme and form the basis of JRC's ERA Action Plan. The Action Plan sets a number of strategic goals for the JRC, with particular focus on the JRC's role in the European Research Area (ERA). Based upon this strategy the Plan identifies a set of actions and targets to be undertaken in order to position the JRC as a prominent research organisation within the ERA. These actions and targets have been defined to ensure an integrated and coherent approach towards the ERA, and address the whole range of the JRC's work for period 2003 – 2006.

Supporting EU enlargement

The JRC supports Enlargement Action works to provide support to the scientific and technical aspects underpinning EU legislation in the fields of environment, health, food, renewable energy, chemicals, agriculture and nuclear safety.

This work is aimed at accelerating uptake of the 'acquis communautaire' the body of EU legislation which new Member States must adopt and implement. JRC is actively assisted in this Action, through National Contact Points, scientific attachés, and participants from the JRC Board of Governors from the new Member States.

Initiatives undertaken by JRC include programmes of workshops and training courses, hosting scientists at JRC sites and information events.

The Joint Research Centre is a research based policy support organisation and an integral part of the European Commission. We are a Directorate General, providing the scientific advice and technical know-how to support EU policies. Our status as a Commission service, which guarantees our independence from private or national interests, is crucial for pursuing our mission.

Our institutes carry out extensive research of direct concern to European citizens and industry. Over the years, the JRC has developed special skills and unique tools to provide autonomous and Europe-wide expertise to improve understanding of the links between technology, the economy and society. Our activities range from the assessment of safety standards for children's toys and improved biomaterials for hip implants to new technologies for recycling water and the use of satellite systems to monitor land use and deforestation.

Our work is split between institutional research in support of Commission policymaking, direct support for specific Directorates-General (DGs) and competitive activities in strategic relationships with the scientific and business communities. Our guideline is that of 'adding value' where appropriate, rather than competing directly with establishments in the EU Member States.

The JRC consists of seven different institutes, each with its own focus of expertise, on five separate sites around Europe. The Institutional and Scientific relations provides co-ordination and serves as a link between the institutes and the policymakers.

http://jrc.cec.eu.int/

EUROPEAN COMMISSION
DIRECTORATE-GENERAL
Joint Research Centre

The Institute for Environment and Sustainability

Located in Ispra (Italy), the Institute for Environment and Sustainability (IES) is one of the institutes that constitute the Joint Research Centre of the European Commission.

In line with the JRC mission, the aim of IES is to provide scientific and technical support to European Union strategies for the protection of the environment contributing to a sustainable development.

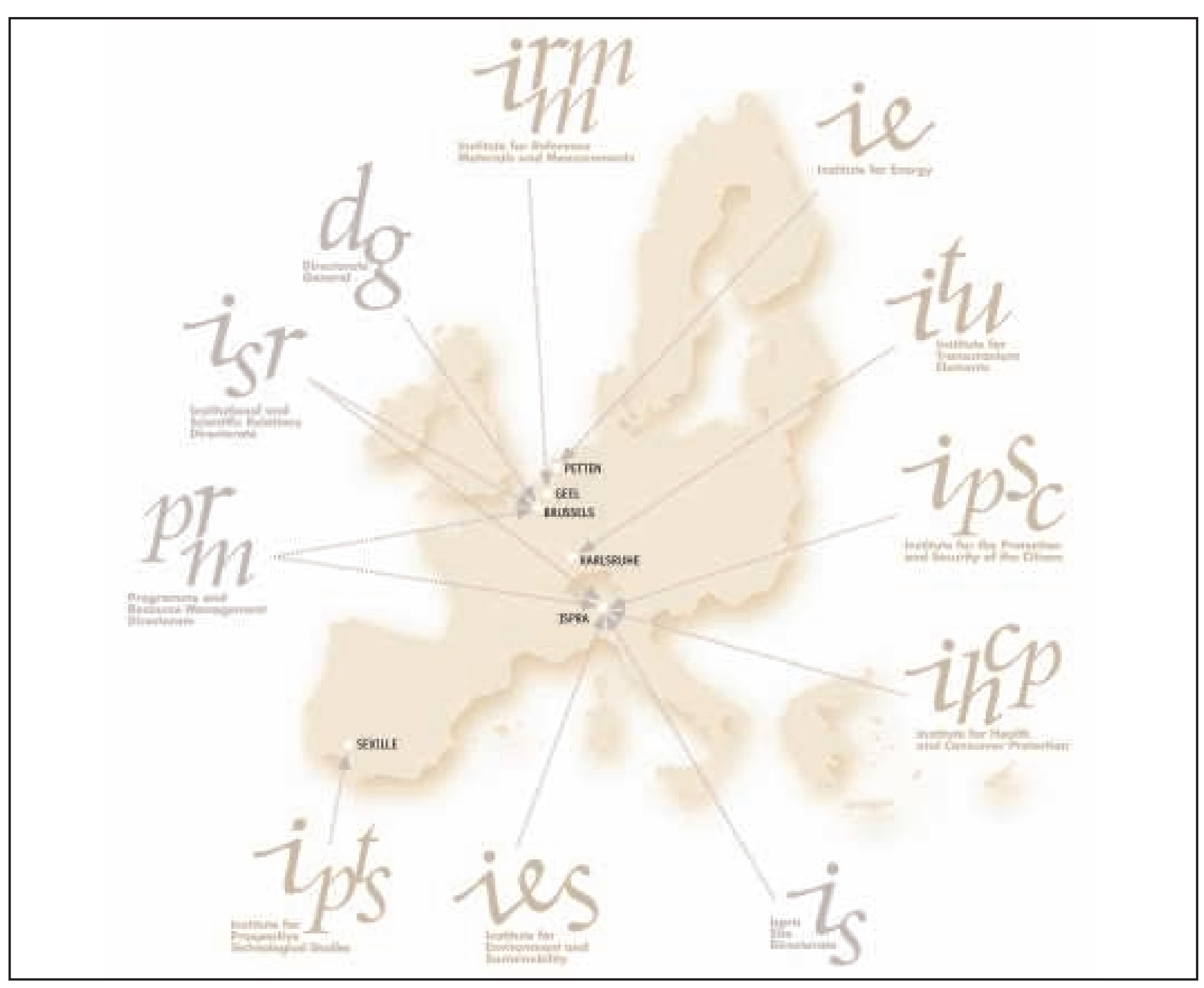
IES works in close collaboration with official laboratories, research centres and industries of the EU's Member States, creating a bridge between the EU's policies and the European citizen.

The combination of complementary expertise in the fields of experimental sciences, modelling, geomatics and remote sensing puts the IES in a strong position to contribute to the implementation of the European Research Area and to the achievement of a sustainable environment.

The mission of the Institute for Environment and Sustainability is to provide scientific and technical support to EU policies for the protection of the environment contributing to a sustainable development in Europe.

Institute for Environment and Sustainability
Joint Research Centre of the European Commission
TP 263
Via Fermium
I 21020 Ispra (VA)

Director: Manfred GRASSERBAUER
http://ies.jrc.cec.eu.int/



Additional Information

European Soil Bureau Network

If you are interested in learning more about the soils of your country or other countries, this page lists the contact details of the European Soil Bureau Network.

Secretary: Luca Montanarella
European Commission
Joint Research Centre
T.P. 280
I-21020 Ispra (VA)
ITALY
email: luca.montanarella@jrc.it

O. Arnalds
Agricultural Research Institute RALA
Keldnaholti
IS-112 Reykjavik
ICELAND
email: ola@rala.is

Arnold Arnoldussen
Norwegian Institute of Land Inventory
PB 115
N-1431 Ås
NORWAY
email: arnold.arnoldussen@nijos.no

Ferdo Basic
Faculty of Agriculture
Deptartment of General Agronomy
Svetosimunska c. 25
HR-10 000 Zagreb
CROATIA
email: fbasic@agr.hr

Stanislaw Bialousz
Warsaw University of Technology
Plac Politechniki 1
PL - 00-661 Warsaw
POLAND
email: s.bialousz@gik.pw.edu.pl

Pavol Bielek
Soil Science and Conservation Research Inst.
Gagarinova 10
SK-82713 Bratislava
SLOVAKIA
email: bielek@vupu.sk

Winfried Blum
University of Natural Resources and Applied Life Sciences (BOKU)
Gregor Mendel-Str. 33
A-1180 Vienna
AUSTRIA
email: herma.exner@boku.ac.at

Jaume Boixadera
Generalitat Servei d'Agricultura DARP
Seccio d'Avaluacio de Recursos i Noves Tecnologies
Alcade Rovira Roure 177
E-25006 Lleida
SPAIN
email: jaume.boix@macs.udl.es

Henrik Breuning-Madsen
Kobenhavns Universitet
Geografisk Institut
Oster Volgade 10
DK-1350 Kobenhavn
DENMARK
email: breuningmadsen@yahoo.dk

Vanda Valerija Buivydaite
Soil Science and Agrochemistry Department
Lithuanian University of Agriculture
Studentu St 11-22,
LT-53361 Akademija, Kaunas R.
LITHUANIA
email: vanda@nora.lzua.lt

Raoul Dudal
Institute Land and Water Management
Vital Decosterstraat 102
B - 3000 Leuven
BELGIUM
email: rudi.dudal@agr.kuleuven.ac.be

Wolf Eckelmann
Bundesanstalt für Geowissenschaften und Rohstoffe
Stilleweg 2
D-30655 Hannover
GERMANY
email: w.eckelmann@bgr.de

Alexandra Freudenschuß
Umweltbundesamt GmbH
Spittelauer Lände 5
A - 1090 Vienna
AUSTRIA
email: alexandra.freudenschuss@umweltbundesamt.at

Maria da Conceição Gonçalves
Estação Agronómica Nacional
Departamento de Ciência do Solo
Av. República 2784
P - 505 Oeiras
PORTUGAL
email: mc.goncalves@netc.pt

C. Hadjiparaskevas
Ministry of Agriculture, Natural Resources & Environment
Deptartment of Agriculture
3 Rafina
Cy-2039 Strovolos
CYPRUS
email: hadjipa@spidernet.com.cy

M. Yli Halla
Institute of Soils and Environment
Agricultural Research Centre
SF-31600 Jokioinen
FINLAND
email: markku.yli-halla@mtt.fi

John Hollis
National Soil Resources Institute
Cranfield University
UK - MK45 4DT Silsoe
UNITED KINGDOM
email: j.hollis@cranfield.ac.uk

Sigbert Huber
Umweltbundesamt GmbH
Spittelauer Lände 5
A - 1090 Vienna
AUSTRIA
email: sigbert.huber@umweltbundesamt.at

Juan-Jose Ibanez
Consejo Superior de Investigaciones Cientificas
Serrano 115 dpdo.
E - 28010 Madrid
SPAIN
email: jjibanez@ccma.csic.es

Selim Kapur
University of Cukurova
Department of Soil Science
TR - 01330 Adana
TURKEY
email: kapur@cu.edu.tr

Aldis Karklins
Latvia University of Agriculture
2 Liela Street
LV - LV-3001 Jelgava
LATVIA
email: karklins@cs.llu.lv

Mark Kibblewhite
National Soil Resources Institute
Cranfield University
UK - MK45 4DT Silsoe
UNITED KINGDOM
email: m.kibblewhite@cranfield.ac.uk

Dominique King
Institut National de la Recherche Agronomique
Unite de Science du Sol
Av. Pomme de Pin BP 20619, Ardon
F-45160 Olivet
FRANCE
email: dominique.king@orleans.inra.fr

Nikola Kolev
Institute of Soil Science N. Poushkarov
Shosse Bankya Str. 7
BG-1080 Sofia
BULGARIA
email: kolev_nv@hotmail.com

S. Kostadinov
Faculty of Forestry Belgrade Univ.
Department of Soil Erosion Control
Kneza Viseslava 1
YO-11 030 Belgrade
SERBIA & MONTENEGRO
email: kost@eunet.yu

Josef Kozak
Czech University of Agriculture
Kamycka 129
CZ - 165 21 Prague
CZECH REPUBLIC
email: kozak@af.czu.cz

Christine Le Bas
Unite de Science du Sol, INFOSOL
Av. Pomme de Pin BP 20619, Ardon
F-45160 Olivet
FRANCE
email: christine.le-bas@orleans.inra.fr

Sherif Lushaj
Soil Science Institute
Instituti i Studimit të Tokave
Tirana
ALBANIA
e-mail: ist@albmail.com

John Lee
Teagasc
Soils and Environment Centre
Johnstown Castle
Wexford
IRELAND
email: j.lee@johnstown.teagasc.ie

Franc Lobnik
University of Ljubljana
Jamnikarjeva 101
SLO - 1000 Ljubljana
SLOVENIA
email: franc.lobnik@bf.uni-lj.si

Donatello Magaldi
Universitá di L'Aquila
Piazzale Pontieri,1
I - 67040 L'Aquila
ITALY
email: magaldi@ing.univaq.it

Erika Micheli
Szent Istvan University
Pater K.1.
H - 2100 Godollo
HUNGARY
email: micheli.erika@mkk.szie.hu

Tatjana Mitkova
University St. Ciril and Methodius - Skopje Faculty of Agriculture
Department of Soil Science
Bul. Alexander Makedonski
MK-910 00 Skopje
REPUBLIC OF MACEDONIA
email: tmitkova@zf.ukim.edu.mk

Gerben Mol
Alterra Green World Research
Droevendaalsesteeg 3
NL - 6708 PB Wageningen
THE NETHERLANDS
email: gerben.mol@wur.nl

Christian Muller
Ministry of Environment
18, Montée de la Pétrusse
L - 2918 Luxembourg
LUXEMBOURG
email: christian.muller@mev.etat.lu

Ioan Munteanu
Research Institute for Soil Science and Agrochemistry
Bd. Marasti 61
RO-71331 Bucharest 32
ROMANIA
email: harti@icpa.ro, munteanu@icpa.ro

Jakob Nievergelt
Swiss Federal Research Station for Agroecology and Agriculture
Reckenholzstrasse 191, CH-8046 Zürich
SWITZERLAND
email: jakob.nievergelt@fal.admin.ch

Mats Olsson
Swedish University of Agricultural Sciences
Deptartment of Forest Soils
Box 7001
S-75007 Uppsala
SWEDEN
email: mats.olsson@sml.slu.se

Loit Reintam
Estonian Agricultural University
Viljandi Rd., Eerika
EST - 51014 Tartu
ESTONIA
email: loit@eau.ee

Husnija Resulovic
Faculty of Agriculture
Institute for Soil Science and Land Reclamation
Dolina 6
BA-71 000 Sarajevo
BOSNIA HERZEGOVINA
email: geodis@bih.net.ba

Sonya Sammut
Ministry for Rural Affairs and the Environment
Ghammieri
M - MRS02 Marsa
MALTA
email: sonia.sammut@gov.mt

Vladimir Stolbovoy
Department of Geography and Classification
Dokuchaev Soil Institute,
109017 Pyzhevski 7, Moscow
RUSSIA
email: vladimir.stolbovoy@jrc.it

Jan J.H. Van den Akker
Alterra, Wageningen UR
P.O. Box 47
NL - 6700 AA Wageningen
THE NETHERLANDS
email: janjh.vandenakker@wur.nl

Eric Van Ranst
Ghent University
Krijgslaan 281 (S8)
B - 9000 Ghent
BELGIUM
email: eric.vanranst@UGent.be

György Várallyay
Research Institute for Soil Science and Agricultural Chemistry
Herman Ottó út 15.
H - H-1022 Budapest
HUNGARY
email: g.varallyay@rissac.hu

Henk Wösten
Alterra, Wageningen UR
P.O. Box 47
NL - 6700 AA Wageningen
THE NETHERLANDS
email: henk.wosten@wur.nl

Nicholas Yassoglou
National Agricultural Reseach Foundation
Agricultural University of Athens
20 Vrilision
GR-15236 Old Penteli
GREECE
email: ynick@hol.gr

Pandi Zdruli
CIHEAM-IAMB
Via Ceglie 9
I - 70010 Valenzano (BA)
ITALY
email: pandi@iamb.it