Basic principals of the manual of procedures (Version 1.1) for the georeferenced soil database of Europe

Finke P., Montanarella L.

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Basic Principals of the Manual of Procedures (Version 1.1) for the Georeferenced Soil Database of Europe

Peter Finke[1] and Luca Montanarella[2]

Introduction

The preparation of a georeferenced soil database at a small scale corresponding to 1:250,000 need a preliminary definition of the concepts and methods required. This is described in detail in the Manual of Procedures of the Georeferenced Soil database for Europe (doc. EUR 18092 EN).

Small-scale soil maps have already been prepared on the European scale (CEC, 1985). Their digitisation and inclusion in a Geographic Information System (GIS) has led to rational management and efficient use of data (Platou et al., 1989); conversely, this approach has also shown its limitations (King et al., 1994). The translation of spatial soil data into a map is limited by the constraints of cartographic representation. In reality, the graphic information has to be limited in order to enable the document to be used easily. This "loss" of information thus has the associated risk of being carried over to databases using soil maps as their support. The European soil map at the scale of 1:1,000,000 is a typical example of the transformation of a map into a database. An extensive program of data enrichment from archives was required to

[1] ALTERRA

[2] European Commission, Directorate General Joint Research Centre - Agricultural and Regional Information Systems, European Soil Bureau, Space Applications Institute

make the base operationally usable in European programs (Burrill and King, 1993).

The aim of the project is to prepare a geographic database by relegating the problem of the cartographic representation of data to a secondary position. We will try to briefly explain the conceptual data model that is the basis of the computerised structuring of the data. The model is spatial, since the objects composing it are situated in space. Spatial relationships among objects are also described. The model is not strictly a "cartographic" one, since it does not consider the problems of representing data in the form of maps. We will nevertheless detail the inquiry procedures for these type of model, in particular its cartographic translation, which remains a priority output.

The focal point of the database is the soil body. The formation of this entity is the result of a multitude of factors (climate, parent rock, vegetation, time, etc.). In a number of cartographic projects or those aimed at preparing geographic databases, these factors sometimes take precedence over the soil itself. In the georeferenced soil database, the soil body is the basic element and is the input key for the information system (Hole, 1978). The soil body is defined principally by soil attributes. Other objects elaborated from the soil body, i.e. the soilscape and soil region, are introduced for a better understanding of the spatial variability of soils and to provide tools for managing and rationalising data on the continental scale. The criteria for the geographic delimitation of these objects are not necessarily soil variables, but may also be related to characteristics of soil forming factors: parent material, relief, vegetation, climate and human influence.

Soil Body and Soil Horizon

As stated above, the differentiation of soils results from the soil genesis factors (Jenny, 1941). If at different locations all factors would be equal in presence and magnitude, comparable types of soil with comparable characteristics would result. This paradigm is at the origin of the development of a number of soil-classification or mapping systems based on soil formation. We shall retain this principle in order to distinguish the main types of soil in a given region, but will also put focus on soil behaviour in its landscape context.

Each soil body is in itself composed of a number of soil horizons and/or layers, which may vary in thickness and properties within one soil body as long as this does not violate the definition of the soil body. The definition of the soil body largely depends on the WRB-classification, which in its turn is based on identification and classification of diagnostic horizons. So, as far as the definition of the soil body is concerned, horizon can be read as "diagnostic horizon". For the characterisation of soil bodies by soil characteristics, soil horizons and soil layers serve as information carriers. Thus, more vertical detail is allowed than can be provided by diagnostic horizons alone. Variations in a vertical sense are mainly caused by soil formation or sedimentation processes, while lateral variation may be caused by slope processes such as erosion and deposition and by microvariations in other genetic factors. The physical organisation of soil horizons within a soil body thus follows certain rules.

Criteria for determining a soil body

It has been debated (Cline, 1977) whether the universe of soils comprehends discrete physical bodies, large enough to enable classification into a taxonomic system or whether it should be considered as a continuum (Marbut, 1935). The soil body is here considered as an artificial but recognisable three-dimensional entity in a soil continuum. Within the soil body we recognise two kinds of variability: (i) *diversity* which results from the possible occurrence of different pedotaxa (artificial classes) within the soil body, and (ii) *spatial variability* of soil properties, which is of a more continuous nature. These two kinds of variability are not necessarily positively correlated (high diversity is not always associated with high variability; Ibàñez *et al*., 1998), and should therefore be separately described. At a scale 1:250,000 and considering the stage of EUSIS, it is not possible to assess the intravariability and intrapedodiversity of all soil bodies, thus for practical purposes we therefore limit ourselves to the following approach:

I. we use only a few diagnostic criteria to classify soil bodies;

II. we describe some tools to deal with diversity within the soil body;

III. we prescribe a measure of the intra-soil body variability on the parameter level.

A soil body is thus a portion of the soil cover with diagnostic characteristics resulting from similar processes of soil genesis. The diagnostic criteria used are those of WRB (FAO, ISRIC and ISSS, 1998), in particular the presence of diagnostic horizons. The WRB-classification should be at the reference soil group level and include two qualifiers, e.g. stn-vr-LV (Endostagnic-Vertic Luvisol) for a Luvisol with a vertic horizon within 100 cm and stagnic properties above this horizon.

In light of the still rather general nature of this typology, we added three additional criteria: parent material, soil texture in five fractions with gravel content class (CEC revised FAO triangle; CEC, 1985) and depth to obstacle for roots. Of coarse it is not intended that the continuous variation of one or a few soil properties induce a classification into 2 soil bodies (e.g. when the top of the vertic horizon locally is below 100 cm in the above soil). For this reason, the concept of "similar soils" is introduced. The maximum degree of "dissimilarity" allowed within a soil body still needs to be assessed empirically, using experiences from pilot projects.

A soil body corresponds to a real portion of the soil cover, but this does not mean that its geometry is precisely known. The first step involves constituting the list of principal soil bodies in a region according to the diagnostic criteria defined. This list will be the reference for general rationalisation.

The description of each soil body is extended with morphological and analytical attributes of the main horizons, e.g. clay content, type of structure, CEC, organic matter content, etc. Mandatory and free attributes are distinguished. Whenever possible, these attributes are expressed quantitatively in order to avoid any *a priori* classification. In contrast to diagnostic criteria, these attributes may possess a degree of variability within the soil body. The modal value, the first quintile and last quintile of each attribute are given for each soil body. These values will generally be obtained from an expert evaluation. The modal value may furnish a false idea of precision, but the difference between the two quintile values will provide an estimation of the spatial variability or, more generally, of the imprecision in our knowledge.

The data are presented in a manner similar to that of Proforma I of the "estimated profiles" of the 1:1,000,000-scale project for European soils. It adds the possibility of describing an intervariability of each body as proposed in the SOTER program (ISRIC, 1993). In addition, a relational table allows describing the «volumetric pattern» of horizons within a soil body. In order to complete these data, it is important to have access to measured basic data. Like Proforma II of the "measured profiles" of the 1:1,000,000-scale project for European soils, the principle soil bodies will be associated with two or more real soil profiles, including field description results and laboratory analyses.

Table 1. Summary of criteria and guidelines for the definition of soil bodies

Object	**Criteria**	**Guidelines**	**Delineation**

	for definition	for delineation		
Soil Body	1 WRB-classification * 2 Parent material 3 Depth to obstacle for roots 4 Dominant texture and gravel content class 0-30 cm **	not applicable	1 One profile with estimated data in database 2 Two or more profiles with measured data in database 3 More than 90% of the area of a soilscape should be described by soil bodies ***	Only in small reference areas

* Reference soil group plus 2 qualifiers

** If an abrupt textural change occurs within the upper 30 cm, dominant texture and gravel content class refer to the layer(s) above the abrupt textural change

*** Including similar soils. Similar soils are soils that show a minor variation in a soil property that induces a different classification.

Spatial organisation of horizons within a soil body

Each soil body is defined by a characteristic combination of parent material and WRB-soil code and horizons within a soil body usually follow a typical vertical sequence. Besides the vertical sequence, also the lateral extension and shape of horizons gives much insight in the behaviour of the soil body, especially with respect to water and solute flow (e.g., Curmi *et al.*, 1997). There are a number of parameters that give useful additional information on these aspects. Examples are the volume shape, the vertical and lateral continuity and transition of each horizon, etceteras.

Soilscape

The soil body is defined as a portion of land with imprecisely known geographic limits. This does not mean that it is not possible to evaluate its surface area, or even to broadly delimit zones in which one has a good chance of encountering it. This difficulty in representing fairly fine typological units on a commonly large-scale map was resolved in the past by creating soil associations (Simonson, 1989). This method enabled different soil units to be combined in a single mapping unit that could be delimited at a given scale. Although the grouping methods are often insufficiently explained, efforts have been made to better define the objects resulting from these groupings (Hewitt, 1993) and to define the criteria used in their construction (Hudson, 1990).

The difficulty in a cartographic representation of a soil body at small scale may have two origins: i) data is often lacking to permit the bodies to be delimited; ii) a soil body may be perfectly known but not representable at a small scale such as 1:250,000. In both cases, grouping this soil body with its neighbours results in a loss of spatial information at the same time as remaining compatible with the chosen geographic precision.

On the basis of the principle of grouping soil bodies, it is necessary to define the units obtained, which we call "soilscapes" and to indicate how the soil bodies are organised within these groupings.

Criteria for determining a soilscape

Considerations

Soilscapes are the information layer in the database that will be used to display soil properties or (estimated) soil behaviour in maps. While displaying these maps, some information is always lost since internal variation within soilscape polygons is not displayed. The best soilscape map is the one that maximally preserves information when compared to the underlying data. If we assume that the most relevant applications of soilscape maps are to make maps of soil behaviour, this leads to the conclusion that individual soilscapes should show a characteristic behaviour. Consequently, at a more detailed scale, each soilscape should have characteristic functional relationships between the soil bodies of which it is composed. In this case, a soilscape could be defined as that portion of the soil cover which groups soil bodies having former or present functional relationships, and that can be represented at 1:250,000 scale. The aspects of soil genesis are then again given preference, thus defining the "soil catena" within which transfers of water, matter and energy are responsible for the vertical and lateral differentiation of the soils (Huggett, 1975).

This view however, can hardly ever be used as a basis to actually map soilscapes save at more detailed scales than 1:250,000. The reason for this is that many types of functional relationships exist, and that these are scale and area dependent. Thus, this approach is not suited for mapping at a predefined scale. Nevertheless, the presence of characteristic functional relationships between soil bodies within a soilscape should be checked after mapping the soilscape at 1:250,000.

Relief is the main diagnostic criterion for delimiting soilscape units. Preference is given to morphological attributes such as altitude, slope intensity, slope length, curvature, landscape dissection, etc. The advantage of these attributes is that they can in principal be extracted from Digital Elevation Models (DEM). This permits a rigorous and comparative approach from one region to another if commonly accepted algorithms exist and the same data sources can be used. Another advantage is that relief often is an indicator of the geological substrate, also an important diagnostic criterion for soilscape delineation. A common DEM for Europe will be included in the database as an independent layer. This basic data is very useful for example in the automatic delineation of watersheds. But these basic data or derived data need also to be interpreted according to the soil body distribution and interrelationships. It will be the main task to be accomplished by soil surveyors and co-ordinators for the delineation and definition of soilscapes.

Satellite images provide good support for digital data, and also guarantee rigor. For example, DEM can be extracted from satellite data like stereoscopic images of SPOT. Satellite data provide also information on soil cover which useful for delineating soilscapes. However soil cover is the combined result of numerous historical or sociological factors that are difficult to separate from physical factors. For this reason, it is not planned to introduce this attribute as a diagnostic criterion; it will be retained merely as a descriptor of the units defined.

A practical approach to soilscape definition and delineation

The definition and delineation of a soilscape is thus an integration of physiography, parent material and geometric criteria. The minimum standardised way to define and delineate soilscapes is a descending approach starting from the Soil Regions. It is proposed to follow the SOTER-methodology (ISRIC, 1993).

This method would yield a Terrain Map based on a subdivision of Soil Regions by physiography and parent material. If the cartographic guidelines allow it, a further subdivision could be made in analogy with the SOTER Terrain Components by surface form, slope, mesorelief and, possibly, texture of unconsolidated parent materials. Applying criteria for subdivision that are considered most relevant by the local experts (pedogenetic criteria and other criteria expressing functional relationships) could continue this approach. During the fieldwork, the Soil Region boundaries should be refined in order to be accurate at the 1:250,000 scale.

A fundamental requirement is that map scale must accommodate legible delineations of the smallest size map units. From a cartographic viewpoint, delineated polygons at 1:250,000 should be consistent with field areas of at least 1.5 km^2. Since soilscapes are mapping units, one soilscape may be presented by more than one polygon.

To avoid the complete elimination of soilscape polygons that are smaller than 1.5 km^2 but are considered important enough to be represented on the map, the following guidelines could be followed:

If a small, 1.5 km^2 window, drawn on the map has most of its area occupied by the small polygon, the latter would be retained.

A second option to obtain mappable soilscapes at 1:250,000 is to group together smaller soilscapes if they form a recurrent pattern. Their association can then be seen as a complex soilscape at a higher hierarchical level. In that case, for example, a measure of the surface roughness, estimated with a GIS, may be helpful to decide if two soilscapes are subsets of a larger system formed by a group of contiguous soil bodies.

Table 2. Summary of criteria and guidelines for the definition and delineation of soilscapes

Object	Criteria		Guidelines	Delineation
	for definition	for delineation		
Soilscape	*Minimally:* characteristic association of physiography and parent material *Additionally*: geomorphology and texture	*Minimally:* physiography and parent material *Additionally:* Geomorphology Texture	1 Minimal size polygon: 1.5 km^2 2 Minimal distance on map of two arcs: 1 mm 3 Minimal size soilscape unit: 6 km^2 4 Soilscape= contiguous group of soil bodies	using DTM, geologic and geomorphologic maps etc.

Spatial organisation of soil bodies within soilscapes

It was noted above that it is rarely possible to delimit a soil body in the context of the graphic limitations at small scale. Nevertheless, the organisation of these units within soilscapes can be described by the use of symbolic attributes of spatial position, e.g. "near", "included in", "above", etc. (King *et al*., 1994).

The percentage of the soil body included in the soilscape is the first attribute to be assessed for determining a quantitative evaluation of soil resources. The localisation of the soil bodies is the second attribute used to indicate the organised or random nature of the soil cover. The shape, pattern, surrounding relationships and boundary contrasts are all data that will lead to a better understanding of the soil systems.

This leads to criteria of rationalisation at European scale for defining soilscapes and for determining the nature of their functions, in particular hydrological. The number of Soil bodies within a Soilscape is not limited. The main point is that more than 90% of the Soilscape must be described by Soil Bodies (or "similar soils"). Furthermore, small but important Soil Bodies must also be described according to their role in land management or environmental aspects.

On the basis of the stated principles for grouping soil bodies, it is possible to have the same soil body in several soilscapes. Within a GIS, it may be possible to define several soilscapes overlapping in the same area, thereby grouping several units of soil bodies. But, it is evident that an exhaustive subdivision of the land into spatially contiguous soilscapes is preferred in order to prepare usable map outputs.

Soil Region and Reference Area

Regardless of the precautions to provide precise definitions of conceptual objects, attributes and their encoding, most operations remain in the field of expert evaluations. This results from the imposed working scale that necessitates processing a vast quantity of information unavailable in formats compatible with digital processing. This fact entails risks of divergence in the interpretation of definitions, as well as drift with time. A structure involving the comparison of methods and rationalisation of information thus becomes necessary. There are two possible levels: i) at a smaller scale to establish discussions on the basis of "natural" regional units and ii) at a larger scale in order to process measured data, thus comparable to different methods of preparation of the georeferenced soil database.

Small-scale: the soil region

The criteria used to describe soil bodies and soilscapes are primarily related to relief and parent material. Climate is also included in this approach, even though it is indirectly present in the WRB nomenclature.

Regardless of the criteria adopted, there is possible risk of having soils attributed to a single soil body, while in reality they belong to geographically differentiated soil regions. Experience acquired in co-ordinating the 1:1,000,000-scale European soil project has clearly shown that rationalisation by member states could lead to incompatibilities in defining soil units. It is thus preferable to determine and rationalise soil bodies and soilscapes within large units having the geologic, morphologic and climatic factors that were responsible for the differentiation of soils.

The large units are called SOIL REGIONS. Typical for these areas is a common geologic-paleogeographic development and therefore a characteristic composition of parent material. But to show the diversity of the soils at European scale the special climatic conditions in the different parts of Europe are very important too. Soil regions therefore are established on the basis of climatic data and parent material associations. And as a next step the FAO names of the dominant soils are added. The results are zoning Europe into soil regions. One of the firsts steps in implementing the 1:250,000 scale manual of procedures in the Mediterranean basin is to extend the current soil region map of Europe to cover the participating Mediterranean countries.

Table 3. Summary of criteria and guidelines for the definition and delineation of soil regions

Object	**Criteria**		**Guidelines**	**Delineation**
	for definition	**for delineation**		
Soil region	1 Climate 2 Parent material association	1 Climate 2 Parent material association	-	concept added to this Manual

Large-scale: reference areas

In order to verify rationalisation between defined intra-regional soil bodies and soilscapes, control points in the field must be available. This is done by choosing reference areas of about 1000 hectares that will be finely mapped at approximately 1:50,000 to 1:20,000 scales. These reference areas will be selected to be representative of the regions at the same time as having a high soil variability and taxonomic pedodiversity in a small area.

Within these areas, representative profiles will be selected that will be sampled and analysed. It will be used to characterise soil bodies as well as for inter-region and inter-country comparisons. In the past, this type of work was limited only to soil profiles, implying a vertical and momentary vision of soils. The soil genesis character of this program, combined with a geomorphologic vision, require a 3-dimensional mapping approach in order to understand the laws of soil distribution within a soilscape. The phase of large-scale cartographic control will be a quality check for verifying work carried out. It will be subsequently applied to small-scale work according to procedures remaining to be defined.

General Structure of the Database

The database has a relational structure, being composed of objects: soil bodies (themselves subdivided into soil horizon), soilscapes and soil regions. Soil bodies are the basic element and contain primarily those data describing the nature and properties of soils. Soilscapes and soil regions indicate the spatial organisation of soils. Each object appears as a key field in several tables.

Relational tables describe the links among objects. The "organization" tables contains information on the distribution of soil bodies within soilscapes, and on soil horizons within soil bodies. The "limits" table enables the nature of the limits separating the different soilscapes in a soil region to be described. These relational tables are entities isolated from other tables, since they establish the link among the different objects of the database. The input of the "organisation" table is composed of a correspondence list indicating the link between a soil body and a soilscape. The attributes describing the organisation of soil bodies within soilscapes are linked to this table.

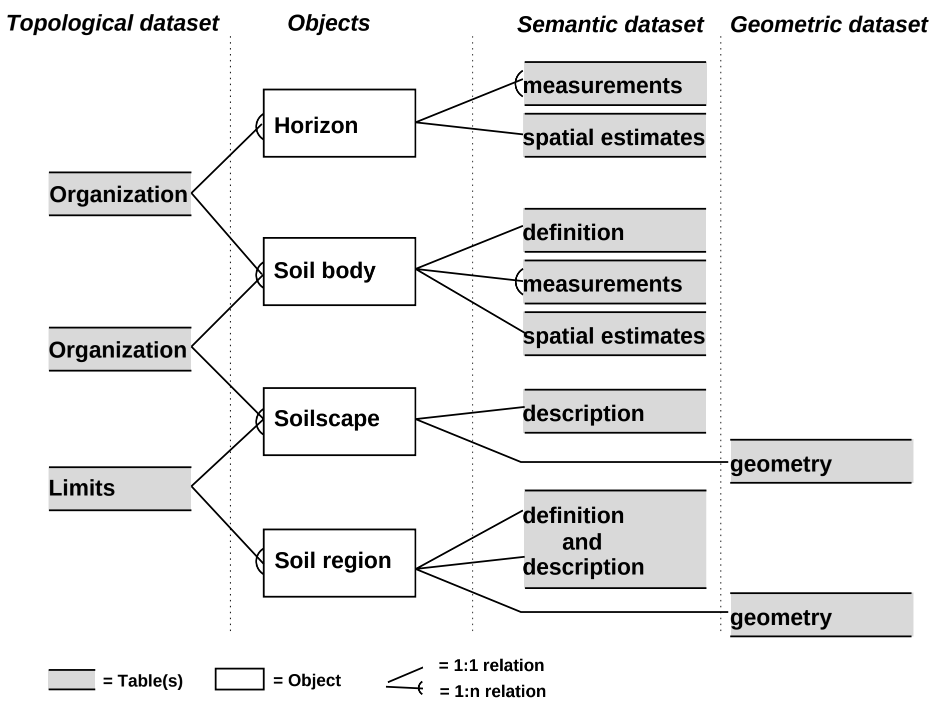

Figure 1. General structure of the database

Within the attributes, distinctions are made according to their functions:

The set of attributes describing the nature of soils is the semantic set. Most of these sets are attached to soil bodies and soil horizons. The set of attributes describing the position and shape of the objects is the geometric set, and the set of attributes describing the organisation of (and within) the objects is the topological dataset. Most of these attributes are attached to soilscapes and soil regions. Attributes describing soil bodies refer either directly to these bodies, e.g. soil depth, or to sub-units, the horizons. The number of horizons composing a soil body is not limited, but we will nevertheless indicate only the major horizons for the vertical differentiation of soils.

For soil bodies and soil horizons, we distinguish the attributes used as identification criteria and those characterising objects. The "criteria" are accompanied by a confidence level corresponding to the reliability accorded to the value furnished by that criterion. For "characters" we demand an estimation of the modal value, and the first and last quintile of individuals constituting the soil body or soil horizon.

The values attributed to characters are the result of expert evaluations. These data are complemented by measured values obtained from soil profiles for which a geographic localisation can be given. In order to lighten this procedural load, mandatory variables are distinguished from variables that required if available. Specific encoding is planned for missing data, whether it is a lack of information, nonsense or an omission.

Relations to other Systems and Databases

Relations to other soil classification and mapping systems

In this section a brief comparison will be made between the concepts developed in this manual and those of the major soil mapping and database construction methods which are applied elsewhere. The USDA-system (Soil Survey Division Staff, 1993), the

FAO-system (FAO, 1990) and its successor WRB, and the SOTER-system (ISRIC, 1993).

In the introduction to FAO-revised legend (FAO, 1990), it is rightfully stated that existing soil classification systems differ most in the concepts on which the subdivision in categories is based on zonality, evolution, morphology, ecology or geography (including relief). Besides this, important differences lie in the degree to which soil taxonomy and the construction of soil map units coincide. Some of these differences are summarised in below.

FAO (1990), WRB (FAO, ISRIC and ISSS, 1998) and SOTER (ISRIC, 1993) are examples of systems in which Soil Taxonomy and the definition of map units or database entries are strongly interweaved, in USDA and this Manual the connection between Soil Taxonomy and map unit definition is not so strong (*italic* entries in indicate that taxonomic names are commonly used to identify map units).

Many other differences exist between the systems, and it is of little value to name them all. In many cases, this manual follows the definitions of WRB and SOTER for soil attributes and diagnostic criteria, in some cases alternative definitions were developed for the purpose of compatibility with existing systems at the European scale or appropriateness.

Structure of the data

The database has an original structure, since it gives preference to an approach that is detached from the limitations of mapping representation and introduces the soil body as a priority input key in the computer system. The proposed approach, involving the establishment of groupings into soilscapes, belongs to the so-called ascending method in which "soil" objects are first defined, which are then grouped into geographic units. Inversely, a descending method first establishes zoning based on criteria indirectly related to soils (relief, soil occupation, etc.) and then identifies the types of soil present within each zone.

Table 4. Some characteristics of different soil classification and mapping systems

<table>
<tr><th>Item</th><th>FAO</th><th>SOTER</th><th>USDA</th><th>Manual</th></tr>
<tr><td rowspan="7">Taxonomic hierarchy/ SMU-identification *</td><td rowspan="2">Major Soil Grouping</td><td rowspan="2">Terrain **</td><td>Order</td><td rowspan="3">Soil Region</td></tr>
<tr><td>Suborder</td></tr>
<tr><td>Soil Units</td><td>Terrain Component **</td><td>Great Group</td></tr>
<tr><td rowspan="4">Soil Subunits</td><td rowspan="4">Soil component</td><td>Subgroup</td><td rowspan="3">Soilscape</td></tr>
<tr><td>Family</td></tr>
<tr><td>Soil Series</td></tr>
<tr><td>Polypedon Pedon</td><td>Soil Body</td></tr>
<tr><td>Purpose of highest level in system</td><td>Taxonomic map legend device</td><td>Map legend and database device</td><td>Taxonomic device</td><td>Map legend and database device</td></tr>
<tr><td>Primary divisive criteria</td><td>Geography, evolution</td><td>geography</td><td>morphology, evolution, zonality</td><td>geography, zonality</td></tr>
<tr><td>Name of highest level</td><td>Major Soil Grouping</td><td>Terrain</td><td>Soil Order</td><td>Soil Region</td></tr>
<tr><td>Typical mapping scale</td><td>1:5,000,000</td><td>1:1,000,000</td><td>usually not mapped</td><td>1:5,000,000</td></tr>
<tr><td>Purpose of lowest level in system</td><td>Map Unit</td><td>Map Unit and Database entry</td><td>Link between soil taxonomy and soil mapping</td><td>Link between soil functioning and map unit, database entry</td></tr>
<tr><td>Name of lowest level</td><td>Soil Subunit</td><td>Soil Component (=Soil Subunit)</td><td>(Poly)pedon</td><td>Soil Body</td></tr>
<tr><td>Typical mapping scale</td><td>1:100,000 - 1:1,000,000</td><td>1:100,000 - 1:1,000,000</td><td>not mapped</td><td>not mapped</td></tr>
</table>

* SMU=soil map unit
** Objects have no pedological nature

This distinction is not systematically clear-cut. The cartographic approach in soil science is often composed of a back-and-forth succession of these two attitudes. This is partially the case in the recommended procedure, since we are proposing: (1) zoning the area of the Mediterranean countries into broad soil regions, (2) determining soil bodies constituting the zones (descending method) and (3) grouping in soilscapes (ascending method).

The procedure is thus different from prior work on the European scale. In particular, we may cite work done for the preparation of the geographic European soils database at 1:1,000,000 scale (CEC, 1985) and the SOTER project (ISRIC, 1993). The former essentially involved obtaining added value from conventional mapping data accompanied by their archives. Updating this database with the assistance of soil scientists from different member states was not sufficient to completely define original conceptual structures, in particular limitations related to cartographic representation. The latter (SOTER project) favoured a descending method using criteria that were more geomorphologic than pedologic. This approach has the advantage of proposing rigorous methods for defining the conceptual objects that are in the database.

In spite of these different concepts, the computer structure of the georeferenced soil database is similar to those of the above-mentioned projects. The soil body corresponds to the Soil Typological Unit (STU) of the 1:1,000,000-scale project and to the "soil component" of the SOTER project. Soilscape has elements of the Soil Mapping Unit (SMU) of the 1:1,000,000-scale project and to the "terrain component" of the SOTER project. The soil region could be related to the "terrain" of the SOTER project. The relational structure of the database is taken from the 1:1,000,000-scale project, as well as the differentiation between estimated and measured variables. The concept of mandatory or facultative variables is taken from the SOTER project. Transfer programs will be implemented in order to assure continuity with these projects.

Nature of variables

The structure of this database is similar to those of the 1:1,000,000-scale and SOTER projects. On the one hand, this implies the search for an ascending compatibility of the modalities of variables. For example, parent materials are described in more detail than in SOTER, at the same time as assuring their equivalence. The corollary to this is a revision of the 1:1,000,000-scale database in order to retain the possibilities of links between the two databases. For example, it is planned to update the 1:1,000,000 database by using the 1990 revised FAO legend and the new list of parental materials.

Some choices were made with respect to the definition of variables. It was chosen not to follow the USDA definition of the soil temperature regime, because measured data lack to make accurate estimates of soil temperature. Instead, climatic data are introduced in the description of the soil regions, and it is advised to incorporate meteorological data if needed by GIS-overlay from weather station networks rather than to put these data directly in the soil database.

Variability

In addition, the characters describing soil bodies and soil horizon are presented in digital form with the attribution of a modal value and two surrounding values. This presentation is similar to that of SOTER and avoids the *a priori* attribution of classes, which has the disadvantage of setting limits that are not always relevant to all types of soils. Furthermore, this type of classes fixes an identical level of precision that prevents conducting more precise investigations. In particular, the reference areas for controlling the database should use the same database structure for approaches at much larger scales. The proposed encoding is very flexible in order to express different ranges of variation without changing the structure of the data. Finally, this type of method enables data conversion into any national or international system using fixed *a priori* classes e.g. estimated particle size values can be converted into any texture triangle; soil moisture conditions are characterised by a range of attributes rather than a classification.

Accuracy

The accuracy of data put in the database is an often-neglected issue that does however eventually determine the quality of the database as a whole. Accuracy is determined by factors related to the measurement such as (i) the method of analysis, (ii) the laboratory that carried out the analysis, but also to the age of the measurements (depending on the type of analysis). For the current version of this manual, it was chosen to document the accuracy of measurements in the database with information on the laboratory and year in which the analysis were carried out, and a data quality assessment by the provider of the data. For existing data, these data will allow the data analysis method to be reconstructed. For data newly sampled, it is advised to follow ISO-standards.

Completeness

The completeness of the database determines its usefulness for applications. At the spatial scales of the soil horizon, the soil body and the soilscape missing data are allowed at the parameter level as long as a mandatory subset of the data is included. Besides this, also the fraction of the area within a soilscape that is adequately covered by data at the soil body and soil horizon scale is important. It is intended to have minimally 90% of the area of each soilscape covered with adequately described soil bodies and soil horizons. However, since soil databases are usually constructed in a number of approximations, the degree of coverage at the soilscape level is an entry in the database, allowing further sampling efforts to be directed to areas where data are most scarce.

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