On-line soil resource inventories: status and prospects

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Abstract

Since 1997 the author has maintained the website "A Compendium of On-Line Soil Survey Information". During these five years, the amount and quality of digital data sets at global, national, regional, and local scales has increased dramatically. Some of this is freely available on-line, via the World Wide Web. This paper presents an inventory of such data, categorised by region, scale, and theme. There is a large discrepancy among countries with respect to their philosophies of public access to foundation data such as soil maps. Key problems remain, most notably the lack of accurate metadata and searchable indices, and thematic and geometric compatibility with related digital data. Emphasis must be given to ease of user access and application by professionals who are not soils specialists.

Keywords: digital_databases, world_wide_web, soil_survey, soil_resource_inventory

Introduction

Soil resource inventories, also known as *soil surveys*, are any spatially explicit information about the distribution of soil types or properties. These are usually presented as maps, which divide the survey area into polygons, with an accompanying report that describes the soils in groups of polygons known as *map units*. This common form is known as the *area-class* soil map, and corresponds to the discrete model of spatial variation (DMSV) (Heuvelink and Webster, 2001). A minority of soil resource inventories corresponds to the continuous model of spatial variation (CMSV): *continuous-field* maps of soil properties, or in very rare cases, classes (de Gruijter et al., 1997). Information about soil properties and behaviour is widely recognised as vital for making decisions on proper land use and management. Especially useful in this regard are interpreted soils information, for example soil survey interpretations, land evaluations for specific land uses, or data prepared for specific classes of models.

Soil survey organisations have typically been concerned to publicise their work and to make sure it reaches potential users. Traditionally, distribution channels were county agents or extension workers and public libraries. Often the main user of the data was the agency itself, perhaps interpreting it for third parties under contract or using it for farm planning. There has been ever-increasing demand by other governmental agencies (e.g. environmental), consultants, industry, NGO's, and researchers for both raw and

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interpreted data. Some of these users want the raw data; others would prefer that a specialist interpret it in a form that they can directly use in their work.

The explosive growth of the world wide web (WWW) has the potential to revolutionise the distribution of soil survey information. In particular, the ease of combining a digital soils theme with spatially related information (land use, land ownership, planning units, infrastructure, ecological surveys etc.) is a synergistic relation that can greatly increase the utility of soil surveys. Availability via the WWW or on CD-ROM, with no or liberal use restrictions, means that anyone can use the data, perhaps in novel and unpredicted ways.

The Compendium

Since 1997 the author has maintained the website "A Compendium of On-Line Soil Survey Information" (Rossiter, 2000), whose purpose to reference all information on soil survey activities, institutions, datasets, research, and teaching that is available on-line, i.e. via the WWW, with eventual downloading via FTP if the referred site so permits. A *compendium* is defined as "a collection of detailed items of information, especially in a book" (Hornby, 1995); here the items are links to on-line resources, annotated by the author to indicate his opinion of their reliability and usefulness.

The Compendium is divided into 8 major sections: (1) Soil survey institutes & activities (2) Learning about soil survey; (3) Soil classification for soil survey; (4) Applications & Models (including soil survey interpretations); (5) Methods & Techniques; (6) Land Evaluation; (7) Digital Soil Geographic Databases; and (8) Computer programs for soil survey. It has smaller sections on (1) selected soil science links, a (2) bibliography, and a (3) list of relevant on-line journals. There is no attempt to cover soil science, mapping, or GIS as such; instead the site is limited to information directly relevant to soil survey.

The major effort has been to provide access to on-line datasets, via the section "Digital Soil Geographic Databases", and to supporting information such as soil mapping procedures and soil classifications. During the past five years, the author has spent several weeks a year actively searching for new information and updating links as web sites are reorganised. This has resulted in a fairly comprehensive picture of what is available.

On a typical workday during the past two years, about thirty people visit the Compendium. The distribution by internet domain corresponds quite closely to the availability of internet access: 50.1% from the USA (.edu, .com, .gov, .mil), 24.0% from Europe, 6.1% from Canada and Australia, 5.7% from Asia, 4.5% from Mexico, South and Central America, 0.7% from Africa, 8.9% from international organisations and networks (.org, .net). We do not know which links are most popular with visitors.

Over 160 web sites include a link to the Compendium; most are libraries, portals, soil science faculties, and soil survey organisations.

Soil survey information available on-line

The simplest digital product is a digitised version of a paper map, with each polygon, line, or spot symbol labelled as on the original map. This makes the information more accessible and easy to incorporate in a GIS, but does not otherwise add value to the paper map. Similar to this is a non-relational database of site observations and accompanying lab data. Typically some cleanup work is done during digitising. Although these are indeed databases, a step further is the true *soil geographic database* (SGDB), which is designed from the start as a digital product, for information retrieval and incorporation into a GIS. It has maps of soil or soil-landscape units, linked to both property and interpretive attribute tables, and often a set of representative point observations with laboratory data.

The following brief inventory is current as of late January 2002; the mentioned datasets are accessible via the Compendium web page.

World

Climate modellers have abstracted the FAO Soil Map of the World (FAO, 1974) to a 0.5°x0.5° grid of relevant soil properties, including general texture, depth, and slope (Post, 2000). This extends the so-called "Zobler" data set. Other derived properties, such as water-holding capacity and organic carbon, are included in datasets available from the Distributed Active Archive Center (DAAC), Oak Ridge National Laboratory, USA. These are conceptually continuous-field maps, at a coarse scale. The FAO polygon map itself (1:5 000 000) is available on CD-ROM ($350, January 2002) but not on-line.

Regional

The outstanding examples of regional soil databases are those made with the SOTER methodology, jointly developed by UNEP, IUSS, ISRIC and the FAO (FAO, 1995; van Engelen and Wen Ting-tiang, 1995). These are currently available for Latin America and the Caribbean (SOTERLAC) (FAO, 1998b) and Central & Eastern Europe (SOVEUR) (FAO, 1998d); both of these are available on-line from ISRIC and as CD-ROM's in the FAO's Land and Water Digital Media Series. ISRIC has also produced a dataset for northeast Africa (FAO, 1998c), available only on CD-ROM. The FAO also publishes a CD-ROM in this series with a soil and physiographic database for North and Central Eurasia (FAO, 1999).

The 1:1 000 000 European soils data set is explicitly *not* distributed outside the European Commission itself, with the explanation that "on the one hand, the copyright of the original provider usually prevents any redistribution. On the other, we do not have the data management facilities required to handle large scale data preparation" (Joint Research Centre, 2002). The second reason is dubious, as a one-time project can prepare a coverage and associated tables. As for the first, the data was re-interpreted for this map and could be considered a new product. The real reason seems to be shortsighted profit seeking at the expense of the Union's citizens. In the introduction to the technical report of the database (Jones and Buckley, 1996) we read: "Data holdings are now viewed as valuable sources of income". At the same time, these authors point out the increasing demand for soils data and the wide variety of users. The contradiction between maximizing income to the data producer and maximizing economic value to the European people does not seem to have been considered. It is to be hoped that as the projected multi-scale European Soil Information System (EURSIS) becomes a reality, attention is paid to mechanisms for the widest possible diffusion to all who might make use of the data.

National

The USA and Canada have complete national coverages at small scale (1:5 000 000) and sectional coverages at medium scale (1:250 000), as well as many detailed surveys (1:24 000 to 1:12 000) available for downloading, along with supporting metadata, interpretive tables, and descriptions of soil types. On-line national coverages at small scale are available for Mexico, Brazil, and Kenya (SOTER); these were not produced by their national agencies, but rather by international data centres (UNEP, EROS, and ISRIC, respectively). Australia's national map (1:2 000 000) is also freely available.

States, Provinces

Many of the United States have established their own geospatial data infrastructure (GDI), usually in the form of "clearing houses", i.e. a site that points to datasets held in various agencies. Soils are always part of these; these are the same coverages available from the national database. Several German states, e.g. Lower Saxony, have on-line references to digital soil maps at various scales that are available for purchase at an accessible price; but there is no on-line access.

Point data

The Soil Survey Laboratory of the US National Soil Survey Center has made available on-line and on CD-ROM the analytical data for about 20,000 pedons of US. soils and about 1,100 from other countries; in most cases the morphological descriptions are included. The geo-reference of these is not precise, because most were collected to represent soil series, not as point samples. A standardized set of profiles for global environmental research was produced during the WISE project (Batjes, 1995); it is available for downloading from ISRIC and DAAC. SOVEUR includes geo-referenced profiles on its CD-ROM.

Soil classification systems

Both the World Reference Base (Bridges et al., 1998; Deckers et al., 1998; FAO, 1998a) and Soil Taxonomy (Soil Survey Staff, 1999) have their own home pages, with complete text and keys both downloadable. National systems on-line include the Australian 1996 and the 2nd Canadian (but not the 3rd, which is only available in print). A few other systems are briefly described on-line, but not in useful detail. Among interpretive classifications, the Unified (engineering) system is provided on-line by the United States Army (United States Army, 1992), the FAO Topsoil classification (Land and Water Development Division, 1998) (partly based on the Fertility Capability Classification (Sánchez et al., 1982; Smith, 1989)) is provided by the FAO, and the UK Land Capability Classification (Bibby et al., 1991) by the British Society of Soil Science.

Methods

The Americans lead the way here, making available the full text of the Soil Survey Manual (Soil Survey Division Staff, 1993), the Field Book for Describing and Sampling Soils (Schoeneberger et al., 1998), the Soil Survey Laboratory Methods Manual (Soil Survey Staff, 1996), and the National Soil Survey Handbook (Soil Survey Staff, 1997), which includes detailed tables for soil survey interpretations.

Cultures of data distribution

The WWW clearly exposes differences in culture among soil survey organizations regarding the nature of their information. This is related to the issue of the legal status of data within a GDI, the relation of public agencies to the private sector and general public (Kabel, 2000), and philosophies of government and civil society.

At one end of the spectrum stands the national co-operative soil survey of the United States, which considers soils information to be a public good which should have the widest possible distribution. Since digital information, especially on the WWW, is extremely easy and cheap to distribute, this philosophy directly implies that digital soils data should be made available for download. In economic terms, it is seen as a "multiplier": the private sector can use public information as it sees fit, and this will lead to economic efficiency for society as a whole, thus fulfilling one of the roles of government, viz. to enable "the pursuit of happiness". Putting data in digital form is done only once, by the data producer. Although soils information produced by the US government could by law be sold, such sale could not be used to favour some parties over others (since the public as a whole has paid for the data); this implies that only costs could be recovered. The decision to sell or not becomes political and social, not economic: "Our philosophy has been that we want the customers to use the information and if we can give it away it will get used more" (Tom Calhoun, personal communication, 2002). Not incidentally, this helps build political support for the agency and its mission when budgets are discussed by the legislature.

This philosophy dates from the earliest days of the soil survey and its precursors. When the United States Department of Agriculture (USDA) was authorised in 1862, it was to "acquire and diffuse among the people of the United States useful information on subjects connected with agriculture [and] rural development ... in the most general and comprehensive sense of those terms" (Soil Survey Staff, 1997). Note the emphasis on "diffusion". The modern enabling act which governs the soil survey, PL89-590 (United States, 1966), states that "the soil survey program ... should be conducted so as to make available soil surveys to meet such needs of the States and other public agencies in connection with community planning and resource development.” The key phrase here is “make available”. US Code Title 44/35 of 1980, amended in 1996, mandates “the dissemination of public information on a timely basis, on equitable terms, and in a manner that promotes the utility of the information to the public and makes effective use of information technology”. This was put into operational form by Executive Order 12906 (Clinton, 1994), which establishes a national spatial data infrastructure (NSDI) and directs all agencies of the federal government to make all its geo-spatial data available to the public, and document this data using standards developed by an inter-agency working group, the Federal Geographic Data Committee (FGDC) (2002). All this costs money, and the executive order solves this problem by making the provision of geo-spatial data part of the regular tasks of each agency, thus as a priority within its regular funding. Finally, each type of data has its own “charter” specifying a lead agency and sub-committee members. In the case of the soils data (Federal Geographic Data Committee, 1996), the mandate is to co-ordinate geo-data collection and processing, to develop data transfer and documentation standards, and, notably, to facilitate the economic and efficient application of soil data.

In the European Community, the situation is clouded by an EC directive (European Community, 1996), which grants database providers, including public agencies, a so-called “extraction right”, which allows them to restrict access; there is not even compulsory licensing. National law may over-rule this. In Europe the data is usually considered proprietary, no matter that the ratepayer has already paid for it to be collected; and this is coupled with mandates from governments for their agencies to be at least partly self-supporting. An extreme example of this group is the Soil Survey and Land Research Centre (SSLRC) of the Soil Survey of England & Wales (2002). Data is available only under license, not for free use. It is the revocable property of the data provider. In particular, without entering into a license agreement with the provider, a consultant or even another agent of the same government can not provide the data to a third-party client, even if interpreted and with value-added by the consultant. Data are supplied under annual renewable licence, and royalties are payable for any application. This is the logical outcome of Thatcher-style privatisation of public services. Obviously, they do not provide data on the web, only a description of what is available for license.

The Dutch fall between these extremes. They are charged with diffusing soil survey information, but at the same time providing some of their funding. They have a four-level pricing policy: (1) Alterra (own organisation), (2) other agencies in the same Ministry, (3) educational organisations sponsored by this Ministry; (4) others, including other universities and the private sector. In any case an agreement for each user must be reached, specifying the terms of use; prices range from approximate €0,30 to €3,00 per km^2 of digital product supplied, depending on the client and use.

An extreme situation obtains in countries such as India (and the former Soviet Union), which consider geo-data to be state secrets (Rossiter, 1998). This is clearly unhelpful for development, and agencies in fact try to work around this, but they must be discreet in doing so.

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Elsewhere, little thought seems to have been given to a database strategy for soils or anything else. In many "developing" and "transitional" countries, the laws governing distribution (as well as many aspects of governmental function) are unclear, contradictory, or unworkable. Here the data distribution relies on personal contacts, there are no common rules, no standard contracts or memoranda of understanding. This unclear and unstable situation is probably the worst model of data distribution, since it provides low benefits to both the state and public.

At the international level, the FAO has a very clear policy of making all of its data and publications easily-available, if not always downloadable. ISRIC "intends [in the near future] to use the Internet as the main outlet for its products and services (datasets, documents, maps, programs, etc.)", including databases produced by other organisations (International Soil Reference and Information Centre (ISRIC), 2001). For this to materialise, ISRIC's well-known skills in international "pedo-politics" will have to be applied to the issues of database access outlined in this paper.

Is the data adequate?

A major issue as soil survey organisations move to widely-distributed digital products is its fitness for use or *adequacy*. This is part of the trend to multi-purpose use of soils information. For surveys originally made only for agricultural land evaluation, it is not obvious that the soil classes and mapping units best meet other needs. This is why a SGDB is preferable to a simple conversion. At a minimum, new interpretations linked to the existing spatial entities are required. Also, the geometry is often quite poor for maps made on unrectified or semi-controlled air photo bases; this makes integration into a multi-theme GIS difficult. Experience has shown that it is necessary to re-compile boundaries onto a reliable topographic or orthophoto base rather than simply to digitise them (D'Avelo and McLeese, 1998). Re-compilation thus seems to be indicated for both thematic and geometric reasons. In the case of new surveys, techniques have been developed for converting photo interpretation directly to maps (Rossiter and Hengl, 2001).

Ensuring correct use

A major concern for any anonymous provision of data is that the recipient (in this case, the web surfer or CD-ROM user) may misuse the data, either wilfully, or more likely because through lack of understanding of the data's origins, lineage, and limitations. One approach to this problem is the provision of *metadata* with clear language on use. The US Content Standard for Digital Geospatial Metadata (Federal Geographic Data Committee, 1998) includes a sub-section on "Use Constraints", which has been used to good effect in the SSURGO (Natural Resources Conservation Service, 1995) and STATSGO (Natural Resources Conservation Service, 1994) metadata to inform the user about the mapping scale and consequent minimum delineation size, and the purposes for which the survey was made. An entire section on "Data Quality" includes sub-sections on "Lineage" (how the dataset was produced, including its source materials and working procedures), as well as subsections on attribute and positional accuracy.

Some usage problems with soils data occur also in other themes, in particular the original mapping scale and consequent problems with enlarging (not possible) and reducing (must deal with both cartographic and categorical generalization). Soils data present special issues with regard to the latter, as map unit composition and type typically change as scale is reduced. A major problem with soils data presented in the DMSV is ensuring that users understand that map units are not pure and may contain a specified proportion of even strongly-contrasting soils. Medium-scale databases such as STATSGO explicitly mention several soil types per map unit; large-scale databases such as SSURGO make reference to map purity standards, but unless the user is already familiar with this concept, it is easy to miss.

Another approach is to encourage data users to register before downloading, and maintain contact with the source agency by e-mail. The above-cited metadata has a sub-section on "Point of Contact", and most web pages from which data can be downloaded have at least an e-mail address. Some, such as the USDA-NRCS Soil Survey Division database access pages, require the user to register.

Future directions

It is to be hoped that more information is made freely available on the Web, or at least on low-cost CD-ROMs, and at the same time matched with metadata and user documentation to ensure its correct use. We can see a clear division between those soil survey organisations, professional societies, and educational institutions that are actively making as much comprehensive information as possible available to any interested party, and those that are continuing with traditional (non-)distribution. The former are to be encouraged, the second to be stimulated to consider the added value to society, especially as synergism with other digital products, and thus justification for their existence as institutions, that would result from a strategic investment in information provision. As we strive to increase public awareness of the value of soils information, it seems only logical that easy access for both primary and interpreted information should be a top priority. A wise man is reported to have said that "No man, when he hath lighted a candle, putteth it in a secret place, neither under a bushel, but on a candlestick, that they which come in may see the light. (Luke 11:33)"; experience, from that day to this, shows that this is, unfortunately, not always true.

Existing digital soils data for developing countries is almost exclusively provided by rich-country or international organisations. The technological barriers to locally-developed and served databases are low; the institutional, legal and cultural barriers are much higher. The development of soils databases will probably mirror development of national data infrastructures in these countries.

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