Knowledge and monitoring of soil resources in France

Pierre Stengel, D. King, M. Jamagne

World Soil Resources Reports 91

ISSN 0532-0488

THE EUROPEAN SOIL INFORMATION SYSTEM

EUROPEAN SOIL BUREAU
EUROPEAN COMMISSION

Food and Agriculture Organization of the United Nations

World Soil Resources Reports 91

THE EUROPEAN SOIL INFORMATION SYSTEM

Proceedings of a Technical Consultation
Rome, Italy, 2-3 September 1999

Sponsored by FAO and the European Commission

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome, 2000

Knowledge and monitoring of soil resources in France

This is a progress report on the main programmes for collecting soil information, soil survey and soil monitoring activity in France.

The Service for the Study of Soils and the Pedological Map of France (French acronym: SESCPF) was founded in 1968. Within the INRA (National Institute of Agronomic Research), it ensures the coordination of most soil mapping and monitoring programmes in France. This is made possible by compiling data received from a number of other public or private organizations that have formed a partnership to develop these programmes: research institutes (CNRS : National Center for Scientific Research, Universities), professional development organizations (Chambers of Agriculture, National Forest Bureau), land development companies and design offices, etc. Work is carried out at the request and with the support of the Agriculture and Environment Ministries, as well as local governments (Regional Councils).

The French territory is composed of 56 percent arable lands, 28 percent forested areas, 8 percent of land surfaces that are unused or have been set apart as protected natural reserves and, finally, 8 percent urban surfaces (IFEN, 1999). Current trends indicate a loss of natural and agricultural lands to development close to 40 000 hectares (100 000 acres) per year, equivalent to one French Department every 10 years. This trend constitutes undoubtedly one of the main threats to the "soil" legacy for future generations. It is also an indicator of the large number of other pressures exerted on soils which may also contribute to their irreversible degradation.

Soil mapping programmes are valuable tools for land management. In spite of this, we are currently witnessing a decrease of the resources allocated to these programmes. In parallel, there is an increase in the requests received for more diversified and more specialized information about the agricultural and environmental functions of soils. A systematic inventory of the country is no longer sufficient to respond to these demands. Besides, we are faced with a multiplicity of activities that must be coordinated at the national scale in conjunction with European programmes.

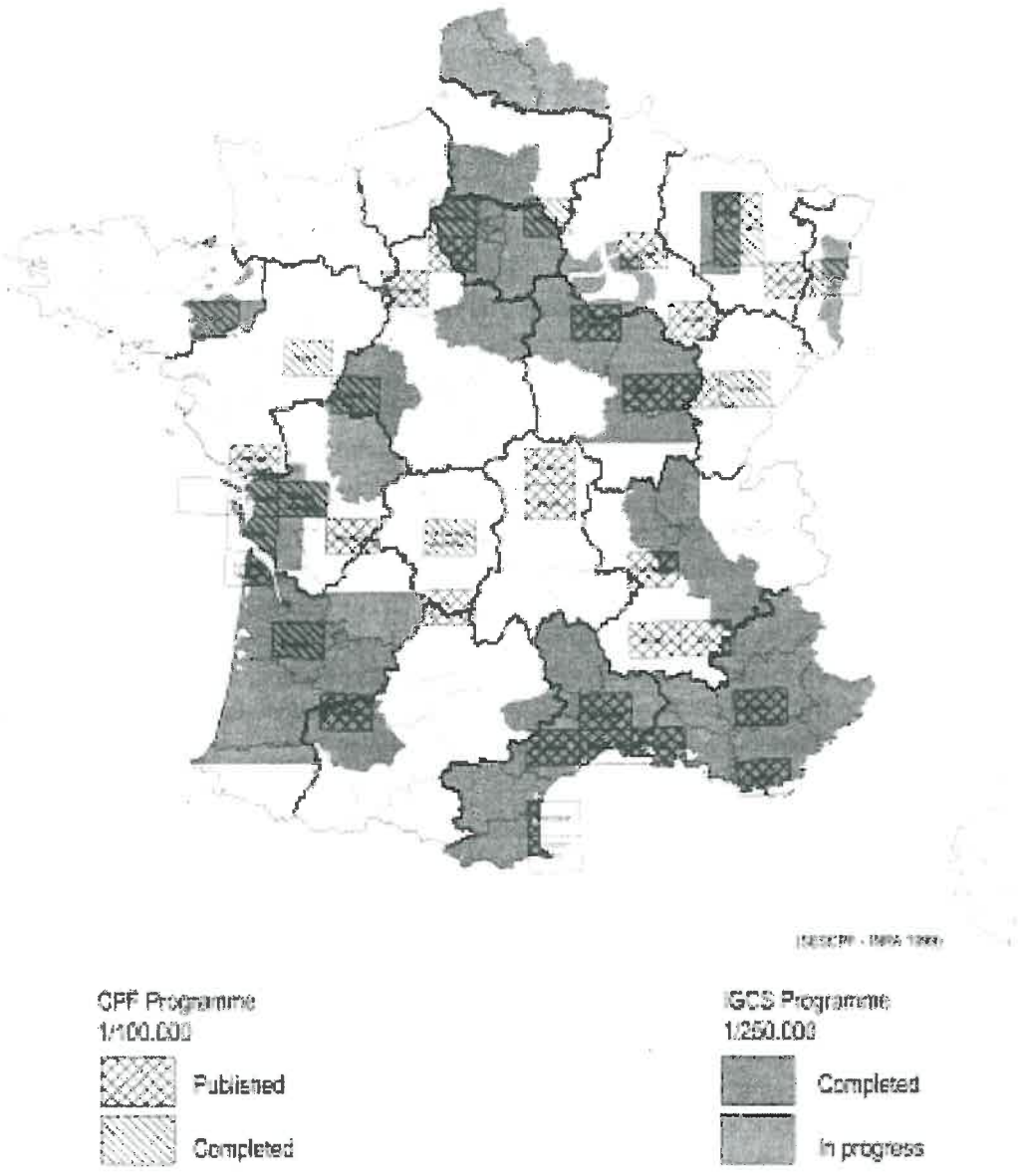
The aim of this paper is to describe several of these activities on the French territory and briefly show their use in long-term natural resource management programmes.

Soil mapping

The "Pedological Map of France" (CPF) programme has been in existence for more than 25 years. It has led to the acquisition of a large quantity of data on the soil resources of our country and of basic understanding of the typology and spatial variability of the main pedological systems (Jamagne *et al.*, 1995). This programme was the reason the SESCPF was created,

P. Stengel, D. King and M. Jamagne
National Institute for Agronomic Research, France

FIGURE 1
State of progress 1999 - CPF and IGCS programmes



leading to the development of a national platform for coordination and cooperation in the field of spatial analysis of soil. By the end of 1998, 27 maps at scale 1:100 000 had been published and 13 additional maps were being prepared, accounting for about 15 percent of the territory (Figure 1).

The resources allocated to this programme are not sufficient to foresee a complete coverage of French territory in the medium term. It was thus decided to change the emphasis of the CPF programme by giving preference to the detailed study of soil distribution laws within areas deemed representative of the main French pedological systems. In concrete terms, this means that older data will be digitalized and new data will be acquired in small selected regions to be surveyed. This programme is intended as a scientific support for inventory at broader scales.

This is the case for the "Soil Inventory, Management and Conservation" (IGCS) programme conducted by the Agricultural Ministry and INRA since 1990. Its initial aim was to prepare a map with an associated database at scale 1:250 000 for each of the French Regions (Bornand *et al.*, 1989, Jamagne *et al.*, 1995). At the present time, three regions have been completed, as well as 12 Departments. All the regions involved account for about 40 percent of the country (Figure 1). A test of data transfer to the European system is under way in the Côte d'Or Department in Burgundy (Finke *et al.*, 1998). The second aim of the programme is to carry out detailed studies, at scale 1:10 000, of small size sample surfaces. Monitoring the agricultural and environmental functioning of these zones provides references that can be generalized and applied to similar soil systems localized at scale 1:250 000 (Favrot, 1987; Favrot and Lagacherie, 1993).

These two programmes do not cover all mapping activities. Several regional or national organizations have started mapping programmes at smaller scales, e.g. 1:50 000 in the Centre Region, 1:25 000 in the Aisne Department, typology of forest stations, regional typologies, etc. In addition, there are many local initiatives for various studies, but it is difficult to make an estimation of that information (Bornand, 1997). Finally, there is the synthesis map at scale 1:1 000,000 that has been revised in the framework of European projects (Jones *et al.*, 1998, Le Bas *et al.*, 1998). Even so, this work is insufficient and the expected coverage at scale 1:250 000 will lead to a thorough revision of this geographic database at scale 1:1 000 000.

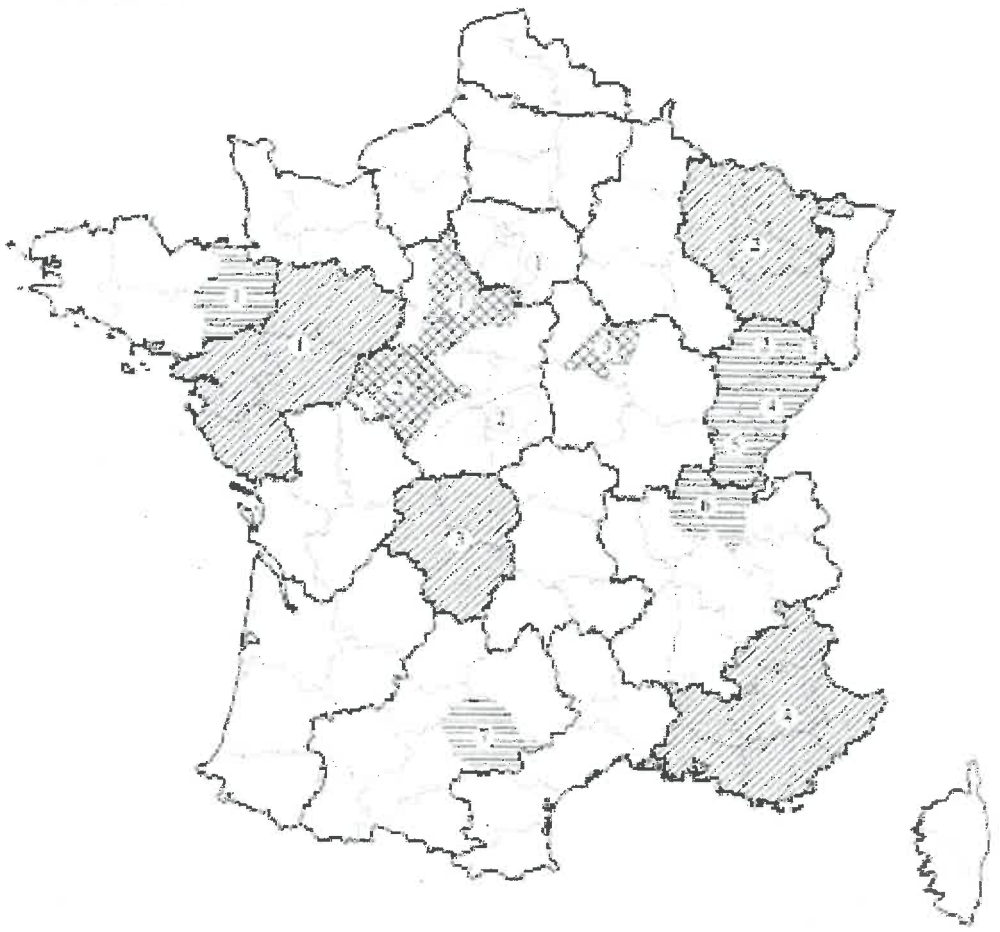
Soil monitoring

There are two main French soil monitoring networks. The first deals with long-term changes in cultivated land and natural non-wooded spaces. The second involves forests.

The main purpose of the " Soil Quality Observatory " (OQS) is to assess the present situation of soils and monitor their changes in order to better develop and implement a soil preservation policy (Martin, 1993). Eleven sites around 1 ha each were chosen on the basis of their representative nature concerning soil and land use. There is a minimum set of parameters that are systematically measured at all sites of the network. For some specific degradation problems, additional measurements may be conducted at some sites, e.g. light fraction C and N, mineralizable C and N, microbial biomass, soil enzymes, earthworms. The recommended time interval is five years. In one agricultural site, continuous pig slurry application was shown to significantly increase the organic carbon content and that of some metals (Cu, Zn). In an acid brown soil under a mature spruce stand, we observed a decrease of total elements in the organic layers, and of the exchangeable elements in organo-mineral horizons, which might have severe consequences for future forest nutrition. A decrease of the lead concentration in forest litter may be considered as an encouraging sign in the campaign to render gasoline greener. Other ongoing work involves the definition of biological indicators and sampling strategy for soil microbial biomass and soil fauna determinations.

The RENECOFOR programme is a long-term monitoring system for forest ecosystems (Figure 2). It was created by the National Forest Bureau in 1992 in order to extend the system for monitoring the health status of forests (Ulrich, 1995). It is the French part of a set of permanent parcels installed in 34 European countries. It covers highly varied areas of forests. Two soil profiles are systematically examined and fertility is monitored. Concerning the "Cataenat" sub-system (total acid load of atmospheric origin), atmospheric deposits have been measured in 27 parcels since 1993, and measurements are conducted on soil solutions taken from 20 and 70 cm in depth from 17 parcels.

FIGURE 2
Soil typology maps



Other monitoring systems including soils have been implemented, but they are concerned with other components of the milieu, especially water resources. In addition, means have been devoted to create databases with old soil analyses conducted individually or in the context of local programmes (for example, see next section on the National Base of Land Analyses, French acronym: BNAT). These data are localized in space and in time and provide information on medium- and long-term changes. It has not yet been decided, however, to continue the systematic collection of the data from the laboratories concerned.

Soil databases

In 1990, a unique database structure was adopted for all nationally integrated programmes. The system is called DONESOL and includes three parts (Gaultier *et al.*, 1993):

- point data obtained from observations and measurements conducted on soil profiles,
- descriptive data of soil mapping units, soil typology units of soils and horizons. Additional data take into account the spatial variability within these entities. These data are provided by expert judgment. Digitized contours are included in a GIS coupled with DONESOL,
- metadata that indicate bibliographic references of the studies as well as their localization and precision (Favrot, 1994). Over the past several years, considerable effort has been devoted to cataloguing all detailed scale pedological studies. This work is currently being extended by studies at medium and small scales. Finally, a directory of soil mapping professionals has been published (Favrot, 1997).

Mapping and monitoring programmes can be found on the INRA Orleans Web site (http://www-sescpf.orleans.inra.fr/public/). One objective is to develop this site, in particular including the metadata described above.

Other databases have been prepared in conjunction with or in parallel to the DONESOL database. In contrast to the above-mentioned programmes, these databases were compiled in the context of targeted research projects, including ASPITET, SOLHYDRO and BNAT.

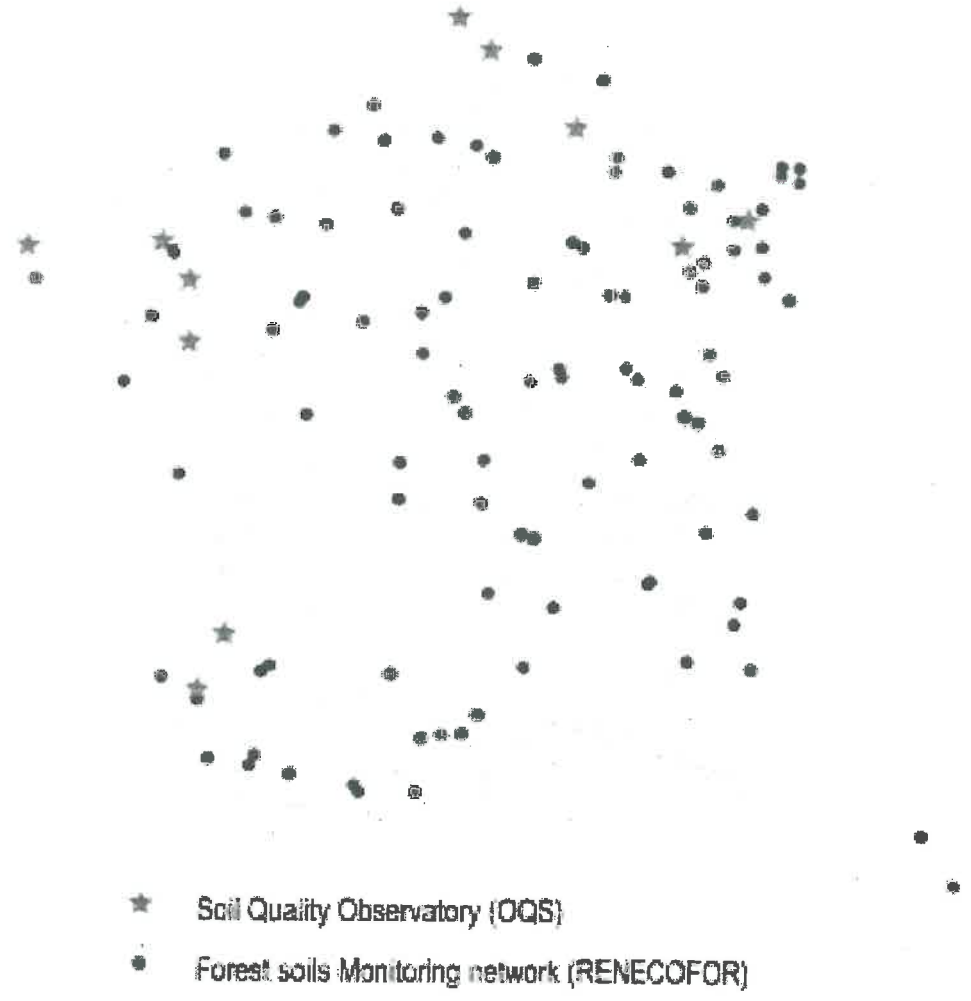
ASPITET: In 1994, the INRA started a research programme entitled "Contributions of a Pedological Stratification for the Interpretation of Trace Elements Contents" (French acronym: ASPITET). The aim of this programme was to acquire reference data on the natural contents of trace elements in soils. The work was carried out by taking into account soil types and geological parent materials. The population studied up to the end of 1998 is composed of 1 310 pedology horizons corresponding to 706 distinct sites. Total trace element concentrations were determined in each sample (systematically Cd, Cr, Cu, Mn, Ni, Pb, Zn, often As, Co, Hg Se, Ti). The results show that the general degree of contamination by human activities is very low in comparison to the stocks of natural trace elements in soils.

SOLHYDRO: A project was started in 1998 to compile an analytical database of the hydraulic properties of French soils. The purposes of this database are to: (i) assemble all data on these properties determined by different research laboratories, as well as any additional analytical or descriptive data, (ii) make these data available to researchers in order to compare measurement methods and prepare pedotransfer functions using the diversity of French soils, (iii) prepare nationally recognized references for users. There are links between this database, DONESOL and the European HYPRES system (Wösten *et al.*, 1998).

BNAT: More than 200 000 soil analyses are carried out by private parties every year. A feasibility study was conducted from 1990 to 1994 in order to recover these data and include them in a database called Base Nationale des Analyses de Terre (National Base of Land Analyses) (Walter *et al.*, 1997, Schvartz *et al.*, 1998). The data were then collated by township and by districts to protect the rights of the analysis owners. Each variable can be expressed in the form of maps or statistical tables and these documents led to the confirmation of spatial structures that are often known but never quantified, especially for variables that are difficult to determine in conventional mapping work (Figure 3). The value of this database involves the analysis of possible changes in soil properties over time. The detection of these changes will require a longer time span.

The collection and structuring of analytical data obtained by private parties is a valuable source for regional or national reviews. In addition to the BNAT, the AGREDE programme conducted by ADEME and INRA recovered close to 12 000 analyses, collected between 1992 and 1997, of heavy metals from studies preceding fertilization by stations for water treatment

FIGURE 3
Localization of monitoring sites in France



of sewage sludges. Maps currently being edited display the general quality of agricultural soils and reveal zones of anomalies, either natural or provoked by local pollution.

Some uses for soil data

Some examples of the use of soil databases described above can be evoked in relation with topics directly involving the soil (erosion), agricultural production (product quality), or natural resources management (aquifers, rivers). These examples were also selected to demonstrate national or regional applications that illustrate in various ways the value of the different databases.

Among the various threats for the soil, erosion is clearly among the most visible, from agricultural (loss of land) and environmental (water pollution, damage to urban and road infrastructures) points of view. A map of "soil erosion" risks has been realized for the French territory, using GIS to combine the various factors responsible for erosion (Le Bissonnais *et*

FIGURE 4
Seasonal erosion risks in France

al., 1998): crusting and soil erodibility determined from the 1:1 000 000 database, plant cover taken from CORINE land cover, slopes and precipitation (quantity and intensity). The various factors were combined using a simple empirical model and a Digital Elevation Model with a 250 m grid. The results were then computed for small drainage basins or for small agricultural regions and shown for each of the four seasons (Figure 4). These results allowed inter-regional comparisons to help define the nature and intensity of erosion. These documents are then compared with regional studies (King *et al.*, 1998) or presented to regional decision makers to foster an increased awareness through sensitization campaigns and to propose remedial measures.

The database obtained from the IGCS programme is rarely used alone to express a soil characteristic. In most cases it is included in combinations with other databases, in particular those containing climatic, topographic and agricultural data. Combinations are created using dynamic models that reproduce past events by simulation (agrometeorological models, hydrological models, etc.). The maps show risks related to a change in agricultural practices or to climatic changes, in the form of frequency analyses. In this field, the number of studies is high (MAPA, 1998): for example, risk of nitrate leaching in Brittany (Saby *et al.*, 1999), irrigation management in the Beauce (Cousin *et al.*, 1999), vulnerability to fertilizing, fertilizing with urban composts (Legros *et al.*, 1991), quality of the agriculture production (Monnet and Gaiffe, 1998), diversification of cultures after removing grapevines (Bornand *et al.*, 1994). In most of these studies, the soil has a predominant role in the results, but it is difficult to discern the weight given to it in the final decision. This results from the modeling methods that use other environment variables and from sociological and political factors that are necessarily present in decision-making processes.

This observation has also been verified for the use of monitoring networks. For example, the objectives concerning air pollution are to reduce the emissions of pollutants that affect ecosystems at long distance. The concept of critical loads enables the effects of atmospheric fallout to be quantified in terms of forest decline and streams pH. In France, the ADEME has implemented and led regional and national work in order to respond to the particular needs of the Environment Ministry at the time of revision of international protocols (e.g. Dambrine *et al.*, 1998, Thomas *et al.*, 1998). The network data used in this case are an essential support for international comparisons.

Future work

Future work is are discussed with reference to three questions : soil mapping, soil monitoring and the circulation of information.

In the field of mapping, 1:250 000 work is continuing in order to obtain exhaustive and integrated information for the entire French territory. This scale, however, is insufficient to respond to all kind of social demands that are highly varied and in need of more precise data. There are no national plans to allocate considerable resources to respond to this demand for precise information. On the other hand, it has been proposed to reinforce existing 1:100 000 studies by organizing the results obtained in knowledge bases. In this way, local governments and institutions, rural land managers or design offices can consult the data and apply this knowledge to the areas they are concerned with. In addition, we are noting an increase in the needs for mapping at highly detailed scales, i.e. down to the level of agricultural plots. This has resulted from progress in techniques of spatial positioning and their associated agricultural techniques (precision farming). It is thus planned to reinforce research on these new techniques, in particular in the use of geophysics and digital elevation models. Finally, this multi-scale approach, from the plot to the region, requires continuation of researches about scale transfer methods (e.g. Lagacherie *et al.*, 1997).

Concerning soil monitoring, French systems are judged satisfactory regarding forested areas but insufficient for agricultural zones. Thus, there is a need to plan for a new system that would include the two land use types. The first would be composed of a large number of sites monitored with a time interval of about 5 years. The objective will be to set up a warning system that makes no prior assumptions on pressures that could be exerted on soils during the coming years. The second would be applied to a limited number of sites to monitor fluxes at shorter time intervals (day, month) and thereby be able to analyze and explain recorded long-term changes. In this context, the Environment Ministry has started a research programme (GESSOL) intended to establish the scientific tools and bases to assess, monitor and even restore soil quality.

Finally, it is recognized that all current or future programmes will be of interest only if the data gathered are circulated as widely as possible and in the most instructive manner. This implies the pursuit of research in the field of combining spatial data and in that of evaluating error propagation during these combinations. In addition, there is a need to develop methods for packaging and circulating information, in particular by the use of modern computer technologies (Web, CD-ROM). It is necessary to obtain more information on user needs in order to develop the tools that can be most efficient in responding to these needs.

Conclusions

Inventory and monitoring of soils are in a decisive phase of their development.

Inventory programmes are from now on regrouped within one information system with multiple scales. They should be better able to answer the diverse needs at the different levels of precision requested.

Monitoring programmes are a priority to develop a coherent policy in order to finally dispose of a cartographic coverage and statistical data both at national level and for each region individually.

Research remains one of the main of driving forces for those different programmes, but it cannot alone face the variety and urgency of expressed needs. It is essential to establish a policy for information diffusion and to help create tools for policy makers.

A regroupment of all activities concerning soil inventory and monitoring of rural areas under one umbrella is now being studied by the different Ministries in charge of agriculture, the environment and land management. To be successful in such a project, the participation of direct or indirect users of soil information should be advocated within the proposed structure.

Concerning the relationship between the geographical soil database at 1:1 M developed by the European Union and the countries still not included in the European zone as defined by the FAO, the European Soil Bureau should introduce a proposition to avoid redundancy with that base at 1:1 M resolution and an actual extension to Eastern Europe.

The European area should be integrated in the world database of FAO. This should involve the transfer of parts of the European database in the SOTER format to the FAO database, with a resolution adjusted to the 1:5 M scale used for the other continents.

The policy engaged by INRA with the European partners and the Ministry of Agriculture (IGCS programme) seems to be well adapted to European and national needs. The scales and methods selected for the works by the national coordination are in conformity with the international standards.

The current international trends support the actual project of reorganization of national programmes of soil data acquisition and management that have been submitted to the concerned authorities (MAP, MATE, IFEN).

References

Baize D., 1997 – Teneurs totales en éléments traces métalliques dans les sols (France). Références and stratégies d'interprétation. *INRA Editions*, Paris. 410p.

Bornand M., Legros J.P., Rouzet C., 1994 - Les banques régionales de données-sols. Exemple du Languedoc-Roussillon. *Etude and Gestion des Sols*. 1. 67-82.

Bornand M., 1998 - Connaissance and suivi de la qualité des sols en France. MAPA-MATE-INRA. INRA Montpellier. 176p.

Dambrine E., Thomas A.L., Party J.P., Probst A., Boudot J.P., Duc M., Dupouey J.L., Gégout J.C., Guérold F., King D., Landman G., Maitat O., Nicolaï M., Pollier B., Thimonier A., 1998 - Acidité des écosystèmes forestiers dans les Vosges gréseuses: distribution, évolution, rôle des dépôts atmosphérique et conséquences biologiques. *C.R. Acad. Agric. Fr*. 84(5). 75-94.

Favrot J.C., Lagacherie Ph., 1993 - La cartographie automatisée des sols: une aide à la gestion ecologique des paysages ruraux.. *C.R. Acad. Agric. Fr.* 93-79 (5). 61-76.

Favrot J.C., 1994 - Note de synthèse sur le volet pédologique and sur le répertoire informatisé REFERSOLS. *INRA Document, Montpellier*. 34p.

Favrot J.C., 1997 - Répertoire des organismes and spécialistes intervenant en cartographie, en analyse des sols and pédologie appliquée (France métropolitaine). *INRA-MAPA Document*. INRA, Montpellier. 88p.

Finke P., Hartwich R., Dudal R., Ibañez J., Jamagne M., King D., Montanarella L., Yassoglou N., 1999 - Georeferenced Soil Database for Europe. Manual of procedures, version 1.1. *ESB-SAI-JRC. Ispra*. 184p.

Gaultier J.P., Legros J.P., Bornand M., King D., Favrot J.C., Hardy R., 1993 - L'organisation et la gestion des données pédologiques spatialisées : le projet DONESOL. *Revue de géomatique*, 3, 235-253.

IFEN, 1999 - L'environnement en France. La découverte. Editions La découverte & Syros et IFEN. Paris and Orléans. 480 p.

Jamagne M., Hardy R., King D., Bornand M., 1995 - La base de données géographique des sols de France. *Etude and Gestion des Sols*. 2(3). 153-172.

King D., Fox D.M., Daroussin J., Le Bissonnais Y., Danneels V., 1998 - Upscaling a simple erosion model from small areas to a large region. *Nutrient Cycling in Agroecosystems*. 50, 143-149.

Le Bissonnais Y., Montier C., Daroussin J. and King D., 1998 - Cartographie de l'aléa érosion des sols de France. IFEN-MATE Report. Collection Etudes et Travaux No. 18, 60 p.

Legros J.P., Bornand M., Viron J.C., 1991 - Recherches des zones aptes à l'épandage de composts urbains dans la région de Montpellier (Hérault, France). GIS Colloquium, Florac. INRA. 229-239.

MAPA, 1998 – Rapport IGCS sur les travaux du Colloque de Poitiers. *Doc. Roneo*. 12 p.

Martin S., 1993 - L'observatoire de la Qualité des Sols, un outil de gestion pour l'agriculture, un instrument d'observation de la biosphère. *Chambre d'Agriculture*. Supplement No. 897. 8-10.

Nouzille C., Nicoullaud B., Duval O., Golaz F., Couturier A., Bruand A., 1999 – Etude de l'alimentation naturelle de la nappe de Beauce. Elaboration d'un modèle de calcul de l'infiltration efficace. INRA Orléans. 78 p. + annexes.

Saby N., Walter C., Combo S., Quidu O., 1999 – Constitution et thématisation de la base de données du référentiel pédologique du sud de l'Ille et Vilaine. Laboratoire de Science du Sol ENSA Rennes. 52p.

Schvartz C., Walter C., Daroussin J., King D., 1998 - Statistical review of the soil tests made in France and comparison with the 1:1 000 000 soil map. *16th World Congress of Soil Science*, Montpellier, 20-26/08/1998.

Thomas A.L., King, D., Dambrine E., Couturier A. and Roque J., - Modelling spatial variability of soils with parameters derived from relief and geologic materials in sandstone part of the Vosges (Northearstern France). *Geoderma*. (in press).

Ulrich E., 1995 - Le reseau RENECOFOR: Objectifs et réalisations. *Revue Forestière Française*. Vol. 2. 107-121.

Walter C., Schvartz C., Claudot B., Bouedo T., Aurousseau P., 1997 - Synthèse nationale des analyses de terre réalisées entre 1990 et 1994. Description statistique et cartographique de la variabilité des horizons de surface cultivés. *Etude et Gestion des Sols*. 4(3). 205-218p.

Wösten J.H.M., Lilly A., Nemes A., Le Bas C., 1999 - Development and use of a database of hydraulic properties of European soils. Geoderma. 90, 169-185.

The designations employed and the presentation of the material in this publication do not imply the expression of any opinion whatsoever on the part of the Food and Agriculture Organization of the United Nations concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries.

ISBN 92-5-104454-6