EUROPEAN SOIL INFORMATION: PRESENT STATUS AND FUTURE PERSPECTIVES

Dominique KING (1) and Luca MONTANARELLA (2)

(1) INRA Soil Science-SESCPF, BP 20619, 45166 Olivet Cedex. France.
(2) JRC-ESB, Ispra 21020 ITALY

Abstract: In Europe, as well as in the world, a thorough knowledge of soil use and soil protection is of vital importance. The European Commission, in particular its Directorates General of Agriculture (DG VI), Environment (DG XI) and Research (DG XII), has supported several programs with this objective in mind. The publication of the 1:1.000.000-scale Soil Map of the European Communities (EC) in 1985 is one of the result of these activities. This paper summaries the different stages of the elaboration of this map and the associated geographical soil database. It focus on the potential use of this information and its limits. This information is presently an important source of data for agriculture and environmental projects. However, the authors highlights the need of more precise data in space and time. Aware of this statement, the Commission through the Joint Research Centre (JRC) created a large thought with the support of the European Environmental Agency (EEA). This led to the creation of the European Soil Bureau as a new body of co-ordination for the Commission. In the same time, the EEA created the European Topic Centre on Soil (ETC-Soil). These two organisations should promote future harmonised programs on soil mapping and monitoring in Europe.

Key words: Soil information, soil mapping, soil database.

Resumen: En Europa, como en el resto del mundo, un conocimiento completo del uso del suelo y su protección es de importancia vital. La Comisión Europea, en particular las Direcciones Generales de Agricultura (DG VI), Medio Ambiente (DG XI) e Investigación (DG XII), ha apoyado diversos programas con este objetivo principal. La publicación en 1985 del Mapa de Suelos de las Comunidades Europeas escala 1:1.000.000 es uno de los resultados de estas actividades. Este artículo resume los diferentes estadios en la elaboración de este mapa y las bases de datos geográficas asociadas. Su enfoque es el uso potencial de esta información y sus limitaciones. Esta información es actualmente una importante fuente de datos para los proyectos de agricultura y medio ambiente. Sin embargo, los autores destacan la necesidad de datos más precisos en el tiempo y en el espacio. Consciente de esta situación, la Comisión Europea a través de los "Joint Research Centre" (JRC) realizó una amplia reflexión con el apoyo de la "European Environmental Agency" (EEA). Esto impulsó la creación de la Oficina de Suelos Europea como un organismo nuevo de coordinación de la Comisión. Al mismo tiempo, la EEA ha creado el "European Topic Centre on Soil (ETC-Soil)". Estas dos organizaciones deberían promover futuros programas coordinados de cartografía y monitorización de suelos en Europa.

Palabras clave: Información de suelos, cartografía, bases de datos de suelos.

INTRODUCTION

Soil is one of the essential elements of the biosphere which necessitates a global policy for management, evaluation and conservation (Borlaug & Dowswell, 1994). To implement such a policy, it is necessary to have information harmonised both in space and time (ISSS, 1988). This statement is particularly true for the European Union (EU) which presently involves fifteen countries.

The Commission is the originator of several programs aiming to acquire soil data (CEC-JRC, 1995). Associated with other sources of information (water, air, land management) these data are a valuable aid for decision support processes, in particular for the control of agricultural production (Vossen & Meyer-Roux, 1995), land management and environmental protection (Blum, 1990). The last major co-ordinated activity for soil information in Europe is the elaboration of the 1:1.000.000 soil geographical database. This information is now available thanks to many previous works.

The first objective of this paper is thus to describe this database after some reminder about the stages which allow to reach its present status. The second objective is to summarize the activities which are following the elaboration of this database. Its use do lead to measure the need of more precise information and to promote a better harmonisation of soil information in Europe. Considering the needs of the EU Commission and the new European Environment Agency, two organisations were created in 1996 for soil management. Their structure and aims are summarised in the last part of this paper.

HISTORICAL BACKGROUND

A general knowledge of soil distribution within a given area is one of the basic requirements for natural resources evaluation. European programs of the CEC on soil knowledge and management are included in such wider-ranging programs as:

- in agricultural production domain (DG VI), by means of the Soil Map of EC at 1:1 M. after an attempt of the FAO on continental Europe as a whole.
- in environment domain (DG XI), by means of CORINE program.

Action of FAO and EU Directorate VI (Agriculture)

From 1952, studies were made of the different soil classification systems in Europe, with a view to eventual harmonisation and common work. The first result was the publication of the FAO soil Map of Europe at scale 1:2.500.000 (FAO, 1965). During the seventies, work continued under the auspices of FAO on the Soil Map of Europe at scale 1:1.000.000. The legend was designed at the same time as that of the World Soil Map at scale 1:5.000.000, which was published in 1975 (FAO, 1975). Because of financial problems, the work was stopped by FAO and the map has never been published. In 1978, the European Commission decided, with agreement of the FAO, to revive the work for the countries of the European Communities. The final Soil Map of the EC was published at scale 1:1.000.000 in 1985 (CEC, 1985). In 1986, the territories of Austria and Switzerland were added to the map at the initiative of UNESCO and the International Soil Science Society (CEC-ISSS, 1986).

During this time, agronomic research was organised by DG VI in different Program Committees with precise objectives, co-ordinated by the Permanent Committee of Agronomic Research (PCAR). The Program Committee for Soil Science first was called "Land Use" and later became "Land and Water Use and Management". Between 1972 and 1985 it worked successively on the following points: 1) inquiries in EC countries to define the main problems affecting land management; 2) drafting of the EC Soil Map (scale 1:1.000.000); 3) organisation of "Workshops" where soil conservation took an increasingly important place; 4) introduction of computerisation in data processing; 5) research into land evaluation, land degradation and conservation

The publication of the 1:1.000.000 scale EC Soil Map was certainly the most powerful stimulus but we have to keep in mind that it was the fruit of more than 30 years work of many regional and national soil survey staff.

Action of EU Directorate XI (Environment)

The main objective of CORINE (DG XI) was the creation of a Co-ordinated Information System on the state of the Environment and Natural Resources of the European Communities. This implied setting up a homogeneous framework for collection, storage, presentation and interpretation of environmental data on the EC countries (Briggs and Martin, 1988).

The CORINE program resulted in the computerisation of the EC Soil Map in 1986, constituting the first spatialized soil database (version 1.0). This work consisted in digitising contours and indicating, for each polygon, the number of the corresponding soil association and the nature of the possible phase (Platou *et al.*, 1989). No more data were used than were drawn on the map.

This database thus was created as part of research into, and the storage and handling of soil parameters that must be considered for both agricultural production and land protection. The first version of the database was rapidly applied to two major problems that required the use of multi-parameter combinations: a map of the buffering capacity (Chadwick and Kuylenstierna, 1990) and a zonation of the southern part of the EC in terms of susceptibility of soil to erosion, associated with another zonation dealing with land quality (Giordarno *et al.*, 1995). Other uses of this information were attempted and were not necessarily published but the number of studies remained weak (Jamagne et al., 1994).

Action of Joint Research Centre through the MARS project

In 1987, the Commission launched a new program to estimate crop surfaces in Europe and to monitor them by using remote sensing (Meyer Roux, 1987): This is the MARS program of the DG VI (Monitoring Agriculture by Remote Sensing) setting up in the Joint Research Centre in Ispra (JRC-Ispra). This technique has many advantages but also some disadvantages. For example, the reflectance is not a direct measure of the yield and satellites do not give continuous information in space and time mainly due to the presence of clouds. It is important to monitor crops without gaps and it was decided to use agrometeorological models (Vossen and Meyer-Roux, 1995). Therefore, at an early stage of the MARS project, agrometeorological modelling was carried out and this methodology led to request soil and climate data.

The soil data in the computerised EC map were insufficient to supply values to the parameters needed by agrometeorological models. The Soil and Geographical Information System (Soil & GIS) support group was created to improve the database stemmed from the EC soil map (Burrill and King, 1993). The program was enlarged to environmental needs in the framework of the European Environmental Agency Task Force of the DG XI. The main steps of the Soil & GIS activities and the results are presented in the next paragraph.

THE 1:1.000.000 SOIL GEOGRAPHICAL DATABASE OF EUROPE

The first action of the Soil & GIS support group created by the MARS program was to list the parameters required by the main EU projects. After that, it investigated what type of soil parameters could be made available from existing soil maps or soil databases in Europe. For example, for the Soil Water Available for Plants, the so-called SWAP parameter, Thomasson (1995) reported different levels of information according to the level of complexity of the used model. Generally, the requested parameters for this range of models are not described in soil maps. This result is highlighted by Magaldi (1995) who described the state of progress of soil mapping in Europe. Furthermore, each country has developed different methods for soil surveys at various scales and objectives. Finally, the percentage of mapped areas in each country is very different from one country to another, and for many countries this percentage is less than 30%. The only common level for the European Communities was the 1:1M scale EC soil map.

Available material at the EU level : the EC soil map

The initial objective of the authors of the EC soil map was to have a basic common language for Europe. They wanted to harmonise pedogenetic concepts according to the FAO legend (1974) but they also wanted to define agronomic constraints (Tavernier, 1985). At that time, GIS techniques did not exist, and the task was oriented to publication of a conventional map. This led to many difficulties in extracting soil parameters for modelling.

As a first problem, the data on the paper map were limited to the "FAO soil name" and the "phase" i.e. the agronomic constraint coding; secondly, the main variable chosen to harmonise and publish this map, was the FAO soil name of the predominant soil unit within soil associations. Using a soil taxonomy, all soil characteristics (e.g. texture, soil depth for the predominant soil unit and especially all the characteristics of the secondary soil units) were completely ignored. It has now become impossible to re-extract this information from the map for various purposes. Computerisation of the soil map in 1986 did not improve the information since only data found on the published map were digitised.

Improvement of the version 1 by using archives and new information

The Soil & GIS group suggested to go back to the primary information. The method is composed of three steps according to the facilities to get the data. The easiest data to obtain are the archives used to elaborate the EC Soil Map. The two other sources of information come respectively from the national experts and from the basic measured data of analytical soil profiles (JRC, 1995).

Improvement from the FAO archives

The archives of the EC soil map were stored in the University of Ghent in Belgium by Professor Tavernier, co-ordinator of the work (table 1). Due to a good harmonisation of the preliminary mapping activities, it was easy to extract the main soil variables. This information was digitised and the computerised soil map was updated (King *et al.*, 1994). The result is called version 2.0. 65 % of the soil mapping units were completely changed during this stage and all soil mapping units received new attributes. Very important variables were added in this second version such as parental material. Furthermore, data were added for each soil typological unit within soil associations and not only for the dominant soil.

Updates by national experts

This first stage was insufficient to obtain the required information for agrometeorological modelling. It was decided to go back to the soil scientists who gathered the basic data for the map. Two sub-directions were suggested. The first one was the development of a soil knowledge database with the support of the DG XI (Van Ranst *et al.*, 1995 ; Jones and Hollis, 1996). The idea was to formalise, as an expert system, the knowledge used to estimate unknown soil parameters from soil variables stored in the database. These estimations were called pedotransfer rules in reference to the concept of pedotransfer functions (Bouma and Van Lanen, 1986).

The second sub-direction was to update the soil mapping units in order to improve the description of soil variables, because those that are stored in the archives and version 2.0 are very old. For this, version 2.0 was sent to all national correspondents asking for an update of the attribute values as well as of the graphic of

Table 1: Example of the data available in FAO archives

Map Unit number	Soil Typological Unit (FAO)	% Area	Texture	Slope classe	Phase	Elevation (m)	Parent material	Land use
42	Bd I Bgg	90 5 5	2	c	Stony, lithic	300-600	Residual stony loam from schists	Forest, pasture, arable land
57	Lgs Lo Be I, Ge	75 10 10 5	4	c	Stony, lithic	250-400	Residual loamy clay of marl	Arable land, pasture, forest
58	Ql Lo Ph	80 10 10	1	c	Stony, lithic	300-450	Residual sand of sandstone	Forest, arable land
8	Lo Be	75 25	2 2	c c	Stony	250-380	Residual stony loam	Pasture arable land

soil boundaries. New attributes were added: depth of an obstacle to roots, depth to textural change, water regime, etc. (INRA, 1995) This final version is called version 3.1. The last task in progress is the border harmonization.

Soil profile database

In order to have reliable data, the database was finally improved with basic soil profile data (Madsen and Jones, 1995). For each dominant soil unit, a representative soil profile was collected with main analytical data. Standard formats were developed for harmonising the various analytical methods in Europe.

Structure of the present European Soil Geographical Database

The soil geographical database has presently four parts (figure 1): (1) the meta-database, (2) the so-called geographical database, (3) the soil profile database, and (4) the knowledge database.

The first part of the database is chronologically the last stage and it is still in progress. The objective is to gather information on the references of pedological studies in Europe. The expected meta-database should be provide a catalogue where users could find more information in detailed national maps. An earlier program was carried out (CEC, 1990) but no update have been made for ten years.

The second part is the heart of the system. It includes the list of the Soil Typological Units (STU) i.e. all soil types within the European Union which were mainly identified with the FAO-UNESCO legend (1975), revised by the CEC (1985). From a semantic point of view (non spatial attributes), STUs are described by soil attributes with an harmonized coding : FAO soil name, parent material, slope, phase, topsoil texture class, textural differentiation, subsoil texture depth, depth to an obstacle to roots, presence of an impermeable layer, water regime, water management. From a geometric point of view, STUs generally are too small to be drawn on a map at the 1:1.000.000 scale. They are clustered in Soil Mapping Units (SMU) which are defined by contour lines and polygons. The "object SMU" is clearly related to the concept of soil association (Simonson, 1971).

The third part of the database contains soil profiles with physical and chemical analysis.

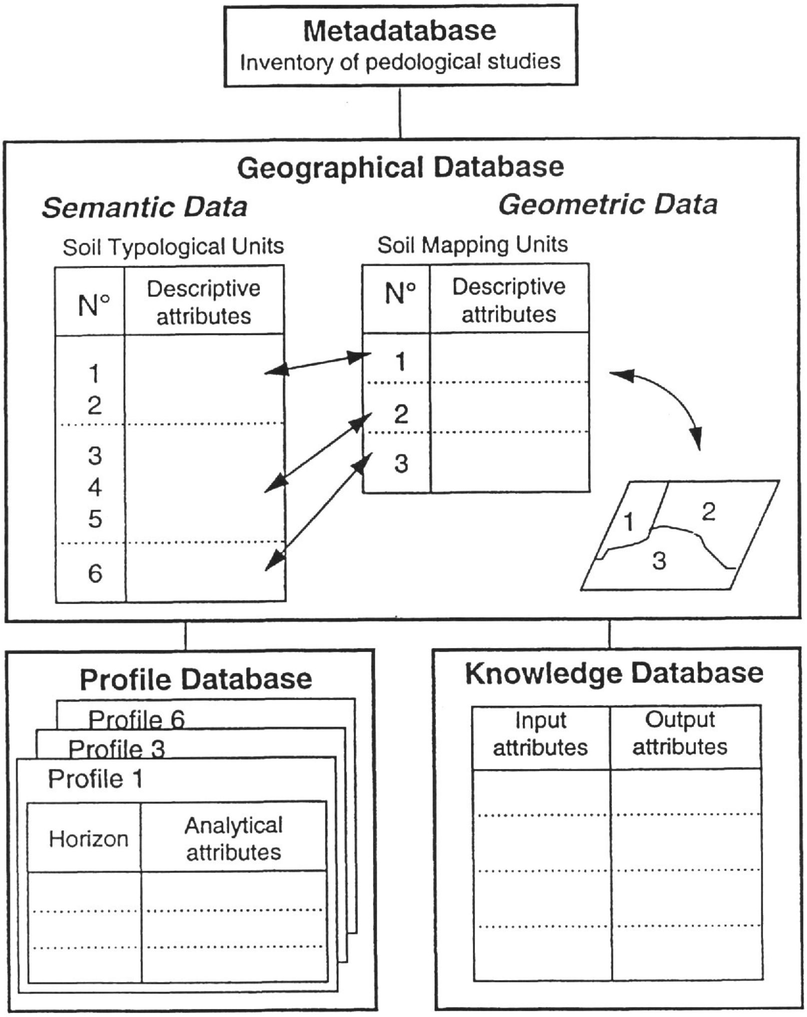

Figure 1: Simplified structure of the European soil geographical database

The difficulties to harmonise all the various analytical methods led to the adoption of two data formats. The first is for measured data which come directly from real georeferenced profiles. A code enables storage of the analytical methods used and missing values are accepted. The second format stores estimated data. The analytical methods are fixed for comparison of the values throughout the various countries of Europe. In this second format, the attributes must be full completed by using guesstimation. About 300 soil profiles are available (table 2) but more are expected in the near future.

The last part of the database contains the pedotransfer rules. These are simple deductive functions that help in estimating new soil parameters from the available data. This fourth part looks like an expert system constructed from expert evaluation by soil scientists and from literature (table 3). Rules are applied at the

Table 2: Availability of soil profile proformas (Madsen and Jones, 1996)

Country	Proforma 1 Estimated data	Proforma 2 Measured data
UK including Scotland	64	90
Denmark	9	8
Belgium	34	34
France	118	0
Germany	69	50
Italy	21	17
Netherlands	20	19
Spain	25	25
Luxembourg	13	13
Greece	0	19
Portugal	0	0
Ireland	0	0

Table 3: Standard table for describing a pedotransfer rule.

INPUT ATTRIBUTES						OUTPUT ATTRIBUTES		REFERENCE ATTRIBUTES		
Regional Codes	1	2	3	...	n	Class	Confidence level	Authors	Date	Notes

STU level and values are mainly qualitative. Such a knowledge database enables to formalise the empirical interpretations that are always made by using soil maps. The main advantage of this system is the possibility of updating in the light of new knowledge.

The columns on the left correspond to values taken by input attributes describing the Soil Typological Units. The central columns provide estimated values and their confidence level i.e. the expert uncertainty. The right-hand columns contain management attributes: author, date of last update, marker for access to explanatory notes. The lines indicate the possible occurrence of the rules, based on the values (or combinations thereof) for the input attributes in the geographic soil database.

Recommendations for using the data

If spatial values for a soil parameter have to be estimated, several ways are possible. If the soil parameter is directly included in the description of the STU, the data can be directly extracted and used for modelling. If the soil parameter is not one of the STU attributes, the knowledge database can estimate it in many cases. If a representative soil profile exists within a STU, quantitative value can be estimated for this soil parameter. For example, if an agrometeorological model needs the SWAP parameter, there is no value of this parameter in the STU file. In that case, one can use either the knowledge database to get a qualitative estimation per STU, or the soil profile database to directly obtain a quantitative local value. Comparison between the two methods will help to highlight the strongest discrepancies where it will be necessary to get more information from regional soil survey.

It was seen before that the main objective of such a database is to deliver parameters for modelling and also to produce derived maps. Most of the SMUs are complex associations and it is difficult to manage this variability on maps. However, it is easy to compute models at the level of the STUs. For example, by using all STUs within each SMU against the predominant STU, a water balance model decreases errors by 20 % (Ngongo *et al.*, 1993).

In a last stage, it is generally necessary to produce maps, either directly from the database (with or without the knowledge database), or indirectly as outputs of models. For example, in order to draw the SWAP parameter over the EU, three classes are chosen : high, medium and low. Only the dominant class within an SMU can be shown. However, in places, this dominant value is less than 50 % of the total area of a SMU ! In order to avoid erroneous interpretation, an automatic process draws a second map, called purity map, showing the percentage of the area represented on the first map (figure 2). Furthermore, attributes and rules needed to derive the SWAP attributes are the results of expert knowledge and is not necessarily 100% reliable. It was thus proposed to add confidence levels to each STU and each rule occurrence. Four classes are proposed, ranging from "high", via "medium" and "low" to "very low". To warn the users against improper use of pedotransfer rules, it was decided that the confidence level of an output value should be the minimum of the confidence levels of the input attribute and its corresponding occurrence. The resulted confidence level can be mapped showing the reliability of the SWAP values (figure 2). For decision makers, these two kinds of maps (the purity and confidence level maps) will be as important as the primary requested map (here, the SWAP map).

TOWARDS A EUROPEAN SOIL INFORMATION POLICY

The development of the 1:1.000.000 European Geographical Soil Database was a good initiative to increase contacts between soil scientists, to exchange information across national borders and to create a first platform for decision makers. However this project also highlights the absence of strong co-ordination not only between countries, but equally between different Directorates-General of the Commission.

In order to remedy this lack, the Joint Research Centre (JRC) created in 1994 a Soil Information Focal Point (SIFP). Following the work and initiatives stimulated by the European Environmental Agency (EEA) Task Force, its functions were to organise thinking on the Commission's future needs and to suggest initiatives for a better harmonization of soil activities in Europe.

Analysis of demand and definition of needs

The SIFP carried out two working groups: A coordination group from the Directorates-General of the Commission (Inter DG Group) which includes the European Environment Agency (EEA), and a "Soil Information System Development" (SISD) working group.

Summary of the inter-DG report

The document "Soils information for

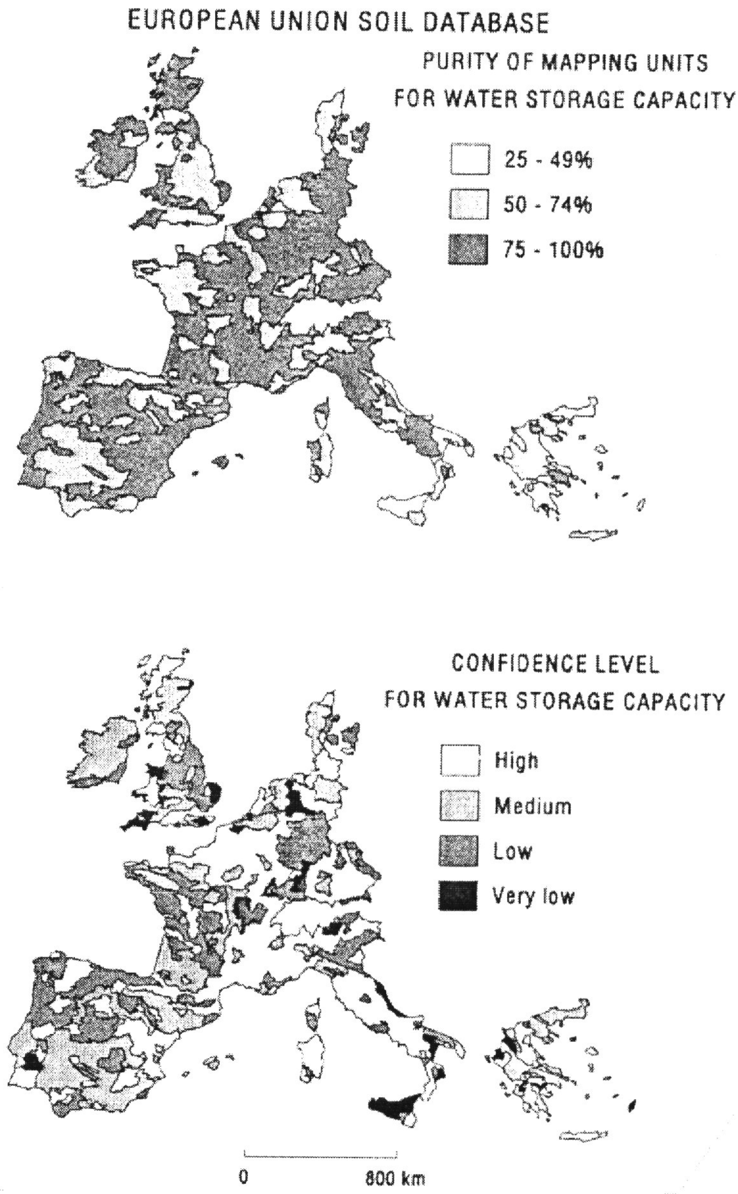

Figure 2: Examples of a purity map and a confidence level map

Europe" published by the Commission (CEC, 1995; Burrill, 1996) identifies the main priorities as follows :

(1) Increased accessibility

Communications facilities, such as the Internet, reduce the technical problem related to data accessibility. However, users have to know where are the data and who is the owner of the data. A solution is to develop a catalogue of all existing data including access facilities.

For the Commission, it is a priority to define the rights of access to the various datasets presently existing within the Commission.

(2) Increased usability of existing data

The present available datasets should be well documented and available in commonly used data formats. These documents should be completed by utility programs to derive raw data to interested information. These programs should be also available and well documented in order to be easy usable.

(3) Standardisation of methods and quality assurance

One of the priority for exchanging information is to get comparable and reliable data. A short-term solution is to make comparison between methods. But for the long term, it should be better to act with international organisation for standardisation (ISO, FAO, CEN, ISRIC) for promoting standard methodology.

(4) Development of new datasets

The main collection of data within the Commission was oriented on specific objectives. The use of data for other activities is often difficult. This is the case between agriculture needs and environmental needs. It is also clear that present data are insufficient to be used in most European programs due to the limited accuracy and scale of the data. Particularly, the Commission needs information on soil monitoring and maps at larger scales than the 1:1.000.000 scale. The Commission needs equally information on the EU territory and the neighbouring countries.

(5) Relation with the member states

All the on-going Commission activities in soil data collection or management are involved numerous contacts between people. But these contacts have an informal basis and it seems important to consolidate them by a more institutional basis. This could be take the form of a European Soil Bureau. Many activities of coordination and standardisation would be facilitate by acting within a such structure.

Summary of the SISD working group

Considering these statements, the SISD working group confirms that the soil is now recognised as a major element of the biosphere. Furthermore, this resource is limited and fragile owing to the increase in human activities. Its main function has always been to provide the water and nutrients necessary for vegetation. However more recently other functions have been identified, in particular the filtration of pollutants and an important role in bio-geochemical cycles.

Even-handed administration of European land area requires command of harmonized information. This implies an effort from member states to standardise protocols for soil sampling and measurement. Control of information will improve the coherence of programs initiated by the different DGs. It is also a means of defending quality standards in relation to countries outside the EU, in particular neighbour states (Continental Europe, Mediterranean basin)

Four complementary initiatives were proposed:

(1) The continuation of studies at the 1/1.000.000 scale for states bordering the EU in order to command a sufficient and coherent level of information to permit a dialogue with all European partners (Continental Europe and Mediterranean basin).

(2) The setting up of a geographical soil information system at 1:250.000 scale with rapid access by the Commission to provide support for decisions and for technical exchanges with states and regions.

(3) The setting up of a long term soil monitoring program within Europe.

(4) The creation of a European Soil Bureau (ESB) as a small administrative unit, charged with leading the harmonization and exchange of data and models.

The European Soil Bureau

The ESB was approved during a second meeting of heads of soil survey (CEC-INRA, 1996) in June 1996. It was officially launched with the approval of representative people of the EU countries. Its functions were defined and working groups were carried out in the continuity of previous studies of the already active groups.

Aims of the European Soil Bureau

The major tasks assigned to the Bureau are:

(1) To serve as a point of contact for coordination of soil data needed for numerous purposes by the Commission or other external bodies.

(2) To respond to the needs of the Commission furnishing information necessary for the programs of the DGs.

(3) To develop and implement a policy and guidelines for the production of harmonized, and therefore compatible soil data.

(4) To develop and implement a policy for the distribution of information concerning soils, with the objective of favouring exchange of data without compromising the interests of the producers.

(5) To develop and distribute the tools facilitating the exchange and use of soil data.

(6) To establish links with international bodies such as FAO, UNEP and ISRIC in order to assure a reciprocal flow of information.

The Bureau is constituted as follows:

(1) An Advisory Committee composed of national representatives of each EU and EFTA Member State, observers from neighbouring countries and international bodies. It would be charged with evaluating and advising Bureau activities.

(2) A Scientific Committee nominated by the Commission according to its specific needs and the objectives specified by the Advisory Committee. This Committee operates by small Working Groups.

(3) A small Secretariat to co-ordinate and catalyse the activities of the Soil Bureau, providing technical support as required. It also provides logistic support for the other elements of the Bureau.

Current status of working groups

Three working groups are presently active under the auspices of the ESB.

(1) The Information Access working group (IAWG) aims to define a data distribution policy of available soil information, particularly the 1:1.000.000 soil geographical database. It is suggested to implement a data licensing and distribution processes according to the type of the demands (Commission itself, contributors, national ministries, private companies, etc.).

(2) The extension of the 1:1.000.000 soil geographical database to neighbouring countries started before the creation of the ESB. The PHARE countries are presently included into the database. New EU countries and neighbouring countries are expected during the next years (figure 3). A major challenge is to integrate the various databases (profile, pedotransfer rules, meta-database, reference catalogue, etc.) into a single European Soil Information System.

(3) According to the conclusions of reports and meetings (Dudal *et al.*, 1993 ; CEC-INRA, 1996), first thinking about a 1:250.000 soil database was carried out. The main task is to write a manual of procedures that should be sufficiently accurate to provide harmonized information. The proposal is to firstly prepare a soil region map (Eckelmann and Hartwich, 1996) and secondly to test the method on pilot areas representative of the main European landscape. Another aim is to link this database to a reference network of small areas mapped at larger scale (1:50.000). This linkage is envisaged to ensure flexibility when new programs are launched and to facilitate dialogue with member states and regions. The link with the 1:1.000.000 is also envisaged.

The European Topic Centre on Soil (ETC-Soil)

Concurrently to the creation of the ESB, The European Environmental Agency (EEA) decided to create a European Topic Centre on Soil in 1996. The EEA had been previously created in 1993 in Copenhagen. This European body operates through national focal points in each Member State and topic centres on different

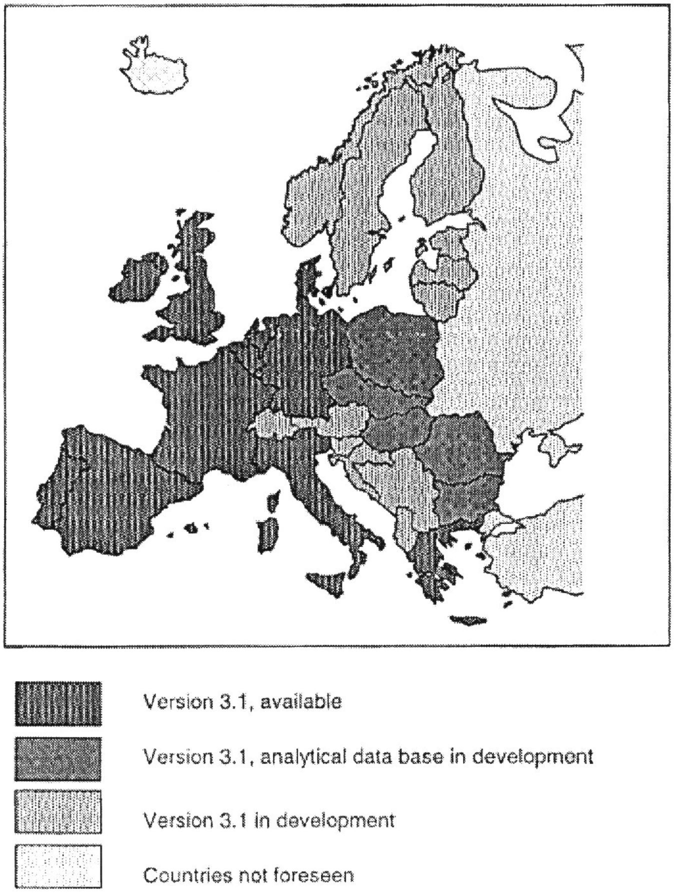

Figure 3: State of progress of the soil geographical database in Europe (October, 1996).

subjects: water, nature, air quality, land cover, etc. Generally, these topic centres are consortia of several countries. For the ETC-Soil, the leader is the CSIC of Spain and the Co-leader is TEAGASC in Ireland. The other members are Denmark, United Kingdom, Austria, France, Germany and Greece.

The tasks of the ETC-soil are oriented towards the environmental aspects. First of all, it aims to review the national and EU policy, legislation and agreements on soil quality and pollution. A review is also planned for the existing soil monitoring network and related databases. From these reviews, a European soil monitoring network will be proposed showing the priority parameters and indicators. In addition, a report will be prepared on soil degradation especially on the desertification problem. Finally, specification will be provided for the definition of contaminated sites in order to assess the extent of contaminated land, the level of contamination and the extent of remediation. The ETC-Soil thus should provide first element to answer to the SISD report about the need of a large European soil monitoring action. The ETC-Soil is not duplicating any activity of the ESB, but the two institutions are highly complementary.

CONCLUSION

A usable Soil Geographical Database at 1:1.000.000 scale is available at the EU level and several projects are asking for using it. Information in such a database is regularly updated due to new knowledge or adding of new territories. Management of this information is taken in charge by the European Soil Bureau. It should ensure the quality control of the updates and should deliver licenses for users. Accessibility and usability of data are two important points for the future of this database.

The role of the European Soil Bureau is extended to promote a better harmonization of EU soil programs. The various active groups (Inter-DG group, advisory committee, scientific working groups) acting within the ESB are opportunities to exchange ideas and develop new programs. One of the priorities is to elaborate a 1:250.000 soil database. This project is not really an improvement of the 1:1.000.000 database but it should use new methods in order to develop a more flexible and reliable information. Digital Elevation Model, Remote Sensing and Geographical Information System are the main techniques which would be integrated in this future project.

Soil monitoring is taken in charge by the European Topic Centre on Soil. The objectives are limited to environmental problems. But this action will be complementary of soil mapping activities. Coordination is already set up by mutual exchange of representative people in scientific working groups and administrative committees. Other programs exist within the Commission. The ESB and the ETC-Soil will be good means to inform each other on their development.

The challenge for these two new European bodies is to organise the collection of ad-hoc soil information essential for future needs. Basic data are certainly indispensable but not sufficient. It will also necessary to increase knowledge on soil processes in order to predict phenomena. This will certainly involve research programs on modelling.

ACKNOWLEDGEMENTS

The present paper is not the result of a personal activity but it is a summary of numerous activities on soil information in Europe thanks to a large collaboration. The authors thank all the people who were or are still involved in these activities, mainly Dr M. Jamagne, J. Daroussin and C. Le Bas for the management of the Soil Database. It will too long to mention the names of the members of all working groups that have been acting for European soil information during the last years. The authors thank particularly the members of the Soil & GIS Support Group, the Inter-DG group and the SISD working group without forgetting the PHARE committee and the ESB advisory Committee. Many activities were financially supported by the EU Commission through the Directorates VI, XI and XII. The authors wish to express their sincere thanks to Dr P. Vossen, A. Burrill and J. Meyer-Roux of the MARS project in JRC-Ispra for support, help and advice.

REFERENCES

Blum, W.E.H. (1990). The challenge of soil protection in Europe. *Environmental conservation*, **17**. 72-74.

Borlaug, N.E. and Dowswell, C.R. (1994). Feeding a human population that increasingly crowds a fragile planet. *15th World Congress of Soil Science*, Acapulco, July 10-16 1994. Keynote lecture. 1-15.

Bouma, J. and Van Lanen, H.A.J. (1986). Transfer functions and threshold values: from soil characteristics to land qualities. In: Proceedings of the international workshop on quantified land evaluation procedures. 27/04 - 2/05/1986. Washington D.C. 106-110.

Briggs, D.J. and Martin, D.M. (1988). CORINE: an environmental information system for the European Community. Environment Review. **2**, 29-34.

Burrill A. (1996). The European Commission's soils information focal point. In: Soil databases to support sustainable development, C. Le Bas and M. Jamagne (eds.). INRA-JRC, 109,114.

Burrill, A. and King, D. (1993). The soils database of the European Union. Proceedings of the International Congress Eurocarto XII. Kiruna, Sweden. 10 pp.

CEC (1985). Soil Map of the European Communities 1:1.000.000. Directorate General for Agriculture, Coordination of Agricultural Research. Office for Official Publications of the European Union, Luxembourg, 124 pp. + 7 maps.

CEC (1990). Computerised land evaluation databases in the European Communities. Catalogue of a questionnaire survey. 2nd edition. CEC publication. DG VI.

CEC-ISSS. (1986). Soil Map of Middle Europe 1:1 M. EEC publications. Luxembourg. 124 pp.

CEC (1991). Soil survey. A basis for European soil protection. Ed: Hodgson, J.M. Proceedings of the meeting of European Heads of soil survey. 11/13-12/89. CEC publication. Brussels. 214 pp.

CEC-JRC (1995). Soils Information for Europe. JRC Ispra DGXII. 21 pp.

CEC (1995).

CEC-INRA (1996).

Chadwick, M.J. and Kuylenstierna, J.C.I. (1990). The relative sensitivity of ecosystems in Europe to acidic depositions. Stockholm Env. Inst. Sweden. 1 map, 65 pp.

Dudal, R., Bregt, A.K. and Finke, P.A. (1993). Feasibility study on the creation of a soil map of Europe at a scale of 1:250.000. CEC DG XI, Task Force European Environment Agency. 69 pp.

Eckelmann, W. and Hartwich, R. (1996). Soil mapping and the FISBo BGR soil information system. In: Soil databases to support sustainable development, C. Le Bas and M. Jamagne (eds.). INRA-JRC, 49-55.

FAO. (1965). Carte des sols d'Europe au 1/2.500.000.

FAO. (1974).

FAO. (1975). Soil Map of the World at 1:5.000.000. UNESCO. Paris.

Giordano, A., Peter, D. and Maes, J. (1995). Erosion risk in southern Europe. In: European land information systems for agro-environmental monitoring. King, D., Jones, R.J.A. and Thomasson, A.J. (Eds). CEC-JRC DGXII, Luxembourg. 167-177.

INRA. (1995). Users guide for the elaboration of the European soil database, version 3.1. INRA publication. Orleans. 16 pp.

INRA-JRC. (1996). Soil databases to support sustainable development. Ed: Le Bas, C. and M. Jamagne. Proceedings of the second meeting of European Heads of soil survey and database management. 12/8-9/94. INRA-JRC publication. Orleans. 149 pp.

ISSS. (1988). Land qualities in space and time. Proceedings ISSS, Wageningen, August 22-26 1988. 352 pp.

Jamagne, M., King, D., Le Bas, C. and Daroussin, J. (1993). Elaboration and use of a European soil geographical data base. In: Soil cover structure, Moscow, 6-11/09/1993, 97-100.

Jones, R.J.A. and Hollis, J.M. (1996). Pedotransfer rules for environmental interpretations of the EU Soil Database. In: Soil databases to support sustainable development, C. Le Bas and M. Jamagne (eds.). INRA-JRC, 125-133.

JRC. (1995). European land information systems for agro-environmental monitoring. Eds: King D., Jones R.J.A. and Thomasson A.J. EU-JRC, Ispra. 284 pp.

King, D., Daroussin, J. and Tavernier, R. (1994). Development of a soil geographic database from the soil map of the European Communities. *CATENA*. **21**, 37-56.

Madsen, H.B. and Jones, R.J.A. (1996). A soil profile analytical database for the European Union. In: Soil databases to support sustainable development, C. Le Bas and M. Jamagne (eds.). INRA-JRC, 135-144.

Magaldi, D. (1995). Soil mapping in EU countries: a short review. In: European land information systems for agro-environmental monitoring. CEC publication. JRC Ispra. 171-186.

Meyer-Roux, J. (1987). The ten-year research and development plan for the application of remote sensing in agricultural statistics. DG VI, JRC Ispra. 23 pp.

Ngongo, L., King, D., Nicoullaud, B., Brisson, N. and Ruget, F. (1993). The accuracy of methods for the selection of soil data in estimating regional moisture deficit from soil maps. *Pédologie*. **XLIII-2**, 285-299.

Platou, S.W., Norr, A.M. and Madsen, H.B. (1989). Digitisation of the soil map of the European Communities. In: Agriculture: Computerization of land use data. R.J.A. Jones and B. Biagi (Eds.): Proceedings of a symposium in the comunity programme for coordination of agricultural research. Pisa 1987, Commission of the European Communities, EUR 11151 EN, 12-24. Luxembourg.

Simonson, R.W. (1971). Soil association maps and proposed nomenclature. Proceedings, Soil Science Society of America, **35**, 959-965.

Tavernier, R. (1985). Introduction and history of the EC soil map. In: Soil map of the European Communities. CEC, Brussels and Luxembourg. 1-2.

Thomasson A.J. (1995). Assessment of soil water reserves available for plants (SWAP): a review. In: European land information systems for agro-environmental monitoring. King, D., Jones, R.J.A. and Thomasson, A.J. (Eds). CEC-JRC DGXII, Luxembourg. 115-130.

Van Ranst, E., Vanmechelen, L., Thomasson, A.J., Daroussin J., Hollis, J.M., Jones, R.J.A., Jamagne, M. and King, D. (1995). Elaboration of an extended knowledge database to interpret the 1:1,000,000 EU Soil Map for environmental purposes. In: D. King, R.J.A. Jones and A.J. Thomasson (eds.). European land Information Systems for Agro-environmental Monitoring. Office for Official Publications of the European Communities. Luxembourg, EUR 16232 EN, 71-84.

Vossen, P. and Meyer-Roux, J. (1995). Crop monitoring and yield forecasting activities of the MARS project. In: European land information systems for agro-environmental monitoring. King, D., Jones, R.J.A. and Thomasson, A.J. (Eds). CEC-JRC DGXII, Luxembourg. 11-29.