7.3 Soil

Definition:

(INSPIRE, 2007) Soils and subsoil characterised according to depth, texture, structure and content of particles and organic material, stoniness, erosion, where appropriate mean slope and anticipated water storage capacity.

Description:

The proposed Soil Framework Directive (COM(2006) 232 final), which aims at the establishment of a framework for the protection of soil, specifies in *Article 1* that soil is "the top layer of the earth's crust situated between the bedrock and the surface, excluding groundwater as defined in Article 2(2) of Directive 2000/60/EC of the European Parliament and of the Council". In the Communication from the Commission regarding the Thematic Strategy for Soil Protection (COM(2006)231 final), it is mentioned that "soil is generally defined as the top layer of the earth's crust, formed by mineral particles, organic matter, water, air and living organisms. It is the interface between earth, air and water and hosts most of the biosphere".

As soil formation is an extremely slow process, soil can be considered essentially as a non-renewable resource. Soil provides us with food, biomass and raw materials. It serves as a platform for human activities and landscape and as an archive of heritage and plays a central role as a habitat and gene pool. It stores, filters and transforms many substances, including water, nutrients and carbon. In fact, it is the biggest carbon store in the world. These functions must be protected because of both their socio-economic and environmental importance.

Soil is an extremely complex and variable medium. Over 320 major soil types have been identified in Europe and within each there are enormous variations in physical, chemical and biological properties. Soil's structure plays a major role in determining its ability to perform its functions. Any damage to its structure also damages other environmental media and ecosystems.

Soil is subject to a series of degradation processes or threats. These include erosion, decline in organic matter, local and diffuse contamination, sealing, compaction, decline in biodiversity, salinisation, floods and landslides. A combination of some of these threats can ultimately lead arid or sub-arid climatic conditions to desertification."

Typically, **soil** is **characterized** on the basis of soil profile descriptions, analysed by taking samples from genetic horizons or depth classes, and classified according to national or international nomenclature. Soil maps contain the borders of typical combinations of soil development factors of the target mapping scale. There is no internationally defined aggregation scheme between the various map scales.

The collection of soil information can be broadly classified into three categories:

a) **Soil mapping**, enabling to identify areas of land for management purposes.
b) **Soil inventories**, providing a one-off assessment of soil conditions and/or properties at a point in time, and **soil monitoring**, providing a series of assessments showing how soil conditions and/or properties change over time.
c) **Soil thematic mapping**

(a) Soil maps

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

(b) Soil inventories and soil monitoring

Soil inventories (predominantly based on "soil profiles") provide information on the soil condition. It can be introduced to soil maps as attribute (semantic) data describing soil properties. Soil monitoring in national or Europe-wide grid systems, or in stratified sampling regimes, is designed to provide information about how soils are changing with time (see also INSPIRE Theme 'Environmental Monitoring Facilities'). Geochemical surveys also gather soil information and are specifically targeted to provide information on natural background values and on overimposed anthropic pollution.

(c) Thematic data/risk maps in soil protection and environmental reporting
The general adoption of GIS technology and the creation of databases of georeferenced soil information have allowed a number of new types of assessments producing more policy relevant information than the basic soil maps. For example, modelling approaches using the existing soil inventories allow deriving information like soil erosion risk, organic matter content, diffuse contamination, soil compaction, salinisation, etc.

Scope, use examples:

Soil maps: soil maps have been prepared for regional and national environmental assessment and reporting in **overview scales**, involving the scales 1:5,000,000 (Europe), 1:1,000,000 (Europe, countries), and 1:250,000 (countries, regions). On the basis of the work conducted by the European Soil Bureau Network (ESBN), the soil classification has been agreed to be the World Reference Base for Soil Resources (WRB) (FAO 2006). All three scales are used within the context of the European Soil Information System (EUSIS). Manuals have been developed by the European Soil Bureau Network to improve harmonized soil mapping in overview scales (Finke et al. 2001; Lambert et al. 2001).

In contrast to overview scales, **basic soil data/soil maps** are available throughout Europe (countries, regions) at different larger scales (scale > 1:50,000) and are using different classification systems, mapping reference dates, and map legends. They are the results of extensive national and regional soil surveys performed in the past 50 years, mostly for agricultural purposes (see also Jones et al. 2005). In order to facilitate comparability of these data, harmonization methods are needed which refer national nomenclatures to WRB (FAO 2006a, b).

Soil monitoring: There are only few examples in Europe at national or regional level of fully operational soil monitoring systems. Many of the national systems have performed only one observation in time, and therefore cannot be considered as fully operational systems. Van-Camp et al. (2004) conclude that a minimum set of common parameters to be monitored by the existing soil monitoring systems at national level still need to be selected. The same holds true for standardised methods and procedures. More information can be received in the review of existing soil monitoring systems by Huber et al. (2001), updated but unpublished by EEA/ETC-TE (2003). A recent update on existing soil monitoring schemes is found in Morvan et al. (2007, submitted). The FP6 ENVASSO project (www.envasso.com) develops an extensive manual with Procedures and Protocols for soil monitoring in Europe, to be available by the beginning of 2008.

For Europe as a whole, two main soil inventory activities are established: (1) the Geochemical Atlas of Europe provides information about the regional pattern and background values for 60 elements in the topsoil (Salminen et al. 2006). (2) The forest soil condition monitoring, conducted by the ICP Forests network (16x16 km grid; 1990-1995; see also Vanmechelen et al. 1995) has recently been repeated in the frame of the Forest Focus demonstration project BioSoil.
Thematic data: In order to facilitate the application of the soil data (i.e. to estimate integrative parameters difficult to measure, and to estimate the susceptibility of the soil to pressures), the European Soil Bureau Network (ESBN) developed a set of pedotransfer rules, available as a separate method compilation which comes with the 1:1,000,000 European Soil Database (Van Ranst et al. 1995; ESBN 1998). At national level, such rules and functions also exist, the most comprehensive compilation is found in Ad-hoc-AG Boden (2000).

Important feature types and attributes:

The basic scheme for soil data relies on soil profiles or soil cores. Depending on the respective soil nomenclature, macro-morphological characteristics of soil profiles or soil cores are described. Samples are taken for genetic horizons or depth classes, and analysed for soil chemical, soil biological and soil physical properties. Using this information, soil is classified in order to compare and describe different sites. The type of data in soil data bases varies greatly, between soil maps and resolutions, and between projects. As an example, within the Soil Geographical Data Base for Europe 1:1,000,000, soil information is provided for soil typological units (STU). At this geographical representation, it is technically not feasible to delineate each STU. Therefore STU's are grouped into Soil Mapping Units (SMU) to form soil associations. The criteria for soil groupings and SMU delineation have taken into account the functioning of pedological systems within the landscape. STU's characterize distinct soil types that have been identified and described by attributes (variables) specifying the nature and properties of the soils, for example the texture, the moisture regime, the stoniness, etc.

The mapping concept at a scale of 1:250,000 (as described in the Manual of Procedures, Finke et al. 2001) is slightly different in nature and distinguishes soil bodies and soilscapes. A soil body represents a portion of land with imprecisely known geographical limits. It describes a three-dimensional entity in a soil continuum using the WRB soil classification (FAO 1998), parent material, depth to obstacle for roots and dominant surface texture. Similar to the STU, the soil body thus contains the relevant attributes describing the soil. The soilscape is delineated at the 1:250,000 scale and groups the soil bodies.

The European Soil Regions Map 1:5,000,000 represents the regionally restricted part of the soil cover characterized by climate type and parent material (Finke et al. 2001).

Examples for feature types and attributes in European soil maps:

Soil Geographical Data Base for Europe 1:250,000	soil body soilscape	- soil attributes for genetic horizons of one or more **soil profiles** characterizing a soil body - dominant soil - major landform - regional slope - relief intensity - wetness index - dominant land use, etc.
Soil Geographical Data Base for Europe 1:1,000,000	soil mapping unit (SMU) and soil typological unit (STU)	- dominant soil - co-dominant soil - limitation to agricultural use - soil code - presence of an impermeable layer - dominant parent material - obstacle to roots - slope class - textural change - textural class - land use - presence, type of an existing water management system - soil water regime class - elevation above sea level, etc.

In addition, each mapping unit can be described based on additional soil properties received from described and/or analyzed soil profiles for the dominating and/or associated soil types.

Perspective for the collection and harmonzation of soil data at European level: the GRID approach:

The European Soil Database (ESDB), covering EU-25 has been developed jointly with European partners and is the only harmonized coverage of digital soil information for Europe. It is the result of a complex and time-consuming undertaking, due to the vast heterogeneity of soil data in countries. In the light of updates to such a database and of collecting data in relation to the upcoming Soil Framework Directive, simplification is needed through a more suitable technical framework. One idea is to conduct reporting of soil data on the basis of a hierarchical system of grids (or rasters) with a common point of origin and a standardized location and size of grid cells. This system constitutes a suitable framework for the building of a nested European system of soil data and facilitates interoperability through a common coordinate reference system, a unique grid coding system, a set of detailed and standardized metadata and an exchangeable and open format. It will lay the basis for a multi-scale European Soil Information System (MEUSIS), a system whereby soil data produced at a certain scale can easily be integrated or compared with soil data produced at another scale, provided that the rules for representation of the data are equal at all scales. In order to achieve this, a common standard for the collection of harmonized soil information is going to be developed and implemented. It should be stressed that, in order to provide soil data in grid format, country data providers most likely will need to process their original soil data, held in traditional vector-based soil databases, in order to fit a grid. The final result of MEUSIS developments will be the existence of a harmonized soil information system for Europe which will streamline better the flow of information from the data producer at a local or regional scale to the data users at higher scales (National, European and Global scales).

Overlaps and links with other themes

- Protected sites; area management/restriction/regulation zones and reporting units; habitats and biotopes; species distribution:
  soil conditions can be indirect delineation criteria (wet soils in combination with a specific vegetation type; soil conditions affecting historic land use, etc.)
- Elevation: important factor to soil formation
- Land cover, Land use, agricultural and aquacultural facilities: anthropogenic factors affecting the soil condition
- Geology: parent material is major soil forming factor; with regard to hydrogeology, soil physical characteristics control seepage water and run-off
- Environmental monitoring facilities: soil monitoring systems
- Natural risk zones: relevant in soil protection policies (landslides, floods); can cause important soil loss; soil condition (e.g. clay content) affects the susceptibility and severity of degradative processes
- Atmospheric conditions; meteorological geographical features: important site factor; controls soil processes
- Bio-geographical regions: regional stratification of soil forming conditions; used in soil mapping and soil information application

Reference documents:

Soil Data Specification and manuals

ESBN [European Soil Bureau, Scientific Committee] (1998). Georeferenced Soil Database for Europe: Manual of Procedures Version 1.0. EUR 18092 EN 184pp. (1998). Office for Official Publications of the European Communities, Luxembourg.

Finke, P., R. Hartwich, R. Dudal, J. Ibàñez, M. Jamagne, D. King, L. Montanarella and N. Yassoglou (2001) Georeferenced Soil Database for Europe: Manual of Procedures Version 1.1. European Soil Bureau, Scientific Committee. EUR 18092 EN 184 pp. Office for Official Publications of the European Communities, Luxembourg.

FSEP [Forest Soil Expert Panel] and FSCC [Forest Soil Coordinating Centre] (2003). Manual on methods and criteria for harmonized sampling, assessment, monitoring and analysis of the effects of air pollution on forests. Part IIIa - Sampling and Analysis of soil. Upgrade of the 4th edition of the ICP Forests manual. Version 4.0. UN/ECE Convention on Long-Range Transboundary Air Pollution Effects on Forests. Ghent, 2003.

Lambert, J.J., J. Daroussin, M. Eimberck, M. Jamagne, D. King and C. Le Bas (2001). Instructions Guide for the elaboration of the soil geographical database of Eurasia and Mediterranean countries at 1:1 million scale, Version 4.0. Office of the Official Publications of the European Communities, EUR 20422 EN, Luxembourg.

UN/ECE ICP Forests (1994). Manual on methods and criteria for harmonized sampling, assessment, monitoring and analysis of the effects of air pollution on forests. Hamburg, Prague, 1994.

Norwegian feature catalogue including a UML application schema for addresses (in the process of being translated to English):
http://www.statkart.no/sosi/UMLfullmodell/Jordsmonn/Jordsmonn.htm

Soil Classification (international)

FAO (1998): World Reference Base for Soil Resources. – World Soil Resources Reports 84, ISSN 0532-0488, 88 p., Food and Agriculture Organization of the United Nations, Rome, 1998.

FAO (Food and Agriculture Organization of the United Nations) (2006a): World reference base for soil resources 2006 - A framework for international classification, correlation and communication. World Soil Resources Reports 103. Food and Agriculture Organization of the United Nations, Rome, 2006.

FAO (Food and Agriculture Organization of the United Nations) (2006b): Guidelines for soil description, 4th ed. Rome.

Relevant reviews at European level:

Dobos, E., F. Carré, T. Hengl, H.I. Reuter and G. Toth (2006). Digital soil mapping as a support to the production of functional maps. European Soil Bureau Network: Digital Soil Mapping Working Group. EUR 22123 EN (2005). 68 pp. Office for Official Publications of the European Communities, Luxembourg.

Eckelmann, W., R. Baritz, S. Bialousz, F. Carre, B. Jones, M. Kibblewhite, J. Kozak, C. Le Bas, G. Toth, G. Varallyay, M. Yli Halla and M. Zupan (2005). Common Criteria for Risk Area Identification according to Soil Threats. Soil Information Working Group (SIWG) European Soil Bureau Network (ESBN). EUR 22185 EN, Office for Official Publications of the European Communities, Luxembourg.

Ad-hoc-AG Boden (coordination V. Hennings, 2000). Methodendokumentation Bodenkunde. Auswertungsmethoden zur Beurteilung der Empfindlichkeit und Belastbarkeit von Böden. - 2. Aufl., Geologisches Jahrbuch, SG 1; Hannover. [*Method documentation soil science: evaluation methods to assess the vulnerability and stress resistance of soils]*

Huber, S., A. Freudenschuss, and U. Staerk (2001). European Soil Monitoring and Assessment Framework. EIONET workshop proceedings. EEA Technical Report 67 (2001). 52 pp. European Environment Agency, Kopenhagen.

Jones, R.J.A., Houskova, B., Montanarella, L. and P. Bullock (2005). Soil Resources of Europe: including Neighbouring Countries. European Soil Bureau Research Report No. 9, EUR 20559 EN (2005). 350 pp. Office for Official Publications of the European Communities, Luxembourg.

Morvan, X., N.P.A. Saby, D. Arrouays, C. Le Bas, R.J.A. Jones, F.G.A. Verheijen, P.H. Bellamy, M. Stephens and M.G. Kibblewhite (2007, submitted). Soil monitoring in Europe: a review of existing systems and requirements of harmonization. Science of the Total Environment (2007, submitted).

Salminen R. et al. (2006). Geochemical Atlas of Europe (edited and printed by the Geological Survey of Finland). http://www.gtk.fi/publ/foregsatlas/.

Van-Camp, L., B. Bujarrabal, A.R. Gentile, R.J.A. Jones, L. Montanarella and C. Olazabal (2004). Reports of the technical working groups established under the soil thematic strategy for soil protection Volume 5 Monitoring. EUR 21319 EN/5. Luxembourg: Office for Official Publications of the European Communities.

Vanmechelen, L., Groenemans, R. and E. van Ranst (eds) (1997). Forest Soil Condition in Europe - Results of a Large-Scale Soil Survey. – Forest Soil Co-ordinating Centre, University of Gent, EC - UN/ECE, Brussels, Geneva.

Van Ranst, E., L. Vanmechelen, A.J. Thomasson, J. Daroussin, J.M. Hollis, R.J.A. Jones, M. Jamagne and D. King. 1995. Elaboration of an extended knowledge database to interpret the 1:1,000,000 EU soil map for environmental purposes. In: King, D., R.J.A. Jones and A.J. Thomasson (eds.). European land information systems for agro-environmental monitoring, pp. 71-84. Office for Official Publications of the European Communities, Luxembourg.

Soil Information Systems:

European Soil Information System (EUSIS), a framework for the integration of European soil data at various scales (for more information see documents at eusoils.jrc.it)

Soil Resources of Europe, Second edition, R.J.A. Jones, B. Houskova, P. Bullock and L. Montanarella. EUR 20559 EN (2005).

Baritz, R. and E. Eberhardt (2007). Data base design and selection. FP6-Environmental Assessment of Soils for Monitoring (ENVASSO). Contract No. 022713. Final report. Hannover, 2007 (submitted). www.envasso.com

Heineke H.J., W. Eckelmann, A.J. Thomasson, R.J.A. Jones, L. Montanarella and B. Buckley (eds.) (1998). Land Information Systems: Developments for planning the sustainable use of land resources. EUR 17729 EN. 546 pp. Office for Official Publications of the European Communities, Luxembourg.

King D., R.J.A. Jones and A.J. Thomasson (eds.) (1995). European Land Information Systems for Agro-environmental Monitoring. EUR 16232 EN. 284 pp. Office for the Official Publications of the European Communities, Luxembourg.

Examples for fully operational national soil information systems:

Austrian Soil Information System (BORIS): http://www.umweltbundesamt.at/umweltschutz/boden/boris/

French national soil information system (DONESOL): http://gissol.fr/programme/programmes.php

Sectoral soil information system of the BGR (FISBo BGR): http://www.bgr.bund.de/cln_030/nn_454934/DE/Themen/Boden/boden__node.html__nnn=true

Land information system (LandIS): http://www.silsoe.cranfield.ac.uk/nsri/services/cf/gateway/ooi/intro.cfm .

From the reference material submitted by SDICs and LMOs, the following may be relevant to this theme:

Ad-hoc-AG Boden (2005). Bodenkundliche Kartieranleitung [*German soil mapping guide*]. 5. edition, 438 p., E. Schweizerbart'sche Verlagsbuchhandlung, Stuffgart. 2005.

Regione Emilia-Romagna: Capitolato tecnico – Realizzazione della terza edizione della carta e del database dell'uso del suolo della Regione Emilia-Romagna

Statkart Norway: http://www.statkart.no/sosi/UMLfullmodell/Jordsmonn/Jordsmonn.htm (feature catalogue including a UML application schema for soil. The model is based upon Norwegian user requirements)

SIKP, The Netherlands: http://www.sikb.nl/ (SIKB-protocol 0101, version 5.0.0 for the digital exchange of soil data)

Other:

ISO TC 190 (Soil Quality), SC 1 (Evaluation Criteria, Terminology and Codification), WG 3 (Data codification and management). Work Item N 12 (Recording and exchange of soil related data) [*ongoing*].