ACCESS TO SOIL DATABASES AND THEIR USE IN A EUROPEAN CONTEXT

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Abstract: This paper describes some of the digital soil databases that exist for the UK and the European Union as a whole and the access procedures currently in place or proposed for distribution of the data. The need for soil data, as input to decision support systems for planning the sustainable use of land, has grown steadily since the 1970s. The potential uses for such data have expanded considerably from the traditional topic areas of crop production and soil conservation into the utilities (water, gas and electricity supply), finance and environmental sectors. These new uses include: suitability for alternative land uses, environmental risk assessment and geotechnical applications. With this expanding market for soil data, availability and access have become important issues. Data holdings are now viewed as valuable sources of income. Procedures for accessing the data should address ownership, intellectual property rights (IPR), controls and charges for commercial use. Increasingly, scientific research organisations that compile data sets will have to give due attention to these issues if their long-term survival is to be assured.

Key words: Soil, databases, access, use, European.

Resumen: Este trabajo describe algunas de las bases de datos digitales de suelos existentes en el Reino Unido y en la Unión Europea, y los procedimientos de acceso, existentes o propuestos, para distribuir los datos. La necesidad de datos de suelos como input para los sistemas de toma de decisiones en la planificación del uso sostenible del territorio ha aumentado desde los años 70. Los usos potenciales de estos datos no son simplemente los tradicionales para producción de cosechas y conservación de suelos; hoy las empresas de aguas, gas y electricidad, financieras, de seguros y medioambientales los necesitan. Estos nuevos usos incluyen aptitud para usos alternativos del suelo, evaluación del impacto ambiental y aplicaciones geotécnicas. Con el mercado de datos de suelos en expansión la disponibilidad y el acceso a los mismos son aspectos importantes. La posesión de datos es ahora una fuente valiosa de ingresos. Los procedimientos para acceder a los datos deben cubrir la posesión, la propiedad intelectual, controles de uso y precios para su uso comercial. Las organizaciones científicas de investigación que compilen tales datos deben considerar estos aspectos para asegurar su supervivencia.

Palabras clave: Suelo, bases de datos, acceso, uso, europeo.

INTRODUCTION

In a world where environmental problems are increasingly seen as a threat to human survival, provision of soil information has become a high priority as research efforts concentrate on environmental protection and the search for sustainable systems of land use. At the same time, public support for fundamental research is shrinking in relative terms and scientists now have to pursue alternative sources of revenue to fund their activities.

The increasing sophistication and complexity of experimental soil science is leading to unrealistic demands on the funding that can be provided by national and international agencies. Primary data collection underpins most fundamental research programmes so this activity is severely contrained as well. In only very few countries of Europe are basic soil survey and associated data collection currently actively supported by government or private agencies (Hodgson, 1991) and this is true elsewhere in the world.

In the UK, the 'privatisation' of research is well advanced and research institutes are being asked to rely on their accrued intellectual capital and data holdings as a means of funding future activities. Experience to date is variable. Great difficulties have been encountered in the agricultural sector where there is a tradition of 'free' advice and 'free' or low-cost supply of data underwritten by government funding. However, in the utilities (water, electricity, gas) and finance (insurance, investment) sectors, the users of environmental data are willing to pay a realistic price largely because of the perceived value of environmental information to their businesses. Moreover, profit margins are greater in these sectors than in agriculture, thus higher prices can be charged.

Soil is a fundamental factor in the environment, but throughout much of the twentieth century soils data have been extremely sparse. The Cranfield University Soil Survey and Land Research Centre (SSLRC) has been developing soil and land information systems for nearly two decades. A number of fully computerised information systems have now been developed from this early experimentation and their capabilities have increased dramatically with the vast improvements in computer processing power that have occurred in recent years. The uses to which these data and systems have been applied are wide and varied.

Following transfer from the government research sector to Cranfield University in 1987, SSLRC has had to develop a self-supporting/ sustaining approach to the release of soil data to the user community to ensure long-term survival of the data and the expertise to interpret them. Preservation of a national digital soil and land database for 'the public good' is seen as a primary aim of SSLRC.

The kinds of soil databases that are available in the UK are described briefly below. A parallel situation is developing on the European continent where EU databases are about to be released to the user community under licence. These EU databases are also described. Finally, the procedures for access and distribution are outlined and the sectors using soil data are identified.

SOIL DATABASES

Two database developments are central to the context of this paper:

• Land Information System (LandIS) - England & Wales (UK)

• European Soil Database - European Union (EU)

Other information systems have been or are still being developed by SSLRC - Soil Information System for Ethiopia (SISE), Jordan Soil and Climate Information System (JOSCIS), Sistema de Información de Tierras de Venezuela (SITVEN), Natural Resources Information Centre for Tanzania (TANRIC), Spatial Soil Information System for Pakistan (SISPAK) - but these systems are based largely on the LandIS model.

Satellite systems have also been developed from the LandIS information base. These systems have been developed for the commercial market as solutions to specific business problems. These are as follows:

• CatchIS - Catchment Information System (Breach *et al.*, 1994), for use in maintaining water quality;

• SEISMIC - Spatial Environmental Information System for Monitoring the Impact of Chemicals (Hallett *et al.*, 1995), for use in the research of pollutant transfer;

• Insure - Information System for Underwriting Risk Evaluation (Hallett *et al.*, 1994; Jones *et al.*, 1995a), for use in the insurance industry.

LandIS

LandIS contains a large information base on soils and related properties (climate, land use, etc.) for England and Wales. The main data sets are:

1 National Soil Map at 1:250,000 scale (NATMAP) - a digital image at 100m resolution of the published maps for England and Wales (Soil Survey Staff, 1983).

2 National Soil Inventory (NSI) at 5km resolution with analytical data relating to topsoils, e.g. particle-size, organic matter, soluble nutrients and trace elements.

3 National Catalogue of Soils (NATCAT) comprising detailed data on each of the 720 national soil series (Clayden and Hollis, 1984) that have been identified and mapped.

4 Soil and site descriptions for 2000 representative and benchmark profiles excavated to 1.2 to 1.5 m depth to characterise the 720 national soil series and for 142,000 auger bore holes excavated to 1m depth to delineate soil mapping units.

5 Chemical and physical data - up to 145 different analyses of samples taken from representative and benchmark profiles; for example, particle-size, density, pH, organic carbon etc.

6 Agroclimatic Databank (Jones and Thomasson, 1985) containing averages (for International Standard Periods) of precipitation, evapotranspiration, moisture deficit, field capacity and accumulated temperatures above various base values (see also Hallett and Jones, 1993).

Data storage is in relationally structured files managed by a relational database management system (RDBMS). The design is flexible and to a degree object-oriented (Ragg and Proctor, 1983; Proctor *et al.*, unpubl.). The system is further supported by a number of satellite systems for validating and pre-processing raw data. It has the capability to manipulate central databases and update master files; and there is a user-friendly menu system providing access. Further descriptions of LandIS can be found in Jones *et al.* (1993) and Hallett *et al.* (1996).

LandIS is now being re-engineered because of rapid technological change in both hardware and software and to improve connectivity with other UK environmental databases. The database structures are currently being transferred to Oracle (v7.0) under SQL and the system functions on a dedicated database server (Digital Alpha AXP) at Silsoe (Jones *et al.*, 1992). A number of applications are also under development for the desktop PC running MS_Windows (Jones and Bullock, 1996).

European Soil Database

Currently, there are three European soil databases in existence:

• EU Soil Map - Graphical database comprising polygons representing soil map units and an extended legend

• EU Soil Profile Database - analytical data

• EU Methodological Database - pedotransfer rules

Graphical database

The EU Soil Map, published as a paper map (CEC, 1985), was digitized for the CORINE Programme (Platou *et al.*, 1989). This original version EC Soil Map was made in the 1970s and, following appraisal by soil experts, a programme of updating the map was instigated by the EU Joint Research Centre, Ispra (Italy) (King *et al.*, 1995b) and this has been under way for the past five years. A new version (3.1) of the digital database is nearing completion - the graphical database has been expanded to include Eastern and Central Europe and the Nordic countries - and will be ready for distribution soon (Jones *et al.*, 1995b). An expanded legend for the map has also been compiled and pedotransfer rules developed for environmental interpretations of the Soil Map (Van Ranst *et al.*, 1995).

Soil Profile Database

A Soil Profile Database for the EU was proposed in the late 1980s (Madsen, 1991) and compilation began in 1993. A *Soil Profile Analytical Database*, containing information for the dominant soil in each EU soil map unit (at country level), has now been compiled (Madsen and Jones, 1995). A *Soil Profile Morphological Database* still needs to be compiled so that the relevant soil structural information becomes available together with the relevant analytical data for further interpretation of the EU Soil Map.

ACCESS PROCEDURES

The exchange of digital information on soils and the environment requires a clear policy covering the following aspects:

1 Availability
2 Access
3 Use
4 Control

Availability means 'where are the data and are they accessible?' Catalogues, the traditional means of identifying data, are now increasingly being replaced by *metadatabases* that contain detailed information about data but not the data themselves.

Access requires permission from the owner. This permission is increasingly being granted through a formal agreement or *licence* to use the data. Distribution mechanisms go together with authorisation and require an administrative framework and technical support, especially if there is a charge for use of the data.

There has been a radical change in attitude concerning the availability of environmental data within the last few years, from the extreme viewpoint that "all data should be available free of charge to everybody" to the policy that "no data should be supplied without charge" and with due consideration to Intellectual Property Rights (IPR). Furthermore, the potential user base for the data has expanded considerably.

Increasingly in the UK and in other countries such as the Netherlands, organisations take the view that, to protect their interests, data should be *leased:* ie released under *licence*, but not *sold*. A *data licence* defines the *use* to which the data would be put. In the UK, and subsequently at EU level, a standard form of licence for soil data has been defined (Jarvis, unpubl.). Each data licence may be the subject of individual negotiation and documentation but charges are generally standardised. A Licence is an attempt to *control* the process by placing limitations on the *use* of data.

Important criteria in the modern age of data management are the *ownership* and *value* of data. Safeguarding the ownership and protecting data, so that the value can be realised into the future, are important aspects of the sustainability (financial viability) of data providers. There is no such thing as free data! Somebody or some organisation has had to pay for collection, validation, storage and retrieval at some time during the life cycle of a data set or database, even if it is supplied without charge at the point of delivery.

Ownership

Ownership needs to be established and acknowledged. The copyright issue must be addressed in the licence agreement. However, it may not be a simple matter. The concept of IPR is that the knowledge of experts together with unique information are encapsulated in an item of data, a data holding on a whole information system. The ownership or 'property right' rests with the initiator of the original idea, the collector of the original data or the sponsor of the primary data collection process. These principles apply to digital soil data in the same way as for any other data.

Data custodians

Custodians of data are agencies that supply data. They may also be the agencies that own the data and retain the copyright. In modern terminology, they can be regarded as *data centres*. However, some data were collected so long ago that ownership is difficult to establish - the original collectors of the data may be deceased and/or the organisation may no longer exist. Thus custodians of data can effectively become *owners* of data in their possession.

The boundaries around custodians of data are not clear. An agency can be both a user and a custodian. A custodian can range from an individual to a large agency. Custodians may collect data as well as be responsible for their management. These aspects will in future be as important as the technology and capability of individual information systems to extract and manipulate data.

Protection of data

By their very nature, computerized information systems make large quantities of data available to a wide range of users. Organisational changes in most countries are seeing less central government funding of research institutions than in the past. This is leading to the realisation that the data holding of an institution needs to be carefully valued to realise the income generating capacity. Protection of data, i.e. guarding against unauthorized access or theft, is thus an important issue. Security procedures, both physical and electronic (passwords, etc.), must be introduced and monitored for their effectiveness.

Data licensing

In the data licence agreements formulated by the UK and other European countries, the *Licensor* is the owner or custodian of the database and the *Customer* is the receiver and/or user of the data. The licences are made project-specific to simplify the specification of use and to facilitate control, thereby safeguarding both the licensor and the customer. In summary, licences should:

- cover the use of all components of the database or data set as defined and specified in the detailed agreement;
- specify the purpose of the use of the data; define the limitations and restrictions on use of the data;
- be *project-* and *time-* specific [minimum period of operation is 1 year];
- specify that the customer shall have no right to sell, assign, rent, give or make available to others, otherwise transfer or dispose of the *Database*, or products derived therefrom without the prior written consent of the *Licensor*.

A typical procedure to be followed by a data custodian/centre as the licensor of soil data would be as follows:

1. Receipt of request from customer;
2. Evaluation of customer's request;
3. Specification of the data to be drawn up as a Schedule to the licence;
4. Signing of the licence by the appropriate authorities - data centre and customer;
5. Exchange of signed copies of the licence with customer;
6. Supply of data on media (magnetic tape, CD-Rom, diskette) on receipt of signed licence from customer;
7. Document transactions;
8. Monitor use of the licensed data by the customer -check for infringements
9. Invoice customer annually or terminate licence.

Once a licence is issued, the licensor is obliged to monitor use of the leased data and take vigorous action against any infringements. Because payments are usually involved, this is as much in the interests of the customer as it is for those of the licensor.

Data use

Users generally fall into the following categories: Education, Research, Government and Private/Commercial. Charges for data or their interpretation have to be worked out and this is not easy in an environment where soil data have traditionally been supplied without charge. Government is a special case because, in most countries, it funds much of the collection of natural resource data as well as being a major user. In a cost-recovery situation, charges must reflect this underlying support for the data collection process.

Data costs and pricing structures

The main digital data sets of any data collection need to be carefully costed. Pricing should be realistic and in principle should take account of the following costs:

1 Collection (and compilation);
2 Initial processing;
3 Maintenance;
4 Extraction;
5 Data value;
6 Updating;
7 Administration and documentation.

Experience at this time suggests that a variable scale of charges is the best way to accommodate the different capabilities of potential users to pay for data. The model adopted in UK and NL (Bregt, pers. comm.) has three tiers:

- *zero* charge - for a customer that sponsored the collection and computerization of the data;
- *medium* charge - for academic or non-profit making research organisations;
- *high* charge - reserved for commercial customers.

Charging rates should at least reflect the investment in the database and the running costs of the systems that would deliver the data. A simple model is to estimate the overall costs of compiling, processing, maintaining and updating the data, and divide by the estimated number of potential customers. Judgment has to be exercised here because, in the first instance, this calculation may result in a price that is too high for the market.

In conclusion, therefore, there is a need to recognise the ownership of digital data, assess the value of the main data holdings develop procedures for the supply of information to third parties and actively promote the databases that exist within the organisation. Because soils are such an important part of the environment, the main aims in supplying users should be to encourage maximal use of soil data and to safeguard the 'public good'.

USES OF SOIL DATA

The use of soil data, in such fields as research, education, etc., has been mentioned above. This section briefly describes the technical aspects of use and gives some examples. Although the main soil databases in Europe were compiled in the 1960s and 1970s to support agricultural production, the challenge of the latter part of the 1980s and the early 1990s has been the use of these databases for applications not imagined at the time the data were being collected. In the experience of SSLRC, the traditional uses of soil data, for land management, crop suitability and soil erosion studies, have expanded to include the following:

- Land use policy
  Land management and crop suitability
- Pollutant transport
  Nitrate sensitivity and pesticide leaching
- Acidification
- Waste disposal
- Soil quality and protection
  Soil erosion and land degradation
- Contamination
- Geotechnical aspects
  Ground movement and corrosivity
- Climate change impacts

Land use policy

Most soil databases were originally set up to satisfy the demands of productive agriculture, to answer questions such as: 'Where are the most suitable areas for growing a particular type of crop?. Soil data have been, and still are being used, for assessing suitabilities for specific crops

(Jones and Thomasson, 1987; Thomasson and Jones, 1991) and for developing new strategies for managing land (Blackmore *et al.*, 1995). Because of the strategic importance of agriculture in most European countries, this will continue to be an important use for soil information.

Pollutant transport

By the middle 1980s, the environmental impact of modern farming in Europe was becoming apparent through problems of nitrate pollution, pesticide contamination, heavy metal deposition, erosion and farm waste disposal (Thompson, 1996). In common with other soil research organisations, SSLRC was called upon to divert attention away from examining the factors affecting agricultural production to specifically identifying the causes and pathways of pollution. Attention has focussed on nitrate pollution and pesticide vulnerability.

Nitrate leaching

The risk of nitrate leaching has been estimated from a simple model based on soil permeability and porosity, climate in the form of excess or leaching rainfall, and land use/ management. Maps of potential nitrate leaching losses have been produced by Jones *et al.* (1989) and Jones and Thomasson (1990) and these show that, under the present land use, much of the agricultural lowlands of England is potentially leaking nitrates through the soil profile at concentrations above the EC limit of 11.3 mg N/l (50 mg NO_3^-/l). This research shows that computerized soil and climate data from LandIS, an appropriate model and a GIS can provide an objective basis for decision support.

Pesticide contamination

Aquifer and surface water vulnerability to pestcide contamination is now of increasing concern in the delivery of potable water supplies in Europe. The recently imposed EC limit (0.1 ug/l) for the concentration of individual pesticide compounds in drinking water has focussed attention on the movement of pesticides beyond the root zone. Vulnerability assessments are built up by integrating a soil vulnerability classification, based on soil hydrology and organic matter content, with a physicochemical classification of pesticide active ingredients (Hollis, 1991).

CatchIS - a Catchment Information System - has been developed specifically to identify the areas where surface or ground waters are most vulnerable to pollution from pesticides. It contains models that assess the best and worst cases of aquifer and surface water vulnerability. CatchIS started as a research project but is now used as an operational tool by a major water supply company in the UK (Breach *et al.*, 1994). It is envisaged that it will become a regulatory tool in the future.

Acidification

By combining pH and soil texture, the capacity of the soil to absorb or buffer the effects of acid rain has been assessed. The approach uses soil analytical data (particle size class and pH) and relates these properties to soil series and hence soil map unit. A spatial distribution of soil buffering classes (Loveland, pers. comm.) for England and Wales has been produced by spatial analysis of LandIS data (Jones *et al.*, 1993). The results are now available for formulating a soil protection strategy and have been used for estimating critical loads by the UK Department of Environment.

Waste disposal

Farm wastes

The disposal of farm waste has now become a serious problem arising from the intensification of farming, particularly animal production. Consequently, a model has been developed for assessing the suitability of land for slurry acceptance. Slurry is the liquid animal effluent which is produced in large quantities by intensive cattle and pig farming systems. Storage is difficult and expensive, and disposal on unsuitable land can cause severe pollution of water courses and underground water supplies.

Spatial soil and climatic data from LandIS have been used to identify areas in south-west England where slurry can be spread safely (Clarke *et al.*, 1989). The model uses data originally collected for soil hydrological and workability assessments, and has been applied in other areas in England.

Sewage sludge

Dumping of raw sewage will soon be banned or so severely restricted in many of the seas around Europe; other means of disposal including spreading on land will have to be carefully researched. The suitability of land for accepting sewage sludge has been modelled spatially using soil and enviromental data stored in LandIS (Thompson, pers. comm.). The significant properties used for the modelling were soil texture, structure and permeability, heavy metal content, e.g. lead, nickel, cadmium (McGrath and Loveland, 1992), acidity (pH) and mechanical accessibility (workability, Thomasson and Jones, 1989). The approach provides a rapid means of identifying the location and area of potentially suitable land.

Soil protection (erosion)

Water erosion has been widely reported in England and Wales in the last decade and SSLRC has used monitoring techniques in conjunction with digital databases for a number of projects to determine the extent, frequency and rate of removal of soil particles. Erosion and deposition events over part of southern Britain have been mapped (Harrod, 1993) and the relationship between soil, slope, predicted erosion risk and land use, and the resulting erosion/deposition has been examined. Erosion was most prevalent on bare soil surfaces between cultivation and establishment of winter sown crops on fine sandy silt loam soils (Hodgson, 1974). It was also found to have occurred even on gentle slopes (<5°).

Geotechnical aspects

Ground movement and subsidence

The capacity of a soil to shrink and swell as its water content changes with the seasons and with extremes of climate depends on the clay content and type. The mechanisms are well understood and have been documented by Jarvis (1993). The shrinking and swelling of soil can lead to ground movement and then subsidence which can have a devastating effect on building structures.

SSLRC has developed Insure - Information System for Underwriting Risk Evaluation - for use in the finance sector (Hallett *et al.*, 1994; Jones *et al.*, 1995a). Insure predicts the likely risk of subsidence, flood and storm on a spatial basis for each UK Postcode Unit (normally between 10-50 houses in urban areas). It provides a scientific basis for setting household insurance rates.

Corrosivity

The corrosion of metal buried in the soil is a complex electro-chemical process and it is difficult to identify all the contributing factors. Although there is no national standard for assessing corrosivity of soil, SSLRC has produced a model for assessing the aggressiveness of soil to buried metalwork (Jarvis and Hedges, 1994). This has been used in conjunction with spatial soil data to identify the most corrosive areas (Jones *et al.*, 1993). The real benefit is for water supply companies as the results allow them to assess the overall risks to the buried pipe network and focusses attention on the parts that are most liable to leakage. This is currently of high priority in the water supply industry.

CONCLUSION

The existence of digital soil data in the UK and Europe is highlighted and some examples are described. More information on soil databases at European level is given in King *et al.* (1995a) and Le Bas and Jamagne (1996). The value of such data is becoming appreciated and the potential uses are wide and varied, extending well beyond the agricultural industry.

For the security and value of digital soil data to be fully realised, attention must be directed to the access procedures. These have been described in some detail and a *data licence* issued by an owner to a customer is proposed as a central part of the whole process. The *licence* must clearly specify ownership of the data and, so that appropriate safeguards are built into the distribution process, the Intellectual Property Rights (IPR) of the owner must be recognised by the *customer*.

Data holdings are crucially important to soil research organisations and they will increasingly contribute to the sustainability (financial viability) of these organisations in the future. Licensing of primary and manipulated soil and environmental data will become an important means whereby the funding needed to support future research activities can be generated. Much of this research will be directed towards the *sustainable* use of land resources and therefore will be in the 'public good'.

ACKNOWLEDGEMENT

The author wishes to thank many colleagues in the Soil Survey and Land Research Centre (SSLRC) for support over the years in the collaborative research efforts that are reviewed here. Particular thanks are owed to Professor P. Bullock, Director of SSLRC, for his encouragement for all information systems activities, Mary Proctor, Database Administrator (SSLRC) for her design and implementation of LandIS, Michael Jarvis, Head of Land Resource Management (SSLRC) for his pioneering work in developing the data licensing procedures described here, and Barbara Buckley for unstinting support in preparing this paper.

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