Report 97/06

Guidelines for the Compilation of a 1:2,500,000 SOTER Database (SOVEUR Project)

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ACKNOWLEDGEMENTS

The current guidelines were prepared specifically for a project on Mapping of Soil and Terrain Vulnerability to Pollution in Central and Eastern Europe (SOVEUR). This SOVEUR project is carried out by the Food and Agriculture Organization of the United Nations (FAO) in cooperation with the International Soil Reference and Information Centre (ISRIC), under a Contractual Service Agreement which included Letters of Agreement with National Collaborators within the frame of their National Institutes representing their countries in the project (13 participatory countries). The project was implemented within the Framework of the FAO/Netherlands Government Cooperative Programme (GCP/RER/007/NET).

The guidelines are largely derived from *Global and National Soils and Terrain Digital Databases (SOTER): Procedures Manual (revised edition)* — a joint publication, edited by Van Engelen and Wen (1995), of the United Nations Environment Programme (UNEP), International Society of Soil Science (ISSS), International Soil Reference and Information Centre (ISRIC) and Food and Agriculture Organization of the United Nations (FAO) — with simplifications necessary to accommodate for the field scale of 1:2.5 million adopted for SOVEUR. Constructive comments by Dr V. Stolbovoy, Prof. G. Várallyay and Dr L.R. Oldeman on an earlier version of the current guidelines are gratefully acknowledged.

1 INTRODUCTION

1.1 Background

The quality of Europe's environment has decreased as a result of pollution, notably in the former centralized economies of Central and Eastern Europe. In contrast with the earlier concern for the atmosphere and hydrosphere, the need to protect the soil has been appreciated only more recently. Soil pollution can severely affect food production, the quality of surface and groundwaters, and ultimately biodiversity and human health. A preceding study of the status of human-induced land degradation worldwide (Oldeman *et al.*, 1991) showed 22 million hectares have been polluted, of which 19 million occur in Europe (incl. the former USSR). Loss of fertile topsoil, as a result of erosion by rainfall, was estimated at 114 million hectare. About 30 percent of Europe's agricultural land has been affected adversely by physical and chemical degradation. Policy measures and conservation methodologies thus are needed to halt and reverse this trend (Van Lynden, 1995a).

The capability of a soil to be harmed in its ecological functions - its vulnerability - varies with climate, soil type, land use, the chemicals involved and the degree of loading with these contaminants (Batjes and Bridges, 1993). Once degraded, for example by water erosion, heavy metals or acid deposition, the ecological functions of soils will return only slowly. Thus, knowledge of the currently degraded land and areas potentially at risk (vulnerable land) is critical for sustainable development and the formulation of conservation or remediation technologies.

In early 1997, an agreement was concluded between the Food and Agriculture Organization of the United Nations (FAO) and the International Soil Reference and information Centre (ISRIC) — within the Framework of the FAO/Netherlands Government Cooperative Programme(GCP/RER/007/NET) — for a project on Mapping of Soil and Terrain Vulnerability in Central and Eastern Europe (SOVEUR).

The SOVEUR project calls for the development of a soil and terrain database for Central and Eastern Europe in close collaboration with soil survey institutes in Belarus, Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Moldova, Poland, Romania, the Russian Federation, Slovak Republic and the Ukraine. Using this system and auxiliary data on climate, land use and the type of soil pollution, the status of human-induced soil degradation (Oldeman, 1988; Van Lynden, 1995b) and the areas considered vulnerable to defined pollution scenarios (Batjes, 1997) will be identified and mapped (field scale of 1:2.5 million). Different methodological guidelines are needed for each of these activities.

1.2 Objectives

The current report presents procedures for the compilation of a 1:2.5 million Soil and Terrain (SOTER) digital database for Central and Eastern Europe. This activity may be seen as an interim step in the construction of a 1:5 million SOTER database for the world (Oldeman and Van Engelen, 1993). The present guidelines focus on the modifications that have been introduced with respect to the approach used for the 1:5 million SOTER map of South America and the Caribbean (Van Engelen and Peters, 1995). Large sections of the SOTER Procedures Manual (Van Engelen and Wen, 1995) have been included in this report to ensure uniformity. The current guidelines can be used as a "stand-alone" version in conjunction with the Revised Legend of the FAO-Unesco Soil Map of the World (FAO, 1990).

Upon its completion, the 1:2.5 million SOTER map/database will provide the basis for mapping the "current status of human-induced soil degradation", using the methodology of Van Lynden (1997), and for identification of areas considered vulnerable to defined pollution scenario's (Batjes, 1997) in the SOVEUR project area. Earlier, the SOTER methodology has been applied successfully for evaluating the susceptibility of soils to various degradation processes in Hungary (Várallyay *et al.*, 1994).

There are 3 chapters and 8 appendices in this report. Chapter 2 describes the methodology, including the overall mapping approach (2.1) and database structure (2.2). The appendices include: detailed information on mapping of SOTER units (1); additional mapping conventions (2); attribute definitions and coding conventions (3); *pro forma* SOTER data entry forms (4); a hierarchy of landforms (5); FAO soil unit codes (6); and, ISO country codes for the 13 participating countries (7).

2 METHODOLOGY

2.1 Mapping approach

SOTER is a land resources information system based on the concept that features of land — and those of its component terrain and soils — are the result of interacting physical, biological and social processes over time.

In many respects the SOTER mapping approach resembles physiographic soil mapping. The main difference lies in the emphasis that the SOTER methodology puts on the terrain-soil relationships in comparison to what is often done in traditional soil mapping, notably at the considered scale of 1:2.5 million.

The guiding principle in the SOTER methodology therefore is the identification of areas of land with a distinctive and often repetitive pattern of landform, slope, general lithology[1], and soils. Uniform expanses of land distinguished in this manner are called SOTER units. SOTER units can be delineated in various ways, depending on the type of source materials available; detailed procedures for mapping SOTER units are given in Appendix 1 and 2.

Each SOTER database is comprised of two main elements. The *geometric data base* holds information on the location, extent and topology of each SOTER unit. Spatial information on the geometry is managed and handled with commercially available Geographic Information System (GIS) software.

Each SOTER unit in the geometric database has a unique identifier, called SOTER unit_ID. This "primary key" provides a link to the attribute data for its constituent terrain unit, terrain component(s) and soil component(s), as visualized in Figure 1. The exact location of the individual components of a SOTER unit cannot be mapped explicitly at the reference scale of 1:2.5 million (Figure 2). The spatial relation between the 3 hierarchical levels of differentiation, however, can be described in the *attribute data base*. As a result, full tabular information about the attributes of the terrain unit, terrain components and soil components can be generated by SOTER unit. The respective attribute data are stored in a separate set of files (see 2.2), the contents of which can be handled by a Relational Database Management System (RDBMS). Definitions and coding conventions for the attribute data are listed in Appendix 3. *Pro forma* data entry sheets are attached as Appendix 4; they illustrate how the unique SOTER unit labels will allow for interactive use of the geometric and attribute data.

[1] General lithology refers to the dominant type of bedrock that essentially gave rise to the landform of the Terrain Unit; it need not, however, always be the parent material of all soils in the considered Terrain Unit. The parent material of the major soils, in each Terrain Component, is characterized at the level of the Terrain Component in SOTER (see App. 3).

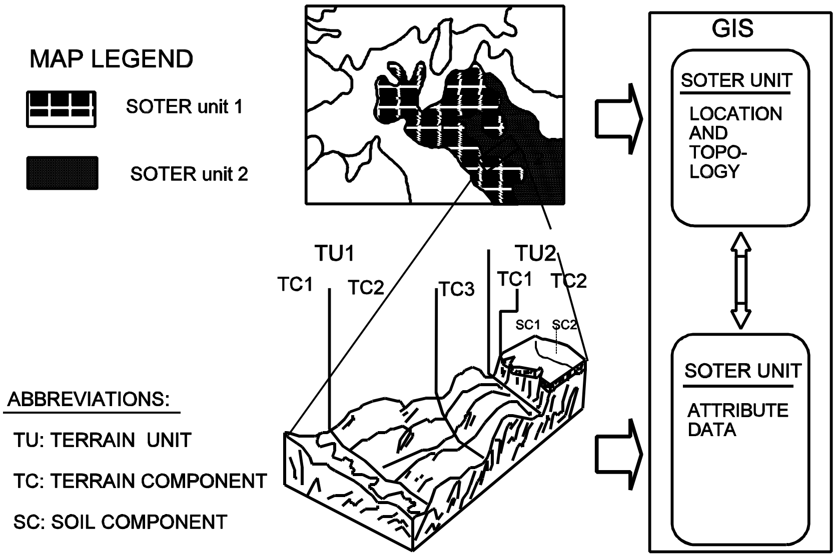

Figure 1. Schematic representation of a SOTER unit with its terrain and soil components (Source: Van Engelen and Wen, 1995)

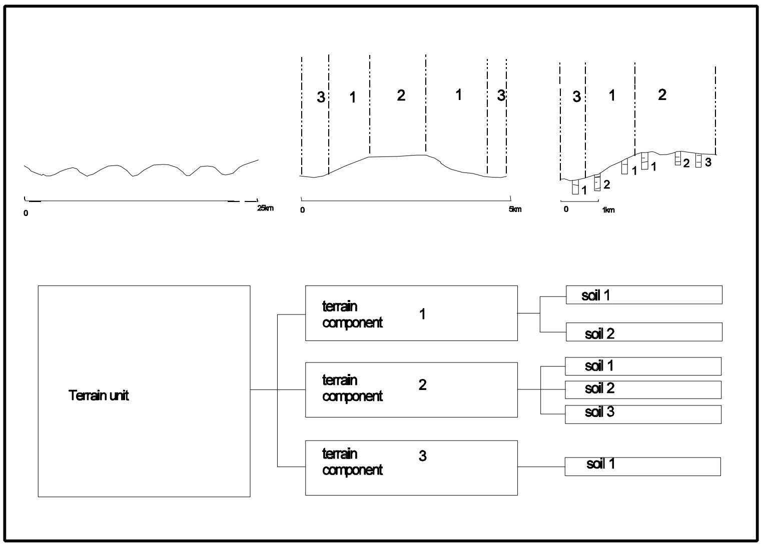

Figure 2. Schematic representation of a SOTER unit having 3 terrain components and 6 soil components.

2.2 Database structure

The overall database structure for use at a scale of 1:2.5 million is similar to that for a 1:1 million SOTER database, but a number of simplifications were necessary in view of the about 6-fold smaller map resolution:

- a maximum of 3 terrain components can be accommodated by SOTER unit;
- a maximum of 6 soil components can be defined by SOTER unit, as schematized in Figure 2;
- individual soil components are described using one representative soil profile only;
- the list of attributes is less extensive, comprising 74 items (Table 1);
- attributes for the terrain component are presented in one table.
- expert estimates are *not* allowed for any of the numerical data.

The SOTER attribute data are stored in 5 digital files (Figure 3):

1) The *terrain unit* table lists the main, unique, features of a SOTER unit.
2) The *terrain component* table specifies the attribute data by terrain component (with a maximum of 3) and gives its relative area in a terrain unit.
3) The *soil component* table specifies the relative area of the individual soil components (with a maximum of 6) within a SOTER unit as well as its overall position within a terrain component. Each soil component is characterized by one regionally representative profile.
4) The *profile* table lists the common attributes of the representative profile.
5) The *horizon* table holds morphological, chemical and physical data by individual horizon.

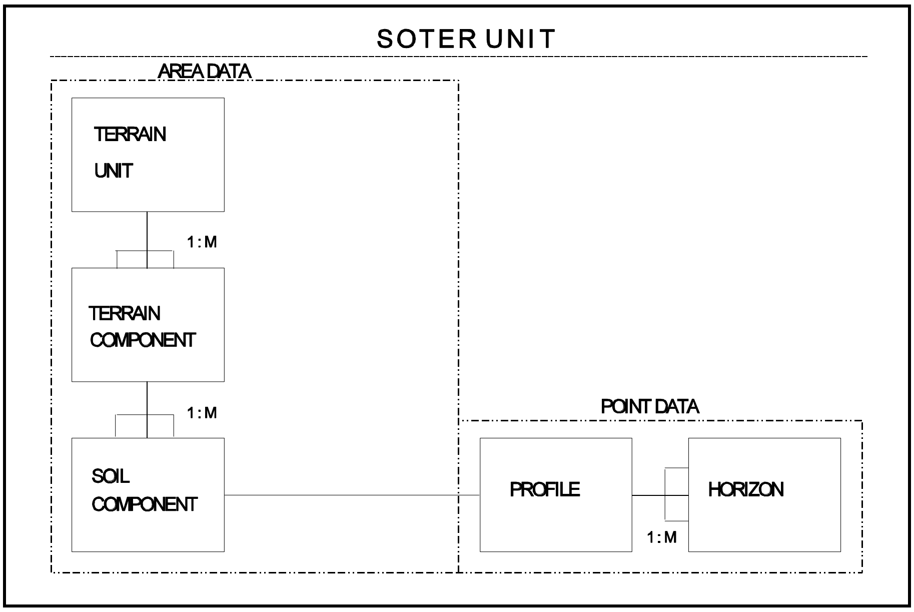

Figure 3. SOTER attribute database structure with area and point data (1:M = one to many, M:1 = many to one relations).

The type of attributes that are to be described in each file is listed in Table 1.

Table 1. Non-spatial attributes of a SOTER unit

TERRAIN UNIT

1 *SOTER unit_ID*	[1]
2 year of data collection	[2]
3 *map_ID*	[3]
4 major landform	[8]
5 regional slope	[9]
6 hypsometry	[10]
7 general lithology	[12]

TERRAIN COMPONENT

8 *SOTER unit_ID*	[14]
9 *terrain component number*	[15]
10 prop. of TC in SOTER unit	[16]
11 dominant slope	[9]
12 local surface form	[22]
13 depth to bedrock	[27]
14 parent material	[25]
15 surface drainage	[28]
16 depth to groundwater	[29]
17 frequency of flooding	[30]
18 duration of flooding	[31]

SOIL COMPONENT

19 *SOTER unit_ID*	[33]
20 *terrain component number*	[34]
21 *soil component number*	[35]
22 prop. of SC in SOTER unit	[36]
23 *profile_ID*	[37]
24' position in terrain component	[39]
25 surface rockiness	[40]
26 surface stoniness	[41]
27 rootable depth	[46]

PROFILE

28 *profile_ID*	[48]
29 *profile database_ID*	[49]
30 latitude	[50]
31 longitude	[51]
32 elevation	[52]
33 sampling date	[53]
34 lab_ID	[54]
35 drainage	[55]
36 infiltration rate	[56]
37 FAO classification (1990)	[58]
38 FAO phase (1990)	[62]
39 national classification	[60]

HORIZON (***** = optional)

40 *profile_ID*	[63]
41 *horizon number*	[64]
42 upper depth	[--]
43 lower depth	[68]
44 diagnostic horizon	[65]
45 diagnostic property	[66]
46 horizon designation	[67]
47 moist colour	[70]
48 dry colour	[71]
49 type of structure	[74]
50 abundance of coarse fragments	[75]
51 total sand	[82]
52 silt	[83]
53 clay	[84]
54 particle size class (USDA)	[85]
55 pH H_2O	[90]
56***** pH KCl	[91]
57***** electrical conductivity	[92]
58***** exch. Ca^{2+}	[93]
59***** exch. Mg^{2+}	[94]
60***** exch. Na^{+}	[95]
61***** exch. K^{+}	[96]
62***** exch Al^{3+}	[97]
63***** exch. acidity (H^{+}+Al^{3+})	[98]
64 CEC soil	[99]
65 total org. carbon	[102]
66***** total nitrogen	[103]
67***** total carbonate equiv.	[100]
68***** gypsum content	[101]
69***** bulk density	[86]
70***** soil water retention at pF1.7	[87]
71***** soil water retention at pF2.0	[87]
72***** soil water retention at pF2.5	[87]
73***** soil water retention at pF3.7	[87]
74***** soil water retention at pF4.2	[87]

Numbers in brackets, like "[--]", refer to the original item number in the SOTER Procedures Manual (Van Engelen and Wen, 1995).
Entry of all attributes listed for the Terrain Unit, Terrain Component, Soil Component, Profile and Horizon is mandatory, unless otherwise specified (*****).
All *primary keys* are in italics.

In using a relational structure for the SOTER database and unique IDs, identical soil profile descriptions may be used to characterize similar soils occurring in different terrain units or terrain components. Thereby, these profile data need to be entered coded/entered once in the database.

Besides the above described set of 5 files, there are 4 additional files for characterization of various source materials, be it the map base (i.e. map_ID) or the name of the laboratory where the soils were analyzed (i.e. lab_ID). The lab_ID provides the logical link to the type of analytical methods used (i.e. method of analysis_ID) and to a brief description of each uniquely coded analytical method (see Form 5 in App. 4). Scrupulous recording of the various source materials — and other attribute data — is critical in the compilation of databases that originate from disparate sources. Proper screening and documentation will largely determine the future confidence of users will have in the data.

3 DATABASE IMPLEMENTATION

There are three main tasks in the SOVEUR project. The first will be the preparation of a 1:2.5 million scale SOTER database for the region. In conjunction with this activity, the status-of-human induced soil degradation will be assessed by SOTER unit using the methodological guidelines of Oldeman (1988) and Van Lynden (1995b). Upon its completion, the SOTER database plus auxiliary data on climate, land use and pollution, will be used to map areas considered vulnerable to defined pollution scenarios (Batjes, 1997).

There will be 7 main stages in the development of a SOTER database for Central and Eastern Europe:

1) Delineation of SOTER units for Central and Eastern Europe, by two regional coordinators, at a scale of 1:2.5 million and entry into GIS.

2) Checking of delineations on the draft physiographic SOTER map by country with a view to updating SOTER unit boundaries where necessary, indicating a unique sequential number for every mapping unit on the map.

3) Subdivision of SOTER units into their constituent terrain unit, terrain component(s), and soil component(s) by the national partners, including recording on standard data entry sheets using the uniform coding conventions. For every SOTER (mapping) unit a full set of coding forms must be prepared, specifying all the (non-mappable) subdivisions of the mapping unit, i.e. for the terrain unit, terrain components, soil components, representative soil profiles and their horizon data.

4) Full documentation of base materials such as source maps and analytical methods (by profile) to make the data traceable and to permit subsequent comparison of the different analytical data sets.

5) Data entry into SOTER (software under development).

6) Database screening, validation and testing and subsequent in-filling of eventual gaps.

7) Cross-border correlation of spatial data between neighbouring countries, under overall supervision of the regional coordinators.

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APPENDICES

Appendix 1. Mapping of SOTER units

General

The major criteria for the differentiation of SOTER units must be applied in sequence, each step leading to a better identification of the land under consideration. Through this process, each landscape is divided progressively into its constituent terrain units, each with its own terrain components and soil components (Figure 1, p. 3). The ultimate result of the mapping, will be the demarcation and characterization of map units, or SOTER units, that will be as homogenous as possible (in their complexity) at the considered scale of 1:2.5 million.

The level of de-aggregation required at each step in the analysis of the land varies with the level of detail or scale (resolution) and the available information (Van Engelen and Wen, 1995). This appendix provides procedures for defining SOTER units at a scale of 1:2.5 million.

Appendix 1 relates mainly to those situations in which there are no small scale (about 1:1 to 1:2.5 million) digital topographic and soil maps/databases yet for a country or region. Otherwise, when appropriate digital sets exist, Digital Elevation Models and GIS technology may be used to generate the physiographic (terrain unit and terrain component) information for the 1:2.5 million SOTER database. However, irrespective of the approach adopted, it is *imperative that all mandatory attributes specified for the various data files (App. 3) are filled in-full for all SOTER units — using the standard definitions and coding conventions — to ensure uniformity*. The later is critical in view of the future merging of the 1:2.5 million database into a global 1:5 million SOTER database.

Upon its completion, the 1:2.5 million SOTER database will provide the basis for characterizing the "current status of human-induced soil degradation" (Van Lynden, 1997) and "areas vulnerable to chemical pollution" (Batjes, 1997) for the 13 countries considered in the SOVEUR project.

Delineation of Terrain units

Physiography

Physiography is the first differentiating criterion in the ultimate characterisation of SOTER units, permitting delineation of major landforms based on dominant slope and overall relief intensity (see 2.1). In combination with a hypsometric grouping, which expresses the absolute elevation above sea-level, and information on the degree of dissection of the land, distinct tracts of land can be mapped. Individual demarcations

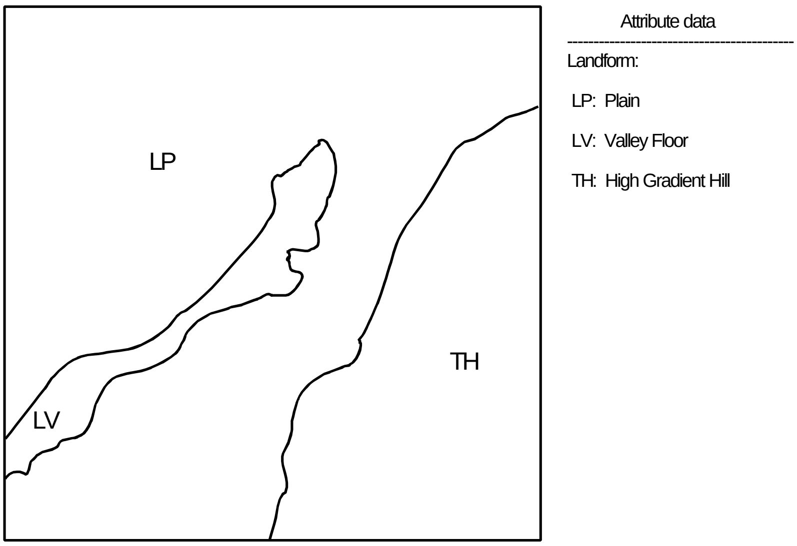


Figure 4. Delineation of broad terrain units according to major landform.
(Note: For code definitions see Appendix 3)

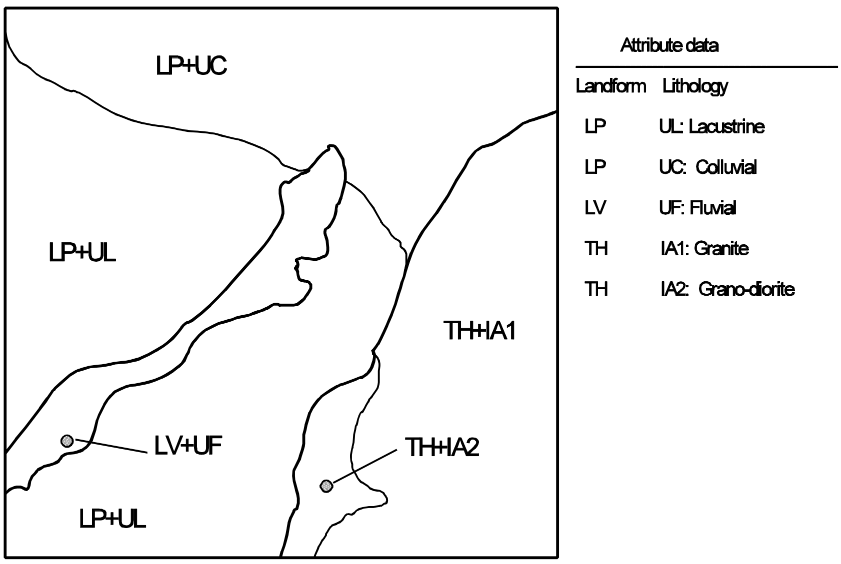


Figure 5. Delineation of terrain units according to major landform and general lithology.

will correspond with first and second level major landforms (see Table 2 in App. 2). As an illustration, three major landforms are distinguished in Figure 4 which corresponds with the "geometric database"; a Plain (LP), Valley Floor (LV) and High Gradient Hill (TH). The codes, shown in brackets, are to be written on the Data Entry Forms (App. 4), corresponding with the attribute database.

General lithology

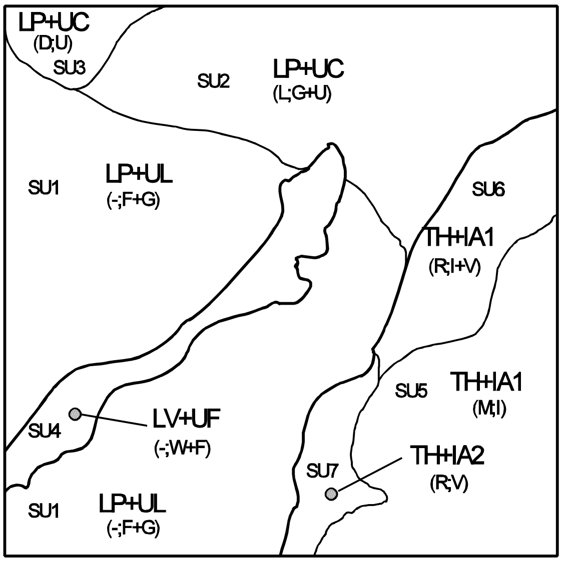
Major regional landforms are characterized further according to general lithology (see App. 3 for criteria). As an hypothetical example, Figure 5 shows that unit-LP, is comprised of lacustrine deposits (UL) and colluvial deposits (UC) which occur in proximity of the High Gradient Hills (TH); unit-LV consists of fluvial (UF) deposits only; while unit-TH, encompasses areas of both granite (IA1) and grano-diorite (IA2). Again, the codes for the general lithology will be documented in the attribute database.

From the above it follows that at this stage, in the SOTER terminology, each *landscape* is defined into unique areas (or broad map units) with a specific landform and general lithology; these are termed terrain units. Although fairly homogeneous in their characteristics, there can be several typical combinations of surface form, mesorelief, parent materials and soils within a terrain unit. Being recognizable or known, these differentiating criteria provide the basis for a further characterization of a terrain unit into its constituent terrain components and soil components; these recognized entities, however, cannot always be mapped explicitly at a scale of 1:2.5 million.

Characterisation of Terrain Components

The next step in database compilation is the characterization of uniform areas, within a terrain unit, that have a similar and specific combination of local surface form, slope, mesorelief and lithology of surficial material. These subdivisions are called terrain components. For example, the area of LP-UC in Figure 5 may consist of both a slightly dissected (L) part, with gently undulating (G) and undulating (U) slopes, and a strongly dissected (D) part with mainly undulating (U) slopes. In the current example, these compound units can still be mapped adequately at a scale of 1:2.5 million (Figure 6). Figure 7 is a representation of the resulting map or geometric database, with its unique SOTER units or mapping units.

The cartographically allowed, and thus most detailed possible subdivision of the terrain at the considered scale of mapping (see App. 2), will determine the actual content/complexity of a SOTER unit. In a fairly homogenous area, as is the case for unit SU4 for example, there may be 1 terrain component with 2 soil components, each of which is characterized using a representative profile (Figure 8). In a more intricate situation, such as is depicted for SU6, the terrain (SOTER) unit consists of 2 terrain components, having respectively 2 and 1 soil components (Figure 8). Generally, there should be no more than 6 components in a SOTER unit (e.g., Figure 2, p. 4). The various "non-mappable" elements in a terrain unit, can be characterized in the attribute database, using the SOTER unit_ID as the unique identifier (see Figure 7 and 8). Thereby, the SOTER methodology provides an "added-value" as compared to traditional small scale maps, such as the Soil Map of the World (FAO-Unesco, 1974).



SOTER Unit	Attribute data Landf.	Lith.	Meso-relief	slope
SU1	LP	UL	-	F+G
SU2	LP	UC	L	G+U
SU3	LP	UC	D	U
SU4	LV	UF	-	W+F
SU5	TH	IA1	M	I
SU6	TH	IA1	R	I+V
SU7	TH	IA2	R	V

Figure 6. Terrain units subdivided into terrain components according to local surface form and slope gradient (see Figure 7 for SOTER units).

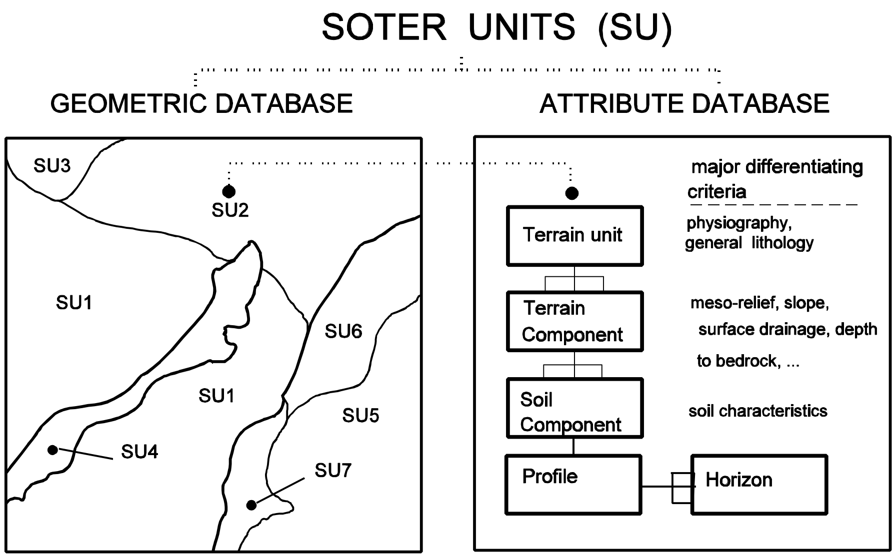


Figure 7. SOTER units as shown on a map and characterized in the attribute database.

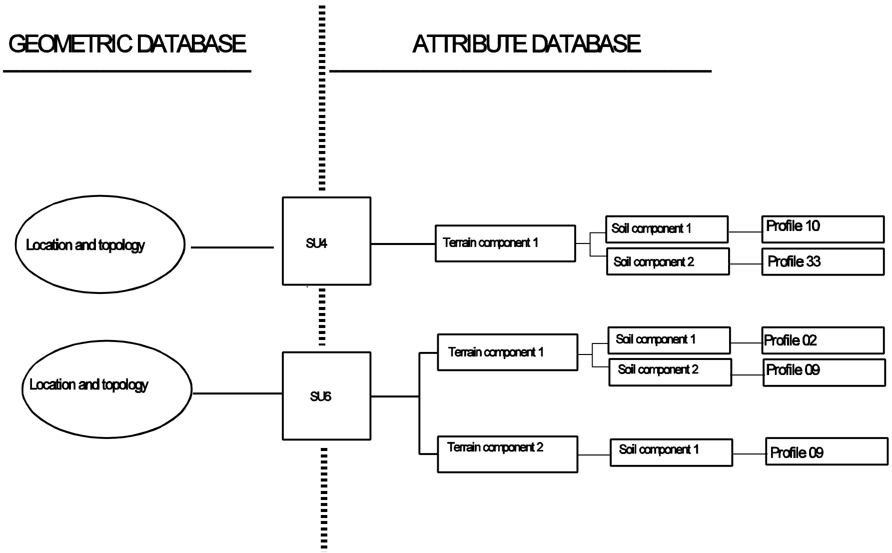


Figure 8. Examples of hypothetical SOTER units with their terrain components, soil components and representative profiles.

Soil Components

In traditional soil mapping, the terrain components would correspond with soil association or soil complexes. Thus, the final step in the characterization of a terrain unit will be the description of soil components within each terrain component. The main characteristics of each soil component (within a terrain component) can be characterized in the attribute database, but the individual soil components are not mappable at a scale of 1:2.5 million.

At a scale of 1:2.5 million, in most cases, 6 soil components (occurring in up to 3 terrain components) should be adequate to characterize individual terrain units. The relative area of each terrain component and soil component in a SOTER unit is given in percent, with the total always being 100%.

Profile and Horizon data

In the SOTER methodology, each soil component is to be characterised by one reference profile, which regional experts are to select from available profile descriptions (Van Engelen and Wen, 1995). For the SOVEUR project, all soil components must be characterized up to the soil unit level of the Revised FAO-Unesco Soil Map of the World Legend (FAO, 1990). The main criteria for separating soil components within a terrain component thus are based largely on FAO diagnostic horizons and properties. The example in Figure 8 illustrates that data from a single representative soil profile, i.e. "profile 09", have been be used to characterize different soil components in

SOTER unit SU6. In practical terms, this means that the data for 'profile 09' will only have to be entered once in to the database. In other words, this also means that the actual (total) number of soil profiles in the database may be lower than the total number of soil components considered.

Individual soil components can be differentiated further according to factors that may adversely affect land use or land degradation. These criteria, which are listed by FAO as phases, consider both soil (sub-surface) and terrain (surface, e.g. micro-relief) features.

Selected morphological, chemical and physical data are described by horizon for the representative profile, using the definitions and coding conventions in Appendix 3. The definitions largely follow those of the FAO Guidelines for Soil Description (FAO, 1990). Profiles originally described according to other (national) standards, will have to be "translated" in to the SOTER terminology prior to their entry in the database. At this stage, the source of the data and original analytical methods must be documented also.

The recommended number of horizons by profile is set at 5 subjacent horizons, with maximum of 9. Profile descriptions should extend to a depth of at least 150 cm, where pedologically relevant. The properties of each horizon are characterised in the Horizon database, paying due attention the mandatory and optional data (see App. 3).

Appendix 2. Additional mapping conventions

General

The conventions described in this section supplement those described in Appendix 1 and 3. They mainly concern rules for: coding of SOTER units; maximum number of soil components allowed by SOTER unit; minimum size of a SOTER unit, both in absolute and relative terms; broad criteria for selection of representative profile descriptions; and, handling of missing soil profile data.

Coding of SOTER units

Each SOTER unit is assigned a simple code that is unique for the national database in question. Each code consists of the ISO code for the country under consideration plus a number ranging from 1 to 9999.

Individual terrain components within a terrain unit are numbered in sequence (i.e. from 1 to the allowed maximum of 3), starting with the most extensive component. Similarly, soil components within each terrain component are numbered from 1 upwards starting with the most extensive soil component in the terrain unit under consideration. Ideally, there should not be more than 6 soil components in each SOTER unit (Figure 2), each of these covering at least 15% of the unit. In some cases, however, more than 6 soil components can be accommodated if the corresponding soils are of particular importance for specific uses (e.g., small areas of Fluvisols or Histosols)

The numbers of the various constituents of a SOTER unit are separated by a slash "/". For example, SOTER unit_ID "RU0199/2/3" would refer to terrain unit number 199 in Russia, specifically its second (2) terrain component, and its third (3) soil component (Figure 2).

National SOTER databases will be compiled for the 13 participating countries in SOVEUR, under supervision of regional coordinators. Ultimately, the national databases will have to be merged into one regional database. At that stage, cross-border correlation of the SOTER units will be necessary.

Minimum size for delineation of a SOTER unit

As a rule of thumb, the minimum size of a cartographic unit on a map should be at least 0.25 cm^2. At a scale of 1:2.5 million this corresponds with ≈ 156 km^2 in the field. Generally, such small units will correspond with narrow elongated features in the landscape, such as floodplains and valleys, or with strongly contrasting terrain and soil features. Most SOTER units at a scale of 1:2.5 million, however, should be much larger than 0.25 cm^2.

Maximum number of soil and terrain components by SOTER unit

The relative area of individual terrain components and soil components in a given SOTER unit can vary, keeping in consideration the above cartographic limitations. In theory, this would allow for an unlimited number of terrain components within each SOTER unit, or soil components within each terrain component. In practice this is unlikely to occur, as many terrain components and soil components cover sizeable areas.

A minimum (relative) area of 15% of a 1:2.5 million SOTER unit is required when defining new terrain components . At the considered scale, most SOTER units should be divided in up to 3 terrain components. Individual soil components will generally cover at least 15% of the corresponding SOTER unit (see p. 17) . Inherently, the sum of the relative area of the various soil components of the various terrain components in each SOTER unit, with a recommended maximum of 6, must always be 100%.

Criteria for defining new SOTER units

The above restrictions have been introduced so that map compilers must exercise restraint in subdividing terrain units into terrain components and soil components. Only those criteria that can be considered important for characterizing a landscape and its main soil components should be considered at a scale of 1:2.5 million.

Significant spatial changes in parent material, surface form and slope gradient would qualify as criteria for defining new SOTER units. When changes in the landscape or terrain features are gradual, new SOTER units must be delineated when the area of any one terrain component or soil component in a terrain unit changes by more than 50%.

Terrain components must be split into soil components only if there are clear changes in the differentiating criteria which will affect land use or land resilience/degradation. Minor changes in any of these criteria should be considered as part of the natural variability which can be expected to occur within each SOTER unit at a scale of 1:2.5 million. Discretion is absolutely necessary in defining terrain and soil components! Consideration of an excessive number of components would lengthen the time required for coding, entering and processing of data, yet hardly improve the reliability of the information shown on the map.

Criteria for selection of representative soil profiles

Selection of a regionally representative soil profile for each soil component will be difficult in view of the intrinsic variation of land qualities in space and time. Often, the profile must be chosen from a number of reference profiles with similar characteristics and FAO (1990) classification, as present in their national archives.

Ideally, all the reference profiles considered should be stored in a national soil profile database, preferably based on the FAO-ISRIC Soil Database format (Van Waveren *et al.*, 1988), but this is seen as a separate activity.

Base maps

The 1:2.5 million SOTER map for Central and Eastern Europe will cover 13 countries, so that strict mapping criteria are needed. Basic data sources for the demarcation of the SOTER units are topographic, geomorphological, geological and soil maps at a scale of 1:2.5 million or larger, i.e. mostly exploratory and reconnaissance maps. The 1:1 million Operational Navigation Charts (ONC) and their digital counterpart, the Digital Chart of the World (DMA, 1992), will form the reference base map for the demarcation of country and other administrative boundaries, on the 1:2.5 million scale SOTER. In addition, the recently released 1 km x 1 km digital topographic database may be used to generate separate data layers on e.g. regional slope and elevation, using a digital elevation model. When available, digital soil maps may be used also to generate the required spatial information, using appropriate GIS techniques.

In principle, all exploratory soil maps with sufficient accompanying analytical data for characterizing soils according to the soil unit level of the revised FAO-Unesco Soil Map of the World Legend (FAO, 1990) can be used for mapping SOTER units. However, the available reports and maps seldom will contain all the required soil and terrain data. Larger scale (semi-detailed and detailed) soil and terrain maps may be useful for the exercise, in providing detailed profile descriptions.

If there is no adequate map for a certain study area, or in situations there are gaps in the available data, it may be possible to extract some information from available small(er) scale maps, such as the 1:5 million Soil Map of the World (FAO-Unesco, 1971-1981; FAO, 1995) and similar national maps. The later, provided that some additional fieldwork is carried out in conjunction with use of satellite imagery, as necessary. Hence, there may be a need for additional field checks, sometimes supported by satellite imagery interpretation, and additional supporting analytical work to complement the existing soil and terrain information. This should be carried out, however, within the context of complementing, updating or correlating existing surveys. It must be stressed that both SOVEUR and SOTER specifically excludes the undertaking of new land resource surveys within its programme.

Handling of missing attribute data

Entry of all the attributes listed under terrain unit, terrain component and soil component in Table 1 is mandatory! Where necessary, expert judgement may be used (e.g. for depth to groundwater table) to characterize the attributes for the terrain unit and terrain components.

Contrary to what has been the case for the 1:5 M SOTER approach, some missing data will be allowed for the <u>optional</u> attributes in the horizon database only! This is necessary, as some chemical attributes are analyzed only if there are pedological grounds for doing so (e.g. $CaCO_3$ content at pH> 6.5). Similarly, soil physical attributes are seldom measured on a routine basis. All mandatory horizon attributes are clearly flagged in Table 1 and Appendix 3. It is the intention to fill eventual gaps in "horizon" data at a later stage, by weighted depth zone, using a combination of taxotransfer or pedotransfer rules (see Batjes *et al.*, 1997). In using this approach, users will know that they will always dealing with measured data in the 1:2.5 million SOTER database.

Appendix 3. Attribute coding conventions.

GENERAL

The numbers in brackets that follow the attributes in Table 1 are identical to those used in the SOTER Procedures Manual (Van Engelen and Wen, 1995), for ease of reference. The numbers used in this Appendix are sequential, and are also used on the data entry forms in Appendix 4.

In the current Appendix, all the following conventions apply for classes: the value for the upper limit of each class is included in the next class. For example, the slope class of 2-5% will include all slopes from 2.0 to 4.9%.

TERRAIN UNIT

1 *SOTER unit_ID*

The SOTER unit_ID is the unique identification code of a SOTER unit on the map and in the database. It links the mapped area to the attributes in the database and in particular, it identifies which terrain belongs to a SOTER unit. SOTER units which have identical attributes carry the same SOTER unit_ID. In other words the SOTER unit_ID is similar to a code for a mapping unit on a conventional soil map.

Each SOTER map is given a unique code, consisting of the ISO country code plus 4 digits (e.g. LT0025).

Note: Inherently, some of the SOTER unit_IDs will have to be changed (merged) after the final cross-border correlation.

2 *year of data collection*

The year in which the original terrain data were collected will serve as the time stamp for each SOTER unit. Where the SOTER unit has been defined on the basis of several sources of information, the major source will determine the year of data collection. This will provide a logical link between the SOTER unit map and the major source of information, which is to be listed under map_ID. The assumption is that the year in which the terrain date were collected will also apply to the accompanying terrain component data.

3 *map_ID*

Identification code for the source map used for the compilation of the SOTER unit map. Each map unit_ID should start with the national ISO-number (App. 7). Up to 12 characters can be accommodated in the database.

4 *major landform*

Landforms are described foremost by their morphology and not by their genetic origin nor the processes responsible for their formation and shape. The regionally dominant slope class is the main differentiating criterion, followed by relief intensity. The relief intensity is normally given in meters per kilometre, but for distinction between hills and mountains it is more practical to use two kilometre intervals (Table 2).

At the highest level of separation, four groups of landform are distinguished (after Remmelzwaal, 1991). These first level units can be divided into second level units based on their position *vis-a-vis* the surrounding land.

Second level landforms can be differentiated also according to Appendix 5, when slope gradient or relief intensity do not allow for this.

Table 2. Hierarchy of major landforms.

1st level	2nd level	gradient (%)	relief intensity
L level land	**LP** plain	<8	<100m/km
	LL plateau	<8	<100m/km
	LD depression	<8	<100m/km
	LF low-gradient footslope	<8	<100m/km
	LV valley floor	<8	<100m/km
S sloping land	**SM** medium-gradient mountain	15-30	>600m/2km
	SH medium-gradient hill	8-30	>50m/slope unit
	SE medium-gradient escarpment zone	15-30	<600m/2km
	SR ridges	8-30	>50m/slope unit
	SU mountainous highland	8-30	>600m/2km
	SP dissected plain	8-30	<50m/slope unit
T steep land	**TM** high-gradient mountain	>30	>600m/2km
	TH high-gradient hill	>30	<600m/2km
	TE high-gradient escarpment zone	>30	>600m/2km
	TV high gradient valleys	>30	variable
C land with composite landforms	**CV** valley	>8	variable
	CL narrow plateau	>8	variable
	CD major depression	>8	variable

Notes: Water bodies are coded by the letter W.

5 *regional slope*

The dominant (regional) slope class within a major landform is defined differently for (a) simple landforms or (b) complex landforms, as follows:

a) Simple landforms

W	0- 2 %	flat, wet*
F	0- 2 %	flat
G	2- 5 %	gently undulating
U	5- 8 %	undulating
R	8-15 %	rolling
S	15-30 %	moderately steep
T	30-60 %	steep
V	≥ 60 %	very steep

* The code W for wet is used when 50 to 90% of a SOTER unit is covered by permanent water.

b) Complex landforms**

CU	Cuesta-shaped
DO	Dome-shaped
RI	Ridged
TE	Terraced
IN	Inselberg covered (occupying at least 1% of level land)
DU	Dune-shaped
IM	With intermontane plains (occupying at least 15%)
WE	With wetlands (occupying at least 15%)
KA	Strong karst

** In the case of complex landforms, the protruding landform should be at least 25 m high (if not it is to be considered mesorelief) except for terraced land, where the main terraces should have elevation differences of at least 10 m.

6 *hypsometry*

For level and slightly sloping land (relief intensity of less than 50 m), the hypsometric level gives an indication of the height above sea level of the local base level. For lands with a relief intensity of more than 50 m, the hypsometric level refers to the height above the local base (i.e. local relief).

a) Level lands and sloping lands (relief intensity < 50 m/slope unit)

1	< 300 m	very low level (plain etc.)
2	300- 600 m	low level
3	600-1500 m	medium level
4	1500-3000 m	high level
5	≥ 3000 m	very high level

b) Sloping lands (relief intensity > 50 m/slope unit)

6	< 200 m	low (hills etc.)
7	200-400 m	medium
8	≥ 400 m	high

c) Steep and sloping lands (relief intensity > 600 m / 2km)

9	600-1500 m	low (mountains etc.)
10	1500-3000 m	medium
11	3000-5000 m	high
12	≥ 5000 m	very high

7 *general lithology*

For each SOTER unit a generalized description of the consolidated or unconsolidated surficial material, that underlies the larger part of the terrain, is given. Major differentiating criteria are petrology and mineralogical composition (Holmes, 1968; Strahler, 1969). At the 1:2.5 million scale the general lithology should at least be specified down to the group (Table 3).

Table 3. Hierarchy of lithology.

	Major class		Group		Type
I	igneous rock	**IA**	acid igneous	**IA1**	granite
				IA2	grano-diorite
				IA3	quartz-diorite
				IA4	rhyolite
		II	intermediate igneous	**II1**	andesite, trachyte, phonolite
				II2	diorite-syenite
		IB	basic igneous	**IB1**	gabbro
				IB2	basalt
				IB3	dolerite
		IU	ultrabasic igneous	**IU1**	peridotite
				IU2	pyroxenite
				IU3	ilmenite, magnetite, ironstone, serpentine
M	metamorphic rock	**MA**	acid metamorphic	**MA1**	quartzite
				MA2	gneiss, migmatite
				MA3	slate, phyllite (pelitic rocks)
				MA4	schist
		MB	basic metamorphic	**MB1**	slate, phyllite (pelitic rocks)
				MB2	schist
				MB3	gneiss rich in ferro-magnesian minerals
				MB4	metamorphic limestone (marble)
S	sedimentary rock	**SC**	clastic sediments	**SC1**	conglomerate, breccia
				SC1	sandstone, greywacke, arkose
				SC3	siltstone, mudstone, claystone
				SC4	shale
				SC5	ironstone
		SO	organic	**SO1**	limestone, other carbonate rocks
				SO2	marl and other mixtures
				SO3	coals, bitumen & related rocks
		SE	evaporites	**SE1**	anhydrite, gypsum
				SE2	halite
U	unconsolidated	**UF**	fluvial	**UF1**	calcareous
				UF2	non-calcareous
		UL	lacustrine	**UL1**	calcareous
				UL2	non-calcareous
		UM	marine	**UM1**	calcareous
				UM2	non-calcareous
		UC	colluvial	**UC1**	calcareous
				UC2	non-calcareous
		UE	eolian	**UE1**	calcareous
				UE2	non-calcareous
		UG	glacial	**UG1**	calcareous
				UG2	non-calcareous
		UP	pyroclastic	**UP1**	non-acid
				UP2	acid
		UO	organic	**UO1**	calcareous
				UO2	non-calcareous

TERRAIN COMPONENT

8 *SOTER unit_ID*

See SOTER unit_ID under Terrain unit.

9 *terrain component number*

The sequential number of the terrain component in the terrain unit. The largest terrain component in the SOTER unit is numbered first, followed by the second in size, and so on. The combination SOTER unit_ID and terrain component number. For example, "RU2034/1" would refer to the first, thus spatially dominant, terrain component in SOTER unit "RU2034".

10 *proportion of SOTER unit*

The proportion that the terrain component occupies within the SOTER unit. As stated earlier, a terrain component normally covers at least 15 % of a terrain. The sum of the relative areas of all terrain components in a SOTER unit always be 100 %, as is shown in the box below.

Example

SOTER unit_id = RU2034,	SOTER unit_id = RU2034
terrain component numbe r= 1	terrain component number = 2
proportion within SU = 70%	proportion within SU = 30%

11 *dominant slope*

Dominant slope gradient of the terrain component, expressed as classes (see 5a).

12 *local surface form*

A number of characteristic meso-relief or local surface forms can be recognised at scale 1:2.5 million, in addition to the slope form as listed below (this list is not exhaustive).

H	hummocky	very complex pattern of slopes extending from somewhat rounded depressions or kettleholes of various sizes to irregular conical knolls or knobs. There is a general lack of concordance between knolls or depressions. Slopes ranges are large and vary generally between 4 % and 70 %.
M	mounded	coverage (at least 5 %) by isolated mounds more than 2.5 m high.
K	towered	coverage (at least 5 %) by isolated steep sided karst towers more than 2.5 m high.
R	ridged	coverage (at least 5 %) by parallel, sub-parallel or intersecting usually sharp-crested ridges (elongated narrow elevations) more than 2.5 m high.

T	terraced	level areas (less than 2 % slope) bounded on one side by a steep slope more than 2.5 m high with another flat surface above it.
G	gullied	coverage (at least 5 %) by steep-sided gullies more than 2.5 m deep.
S	strongly (dissected)	areas with a drainage density of more than 25 km km^{-2}, the depth dissected of the drainage lines being at least 2.5 m.
D	dissected	areas with a drainage density of more than 10 km km^{-2}, the depth of the drainage lines being at least 2.5 m.
L	slightly (dissected)	areas with a drainage density of less than 10 km km^{-2}, the depth of the dissected drainage lines being at least 2.5 m.

13 *depth to bedrock*

The average depth to consolidated bedrock in metres, when applicable. For depths less than 2 m the unit is 0.1 m. If over 10 m, the depth must be rounded to the nearest 5 m.

14 *parent material*

Description of the consolidated or unconsolidated surficial materials (sensu parent material) on/in which the major soils in the terrain component are formed. In accordance with the SOTER methodology (Van Engelen and Wen, 1995), these include the types of rock from which parent material is derived, and other unconsolidated mineral or organic deposits. Coding conventions are identical to those in Table 3. If there is more than 1 terrain component, the code for surficial lithology may differ from the code for general lithology recorded for the terrain unit (and thus also for the dominant terrain component).

15 *surface drainage*

Surface drainage of the terrain component (after Cochrane *et al.*, 1985; Van Waveren and Bos, 1988):

E	extremely slow	water ponds at the surface, and large parts of the terrain are waterlogged for continuous periods of more than 30 days
S	slow	water drains slowly, but most of the terrain does not remain waterlogged for more than 30 days continuously
W	well	water drains well but not excessively, nowhere does the terrain remain waterlogged for a continuous period of more than 48 hours
R	rapid	excess water drains rapidly, even during periods of prolonged rainfall
V	very rapid	excess water drains very rapidly, the terrain does not support growth of short rooted plants even if there is sufficient rainfall

16 *depth of groundwater*

The estimated median depth, in metres, of the ground water level as observed for the terrain component over a number of years.

17 *frequency of flooding*

Frequency of the natural flooding of the terrain component in classes after FAO (1990).

N none

D daily

W weekly

M monthly

A annually

B biennially

F once every 2-5 years

T once every 5-10 years

R rare (less than once in every 10 years)

U unknown

18 *duration of flooding*

Median duration of the flooding of the terrain component in classes after FAO (1990).

1 less than 1 day

2 1-15 days

3 15-30 days

4 30-90 days

5 90-180 days

6 180-360 days

7 continuously

SOIL COMPONENT

19 *SOTER unit_ID*

See SOTER unit_ID under terrain unit.

20 *terrain component number*

See terrain component number under terrain component.

21 *soil component number*

The sequential number of the soil component within a terrain component according; the largest soil component is given number 1, the second largest number 2, etc. In the attribute database, a soil components corresponds with the lowest level of differentiation of a SOTER unit.

By convention, each soil component will be characterized by one single profile (after Van Engelen and Peters, 1995).

22 *proportion of SC in SOTER unit*

The relative area of the soil component in a SOTER unit, with a minimum of 15% The sum of the relative area for all soil components in a SOTER unit must be 100%.

23 *profile_ID*

Code for the representative profile. Any national code is permitted provided it is unique at a national level. The country ISO code (App. 7) should precede the national code. There is room for up to 12 characters.

24 *position in terrain component*

The relative position of the soil component within the terrain component is coded as follows:

H	high	interfluve, crest or higher part of the terrain component
M	middle	upper and middle slope or any other medium position within the terrain component
L	low	lower slope or lower part of the terrain component
D	lowest	depression, valley bottom or any other lowest part of the terrain component
A	all	all positions within the terrain component

25 *surface rockiness*

The percentage coverage of rock outcrops according to the following classes (FAO, 1990):

N	none	0 %
V	very few	0- 2 %
F	few	2- 5 %
C	common	5-15 %
M	many	15-40 %
A	abundant	40-80 %
D	dominant	≥ 80 %

26 *surface stoniness*

The percentage cover of coarse fragments (> 0.2 cm) that occur completely or partly at the surface, according to the following classes of FAO (1990):

N	none	0 %
V	very few	0 -2 %
F	few	2- 5 %
C	common	5-15 %
M	many	15-40 %
A	abundant	40-80 %
D	dominant	≥ 80 %

27 *rootable depth*

Estimated depth in cm to which root growth is unrestricted by any physical impediment, such as an impenetrable layer (*Note*: This definition differs from the one used in Van Engelen and Wen (1995)). Strongly fractured rocks, such as shales, may be considered as rootable. Classes are after FAO (1990).

V	very shallow	< 30 cm
S	shallow	30- 50 cm
M	moderately deep	50-100 cm
D	deep	100-150 cm
X	very deep	≥ 150 cm

PROFILE

28 *profile_ID*

Same as profile_ID under soil component.

29 *profile database_ID*

Identification code for the owner, institute or organisation that holds (part of) the national soil profile database. The code consists of an ISO code for the country (App. 5) and a sequential number (App. 1).

30 *latitude*

The latitude is stored in *decimal* degrees north. Latitudes in the southern hemisphere are negative (For example: 52 deg 20 min N is to be entered as +52.33 decimal degrees). Profiles for which the location, accurate to the nearest full minute, is not known will <u>not</u> be accepted by the SOTER database software!

31 *longitude*

The longitude is stored in *decimal* degrees East. Longitudes in the western hemisphere are negative (i.e. 30° 30' W is entered **-**30.50 decimal degrees).

32 *elevation*

The (estimated) elevation of the representative profile in metres above sea level, and at least indicated to the nearest 50 m contour. (If this is not possible, the field can be left blank).

33 *sampling date*

The date at which the profile was described and sampled. In case these two activities were carried out on different dates, the date of sampling should be taken. The format is MM/YYYY.

34 *lab_ID*

Unique code for the soil laboratory that analyzed the samples, consisting of ISO country code plus a number (e.g. LT001).

35 *drainage*

The present (internal) drainage of the soil component is described according to one of the classes mentioned below (after FAO, 1990).

E	excessively drained	Water is removed from the soil very rapidly.
S	somewhat exc. drained	Water is removed from the soil rapidly.
W	well drained	Water is removed from the soil readily but not rapidly.
M	moderately well drained	Water is removed from the soil somewhat slowly during some periods of the year. The soils are wet for short periods within rooting depth.
I	imperfectly drained	Water is removed slowly so that the soils are wet at shallow depth for a considerable period.
P	poorly drained	Water is removed so slowly that the soils are commonly wet for considerable periods. The soils commonly have a shallow water table.
V	very poorly drained	Water is removed so slowly that the soils are wet at shallow depth for long periods. The soils have a very shallow water table.

36 *infiltration rate*

The basic infiltration rate, in cm h^{-1}, is indicated according to the following 7 categories (Landon, 1991).

V	very slow	< 0.1 cm h^{-1}
S	slow	0.1- 0.5 cm h^{-1}
D	moderately slow	0.5- 2.0 cm h^{-1}
M	moderate	2.0- 6.0 cm h^{-1}
R	rapid	6.0-12.5 cm h^{-1}
Y	very rapid	12.5-25.0 cm h^{-1}
E	extremely rapid	≥25 cm h^{-1}

37 *classification*

Characterisation of profile according to the revised FAO-Unesco Soil Map of the World Legend (FAO, 1990), using the codes in Appendix 6. The characterization must be up to soil unit (e.g. Calcic Chernozems (CHk)).

38 *phase (FAO, 1990)*

Phases are limiting factors related to surface or subsurface features of the terrain. They are not necessarily related to soil formation and generally cut across the boundaries of different soil components (or soil units). These features may form a constraint to the use of the land. Sixteen phases are recognized in accordance with definitions of FAO (1990).

AN	Anthraquic
DU	Duripan
FR	Fragipan
GE	Gelundic
GI	Gilgai
IN	Inundic
LI	Lithic
PF	Petroferric
PH	Phreatic
PL	Placic
RU	Rudic
SA	Salic
SK	Skeletic
SO	Sodic
TK	Takyric
YR	Yermic

39 *national classification*

The national classification of the representative profile. Up to 12 characters can be accomodated.

HORIZON DATA

In general, no more than 5 horizons should be described by profile, but a maximum of 9 is possible. Mandatory attributes must always be filled in on the forms (Table 1). If these measured data are not available, expert estimates are required in case of qualitative data such as rooting depth and depth to groundwater table. Expert estimates should never be introduced for any of measured soil properties (e.g. CECsoil or bulk density); they should be coded as "-1". When required, derived data for these attributes can be computed at a later stage from the data available for similar soil units.

All mandatory attributes are clearly marked in Table 1.

40 *profile_ID* (mandatory)

Same as profile_ID under profile.

41 *horizon number* (mandatory)

A consecutive number, starting with the surface horizon, is allocated to each horizon.

42 *Upper depth* (mandatory)

Contrary to what is the case in the SOTER Procedures Manual, the upper depth is also required for each horizon. It is the average depth of the upper boundary in cm (the upper boundary in the case of an **O** horizon). It has been added to facilitate computations for the analytical data, by control section. In case of organic surficial layers, depth are codes as **-** x cm, i.e. x cm above the mineral surface. The sequential horizon number, however, will nonetheless start at 1.

43 *lower depth* (mandatory)

The average depth of the lower boundary in cm (the upper boundary in the case of an **O** horizon).

44 *diagnostic horizon* (mandatory)

Descriptions are taken from the Revised Legend of the FAO/Unesco Soil Map of the World (FAO, 1994). For more precise definitions refer to this publication.

HI	histic	An horizon which is more than 20 cm but less than 40 cm thick. It can be more than 40 cm but less than 60 cm thick if it consists of 75 percent or more, by volume, of sphagnum fibres or has a bulk density when moist of less than 0.1 kg dm^{-3}. A surface layer less than 25 cm thick qualifies as a histic horizon if, after having been mixed to a depth of 25 cm, it has 16% or more organic carbon and the mineral fraction contains more than 60% clay, or 8% or more organic carbon for intermediate contents of clay.
MO	mollic	A horizon with the following properties for the upper 18 cm: 1) the soil structure is sufficiently strong that the horizon is not both massive and hard or very hard when dry. Very coarse prisms larger than 30 cm in diameter are included in the meaning of massive if there is no secondary structure within the prisms. 2) the chroma is less than 3.5 when moist, the value darker than 3.5 when moist and 5.5 when dry; the colour value is at least one unit darker than that of the C (both moist and dry). If a C horizon is not present, comparison should be made with the horizon immediately underlying the A horizon. If there is more than 40% finely divided lime, the limits of the colour value dry are waived; the colour value moist should then be 5 or less. 3) the base saturation (by NH_4OAc) is 50% or more 4) the organic carbon content is at least 0.6% throughout the thickness of mixed soil, as specified below. It is at least petrocalcic or a petrogypsic horizon or a petroferric phase.
FI	fimic	A man made surface layer 50 cm or more thick which has been produced by long continued manuring with earthy mixtures. If a fimic horizon meets the requirements of the mollic or umbric horizon, it is distinguished from it by an acid-extractable P_2O_5 content which is higher than 250 mg kg^{-1} soil by 1 percent citric acid. Examples are the plaggen epipedon and the anthropic epipedon of Soil Taxonomy.
UM	umbric	Comparable to mollic in colour, organic carbon and phosphorus content, consistency, structure and thickness. However, the base saturation is less than 50%.
OC	ochric	The horizon is too light in colour, has too high a chroma, too little organic carbon, or is too thin to be a mollic or umbric, or is both hard and massive when dry. Finely stratified materials do not qualify

as an ochric horizon, e.g. surface layers of fresh alluvial deposits.

AR argic — A subsurface horizon which has a distinctly higher clay content than the overlying horizon. This difference may be due to an illuvial accumulation of clay, or to a destruction of clay in the surface horizon, or to a selective surface erosion of clay, or to biological activity or to a combination of two or more of these different processes. Sedimentation of surface materials, which are coarser than the subsurface horizon, may enhance a pedogenic textural differentiation. However, a mere lithological discontinuity, such as may occur in alluvial deposits, does not qualify as an argic horizon. When an argic horizon is formed by clay illuviation, clay skins may occur on ped surfaces, in fissures, in pores, and in channels. The texture must be sandy loam or finer with at least 8% clay.

NA natric — An argic horizon with
1) a columnar or prismatic structure in some part of the horizon, or a blocky structure with tongues of an eluvial horizon in which there are uncoated silt or sand grains extending more than 2.5 cm into the horizon, and
2) an exchangeable sodium percentage of more than 15% within the upper 40 cm of the horizon; or more exchangeable magnesium plus sodium than calcium plus exchange acidity within the upper 40 cm of the horizon if the saturation with exchangeable sodium is more than 15% in some subhorizon within 200 cm of the surface.

CB cambic — An altered horizon lacking properties that meet the requirements of an argic, natric or spodic horizon; lacking the dark colours, organic matter content and structure of the histic horizon, or the mollic and umbric horizons. The texture is sandy loam or finer, with at least 8% of clay; the thickness is at least 15 cm with the lower depth at least 25 cm below the surface; soil structure is at least moderately developed or rock structure is absent in at least half the volume of the horizon; the CEC is more than 160 $mmol_c\ kg^{-1}$ clay, or the content of weatherable minerals in the 0.050 to 0.200 mm fraction is 10% or more; the horizon shows alteration in a) stronger chroma, redder hue, or higher clay content than the underlying horizon, or b) evidence of removal of carbonates, or c) if carbonates are absent in the parent material and in the dust that falls on the soil, the required evidence of alteration is satisfied by the presence of soil structure and the absence of rock structure in more than 50% of the horizon; shows no cementation, induration or brittle consistence when moist.

SP spodic — A spodic horizon meets one of the following requirements below a depth of 12.5 cm:
1) a subhorizon more than 2.5 cm thick that is continuously cemented by a combination of organic matter with iron and/or aluminium
2) a sandy or coarse-loamy texture with distinct dark pellets of coarse silt size or larger or with sand grains covered with cracked coatings which consist of organic matter and aluminium with or without iron.
3) one or more subhorizons in which a) if there is 0.1% or more extractable iron, the ratio of iron plus Al extractable by pyrophosphate at pH 10 to clay% is 0.2 or more, or if there is less than 0.1% extractable iron, the ratio of Al plus organic carbon to clay is 0.2 or more; and b) the sum of pyrophosphate-extractable Fe+Al is half or more of the sum of dithionite-citrate extractable Fe+Al; and c) the thickness is such that the index of accumulation of amorphous material in the subhorizons that meet the preceding requirements is 65 or more. This index is calculated by subtracting half the clay% from CEC at pH 8.2 $mmol_c\ kg^{-1}$ clay and multiplying the remainder by the thickness of the subhorizon in cm. The results of all subhorizons are then added.

FA ferralic — The ferralic horizon has a texture that is sandy loam or finer with at least 8% of clay; is at least 30 cm thick; has a CEC equal to or less than 160 $mmol_c\ kg^{-1}$ clay or has an effective CEC equal to or less than 120 $mmol_c\ kg^{-1}$ clay (sum of NH_4OAc exchangeable bases plus 1 M KCl-exchangeable acidity); has less than 10% weatherable minerals in the 0.050 to 0.200 mm fraction; has less than 10% water-dispersible clay; has a silt-clay ratio which is 0.2 or less; does not have andic properties; has less than 5% by volume showing rock structure.

CA calcic — A horizon of accumulation of calcium carbonate. The horizon is enriched with secondary calcium carbonate over a thickness of 15 cm or more, has a calcium carbonate content of 15% or more and at least 5% greater than that of a deeper horizon. The latter requirement is expressed by volume if the secondary carbonates in the calcic horizon occur as pendants on pebbles, or as concretions or soft powdery forms. If such a calcic horizon rests on very calcareous materials (40% or more calcium carbonate equivalent), the percentage of carbonates need not decrease with depth.

PC	petrocalcic	A continuous cemented or indurated calcic horizon, cemented by calcium carbonate and in places by calcium and some magnesium carbonate. Accessory silica may be present. The petrocalcic horizon is continuously cemented to the extent that dry fragments do not slake in water and roots cannot enter. It is massive or platy, extremely hard when dry so that it cannot be penetrated by spade or auger, and very firm to extremely firm when moist. Non-capillary pores are filled; hydraulic conductivity is moderately slow to very slow. It is usually thicker than 10 cm.
GY	gypsic	The gypsic horizon is enriched with secondary calcium sulphate ($CaSO_4.2H_2O$), is 10 cm or more thick, has at least 5% more gypsum than the underlying horizon, and the product of the thickness (cm) and the percent of gypsum is 150 or more.
PG	petrogypsic	A gypsic horizon that is so cemented with gypsum that dry fragments do not slake in water and roots cannot enter. The gypsum content usually exceeds 60%.
SU	sulphuric	The sulphuric horizon forms as a result of artificial drainage and oxidation of mineral or organic materials which are rich in sulphides. It is at least 15 cm thick and characterized by a pH-H_2O less than 3.5 and generally has jarosite mottles with a hue of 2.5Y or more and a chroma of 6 or more.
AL	albic	Clay and free iron oxides have been removed, or the oxides have been segregated to the extent that the colour of the horizon is determined by the colour of the primary sand and silt particles rather than by coatings of these particles. An albic horizon has a colour value moist of 4 or more, or a value dry of 5 or more, or both. If the value dry is 7 or more, or the value moist is 6 or more, the chroma is 3 or less. If the value dry is 5 or 6, or the value moist 4 or 5, the chroma is closer to 2 than to 3. If the parent materials have a hue of 5YR or redder, a chroma moist of 3 is permitted in the albic horizon where the chroma is due to the colour of uncoated silt or sand grains.

45 *diagnostic property* (mandatory)

Diagnostic properties are according to FAO (1994):

TC	abrupt textural change	A clay increase between two layers, which takes place over a distance of less than 5 cm, where the lower layer shows a clay content of twice the clay content of the overlying layer if the latter has less than 20% clay, or an increase of 20% or more if the latter has 20% clay or more.
AD	andic properties	Soil materials which meet one or more of the following requirements: 1) acid oxalate extractable Al plus 1/2 acid oxalate extractable Fe is 2.0% or more in the fine earth fraction; bulk density of the fine earth fraction, measured in the field moist state, is 0.9 kg dm^{-3} or less; phosphate retention is more than 85%. 2) more than 60% by volume of the whole soil is volcani-clastic material coarser than 2 mm; acid oxalate extractable Al plus 1/2 acid oxalate extractable Fe is 0.40% or more in the fine earth fraction. 3) the 0.02 to 2.0 mm fraction is at least 30% of the fine earth fraction and meets one of the following: a) if the fine earth fraction has acid oxalate extractable Al plus 1/2 acid oxalate extractable Fe of 0.40% or less, there is at least 30% volcanic glass in the 0.02 to 2.0 mm fraction; or b) if the fine earth fraction has acid oxalate extractable Al plus 1/2 acid oxalate extractable Fe of 2.0% or more, there is at least 5% volcanic glass in the 0.02 to 2.0 mm fraction; or c) if the fine earth fraction has acid oxalate extractable Al plus 1/2 acid oxalate extractable Fe of between 0.40 and 2.0%, there is a proportional content of volcanic glass in the 0.02 to 2.0 mm fraction between 30 and 5%.

CO	calcareous	Soil material which shows strong effervescence with 10% HCl or which contains more than 2% calcium carbonate equivalent.
CA	calcaric	Soils which are calcareous throughout the depth between 20 and 50 cm.
RO	continuous hard rock	The underlying material is sufficiently coherent and hard when moist to make hand digging with a spade difficult. The material is continuous except for a few cracks produced in place without significant displacement of the pieces and horizontally distant to an average of 10 cm or more. The material considered here does not include subsurface horizons such as a duripan, a petrocalcic or a petrogypsic horizon or a petroferric phase.
FA	ferralic properties	The term 'ferralic properties' is used in connection with Cambisols and Arenosols which have a CEC of less than 240 $mmol_c\ kg^{-1}$ clay or less than 40 $mmol_c\ kg^{-1}$ soil in at least one subhorizon of the cambic horizon or the horizon immediately underlying the A horizon.
FI	ferric properties	Many coarse mottles with hues redder than 7.5YR or chromas more than 5 or both; discrete nodules, up to 2 cm in diameter, the exteriors of the nodules being enriched and weakly cemented or indurated with Fe and having redder hues or stronger chromas than the interiors (Luvisols, Alisols, Lixisols and Acrisols).
FL	fluvic properties	Fluviatile, marine and lacustrine sediments, which receive fresh materials at regular intervals, and which, unless empoldered, have one or both of the following properties: 1) an organic carbon content that decreases irregularly with depth or that remains above 0.20% to a depth of 125 cm. Thin strata of sand may have less organic carbon if the finer sediments below, exclusive of buried horizons, meet the requirement; 2) stratification in at least 25% of the soil within 125 cm of the surface.
GE	geric properties	Soil materials which have either: 1) 1.5 $cmol_c\ kg^{-1}$ clay or less of exchangeable bases (Ca, Mg, K, Na) plus unbuffered 1M KCl exchangeable acidity; or 2) a delta-pH (pH KCl minus pH H_2O) of +0.1 or more.
GL	gleyic and stagnic	Soil materials which are saturated with water at some period of the year, or throughout the year, in most years, and which show evidence of reduction processes or of propertiesreduction and segregation of iron.
GY	gypsiferous	Soil material which contains 5% or more gypsum.
IN	inter fingering	Penetrations of an albic horizon into an underlying argic or natric horizon along ped faces, primarily vertical faces. The penetrations are not wide enough to constitute tonguing, but form continuous skeletans (ped coatings of clean silt or sand, more than 1 mm thick on the vertical ped faces).
NI	nitic properties	Soil material that has 30% or more clay, has a moderately strong angular blocky structure which falls easily apart into flat edged ('polyhedric' or 'nutty') elements which show shiny ped faces that are either thin clay coatings or pressure faces. This soil structure is apparently associated with the presence of significant amounts of active iron oxides and is indicative of a high effective moisture storage and favourable phosphate sorption - desorption properties.
OR	organic soil materials	Organic soil materials are: 1) saturated with water for long periods or are artificially drained and, excluding live roots, a) have 18% or more organic carbon if the mineral fractions is 60% or more clay, b) have 12% or more organic carbon if the mineral fraction has no clay, or c) have a proportional content of organic carbon between 12 and 18% if the clay content of the mineral fraction is less than 60%; or 2) never saturated with water for more than a few days and have 20% or more organic carbon.
PE	permafrost	Permafrost is a layer in which the temperature is perennially at or below 0°C.
PL	plinthite	Plinthite is an iron-rich, humus-poor mixture of clay with quartz and other diluents. It occurs commonly as red mottles, usually in platy, polygonal or reticulate patterns, and changes irreversibly to a hardpan or to irregular aggregates on exposure to repeated wetting and drying. In

		a moist soil, plinthite is usually firm but it can be cut with a spade. When irreversibly hardened the material is no longer considered plinthite. Such hardened material is shown as a petroferric or a skeletic phase.
SA	salic properties	The electric conductivity of the saturation extract is more than 15 dS m^{-1} within 30 cm of the surface, or more than 4 dS m^{-1} within 30 cm of the surface if the pH-H_2O exceeds 8.5.
SI	slicken-sides	Slickensides are polished and grooved surfaces that are produced by one mass sliding past another. Some of them occur at the base of a slip surface where a mass of soil moves downward on a relatively steep slope. Slickensides are very common in swelling clays in which there are marked seasonal changes in moisture content.
SM	smeary consistence	Thixotropic soil material; it changes under pressure or by rubbing from a plastic solid into a liquefied stage and back to the solid condition. In the liquefied stage the material skids or smears between the fingers (Andosols).
SO	sodic properties	The exchangeable sodium percentage is 15% or more, or exchangeable sodium plus magnesium is 50% or more.
SL	soft powdery lime	Translocated authigenic lime, soft enough to be cut readily with finger nail, precipitated in place from the soil solution rather than inherited from a soil parent material. It should be present in a significant accumulation (coatings on pores or structural faces).
HU	strongly humic	Soil material with an organic carbon content of more than 14 g/kg fine earth as a weighted average over a depth of 100 cm from the surface. This calculation assumes a bulk density of 1.5 kg dm^{-3}.
SU	sulphidic materials	Sulphidic materials are waterlogged mineral or organic soil materials containing 0.75% or more sulphur (dry weight), mostly in the form of sulphides, having less than three times as much calcium carbonate equivalent as sulphur, and having a pH above 3.5. Sulphidic materials accumulate in a soil that is permanently saturated and having a pH above 3.5, generally with brackish water. If the soil is drained the sulphides oxidize to form sulphuric acid. The pH, which is normally near neutrality before drainage, drops below 3.5. At this point these materials become a sulphuric horizon. Sulphidic material differs from the sulphuric horizon in its reduced condition, its pH and the absence of jarosite mottles with a hue of 2.5Y or more or a chroma of 6 or more.
TO	tonguing	An albic horizon penetrates an argic horizon along ped surfaces, if peds are present. Tongues must have greater depth than width, have horizontal dimensions of 5 mm or more in fine textured argic horizons (clay, silty clay and sandy clay), 10 mm or more in moderately fine textured argic horizons, and 15 mm or more in medium or coarser textured argic horizons (silt loams, loams and sandy loams), and must occupy more than 15% of the mass of the upper part of the argic horizon.
VE	vertic properties	In connection with clayey soils which at some period in most years show one or more of the following: cracks, slickensides, wedge-shaped or parallelepiped structural aggregates, that are not in a combination, or are not sufficiently expressed, for the soils to qualify as Vertisols.
WM	weatherable minerals	Minerals included are those that are unstable in a humid climate relative to other minerals, such such as quartz and 1:1 lattice clays, and that, when weathering occurs, liberate plant nutrients and iron or aluminium. They include: 1) clay minerals: all 2:1 lattice clays except aluminium-interlayered chlorite. Sepiolite, talc and glauconite are also included in the meaning of this group of weatherable clay minerals, although they are not always of clay size. 2) silt- and sand-size minerals: feldspars, feldspathoids, ferromagnesian minerals, glasses, micas, and zeolites.

46 *horizon designation*

Master horizon with subordinate characteristics are listed according to the rules given below master horizons and subordinate properties(for more details see FAO, 1994):

a) *Master horizons*

H H horizon/layer. Layer dominated by organic material, formed from accumulations of (partially) undecomposed organic material at the soil surface, which may be underwater. All H horizons are saturated with water for prolonged periods, or were once saturated but are now artificially drained. An H horizon may be on top of mineral soils or at any depth beneath the surface if it is buried.

O O horizon/layer. Layer dominated by organic material, consisting of (partially) undecomposed litter, such as leaves, twigs, moss etc., which has accumulated on the surface. They may be on top of either mineral or organic soils. An O horizon are not saturated with water for prolonged periods. The mineral fraction of such material is only a small percentage of the volume of the material and generally is much less than half the weight. An O horizon may be at the surface of a mineral soil or at any depth beneath the surface if it is buried.

A A horizon. Mineral horizon which formed at the surface or below an O horizon, and in which all or much of the original rock structure has been obliterated. The A horizon is characterised by one or more of the following:

- an accumulation of humified organic matter intimately mixed with the mineral fractions and not displaying properties characteristic of an E horizon (see below);
- properties resulting from cultivation, pasturing, or similar kinds of disturbance; or
- a morphology which is different from the underlying B or C horizon, resulting from processes related to the surface (e.g. vertisols).

E E horizon. Mineral horizon, in which the main feature is a loss of silicate clay, iron, aluminum, or some combination of these, leaving a concentration of sand and silt particles, and in which all or much of the original rock structure has been obliterated.

An E horizon is most commonly differentiated from an underlying B horizon by colour of higher value or lower chroma, or both; by coarser texture; or by a combination of these. Although an E horizon is usually near the surface, below an O or A horizon, and above a B horizon, the symbol E may be used without regard to position in the profile for any horizon that meets the requirements, and that has resulted from soil genesis.

B B horizon. A B horizon has formed below an A, E, O or H horizon, and has as dominant feature the obliteration of all or much of the original rock structure, together with one or a combination of the following:

- illuvial concentration, alone or in combination, of silicate clay, iron, aluminum, humus, carbonates, gypsum or silica;
- evidence of removal of carbonates;
- residual concentration of sesquioxides;
- coating of sesquioxides that make the horizon conspicuously lower in value, higher in chroma, or redder in hue than overlying and underlying horizons without apparent illuviation of iron;
- alteration that forms silicate clay or liberates oxides or both and that forms a granular, blocky or prismatic structure if volume changes accompany the changes in moisture content, or
- brittleness.

Layers with gleying but no other pedogenetic change are not considered a B horizon.

C C horizon/layer. A horizon or layer, excluding hard bedrock, that is little affected by pedogenetic processes and lacks properties of H, O, A, E or B horizons. Most are mineral layers, but some siliceous or calcareous layers (e.g. shells, coral and diatomaceous earth) are included. Sediments, saprolite and unconsolidated bedrock and other geological materials that commonly slake within 24 hours are included as C layers. Some soils form in highly weathered material that is considered a C horizon if it does not meet the requirements of an A, E or B horizon.

R R layer. Hard rock underlying the soil. Air dry chunks of an R layer will not slake within 24 hours if placed into water.

b) *Subordinate properties*

Subordinate distinctions and features within master horizons are indicated with lower case letters used as suffixes. The following subordinate properties may be used (FAO, 1994 for more details).

b buried genetic horizon

c concretions or nodules

f frozen soil

g strong gleying

h accumulation of organic matter

j jarosite mottling

k accumulation of carbonates

m cementation or induration

n accumulation of sodium

o residual accumulation of sesquioxides

p ploughing or other disturbance

q accumulation of silica

r strong reduction

s illuvial accumulation of sesquioxides

t accumulation of silicate clay

v occurrence of plinthite

w development of colour or structure

x fragipan character

y accumulation of gypsum

z accumulation of salts more soluble than gypsum

47 *moist colour* (mandatory)

The Munsell hue, value and chroma, when moist, should be given. Only integer values and chromas are accepted.

48 *dry colour*

The Munsell colours (dry soil) should be given. Only integer values and chromas are accepted.

49 *type of structure* (mandatory)

P	platy	particles arranged around a generally horizontal plane
R	prismatic	prisms without rounded upper end
C	columnar	prisms with rounded caps
A	angular blocky	bounded by plains intersecting at largely sharp angles.
S	subang. blocky	mixed rounded and plane faces with vertices mostly rounded
G	granular	spheroidical or polyhedral, relatively non-porous
B	crumb	spheroidical or polyhedral, porous
M	massive	no structure
N	single grain	no structure, individual grains
W	wedge shaped	structure in horizons with slickensides

50 *abundance of coarse fragments* (mandatory)

Classes of volume % of rock or mineral fragments (> 2 mm) in soil matrix (FAO, 1990).

N	none	0 %
V	very few	0- 2 %
F	few	2- 5 %
C	common	5-15 %
M	many	15-40 %
A	abundant	40-80 %
D	dominant	≥ 80 %

51 *total sand* (mandatory)

Weight % of particles 2.0-0.05 mm in fine earth fraction (USDA standards; see Soil Survey Staff, 1993); *if other class limits are used this should be indicated clearly under the laboratory methods*). The total sand fraction, either as an absolute value, or as the sum of the sub-fractions.

52 *silt* (mandatory)

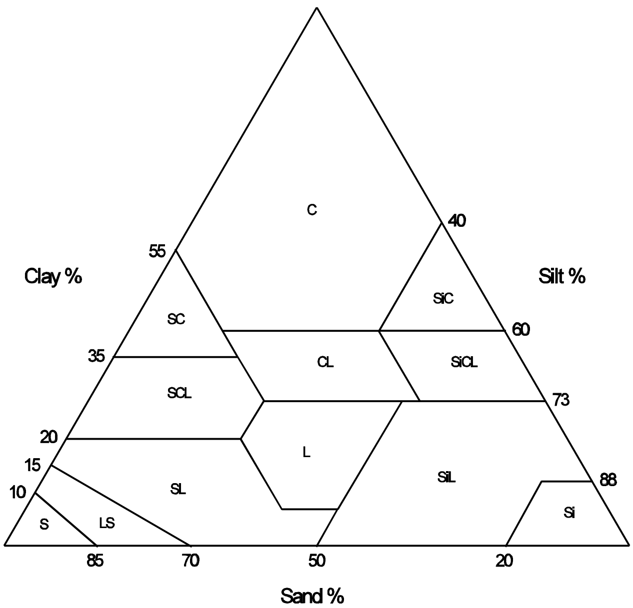
Weight % of particles 0.05-0.002 mm in fine earth fraction.

53 *clay* (mandatory)

Weight % of particles < 0.002 mm in fine earth fraction.

54 *particle size class*

The particle size class is derived from the particle size analysis according to Figure 9
.



S	sand
LS	loamy sand
SL	sandy loam
SIL	silty loam
SI	silt
L	loam
SCL	sandy clay loam
CL	clay loam
SICL	silty clay loam
SC	sandy clay
SIC	silty clay
C	clay

Figure 9. Texture classes of fine earth. (Soil Survey Staff, 1993)

55 *pH (H_2O)* (mandatory)

The pH is determined in the supernatant suspension of a 1:v soil-water mixture (mandatory; v is to be defined under laboratory methods).

56 *pH (KCl)*

The pH is determined in the supernatant suspension of a 1:v soil-1 M KCl mixture.

57 *electrical conductivity (EC$_e$)*

The electrical conductivity of saturation extract, dS m^{-1} (= mmho cm^{-1}), only mandatory if the soil contains salts.

58 *exchangeable Ca^{++}*

The exchangeable Ca in $cmol_c$ kg^{-1} (= meq/100 g fine earth), measured in 1 *M* NH_4OAc, buffered at pH 7.

59 *exchangeable Mg^{++}*

The exchangeable Mg in $cmol_c$ kg^{-1}.

60 *exchangeable Na^{+}*

The exchangeable Na in $cmol_c$ kg^{-1}.

61 *exchangeable K^{+}*

The exchangeable K in $cmol_c$ kg^{-1}.

62 *exchangeable Al^{+++}*

The exchangeable Al in $cmol_c$ kg^{-1}, measured in 1 *M* KCl.

63 *exchangeable acidity*

The exchangeable acidity, as determined in 1 *M* KCl, in $cmol_c$ kg^{-1}.

64 *CEC soil* (mandatory)

The cation exchange capacity of the soil at pH 7.0, measured in 1 *M* NH_4OAc, in $cmol_c$ kg^{-1}.

65 *total organic carbon* (mandatory)

The content of total organic carbon in g kg^{-1} (i.e. as ‰).

66 *total nitrogen*

The content of total N in g kg^{-1} (i.e. as ‰).

67 *total carbonate equivalent*

The content of carbonates, as $CaCO_3$, in g kg^{-1} (i.e. as ‰).

68 *gypsum*

The gypsum content, as $CaSO_4.2H_2O$, in g kg^{-1} (i.e. as ‰).

69 *bulk density* (mandatory)

The (bulk density in kg dm^{-3}.

70-74 *moisture content at various tensions*

The database accepts the soil moisture content (volume %) at 5 different pre-defined tensions. Ideally, these should include the moisture content at field capacity (-33 kPa) and at wilting point (-1500 kPa). [Note: 1 bar = 1017 cm of water = 100 kPa = 0.987 atmosphere; pF= $\log_{10}$[head(cm of water)])

≈ kPa	-5.1	-10	-33	-510	-1500
pF	1.7	2.0	2.5	3.7	4.2

Appendix 4. Hierarchy of landforms

The term landform as used in this manual, is land with a characteristic slope (see also Remmelzwaal, 1990). Landform separation (first and second level) is thus based on morphometric criteria, chief amongst which is the slope gradient. The relief intensity is the second most important criterion used to subdivide the landscape. Subdivisions of level lands also take into account the position of the landform vis-á-vis the surrounding land. Further separation of the landforms according to hypsometric criteria is different for each 1st level landform (see item 6). Exceptions to this are noted with the description of the 2nd level landforms. The classification as presented here has been tested for a 1:5 million physiographic inventory of Africa and South America (Eschweiler, 1993; Wen, 1993).

FIRST LEVEL LANDFORMS

L: Level lands are all lands with dominant slopes between 0 and 8% (0º and 4º40'). Moreover, the relief intensity is such that the difference between the highest and the lowest point within one slope unit is mostly less than 50 m.

S: Sloping land includes all landforms that have dominant slopes between 8% and 30%, combined with in most cases a relief intensity of more than 50 m per slope unit. In general, sloping land will be more heterogeneous with respect to its slope than level land.

T: Steep land is mainly confined to mountainous country, where average slopes are over 30% (the variability of slope gradients may be so much as to make it difficult to recognize a dominant slope) and the relief intensity is more than 600 m/2 km.

C: Lands with composite landforms comprise two strongly contrasting landforms, which are not separable at the scale of mapping. These landforms may be combined if they are part of a striking landform that can be mapped at the considered scale. Examples of such composite landform (associations) are: valleys, comprising side-slopes and a valley bottom; a narrow plateaux where a level surface is surrounded by relative steeply sloping land. Not all possible combinations are given in the current guidelines; the user may define other composite landform when the need arises (e.g., a deeply incised plateau, consisting of a plateau and high-gradient valleys).

SECOND LEVEL LANDFORMS

L Level lands

Except for low-gradient footslopes, all types of level lands that can be distinguished meet the same criteria, although they differ in their relationship towards the surrounding land. As the upper slope limit for level land is a gradient of 8%, areas with a perceptible slope may still be considered level land.

LP Plains
Plains are all level lands that are not enclosed between higher lying lands, that do not protrude above the surrounding country, or that do not rise gently against land with a considerable steeper slope.

LL Plateaux
Plateaux are level lands that are, compared with the surrounding landscapes, situated at relatively elevated positions. Plateau can be very extensive, but must always on at least one side be bounded by a slope or escarpment (8% ore more), connecting it with lower lying land. Many so-called plateaux are in fact elevated plains, and should be classified as such.

LD Depressions
A depression is an area of level land that is on all sides surrounded by higher lying level or sloping land. The area occupied by the band of sloping land that forms the transition from the higher ground to the floor of the depression is small compared to the area within the depression taken up by level land.

LF Low-gradient footslopes
Steadily rising level land, abutting strongly sloping or steep lands, are classified as low level footslopes. They merge into other types of level land, including low gradient footslopes that rise in an opposite direction. Pediments, (coalescing) alluvial fans and other similar landforms can all be considered low level footslopes. Footslopes with a higher gradient than 8% are accommodated under hills, as such slopes are usually incised to the extent that they take a hilly character.

LV Valley floors
Elongated strips of level land, on both sides flanked by areas with sloping or steep land, constitute valley floors. Valley floors normally taper off at one end, where they are embraced by steeper land on three sides. They may connect with other types of level land or sloping land at the other end. In mountainous areas valley floors can be surrounded on all sides by steep lands, and do not necessarily have to be elongated.

S Sloping land

Sloping land is land with a gradient of between 8 and 30%. In most cases the relief intensity of sloping land is more than 50 m per slope unit.

SM Medium-gradient mountains
Relatively gently sloping (15-30% gradient) mountains with a local relief intensity of more than 600 m. Many volcanoes will fall into this category, as do several foothill zones of major mountain systems.

SH Medium-gradient hills
All sloping land with an undulating relief (minimum relief intensity 50 m per slope unit), not elongated, or more than 600 m high, or incorporated in mountainous terrain,

are considered hills. This group does not only include hilly landforms, but also accommodates other landforms such as medium-gradient footslopes.

SE Medium-gradient escarpment zone
Relatively gently sloping (usually 15-30% gradient) zone that forms a transition between high and low lying country. The local relief intensity of this landform is normally less than 600 m/2 km.

SR Ridges
A ridge meets all the qualifications of medium-gradient hills, but has an elongated shape with a single crest, which may have a more or less constant elevation, or may contain a number of peaks. Relatively narrow plateaus are excluded from this landform group.

SU Mountainous highland
Land which, although forming part of a mountain range (slopes of more than 30% and relief intensities in excess of 600 m per 2 km), constitute a restricted zone with less steep slopes and subdued relief. Mountainous highland always forms part of a mountain system, and is thus on at least at one side bounded by high-gradient mountains. Hypsometric subdivision of this category is according to the qualifiers for steep lands.

SP Dissected plains
Sloping land with a more or less constant crest level, and relief intensities of less than 50 m per slope unit.

T Steep land

All land with slopes in excess of 30% is considered steep land. The main landform in this category is mountainous land.

TM High-gradient mountains
All steep land with a relief intensity of more than 600 m per 2 km, and surrounding one or more outstanding peaks.

TH High-gradient hills
Steep but low relief land (relief intensity of less than 600 m per 2 km). Badlands would be a landform taken care of by this group, which is hypsometrically subdivided according to the qualifiers for sloping land.

TE High-gradient escarpment zone
Steep land that forms the transition between high and low lying country and lacks outstanding peaks. The relief intensity is normally more than 600 m per 2 km.

TV High-gradient valleys
Very steep valleys, with normally very little valley floor. No height limit is given, as the lack of valley floor and the presence of steep slopes ensure that only deep valleys will

cover sufficient area to produce mappable delineations. Mostly incised elevated sedimentary plateaux.

Lands with composite landforms

Landforms, containing both level and steep or sloping land, which cannot be separated at the scale of the mapping, are considered composite landforms. Composite landforms are using hypsometric qualifiers according to the characteristics of their level part.

CV Valleys
The valley, made up of sideslopes and a valley bottom, is taken as one landform.

CL Narrow plateaus
A narrow strip of level land surrounded on all sides by sloping or steep falling land form together a narrow plateau.

CD Major depressions
A large tract of level land, surrounded on all sides by high, rising sloping or steep land, is characterized as a major depression. Uvalas are typical for this group.

Appendix 5. FAO soil unit codes (Revised Legend)

FL FLUVISOLS
- **FLe** Eutric Fluvisols
- **FLc** Calcaric Fluvisols
- **FLd** Dystric Fluvisols
- **FLm** Mollic Fluvisols
- **FLu** Umbric Fluvisols
- **FLt** Thionic Fluvisols
- **FLs** Salic Fluvisols

GL GLEYSOLS
- **GLe** Eutric Gleysols
- **GLk** Calcic Gleysols
- **GLd** Dystric Gleysols
- **GLa** Andic Gleysols
- **GLm** Mollic Gleysols
- **GLu** Umbric Gleysols
- **GLt** Thionic Gleysols
- **GLi** Gelic Gleysols

RG REGOSOLS
- **RGe** Eutric Regosols
- **RGc** Calcaric Regosols
- **RGy** Gypsic Regosols
- **RGd** Dystric Regosols
- **RGu** Umbric Regosols
- **RGi** Gelic Regosols

LP LEPTOSOLS
- **LPe** Eutric Leptosols
- **LPd** Dystric Leptosols
- **LPk** Rendzic Leptosols
- **LPm** Mollic Leptosols
- **LPu** Umbric Leptosols
- **LPq** Lithic Leptosols
- **LPi** Gelic Leptosols

AR ARENOSOLS
- **ARh** Haplic Arenosols
- **ARb** Cambic Arenosols
- **ARi** Luvic Arenosols
- **ARo** Ferralic Arenosols
- **Ara** Albic Arenosols
- **ARc** Calcaric Arenosols
- **ARg** Gleyic Arenosols

AN ANDOSOLS
- **ANh** Haplic Andosols
- **ANm** Mollic Andosols
- **ANu** Umbric Andosols
- **ANz** Vitric Andosols
- **ANg** Gleyic Andosols
- **ANi** Gelic Andosols

VR VERTISOLS
- **VRe** Eutric Vertisols
- **VRd** Dystric Vertisols
- **VRk** Calcic Vertisols
- **VRy** Gypsic Vertisols

CM CAMBISOLS
- **CMe** Eutric Cambisols
- **CMd** Dystric Cambisols
- **CMu** Humic Cambisols
- **CMc** Calcaric Cambisols
- **CMx** Chromic Cambisols
- **CMv** Vertic Cambisols
- **CMo** Ferralic Cambisols
- **CMg** Gleyic Cambisols
- **CMi** Gelic Cambisols

CL CALCISOLS
- **CLh** Haplic Calcisols
- **CLl** Luvic Calcisols
- **CLp** Petric Calcisols

GY GYPSISOLS
- **GYh** Haplic Gypsisols
- **GYk** Calcic Gypsisols
- **GYl** Luvic Gypsisols
- **GYp** Petric Gypsisols

SN SOLONETZ
- **SNh** Haplic Solonetz
- **SNm** Mollic Solonetz
- **SNk** Calcic Solonetz
- **SNy** Gypsic Solonetz
- **SNj** Stagnic Solonetz
- **SNg** Gleyic Solonetz

SC SOLONCHAKS
- **SCh** Haplic Solonchaks
- **SCm** Mollic Solonchaks
- **SCk** Calcic Solonchaks
- **SCy** Gypsic Solonchaks
- **SCn** Sodic Solonchaks
- **SCg** Gleyic Solonchaks
- **SCi** Gelic Solonchaks

KS KASTANOZEMS
- **KSh** Haplic Kastanozems
- **KSl** Luvic Kastanozems
- **KSk** Calcic Kastanozems
- **KSy** Gypsic Kastanozems

CH CHERNOZEMS
- **CHh** Haplic Chernozems
- **CHk** Calcic Chernozems
- **CHl** Luvic Chernozems
- **CHw** Glossic Chernozems
- **CHg** Gleyic Chernozems

PH PHAEOZEMS
- **PHh** Haplic Phaeozems
- **PHc** Calcaric Phaeozems
- **PHl** Luvic Phaeozems
- **PHj** Stagnic Phaeozems
- **PHg** Gleyic Phaeozems

GR GREYZEMS
- **GRh** Haplic Greyzems
- **GRg** Gleyic Greyzems

LV LUVISOLS
- **LVh** Haplic Luvisols
- **LVf** Ferric Luvisols
- **LVx** Chromic Luvisols
- **LVk** Calcic Luvisols
- **LVv** Vertic Luvisols
- **LVa** Albic Luvisols
- **LVj** Stagnic Luvisols
- **LVg** Gleyic Luvisols

PL PLANOSOLS
- **PLe** Eutric Planosols
- **PLd** Dystric Planosols
- **PLm** Mollic Planosols
- **PLu** Umbric Planosols
- **Pli** Gelic Planosols

PD PODZOLUVISOLS
- **PDe** Eutric Podzoluvisols
- **PDd** Dystric Podzoluvisols
- **PDj** Stagnic Podzoluvisols
- **PDg** Gleyic Podzoluvisols
- **PDi** Gelic Podzoluvisols

PZ PODZOLS
- **PZh** Haplic Podzols
- **PZb** Cambic Podzols
- **PZf** Ferric Podzols
- **PZc** Carbic Podzols
- **PZg** Gleyic Podzols
- **PZi** Gelic Podzols

LX LIXISOLS
- **LXh** Haplic Lixisols
- **LXf** Ferric Lixisols
- **LXp** Plinthic Lixisols
- **LXa** Albic Lixisols
- **LXj** Stagnic Lixisols
- **LXg** Gleyic Lixisols

AC ACRISOLS
- **ACh** Haplic Acrisols
- **ACf** Ferric Acrisols
- **ACu** Humic Acrisols
- **ACp** Plinthic Acrisols
- **ACg** Gleyic Acrisols

AL ALISOLS
- **ALh** Haplic Alisols
- **ALf** Ferric Alisols
- **ALu** Humic Alisols
- **ALp** Plinthic Alisols
- **ALj** Stagnic Alisols
- **ALg** Gleyic Alisols

NT NITISOLS
- **NTh** Haplic Nitisols
- **NTr** Rhodic Nitisols
- **NTu** Humic Nitisols

FR FERRALSOLS
- **FRh** Haplic Ferralsols
- **FRx** Xanthic Ferralsols
- **FRr** Rhodic Ferralsols
- **FRu** Humic Ferralsols
- **FRg** Geric Ferralsols
- **FRp** Plinthic Ferralsols

PT PLINTHOSOLS
- **PTe** Eutric Plinthosols
- **PTd** Dystric Plinthosols
- **PTu** Humic Plinthosols
- **PTa** Albic Plinthosols

HS HISTOSOLS
- **HSl** Folic Histosols
- **HSs** Terric Histosols
- **HSf** Fibric Histosols
- **HSt** Thionic Histosols
- **HSi** Gelic Histosols

AT ANTHROSOLS

- **ATa** Aric Anthrosols
- **ATc** Cumulic Anthrosols
- **ATf** Fimic Anthrosols
- **ATu** Urbic Anthrosols

Appendix 6. Country ISO codes

ISO code*	Name
BY	Belarus
BG	Bulgaria
CZ	Czech
EE	Estonia
HU	Hungary
LV	Latvia
LT	Lithuania
MD	Moldova
PL	Poland
RO	Romania
RU	Russia
SK	Slovakia
UA	Ukraine

* For countries in SOVEUR project area.

Appendix 7. Miscellaneous reference files

Miscellaneous data refer to background information that is not directly associated with land resources (Van Engelen and Wen, 1995). In SOTER, information on map source material, laboratory methods, and soil databases from which profile information has been extracted is stored in special reference files.

The SOTER reference files contain information on the source materials used for the compilation of the SOTER units, generally soil maps, the laboratories that analyzed the soil samples, the laboratory methods and the organisations responsible for the national profile database (Table 4)

Table 4. Attributes of SOTER reference files

SOURCE MAP	LABORATORY	PROFILE DATABASE
1 map_ID	1 lab_ID	1 soil profile database_ID
2 map title	2 laboratory name	2 name of institute
3 year		
4 scale	LABORATORY METHOD	
5 minimum latitude		
6 minimum longitude	3 lab_ID	
7 maximum latitude	4 date	
8 maximum longitude	5 attribute	
9 type of map	6 method of analysis_ID	
	ANALYTICAL METHOD	
	7 method of analysis_ID	
	8 description	

Source map [SOURCMAP]

In this file information on type of map, scale, location and date are stored. As the location in max and min X and Y-coordinates is recorded, the GIS can be used to overlay this information on the SOTER map. There exists a direct link (primary key 'map_ID') between the terrain table and the source map table. The attributes are shown in table "8" above.

1 *map_ID*

The source map identification code from which the data were derived for the compilation of the SOTER units. See also map_ID in Report 97/06, p. 22.

2 **2** *map title*

The citation of the source map title. There is room for 40 characters.

3 **3** *year*

The year of publication of the source map.

4 **4** *scale*

The scale of the source map as a representative fraction.

5 **5** *minimum latitude*

The minium latitude (Y-coordinate) of the source map, in decimal degrees East. Latitude West is a negative figure.

6 ***6*** *minimum longitude*

The minimum longitude (X-coordinate) of the source map, in decimal degrees North. Longitude South gets a negative number.

7 ***7*** *maximum latitude*

The maximum latitude (Y-coordinate) of the source map, in decimal degrees East.

8 **8** *maximum longitude*

The maximum longitude (X-coordinate) of the source map, in decimal degrees North.

9 **9** *type of source map*

The type of source map:

S pure soil map
M morpho-pedological map (soil-landscapes)
O other map

Laboratory information

Every method of analysis that has been applied in a particular laboratory must be entered as separate entries in the Laboratory Information tables:

Laboratory [LABMNAM]

1 *lab_ID*

Identification code for the laboratory that analyzed the reference soil profile. A country code with a sequential number is given. See list of country codes (App. 6).
For example: NL/01.

2 *laboratory name*

Name of the laboratory, in full (up to 40 characters).
For example: ISRIC lab., Wageningen, the Netherlands.

Laboratory method [LABMETH]

3 *lab_ID*

Laboratory code (see attribute 1, lab_ID).

2 **4** *date*

Date at which the laboratory introduced a method for a given attribute. Format is MM/YYYY.

5 *attribute*

Code for the profile-layer attribute under consideration. The item code that follows the attribute in Table 1 (Report 97/06, p. 6), i.e. is in the <u>right hand</u> margin, is used: that is the numbers between brackets [--], for example: code 86 for bulk density.

6 *method of analysis_ID*

Identification code for the analysis method applied. This code consists of the attribute code (item 5) followed by a sequential number.
For example: 86/01 for bulk density, method 1.

Analytical method [ANAMETH]

7 *method of analysis_ID*

Method code (see attribute 6).

8 *description*

A brief description of the analytical method used. There is room for 60 characters.
For example: bulk density, core method (100 cc rings).

Soil profile database [PROFILDB]

Information on the (national) soil profile database that has been consulted for the selection of the SOTER profile data can be found as an additional file. A code for the country (ISO code from Annex 7, Report 97/06) followed by a sequential number is given. Also the name of the organisation can be indicated.

1 *profile database_ID*

The identification code for the owner, institute or organisation that holds (part of) the national soil profile database. The code consists of an ISO code for the country (see annex 7) and a sequence number.

2 *name*

Name (in full) of the owner, institute or organisation of the national soil profile database and address, up to 60 characters.

Appendix 8. Structure of SOTER database files[2]

a) TERRAIN UNIT (file: TERRAIN.DBF)

FLD_NAME	FLD_TYPE	FLD_LEN	FLD_DEC	Description
ISO	C	2	0	Country ISO code
SUID	N	4	0	Number of SOTER unit
DATE	N	4	0	Year of data collection
MAPI	C	12	0	Reference code for source map
LNDF	C	2	0	Code for major landform (see App. 3)
RSLO	C	2	0	Code for regional slope
HYPS	C	2	0	Code for hypsometry
LITH	C	3	0	Code for parent material (lithology)
NEWSUID	C	6	0	Unique code for SOTER unit (= ISO + SUID code)

* FLD stands for FIELD.

b) TERRAIN COMPONENT (file: TERRCOMP.DBF)

FLD_NAME	FLD_TYPE	FLD_LEN	FLD_DEC	Description
ISO	C	2	0	Country ISO code
SUID	N	4	0	Number of SOTER unit
TCID	N	1	0	Number of Terrain Component
PROP	N	3	0	Proportion (%) of TCID in SUID
SCGR	N	2	0	Code for dominant (regional) slope
MRSF	C	1	0	Code for local surface form
BEDR	N	2	0	Depth to bedrock (see App. 3)
LITH	C	3	0	Code for parent material

2

Note:

1) Refer to Appendix 3 for the attribute coding conventions plus descriptions.

2) SOTER databases at a scale of 1:2,500,000 do not include files for Climate and Land Use, unlike 1:1,000,000 scale SOTER databases (see Van Engelen and Wen, 1995)

FLD_NAME	FLD_TYPE	FLD_LEN	FLD_DEC	Description
SDRA	C	1	0	Code for surface drainage
GWAT	N	2	0	Code for mean depth to groundwater
FLFR	C	1	0	Code for median frequency of flooding
FLDU	C	1	0	Code for median duration of flooding
NEWSUID	C	6	0	Unique code for SOTER unit (= ISO + SUID code)

c) SOIL COMPONENT (file: SOILCOMP.DBF)

FLD_NAME	FLD_TYPE	FLD_LEN	FLD_DEC	Description
ISO	C	2	0	Country ISO code
SUID	N	4	0	Number of SOTER unit
TCID	N	1	0	Number of Terrain Component in SUID
SCID	N	1	0	Number of Soil Component in TCID/SUID
PROP	N	3	0	Proportion of SCID in SUID (%)
PRID	C	12	0	Code for representative soil profile (Note: provides the logical link to the FAO classification)
POSI	C	1	0	Code for position in Terrain component
RKSC	C	1	0	Code for surface rockiness
STSC	C	1	0	Code for surface stoniness
RDEP	C	1	0	Code for (physically) rootable depth
NEWSUID	C	6	0	Combination of ISO +SUID code

d) PROFILE DATA (file: PROFILE.DBF)

FLD_NAME	FLD_TYPE	FLD_LEN	FLD_DEC	Description
PRID	C	12	0	Unique profile identification number
PDID	C	5	0	Profile database ID-number
LATI	N	6	2	Latitude of profile pit
LONG	N	8	2	Longitude of profile pit
ELEV	N	4	0	Elevation of profile pit
DATE	C	7	0	Date of sampling
LABO	C	5	0	Code for laboratory
DRAI	C	1	0	Code for soil drainage class
INFR	C	1	0	Code for infiltration rate
CLAF	C	3	0	Code for FAO (1988) classification
PHAS	C	2	0	Code for FAO (1988) phase
CLAN	C	60	0	National soil classification

e) PROFILE DATABASE (file: PROFILEDB.DBF)

FLD_NAME	FLD_TYPE	FLD_LEN	FLD_DEC	Description
PDID	C	5	0	Unique profile database ID-number
DOWN	C	60	0	Name of (national) profile database

f) LABORATORY NAME (file: LABNAME.DBF)

FLD_NAME	FLD_TYPE	FLD_LEN	FLD_DEC	Descrition
LABO	C	5	0	Unique laboratory ID-number
LNAM	C	60	0	Name of laboratory

g) ANALYTICAL METHODS (file: ANAMETH.DBF)

FLD_NAME	FLD_TYPE	FLD_LEN	FLD_DEC	Description
LABO	C	5	0	Unique laboratory ID-number
DATE	C	6	0	Date analysis method was introduced
ATTR	C	3	0	Code for analytical attribute
AMID	C	12	0	Unique code for analytical method

h) LABORATORY METHODS (file: LABMETH.DBF)

FLD_NAME	FLD_TYPE	FLD_LEN	FLD_DEC	Description
AMID	C	12	0	Unique code for analytical method
AMET	C	60	0	Description of analytical method

i) SOURCE MAP (file: SOURCMAP.DBF)

FLD_NAME	FLD_TYPE	FLD_LEN	FLD_DEC	Description
MAPI	C	12	0	Unique map ID-number
TITL	C	40	0	Title of map
YEAR	N	4	0	Year of publication
SCAL	N	10	0	Map scale (as fraction)
MLAT	N	6	2	Minimum latitude of mapped area
MLON	N	7	2	Minimum longitude of mapped area
XLAT	N	6	2	Maximum latitude of mapped area
XLON	N	7	2	Maximium longitude of mapped area
TYPE	C	1	0	Code for type of map

Appendix 9. SOTER data input forms.

SOTER data entry sheet [1:2.5 million database] Form 1

TERRAIN UNIT

1 *SOTER unit_ID* [*] |_|_| + |_|_|_|_|
2 year of data collection |_|_|_|_|
3 map_ID |_|_|_|_|_|_|_|_|_|_|_|_|
4 major landform |_|_|
5 regional slope |_|_|
6 hypsometry |_|_|
7 general lithology |_|_|_|

[*] Country ISO code plus sequential number (unique IDs)

TERRAIN COMPONENT

8 *SOTER unit_ID* |_|_| + |_|_|_|_|
9 *terrain component number* |_| |_| |_|
10 proportion of TC in SOTER unit |_|_|_| |_|_| |_|_|
11 dominant slope |_|_| |_|_| |_|_|
12 local surface form |_| |_| |_|
13 depth to bedrock (m) |_|_| |_|_| |_|_|
14 parent material |_|_|_| |_|_|_| |_|_|_|
15 surface drainage |_| |_| |_|
16 depth to groundwater |_|_| |_|_| |_|_|
17 frequency of flooding |_| |_| |_|
18 duration of flooding |_| |_| |_|

[*] One Sheet must be filled-in for each terrain unit; there may be up to 3 terrain components to a terrain unit; total for "proportion of TC in SOTER unit" must always be 100%.

SOTER data entry sheet [1:2.5 million database] — Form 2

SOIL COMPONENT

19 *SOTER unit_ID* |_|_| + |_|_|_|_|
20 *terrain component number*[*] |_|
21 *soil component number (SC)* |_| |_| |_|
22 prop. of SC in SOTER unit |_|_|_| |_|_| |_|_|
23 *profile_ID* |_|_|_|_|_|_|_|_|_|_|_|_| |_|_|_|_|_|_|_|_|_|_|_|_| |_|_|_|_|_|_|_|_|_|_|_|_|
24 position in terrain component |_| |_| |_|
25 surface rockiness |_| |_| |_|
26 surface stoniness |_| |_| |_|
27 rootable depth |_| |_| |_|

[*] One sheet must be prepared for each of the soil components in a given terrain component (and terrain unit).
Each soil component is to be characterized by one representative soil profile (see Forms 3 and 4).

SOTER data entry sheet [1:2.5 million database] — Form 3a

PROFILES

28 profile_ID |_|_|_|_|_|_|_|_|_|_|_|_|
29 profile database_ID |_|_|_|_|_|
20 latitude (dec. degrees) |_||_|_|_|.|_|_|
31 longitude (dec. degrees) |_||_|_|_|.|_|_|
32 elevation |_|_|_|_|
33 sampling date |_|_|/|_|_|
34 lab_ID |_|_|_|_|_|_|
35 drainage |_|
36 infiltration rate |_|
37 FAO classification (1990) |_|_|_|
38 FAO phase (1990) |_|_|
39 national classification |_|_|_|_|_|_|_|_|_|_|_|_|

Use Form 3b for corresponding horizon data.

HORIZON representative profile

<table>
<tr><td>40 profile_ID</td><td>|_|_|_|_|_|_|_|_|_|_|_|_|</td><td></td><td></td><td></td><td></td></tr>
<tr><td>41 horizon number</td><td>|_|</td><td>|_|</td><td>|_|</td><td>|_|</td><td>|_|</td></tr>
<tr><td>42 upper depth</td><td>|_|_|_|</td><td>|_|_|_|</td><td>|_|_|_|</td><td>|_|_|_|</td><td>|_|_|_|</td></tr>
<tr><td>43 lower depth</td><td>|_|_|_|</td><td>|_|_|_|</td><td>|_|_|_|</td><td>|_|_|_|</td><td>|_|_|_|</td></tr>
<tr><td>44 diagnostic horizon</td><td>|_|_|</td><td>|_|_|</td><td>|_|_|</td><td>|_|_|</td><td>|_|_|</td></tr>
<tr><td>45 diagnostic property</td><td>|_|_|</td><td>|_|_|</td><td>|_|_|</td><td>|_|_|</td><td>|_|_|</td></tr>
<tr><td>46 horizon designation</td><td>|_|_|_|_|_|</td><td>|_|_|_|_|_|</td><td>|_|_|_|_|_|</td><td>|_|_|_|_|_|</td><td>|_|_|_|_|_|</td></tr>
<tr><td>47 moist colour</td><td>|_|_|_|_|_|_|_|_|_|</td><td>|_|_|_|_|_|_|_|_|_|</td><td>|_|_|_|_|_|_|_|_|_|</td><td>|_|_|_|_|_|_|_|_|_|</td><td>|_|_|_|_|_|_|_|_|_|</td></tr>
<tr><td>48 dry colour</td><td>|_|_|_|_|_|_|_|_|_|</td><td>|_|_|_|_|_|_|_|_|_|</td><td>|_|_|_|_|_|_|_|_|_|</td><td>|_|_|_|_|_|_|_|_|_|</td><td>|_|_|_|_|_|_|_|_|_|</td></tr>
<tr><td>49 type of structure</td><td>|_|</td><td>|_|</td><td>|_|</td><td>|_|</td><td>|_|</td></tr>
<tr><td>50 abund. of coarse fragments</td><td>|_|</td><td>|_|</td><td>|_|</td><td>|_|</td><td>|_|</td></tr>
<tr><td>51 sand</td><td>|_|_|_|</td><td>|_|_|_|</td><td>|_|_|_|</td><td>|_|_|_|</td><td>|_|_|_|</td></tr>
<tr><td>52 silt</td><td>|_|_|_|</td><td>|_|_|_|</td><td>|_|_|_|</td><td>|_|_|_|</td><td>|_|_|_|</td></tr>
<tr><td>53 clay</td><td>|_|_|_|</td><td>|_|_|_|</td><td>|_|_|_|</td><td>|_|_|_|</td><td>|_|_|_|</td></tr>
<tr><td>54 USDA particle size class</td><td>|_|_|_|_|</td><td>|_|_|_|_|</td><td>|_|_|_|_|</td><td>|_|_|_|_|</td><td>|_|_|_|_|</td></tr>
<tr><td>55 pH H_2O</td><td>|_|_|.|_|</td><td>|_|_|.|_|</td><td>|_|_|.|_|</td><td>|_|_|.|_|</td><td>|_|_|.|_|</td></tr>
<tr><td>56 pH KCl</td><td>|_|_|.|_|</td><td>|_|_|.|_|</td><td>|_|_|.|_|</td><td>|_|_|.|_|</td><td>|_|_|.|_|</td></tr>
<tr><td>57 electrical conductivity</td><td>|_|_|.|_|</td><td>|_|_|.|_|</td><td>|_|_|.|_|</td><td>|_|_|.|_|</td><td>|_|_|.|_|</td></tr>
<tr><td>58 exch. Ca</td><td>|_|_|.|_|</td><td>|_|_|.|_|</td><td>|_|_|.|_|</td><td>|_|_|.|_|</td><td>|_|_|.|_|</td></tr>
<tr><td>59 exch. Mg</td><td>|_|_|.|_|</td><td>|_|_|.|_|</td><td>|_|_|.|_|</td><td>|_|_|.|_|</td><td>|_|_|.|_|</td></tr>
<tr><td>60 exch. Na</td><td>|_|_|.|_|</td><td>|_|_|.|_|</td><td>|_|_|.|_|</td><td>|_|_|.|_|</td><td>|_|_|.|_|</td></tr>
<tr><td>61 exch. K</td><td>|_|_|.|_|</td><td>|_|_|.|_|</td><td>|_|_|.|_|</td><td>|_|_|.|_|</td><td>|_|_|.|_|</td></tr>
<tr><td>62 exch Al</td><td>|_|_|.|_|</td><td>|_|_|.|_|</td><td>|_|_|.|_|</td><td>|_|_|.|_|</td><td>|_|_|.|_|</td></tr>
<tr><td>63 exch. Acidity (H+Al)</td><td>|_|_|.|_|</td><td>|_|_|.|_|</td><td>|_|_|.|_|</td><td>|_|_|.|_|</td><td>|_|_|.|_|</td></tr>
<tr><td>64 CEC soil</td><td>|_|_|_|.|_|</td><td>|_|_|_|.|_|</td><td>|_|_|_|.|_|</td><td>|_|_|_|.|_|</td><td>|_|_|_|.|_|</td></tr>
<tr><td>65 total org. carbon</td><td>|_|_|_|.|_|</td><td>|_|_|_|.|_|</td><td>|_|_|_|.|_|</td><td>|_|_|_|.|_|</td><td>|_|_|_|.|_|</td></tr>
<tr><td>66 total nitrogen</td><td>|_|_|_|.|_|</td><td>|_|_|_|.|_|</td><td>|_|_|_|.|_|</td><td>|_|_|_|.|_|</td><td>|_|_|_|.|_|</td></tr>
<tr><td>67 total carbonate equiv.</td><td>|_|_|_|.|_|</td><td>|_|_|_|.|_|</td><td>|_|_|_|.|_|</td><td>|_|_|_|.|_|</td><td>|_|_|_|.|_|</td></tr>
<tr><td>68 gypsum content</td><td>|_|_|.|_|</td><td>|_|_|.|_|</td><td>|_|_|.|_|</td><td>|_|_|.|_|</td><td>|_|_|.|_|</td></tr>
<tr><td>69 bulk density</td><td>|_|_|.|_|_|</td><td>|_|_|.|_|_|</td><td>|_|_|.|_|_|</td><td>|_|_|.|_|_|</td><td>|_|_|.|_|_|</td></tr>
<tr><td>70 Soil water retention at -5 kPa</td><td>|_|_|</td><td>|_|_|</td><td>|_|_|</td><td>|_|_|</td><td>|_|_|</td></tr>
<tr><td>71 Soil water retention at -10 kPa</td><td>|_|_|</td><td>|_|_|</td><td>|_|_|</td><td>|_|_|</td><td>|_|_|</td></tr>
<tr><td>72 Soil water retention at -33 kPa</td><td>|_|_|</td><td>|_|_|</td><td>|_|_|</td><td>|_|_|</td><td>|_|_|</td></tr>
<tr><td>73 Soil water retention at -510 kPa</td><td></td><td>|_|_|</td><td>|_|_|</td><td>|_|_|</td><td>|_|_||_|_|</td></tr>
<tr><td>74 Soil water retention at -1500kPa</td><td></td><td>|_|_|</td><td>|_|_|</td><td>|_|_|</td><td>|_|_||_|_|</td></tr>
</table>

SOTER data entry sheet **form 4**

LABORATORY NAME

1 lab_ID |_|_|_|_|_|

2 laboratory name |_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_| (max. 24 chars)

LABORATORY METHODS

3 lab_ID |_|_|_|_|_|

4 date |_|_|/|_|_|_|_|

5 attribute |_|_|_|_|

6 method of analysis_ID |_|_|_|_|

ANALYTICAL METHODS

7 method of analysis_ID |_|_|_|_|

8 description |_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_| (max. 24 chars)

SOURCE MAP

1 map_ID |_|_|_|_|_|_|_|_|_|_|_|_|

2 map title |_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_| (max. 24 chars)

3 year |_|_|_|_|

4 scale 1:|_|_|_|_|_|_|_|

5 minimum latitude |_| |_|_|_|.|_|_|

6 minimum longitude |_| |_|_|_|.|_|_|

7 maximum latitude |_| |_|_|_|.|_|_|

8 maximum longitude |_| |_|_|_|.|_|_|

9 type of map |_|