Soil Information in Germany: The 1998 Position

W. Eckelmann
Federal Institute for Geosciences and Natural Resources,
Stilleweg 2, D-30655 Hannover; GERMANY

Introduction

Oelkers (1991) and Eckelmann and Hartwich (1996) have previously reported on soil information in Germany. The latter report was part of a documentation of the status of soil surveying in Europe, which was edited by C. Le Bas and M. Jamagne (1996) after the "Meeting of European Heads of Soil Surveys", held at the Service d'Étude des Sols et de la Carte Pedologique de France at Orléans, December 1994. The next meeting of this body took place at Cranfield University at Silsoe, Bedford (UK) in 1998. The description of progress with soil survey in Germany given at that meeting, reported here, relates to developments 1994 – 1998.

Some developments concerning the BGR soil information system, FISBo BGR, have been finished, whereas others, mainly in cooperation with the German state soil surveys, are still in progress. Because in Germany soil surveying is influenced by the federal character of the republic, the co-operation with the soil surveys of the component states of Germany has high priority for all national work. Another challenge has been to co-operate with an increasing number of partners across the European Union. A working group consisting of the heads of each state soil survey and of the national soil survey of the Federal Institute for Geosciences and Natural Resources (BGR) co-ordinates most of the pedological work.

Recently, Oelkers and Voss (1998) reported in detail on the Lower Saxony Soil Information System, NIBIS, and on the development of similar systems in the other federal states.

Soil Protection in Germany – General Outline

The ongoing discussion on soil protection has led to an increased demand for pedological information.

The first German *Act On Soil Protection* at a national level (BUNDESREGIERUNG, 1998) will entail an ongoing need for soil information. This act was accepted by both houses of the German Parliament in March 1998 and has been designed as a skeleton law. It was signed on March 17, 1998 and was put into force on March 1, 1999.

Currently, a number of technical annexes are in preparation to form a subordinate *Ordinance on Soil Protection*, specifying the German Act on Soil Protection. These annexes will define soil quality criteria as well as 'precaution levels', 'trigger levels' and 'action levels' and procedures to explain how soil protection measures will be processed.

As a result, data availability and data access have become priorities at national and individual state levels in Germany as well as for the needs of the European Union. To meet this need at the national level, BGR has strengthened its activities to improve and extend the soil information system for Germany.

BGR Soil Information System: Objectives, Aims and Structure

The soil information system for Germany, called FISBo BGR, is one of a number of linked geo-information systems, e.g. geology, soils, geomorphology, hydrology. Together they form a geo-information network which enables broad inter-disciplinary evaluation of different topics. The structure of such an information system has been described by Vinken (1992). The principles of the BGR Soil Information System have been described by Eckelman *et al.,* (1995) and Eckelmann (1996). These and other papers give an overview of current work on information systems in Germany.

FISBo BGR's detailed objectives and aims are to:

1. extend and provide a database of soil information in co-operation with the German federal states according to the needs of the federal government;
2. analyse this database to answer requests for information from the federal government (e.g. for preparing presentations of the current situation);
3. aid the compilation of basic and thematic maps for prognosis and for drafting guidelines as required by the new Act on Soil Protection;
4. provide a basis for answering questions submitted by European Union agencies or international bodies;
5. provide a basis for co-operation with other research institutions (e.g. for nationwide analyses).

The following main structural components are being developed at BGR at present, analogous to the information systems of the individual German states:

1. Spatial database that maintains a number of already existing soil and related maps including the geometric-topographical data;
2. Soil profile and laboratory database that contains both the observations of soil surveys as well as the results of all soil chemical and physical analyses;
3. Method database that defines the data processing techniques (for determining groundwater recharge, water retention and filter functions, soil productivity, etc.) underpinning interpretation of soil maps and the relevant principal and supplementary data;

With respect to future co-operation with organisations of the European Union, these structure components need to be adjusted to those of the European Union level. This demonstrates above all the need for compatible data field registers, data sets and methods.

Soil Mapping Methods

The 4th Edition of the German Soil Mapping Guide KA 4 (ARBEITSGRUPPE BODENKUNDE, 1995) was published in 1995. It includes all the soil taxonomies that existed before German reunification. It also contains data keys, symbols and all parameters used in soil mapping and site description, replacing older versions relating to GDR and FRG state soil surveys. Together with the definition of the principles of the soil information system (Heineke *et al.*, 1995), these data keys are assigned to data fields to be used in digital management.

The German Soil Mapping Guide KA 4 deals only with the German Soil Taxonomy. Until now, there were no links to international soil taxonomies, e.g. the FAO Soil Classification System (FAO, 1990; FAO-UNESCO, 1990). These links will become more important in the future, particularly at the European Union level. Therefore, BGR is presently supporting a project to develop a translation manual for the old and new German Soil Mapping Guide as well as for the FAO Soil Classification System. At a later stage, the results of this project will be integrated into the German Soil Mapping Guide KA 4.

There are also other guidelines existing in Germany for special soil mapping, e.g. mapping of forest sites, as already mentioned by Oelkers (1991). Soil maps compiled using these special mapping guides are integrated into the geological survey's soil mapping activities as far as possible. Naturally this requires transformation of all available data into the standard form as given in the Geological Survey's German Soil Mapping Guide.

Progress in Soil Mapping

Zitzmann (1994) documented soil maps existing in Germany. The information that he obtained, showing the availability of 1:25,000 to 1:200,000 soil maps, emphasised the problem of incomplete coverage. Besides these scales, several state geological surveys published soil maps at scales of 1:5,000 and 1:10,000 and/or soil maps of the entire state at scales of 1:300,000 to 1:500,000. Although some state geological surveys could improve soil information, the availability of soil maps at identical scales and quality is still unsatisfactory with respect to national requirements.

To solve this problem, the individual state soil surveys and the national soil survey of BGR agreed on a programme to compile and publish a joint 1:200,000 Soil Map of Germany. Production of this map is to be co-ordinated by BGR. The first maps have already been published. The overview in Figure 1 shows the planned procedure for printing during 1998/1999.

In addition to this scale, the spatial database established at the FISBo BGR needs to hold soil maps in order to fulfil its duty for the federal government as well as for co-operation with the European Union. These maps for national and international needs, and representing the digital soil geographical databases, include (Behrens *et al.*, 1998):

1. Digital Cartographical Database of Europe (EURODB) to serve as the basic map.
2. 1:200,000 soil map as the joint base map to be compiled jointly with the individual state soil surveys.
3. 1:1,000,000 Soil Map of Germany as the most important geographical database for national requirements (Hartwich *et al.*, 1995).
4. 1:1,000,000 EU Soil Map, representing the German part of the Soil Geographical Database of Europe at a scale of 1:1,000,000.
5. Soil Regions map at a scale of 1:1,000,000 to show landscape relations and to give an overall view of soil information.
6. 1:2,000,000 Soil Map of Germany, representing a part of the Hydrological Atlas (under preparation).
7. Soil Regions Map of Europe at scale 1:5,000,000, which has been drawn up in co-operation with the European Soil Bureau.

The main objective in soil mapping nationwide is at least to compile and have available *a nested system* of soil maps at different scales, which can be used for a wide range of applications, for all co-operations between the federal state, the national level and the EU.

The 1:200,000 Soil Map

In order to co-ordinate the production of a 1:200,000 soil map for Germany, BGR and the sixteen state soil surveys have produced a 1:200,000 scale mapping Manual including the following elements:

1. Guidelines for soil map units and soil profile descriptions including flow charts showing all steps to be taken by the state soil surveys of Germany as well as those taken by BGR;
2. Data sheets with 42 data fields for data collection related to the soil units of the 1:200,000 soil maps;
3. Rules for amalgamating soil survey maps to other scales;
4. General legend for the standardised 1:200,000 soil map;
5. Soil Regions Map of Germany at a scale of 1:1,000,000.

A system of landscape relations has been defined for Germany to ensure that the soil surveys describe similar soil units for the 1:200,000 soil map in a comparable way. This hierarchical system classifies landscapes according to geology, morphology, climate, and vegetation.

Areas with generally similar geology and morphology are defined, and within these areas climate, water regime and relief show only limited variation. It follows that parent material and soil genesis in such an area also vary little, and this in turn permits dominant soil types to be defined for each area. Such an area is called “Bodenlandschaft” or “soil landscape”.

On a higher hierarchical level, several soil landscapes are united to form a “Bodengroßlandschaft” or “Soilscape” (after Dudal *et al.*, 1993), and several of these form a “Bodenregion” or “Soil Region”, of which there are twelve in Germany.

When drafting the 1:200,000 soil map, soil scientists pay attention to ensuring that similar soil landscapes have similar soil inventories, or the soil landscape boundaries would need to be changed. Using this procedure, it will be possible to produce 1:200,000 soil maps in co-operation with the state soil surveys of Germany.

As already proposed by Dudal *et al.* (1993), these principles have been used in the compilation of the 1:250,000 European Union Soil Map Manual (ESB, 1998).

The 1:1,000,000 Soil Map

Now the 1:1,000,000 Soil Map of Germany has been established digitally, it is the most important part of the spatial database and is integrated in the FISBo BGR Soil Information System. In addition to the characteristic soil profiles (“Leitprofile”), thematic maps dealing with nationwide problems of soil use and soil protection have been derived. The 1:1,000,000 scale makes the soil map especially suitable for evaluating problems at both national and European Union level (Jamagne *et al.*, 1995).

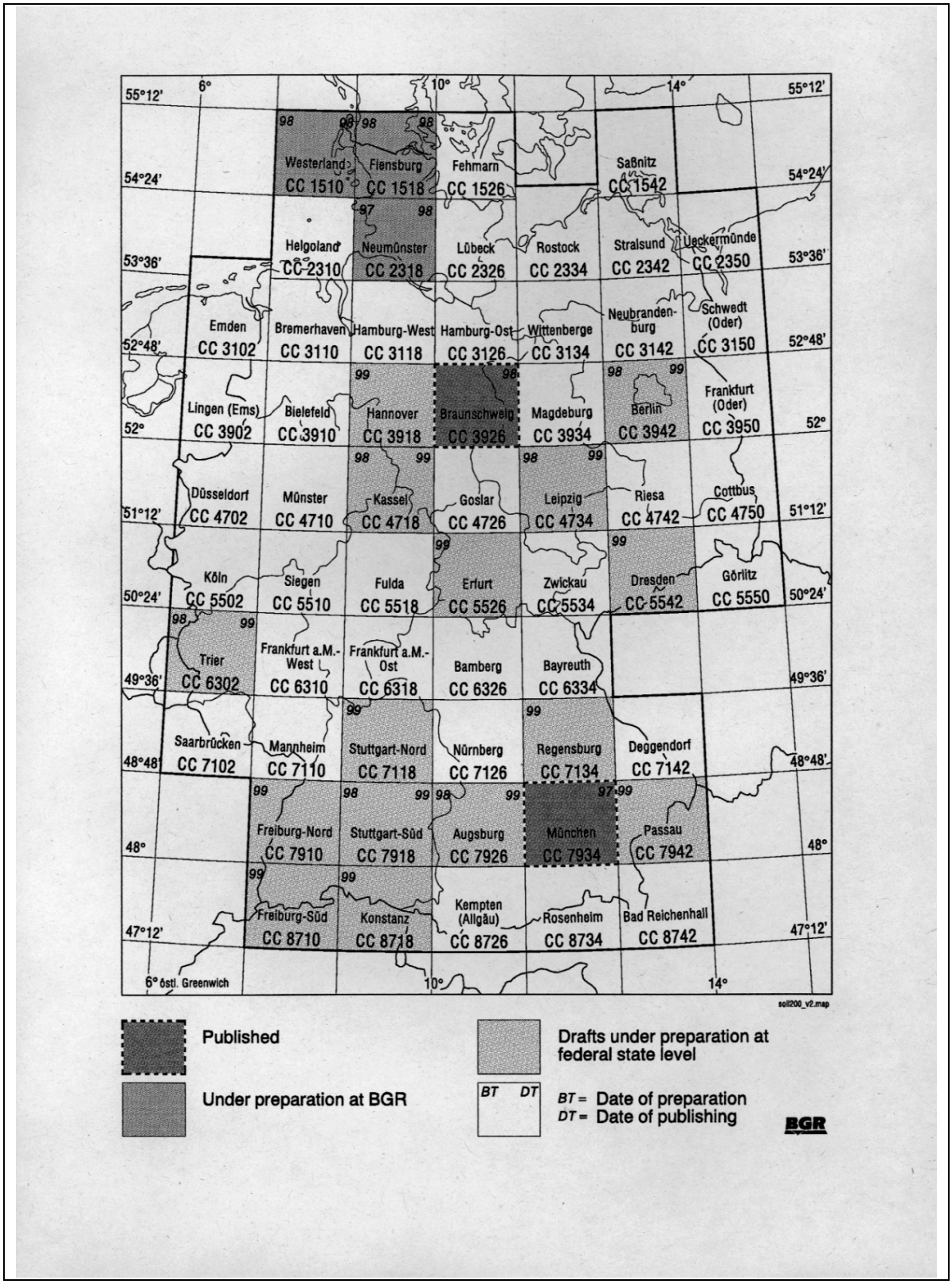

Figure 1: Programme of soil mapping at 1:200,000 scale in Germany.

In the course of preparation of thematic maps, the needs of some users made it necessary to improve and complete the 1:1,000,000 spatial database with more precise information on land cover. This work is presently being done using the CORINE Land Cover data set and has led to changes in the description of the variability of soil map units. Other improvements will be made using geomorphological and climatological information.

Nevertheless, the 1:1,000,000 Soil Map of Germany remains the most important data set available to science, administration and industry, using a BGR specific leasing procedure.

Soil Profile and Laboratory Database

The soil profile and laboratory database of the FISBo BGR stores all soil attribute data extracted from point observations of fully described and analysed reference profiles in sets of digital files for later retrieval. Links between the files, that is tables, are maintained through primary keys. Depending on regional or national requirements, the soil database may be set up according to various soil classification systems. In addition to the German system, the FAO soil classification system has been included so far. The latter has been done in order to cater specifically for international co-operation. Similarly, a soil database is presently being developed according to the U.S. Soil Taxonomy (widely used in Asia and the Americas).

In a further step towards harmonisation of global soil information (Van Engelen and Wen, 1995), BGR recently also adopted the terminology and components of the Multilingual Soil Database (FAO, ISRIC and CSIC, 1995) for its FAO soil database version. Unlike the FAO-ISRIC-CSIS Soil Database (SDBm), the FISBo BGR soil database can be easily tailored to meet customers needs and wishes. Based on the standard software (i.e. MS Access), soil and other components (e.g. vegetation) can readily be added to or removed from the database by individual users or customers.

One essential purpose of the harmonised, site-specific soil data is to develop representative soil profiles for small scale soil maps for making spatial interpretations on various themes (Hennings, 1994). Additionally, this soil profile and laboratory database can be used to create pedotransfer functions, which relate different soil properties to one another or to soil texture (Bouma and Van Lanen, 1987). The pedotransfer functions are essential for creating standardised data sets from inhomogeneous data. These data can be used to analyse the spatial structure of specific soil properties using geostatistics or to determine the background values of soils for selected inorganic or organic pollutants (Utermann *et al.*, 1996).

With reference to the new German Act on Soil Protection (BUNDESREGIERUNG 1998), it was necessary to improve information on heavy metal contents in soils for use in the technical annexes to the given act. Three federal states (Bavaria, Saxonia and Thuringia) supported the BGR soil profile and laboratory database with additional data on heavy metals from their state level. Such co-operation is a welcome support, enabling BGR to answer questions at the national level.

A first edition of the "Guidelines for Taking Soil Samples" (Ad-hoc-AG Boden 1996) has been published jointly by the individual state soil surveys of Germany and BGR. In another co-operation, the same state soil surveys agreed to define a common Soil Laboratory Database, which includes the description of all important analytical methods. This digital database version will be available to the public shortly.

Contents and Use of a Method Database

Processing of pedological data, e.g. to make interpretations of soil maps on various themes or to analyse specific topics, requires not only the availability of the necessary data within an efficient information system, but also well defined methods to be applied from a digital method database. The method database contains algorithms to derive land qualities from pedological base data (e.g. maps).

The methods themselves consist of pedotransfer functions (in modular form). These pedotransfer functions, once established as reliable and accurate, permit key parameters (relationships) to be calculated, thus, greatly simplifying the data required in modelling (Wagenet *et al.*, 1991). Furthermore, the methods collected in such a method database must be programmed according to a single system so that they can be used by both BGR and the German state soil surveys.

An up-to-date documentation of a large number of methods has been published (Hennings, 1994). This set of methods was prepared by a joint working group of the soil surveys of the German individual states and the Federal Institute for Geosciences and Natural Resources (BGR), set up to study various methods for processing basic pedological data, to assess these methods, and to compile suitable documentation.

After publishing the new version of the German Soil Mapping Guide (KA 4), it became necessary to update a number of these methods. This work has been done recently and a publication of an updated version of the method documentation is imminent.

The methods are restricted to calculating specific soil properties, parameters or functions and determining the vulnerability of the soil to specific hazards:

1. potential susceptibility to compaction;
2. retention capacity for heavy metals;
3. vulnerability to erosion by water;
4. groundwater recharge;
5. nitrate retention capacity;
6. potential agricultural yield;
7. vulnerability to erosion by wind;
8. vulnerability of forest soils to acidification.

All of the methods in the method database are deterministic models based on simple empirical relationships. Sometimes these models considerably simplify the physical and chemical processes concerned and provide only an approximate estimate of the parameter of interest. Information about the kind of input data needed, the appropriate scale, and whether the result is qualitative or quantitative is given for each method, so that the different methods available in the method database for the same applicable parameters can be compared.

This documentation describes methods whose applicability is restricted to certain areas or to maps of a certain scale. Therefore, all of the methods must be checked and developed further (Hennings, 1994).

Much emphasis is being given to the optimisation of algorithms for the pedotransfer functions. Several pedotransfer functions for estimating soil hydraulic properties were published in the 1980s. Existing algorithms need to be tested using an existing soil profile database to prevent repetition and to identify the approaches best suited for a target-oriented selection of methods for the method database of a soil information system. The main objectives of such an investigation are to:

1. quantify the validity of pedotransfer functions for estimating hydraulic properties in general
2. compare existing approaches on a common database
3. obtain a ranking according to the accuracy of the predicted values.

The EU scientific co-operation network project "Using existing soil data to derive hydraulic parameters for simulation models in environmental studies and in land use planning", co-ordinated by the Winand Staring Centre for Integrated Land, Soil and Water Research, Wageningen is an important step forward.

The final report has recently been published (Wosten *et al.*, 1998) and informs on the establishment of the HYPRES Database (**Hy**draulic **Pr**operties of **E**uropean **S**oils), which has been supported by copious data, e.g. from BGR and the Lower Saxony Soil Survey. These data were used for the derivation of class and continuous pedotransfer functions. These functions and the Soil Geographical Database of Europe have been combined to generate a map of the availability water in European soils.

In addition to the above-mentioned method documentation, some methods still need to be standardised. To this end, the individual state environmental agencies of Germany and BGR have agreed on a set of thematic maps, which need to be processed for the purpose of soil protection in the near future.

Use of the Soil Information System

The various soil information systems will be used to advise the German federal government and the individual state governments on the needs of the German Act on Soil Protection. This will require close co-operation with the environmental agencies of the individual states and the German government. The information systems will be applied to develop pedotransfer functions and varyingly complex methods for evaluating soil data. Provided the individual state soil surveys and the BGR are using the same standardised methods, comparable results can be expected. It will also be a basis for co-operation with other institutes at the European Union and global levels.

With respect to other applications, the structures of the FISBo BGR will be developed further for the special needs of developing countries. It will then be possible for data from technical co-operation projects to be processed in the project area as well as in BGR and be used in a global soil information database.

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