Global and National Soils and Terrain Digital Databases (SOTER)

Procedures Manual

Version 2.0

World Soil Information

ISRIC Report 2013/04

V.W.P. van Engelen and J.A. Dijkshoorn

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ISRIC World Soil Information

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Preface

Soil is one of the most important natural resources and it plays a vital role in the Earth's ecosystem: foothold for plant roots, storage of nutrients for plants to grow, filtering of rainwater and regulating its discharge, storage of organic matter, buffering of pollutants. Sustainable use of this resource can only be assured if adequate information on its spatial and temporal variation can be provided.

The standardized SOil and TERrain SOTER methodology has been proposed by the International Union of Soil Sciences (IUSS) as a method to make soils and terrain information available to a wide spectrum of land users. The 1995 version of the Procedures Manual has been the outcome of extensive consultations and applications of earlier versions of the method. Since then, new techniques for capturing soil and terrain information have been developed; some of these have been incorporated in the present version of SOTER.

Compatibility of this version of the Procedures Manual with earlier versions is maintained in so far as possible. Further, the input software for version 2.0 will allow for a conversion of the previous format into the current one.

Comments on this version are welcome and should be sent to the Manager of the SOTER project[1].

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Background

Adequate soil and terrain information is essential for the proper management of natural resources, not only for sustainable agricultural production but also for the protection of water resources and for the use and conservation of forests and natural ecosystems. Any use of the land will have an impact on the natural resources. Therefore, human activities and interventions should be based on reliable information in space and time on soils and terrain.

Human interventions in the land have often detrimental effects like soil erosion, contamination, acidification and loss of organic carbon. Most of these issues do not stop at international borders. Whether any regionally suitable action will be effective, will depend amongst others on the availability of standardized soil and terrain information. Globally such information is available as the 1:5M FAO-UNESCO Soil Map of the World (SMW) (FAO *et al.* 1974) based on data collected in the pre-1970 years. Newer data has been incorporated in the Harmonized World Soil Database (FAO *et al.* 2008 and 2012), which has a nominal resolution of 1x1 km, that includes amongst others existing regional SOTER databases, the European soil database and an update of the national soil map of China. For areas not covered by these revised data material from the FAO-Unesco SMW is maintained. Thus there is a continued need for up-to-date quantitative soil coverage at a global scale. At the same time, regional and national institutions and organizations will also need such information, often at a larger resolution.

Based on a discussion paper 'Towards a Global Soil Resources Inventory at Scale 1:1M' prepared by Sombroek (1984), the International Society of Soil Science (ISSS)[2] convened a workshop of international experts on soils and related disciplines in January 1986 in Wageningen, the Netherlands, to discuss the 'Structure of a Digital International Soil Resources Map annex Data Base' (Baumgardner and Oldeman 1986). Based on the findings and recommendations of this workshop a project proposal was written for SOTER, a World **SO**ils and **TER**ain Digital Data Base at a scale of 1:1 million (Baumgardner 1986).

A small international committee was appointed to propose criteria for a 'universal' map legend suitable for compilation of small scale soil-terrain maps, and to include attributes required for a wide range of interpretations such as crop suitability, soil degradation, forest productivity, global environmental change, irrigation suitability, agro-ecological zonation, and risk of drought. The committee compiled an initial list of attributes. The SOTER approach received further endorsement at the 1986[2] ISSS Congress in Hamburg, Germany.

A second meeting, sponsored by the United Nations Environment Programme (UNEP), was held in Nairobi, Kenya, in May 1987 to discuss the application of SOTER for preparing soil degradation assessment maps. Two working groups (legend development and soil degradation assessment) met concurrently during this meeting. The legend working group was charged with the task of developing guidelines for a World Soils and Terrain Digital Database at a 1:1 M scale, to propose general legend concepts, to prepare an attribute file structure, and to draft an outline for a Procedures Manual (Van de Weg 1987).

[2] Presently the International Union of Soil Science (IUSS).

Following the Nairobi meeting, UNEP formulated a project document: 'Global Assessment of Soil Degradation' and asked ISRIC to compile, in close collaboration with ISSS, FAO, the Winand Staring Centre[3] and the International Institute for Geo-Information Science and Earth Observation (ITC)[4], a global map on the status of human-induced soil degradation at a scale of 1:10 million, and to have this accompanied by a first pilot area at 1:1 million scale in South America where both status and risk of soil degradation would be assessed on the basis of a digital soil and terrain database as envisaged by the SOTER proposal. In this context ISRIC subcontracted the preparation for a first draft of a Procedures Manual for the 1:1 M pilot study area to the Land Resource Research Centre of Agriculture Canada[5].

The first draft of the Procedures Manual (Shields and Coote 1988) was presented at the First Regional Workshop on a Global Soils and Terrain Digital Database and Global Assessment of Soil Degradation held in March 1988 in Montevideo, Uruguay (Peters 1988). The proposed methodology was then tested in a pilot area, covering parts of Argentina, Brazil and Uruguay (LASOTER). Soil survey teams of the participating countries collected soils and terrain data to assess the workability of the procedures as proposed in the draft Manual. During two correlation meetings and field trips minor changes were suggested, while further modifications were recommended at a workshop that concluded the data collection stage. The comments from both workshops were incorporated in the January 1989 draft of the Procedures Manual (Shields and Coote 1989).

Application of the SOTER methodology in an area along the border between the USA and Canada (NASOTER) revealed some shortcomings in the second draft of the Manual. Also, the first tentative interpretation of the LASOTER data as well as the integration of the attribute data into a Geographic Information System demonstrated the need for further modifications.

A third draft of the Manual was compiled by the SOTER staff (Van Engelen and Pulles 1990) and circulated for comments amongst a broad international spectrum of soil scientists and potential users of the database. A workshop on Procedures Manual Revisions was subsequently convened at ISRIC, Wageningen, to discuss the revised legend concepts and definitions (Batjes 1990).

Based on the recommendations of this workshop, the proposed modifications were further elaborated, resulting in a fourth draft of the Procedures Manual (van Engelen and Pulles 1990). This Manual consisted of three parts, the first of which dealt with terrain and soil characteristics. The second part treated land use in a summary way in the expectation that a more comprehensive structure for a land use database would become available from other organizations. In the third part information on related files and climatic data needed for SOTER applications were described. In each section definitions and descriptions of the attributes to be coded were given, while in the first section an explanation of the mapping approach was provided.

Unlike the 1st and 2nd draft editions of the initial Manual, the later versions did not elaborate upon the soil degradation assessment as this is considered to be either an interpretation of the database or a separate information layer. Technical specifications (e.g. table definitions, primary keys, table constraints etc.) and a user manual for the SOTER database were also published (Tempel 1994a, 2002).

After the first SOTER workshop in 1986 in Wageningen, a second SOTER workshop organized by UNEP was convened in February 1992 in Nairobi. At this meeting, FAO expressed its full support for the SOTER

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3 Presently Alterra Green World Research (Environmental Sciences Group of Wageningen University and Research Centre).

4 Presently Faculty of Geo-Information and Earth Observation (ITC) of the University of Twente.

5 Presently Centre for Land and Biological Resources Research.

programme and indicated that it was prepared to use the SOTER methodology for storing and updating its own data on world soil and terrain resources. To facilitate the use of SOTER data by FAO it was decided to use the FAO-Unesco Soil Map of the World Revised Legend (FAO 1988, 1990) as a basis for characterising the soils component of the SOTER database.

To take account of these decisions a fifth draft of the Manual was prepared in 1993 with active participation by FAO and published as a World Soil Resources Report (FAO 1993). The main arrangement of this latest version of the Manual is similar to the fourth draft, with the difference that the Manual now consists of two parts only, the first one dealing with soils and terrain, and the second one dealing with the accessory databases in which land use, vegetation and climatic data can be stored.

Slight modifications in the number of attributes were applied in the updated version of 1995. Since that time new procedures have been developed and tested e.g. landform classification using SRTM data, partly in the framework of the EU-funded e-SOTER project, resulting in the present revision (Ver. 2.0) of the '1995 Procedures Manual'.

Notice with this edition (Version 2.0)

The methodology was initially designed for use at a 1:1 million scale to replace the 1:5 million scale FAO-Unesco Soil Map of the World. However, since the publication of the revised edition in 1995 the SOTER methodology has been applied by a large variety of users in various areas and at scales ranging from 1:5 million towards 1:50 000 (Oliveira and van den Berg, 1992, FAO et al., 2003, Dijkshoorn et al., 2005).

The early users of the SOTER methodology had to compile their databases from traditional sources like maps and profile data archives. Currently, however, there is a wealth of digital data that can be used to compile a SOTER database. This requires adaptations in the methodology, notably in the attributes of the soil profile and horizon tables. The use of Digital Elevation Models (DEM) for the definition and delineations of physiographic units also requires adaptations of the methodology. Changes in the procedures in version 2.0 draw partly on the results of the EU sponsored e-SOTER research project (e-SOTER 2012).

The revision was also used for correction of shortcomings that have been noticed by users when applying the methodology at scales outside the range initially defined for SOTER.
In this version the major modifications are:
- Change in the data structure: It is now possible to store more than one soil profile per soil component. Data are stored in the new *soils* table. This makes the existence of tables with minimum and maximum values per horizon as used in the previous versions redundant.
- Change in the position of some attributes: e.g. soil classification as legend unit is now given at the level of the soil component.
- Changes in the landform attributes to make them more in line with automatic delineation and definitions derived from DEMs (see Dobos *et al.* 2005).
- Changes in parent material definitions to put more emphasis on the influence of the (chemical) composition on the soil forming process. The new scheme has been developed in the framework of the e-SOTER project (Schuler *et al.*, 2013).
- Updating of attributes: soil classification according to Legend for the World Reference Base for soil resources (IUSS 2007).
- Additional information is provided on land use and land cover at profile location, which was felt as lacking for carbon sequestration assessments, while land use and cover at the SOTER unit level has been deleted.
- Addition of some extra attributes from the profile descriptions: e.g. upper limit soil horizon, mottling, etc.
- The option to store climate data has been removed.

PART I SOILS AND TERRAIN

1 General introduction

1.1 Objectives

The aim of the SOTER program is to establish a World Soils and Terrain Database, containing digitized map units – area class maps - and their attribute data (Baumgardner and Oldeman 1986). SOTER is composed of sets of relations for use in a Relational DataBase Management System (RDBMS) and Geographic Information System (GIS) allowing for handling of a large amount of soil and terrain information. The main function of this Geographical Database is to hold the necessary data for improved mapping, management and potentially monitoring of changes of world soil and terrain resources. At the same time, the methodology can be applied at national level at a finer scale than originally foreseen (see below).

The methodology has originally been designed for application at a scale of 1:1 million to replace the existing global coverage of soils – the FAO-Unesco Soil Map of the World – SMW (1971-1981) at scale 1:5 million. In 2009 the then existing SOTER products, with gaps in the measured data filled using taxotransfer procedures derived from the WISE database (e.g. Batjes *et al.,* 1997, 2007), were incorporated in the successor of the SMW: the Harmonized World Soil Database – HWSD (FAO *et al.* 2008, 2012). For consistency reasons – the development of a consistent global soils and terrain database – the methodology maintains a strict set of rules for delineation and definition of soil and terrain units. The methodology can be used at various scales ranging from 1:5 million to 1:250,000 (Oliveira and van den Berg, 1992, FAO et al. 2003, Dijkshoorn et al. 2005).

The database has the following characteristics:
- allow for storage and retrieval of standardized information on the spatial distribution and properties of the soil and terrain cover in an area,
- accommodates data required for a wide range of applications,
- compatible with global databases of other natural resources with similar scales,
- accessible to a broad array of international, regional and national natural resources specialists through the provision of standardized natural resources maps, interpretative maps and tabular information essential for the development, management and conservation of natural resources, either as downloadable files or as web-services

1.2 Procedures

The current report translates SOTER's overall objectives into a workable set of arrangements for the selection, standardization, coding and storing of soil and terrain data.

SOTER requires soils from all countries of the world to be characterised under a single set of rules. As the FAO-Unesco (1971-1981) Soil Map of the World was designed for this purpose, earlier versions of SOTER have adopted the Revised Legend of FAO (FAO 1988, 1990; FAO *et al.,* 1994). This legend has been superseded by the World Reference Base for Soil Resources (ISSS *et al.,* 1998; IUSS 2007) as the main tool for differentiating and characterizing soil components in SOTER.

Similarly, terrain units (SOTER acronym for landforms), should be characterised consistently. As there is no universally accepted system for a world-wide classification of terrain, SOTER has designed its own system based on visual interpretation of topographic information (see Chapter 6.1). This approach is partly based on earlier FAO work (Remmelzwaal 1991), global SRTM DEM (USGS 2003) analyses developed by Dobos *et al*. (2005) as further elaborated during the e-SOTER project (e-SOTER 2012).

The input of soil and terrain data into the SOTER database is contingent upon the availability of, and accessibility to sufficiently detailed information. Although some additional information gathering may be required when preparing existing data for inclusion in the database, the SOTER approach is not intended to replace traditional soil surveys. Hence this manual should not be used as guidelines for soil survey procedures or any other methodology for the collection of field data. Further, it does not present a methodology for the interpretation of remotely sensed data. Several handbooks are available for this.

2 Mapping approach and database construction

This Chapter defines:

a) The procedure for delineating areas with a homogeneous set of soil and terrain characteristics – the SOTER mapping approach, and
b) The format of data storage of attributes of the mapping units based on well-defined differentiating criteria – the SOTER attributes database.

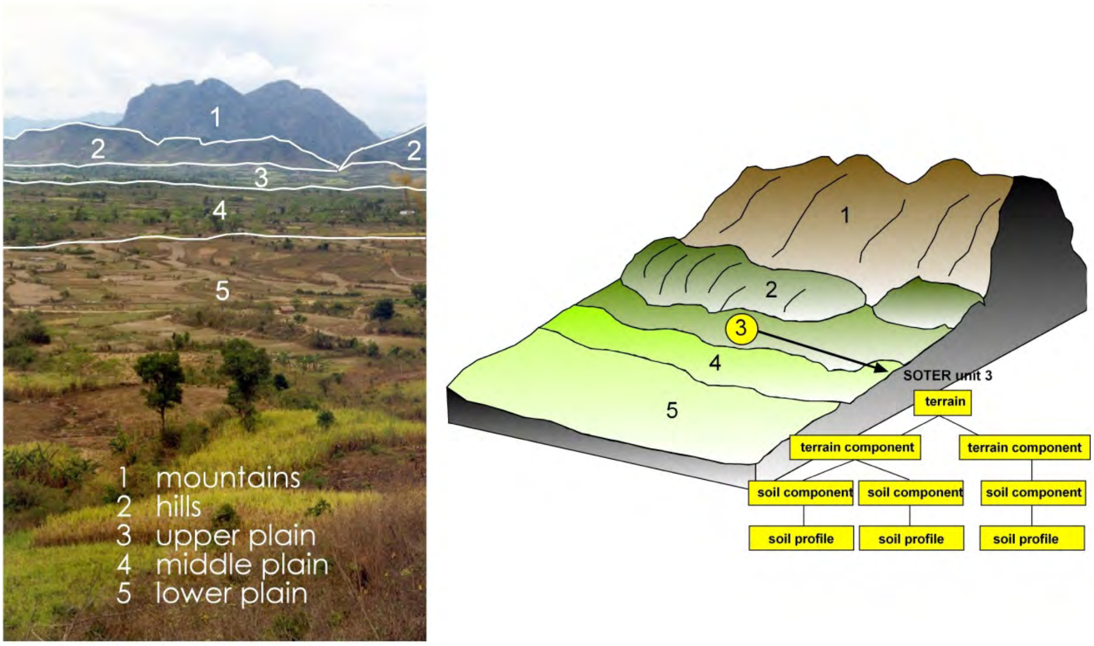
2.1 Mapping approach

SOTER is a land resources information system based on the concept that features of the land - in which terrain and soil occur - incorporate processes and systems of interrelationships between physical, biological and social processes over time. This idea was developed initially in Russia and Germany (landscape science) and became gradually accepted throughout the world. A similar integrated concept of land was used in the land systems approach developed in Australia by Christian and Stewart (Christian and Stewart 1953) and evolved further by Cochrane *et al.* (1981), McDonald *et al.* (1990) and Gunn *et al.* (1988). Landscapes are also recognized in major soil survey manuals (European Soil Bureau Scientific Committee 1998; McKenzie *et al.* 2008; Soil Survey Division Staff 1993). Similarly, SOTER has continued this development by viewing land as being made up of natural entities consisting of combinations of terrain and soil bodies.

Underlying the SOTER methodology is the identification of *areas of land with a distinctive, often repetitive, pattern of landform, lithology, surface form, slope, parent material, and soil*. Tracts of land distinguished in this manner are named SOTER units. Each SOTER unit thus represents one unique combination of terrain and soil characteristics. Figure 1 shows the representation of a SOTER unit in the database and gives an example of a SOTER map, with polygons that have been mapped at various levels of differentiation.

In many respects, the SOTER mapping approach resembles traditional physiographic soil mapping. However, the focus is on the mapping of the terrain-soil relationship, particularly at smaller mapping scales / lower resolutions. Further, SOTER implements rigorous data entry formats necessary for the construction of a global soil and terrain database. As a result of this approach the data 'accepted' by the database will be stored in a consistent format.

Attributes of terrain and soil units as defined in SOTER are hierarchically structured to facilitate the use of the procedures at scales other than the reference scale of 1:1 million.



Unit	*SOTER description*
1	one terrain type with one terrain component and one soil component.
2	one terrain type consisting of an association of two terrain components each having a particular soil component.
③	one terrain type, consisting of an association of two terrain components, the first having two soil components and the second one soil component. Each soil component is characterised using a regionally representative soil profile.
4	one terrain type, consisting of an association of two terrain components, the first having one soil component, the second having an association of three soil components.
5	one terrain type with one terrain component, having an association of two soil components.

Figure 1
Relation between SOTER units and their composing parts.

2.2 SOTER source material

Basic data sources for the construction of SOTER units are topographic, geomorphological, geological and soil maps at a scale of 1:1 million or larger (mostly exploratory and reconnaissance maps), as well as digital data such as Digital Elevation Models (DEM) and satellite imagery. In principle any soil map that is accompanied by sufficient analytical data for soil characterization according to the revised FAO-Unesco Soil Map of the World Legend (FAO 1988, 1990) and World Reference Base (IUSS WG 2006, 2007) can be used for map compilation. Seldom, however, will a map and accompanying report contain all the required soil and terrain data. Larger scale (semi-detailed and detailed) soil and terrain maps are only suitable if they cover sufficiently large areas. In practice such information will be mostly used to support source material at smaller scales.

As SOTER map sheets will cover large areas they will generally include more than one country; trans boundary correlation of soil and terrain units may be required as a result. Where there are no maps of sufficient detail for a certain study area, or where there are gaps in the available data, it may still be possible to extract information from smaller scale maps (e.g. the FAO-Unesco Soil Map of the World at 1:5 million scale or similar national maps), provided that some additional fieldwork is carried out, where necessary in conjunction with the analysis of satellite imagery, and extra analytical work to complement the existing soil and terrain information. Such work should be carried out, within the context of complementing, updating or correlating existing surveys. As indicated earlier, however, SOTER specifically excludes the undertaking of new land resource surveys within its programme.

Should it be necessary to include an area in a SOTER Database for which there are insufficient source data, it is recommended to carry out a survey according to national soil survey standards. Such surveys should consider all parameters required by SOTER additional to their national requirements.
SOTER uses the 1:1 million Operational Navigation Charts and its digital version, the Digital Chart of the World (DMA 1993), for its base maps. Although it aims at a world-wide coverage, the SOTER approach does not envisage a systematic mapping programme, and hence does not prescribe a standard block size for incorporation in the database. Nevertheless, SOTER does recommend that at its reference scale of 1:1 million a block should cover a substantial area (e.g. > 100,000 km^2).

2.3 Associated and miscellaneous data

SOTER is a land resource database with a focus on soil and terrain conditions. Generally, SOTER applications will require auxiliary data (e.g. land cover and climate), which may be derived from other sources (e.g. worldgrids.org).

Miscellaneous data, as used here, refers to background information that is not directly associated with land resources. SOTER stores information on map source material, laboratory methods, and soil databases from which profile information has been extracted.

3 SOTER differentiating criteria

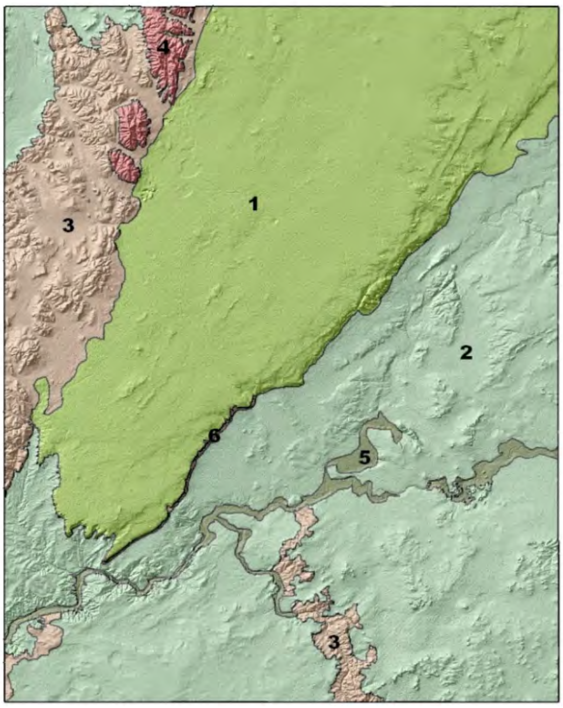
The major differentiating criteria, as discussed in Chapter 2, are applied in a step-by-step process that gradually leads to an optimal delineation of the land area under consideration. Thereby, a SOTER unit can be defined progressively into terrain, terrain component and soil component. Successively, an area can thus be characterized by its terrain, its consisting terrain components and their soil components.

The level of disaggregation possible at each step in the analysis of the land will depend on the level of detail or resolution required and the information available. As indicated earlier, the reference scale of SOTER is 1:1 million; this Manual provides the necessary detail to allow mapping at that scale.

3.1 Terrain

Physiography

Physiography is the first differentiating criterion to be used in the characterisation.



Legend

1. Plateau
2. Plain
3. Medium-gradient hill
4. High-gradient hill
5. Valley floor
6. Medium-gradient escarpment zone

Figure 2
Terrain subdivided according to major landform.

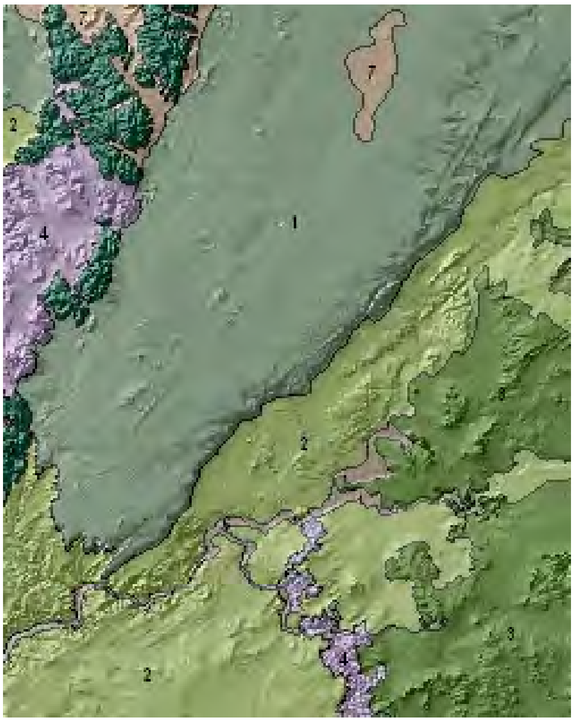
It can best be described as identifying and quantifying the major landforms, based on the dominant gradient of their slopes and their relief index (see Chapter 6.1).

In combination with the hypsometric grouping (absolute elevation above sea-level) and a factor characterizing the degree of dissection, an area can be subdivided into first and second level landforms (Figure 2; Table 2).

Increasingly, Digital Elevation Model (DEMs) - based GIS procedures are being used to consistently delineate SOTER terrain units (Dobos *et al.* 2005). These automated procedures will replace manual methods used previously (van Engelen and Wen 1995).

Parent material

Areas corresponding to a major or regional landform can be subdivided according to lithology or parent material (see Chapter 6.1).



Legend

1. Limestone
2. Clastic sedimentary rock
3. Shale
4. Andesite, trachyte
5. Ironstone
6. Fluvial sediments
7. Aeolian sediments

Figure 3
Terrain subdivided according to parent material.

This combination of the physiographic units and parent materials will form the terrain units, as illustrated in Figure 3.

Terrain, in the SOTER context, is thus defined as an area with a particular combination of landform and parent material. It often possesses also one or more typical combinations of surface form, mesorelief, deviating parent material and aspect; these criteria provide the basis for further subdivision of the terrain unit into terrain components.

At most nine subdivisions can be used for a given terrain unit (and terrain components). However, in most cases a maximum of 3 or 4 terrain components will suffice for an adequate description of the terrain unit at scale 1:1M. These adequate maximum numbers may differ for various scales.

3.2 Terrain components

The next step involves the possible subdivision of the terrain unit into terrain components that show a particular (pattern of) surface form, slope, meso-relief, etc. A similar partitioning can be made in areas covered by parent material deviating from the dominating one of the terrain unit, e.g. by parts of unconsolidated parent material or by a different texture of parent material.

Generally, at this level of separation (at 1:1 million scale) it is not possible to map terrain components individually, because of their complexity. Therefore, the attribute information for the non-mapable terrain components is stored only in the attribute database. (See Chapter 6.1).

3.3 Soil components

The final step in the differentiation of the terrain unit is the identification of soil components within the terrain components. As with terrain components, soil components are usually non-mapable at the scale of 1:1 million. In the occasional situation of mapable soil components, the soil component will become a SOTER unit with a single soil component.

However, at a scale of 1:1 million it often is impossible to separate single soil units spatially, and a terrain component traditionally is likely to comprise a number of non-mapable soil components. In conventional soil mapping such a 'cluster' is known as a soil association or soil complex (two or more soils that, at the scale of mapping, cannot be separated). Non-mapable terrain components are by definition associated with non-mapable soil components. Nevertheless, in the attribute database each non-mapable terrain component can be linked to one or more specific (but non-mapable) soil components. Non-mapable soil components, as in the case of the non-mapable terrain components, do not appear in the geometric database.

Legend

1. Petric Calcisols
2. Chromic Cambisols
3. Calcaric Cambisols
4. Haplic Arenosols
5. Ferralic Arenosols
6. Lithic Leptosols
7. Calcic Solonchaks

Figure 4
Terrain after differentiation for soil components.

As for the terrain components, the proportion of each soil component within the terrain component is estimated and stored in the database. The relative position and relationship of soil components vis-à-vis each other within a terrain component is also recorded in the database.

3.4 SOTER unit identification

The SOTER unit identification is done last, once the characteristics of the terrain unit, terrain components and soil components have been taken into account.

It is the identification of a tract of land that has a distinctive, often repetitive, pattern of landform, parent material and association of soils. Mapping units identified in such a way are called the SOTER units. Each SOTER unit represents a unique combination of terrain and soil characteristics. Figure 5 gives the SOTER map.

Each SOTER unit is given a unique identification number (SUID, **SO**TER **U**nique **I**Dentifier) which provides the logical link between the geometric database and attribute database. Polygons with identical SUIDs belong to the same SOTER unit. The ISO-country code in combination with the SUID provides a unique code (e.g., KE0001) which is used when combining several national databases into regional SOTER databases.

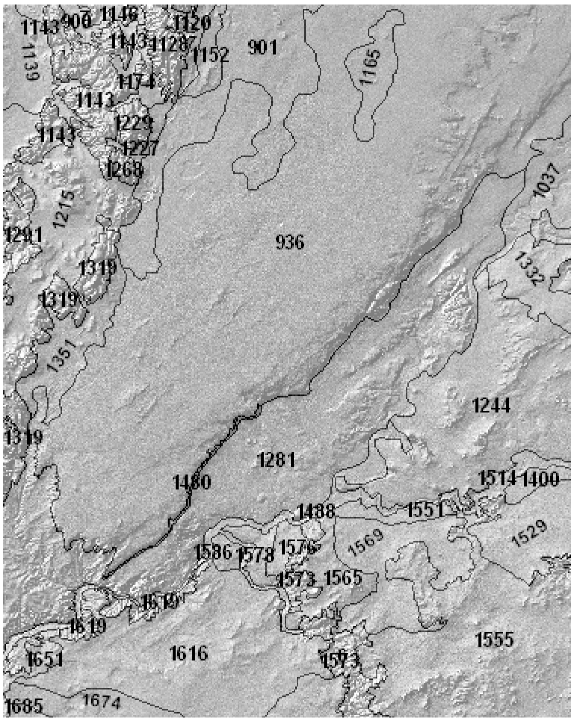


Figure 5
SOTER map with SOTER unit identification numbers.

3.5 Additional conventions

Differences in classification

The soil components in SOTER are characterized according to the WRB-Soil Reference Legend (IUSS *et al.,* 2009) derived from the World Reference Base for Soil Resources 2007 (IUSS WG 2007). The WRB Legend considers soil management relevant qualifiers similar to those used for the Revised Legend of the FAO-Unesco Soil Map of the World. Thus the criteria used for separating soil components are based on FAO diagnostic horizons, properties and diagnostic materials. At the SOTER reference scale of 1:1 million, soils must, in general, be characterized up to the second (i.e. qualifier level (see Annex 4). In addition to this, the representative profile is classified in full in the *profile* table according to the World Reference Base for Soil Resources (ISSS *et al.* 1998) (IUSS 2007).

For soils classified according to Soil Taxonomy (Soil Survey Division Staff, 1975, 1990 and 1999), the FAO subunit level corresponds roughly to the subgroup level. As many of the diagnostic horizons and properties as used by Soil Taxonomy are similar to those employed by WRB, generally there will not be many problems at this level of classification in translating Soil Taxonomy units into World Reference Base (sub)units. A major difference between the two systems is that Soil Taxonomy uses soil temperature and soil moisture regimes, particularly at suborder level. By design, these characteristics are not considered in WRB and the former FAO classification and hence in SOTER. Therefore a more drastic conversion will be required for Soil Taxonomy units, as these are defined in terms of soil temperature and soil moisture regimes. Alternatively, experience has shown that conversion from Soil Taxonomy great groups to FAO/WRB subunits usually will not necessitate major adjustments to the boundaries of the soil mapping units.

Correlation between the French system (Baize & Girard, 1995) and FAO and WRB Legend is less straightforward. Neither their diagnostic horizon nor properties as their classification system comply with the present SOTER standards. Inherently, conversion to the FAO and WRB Legend is prerequisite for SOTER and this will require reclassification of each soil profile. Possibly, this may involve re-mapping of the soil boundaries, which is seldom feasible.

Differences in use

In addition to diagnostic horizons and properties, soil components can also be separated according to other factors, closely linked to soils that have a potentially restricting influence on land use or may affect land degradation. These criteria, several of which are listed by FAO as phases, can include both soil (subsurface) and terrain (surface, e.g. microrelief) factors.

Soil profiles

For every soil component at least one, but preferably more, fully described and analysed reference profiles should be selected from existing soil information sources. Following judicious selection, one of these reference profiles will be designated as the representative profile for the soil component. The data from this representative profile must be entered into the SOTER database as described in Sections 6.6 and 6.7. The adopted format is largely based upon the FAO Guidelines for Soil Description (FAO 2006; FAO and ISRIC 1990). By implication, profiles described according to earlier FAO Guidelines or to the Soil Survey Manual (Soil Survey Division Staff 1951, 1993), from which FAO has derived many of its criteria, can be entered with little or no reformatting required. Compatibility between the FAO-ISRIC Soil Database (FAO and ISRIC, 1989, FAO *et al.* 1995) and the relevant parts of the SOTER database also will facilitate transfer of data already stored in databases set up according to FAO-ISRIC standards.

Horizons

It is recommended that for SOTER the number of horizons per profile is restricted to the original number of (sub)adjacent horizons, reaching a depth of at least 150 cm where possible. Except for general information on the profile, including landscape position and drainage, each horizon has to be fully characterised in the database by a full set of measured attributes, based on chemical and physical properties in so far these values are available. The set consists of measured single value data that belong to the selected representative profile. If there is more than one reference profile for a soil component then the link to these profiles must be stored in the *Soils* table; the *profile* and *horizons* data will be stored in their representative tables.

Measured and estimated data

Ideally, the representative profile must have measured data or indicate missing value. Where the measured data is missing, it is recommended not to fill these gaps in the SOTER database with expert estimate values preventing a mix-up of measured and estimated values. A practical solution is to create a separate secondary dataset (SOTWIS database), in which the missing values are filled using a fixed set of taxotransfer rules (Batjes 2003) and the type of taxotransfer rules are flagged to provide an indication of the possible confidence in the derived data. Examples of the application of this procedure can be found e.g. in Batjes *et al.* (1997) and Batjes *et al.* (2007).

3.6 SOTER unit mapability

SOTER units in database and map

At the reference scale of 1:1 million, a SOTER unit is composed of a unique combination and pattern of terrain, terrain component and soil components. Each SOTER unit is labelled by a unique SOTER unit identification code (SUID) that allows retrieval from the database of all related terrain, terrain component and soil component data, either in combination or separately. Inclusion of the three levels of differentiation in the attribute database does not imply that all components of a SOTER unit can be represented on a map (at the given scale), as the size of individual components, or the intricacy of their occurrence, may preclude cartographic presentation. The areas shown on a SOTER map can thus correspond to any of the three levels of differentiation of a SOTER unit: terrain, terrain components or soil components. Attributes for non-mapable components are included in the database, although their exact location and extent cannot be displayed on a 1:1 million map.

Differences

In an ideal situation, at least from the point of view of geo-referencing, a SOTER unit on the map would be similar to a soil component in the database, i.e. the soil component of the SOTER unit could be delineated on a map. However, at the SOTER reference scale of 1:1 million it is unlikely that many SOTER units can be distinguished on the map at soil component level. This would only be possible if the landscape is rather simple. A more common situation at this scale would be for a SOTER unit to consist of terrain unit with non-mapable terrain components linked to an assemblage of non-mapable soil components (a terrain component

association) or, alternatively, a SOTER unit with mapable terrain components that contain several non-mapable soil components (a similar situation as with a soil association on a traditional soil map).
Thus, while in the attribute database a SOTER unit will hold information on all levels of differentiation, a SOTER map will display units whose content varies according to the mapability of the SOTER unit components. The disadvantage of not being able to accurately locate terrain components and/or soil components is therefore only relevant when data of complex terrains are being presented in map format. It does not affect the capability of the SOTER database to generate full tabular information on terrain, terrain component and soil component attributes, while at the same time indicating the spatial relationship between and within these levels of differentiation.

3.7 The SOTER approach at other scales

Smaller scales

The methodology presented in this manual has been developed for applications at a scale of 1:1 million, which is the smallest scale still suitable for land resource assessment and monitoring at national level. Flexibility to cater for a wide range of scales is achieved through adopting a hierarchical structure for various major attributes, in particular those that are being used as differentiating criteria (landform, lithology, surface form, etc.). Examples of such hierarchies are given in this Manual for land use and vegetation (see Chapter 7). Different levels of these hierarchies can be related to particular scales. A hierarchy for the soil components can be derived from the WRB Soil Reference Legend (IUSS 2010) and the Revised Legend of FAO-Unesco Soil Map of the World with the level of soil groupings being related to extremely small scale maps, as exemplified by the map of world soil resources at 1:25 million (FAO, 1991). Soil units (2nd level) can be used for 1:5 million World Soil Inventory maps, while the soil subunits are most suitable for 1:1 million mapping. The density per unit area of point observations will vary according to the scale employed, with larger scales requiring a more compact ground network of representative profiles, as soils are being characterised in more detail.

Larger scales

As a systematic and highly organized way of mapping and recording terrain and soil data, the SOTER methodology can easily be extended to include reconnaissance level inventories, i.e. at a scale between 1:1 million and 1:100 000, e.g. (Oliveira and Van den Berg 1992) or at www.esoter.net.

Adjustments to the content of the attribute data set may be necessary if SOTER maps at scales other than 1:1 million are being compiled. With an increase in resolution, the highest level constituents of a SOTER unit, i.e. the terrain, will gradually lose importance, and may disappear altogether at a scale of 1:100 000. This is because in absolute terms the area being mapped is becoming smaller, and terrain alone may not continue to offer sufficient differentiating power. Conversely, the lower part of the SOTER unit will gain in importance with more detailed mapping. At larger scales SOTER units will thus become delineations of soil entities, with the information on terrain becoming incorporated in the soil attributes. Hence scale increases require more detailed information on soils for most practical applications. Additional attributes which might be included could be soil micronutrient content, composition of organic fraction, detailed slope information, etc.

4 SOTER database structure

In every discipline engaged in mapping of spatial phenomena, two types of data can be distinguished:

1) Geometric data, i.e. the location and extent of an object represented by a point, line or surface, and topology (shapes, neighbours and hierarchy of delineations).
2) Attribute data, i.e. characteristics of the object.

These two types of data are present in the SOTER database. Soils and terrain information consist of a geometric component, which indicates the location and topology of SOTER units, and of an attribute part that describes the non-spatial SOTER unit characteristics. The geometry is stored in that part of the database that is handled by Geographic Information System (GIS) software; while the attribute data is stored in a separate set of attribute files, manipulated by a Relational Database Management System (RDBMS). A unique label attached to both the geometric and attribute database connects these two types of information for each SOTER unit (see Figure 6, in which part of a map has been visualized in a block diagram).

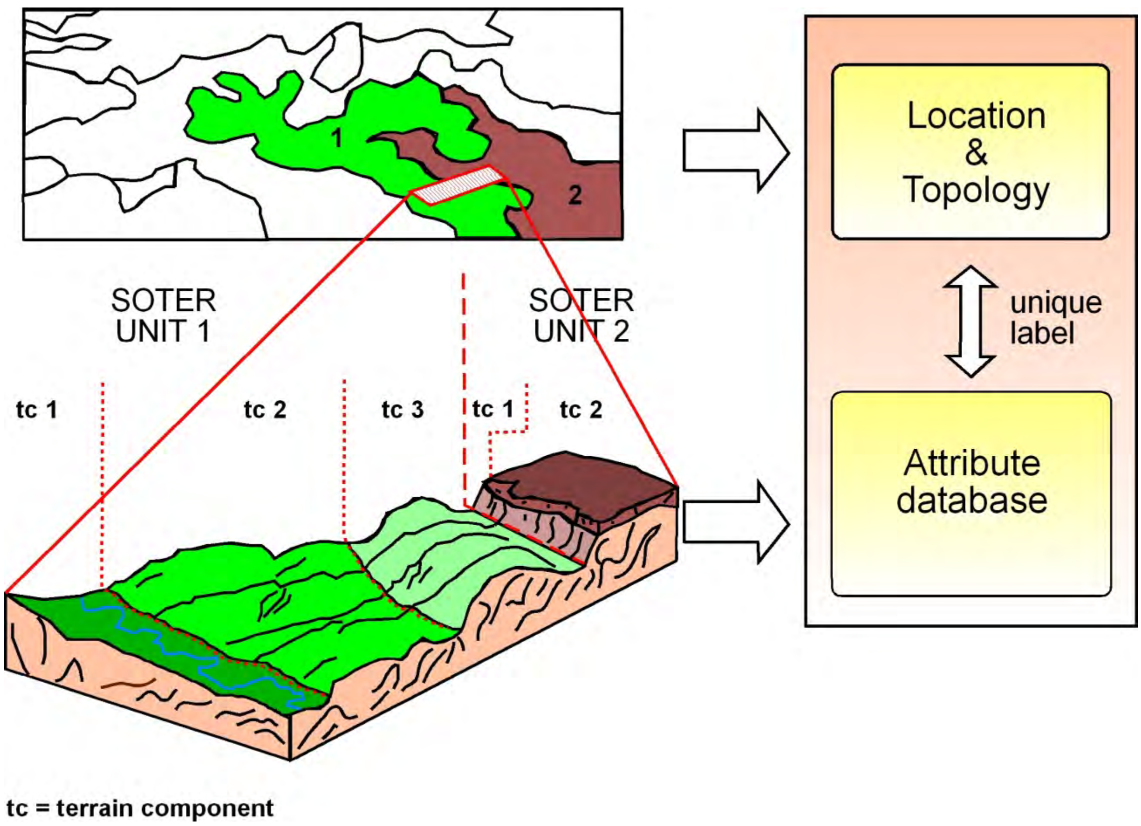


Figure 6
SOTER unit, their terrain components (tc), attributes and location.

The overall system (GIS plus RDBMS) stores and handles both the geometric and attribute database. This manual limits itself only to the attribute part of the database, in particular through elaborating on its structure and by providing the definitions of the attributes (Chapter 6). A full database structure definition is given by Tempel (1994, 2002).

A relational database is one of the most effective and flexible tools for storing and managing non-spatial attributes in the SOTER database (Pulles, 1988). Under such a system the data is stored in tables, whose records are related to each other through the specific identification fields (primary keys), such as the SOTER unit identification code. These codes are essential as they form the link between the various subsections of the database, e.g. the terrain table, the terrain component and the soil component tables. Another characteristic of the relational database is that when two or more components are similar, their attribute data need only to be entered once. Figure 7 gives a schematic representation of the structure of the attribute database. The blocks represent the tables of a SOTER database and the solid lines between the blocks indicate the links between the tables.

4.1 Geometric database

The geometric database contains information on the delineations of the SOTER unit. It also holds the base map data (cultural features such as roads and towns, the hydrological network and administrative boundaries). In order to enhance the usefulness of the database, it will be possible to include additional overlays for boundaries outside the SOTER unit mosaic. Examples of such overlays could be socio-economic areas (population densities), hydrological units (watersheds) or other natural resource patterns (vegetation, agro-ecological zones).

4.2 Attribute database

The attribute database consists of sets of files for use in a Relational DataBase Management System (RDBMS). The attributes of the terrain and terrain component are either directly available or can be derived from other parameters during the compilation of the database. Together with the soil component they represent the spatial attribute data. Profile and horizon data are available from point (profile) observations. Attributes can be divided into descriptive (e.g. landform) and numerical (e.g. pH, slope gradient) data.

Many of the horizon parameters of the soil component consist of measured characteristics that can be inserted directly into the database. Its availability can vary considerably per country and per data source. However, there is a minimum set of soil attributes that are generally needed if any realistic interpretation of the soil component of a SOTER unit is to be expected. Therefore their presence is considered as ‘mandatory’ and no soil profile is entered with these data missing. Other soil horizon attributes are of lesser importance and their presence in the database is considered as ‘optional’, profiles might miss these attribute data, but the profile can still be used in the database. It is imperative that a complete set of attributes is entered for each soil component, including all the measured attribute data when available.

The following attributes are mandatory: horizon depth (as defined by the upper and lower limit), matrix colour, structure, texture, pH, CEC, cation composition, CaCO3, organic Carbon and total Nitrogen with information on the analytical procedures used.

Under the SOTER system of labelling (see Chapter 5.1) all SOTER units are given a unique identification code, consisting of maximal 4 digits. In the terrain component and soil component tables this identification code is completed with a numbered subcode for terrain component and soil component.

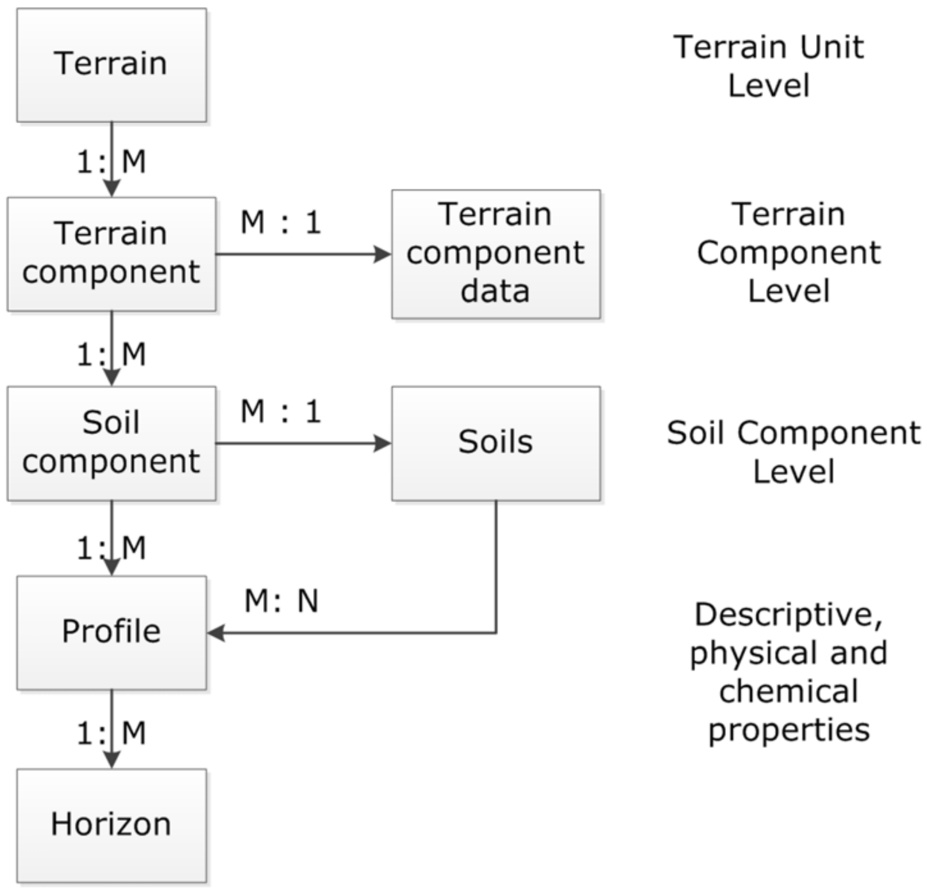


Figure 7
SOTER attribute database structure (1:M = one to many, M:1 = many to one relations).

Where identical terrain components and soil components occur in several SOTER units in different proportions, a separation between the tables holding the data on proportion/position of the terrain component and soil component (terrain component block and soil component block) and the tables holding the data of the terrain component and soil component (terrain component data block and profile and horizon blocks) is made (see Figure 7).

Thus, the terrain component information is split into two tables:
1) The terrain component table which indicates the SOTER unit to which the terrain component belongs and the proportion that it occupies within that unit.
2) The terrain component data table which holds all specific attribute data for the terrain component.

In the first table there is space for an entry for each individual terrain component within a SOTER unit, while in the second table only entries are made for data of these terrain components if they possess a not previously occurring set of attribute values.
In the same way the soil component information is stored in four tables:
1) The soil component table holds the proportion of each soil component within a SOTER unit/terrain component combination, their soil legend unit (WRB Soil Reference Legend and the Revised Legend) and its position within the terrain component.
2) The profile table holds all attribute data for the soil profile as a whole.
3) The horizon table holds the data for each individual soil horizon.
4) The soils table holds the data of soil profiles - other than the representative profile - that occur within the soil component.

For the profile and horizon tables the same conditions as for the terrain component data table are valid. Only soil profiles not previously described may be entered. For profile/horizon data describing soils occurring in various soil components only one entry is necessary. A profile description status is added to indicate a certain level of the quality of the entered data.

The horizon tables must contain at minimum the mandatory set of measured data: this forms the primary SOTER data set. Otherwise, another profile has to be located. Inherently, there will be gaps in the measured data held in SOTER. In such cases of missing numbers, values can be filled using taxotransfer rules as outlined above.

All attributes for the soil component, as well as all other non-spatial attributes of the SOTER units, are listed in Table 1. The listing for the soil component attributes is compatible, but contains some additional items, with the data set that is stored in the FAO-UNESCO-ISRIC Soil Database (FAO, 1988, 1990).

Table 1
Non-spatial attributes of a SOTER unit.

Terrain

1	ISO country code
2	SOTER unit_ID
3	Year of data collection
4	Map_ID
5	Minimum elevation
6	Maximum elevation
7	Median elevation
8	Median slope
9	Relief index
10	Potential drainage density
11	Major landform
12	Slope class
13	Hypsometry
14	Parent material
15	Permanent water surface

Terrain component

16	SOTER unit_ID
17	Terrain component number
18	Proportion of SOTER unit
19	Terrain component data_ID

Terrain component data

20	Terrain component data_ID
21	Dominant slope
22	Length of slope
23	Form of slope
24	Lithology of surficial material
25	Origin of non-consolidated parent material (regolith)
26	Texture of non-consolidated parent material
27	Depth to bedrock
28	Surface drainage
29	Depth to groundwater
30	Frequency of flooding
31	Duration of flooding
32	Start of flooding

Soil component

33	SOTER unit_ID
34	Terrain component number
35	Soil component number
36	Proportion of SOTER unit
37	WRB Legend unit
38	WRB Legend suffixes
39	Revised Legend -FAO'88
40	Phase
41	Textural class of the topsoil
42	Profile_ID
43	Position in terrain component
44	Surface rockiness
45	Surface stoniness
46	Types of erosion/deposition
47	Area affected
48	Degree of erosion
49	Sensitivity to capping
50	Rootable depth

Soils

51	ISO country code
52	SOTER unit_ID
53	Terrain component number
54	Soil component number
55	Profile_ID

Profile

56	Profile_ID
57	Soil profile database_ID
58	Profile description status
59	Sampling date
60	Lab_ID
61	Latitude
62	Longitude
63	Profile location status
64	Elevation
65	Land use at profile location
66	Vegetation at profile location
67	Parent material profile location
68	Drainage
69	RSG prefix and suffix, qualifiers
70	WRB specifiers
71	Revised Legend classification
72	National classification
73	Soil Taxonomy
74	Soil Taxonomy version

Horizon

75	Profile_ID
76	Horizon number
77	Diagnostic horizon
78	Diagnostic property
79	Diagnostic materials
80	Horizon designation
81	Upper horizon boundary
82	Lower horizon boundary
83	Distinctness of transition
84	Moist colour
85	Dry colour
86	Colour of mottles
87	Abundance of mottles
88	Size of mottles
89	Grade of structure
90	Size of structure elements
91	Type of structure
92	Nature of concretions and nodules
93	Abundance of concretions and nodules
94	Size of concretions and nodules
95	Abundance of coarse fragments
96	Size of coarse fragments
97	Very coarse sand
98	Coarse sand
99	Medium sand
100	Fine sand
101	Very fine sand
102	Total sand
103	Silt
104	Clay
105	Particle size class
106	Bulk density
107	Soil moisture at various tensions
108	Electrical conductivity
109	pH H_2O
110	pH KCl
111	pH-$CaCl_2$
112	Elect. conductivity saturation. extract
113	Soluble Na^+
114	Soluble Ca^{++}
115	Soluble Mg^{++}
116	Soluble K^+
117	Soluble Cl^-
118	Soluble SO_4^-
119	Soluble HCO_3^-
120	Soluble CO_3^-
121	Exchangeable Ca^{++}
122	Exchangeable Mg^{++}
123	Exchangeable Na^+
124	Exchangeable K^+
125	Exchangeable Al^{+++}
126	Exchangeable acidity
127	CEC soil
128	Total carbonate content
129	Gypsum
130	Total carbon
131	Organic carbon
132	Total nitrogen
133	Available P
134	Total P
135	Phosphate retention
136	Fe, dithionite extractable
137	Al, oxalate extractable
138	Fe, oxalate extractable
139	Clay mineralogy

5 Additional SOTER conventions

The conventions described in this chapter are additional to those characterized in Chapter 2 and 3. They concern mainly the rules governing the minimum size of a SOTER unit, both in absolute and relative terms, as well as criteria for determining the selection of representative profiles, relations with associated databases, type of data and missing data.

SOTER database management procedures, such as date stamps and backup procedures are described in a separate manual (Tempel 2002).

5.1 SOTER unit codes

Each SOTER unit is assigned an identifying code that is unique for the database in question. Tentatively, the SOTER coding will consist of a simple numbering system. This code will normally range from 1 to 9999 for large maps. Terrain components within each terrain unit are given a single digit extension number and ranked according to the relative proportion of the component (from high to low). A similar single digit extension number is used to code the soil components. A maximum of 9 terrain components (first digit with values from 1-9), each with 9 soil components (second digit), can be stored in the database. The component extension numbers are separated from the SOTER unit code and stored in separate fields in the database. The identification code of a soil component in the database thus can range from 1/1/1 to 9999/9/9[6]. Numbering is sequential starting with the spatially dominant components. Generally, the total number of terrain components per terrain (SOTER) unit as well as the number soil components per terrain component is limited (see Chapter 5.4). As a result, identification codes like 1/1/7 (7 soil components within terrain component 1) or 25/5/3 (3 soil components in terrain component 5) are unlikely to occur.

When national databases are merged into regional and global datasets, the SOTER identification codes have to be preceded by the ISO-code for the country. When databases for neighbouring countries are entered into one common database, cross-boundary SOTER units will have different codes in each country. If a GIS is used, the SOTER units of one country can automatically be given the code of their counterpart on the other side of the border (assuming that proper correlation has been carried out), otherwise this has to be done manually.

5.2 Minimum size of the SOTER unit

As a rule of thumb, the minimum size of a single SOTER unit is 0.25 cm^2 on the map; at a scale of 1:1 million this corresponds with 25 km^2 in the field. This is the smallest area that can still be cartographically represented. Mostly, such tiny units will correspond to narrow elongated features (floodplains, ridges, valleys) or strongly contrasting terrain and soil features. Therefore, often the minimum size of 100 km^{-2} is practiced. In general, however, most SOTER units will be much larger.

6 The slash indicates different fields.

If there are gradual changes in landscape features, new SOTER units can be delineated when any one terrain component or soil component of a unit changes in area by more than 50%.

5.3 Number of soil and terrain components

Within a SOTER unit terrain, individual terrain components and soil components can occupy any percentage of the terrain and terrain component respectively, provided the total area of each component is not less than what is indicated in Section 5.2. 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. SOTER recommends that a minimum area of 15% of the SOTER unit is taken into account when defining terrain components and 10% for the soil components, unless the SOTER unit in question is very large or involves strongly contrasting terrain or soil components; in such cases the percentage coverage can be less.

Generally, a SOTER unit will consist of 3 or 4 terrain components, each of these having no more than 3 soil components; hence a maximum of 12 subdivisions. By definition, the total proportion of all soil components within each terrain component adds up to the total proportion of the terrain component. Alternatively, for the terrain components within each SOTER unit this will always be 100%.

It is recommended that map compilers exercise restraint when subdividing terrain into terrain and soil components. Only those criteria that can be considered important for analysing a landscape in subsequent interpretations should be selected. Significant changes in attributes such as parent material, surface form and slope gradient, which at the same time should cover substantial areas, qualify as criteria for defining new SOTER units. Terrain components should be split into soil components only if there are clear changes in diagnostic criteria that will be reflected in land use or land degradation aspects. Minor changes in any of these criteria should be considered as part of the natural variability that at a scale of 1:1 million can be expected to occur within each SOTER unit. Discretion in defining terrain and soil components is absolutely necessary in order not to generate an excessive number of components and so lengthening the time required for coding, entering and processing of data.

5.4 Representative soil profiles

The so-called representative soil profile, which is used to represent a specific soil component, is chosen from a number of reference profiles with similar characteristics in terms of the WRB Soil Reference Legend (IUSS *et al.* 2010; IUSS 2007). Whenever possible, SOTER will rely on a selection of reference profiles made by the original surveyors. It is recommended that all the considered reference profiles be stored in the SOTER database or in a national soil profile database. The table Soils, introduced in version 2.0 of the SOTER database, stores the link between the reference profiles and the corresponding SOTER unit and soil component. Sometimes, the same reference profile can be used to characterise different soil components and SOTER units (See Chapter 6.5).

5.5 Updating procedures

SOTER units and their attributes are unique in both space and time, and although soil and in particular terrain characteristics are considered to have a high degree of temporal stability, it might become necessary to update certain attributes from time to time. At present, there is no procedure for updating of geographic data, such as the boundaries of the SOTER units. However, replacing (parts of) map sheets with more recent maps will involve changes in attribute data as well, for which the guidelines below can be used.

Updating the attribute database could become necessary because of *missing data*, *incorrect data* or *obsolete data*. If there are some data gaps, the voids can be filled when additional data become available. Incorrect data, which include data that is being replaced by (a set of) more reliable data (e.g. a representative profile is being substituted by another, more representative profile) can be replaced by new data. In contrast, obsolete data is not simply replaced by more up-to-date information. Instead, old data can be downloaded into a special database containing obsolete data, after which the latest data is entered into the regular database. In this way the database with obsolete data can, in principle, be used for monitoring changes over time. When certain parameters are measured at regular intervals, then periodic updating will become necessary with different timestamps.

The **S**OTER **U**nit **ID**entification code indicates to which level of differentiation the SOTER unit can be mapped. The database management system is capable of generating a number of relational data that are pertinent to each SOTER unit, and between the SOTER units (e.g. percentage of each soil component within terrain component or SOTER unit, total area of all terrain components with identical terrain component data code, etc.).

5.6 Miscellaneous polygons

In SOTER miscellaneous units (polygons) are defined as areas of land that have a 'non soil' cover (FAO *et al.* 1994), that are used for miscellaneous purposes, or are composed of inland water or glaciers and permanent snow, etc. Please refer to Annex 1 for details; the coding is according to the symbology of the Harmonized World Soil Database (FAO *et al.* 2008).

Non-soil areas or non-soil units are defined where there is no soil cover. These areas include inland water and lakes, rock outcrops, glaciers and land ice, shifting sands, urban areas and mining areas. In principle, two situations can exist; the area of non-soil units covers an entire map unit and can be delimited on the map as a separate, miscellaneous SOTER unit. Alternatively, the area with non-soil covers only for a part of the SOTER unit and can be considered at soil component level.

6 Attribute coding

This part of the SOTER procedures manual is focussed on SOTER database compilation and mapping at broad-scale (low resolution), roughly 1:250 000 or smaller.

The SOTER unit identification code, referring to the map unit, is completed in the database by two additional, separate digits, as sequential numbers. The first digit represents the terrain component number. The second digit constitutes the soil component number. Eventually, the SOTER unit identification code will be used to form the unique identifier for SOTER units on a world-wide scale, by adding a two-digit identification code for the country name (ISO 2006) (See Section 5.1).

Class limits, as used here are defined as follows. The upper class limit is included in the next class, e.g. slope class 2-5% (item 11) includes all slopes from 2.0 to 4.9%. Hence, a slope of 5% would fall in slope class 5-10%. Conversely, measured soil analytical data are always given as numbers (e.g. pH_{water}= 4.8)

The numbers preceding the attributes in Table 1 are identical to the numbers of the attributes in this Chapter, written in the left margin. They also figure on the SOTER data entry forms.

Note that the sequential code number (e.g. 1 for ISO country code) varies from codes used for same attribute in earlier versions of SOTER).

6.1 Terrain

1. ISO country code
The ISO country code, an internationally accepted two-digit identifier for the country name, indicates the country in which the SOTER units are identified (ISO 2006) (See Annex 7). Combined, the ISO country code and the SOTER unit_ID form a unique identifier (primary key) for SOTER units on a world-wide scale.

2. SOTER unit_ID
The SOTER unit_ID is the identification code of a SOTER unit on the map, in the GIS file and in the attribute database. It links the mapped area to the corresponding attributes in the database and in particular, it identifies which terrain units belong to a given SOTER unit. SOTER units that have identical attributes in terms of landform characteristics, parent material and soils carry the same SOTER unit_ID; several polygons on the map thus may have the same SOTER unit_ID. As such, the SOTER unit_ID is similar to a code for a mapping unit on a traditional soil map. For each SOTER map, a unique code (up to 4 digits) is assigned to every SOTER unit. In general, a sequential number is used; on most SOTER maps 2 or 3 digits will suffice. The combination of ISO country code with the SOTER unit_ID forms a unique identifier for the map units at regional and global level.

3. Year of data collection
The year in which the original soil and terrain data were collected serves as the time stamp for each SOTER unit. Where the SOTER unit has been derived from several sources of information, it is advised to use the major source for dating it. In this manner a link between the SOTER unit and the major source of information, which must be listed under map_ID, can easily be made. The year of compiling the data according to SOTER procedures is thus not recorded, unless the compilation itself has resulted in some major reinterpretation based on additional sources of information, like new satellite imagery. The year of data collection is also considered to apply to the terrain component data.

4. Map_ID

A unique code for the source material, from which data were derived for the compilation of the SOTER units, up to 12 characters in length.

5. Minimum elevation

Absolute minimum elevation observed within a SOTER unit, in metre above mean sea level. It can be derived from Digital Elevation Models, e.g. the SRTM-90m DEM[7] (CGIAR-CSI 2004) or read from contour lines on topographic maps.

6. Maximum elevation

Absolute maximum elevation within the SOTER unit, in metre above mean sea level. It can be derived in the same way as for the minimum elevation.

7. Median elevation

Median value for the range in elevation observed within a SOTER unit, in metres above mean sea level. It can be derived with the Zonal Statistics Module (ZSM) in ArcGIS® using SRTM-DEM derived data (ESRI 2006) or, conventionally estimated from topographic maps by measuring distances between contour lines.

8. Median slope

The median slope angle of the SOTER unit, expressed as a percentage, prevailing in the terrain; generally it can be derived with the Zonal Statistics Module (ZSM) in ArcGIS®, using slope derived for example from the SRTM-DEM (ESRI 2006).

9. Relief index

Relief index (RI) is derived here as the median difference between the highest and lowest point within the terrain per specified distance. This distance can be variable, but RI is always expressed in m/km in the database.

The relief index can be calculated in various ways: e.g. by the Zonal Statistics Module (ZSM) in ArcGIS® and using SRTM-derived DEM data (ESRI 2006). The RI gives the median difference in elevation within one km^2 circle around the pixel under consideration and is derived from a SRTM three arcsecond (90 m) resolution DEM (Dobos *et al.* 2005).

10. Potential drainage density

The potential drainage density (PDD) is an index for the degree of dissection of the SOTER unit (Dobos *et al.* 2005). It is derived from SRTM-DEM data and defined as the number of 'receiving' pixels within a 10 by 10 pixel window. PDD is calculated in an ArcGIS® environment e.g. using ArcHydro Tools. The median value of PDD for the SOTER unit is recorded in the database.

11. Major landform

Landforms in SOTER are described foremost by their morphology and not by their genetic origin, or processes responsible for their shape. The dominant slope is the most important differentiating criterion, followed by the relief index. At the highest level of landform separation, suitable for scales equal to or broader than 1:10 million, three major landforms (Level, Sloping, Steep) are distinguished (adapted from Remmelzwaal 1991). They can be subdivided using the position of the landform vis-a-vis the surroundings. Where not clear from the slope gradient or relief index, the distinction between the various second level landforms is made according to criteria given in Annex 2.

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[7] SRTM Shuttle Radar Topography Mission 90 meter Digital Elevation Model.

A systematic approach has been developed to characterize the landform. Using SRTM global elevation data is the current procedure, which draws heavily on GIS analyses. Changing from the manual procedures used so far (van Engelen and Wen 1995), some class limits have been adapted accordingly. Potential drainage density is used as a third criterion to define landforms on basis of the flow interpretation (van Engelen and Huting 2004). However, in analyses for broad-scale mapping, (e.g. 1:1 million), the potential drainage density index is generally left out as a discriminative criteria. The methodology and procedures are described in Dobos *et al.* (2005). The potential drainage density (PDD) classes are given in Table 2. Some map units may consist of miscellaneous or non-soil units, such as inland water, glaciers, urban areas, quarries, salt flats, etc.; these are dealt with in Section 5.6 (See also Annex 1). Non-soil units are coded using the symbology of the Harmonized World Soil Database (FAO *et al.* 2008).

Table 2
Hierarchy of major landforms.

1st level	2nd level	Gradient (%)	Relief index (m km^{-2})	Drainage density (PDD)[a]
L level land	**LP** plain	<10	<50	0-25
	LL plateau	<10	<50	0-25 [b]
	LD depression	<10	<50	16-25
	LF low gradient footslope	<10	<50	0-10
	LV valley floor	<10	<50	6-15
S sloping land	**SE** medium-gradient escarpment zone	10-30	100-150	<6
	SH medium-gradient hill	10-30	100-250	0-15
	SM medium-gradient mountain	15-30	150-300	0-15
	SP dissected plain	10-30	50-100	0-15
	SV medium-gradient valley	10-30	100-150	6-15
T steep land	**TE** high-gradient escarpment zone	>30	150-300	<6
	TH high-gradient hill	>30	150-300	0-15
	TM high-gradient mountain	>30	>300	0-15
	TV high-gradient valley	>30	>150	6-15

a) PDD, the *potential drainage density*, is expressed as number of 'receiving' pixels within a 10 by 10 pixel window.
b) For a comprehensive definition of plateau see Annex 2.

Regional landforms

Major landforms can be further characterized using:
1. Slope class.
2. Hypsometry.

The differentiating power of these additional criteria is strongest with respect to level land, although they can also be used for sloping land with relief index of less than 300 m km^{-1}. Conversely, for steep land with high *relief index* the hypsometric level may be used.

12. Slope class

For the actual characterization of the SOTER unit, more detailed *slope classes* are used. They can be derived from traditional contour maps, but currently also from frequently used GIS-based analysis of SRTM-DEM data and the Zonal Statistics Module in ArcGIS®. The following classes can be used (adapted; FAO 1990, 2006).

Major Landform	Class[a]		Description
L level land	**W0**	0-0.5 %	Flat, (wet) [b]
	F0	0.5-2 %	Flat
	G0	2-5 %	Gently undulating
	U0	5-10 %	Undulating
S sloping land	**R0**	10-15 %	Strongly sloping
	S0	15-30 %	Moderately steep
T steep land	**T0**	30-45 %	Steep
	V0	45-60 %	Very steep
	E0	>60 %	Extremely steep

[a] Some class boundaries have slightly changed compared to previous SOTER versions, hence the use of different coding conventions.

[b] Wet is defined as having between 50 and 90% permanent water surface (see also item 15).

13. Hypsometry

The hypsometric level of a landform reflects the height range above mean sea level expressed in meters.

Description	Class	**Elevation level** (m a.m.s.l)
Very low elevation	**E1**	< 10
Very low elevation	**E2**	10 - 50
Very low elevation	**E3**	50 - 100
Low elevation	**E4**	100 - 200
Low elevation	**E5**	200 - 300
Low elevation	**E6**	300 - 600
Medium elevation	**E7**	600 - 1000
Medium elevation	**E8**	1000 - 1500
High elevation	**E9**	1500 - 2000
High elevation	**E10**	2000 - 3000
Very high elevation	**E11**	3000 - 5000
Extremely high elevation	**E12**	> 5000

14. Parent material

A generalized description of the parent material, either consolidated or unconsolidated, that is underlying a dominant part of the terrain of the SOTER unit. The revision of the parent material is based on the results of the e-SOTER project (www.esoter.net, 2012). Important differentiating criteria of the revised parent material classification of both consolidated and unconsolidated material are the geochemical and physical properties, while genesis is kept at lower level (Schuler *et al.*, 2013). Using the criteria for events and surface processes more distinction can be made between the unconsolidated parent rocks. At scale 1:1 million, the *parent material* should at least be specified at level 3 and preferably at level 5. The keys and the codes are shown below and the lowest levels in Table 3.

Key of the revised parent material classification

The revised parent material (PM) classification is hierarchically structured and consists of 5 levels. It can be applied to single rocks and to rock sequences. For the correlation to soil types it is recommended to classify at least up to level 3. The additional classification of event and surface processes, together with its relative age, will provide further soil relevant information.

Key to level 1	
Parent material (PM) or parent rock sequence that is hardened by compaction, dissolution, cementation, replacement and recrystallization.	**consolidated C**
Other PM or parent rock sequence that is slightly hardened by compaction, dissolution, cementation, replacement and recrystallization.	**semi-consolidated S**
Other PM or parent rock sequence that is not hardened by compaction, dissolution, cementation, replacement and recrystallization.	**unconsolidated U**
Other parent material or parent rock sequence.	**unspecified X**
Key to level 2	
PM or parent rock sequence of level 1 consisting mostly of halite or other, more soluble salts.	**saline Y**
Other PM or parent rock sequence of level 1 consisting mostly of gypsum, anhydrite or evaporites less soluble than halite.	**gypsiferous G**
Other PM or parent rock sequence of level 1 containing evaporites.	**evaporitic rock sequence E**
Other PM or parent rock sequence of level 1 having at least 50% calcium carbonate.	**calcareous C**
Other PM or parent rock sequence of level 1 containing carbonates.	**calcareous rock sequence K**
Other PM or parent rock sequence of level 1 having at least 15% iron.	**iron bearing F**
Other PM or parent rock sequence of level 1 having at least 20% organic material.	**organic O**
Other PM or parent rock sequence of level 1 that is contaminated with nuclear waste.	**radioactive contaminated R**
Other PM or parent rock sequence of level 1 having silica.	**silica bearing S**
Key to level 3	
PM that is calcareous (C) according to level 2 of which more than 90% of the primary and/or recrystallized constituents are carbonate minerals.	**pure calcareous P**
PM that is calcareous (C) according to level 2 with less than 90% of the primary and/or	**impure calcareous I**

recrystallized constituents consisting of carbonate minerals.	
PM that is calcareous (C) according to level 2 with unknown concentrations of primary and/or recrystallized constituents consisting of carbonate minerals.	**unspecified calcareous X**
PM that is silica bearing (S) according to level 2 with more than 66% SiO_2.	**acid siliceous A**
PM that is silica bearing (S) according to level 2 with more than 52% SiO_2.	**intermediate siliceous I**
PM that is silica bearing (S) according to level 2 with more than 45% SiO_2.	**basic siliceous B**
PM that is silica bearing (S) according to level 2 with less than 45% SiO_2.	**ultrabasic siliceous U**
PM that is silica bearing (S) according to level 2 with unknown SiO_2 contents.	**unspecified siliceous X**
Other parent material or parent rock sequence.	**unspecified X**
Key to level 4	
PM or parent rock sequence that is dominantly formed by igneous processes.	**igneous I**
PM or parent rock sequence that is dominantly formed by solid-state mineralogical, chemical and/or structural changes to pre-existing rock, in response to marked changes in temperature, pressure, shearing stress and chemical environment.	**metamorphic M**
PM or parent rock sequence that is dominantly formed by accumulation and cementation of solid fragmental material deposited by air, water or ice, or as a result of other natural agents, such as the precipitation from solution, the accumulation of organic material, or from biogenic processes, including secretion by organism. Includes epiclastic deposits. **or** PM or parent rock sequence that consists of an aggregation of particles transported or deposited by air, water or ice, or that is accumulated by other natural agents, such as chemical precipitation, and forms layers on the earth's surface. Includes epiclastic deposits.	**sediments or sedimentary rock S**
PM of human origin or that result from human activities.	**anthropogenic A**
Other parent material or parent rock sequence.	**unspecified X**
Key to level 5	
See Table 3.	
Events and surface processes	
Level 1- 3. See Table . Note: It is important to specify the relative age of an event or surface process, for instance r = recent (Holocene), f = fossil (Pleistocene or older).	

Table 3
The revised soil parent material classification (after Schuler et al., 2013).

LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4	LEVEL 5[1]
C consolidated	**CS** siliceous	**CSA** acid ($>66\%$ SiO_2)	**CSAI** igneous	**CSAI1** quartz rich granitic rock, quartzolite
				CSAI2 aplite (75% SiO_2), rhyolite (74% SiO_2), rhyolitic tuff, alkali feldspar rhyolite (73% SiO_2), quartz latite (73% SiO_2), granite (72% SiO_2), monzogranite (72% SiO_2), syenogranite (72% SiO_2), pegmatite (71% SiO_2), alkali feldspar granite (70% SiO_2)
				CSAI3 dacite (68% SiO_2), granodiorite (68% SiO_2), quartz syenite (67% SiO_2),
			CSAM metamorphic	**CSAM1** quartzite (81% SiO_2), siliceous shale, siliceous schist
				CSAM2 migmatite (70% SiO_2), gneiss (69% SiO_2), paragneiss, orthogneiss, psammite (69% SiO_2), meta-felsic rock
				CSAM3 semipelite
			CSAE metasomatic	**CSAE1** spilite (71% SiO_2)
			CSAS sedimentary rock	**CSAS1** chert (77% SiO_2), flint, radiolarite, spiculite
				CSAS2 quartz arenite, quartz wacke, sandstone (76% SiO_2), conglomerate (73% SiO_2), breccias consisting of acid rock fragments, fanglomerate, arkose (71% SiO_2), arkosic arenite
				CSAS3 greywacke (66% SiO_2), feldspathic greywacke, arkosic wacke
		CSI intermediate (52-66% SiO_2)	**CSII** igneous	**CSII1** tonalite (65% SiO_2), latite (65% SiO_2), obsidian (65% SiO_2), quartz monzonite (64% SiO_2), syenite (63% SiO_2), trachyte (63% SiO_2), quartz alkalifeldspar syenite, quartz alkalifedspar trachyte, quartz diorite, quartz gabbro, quartz anorthosite, foid-bearing syenite,foid-bearing alkali feldspar syenite, foid-bearing alkali feldspar trachyte
				CSII2 monzonite (59% SiO_2), monzodiorite (59% SiO_2), benmoreite (58% SiO_2), andesite 58% SiO_2), boninite, diorite (57% SiO_2), monzogabbro (56% SiO_2), keratophyre[2] (56% SiO_2), phonolite (55% SiO_2), kersantite (55% SiO_2), foid-bearing monzonite, foid-bearing diorite, foid-bearing monzodiorite, foid-bearing monzogabbro

LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4	LEVEL 5[1]
				CSII3 alkali feldspar syenite (54% SiO_2), alkali feldspar trachyte, trachyandesite (52% SiO_2),
			CSIM metamorphic	**CSIM1** pelite (63% SiO_2), slate (63% SiO_2), phyllite (62% SiO_2), hornfels (61% SiO_2), schist (60% SiO_2), mica schist, metamudstone
				CSIM2 granofels (56% SiO_2)
				CSIM3 granulite (53% SiO_2)
			CSIS sedimentary rock	**CSIS1** diamictite (61% SiO_2), tillite
				CSIS2 siltstone (61% SiO_2), claystone (61% SiO_2), mudstone (60 SiO_2)
		CSB basic (45-52% SiO_2)	**CSBI** igneous	**CSBI1** basalt (50% SiO_2), dolerite (50% SiO_2), gabbro (49% SiO_2), anorthosite (49% SiO_2), lamprophyre (48% SiO_2), alkali basalt, tholeiite, diabase, foid-bearing gabbro, foid-bearing anorthosite
				CSBI2 theralite (46% SiO_2), basanite (46% SiO_2), limburgite (46% SiO_2), pyroxenite (46% SiO_2), tephrite (45% SiO_2)*, basanite (45% SiO_2)
			CSBM metamorhic	**CSBM1** amphibolite (50% SiO_2)
				CSBM2 meta-basic rock, meta-mafic rock, greenstone, greenschist, blueschist
				CSBM3 eclogite (50% SiO_2)
				CSBM4 calc-silicate rock (49% SiO_2)
			CSBS sedimentary rock	**CSBS1** breccia (51% SiO_2)
			CSBA artificial	**CSBA1** acid slag (45-50% SiO_2)
		CSU ultrabasic (< 45% SiO_2)	**CSUI** igneous	**CSUI1** foid syenite, foid monzonite, foid monzodiorite, foid monzogabbro, foid diorite, foid gabbro
				CSUI2 leucitite (44% SiO_2), nephelinite (44% SiO_2), foidolite, foidite
				CSUI3 picrite (43% SiO_2), komatiite (41% SiO_2), meimechite
				CSUI4 hornblendite (41% SiO_2)
				CSUI5 peridotite (39% SiO_2)
				CSUI6 melilitite (37% SiO_2)
				CSUI7 kimberlite (29% SiO_2)
			CSUM metamorphic	**CSUM1** meta-ultramafic rock

LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4	LEVEL 5[1]
			CSUT metasomatic	**CSUT1** serpentinite (43% SiO_2), skarn (42% SiO_2)
			CSUA artificial	**CSUA1** basic slag (25-30% SiO_2)
		CSX unspecified	**CSXI** igneous	**CSXIx** igneous rock (unspecified)
				CSXI1 agglomerate, pyroclastic breccia, scoria
				CSXI2 tuff-breccia
				CSXI3 lapilli-stone, lapilli-tuff
				CSXI4 tuff, ignimbrite (welded tuff).
			CSXM metamorphic	**CSXMx** metamorphic rock (unspecified)
				CSXM1 suevite, impactite, impact-melt breccias, impact-melt rock
				CSXM2 cataclasite, mylonite
			CSXS sedimentary rock	**CSXSx** sedimentary rock (unspecified)
				CSXS1 tuffaceous-sedimentary rock, tuffite
	CC calcareous	**CCP** pure	**CCPM** metamorphic	**CCPM1** marble
			CCPS sedimentary rock	**CCPS1** limestone, travertine
				CCPS2 dolomite
		CCI impure	**CCIS** sedimenatary rock	**CCIS1** impure limestone, impure dolomite, marlstone
		CCX unspecified	**CCXI** igneous	**CCXI1** carbonatite
			CCXM metamorphic	**CCXMx** metacarbonate rock
			CCXS sedimentary rock	**CCXSx** carbonatic sedimentary rock (unspecified)
	CY saline	**CYX** unspecified	**CYXS** sedimentary rock	**CYXS1** alkali chloride, earth alkali chloride
	CG gypsic	**CGX** unspecified	**CGXS** sedimentary rock	**CGXS1** alkali sulphate, earth alkali sulphate
	CP phosphatic	**CPX** unspecified	**CPXS** sedimentary rock	**CPXS1** phosphorite, guano
	CO organic	**COX** unspecified	**COXS** sedimentary rock	**COXS1** bituminous coal, anthracite, graphite
	CF iron bearing	**CFX** unspecified	**CFXS** sedimentary rock	**CFXS1** ironstone, iron ore
S semi-consolidated	**SS** siliceous	**SSA** acid	**SSAR** residual deposit	**SSAR1** kaolin

LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4	LEVEL 5[1]
	SC calcareous	**SCX** unspecified	**SCXS** sedimentary rock	**SCXS1** chalk
				SCXS2 tufa
	SF iron bearing	**SFX** unspecified	**SFXS** sedimentary rock	**SFXS1** laterite, bauxite
	SO organic	**SOX** unspecified	**SOXS** sedimentary rock	**SOXS1** lignite
				SOXS2 asphalt
U unconsolidated	**US** siliceous	**USA** acid (>66% SiO_2)	**USAI** igneous	**USAI1** pumice
			USAS sediment	**USAS1** sand (77% SiO_2)
				USAS2 gravel (67% SiO_2)
		USI intermediate (52-66% SiO_2)	**USIS** sediment	**USIS1** clay (59% SiO_2)
				USIS2 silt (57% SiO_2)
		USX unspecified	**USXI** igneous	**USXIx** igneous unconsolidated (unspecified)
				USXI1 block-tephra, bomb-tephra
				USXI2 ash-breccia
				USXI3 lapilli-tephra
				USXI4 lapilli-ash
				USXI5 ash, unconsolidated ingnimbrite (nonwelded sillar)
			USXS sediment	**USXSx** sediment (unspecified)
				USXS1 breccia
				USXS2 loess
				USXS3 loam
				USXS4 mud, siliceous ooze
				USXS5 diamicton, till
			USXA anthropogenic	**USXA1** waste
				USXA2 heap material
				USXA3 ash (anthropogenic)
				USXA4 brick
				USXA5 mud
	UC calcareous	**UCX** unspecified	**UCXS** sediment	**UCXS1** carbonate sand
				UCXS2 carbonate mud, carbonate ooze
				UCXS3 carbonatic diamicton
				UCXS4 carbonatic sediment,marl

LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4	LEVEL 5[1]
			UCXA anthropogenic	**UCXA1** lime plaster, cement plaster
				UCXA2 concrete
				UCXA3 waste combustion ash
	UO organic	**UOX** unspecified	**UOXS** sediment	**UOXS1** half-bog
				UOXS2 peat
				UOXS3 sapropel
			UOXA anthropogenic	**UOXA1** plaggen
				UOXA2 coal-, coke-dump-material
				UOXA3 road construction material: tar, asphalt, bitumen)
	UY saline	**UYX** unspecified	**UYXS** sediment	**UYXS1** salt mud
			UYXA anthropogenic	**UYXA1** saline material
	UG gypsic	**UGX** unspecified	**UGXS** sediment	**UGXS1** gypsum-mud
			UGXA anthropogenic	**UGXA1** gypsum plaster
	UP phosphatic	**UPX** unspecified	**UPXS** sediment	**UPXS1** phosphoric-mud
	UF iron bearing	**UFX** unspecified	**UFXS** sediment	**UFXS1** iron-sediment
			UFXA anthropogenic	**UFXA1** red mud
				UFXA2 metal-sludge
	UR radioactive contaminated	**URX** unspecified	**URXA** anthropogenic	**URXA1** nuclear waste
X unspecified	**X** unspecified	**X** unspecified	**X** unspecified	**x** unspecified

Rock sequences				
C or **S** or **U**	**E**	**X**	**X**	**x** evaporitic rock sequence
C or **S** or **U**	**K**	**X**	**X**	**x** calcareous rock sequence
C or **S** or **U**	**L**	**X**	**X**	**x** organic rock sequence
C or **S** or **U**	**M**	**X**	**X**	**x** iron bearing rock sequence
C or **S** or **U**	**N**	**X**	**X**	**X** iron and organic bearing rock sequence

1 Average SiO_2 content according to OZCHEM database (2007).
2 Average SiO_2 content according to Xihua *et al.* (1996).

Table 4
Event and surface processes.

LEVEL 1	LEVEL 2	LEVEL 3 [8](examples)
a aeolian deposition	**ab** sandy	**abs** aeolian sand
	as sandy-silty	**asi** sandy loess
	al silty	**all** loess
b biological deposition	**bs** shell marl	**bsx** unspecified
	bd diatomite	**bdx** unspecified
	bh shell bank deposition	**bhx** unspecified
	bb bioclastic sand deposition	**bbx** unspecified
c chemical deposition	**ce** encrusted, duricrust	**cec** calcrete
		ceg gossan
		cef ferricrete
		ces silcrete
		cey gypcrete
	cd disperse	**cdx** unspecified
	cm massive	**cmx** unspecified
d (terrestrial) deposition	**da** alluvial fan deposition	**dxx** unspecified
e erosion	**ea** water erosion	**eas** sheet erosion
		ear rill erosion
		eag gully erosion
	ei wind erosion	**eix** unspecified
f fluvial deposition	**fm** meandering river deposition	**fmc** clay, silt and loam
		fms sand and fine gravel
	fb braided river deposition	**fbg** gravel and sand
	fx unspecified	
g glacial deposition	**gi** glacial	**gik** kame and kettle deposition
		gie esker deposition
	gf glaciofluvial	**pfo** glaciofluvial deposition
		pfs glaciofluvial sheet deposition
	gn morainic deposits, till (glacial diamicton)	**gng** ground moraine
		gne end moraine
		gnp push moraine

[8] Common examples, level 3 can be extended.

LEVEL 1	LEVEL 2	LEVEL 3 [8](examples)
	gl glaciolacustrine deposits	**glb** beach deposition
		gll lake-bed deposition
		gld deltaic deposition
	gs subaqueous fan deposits	**gsx** unspecified
	gm glaciomarine deposits	**gmd** deltaic deposition
		gmb beach deposition
		gms subtidal sea-bed deposition
h human activity	**hn** natural material redepostion	**hnx** unspecified
	hi industrial/artisanal deposition	**hix** unspecified
	hx unspecified	**hxx** unspecified
l lacustrine deposition	**ld** lacustrine deltaic deposition	**ldc** silt and clay
	lb lacustrine beach deposition	**lbs** sand
	ls lacustrine shoreface deposition	**lsx** unspecified
m marine deposition	**mb** subtidal deposition	**mbx** unspecified
	mi intertidal deposition	**mib** beach deposition, sand
		mir tidal river or creek deposition
		mif tidal flat deposition, clay and silt
	mu supratidal deposition	**mus** storm beach deposition
		mut tsunami deposition
		muw washover fan
		mub coastal barrier deposition
		muc chenier deposition
	md deltaic deposition	**mdc** clay and silt
	mx unspecified	
n marsh formation	**ns** desalination	**nsx** unspecified
	nc decalcification, acidification	**ncx** unspecified
p periglacial alteration	**pc** cryoturbation	**pcx** unspecified
	ps solifluction	**psx** unspecified
s mass movements	**sl** landslide	**slf** falls
		slt topples
		sls slides
		slp spreads
		sll flows, creep
		slc complex landslide

LEVEL 1	LEVEL 2	LEVEL 3 [8](examples)
	sc colluvial	**sch** hillwash deposition
		scd dry valley deposition
o organic accumulation	**op** peat (mire)	**opg** groundwater-fed bog peat
		opr rainwater-fed moor peat (raised bog)
	ox unspecified	
t eruption	**th** Hawaiian-type eruption	**thx** unspecified
	tp Pelean-type eruption	**tpx** unspecified
	ts Strombolian-type eruption	**tsx** unspecified
	tv Vulcanian-type eruption	**tvx** unspecified
	tx unspecified	
w weathering	**wp** physical, mechanical weathering	**wpf** frost shattering
		wpb blockfield
	wc chemical weathering	**wcb** bauxite, laterite
		wcc clay-with-flints
	wx unspecified weathering	**wxr** regoliths
x deposition of unknown origin	**xx** unspecified	**xxx** unspecified

* Additional information can be added to the different levels, e.g. v =active ; i= inactive, fossil process; x = unknown age of process; c = contains carbonates. For example: fxv = fluvial deposition, active; fxi = fluvial deposition, inactive; fxx = fluvial deposition of unknown age; fmcvc = fluvial depositions of clay and silt, active, calcareous.

15. Permanent water surface
The proportion of the SOTER unit that is covered permanently by water (i.e. more than 10 months/year). Conversely, bodies of water large enough to be delineated on the map, as single unit at the considered scale, are not considered part of a SOTER unit.

6.2 Terrain component

This section describes attributes used to characterize a terrain component. Terrain components cannot be mapped at the broad scale used for SOTER mapping, but their attributes are described in the relational database management system (RDBMS) (Section 6.3).

16. SOTER unit_ID
Primary key, as defined in Section 6.1 Terrain.

17. Terrain component number
A sequential number for the terrain components in a SOTER unit; the largest terrain component with the largest proportion comes first, followed by the second in size, etc. The combination SOTER unit_ID and terrain component number (e.g. 2034/1) forms the complete identification code for each terrain component in the attribute database.

18. Proportion of SOTER unit

The estimated proportion of the terrain component within the SOTER unit. As stated in Section 5.3, a terrain component normally covers at least 15% of a SOTER unit. Summed, the proportion of all terrain components within the SOTER unit is 100%. The example below is for a SOTER unit with two terrain components:

SOTER unit_ID:	**2034**	*SOTER unit_ID*:	**2034**
Terrain component number:	1	*Terrain component number*:	2
Proportion within SU:	70%	Proportion within SU:	30%
Coding:	2034/1	Coding:	2034/2

Only in very specific cases terrain components covering less than 15% of the SOTER unit can be used; for example, for small but agriculturally important areas such as a wadi in a desert plain.

19. Terrain component data_ID

Different SOTER units on the map may have similar terrain components. In such cases, the corresponding attribute data need only be entered once in the database. The data code has the general format *SOTER unit_ID/ terrain component number*. When referring to a previously described terrain component data_ID, the corresponding *terrain component data _ID* is used; see below for examples.

Case A:

SOTER unit with two terrain components, not yet described in the attribute database

SOTER unit_ID:	2034	*SOTER unit_ID:*	2034
Terrain component number:	1	*Terrain component number:*	2
Proportion within SU:	70%	Proportion within SU:	30%
Terrain component data_ID:	2034/1	Terrain component data_ID:	2034/2

Case B:

SOTER unit with two terrain components, of which one terrain component is already described in the database for another SOTER unit

SOTER unit_ID:	2035	*SOTER unit_ID:*	2035
Terrain component number:	1	*terrain component number:*	2
Proportion within SU:	60%	proportion within SU	40%
Terrain component data_ID:	2034/2	terrain component data_ID:	2035/2

6.3 Terrain component data

20. Terrain component data_ID

See *terrain component data_ID* under Section 6.2.

Slope characteristics

Items 21 - 23 characterize the slope of the terrain component.

21. Dominant slope
Dominant slope gradient of the terrain component, in %.

22. Length of slope
Estimated dominant *length of slope*, in m.

23. Form of slope
The form of the dominant slope (only entered if the dominant slope gradient is larger than 2%).

U	Uniform (straight) slope.
C	Concave, lower slope with decreasing gradient downslope.
V	Convex, upper slope with decreasing gradient upslope.
I	Irregular (complex) slope

Surficial lithology characterics

The items 24 – 27 characterize the unconsolidated parent material in which the soil is formed. The unconsolidated regolith is described in terms of origin, texture and thickness to the bedrock.

24. Lithology of surficial material
Code for the parent material of the individual terrain components forming a SOTER unit, using the key and the codes of Tables 3 and 4. An entry can be made for consolidated or unconsolidated surficial material. These include the types of rockmass from which parent material is derived and other unconsolidated mineral or organic deposits. The same list of parent materials is used for characterization as given for the parent material of the SOTER unit.

25. Origin of non-consolidated parent material (regolith)
The origin of the non-consolidated parent material (regolith) in which the soils have developed.

U	Unknown	origin of regolith not known
R	Residuum	regolith formed in situ
T	Transported	regolith transported by water, wind, ice, etc.
M	Mixed origin	mixed origin of regolith

26. Texture of non-consolidated parent material
Code for the texture group of particles9 <2 mm (fine earth fraction) of the non-consolidated parent material at 2 m, if the soil is deeply developed. If shallower, give the dominant texture of the nonconsolidated material in which the soil has formed. See Figure 8.

[9] Where the sand fraction is between 2 – 0.050 mm, silt fraction between 0.050 – 0.002 mm and the clay fraction smaller than 0.002 mm.

Y	Very clayey	more than 60% clay
C	Clayey	sandy clay, silty clay and clay texture classes
L	Loamy	loam, sandy clay loam, clay loam, silt, silt loam and silty clay loam texture classes
S	Sandy	loamy sand and sandy loam texture classes
X	Extremely sandy	sand texture classes

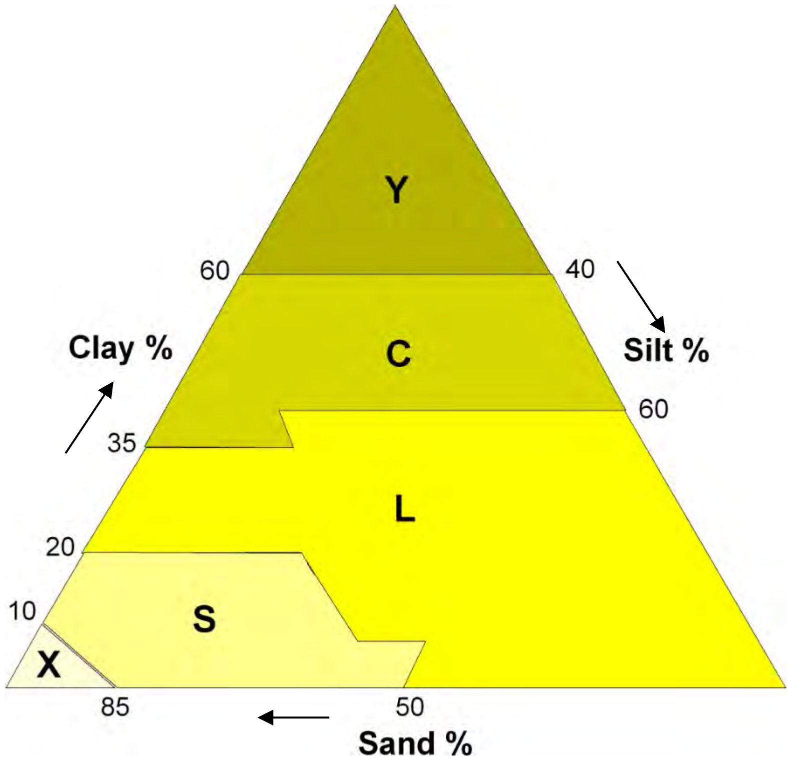


Figure 8
Texture groups of parent material (FAO 2006).

27. Depth to bedrock
The average depth to consolidated bedrock in metre. For depths less than 2 m the depth is rounded to nearest 0.1 meter; for depths between 2-10 m to the nearest 1 m and for depths more than 10 m to the nearest 5 metres.

28. Surface drainage
Surface drainage of the terrain component classified after (Cochrane *et al.* 1985) and (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

29. Depth to groundwater

The mean depth in metres of the ground water level observed over a number of years as experienced in the majority of the terrain component. If there is no groundwater information, the depth to the layer with reducing conditions shown by matrix colours (Munsell) 2.5Y, 5Y, 5G, 5B or N1/ to N8/ can be used as a proxy for groundwater depth (FAO 2006).

Flooding

Flooding is characterized by items 29-31:

30. Frequency of flooding

Frequency of the natural flooding of the terrain component in classes after (FAO and ISRIC 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

31. Duration of flooding

Duration, in days per year, of the flooding of the terrain component in classes (FAO and ISRIC 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

32. Start of flooding
The month (indicated by a number; e.g. 1 for January) during which flooding of the terrain component starts in most years. Three entries are possible to cater for most likely occurrances.

6.4 Soil component

This section specifies the attributes used to characterize the soil components. General attributes linked to the representative soil profile and horizon attributes are described in the Sections 6.6 and 6.7. Inherently, soil components are not mapable at the broad scale of SOTER (scales smaller than 1:250 000); they are only characterized in the RDBMS.

33. SOTER unit_ID
See *SOTER unit_ID* defined in Section 6.1, Terrain; ***primary key*** for the SOTER unit under consideration.

34. Terrain component number
See *terrain component number* under Section 6.2, Terrain component; ***primary key*** for the terrain component of the SOTER unit under consideration.

35. Soil component number
A sequential number for the soil component within the given terrain component; assigned, according to its proportional ranking from largest to smallest; ***primary key***.

36. Proportion of SOTER unit
The estimated proportion a soil component occupies within the SOTER unit. As stated in Section 5.3, a soil component normally occupies at least 10% of a SOTER unit.
The proportion of the soil components summed, corresponds with the total proportion of the corresponding terrain components. Thus, the sum of the proportion of all soil components in a SOTER unit is always 100%[10].

37. WRB-Legend unit
Each soil component is characterized according to the WRB Legend as given in Annex 4, which is based on selected classes of the World Reference Base for Soil Resources (IUSS 2006, 2007; IUSS *et al.* 2010). The soil mapping units at SOTER working scales (generally > 1:250 000) are usually soil associations or comprise compound units. These are then converted from the 'traditional soil map' into the various soil components of the SOTER unit. Soil components should at least be characterized up to the first prefix qualifier of the Reference Soil Group (RSG) of the WRB Legend e.g. Calcic Vertisols, to comprise the standard SOTER legend (see Annex 4). If more prefixes are included, they follow the sequential row of the RSG of the WRB Legend.
Each soil component is further characterized by a representative profile (See *profile_ID*, PRID), classified according to WRB system (IUSS 2006, 2007).

[10] Always start with the dominant one; avoid using equal percentages of 50-50% in case two or more soil components are identified (i.e. rather use 55-45 %); the same rule applies for the terrain components.

38. WRB-Legend suffixes

Suffixes can additionally be given as characterization of the RSG of the WRB Legend if relevant to a mapping unit. Full characterization of a representative profile is given in Chapter 6.6 and 6.7.

39. Revised Legend – FAO'88

The characterization of the soil component according to the Revised Legend (FAO-Unesco 1988). The FAO'88 Revised Legend is the standard Legend for all previously compiled continental and global SOTER databases; it also functions as standard legend for a Global SOTER. (See also Harmonized World Soil Database, (FAO *et al.* 2008, 2012)).

40. Phase[11]

Phases can be introduced to reflect a potentially limiting factor for soil management related to surface or subsurface features of the terrain component that are not specifically described in the classification of the WRB unit. The coding for phases is based on selected classes of the Revised Legend (FAO and ISRIC 1988).

41. Textural class of the topsoil

The textural class of the topsoil (see Figure 9), taking into account the upper 30 cm of the soil. Codes and classes are given according to (CEC 1985; ESB 1998).

X	Undefined	Synthetical profiles[12]
0	no texture	peat and organic soil layers
1	coarse	clay ≤ 18 % and sand > 65 %
2	medium	18 % ≤ clay <35 % and ≥ 15 % sand, or clay ≤ 18 % and 15 % ≤ sand < 65 %
3	medium fine	<35 % clay and <15 % sand
4	fine	35% ≤ clay < 60 %
5	very fine	≥ 60 % clay

11 WRB Legend phases are still under review.

12 In case there are no profile data but thje soil has a WRB name.

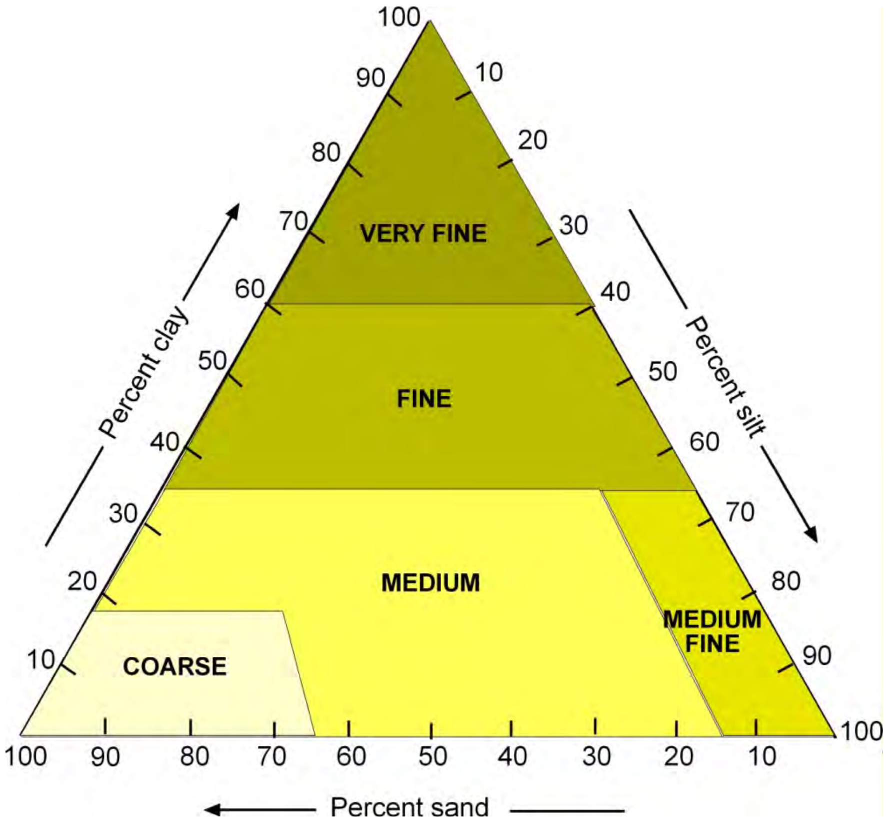


Figure 9
Texture classes of the topsoil according to (CEC 1985; ESB 1998).

42. Profile_ID

Unique code for the representative profile considered typical for the corresponding soil component. Any code is permitted provided it is unique at national level and preceded by the *ISO country code* (Annex 7); there is room for 15 characters in the database. A logical code must be used in such a way that the source and the number of the profile can be traced back to its origin (example: PEucIN50/P8; Peru, Ucayali province, report number 50, profile 8).

43. Position in terrain component

The relative position of the soil component within the terrain component:

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

44. Surface rockiness

The percentage coverage of rock or rock outcrops according to (FAO 2006; FAO and ISRIC 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%

45. Surface stoniness

The percentage cover of coarse fragments (> 2 mm), completely or partly at the surface, according to (FAO 2006; FAO and ISRIC 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%

Observable erosion

Any visible signs of (accelerated) erosion are to be indicated according to type, area affected and degree. If more than two types of erosion are active at the same time, then only the dominant type is indicated (items 44-47).

46. Types of erosion/deposition

Characterization of the erosion or deposition type according to FAO and ISRIC (1990):

N	no visible evidence of erosion
S	sheet erosion
R	rill erosion
G	gully erosion
T	tunnel erosion
P	deposition by water
W	water and wind erosion
L	wind deposition
A	wind erosion and deposition
D	shifting sand
Z	salt deposition
M	mass movement (landslides)
E	deposition and erosion

47. Area affected

The total area affected by the above mentioned erosion, as proportion of the soil component, according to UNEP and ISRIC (1988).

0	0%
1	0 - 5%
2	5 - 10%
3	10 - 25%
4	25 - 50%
5	> 50%

48. Degree of erosion

Rated after FAO (2006); FAO and ISRIC (1990)

S	slight	Some evidence of loss of surface horizons. Original biotic functions largely intact
M	moderate	Clear evidence of removal or coverage of surface horizons. Original biotic functions partly destroyed
V	severe	Surface horizons completely removed (with subsurface horizons exposed) or covered up by sedimentation of material from upslope. Original biotic functions largely destroyed
E	extreme	Substantial removal of deeper subsurface horizons (badlands). Complete destruction of original biotic functions

49. Sensitivity to capping

The degree in which the soil surface has a tendency to capping and sealing after drying (FAO and ISRIC 1990):

N	none	no capping or sealing observed.
W	weak	the soil surface has a slight sensitivity to capping. Soft or slightly hard crust less than 0.5 cm thick.
M	moderate	the soil has a moderate sensitivity to capping. Soft or slightly hard crust more than 0.5 cm thick, or hard crust less than 0.5 cm thick.
S	strong	the soil surface has a strong sensitivity to capping. Hard and very hard crust more than 0.5 cm thick.

50. Rootable depth

Estimated average depth to which root growth is not restricted by any physical or chemical impediment, such as impenetrable or toxic layers, to be determined as effective soil depth using land evaluation. Strongly fractured rocks, such as shale, may be considered as rootable. Classes after FAO and ISRIC (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

6.5 Additional soil profiles

This Section of the attribute database can record the *profile_ID* of additional (reference) soil profiles, i.e. the set of profiles from which the representative profile was chosen to best characterize the properties and characteristics of the soil component under consideration. Through a unique code each of these profiles (see 6.4; *profile_ID*) is linked to a soil component and represents the soil component together with the related representative profile. Note that the same reference profile (PRID) can serve as representative profile for different SOTER units with identical soil components, making use of the relational structure of the database. The availability of additional soil profiles per soil component may allow the user to get a better insight in the attribute variations within the soil component, e.g. for land evaluation studies. The attribute data of the additional soil profiles is stored in the tables *profile* and *horizon* data.

51. ISO Country code
The *ISO country code* is given according to ISO-3166 (ISO, 2006) (See Annex 7).

52. SOTER unit_ID
The *SOTER unit_ID* for the SOTER unit. (See *SOTER unit_ID* under Section 6.1).

53. Terrain component number
The *terrain component number* of the corresponding terrain component (See Section 6.2; Terrain component).

54. Soil component number
Sequential number of the soil component within the corresponding terrain component, ranked sequentially according to proportion. (The largest soil component is given number 1, the second largest number 2, etc.).

55. Profile_ID
Unique identification code for a soil profile; this key provides a logical link to the soil component and attribute data.

6.6 Profile

56. Profile_ID
As defined earlier in Section 6.4.

57. Soil profile database_ID
Identification code for the owner, institute or organisation that holds the national soil profile data, respectively the report from which these data were derived. It consists of an ISO code for the country (see Annex 7) and a sequential number. (See also Section 8.3).

58. Profile description status
The soil *profile description status* refers to the inferred quality of the soil description and the completeness of analytical data. It is indicative for the reliability of the soil profile information entered into the database. Classes are adapted from FAO (2006).

1	reference profile description	All essential elements or details are complete. The accuracy and reliability of the description, sampling and analysis permit the full characterization of all soil horizons to a depth of 125 cm, or more if required for classification, or down to a C or R horizon, which may be shallower.
2	routine profile description	No essential elements are missing from the description, sampling or analysis. The number of samples collected is sufficient to characterize all major soil horizons, but may not allow precise definition of all sub-horizons. The profile depth is 80 cm or more, or down to a C or R horizon, which may be shallower.
3	incomplete description	Certain relevant elements are missing from the description, insufficient samples were taken, or the reliability of the analytical data does not permit a complete characterization of the soil. However, the description may still be useful for specific purposes and provides a satisfactory indication of the nature of the soil at high levels of soil classification.
4	other descriptions	Essential elements are missing from the description, preventing a satisfactory soil characterization and classification. May still be useful in data scarce regions

59. Sampling date

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

60. Lab_ID

Unique code for the soil laboratory where the samples were analysed. Given as *ISO country code* followed by a number, e.g. PE002.

61. Latitude

Latitude in decimal degrees[13], if possible to the nearest third decimal. Latitudes in the Northern hemisphere are positive; in the Southern hemisphere negative. The default geometric datum for all SOTER maps is WGS 1984.

62. Longitude

Longitude in decimal degrees, if possible to the nearest third decimal. Longitudes in the Eastern hemisphere are positive; in the Western hemisphere negative.

63. Profile location status

The conditions from which the profile locations were derived; it is indicative for the accuracy of the profile location.

1	derived from GPS measurements
2	converted from DMS data, available up to seconds
3	converted from DMS data, available only up to minutes
4	converted from other sources (location description, etc.)

[13] Conversion program can be found: http://www.fcc.gov/mb/audio/bickel/DDDMMSS-decimal.html

64. Elevation

Elevation of the profile in meter above mean sea level; indicated to the nearest 10 m contour or taken from the digital elevation model. Assumes locations are accurate.

65. Land use at profile location

Code for the land use observed at the location of the soil profile at time of description/sampling, according to Table 6 (part II, Land Use and Vegetation).

66. Vegetation at profile location

Codes for the (largely undisturbed) vegetation at the location of the profile at time of description, according to Table 7 (part II, Land use and Vegetation).

67. Parent material at profile location

Codes for the parent material of the soil at the profile location, according to Tables 3 and 4

68. Drainage

The *drainage* of the profile is described according to the classes (FAO and ISRIC 1990; Soil Survey Staff 1993):

E	excessively drained	Water is removed from the soil very rapidly.
S	somewhat excessively	Water is removed from the soil rapidly drained.
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.

69. Reference Soil Group/prefix and suffix qualifiers

Classification of representative profiles according to the World Reference Base for Soil Resources (IUSS 2007), preferably up to the lowest level of the Reference Soil Group (RSG) and its qualifiers (prefixes and suffixes). The sequential order of the lower level qualifiers follow the priority listing of the lower level units of the RSG; for details see Annex 3, Section 3.4.

70. WRB specifiers

Specifiers in WRB indicate the depth of occurrence or degree of expression of the soil characteristics or properties of the profile; for coding conventions see (ISSS *et al.* 1998; IUSS *et al.* 2007; IUSS 2006, 2007).

71. Revised Legend classification

Code for classification at soil unit level according to Revised Legend of the FAO-Unesco Soil Map of the World (FAO 1988, 1990); needed to maintain consistency with 'older' SOTER products (e.g. the SOTERLAC database (Dijkshoorn *et al.* 2005)) and the Harmonized World Soil Database (FAO *et al.* 2008, 2012).

72. National classification
The classification according to the national system, if different from item 69 and 71.

73. Soil Taxonomy
USDA Soil Taxonomy classification (Soil Survey Division Staff 1999) or earlier version, as provided in the source material or indicated in the national database or relevant report.

74. Soil Taxonomy version
The year of publication of the Soil Taxonomy version.

6.7 Horizon data

This section lists the attributes for soil horizons of the profiles considered in SOTER database. Only measured data are accepted in SOTER.

75. Profile_ID
See *profile_ID*, Section 6.4.

76. Horizon number
A consecutive number, starting with the uppermost surface horizon, is allocated to each horizon. Horizons are identified according to FAO (2006).

77. Diagnostic horizon
Characterization of the *diagnostic horizon* according to the World Reference Base for Soil Resources 2nd edition (IUSS 2006, 2007).
(Note: SOTER databases completed before 2006 use criteria of the Revised Legend).
The full definition of all the *diagnostic horizons* is given in Annex 3.

Organic surface horizons

FO	folic	the folic horizon consist of well-aerated organic material occurring at the surface or at shallow depth and is water saturated for less than one month in most years.
HI	histic	the histic horizon consists of poorly aerated organic material and is water saturated for more than one month in most years (unless artificially drained).

Mineral surface horizons

MO	mollic	the mollic horizon is a thick, well structured, dark-coloured surface horizon with a high base saturation and a moderate to high content in organic matter. The requirements for a mollic horizon must be met after the first 20 cm is mixed, as in ploughing.
UM	umbric	resembles a mollic in all properties; in colour, organic carbon, structure and thickness, except that the umbric horizon has a base saturation of less than 50%.
VO	voronic	the voronic horizon is a special type of mollic horizon. It is a deep, well structured, blackish surface horizon with a high base saturation, a high content of organic matter and a high biological activity.
OC	ochric	(obsolete); the ochric horizon does not meet the requirements for a mollic, umbric or voronic horizon. Note that stratified materials, e.g. surface layers of fresh alluvial deposits, do not qualify as an ochric horizon.

(Sub)surface horizons with strong human influence

AH	anthric	the anthric horizon is a moderately thick, dark coloured surface horizon strongly influenced by long continued cultivation.
AQ	anthraquic	the anthraquic horizon comprises a puddled layer and plough pan of a soil under long-continued paddy cultivation.
HO	hortic	the hortic horizon results from deep cultivation, intensive manuring and/or long-continued application of human and animal wastes, and other organic residues.
HY	hydragic	the hydragric horizon is a human-induced subsurface horizon associated with wet cultivation.
IR	irragric	the irragric horizon is usually light coloured, and gradually builds up by a long-continued application of irrigation with sediment rich water.
PA	plaggic	the plaggic horizon is a black or brown human-induced surface horizon that has built up gradually from continuous addition of a mixture of sods and farmyard manure in medieval times.
TE	terric	the terric horizon has developed through addition to the soil of earthy manures, compost, beach sands or mud over a long period of time.

Dark coloured volcanic horizons high in organic carbon

FU	fulvic	the fulvic horizon is a thick, dark coloured horizon at or near to the surface that is typically associated with short-range-order minerals (commonly allophane) or with organo-aluminium complexes. It has a low bulk density and contains highly humified organic matter.
ME	melanic	the melanic horizon is a thick, black horizon at or near to the surface that is typically associated with short-range-order minerals (commonly allophane) or with organo-aluminium complexes. It has a low bulk density and contains highly humified organic matter.

Eluvial horizon

AL	albic	the albic horizon is a light-coloured subsurface horizon from which 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 sand and silt particles rather than by coatings on these particles. The albic horizon usually has coarser textures than overlying or underlying horizons. Many albic horizons are associated with wetness and contain evidence of reducing conditions.

Subsurface horizons with clay accumulation

AR	argic	the argic horizon is a subsurface horizon with distinct higher clay content than the overlying horizon. This textural differentiation may be caused by an illuvial accumulation of clay, by predominant pedogenetic formation of clay in the subsoil or by destruction of clay in the surface horizon, by selective surface erosion of clay, by biological activity or by a combination of two or more of these different processes. Sedimentation of surface materials that are coarser than the subsurface horizon may enhance a pedogenetic 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.
NA	natric	the natric horizon is a dense subsurface horizon with distinct higher clay content than the overlying horizon(s) and resembles an argic horizon in all aspects, except that it has a high content of exchangeable sodium and/or magnesium (ESP>15%).

Horizons with organic carbon accumulation

SP	spodic	the spodic horizon is a dark coloured subsurface horizon that contains illuvial amorphous substances composed of organic matter and aluminium, or of illuvial iron.
SO	sombric	the sombric horizon is a dark coloured subsurface horizon containing illuvial humus that is neither associated with aluminium nor dispersed by sodium.

(Strongly) weathered horizons

CB	cambic	the cambic horizon shows evidence of alteration relative to the underlying horizon in structure, colour, gypsum or calcium carbonate content.
NI	nitic	the nitic horizon is a clay-rich subsurface horizon with moderately to strongly developed polyhedric structure breaking to flat-edged or nutty elements with many shiny ped faces, which cannot or can only partly be attributed to clay illuviation.
FA	ferralic	the ferralic horizon results from long and intense weathering, in which the clay fraction is dominated by low-activity clays, and the silt and sand fractions by highly resistant minerals resulting in a cation exchange capacity of less than 16 $cmol_c kg^{-1}$ clay.

Horizons with iron (and manganese) segregration

FI	ferric	the ferric horizon is a subsurface horizon, in which segregation of iron and manganese has taken place to such an extent that large mottles or discrete nodules have formed and the intermottle/ internodular matrix is largely depleted of iron.
PL	plinthic	the plinthic horizon is a subsurface horizon that consists an iron-rich, humus-poor mixture of kaolinitic clay with quartz and other constituents, and which changes irreversibly to a layer with hard nodules, a hardpan, or irregular fragments on exposure to repeated wetting and drying.
PP	petroplinthic	the petroplinthic horizon is a continuous, fractured or broken layer of indurated material, in which iron is an important cement and, in which organic matter is absent or present only in traces.
PS	pisoplinthic	the pisoplinthic horizon contains nodules that are strongly cemented and indurated with iron (and in some cases also with manganese) to a diameter of 2 mm or more.

Calcium and gypsum enriched horizons

CA	calcic	the calcic horizon is a horizon in which secondary calcium carbonate ($CaCO_3$) has accumulated either in a diffuse form (calcium carbonate present only in the form of fine particles of 1 mm or less, dispersed in the matrix) or as discontinuous concentrations (pseudomycelia, cutans, soft and hard nodules, or veins).
PC	petrocalcic	the petrocalcic horizon is an indurated calcic horizon that is cemented by calcium carbonate and, in places, by calcium and some magnesium carbonate. It is either massive or platy in nature and extremely hard.
GY	gypsic	the gypsic horizon is a commonly non-cemented horizon, containing secondary accumulations of gypsum ($CaSO_4.2H_2O$) in various forms.
PG	petrogypsic	the petrogypsic horizon is a cemented horizon containing secondary accumulations of gypsum ($CaSO_4.2H_2O$).

(Other) cemented horizons

DU	duric	the duric horizon is a subsurface horizon showing weakly cemented to indurated nodules or concretions cemented by silica (SiO_2), presumably in the form of opal and microcrystalline forms of silica ('durinodes').
PD	petroduric	the petroduric horizon, also known as duripan or dorbank (South Africa), is a subsurface horizon, usually reddish or reddish brown in colour that is cemented mainly by secondary silica. Air-dry fragments of petroduric horizons do not slake in water, even after prolonged wetting. Calcium carbonate may be present as accessory cementing agent. It is either massive or has a platy or laminar structure.
FR	fragic	the fragic horizon is a natural non-cemented subsurface horizon with a pedality and a porosity pattern such that roots and percolating water penetrate the soil only along interped faces and streaks. The natural character excludes plough pans and surface traffic pans.

Surface horizons formed under aridic conditions

TA	takyric	the takyric horizon is a heavy-textured surface horizon comprising a surface crust and a platy structured lower part. It occurs under arid conditions in periodically flooded soils.
YE	yermic	the yermic horizon is a surface horizon that usually, but not always, consists of surface accumulations of rock fragments ('desert pavement') embedded in a loamy vesicular layer that may be covered by a thin aeolian sand or loess layer, occurring under aridic conditions.

Horizons influenced by frost

CY	cryic	the cryic horizon is a perennially frozen soil horizon in mineral or organic soil material.

Other horizons

VE	vertic	the vertic horizon is a clayey subsurface horizon that, as a result of shrinking and swelling, has slickensides and wedge-shaped structural aggregates.
SA	salic	the salic horizon is a surface or shallow subsurface horizon that contains a secondary enrichment of readily soluble salts, i.e. salts more soluble than gypsum.
TH	thionic	the thionic horizon is an extremely acid subsurface horizon in which sulphuric acid is formed through oxidation of sulphides.

78. Diagnostic property

Diagnostic property characterization uses the definitions described in the World Reference Base for Soil Resources (IUSS 2006, 2007).
(Note: SOTER databases completed before 2006 use criteria of the Revised Legend).
The full definition of all the diagnostic properties is given in Annex 3.

TC	abrupt textural change	an abrupt textural change is a very sharp increase in clay content within a limited depth range of 7.5 cm.
TO	albeluvic tonguing	the term albeluvic tonguing is connotative for penetrations of clay- and iron-depleted material into an argic horizon. When peds are present, albeluvic tonguing occurs along ped surfaces.
AD	andic	the andic properties result from moderate weathering of mainly pyroclastic deposits. Their mineralogy is dominated by short-range-order minerals (usually allophane) and commonly part of the weathering sequence in pyroclastic deposits (tephric soil material → vitric horizon → andic horizon). An andic layer has a high content of extractable aluminium and iron, and has low bulk density and high phosphate retention.
AC	aridic properties	the term aridic properties combines a number of properties that are common in surface horizons of soils occurring under arid conditions and where pedogenesis exceeds new accumulation at the soil surface by aeolian or alluvial activity.

RO	continuous hard rock	continuous hard rock is material underlying the soil, exclusive of cemented pedogenetic horizons such as a petrocalcic, petroduric, petrogypsic and petroplinthic horizons that is sufficiently consolidated to remain intact when air-dried specimen 25-30 mm is submerged in water for 1 hour. The material is considered continuous if only a few cracks, 10 cm or more apart, are present and no significant displacement of the rock has taken place.
FC	ferralic	the ferralic properties refer to mineral soil material that has a relative low cation exchange capacity. It also includes soil materials that would qualify for a ferralic horizon except for a coarse texture.
GE	geric	geric properties refer to mineral soil material that has a very low effective cation exchange capacity (ECEC) or even acts as an anion exchanger.
GL	gleyic colour pattern	soil materials develop gleyic colour patterns if they are saturated with groundwater (or were saturated in the past and now drained) for a period that allows reducing conditions to occur (this may range from a few days in the tropics to a few weeks in other areas).
LD	lithological discontinuity	lithological discontinuities are significant changes in particle-size distribution or mineralogy that represent differences in lithology within a soil.
RC	reducing conditions	reducing conditions show the presence of free iron (Fe^{2+}) on a freshly broken and smoothed surface of a field-wet soil by the appearance of a strong red colour after wetting it with 0.2 percent alpha,alpha,dipyridyl solution.
SL	secondary carbonates	the term secondary carbonates refer to lime precipitated in place from the soil solution rather than inherited from a soil parent material. As a diagnostic property, it should be present in significant quantities.
ST	stagnic colour pattern	soil materials develop a stagnic colour patterns if they are, at least temporarily, saturated with surface water, unless drained, for a period long enough that allows reducing conditions to occur (this may range from a few days in the tropics to a few weeks in other areas).
VC	vertic	the term vertic properties is used for soil material that has a clay percentage of 30 or more, and slickensides or wedge-shaped aggregates, or cracks that open and close periodically and are 1 cm or more wide at the surface.
VI	vitric	vitric properties apply to layers with volcanic glass and other primary minerals derived from volcanic ejecta and which contain a limited amount of short-range-order minerals.

79. Diagnostic materials

Diagnostic (soil) materials are intended to reflect (partly) the properties of the original parent material, in which pedogenetic processes have not yet been very active, so that they have only slightly influenced the soil and have not led to significant changes.

AF	artefacts	artefacts are solid or liquid substances that were created or substantially modified by humans as part of an industrial or artisanal manufacturing process.
CO	calcaric	soil material that effervescences strongly with 1*M* HCl in most of the fine earth. It applies to soil material that contains 2 percent or more calcium carbonate equivalent.
CU	colluvic	colluvic material is formed by sedimentation through human induced erosion. It normally accumulates in footslope positions and in depressions or above hedge-walls.

FL	fluvic	fluvic soil material refers to fluviatile, marine and lacustrine sediments that receive fresh materials at regular intervals, or have received it in the recent past. Fluvic soil materials must show textural and/or organic stratification.
GP	gypsiric	gypsiric soil material is mineral soil that contains 5 percent or more gypsum (by volume).
LN	limnic	limnic materials occur as subaquatic deposits (or at the surface after *drainage*). Four types are distinguished; coprogenous earth or sedimentary peat, diatomaceous earth, marl and gyttja.
MR	mineral	in mineral material, the soil properties are dominated by mineral components.
OR	organic	organic material consists of a large amount of organic debris that accumulates at the surface under wet or dry conditions and in which the mineral components does not significantly influence the soil properties.
ON	ornithogenic	ortnithogenic material is material with strong influence of bird excrements. It often has a high content of gravel that has been transported by birds.
SF	sulfidic	sulfidic material is a waterlogged deposit containing sulphur, mostly in the form of sulphides, and only moderate amounts of calcium carbonate.
TR	technic	technic hard rock is consolidated material resulting from an industrial process, with properties substantially different from those of natural material.
TP	tephric	tephric material consists either of tephra, i.e. unconsolidated, non or only slightly weathered pyroclastic products of volcanic eruptions (including ash, cinders, lapilli, pumice, pumice-like vesicular pyroclastics, blocks or volcanic bombs), or of tephric deposits, i.e. tephra that has been reworked and mixed with material from other sources. This includes tephric loess, tephric blown sand and volcanogenic alluvium.

80. Horizon designation

Master horizon and layers, with subordinate characteristics, are coded according to (FAO 2006; FAO and ISRIC 1990).

Master horizons and layers

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 drained artificially. 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 that has accumulated on the surface. It may be on top of either mineral or organic soils. An O horizon is 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 is generally much less than half of 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 that has 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 or B horizon (see below); ***or***
- properties resulting from cultivation, pasturing, or similar kinds of disturbance; ***or***
- a morphology that is different from the underlying B or C horizon, resulting from processes related to the surface (e.g. for Vertisols).

E E horizon. Mineral horizon in which the main feature is loss of silicate clay, iron, aluminium, 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. An E horizon is commonly 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. The 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, aluminium, humus, carbonates, gypsum or silica;
- evidence of removal of carbonates;
- residual concentration of sesquioxides;
- coatings 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.

Included in B horizons are layers of illuvial concentrations of gypsum, carbonates, or silica that are the result of pedogenetic processes and brittle layers that have other evidence of alteration, such as prismatic structure or illuvial accumulation of clay. Layers with gleying but no other pedogenetic changes are not considered a B horizon.

C C horizon/layer. The C horizon or layer, excluding hard bedrock, 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 already highly weathered material that does not meet the requirements of an A, E or B horizon, is considered a C horizon. Changes not considered pedogenetic are those not related to overlying horizons. Layers having accumulation of silica, carbonates, or gypsum, may be included in the C horizon, unless the layer is obviously affected by pedogenetic processes; then it is a 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 in water. The R layer is sufficiently coherent when moist to make hand digging with a spade impractical, although it may be chipped or scraped.

I I layer. Ice lenses and wedges that contain at least 75 percent ice (by volume) and that distinctly separate organic or mineral layers in the soil.

L L layer. Sediments deposited in a body of water (sub-aqueous) and composed of both organic and inorganic materials, also known as limnic material.

W Water layer. Water layer in soils or water submerging soils, either permanently or cyclic within the time frame of 24 hours.

Subordinate characteristics

Subordinate distinctions and features within master horizons and layers are based on profile characteristics observable in the field and are indicated with lower case letters used as suffixes. The following suffixes for subordinate distinction may be used; (FAO 2006; FAO and ISRIC 1990).

a	highly decomposed organic material
b	buried genetic horizon
c	concretions or nodules. In combination with L layer; coprogenous earth
d	dense layer. In combination with L layer; diatomaceous earth
e	moderately decomposed organic material
f	frozen soil
g	stagnic (and gleyic) conditions, reflected in mottling
h	accumulation of organic matter
i	slickensides (in mineral soils) or slightly decomposed organic material (in organic soils)
j	jarosite mottling
k	accumulation of pedogenetic carbonates
l	capillary fringe mottling (gleying)
m	strong cementation or induration (mineral soils) or marl (in combination with L layer)
n	pedogenetic accumulation of exchangeable sodium
o	residual accumulation of sesquioxides
p	ploughing or other artificial disturbance by man
q	accumulation of pedogenetic silica
r	strong reduction
s	illuvial accumulation of sesquioxides
t	accumulation of silicate clay
u	urban and other man-made materials
v	occurrence of plinthite
w	development of colour or structure in B horizons
x	fragipan characteristics
y	pedogenetic accumulation of gypsum
z	pedogenetic accumulation of salts more soluble than gypsum
@	evidence of cryoturbation

81. Upper horizon boundary

The average depth in cm of the upper (top) boundary of each horizon. Note that all horizons have positive depths measured from the top of the surface of the soil downwards, including organic and mineral horizons or layers. See FAO (2006); when necessary 'old' depths should be converted to the new standard.

82. Lower horizon boundary

The average depth in cm of the lower boundary of each horizon.

83. Distinctness of transition

Abruptness of horizon boundary to underlying horizon (FAO 2006; FAO and ISRIC 1990).

A	abrupt	0 - 2 cm
C	clear	2 - 5 cm
G	gradual	5 - 15 cm
D	diffuse	≥ 15 cm

84. Moist colour

The Munsell colours (moist soil) using integer figures for values and chroma.

85. Dry colour

The Munsell colours (dry soil) using integer figures for values and chroma.

Mottling

The colour, abundance and size of mottles according to guidelines for soil description (FAO 2006; FAO and ISRIC 1990).

86. Colour of mottles
The Munsell colour of the dominant mottles.

87. Abundance of mottles
The *abundance of mottles* in the horizon as percentage of exposed surface:

N	none	0%
V	very few	0 - 2%
F	few	2 - 5%
C	common	5 - 15%
M	many	15 - 40%
A	abundant	>40%

88. Size of mottles
Size classes of the individual mottles:

V	very fine	< 2 mm
F	fine	2 - 6 mm
M	medium	6 - 20 mm
C	coarse	> 20 mm

Structure

The grade, size and type of the primary structure elements, defined according to guidelines for soil description (FAO 2006; FAO and ISRIC 1990).

89. Grade of structure

N	structureless	apedal soil with no observable aggregation or no orderly arrangement of natural planes of weakness (massive or single grain)
W	weak	soil with poorly formed indistinct peds, that are barely observable in place even in dry soil, breaks up into very few intact peds, many broken peds and much apedal material
M	moderate	soil with well-formed distinct peds, durable and evident in disturbed soil that produces many entire peds, some broken peds and little apedal material
S	strong	soil with durable peds that is clearly evident in undisturbed (dry) soil, which breaks up mainly into entire peds

90. Size of structure elements

Table 5
Size classes for structure elements of various types according to guidelines for soil description (FAO 2006; FAO and ISRIC 1990; Soil Survey Staff 1951).

Size classes		Ranges of size of structure elements (mm)				
		platy	prismatic/ columnar	(sub)angular blocky	granular	crumb
V	very fine/thin	<1	<10	<5	<1	<1
F	fine/thin	1-2	10-20	5-10	1-2	1-2
M	medium	2-5	20-50	10-20	2-5	2-5
C	coarse/thick	5-10	50-100	20-50	5-10	
X	very coarse	>10	100-500	>50	>10	
E	extremely coarse		>500			

91. Type of structure

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	subangular 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 visible, coherent porous (apedal soil)
N	single grain	no structure, individual grains
W	wedge shaped	structure in horizons with slickensides
K	rock structure	includes fine stratification in unconsolidated materials to unweathered minerals retaining their original position in the saprolite of consolidated rocks

Mineral concretions and coarse fragments

The presence of coarse mineral concretions and any rock and/or coarse fragments (>2 mm) in the horizons are described in nature, abundance and size classes; items 92 – 96. Coarse fragments are described here in the same way as mineral concretions and nodules.

92. Nature of concretions and nodules

The nature of mineral nodules and concretions according to general classes of the dominant constituents (FAO 2006; FAO and ISRIC 1990).

R residual rock fragments
Q silica (siliceous)
F iron (ferruginous)
M manganese (manganiferous)
I iron-manganese (sesquioxides)
K carbonates (calcareous)
G gypsum (gypsiferous)
S salt (saline)
U sulphur (sulphurous)
N not known

93. Abundance of concretions and nodules

Classes of volume percentages of concretions and/or mineral nodules in the soil matrix after (FAO 2006; FAO and ISRIC 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%

94. Size of concretions and nodules

Size of dominant concretions and/or nodules (FAO 2006; FAO and ISRIC 1990).

V	very fine	<2 mm
F	fine	2 - 6 mm
M	medium	6 – 20 mm
C	coarse	>20 mm

95. Abundance of coarse fragments

Classes of volume percentages of rock and/or coarse fragments in the soil matrix after (FAO 2006; FAO and ISRIC 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%

96. Size of coarse fragments

Size of dominant rock and/or coarse fragments in classes (FAO 2006; FAO and ISRIC 1990).

F	fine gravel	0.2 - 0.6 cm
M	medium gravel	0.6 - 2 cm
C	coarse gravel	2 - 6 cm
S	stones	6 - 20 cm
B	boulders	20 - 60 cm
L	large boulders	> 60 cm

Laboratory measured analytical attributes

97. Very coarse sand

Weight percentage of *very coarse sand* particles in fine earth fraction; esd[14] is specified in the methods section (see Section 8.2 Analytical methods).

14 esd = equivalent spherical diameter.

98. Coarse sand
Weight percentage of *coarse sand* particles in fine earth fraction, according to specified methods. (see Section 8.2 Analytical methods).

99. Medium sand
Weight percentage of *medium sand* particles in fine earth fraction. (see Section 8.2 Analytical methods).

100. Fine sand
Weight percentage of *fine sand* particles in fine earth fraction. (see Section 8.2, Analytical methods).

101. Very fine sand
Weight percentage of *very fine sand* particles in fine earth fraction. (see Section 8.2, Analytical methods).

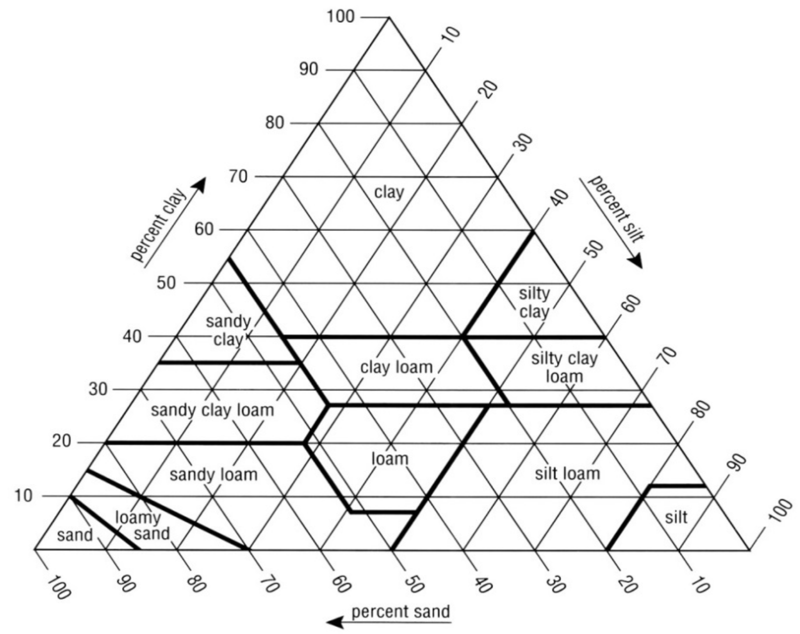
102. Total sand
Weight percentage of *total sand* particles in the fine earth fraction (esd).[15] The total sand fraction, either as an absolute value, or as the sum of the subfractions. (see Section 8.2, Analytical methods).

103. Silt
Weight percentage of *silt* particles in fine earth fraction (esd). (see Section 8.2, Analytical methods).

104. Clay
Weight percentage of *clay* particles in fine earth fraction. (see Section 8.2, Analytical methods).

105. Particle size class
The *particle size class* of the fine earth, derived from Soil Service Division Staff Figure 10.

15 esd = equivalent spherical diameter.



Coding of texture classes	
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 10
USDA texture classes of fine earth fraction (<2 mm). Source: Soil Survey Division Staff (1993).

The particle size class of the fine earth, derived from Figure 10, which assumes particle size fractions (esd) defined according to (Soil Survey Division Staff 1993): sand (2 – 0.05 mm); silt (0.050 – 0.002 mm) and clay (>0.002 mm).

106. Bulk density
The oven-dry *bulk density* in kg dm^{-3}; for methods see Section 8.2, Analytical methods.

107. Soil moisture content at various tensions
Soil moisture content expressed (in volume percentage) at 5 predefined tensions, formerly referred to as pF-values, can be accommodated in the database. The tensions include the moisture content at saturation (-0.1 kPa), the moisture content at -33 kPa (field capacity, according to USDA standards) and the moisture content at wilting point (-1.5 MPa). (see Section 8.2 Analytical methods). For analyses of the soil moisture data, moisture content at fixed suctions is preferable. If data are available the following soil moisture contents could be entered. For intermediate tensions interpolate, e.g.:

kPa[16]	-0.1	-10	-20	-33	-50	-100	-330	-1500
soil moisture (vol. %)	56	41	35	31	27	22	17	9

[16] 10 kPa (pressure unit) refers to 0.1 bar (obsolete) or 100 cm water head or pF2.0 (obsolete, but often used).

108. Electrical conductivity (EC)

The *electrical conductivity* determined in a 1:x soil–water mixture, in dS m^{-1} [17], often measured in the same run as pH-H_2O. See Section 8.2 for coding of analytical methods.

109. pH (H2O)

The pH determined in a 1:x soil-water mixture. See Section 8.2 for coding of analytical methods.

110. pH (KCl)

The pH is determined in the supernatant suspension of a 1:x soil-1 *M* KCl mixture. See Section 8.2 for coding of analytical methods.

111. pH (CaCl2)

The pH is determined in the supernatant suspension of a 1:x soil-0.01 *M* $CaCl_2$ mixture (USDA-SCS 1992). See Section 8.2 for coding of analytical methods.

Soluble salts

The type and amount of soluble salts of a saturated paste, particularly when the $EC_e \geq 4$ dS m^{-1}, are described in items 112-120.

112. Electrical conductivity saturation extract (ECe)

The *electrical conductivity* of the saturation extracts, dS m^{-1}; only given if the soil contains salts.

113. Soluble Na^+

The *soluble Na^+* content of the saturated paste in $cmol_c$ l^{-1} [18]. See Section 8.2 for coding of analytical methods.

114. Soluble Ca^{++}

The *soluble Ca^{++}* content of the saturated paste in $cmol_c$ l^{-1}. See Section 8.2 for coding of analytical methods.

115. Soluble Mg^{++}

The *soluble Mg^{++}* content of the saturated paste in $cmol_c$ l^{-1}. See Section 8.2 for coding of analytical methods.

116. Soluble K^+

The *soluble K^+* content of the saturated paste in $cmol_c$ l-1. See Section 8.2 for coding of analytical methods.

117. Soluble Cl-

The *soluble Cl* content of the saturated paste in $mmol_c$ l^{-1}. See Section 8.2 for coding of analytical methods.

[17] 1dS m^{-1} = 1mS cm^{-1} = 1mMhos cm^{-1} = 1000μS cm^{-1}

[18] Note: $cmol_c$ = 10 x mmol

118. Soluble SO_4^{--}-

The *soluble* SO_4^{-} content of the saturated paste in $cmol_c\ l^{-1}$. See Section 8.2 for coding of analytical methods.

119. Soluble HCO_3^{-}

The *soluble* HCO_3^{-} content of the saturated paste in $cmol_c\ l^{-1}$. See Section 8.2 for coding of analytical methods.

120. Soluble CO_3^{--}

The *soluble* HCO_3^{-} content of the saturated paste in $cmol_c\ l^{-1}$. See Section 8.2 for coding of analytical methods.

Exchangeable cations

121. Exchangeable Ca^{++}

Exchangeable Ca^{++} in $cmol_c\ kg^{-1}$ (= meq/100 g), according to methods specified under analytical methods. See Section 8.2 for coding of analytical methods.

122. Exchangeable Mg^{++}

Exchangeable Mg^{++} in $cmol_c\ kg^{-1}$. See Section 8.2 for coding of analytical methods.

123. Exchangeable Na+

Exchangeable Na^{+} in $cmol_c\ kg^{-1}$. See Section 8.2 for coding of analytical methods.

124. Exchangeable K^{+}

Exchangeable K^{+} in $cmol_c\ kg^{-1}$. See Section 8.2 for coding of analytical methods.

125. Exchangeable Al^{+++}

Exchangeable Al^{+++} in $cmol_c\ kg^{-1}$. See Section 8.2 for coding of analytical methods.

126. Exchangeable acidity

Exchangeable acidity (H^{+} + Al^{+++}), as determined in 1N KCl, in $cmol_c\ kg^{-1}$. See Section 8.2 for coding of analytical methods.

127. Cation exchange capacity of the soil

The *cation exchange capacity* (CEC) of the soil at pH 7.0 in $cmol_c\ kg^{-1}$. See Section 8.2 for coding of analytical methods.

128. Total carbonate content

The content of (inorganic) carbonates of the soil in g kg-1. See Section 8.2 for coding analytical methods.

Note: expressed in g kg-1 of soil or promille (1% is *10‰).*

129. Gypsum

The gypsum content in g kg-1. See Section 8.2 for coding analytical methods.

Note: expressed in g kg-1 of soil or promille (1% is 10‰).

130. Total carbon

The total content of organic and inorganic carbon of the soil layer in g kg^{-1} See Section 8.2 for coding analytical methods.

Note: expressed in g kg^{1} of soil or promille (1% is 10‰).

131. Organic carbon

The content of *organic carbon* in g kg^{-1} (desirable of the A horizon or of the first 25 cm, whichever is deeper). See Section 8.2 for coding of analytical methods.

Note: expressed in g kg^{1} of soil or promille (1% OC is 10‰ OC)

132. Total nitrogen

The content of *total nitrogen* of the soil in g kg^{-1}. See Section 8.2 for coding analytical methods.

Note: expressed in g kg^{1} of soil or promille (1% N is 10‰ N)

133. Available P

The *available P*-content of the soil in mg kg-1. See Section 8.2 for coding analytical methods.

134. Total P

The *total P*-content of the soil in mg kg^{-1}. See Section 8.2 for coding analytical methods.

135. Phosphate retention

The *phosphate retention* in %. See Section 8.2 for coding analytical methods.

136. Fe, dithionite extractable

The Fe fraction, in weight %, extractable in dithionite citrate.

137. Al, oxalate extractable

The Al fraction, in weight %, extractable in oxalate acid.

138. Fe, oxalate extractable

The Fe fraction, in weight %, extractable in oxalate acid.

139. Clay mineralogy

The dominant type of mineral in the clay size fraction.

AL allophane
CH chloritic
IL illitic
IN interstratified or mixed
KA kaolinitic (and halloysite)
MO montmorillonitic (smectite group)
SE sesquioxidic
VE vermiculitic (including mica)

PART II LAND USE AND VEGETATION

7 Coding convention

In the SOTER database (version 2), land use and land cover data are needed at the soil profile location, recorded at the time of sampling or profile description. This information can be related to the organic matter content measured in the profile and differ often completely from the land cover at the SOTER unit level, as derived from auxiliary datasets e.g. from remote sensing data.

7.1 Land use

Hierarchical system of land use according to Remmelzwaal (1990). The land use class codes, as used for characterization at the profile level in the SOTER database, can be derived from Table 6. A full description of the land use classes is given in Annex 5.

7.2 Vegetation

Vegetation can be derived from auxiliary datasets, created by FAO, JRC and others. The vegetation codes as used for the characterization of the profile in the SOTER database can be derived from Table 7 (Unesco 1973). A full description of the vegetation classes is given in Annex 6.

Table 6
Hierarchy of land use.

Order		Group		System	
A	AGRICULTURE	**AA**	annual field cropping	**AA1**	shifting cultivation
				AA2	fallow system cultivation
				AA3	ley system cultivation
				AA4	rainfed arable cultivation
				AA5	wet rice cultivation
				AA6	irrigated cultivation
		AP	perennial field cropping	**AP1**	non-irrigated
				AP2	irrigated
		AT	tree & shrub cropping	**AT1**	non-irrigated tree crop cultivation
				AT2	irrigated tree crop cultivation
				AT3	non-irrigated shrub crop cultivation
				AT4	irrigated shrub crop cultivation
H	ANIMAL HUSBANDRY	**HE**	extensive grazing	**HE1**	nomadism
				HE2	semi-nomadism
				HE3	ranching
		HI	intensive grazing	**HI1**	animal production
				HI2	dairying
F	FORESTRY	**FN**	exploitation of natural forest and woodland	**FN1**	selective felling
				FN2	clear felling
		FP	plantation forestry		
M	MIXED FARMING	**MF**	agro-forestry		
		MP	agro-pastoralism (cropping & livestock systems)		
E	EXTRACTION/ COLLECTING	**EV**	exploitation of natural vegetation		
		EH	hunting and fishing		
P	NATURE PROTECTION	**PN**	nature and game preservation	**PN1**	reserves
				PN2	parks
				PN3	wildlife management
		PD	degradation control	**PD1**	non-interference
				PD2	with interference

Order		Group	System
S	SETTLEMENT/ INDUSTRIES	**SR**	residential use
		SI	industrial use
		ST	transport
		SC	recreational
		SX	excavations
		SD	disposal sites
Y	MILITARY AREA		
O	OTHER LAND AREAS		
U	UNUSED		
N	NOT KNOWN		

Table 7
Hierarchy of vegetation classes.

Class		Subclass		Group	
I	closed forest	**IA**	mainly evergreen forest	**IA1**	tropical ombrophilous forest
				IA2	tropical and subtropical evergreen seasonal forest
				IA3	tropical and subtropical semi-deciduous forest
				IA4	subtropical ombrophilous forest
				IA5	mangrove forest
				IA6	temperate and subpolar evergreen ombrophilous forest
				IA7	temperate evergreen seasonal broad-leaved forest
				IA8	winter-rain evergreen broad-leaved sclerophyllous forest
				IA9	tropical and subtropical evergreen needle-leaved forest
				IA10	temperate and subpolar evergreen needle-leaved forest
..		**IB**	mainly deciduous forest	**IB1**	tropical and subtropical drought-forest
				IB2	cold-deciduous forest with evergreen trees (or shrubs)
				IB3	cold-deciduous forest without evergreen trees
..		**IC**	extremely xeromorphic forest	**IC1**	sclerophyllous-dominated extremely xeromorphic forest
				IC2	thorn-forest
				IC3	mainly succulent forest
II	woodland	**IIA**	mainly evergreen woodland	**IIA1**	evergreen broad-leaved woodland
				IIA2	evergreen needle-leaved woodland
		IIB	mainly deciduous woodland	**IIB1**	drought-deciduous woodland
				IIB2	cold-deciduous woodland with evergreen trees
				IIB3	cold-deciduous woodland without evergreen trees
..		**IIC**	extremely xeromorphic woodland	**IIC$_X$**	subdivisions as extremely xeromorphic forest (See IC)
III	scrub	**IIIA**	mainly evergreen scrub	**IIIA1**	evergreen broad-leaved shrubland (or thicket)
				IIIA2	evergreen needle-leaved and microphyllous shrubland

Class		Subclass		Group	
..		**IIIB**	mainly deciduous scrub	**IIIB1**	drought-deciduous scrub with evergreen woody plants admixed
				IIIB2	drought-deciduous scrub without evergreen woody plants admixed
				IIIB3	cold-deciduous scrub
..		**IIIC**	extremely xeromorphic (subdesert) shrubland	**IIIC1**	mainly evergreen subdesert shrubland
				IIIC2	deciduous subdesert shrubland
IV	dwarf scrub and related communities	**IVA**	mainly evergreen dwarf-scrub	**IVA1**	evergreen dwarf-scrub thicket
				IVA2	evergreen dwarf shrubland
				IVA3	mixed evergreen dwarf-shrubland and herbaceous formation
..		**IVB**	mainly deciduous dwarf-scrub	**IVB1**	facultatively drought-deciduous dwarf-thicket (or dwarf-shrubland)
				IVB2	obligatory, drought-deciduous dwarf-thicket (or dwarf-shrubland)
				IVB3	cold-deciduous dwarf-thicket (or dwarf-shrubland)
..		**IVC**	extremely xeromorphic dwarf-shrubland	**IVC_X**	subdivisions as extremely xeromorphic (subdesert) shrubland (See IIIC)
..		**IVD**	tundra	**IVD1**	mainly bryophyte tundra
				IVD2	mainly lichen tundra
..		**IVE**	mossy bog formations with dwarf-shrub	**IVE1**	raised bog
				IVE2	non-raised bog
V	herbaceous vegetation	**VA**	tall graminoid vegetation	**VA1**	tall grassland with a tree synusia covering 10-40%
				VA2	tall grassland with a tree synusia <10%
				VA3	tall grassland with a synusia of shrubs
				VA4	tall grassland with a woody synusia
				VA5	tall grassland practically without woody synusia
..		**VB**	medium tall grassland	**VB1**	medium tall grassland with a tree synusia covering 10-40%
				VB2	medium tall grassland with a synusia <10%

Class		Subclass		Group	
				VB3	medium tall grassland with a synusia of shrubs
				VB4	medium tall grassland with an open synusia of tuft plants (usually palms)
				VB5	medium tall grassland practically without woody synusia
..		**VC**	short grassland	**VC1**	short grassland with a tree synusia covering 10-40%
				VC2	short grassland with a tree synusia <10%
				VC3	short grassland with a synusia of shrubs
				VC4	short grassland with an open synusia of tuft plants
				VC5	short grassland practically without woody synusia
				VC6	short to medium tall mesophytic grassland
				VC7	graminoid tundra
..		**VD**	forb vegetation	**VD1**	tall forb communities
				VD2	low forb communities
..		**VE**	hydromorphic fresh-water vegetation	**VE1**	rooted fresh-water communities
				VE2	free-floating fresh-water communities
VI	barren	**VIB**	barren	**VIB**	non vegetated or very sparse vegetation less than 5%

PART III MISCELLANEOUS FILES

8 Reference files

Tables containing information on the source materials used for the compilation of SOTER units, generally soil maps, the laboratories that analysed the soil samples, the laboratory methods and the organisations responsible for the national profile database are described in this Chapter.

Table 8
Attributes of source material related tables.

SOURCE MAP		LABORATORY		PROFILE DATABASE	
1	map_ID	1	lab_ID	1	soil profile database_ID
2	map title	2	laboratory name	2	main author (s)
3	year			3	year
4	scale			4	title of document
5	minimum latitude (y)	LABORATORY METHOD		5	name of institute and/or reference document
6	minimum longitude (x)				
7	maximum latitude (y)	3	lab_ID	6	publisher
8	maximum longitude(x)	4	year	7	chapter /page
9	UTM zonetype of map	5	month	8	digital source (url)
10	geodetic datum	6	attribute		
11	minimum easting	7	method of analysis_ID		
12	minimum northing	ANALYTICAL METHOD			
13	maximum easting				
14	maximum northing	8	method of analysis_ID		
15	type of map	9	brief description		

Note: for coding conventions see text.

8.1 Source map

Information on type of map, scale, location and date are stored in the table *source map* (see Table 8). The location in maximum and minimum X and Y-coordinates or in easting and northing can be used in GIS to overlay this information on the SOTER map.

1 map_ID
Code for the source map from which the primary data were derived; it is a combination of the *ISO country code* and a sequential number for the source map. See *map_ID* in Section 6.1.

2 map title
Title of the source map; there is room to cover 200 characters.

3 year
The *year* of publication of the source map.

4 scale

The *scale* of the source map as a representative fraction. For example 1000000 for a 1:1 million map.

5 minimum latitude

The *minimum latitude* (Y-coordinate) of the source map, in decimal degrees North. Latitude South is a negative figure (-).

6 minimum longitude

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

7 maximum latitude

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

8 maximum longitude

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

9 UTM zone

The *UTM zone* of the source map. A number for the longitudinal belt (1-60) combined by a letter for the latitudinal belt (C-X).

10 geodetic datum

The *geodetic datum* of the source map.

11 minimum easting

The *minimum easting* of the source map.

12 minimum northing

The *minimum northing* of the source map.

13 maximum easting

The *maximum easting* of the source map.

14 maximum northing

The *maximum northing* of the source map.

15 type of source map

The *type of source map*:

S (conventional) soil map
D digital soil map
M morpho-pedological map (soil-landscapes)
O other

8.2 Laboratory information

Analytical method applied in a particular laboratory and coded as separate entities.

Laboratory

1 lab_ID
Unique code for the laboratory where the reference soil profiles were analysed. Constitutes of an *ISO country code* plus a sequential number (e.g. BR001).

2 laboratory name
Name of the laboratory in full (up to 200 characters).

Laboratory method

3 lab_ID
Unique laboratory code.

4 year
The *year* in which the laboratory introduced a method for a given attribute. Format is YYYY.

5 month
The *month* in which the laboratory introduced a method for a given attribute. Format MM; in combination with 4 (year of introduction).

6 attribute
The soil horizon *attribute* for which the laboratory method applies. See Annex 8 for attribute coding conventions.

7 method of analysis_ID
Unique code for the analytical method applied. This code consists of the attribute code (item 6), separated by a slash, and followed by a sequential number for the analytical method (e.g. 104/2 = percentage clay according to hydrometer method). This is now obsolete and replaced by e.g. 104/TE03; clay percentage measured by hydrometer method with dispersion treatment. TE03 is the method of analysis_ID *(AM_ID)*. See also Annex 8.

Analytical method

8 method of analysis_ID
Method of analysis_ID code as given under 7.

9 description
A short *description* of the analytical method, including references up to 256 characters long.

8.3 Soil profile database

Holds information on the (national) soil profile database that has been consulted for the selection of the SOTER profile data. Coded using *ISO country code*.

1 profile database_ID
The identification code for the owner, institute or organisation that holds (part of) the reference soil profile database. Code consists of an *ISO country code* (see Annex 7) and a sequential number.

2 main author(s)
The name of the *main author* of the report, study, database or other data source. Sometimes this can be substituted by the name of the institute or organization that is owner of the dataset (200 characters).

3 year
The *year* of publishing the report, study or data source.

4 title
The *title* of the report, study, database or other data source (up to 100 characters).

5 **name of the owner of the data**
Name (in full) of the owner, institute or organisation of the (inter-) national soil profile database and address, or the name of the original soil survey report, regional study, or other reference document from which the profiles were retrieved (up to 100 characters).

6 publisher
Publisher of the document or original source

7 chapter/page
Chapter and/or pages in the document where the original description and analytical data can be found.

8 digital data source
The URL of the *digital data source* from which the data can be downloaded or consulted.

Annex 1 Miscellaneous polygons

Miscellaneous polygons in SOTER are areas of land that have a non-soil cover, an ice mantle or water body, etc. These 'non-soil' areas were mapped as miscellaneous land units (FAO-Unesco 1974). In the Harmonized World Soil Database (FAO *et al.* 2008) they are recoded and harmonized.

Non-soil units and non-soil parts

Non soil units (coded ns) correspond with regions where there is no soil mantle, such as bare rock expanses; glaciers or land ice; shifting sands; urban areas; etc. In principle two situations can exist:

a) the entire SOTER unit is covered and mapable.
b) parts or areas where the non-soil cover represent a proportion of the SOTER unit and can thus be considered at soil component level.

a) Differentiation at SOTER unit level

When the entire polygon consists of a non-soil unit (Table 9), a special entry is made in the GIS database for identification in the map legend; however, they are not treated as SOTER units. In the GIS file these polygons are coded according to the SOTER code (FAO *et al.* 2008); the list can still be extended. See Table 9. In the GIS file, the polygon will be labelled as:

ISO (country code) + (SOTER code): e.g. **BRns1**, signifying a lake (ns1) in Brazil.

Table 9
Codes for non-soil units in the GIS file and attribute database.

SOTER code	FAO symbols[a)]	Description
ns1	WR	lakes, permanent inland water bodies
ns2	GG	glaciers, land ice, permanent snow fields
ns3	ST	salt plains, salt flats
ns4	DS	dunes, (shifting) sands
ns5	RK	rock outcrops, crumbly rocks
ns6	UR	urban, building areas
ns7	QU	quarry, open air mining (coal) and other excavations, etc.
ns8	SW	perennial swamps, inaccessible marshes
ns9	SL	salt lakes
ns10	BL	bad lands
ns11	FP	fish ponds
-	-	-
ns99	NI	no data

[a)] Symbols are according to FAO *et al.* (2008).

b) Differentiation at soil component level

When small areas of lakes, land ice, rock outcrops, etc., cannot be mapped as a mapping unit, they are coded at soil component level as follows:

The normal *SOTER_Unit_ID* is given, including the terrain- and soil component number, but under the field/column where the *profile_ID (PRID)* is stored: the **ISO (country code) # (SOTER code)** is entered; for example **BR#ns1** for say 15% lakes within a SOTER unit in Brazil.

NOTE: The difference in the code (# mark) separates the ISO country code from SOTER code (Table 9).

In a legend, the non-soil coding can follow the 'FAO code' (column: 'FAO symbol'). It substitutes SOTER code for the non-soil units in the listing of the classification according to Revised Legend (FAO-Unesco 1988) or Soil Reference Group of WRB (IUSS 2006).

Annex 2 Hierarchy of landforms

The term landform, as used here, is defined as land with a characteristic slope and relief index (Remmelzwaal 1991). Landform separation (first and second level) is thus based on morphometric criteria, starting with the slope gradient. The relief index is the second most important criterion for subdividing the landscape. Subdivisions of level land also take into account the position of the landform vis-à-vis the surrounding land. Further separation of the landforms according to hypsometric criteria is different for each 1st level landform (see Chapter 6, item 13). Exceptions to this are noted with the description of the 2nd level landforms. The classification as presented here has first been tested for a 1:5 million physiographic inventory of Latin America and Africa (Eschweiler 1993; Wen 1993) and more recently in the e-SOTER project (www.esoter.net).

1st Level landforms

Level land

Level land comprises land with dominant slopes between 0 and 10% (0° and 5°42'). Moreover, the relief index is such that the difference between the highest and the lowest point within one slope unit is mostly less than 50 m.

Sloping land

Sloping land embraces all landforms that have dominant slopes between 10% and 30%, usually combined with a relief index of more than 50 m per slope unit. In general, sloping land will be more heterogeneous with respect to its slope than level land.

Steep land

Steep land is mainly confined to mountainous country, where average slopes are over 30% (the variability of slope gradients may be so great as to make it difficult to recognize a dominant slope) and the relief index is more than 300 m km^{-1} (within a radius of 500 meters).

2nd Level landforms

L Level land

Except for low-gradient footslope, all types of level land 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 10%, areas with a perceptible slope may still be considered level land.

LP Plains

Plain is all level land that is not enclosed between higher lying land, or that do not protrude above the surrounding country, or do not rise against land with a considerable steeper slope.

LL Plateaus

Plateau is level land that is, compared with the surrounding landscape, situated at relatively elevated position. Plateau can be very extensive, but must always on at least one side be bounded by a slope or escarpment (with a slope of 10% or more), connecting it with lower lying land. Many so-called plateaus 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 foot slopes

Steadily rising level land, abutting strongly sloping or steep land, is classified as low gradient footslope. They merge into other types of level land, including low gradient foot slopes that rise in an opposite direction. Pediments, (coalescing) alluvial fans and other similar landforms can all be considered low gradient foot slopes. Foot slopes with a higher gradient than 10% 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, often on both sides flanked by areas of flat, sloping or steep land located near a natural drainage channel (river), constitute valley floors. Valley floors normally taper off at one end, where they are often embraced by steeper land on three sides. They may connect with other types of level land or sloping land at the other end. In flat land the floodplains are considered as valley floors.

S Sloping land

Sloping land is land with a gradient between 10 and 30%. In most cases the relief index of sloping land is more than 50 m per slope unit.

SE Medium-gradient escarpment zone

Relatively gently sloping (usually 15-30% gradient) zone that forms a transition between high and low lying country with distinct lower gradients. The local relief index of this landform is normally less than 300 m km^{-1}.

SH Medium-gradient hills

All sloping land with an undulating relief (minimum relief index 50 m per slope unit) and that is, not more than 300 m high, and not incorporated in mountainous terrain, are considered hills. This group does not only include hilly landforms, but also accommodates other landforms such as medium-gradient footslope, ridges, etc.

SM Medium-gradient mountains

Relatively gentle sloping (15-30% gradient) mountains with a local relief index of more than 300 m km^{-1}. Many volcanoes will fall into this category, as do several foothill zones of major mountain systems.

SP Dissected plains
Sloping land with a more or less constant crest level, resulting in slope gradients of less than 10%, but with relief intensities between 50 and 100 m km^{-1}.

SV Medium gradient valleys
Elongated strips of sloping land, often on both sides flanked by areas, of strongly sloping or steep land, constitute medium gradient 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 sloping land at the other end. In mountainous areas valley floors can be surrounded on all sides by steep land, and do not necessarily have to be elongated.

T Steep land
All land with slope gradients in excess of 30% is considered steep land. The main landform in this category is mountainous land.

TE High-gradient escarpment zone
Steep land that forms the transition between high and low lying country and lacks outstanding peaks. The relief index is normally more than 300 m km^{-1}.

TH High-gradient hills
Steep but low relief land (relief index of less than 300 m km^{-1}). Bad lands would be a landform taken care of by this group.

TM High-gradient mountains
All steep land with a relief index of more than 300 m km-1, and surrounded by one or more outstanding peaks.

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 mapable delineations. Mostly found in incised elevated sedimentary plateaus.

Annex 3 Diagnostic horizons, properties and materials of Soil Reference Groups and WRB Legend

3.1 Diagnostic horizons

Characterization of diagnostic horizons, diagnostic properties and diagnostic materials is according to the World Reference Base for Soil Resources (IUSS 2006, 2007).

AL albic

The albic horizon is a light-coloured subsurface horizon from which clay and free iron oxides have been removed, or in which the oxides have been segregated to the extent that the colour of the horizon is determined by the colour of the sand and silt particles rather than by coatings of these particles. It generally has a weakly expressed soil structure or lacks structural development altogether. The upper and lower boundaries are normally abrupt or clear. Albic horizons usually have coarser textures than the overlying or under lying horizons. However, with respect to an underlying *spodic* horizon, this difference may only be slight. Many albic horizons are associated with wetness and contain evidence of *reducing conditions*. An albic horizon has:

1. a Munsell colour (dry) **e***ither:*
   a) a value of 7 or 8 and a chroma of 3 or less; ***or***
   b) a value of 5 or 6 and a chroma of 2 or less; ***and***
2. a Munsell colour (moist) ***either:***
   a) a value of 6, 7 or 8 and a chroma 4 or less; ***or***
   b) a value of 5 and chroma of 3 or less; ***or***
   c) a value of 4 and a chroma 2 or less. A chroma of 3 is permitted if the parent materials have a hue of 5YR or

      redder, and the chroma is due to the colour of uncoated silt or sand grains; ***and***
3. a thickness of 1 cm or more

AH anthric

The anthric horizon is a moderately thick, dark-coloured surface horizon that is the result of long-term cultivation (ploughing, liming, fertilization, etc.). An anthric horizon is a mineral surface horizon and:

1. meets all colour, structure and organic matter requirements of a *mollic* or *umbric* horizon; ***and***
2. shows evidence of human disturbance by having one or more of the following:
   a) an abrupt lower boundary change at ploughing depth, a *plough pan*; ***or***

b) lumps of applied lime; ***or***

c) mixing of soil layers by cultivation; ***or***

d) 1.5 g kg^{-1} or more P_2O_5 soluble in 1% citric acid; ***and***

3. has less than 5% (by volume) of animal pores, coprolites or other traces of soil animal activity below tillage depth; ***and***
4. has a thickness of 20 cm or more.

AQ anthraquic

The anthraquic horizon is a human-induced surface horizon that comprises a *puddled layer* and *plough pan*. An anthraquic horizon has:

1. a puddled layer with both:
   a) a Munsell colour hue of 7.5YR or yellower, or GY, B or BG hues; a value (moist) of 4 or less, and chroma (moist) of 2 or less; ***and***
   b) sorted soil aggregates and vesicular pores; ***and***
2. a plough pan underlying the puddled layer with all of the following:
   a) a platy structure; ***and***
   b) a bulk density higher by 20% or more (relative) than that of the puddled layer; ***and***
   c) yellowish-brown, brown or reddish-brown Fe-Mn mottles or coatings; ***and***
3. a thickness of 20 cm or more.

AR argic

The argic horizon is a subsurface horizon with distinct higher clay content than the overlying horizon. This textural differentiation may be caused by an illuvial accumulation of clay, by a predominant pedogenetic formation of clay in the subsoil, by destruction of clay in the surface horizon, by selective surface erosion of clay, by upward movement of coarser particles due to swelling and shrinking, by biological activity or by a combination of two or more of these different processes. Sedimentation of surface materials that are coarser than the subsurface horizon may enhance a pedogenetic textural differentiation. However, a mere lithological discontinuity, such as may occur in alluvial deposits, does not qualify as an argic horizon. An argic horizon has:

1. a texture of sandy loam or finer and 8% or more clay in the fine earth fraction; ***and***
2. one or both of the following:
   a) if an overlying coarser textured horizon is present that is not ploughed and not separated from the argic horizon by a *lithological discontinuity*, more total clay than this overlying horizon such that:
      i) if the overlying horizon has less than 15% clay in the fine earth fraction, the argic horizon must contain at least 3% more clay; ***or***
      ii) if the overlying horizon has 15% or more but less than 40% clay in the fine earth fraction, the ratio of clay in the argic horizon to that of the overlying horizon must be 1.2 or more; ***or***
      iii) if the overlying horizon has 40% or more clay in the fine earth fraction, the argic horizon must contain at least 8% more clay; ***or***

b) evidence of clay illuviation in one or more of the following forms:

   i) oriented clay bridging of the sand grains; ***or***

   ii) clay films lining pores; ***or***

   iii) clay films on both vertical and horizontal surfaces of soil aggregates; ***or***

   iv) in thin section, oriented clay bodies that constitute 1% or more of the section; ***or***

   v) a COLE of 0.04 or higher, ***and*** a ratio of fine clay to total clay in the argic horizon greater by 1.2 or more than the ratio in the overlying coarser textured horizon; ***and***

3. if an overlying coarser textured horizon is present that is not ploughed and not separated from the argic horizon by a *lithological discontinuity*, an increase in clay content within a vertical distance of one of the following:

   a) 30 cm, if there is evidence of clay illuviation; ***or***

   b) 15 cm, in all other cases; ***and***

4. does not form part of a *natric* horizon; ***and***

5. a thickness of one tenth or more of the sum of the thickness of all overlying mineral horizons, if present, and one of the following:

   a) 7.5 cm or more, if it is not entirely composed of lamellae (that are 0.5 cm or more thick) and the texture is finer than loamy sand; ***or***

   b) 15 cm or more (combined thickness, if composed entirely of lamellae that are 0.5 cm or more thick).

CA calcic

The calcic horizon is a horizon in which secondary calcium carbonate (CaCO3) has accumulated in a diffuse form (calcium carbonate present only in the form of fine particles of less than 1 mm, dispersed in the matrix) or as discontinuous concentrations (pseudomycelia, cutans, soft and hard nodules, or veins). A calcic horizon has:

1. a calcium carbonate equivalent content in the fine earth fraction of 15% or more; ***and***

2. 5% or more (by volume) *secondary carbonates* ***or*** a calcium carbonate equivalent of 5% or more higher (absolute, by mass) than that of an underlying layer; ***and***

3. a thickness of 15 cm or more.

CB cambic

The cambic horizon is a subsurface horizon showing evidence of alteration relative to the underlying horizons. A cambic horizon has:

1. a texture in the fine earth fraction of very fine sand, loamy very fine sand or finer; ***and***

2. soil structure ***or*** absence of rock structure in 50% or more of the volume of the fine earth; ***and***

3. shows evidence of alteration in one or more of the following:

   a) higher Munsell chroma (moist), higher value (moist), redder hue, or higher clay content than the underlying or an overlying layer; ***or***

b) evidence of removal of carbonates or gypsum; ***or***

c) presence of soil structure ***and*** absence of rock structure in the entire fine earth, if carbonates and gypsum are absent in the parent material and in the dust that falls on the soil; ***and***

4. does not form part of a plough layer, does not consist of *organic* material and does not form part of an *anthraquic, argic, calcic, duric, ferralic, fragic, gypsic, hortic, hydragric, irragric, mollic, natric, nitic, petrocalcic, petroduric, petrogypsic, petroplinthic, pisoplinthic, plaggic, plinthic, salic, sombric, spodic, umbric, terric, vertic* or *voronic* horizon; ***and***

5. a thickness of 15 cm or more.

CY cryic

The cryic horizon is a perennially frozen soil horizon in *mineral* or *organic* materials. A cryic horizon has:

1. continuously for two or more consecutive years one of the following:

   a) massive ice, cementation by ice or readily visible ice crystals; ***or***

   b) a soil temperature of 0° C or less and insufficient water to form readily visible ice crystals; ***and***

2. a thickness of 5 cm or more

DU duric

The duric horizon is a subsurface horizon showing weakly cemented to indurated nodules or concretions cemented by silica (SiO_2), presumably in the form of opal and micro-crystalline forms of silica (*durinodes*). A duric horizon has**:**

1. 10% or more (by volume) of weakly cemented to indurated, silica-enriched nodules (*durinodes*) or fragments of a broken-up *petroduric* horizon that show all of the following:

   a) when air-dry, less than 50% slake in 1 *M* HCl even after prolonged soaking, but 50% or more slake in concentrated KOH, concentrated NaOH or in alternating acid and alkali; ***and***

   b) are firm or very firm and brittle when wet, both before and after treatment with acid; ***and***

   c) have a diameter of 1 cm or more; ***and***

2. a thickness of 10 cm or more.

FA ferralic

The ferralic horizon is a subsurface horizon resulting from long and intense weathering in which the clay fraction is dominated by low-activity clays, and the silt and sand fractions by highly resistant minerals, such as (hydr)oxides of Fe, Al, Mn and titanium (Ti). A ferralic horizon has:

1. a sandy loam or finer particle size and less than 80% (by volume) gravel, stones, pisoplinthic or petroplinthic concretions; ***and***

2. a CEC (by 1 *M* NH_4OAc) of less than 16 $cmol_c kg^{-1}$ clay and an ECEC (sum of exchangeable bases plus exchangeable acidity in 1 *M* KCl) of less than 12 $cmol_c$ kg^{-1} clay; ***and***

3. less than 10% water-dispersible clay, unless it has one or both of the following:

a) *geric* properties; ***or***

b) 1.4% or more organic carbon; ***and***

4. less than 10% (by grain count) weatherable minerals in the 0.05-0.2 mm fraction; ***and***
5. does not have *andic* or *vitric* properties; ***and***
6. a thickness of 30 cm or more.

FI ferric

The ferric horizon is a subsurface horizon in which segregation of Fe, or Fe and Mn, has taken place to such an extent that large mottles or discrete nodules have formed and the intermottle/internodular matrix is largely depleted of Fe. Generally, such segregation leads to poor aggregation of the soil particles in Fe-depleted zones and compaction of the horizon. A ferric horizon:

1. has one or both of the following:
   a) 15% or more of the exposed area occupied by coarse mottles with a Munsell hue redder than 7.5YR and a chroma of more than 5 (moist); ***or***
   b) 5% or more of the volume consisting of discrete reddish to blackish nodules with a diameter of 2 mm or more, with the exteriors of the nodules being at least weakly cemented or indurated, and the exteriors having redder hue or stronger chroma than the interiors; ***and***
2. does not form part of a petroplinthic, pisoplinthic or plinthic horizon; ***and***
3. has a thickness of 15 cm or more.

FO folic

The folic horizon is a (sub-)surface horizon occurring at shallow depth that consists of well-aerated *organic* material. A folic horizon consist of *organic* material that:

1. is saturated with water for less than 30 consecutive days in most years; ***and***
2. has a thickness of 10 cm or more.

FR fragic

The fragic horizon is a natural non-cemented subsurface horizon with pedality and a porosity pattern such that roots and percolating water penetrate the soil only along interped faces and streaks. The natural character excludes plough pans and surface traffic pans.

A fragic horizon:

1. show evidence of alteration, as defined in *cambic* horizon, at least on the faces of structural units; separations between these units which allow roots to enter, have an average horizontal spacing of 10 cm or more; ***and***
2. contains less than 0.5% (by mass) organic carbon; ***and***
3. shows in 50% or more of the volume slaking or fracturing of air-dry clods of 5-10 cm in diameter, within 10 minutes when placed in water; ***and***
4. does not cement upon repeated wetting and drying; ***and***
5. has a penetration resistance at field capacity of 4 MPa or more in 90% or more of the volume; ***and***
6. does not show effervescence after adding a 1 *M* HCl solution: ***and***
7. has a thickness of 15 cm or more.

FU fulvic

The fulvic horizon is a thick, dark coloured horizon at or near to the surface that is typically associated with short-range-order minerals (commonly allophane) or with organo-aluminium complexes. It has a low bulk density and contains highly humified organic matter that shows a lower ratio of humic acids to fulvic acids compared with the *melanic* horizon.

A fulvic horizon has:

1. *andic* properties; ***and***
2. one or both of the following:
   a) a Munsell colour value or chroma (moist) of more than 2; ***or***
   b) a melanic index of 1.70 or more; ***and***
3. a weighted average of 6% or more organic carbon, and 4% or more organic carbon in all parts; ***and***
4. a cumulative thickness of 30 cm or more with less than 10 cm non-fulvic material in between.

GY gypsic

The gypsic horizon is a commonly non-cemented horizon containing secondary accumulations of gypsum ($CaSO_4.2H_2O$) in various forms. A gypsic horizon has:

1. 5% or more gypsum (the percentage gypsum can be calculated as the product of gypsum content, expressed as $cmol_c$ kg^{-1} soil, and the equivalent mass of gypsum (86) expressed as a percentage) and 1% or more (by volume) visible secondary gypsum; ***and***
2. a product of thickness (in cm) times gypsum content (percentage) of 150 or more; ***and***
3. a thickness of 15 cm or more.

HI histic

The histic horizon is a (sub-)surface horizon occurring at shallow depth that consists of poorly aerated *organic* material. A histic horizon consists of organic material that:

1. is saturated with water for 30 consecutive days or more in most years (unless drained); ***and***
2. has a thickness of 10 cm or more. If the histic horizon is less than 20 cm thick, the upper 20 cm of the soil after mixing, or if continuous rock is present within 20 cm depth, the entire soil above, after mixing, must contain 20% or more organic carbon.

HO hortic

The hortic horizon is a human-induced mineral surface horizon that results from deep cultivation, intensive fertilization and/or long-continued application of human and animal wastes and other organic residues (e.g. manures, kitchen refuse, compost, etc). A hortic horizon has:

1. a Munsell colour value and chroma (moist) of 3 or less; ***and***
2. a weighted average organic carbon content of 1% or more; ***and***
3. a 0.5 *M* $NaHCO_3$ extractable P_2O_5 content of 100 mg kg^{-1} fine earth or more in the upper 25 cm; ***and***
4. a base saturation (by1 *M* NH_4OAc) of 50% or more; ***and***
5. 25% (by volume) or more of animal pores, coprolites or other traces of soil

animal activity; ***and***

6. a thickness of 20 cm or more.

HY hydragric

The hydragric horizon is a human-induced subsurface horizon associated with wet cultivation. A hydragric horizon has:

1. one or more of the following:
   a) Fe or Mn coatings or Fe or Mn concretions; ***or***
   b) dithionite-citrate extractable Fe 2 times or more, or dithionite-citrate extractable Mn 4 times or more that of the surface horizon; ***or***
   c) redox depletion zones with a Munsell colour value of 4 or more and chroma of 2 or less (moist) in macropores; ***and***
2. a thickness of 10 cm or more.

IR irragric

The irragric horizon is a human-induced mineral surface horizon that builds up gradually through continuous application of irrigation water with substantial amounts of sediments and which may include fertilizers, soluble salts, organic matter, etc. An irragric horizon has:

1. a uniformly structured surface layer; ***and***
2. a higher clay content, particularly fine clay, than the underlying original soil; ***and***
3. a relative difference among medium, fine and very fine sand, clay and carbonates of less than 20% among parts within the horizon; ***and***
4. a weighted average organic carbon content of 0.5% or more, decreasing with depth, but remaining at 0.3% or more at the lower limit of the irragric horizon; ***and***
5. 25% (by volume) or more of animal pores, coprolites or other traces of soil animal activity; ***and***
6. a thickness of 20 cm or more.

ME melanic

The melanic horizon is a thick, black horizon at or near to the surface that is typically associated with short-range-order minerals (commonly allophane) or with organo-aluminium complexes. It has a low bulk density and contains highly humified organic matter that shows a lower ratio of fulvic acids to humic acids compared with the fulvic horizon. A melanic horizon has:

1. *andic* properties; ***and***
2. a Munsell colour value and chroma (moist) of 2 or less; ***and***
3. a melanic index of less than 1.70; ***and***
4. a weighted average of 6% or more organic carbon, and 4% or more organic carbon in all parts; ***and***
5. a cumulative thickness of 30 cm or more with less than 10 cm non-melanic material in between.

MO mollic

The mollic horizon is a thick, well-structured, dark coloured surface horizon with a high base saturation and a moderate to high content of organic matter.

A mollic horizon, **after mixing** either **the upper 20 cm** of the mineral soil or, if *continuous rock*, a *cryic, petrocalcic, petroduric, petrogypsic* or *petroplinthic* horizon is present within 20 cm from the mineral soil surface, the entire mineral soil above, has:

1. a soil structure sufficiently strong that the horizon is not both massive and hard or very hard when dry in both the mixed part and the underlying unmixed part of the horizon, if the minimum thickness is larger than 20 cm (prisms larger than 30 cm in diameter are included in the meaning of massive if there is no secondary structure within the prisms); ***and***

2. Munsell colours with a chroma of 3 or less when moist, a value of 3 or less when moist and 5 or less when dry on broken samples in both the mixed part and the underlying unmixed part of the horizon, if the minimum thickness is larger than 20 cm. If there is 40% or more finely divided lime, the limits of the dry colour value are waived; the colour value, moist, is 5 or less. The colour value is one unit or more, darker than that of the parent material (both moist and dry), unless the parent material has a colour value of 4 or less, moist, in which case the colour contrast requirement is waived. If a parent material is not present, comparison must be made with the layer immediately underlying the surface layer; ***and***

3. an organic carbon content of 0.6% or more in both the mixed part and the underlying unmixed part of the horizon if the minimum thickness is larger than 20 cm. The organic carbon content is 2.5% or more if the colour requirements are waived because of finely divided lime, or 0.6% more than in the parent material if the colour requirements are waived because of dark coloured parent materials; ***and***

4. a base saturation (by 1 *M* NH_4OAc) of 50% or more on a weighted average throughout the depth of the horizon; ***and***

5. a thickness of one of the following:

    a) 10 cm or more if directly overlying *continuous rock*, or a *cryic, petrocalcic, petroduric, petrogypsic*, or *petroplinthic* horizon; ***or***

    b) 20 cm or more and 1/3 or more of the thickness between the mineral soil surface and the upper boundary of *continuous rock*, or a *calcic, cryic, gypsic, petrocalcic, petroduric, petrogypsic*, *petroplinthic* or *salic* horizon or *calcaric, fluvic* or *gypsyric* material within 75 cm; ***or***

    c) 20 cm or more and 1/3 or more of the thickness between the mineral soil surface and the lower boundary of the lowest diagnostic horizon within 75 cm and, if present, above any of the diagnostic horizons or materials listed under b; ***or***

    d) 25 cm or more in all other cases.

NA natric

The natric horizon is a dense subsurface horizon with distinct higher clay content than the overlying horizon(s). It has a high content in exchangeable Na and/or Mg.

A natric horizon is an argic horizon that has the properties **1 to 3, and 5** of the *argic* horizon **and *additionally***:

1. one or more of the following:

    a) a columnar or prismatic structure in some part of the horizon; ***or***

    b) a blocky structure with tongues of an overlying coarser textured horizon in which there are uncoated silt or sand grains, extending 2.5 cm or more into the natric horizon; ***or***

c) a massive appearance; ***and***

2. an exchangeable Na percentage (ESP) of 15% or more within the upper 40 cm; ***or*** more exchangeable Mg plus Na than Ca plus exchange acidity (at pH 8.2) within the same depth, if the saturation with exchangeable Na is 15% or more in some sub-horizon within 200 cm of the soil surface.

NI nitic

The nitic horizon is a clay-rich subsurface horizon. It has a moderately to strongly developed polyhedric structure breaking to flat-edged or nutty elements with many shiny ped faces, which cannot or can only partially be attributed to clay illuviation. A nitic horizon has:

1. less than 20% change (relative) in clay content over 12 cm to layers immediately above and below; ***and***
2. all of the following:
   a) 30% or more clay; ***and***
   b) a water-dispersible clay to total clay ratio less than 0.10; ***and***
   c) a silt to clay ratio less than 0.40; ***and***
3. moderate to strong, angular blocky structure breaking to flat-edged or nut-shaped elements with shiny ped faces. The shiny ped faces are not, or only partially, associated with clay coatings; ***and***
4. all of the following:
   a) 4% or more citrate-dithionite extractable Fe (*free* iron) in the fine earth fraction; ***and***
   b) 0.20% or more acid oxalate (pH 3) extractable Fe (*active* iron) in the fine earth fraction; ***and***
   c) a ratio between *active* and *free* iron of 0.05 or more; ***and***
5. a thickness of 30 cm or more.

OC ochric

The ochric A horizon is a surface horizon that is too light in colour, has too high chroma, too little organic carbon, or is too thin to be mollic, umbric or voronic, or is both hard and massive when dry. Stratified materials, e.g. surface layers of fresh alluvial deposits, do not qualify as an ochric horizon.

PA plaggic

The plaggic horizon is a black or brown human-induced mineral surface horizon that has been produced gradually by long-continued manuring. In medieval times, sod and other materials were commonly used for bedding of livestock and the manure was spread on fields being cultivated. The mineral materials brought in by this kind of manuring eventually produced an appreciably thickened horizon (in places as much as 100 cm or more thick) that is rich in organic carbon. Base saturation is typically low. A plaggic horizon has:

1. a texture of sand, loamy sand, sandy loam, or loam or a combination of them; ***and***
2. contains *artefacts*, but less than 20%, has spade marks below 30 cm depth or other evidence of agricultural activity below 30 cm depth; ***and***
3. Munsell colours with a value of 4 or less, moist, or 5 or less, dry, and a

chroma of 2 or less; ***and***

4. an organic carbon content of 0.6% or more; ***and***
5. occurs in locally raised land surfaces; ***and***
6. a thickness of 20 cm or more.

PC petrocalcic

The petrocalcic horizon is an indurated *calcic* horizon that is cemented by calcium carbonate and, in places, by calcium and some magnesium carbonate. It is either massive or platy in nature, and extremely hard. A petrocalcic horizon has:

1. very strong effervescence after adding a 1 *M* HCl solution; ***and***
2. induration or cementation, at least partially by secondary carbonates, to the extent that air-dry fragments do not slake in water and roots cannot enter except along vertical fractures (which have an average horizontal spacing of 10 cm or more and which occupy less than 20% (by volume) of the layer); ***and***
3. an extremely hard consistence when dry, so that it cannot be penetrated by spade or auger; ***and***
4. a thickness of 10 cm or more, or 1 cm or more if it is laminar and rests directly on *continuous rock.*

PD petroduric

The petroduric horizon, also known as duripan or dorbank (South Africa), is a subsurface horizon, usually reddish or reddish brown in colour that is cemented mainly by secondary silica (SiO_2, presumably opal and microcrystalline forms of silica). Air-dry fragments of petroduric horizons do not slake in water, even after prolonged wetting. Calcium carbonate may be present as accessory cementing agent. A petroduric horizon has:

1. induration or cementation in 50% or more (by volume) of some subhorizon; ***and***
2. evidence of silica accumulation (opal or other forms of silica) e.g. as coatings in some pores, on some structural faces or as bridges between sand grains; ***and***
3. when air-dry, less than 50% (by volume) that slakes in 1 *M* HCl even after prolonged soaking but 50% or more that slakes in concentrated KOH, concentrated NaOH or in alternating acid and alkali; ***and***
4. a lateral continuity such that roots cannot penetrate except along vertical fractures (which have an average horizontal spacing of 10 cm or more and which occupy less than 20% (by volume) of the layer); ***and***
5. a thickness of 1 cm or more.

PG petro gypsic

The petrogypsic horizon is a cemented horizon containing secondary accumulations of gypsum ($CaSO_4.2H_2O$).

A petrogypsic horizon has:

1. 5% or more gypsum (the percentage gypsum is calculated as the product of gypsum content, expressed as $cmol_c\ kg^{-1}$ soil, and the equivalent mass of gypsum (86) expressed as a percentage) and 1% or more (by volume) visible secondary gypsum; ***and***
2. induration or cementation, at least partially by secondary gypsum, to the extent that air-dry fragments do not slake in water and that roots cannot enter except

along vertical fractures (which have a horizontal spacing of 10 cm or more and which occupy less than 20% (by volume) of the layer); ***and***

3. a thickness of 10 cm or more.

PP petro-plinthic

The petroplinthic horizon is a continuous, fractured or broken layer of indurated material, in which Fe (and in cases also Mn) is an important cement and in which organic matter is either absent or present only in traces. A petroplinthic horizon has:

1. a continuous, fractured or broken sheet of connected, strongly cemented to indurated
   a) reddish to blackish nodules; ***or***
   b) reddish, yellowish to blackish mottles in platy, polygonal, or reticulate pattern; ***and***
2. a penetration resistance of 4.5 MPa or more in 50% or more of the volume; ***and***
3. a ratio between acid oxalate (pH 3) extractable Fe and citrate-dithionite extractable Fe of less than 0.10; ***and***
4. a thickness of 10 cm or more.

PS piso plinthic

The pisoplinthic horizon contains nodules that are strongly cemented to indurated with Fe (and in some cases also with Mn). A pisoplinthic horizon has:

1. 40% or more of the volume occupied by discrete, strongly cemented to indurated, reddish to blackish nodules with a diameter of 2 mm or more; ***and***
2. a thickness of 15 or more.

PL plinthic

The plinthic horizon is a subsurface horizon that consists of an Fe-rich (in some cases also Mn-rich), humus-poor mixture of kaolinitic clay (and other products of strong weathering, such as gibbsite) with quartz and other constituents, and which changes irreversibly to a layer with hard nodules, a hardpan or irregular fragments on exposure to repeated wetting and drying with free access of oxygen.

A plinthic horizon:

1. has within 15% or more of the volume single or in combination:
   a) discrete nodules that are firm to weakly cemented, with a redder hue or stronger chroma than the surrounding material, and which change irreversibly to strongly cemented or indurated nodules on exposure to repeated wetting and drying with free access of oxygen; ***or***
   b) mottles in platy, polygonal or reticulate patterns that are firm to weakly cemented, with a redder hue or stronger chroma than the surrounding material, and, which changes irreversibly to strongly cemented or indurated nodules or mottles on exposure to repeated wetting and drying with free access of oxygen; ***and***
2. does not form part of a *petroplinthic* or *pisoplinthic* horizon; ***and***
3. has both:
   a) 2.5% (by mass) or more citrate-dithionite extractable Fe in the fine earth fraction, or 10% or more in the nodules or mottles; ***and***

b) a ratio between acid oxalate (pH 3) extractable Fe and citrate-dithionite extractable Fe of less than 0.10; ***and***

4. has a thickness of 15 cm or more.

SA salic The salic horizon is a surface or shallow subsurface horizon that contains a secondary enrichment of readily soluble salts, i.e. salts more soluble than gypsum. A salic horizon has:

1. averaged over its depth at some time of the year an electrical conductivity of the saturation extract (EC_e) of 15 dS m^{-1} or more at 25°C, ***or*** an EC_e of 8 dS m^{-1} or more at 25°C if the pH (H_2O) of the saturation extract is 8.5 or more; ***and***
2. averaged over its depth at some time of the year a product of thickness (in cm) times EC_e (in dS m^{-1}) of 450 or more; ***and***
3. a thickness of 15 cm or more.

SP spodic The spodic horizon is a subsurface horizon that contains illuvial amorphous substances composed of organic matter and Al, or of illuvial Fe. The illuvial materials are characterized by a high pH-dependent charge, a relatively large surface area and high water retention. A spodic horizon has:

1. a pH (1:1 in water) of less than 5.9 in 85% or more of the horizon, unless the soil is cultivated; ***and***
2. an organic carbon content of 0.5% or more, ***or*** an optical density of the oxalate extract (ODOE) value of 0.25 or more, at least in some part of the horizon; ***and***;
3. one or both of the following:
   a) an *albic* horizon directly overlying the spodic horizon and has, directly under the albic horizon, one of the following Munsell colours, when moist (crushed and smoothed sample):
      i. a hue of 5YR or redder; ***or***
      ii. a hue of 7.5YR with value of 5 or less and a chroma of 4 or less; ***or***
      iii. a hue of 10YR or neutral and a value and a chroma of 2 or less; ***or***
      iv. a colour of 10YR 3/1; ***or***
   b) with or without an *albic* horizon, one of the colours listed above, or hue of 7.5YR, a value of 5 or less and a chroma of 5 or 6, both when moist (crushed and smoothed sample), ***and*** one or more of the following:
      i. cementation by organic matter and Al with or without Fe, in 50% or more of the volume and a very firm or firmer consistency in the cemented part; ***or***
      ii. 10% or more of the sand grains showing cracked coatings; ***or***
      iii. 0.50% or more Al_{ox} + ½Fe_{ox} and an overlying mineral horizon that has a value less than one-half that amount; ***or***
      iv. an optimal density of the oxalate extract (ODOE) value of 0.25 or more, and a value less than one-half that amount in an overlying

mineral horizon; ***or***

v. 10% or more (by volume) Fe lamellae in a layer 25 cm or more thick; ***and***

4. does not form part of a *natric* horizon; ***and***
5. has a C_{py}/OC and a C_f/C_{py} of 0.5 or more, if occurring under *tephric* material that meets the requirements of an *albic* horizon; ***and***
6. a thickness of at least 2.5 cm or more.

SO sombric

The sombric horizon is a dark-coloured subsurface horizon containing illuvial humus that is neither associated with Al nor dispersed by Na. A sombric horizon has:

1. a lower Munsell colour value or chroma than the overlying horizon; ***and***
2. a base saturation (by 1 *M* NH_4OAc) less than 50%; ***and***
3. evidence of humus accumulation, by a higher organic carbon content with respect to the overlying horizon, or through illuvial humus on ped surfaces or in pores visible in thin sections; ***and***
4. does not underlie an *albic* horizon; ***and***
5. a thickness of 15 cm or more.

TA takyric

The takyric horizon is a heavy-textured surface horizon comprising a surface crust and a platy structured lower part. It occurs under arid conditions in periodically flooded soils. A takyric horizon has:

1. *aridic* properties; ***and***
2. a platy or massive structure; ***and***
3. a surface crust which has ***all*** of the following:
   a) thickness enough that it does not curl entirely upon drying; ***and***
   b) polygonal cracks extending at least 2 cm deep when the soil is dry; ***and***
   c) clay loam, silty clay loam or finer texture; ***and***
   d) very hard consistence when dry, and plastic or very plastic and sticky or very sticky consistence when wet; ***and***
   e) an electrical conductivity of the saturated extract (EC_e) of less than 4 dS m^{-1}, or less than that of the layer immediately below the takyric horizon.

TE terric

The terric horizon is a human-induced mineral surface horizon that develops through addition of earthy manures, compost, beach sand or mud over a long period of time. It builds up gradually and may contain stones, randomly sorted and distributed. A terric horizon has:

1. a colour related to the source material; ***and***
2. less than 20% artefacts (by volume); ***and***
3. a base saturation (by 1 *M* NH_4OAc) of 50% or more; ***and***
4. occurs in locally raised land surfaces; ***and***
5. does not show stratification, but has an irregular textural differentiation; ***and***
6. a *lithological discontinuity* at its base; ***and***

7. a thickness of 20 cm or more.

TH thionic

The thionic horizon is an extremely acid subsurface horizon in which sulphuric acid is formed through oxidation of sulphides. A thionic horizon has:

1. a pH (1:1 in water)of less than 4.0 ; ***and***
2. one or more of the following:
   a) yellow jarosite or yellowish-brown schwertmannite mottles or coatings; ***or***
   b) concentrations with a Munsell hue of 2.5Y or yellower and a chroma of 6 or more, moist; ***or***
   c) direct superposition on *sulfidic* material; ***or***
   d) 0.05% (by mass) or more water-soluble sulphate; ***and***
3. a thickness of 15 cm or more.

UM umbric

The umbric horizon is a thick, dark-coloured surface horizon with low base saturation and a moderate to high content of organic matter. An umbric horizon is comparable to a *mollic* in all its properties, such as colour, organic carbon content, structure and thickness, except for its low base saturation. An umbric horizon must have:

1. ***all*** properties of a *mollic* horizon, except for base saturation; ***and***
2. a base saturation (by 1 *M* NH_4OAc) of less than 50% on a weighted average throughout the depth of the horizon.

VE vertic

The vertic horizon is a clayey subsurface horizon that, as a result of shrinking and swelling, has slickensides and wedge-shaped structural aggregates. A vertic horizon has:

1. 30% or more clay throughout; ***and***
2. wedge-shaped structural aggregates with a longitudinal axis tilted between 10° and 60° from the horizontal; ***and***
3. slickensides; ***and***
4. a thickness of 25 cm or more.

VO voronic

The voronic horizon is a special type of mollic horizon. It is a deep, well-structured, blackish surface horizon with a high base saturation, a high content of organic matter and a high biological activity. A voronic horizon has:

1. a granular or fine subangular blocky soil structure; ***and***
2. Munsell colours with a chroma of less than 2.0 when moist, a value less than 2.0 when moist and less than 3.0 when dry on broken samples. If there is 40% or more finely divided lime, or if the texture of the horizon is loamy sand or coarser, the limits of colour value when dry are waived; the colour value when moist is 3 or less. The colour value is one unit or more, darker than that of the parent material (both moist and dry), unless the parent material has a colour value less than 4.0, moist. If a parent material is not present, comparison must be made with the layer immediately underlying the surface layer. The above colour requirements apply to the upper 15 cm of the voronic horizon, or immediately below any plough layer; ***and***
3. 50% or more (by volume) of the horizon consisting of worm burrows, worm casts, and filled burrows; ***and***

4. an organic carbon content of 1.5% or more. The organic carbon content is 6% or more if the colour requirements are waived because of finely divide lime, or 1.5% more than in the parent material, if the colour requirements are waived because of dark coloured parent materials; ***and***

5. a base saturation (by 1 *M* NH_4OAc) of 80% or more; ***and***

6. a thickness of 35 cm or more,

YE yermic

The yermic horizon is a surface horizon that usually, but not always, consists of surface accumulations of rock fragments (*desert pavement*) embedded in a loamy vesicular layer that may be covered by a thin aeolian sand or loess layer. A yermic horizon has:

1. *aridic* properties; ***and***

2. one or more of the following:

    a) a pavement that is varnished or includes wind-shaped gravel or stones (*ventifacts*); ***or***

    b) a pavement associated with a vesicular layer; ***or***

    c) a vesicular layer below a platy surface layer.

3.2 Diagnostic properties

Characterization of the diagnostic property is according to the definitions described in the World Reference Base for Soil Resources (IUSS 2006, 2007).

TC abrupt textural change

An abrupt textural change is a very sharp increase in clay content within a limited depth range. It requires 8% or more clay in the underlying layer; ***and***

1. a doubling of the clay content within 7.5 cm if the overlying horizon has less than 20% clay; ***or***
2. 20% (absolute) increase in clay content within 7.5 cm if the overlying horizon has 20% or more clay.

TO albeluvic tonguing

The term albeluvic tonguing is connotative of penetrations of clay- and Fe-depleted material into an *argic* horizon. When peds are present, albeluvic tongues occur along ped surfaces. Albeluvic tongues have:

1. the colour of an *albic* horizon; ***and***
2. greater depth than width, with the following horizontal dimensions:
   a) 5 mm or more in clayey *argic* horizons; ***or***
   b) 10 mm or more in clay loam and silty *argic* horizons; ***or***
   c) 15 mm or more in coarser (silt loam, loam or sandy loam) *argic* horizons; ***and***
3. occupy 10% or more of the volume in the first 10 cm of the *argic* horizon, measured on both vertical and horizontal sections; ***and***
4. a particle size distribution matching that of the coarser textured horizon overlying the *argic* horizon.

AC aridic properties

The term aridic properties combines a number of properties that are common in surface horizons of soils occurring under arid conditions and where pedogenesis exceeds new accumulation at the soil surface by aeolian or alluvial activity.

Aridic properties require:

1. an organic carbon content of less than 0.6% if texture is sandy loam or finer, or less than 0.2% if texture is coarser than sandy loam, as a weighted average in the upper 20 cm of the soil or down to the top of a diagnostic subsurface horizon, a cemented layer, or to *continuous rock*, whichever is shallower; ***and***
2. evidence of aeolian activity in one or more of the following forms:
   a) the sand fraction in some layer or in in-blown material filling cracks contains rounded or subangular sand particles showing a matt surface (use a 10 x hand-lens). These particles make up 10% or more of the medium and coarser quartz sand fraction; ***or***
   b) wind-shaped rock fragments (*ventifacts*) at the surface; ***or***
   c) aeroturbation (e.g. cross-bedding); ***or***
   d) evidence of wind erosion or deposition; ***and***

3. both broken and crushed samples with a Munsell colour value of 3 or more when moist and 4.5 or more when dry, and a chroma of 2 or more when moist; ***and***

4. a base saturation (by 1 *M* NH_4OAc) of 75% or more.

AD	andic properties	Andic properties result from moderate weathering of mainly pyroclastic deposits. However, some soils develop andic properties from non-volcanic materials (e.g. loess, argillite and ferralitic weathering products). The presence of short-range-order minerals (allophane) and/or organo-metallic complexes is characteristic for andic properties. These minerals and complexes are commonly part of the weathering sequence in pyroclastic deposits (tephric material → vitric properties → andic properties) Andic properties require the following physical and chemical characteristics: 1. an Al_{ox} + ½Fe_{ox} (acid oxalate extractable Al plus 1/2 acid oxalate extractable Fe) value of 2.0% or more; ***and*** 2. a bulk density of the soil at field capacity (no prior drying) of 0.90 kg dm^{-3} or less; ***and*** 3. a phosphate retention of 85% or more; ***and*** 4. less than 25% (by mass) organic carbon.
RO	continuous rock	Continuous rock is consolidated material underlying the soil, exclusive of cemented pedogenetic horizons, such as *petrocalcic, petroduric, petrogypsic* and *petroplinthic* horizons. Continuous rock is sufficiently consolidated to remain intact when an air-dry specimen 25-30 mm on a side is submerged in water for 1 hour. The material is considered continuous only if cracks, into which roots can enter, are on average 10 cm or more apart and occupy less than 20% (by volume) of the continuous rock, and no significant displacement of rock has taken place.
FC	ferralic properties	Ferralic properties refer to *mineral* soil material that has a relative low CEC. It also includes soil materials that fulfil the requirements of a *ferralic* horizon except texture. Ferralic properties require in some subsurface layer: 1. a CEC (by 1 *M* NH_4OAc) of less than 24 $cmol_c$ kg^{-1} clay; ***or*** 2. a CEC (by 1 *M* NH_4OAc) of less than 4 $cmol_c$ kg^{-1} soil and a Munsell chroma of 5 or more, moist.
GE	geric properties	Geric properties refer to *mineral* soil material that has a very low ECEC or even acts as an anion exchanger. Geric properties require: 1. an ECEC (sum of exchangeable bases plus exchangeable acidity in 1 *M* KCl) of less than 1.5 $cmol_c$ kg^{-1} clay; ***or*** 2. a delta pH (pH_{KCl} minus pH_{H2O}) of +0.1 unit or more.

GL	gleyic colour pattern	Soil materials develop a gleyic colour pattern if they are saturated with groundwater (or were saturated in the past, if now drained) for a period that allows *reducing conditions* to occur (this may range from a few days in the tropics to a few weeks in other areas), and show a gleyic colour pattern. A gleyic colour patterns shows one or both of the following: 1. 90% or more of (exposed area) reductimorphic colours, which comprise neutral white to black (Munsell hue N1/ to N8/) or bluish to greenish (Munsell hue 2.5Y, 5Y, 5G, 5B) colours; ***or*** 2. 5% or more of (exposed area) mottles of oximorphic colours, which comprise any colour, excluding reductimorphic colours.
LD	lithologic discontinuity	Lithological discontinuities are significant changes in particle-size distribution or mineralogy that represents differences in lithology within a soil. A lithological discontinuity can also denote an age difference. Lithological discontinuity requires one or more of the following: 1. an abrupt change in particle size distribution that is not solely associated with a change in clay content resulting from pedogenesis; ***or*** 2. a relative change of 20% or more in the ratios between coarse sand, medium sand, and fine sand; ***or*** 3. rock fragments that do not have the same lithology as the underlying *continuous rock;* ***or*** 4. a layer containing rock fragments without weathering rinds overlying a layer containing rocks with weathering rinds; ***or*** 5. layers with angular rock fragments overlying or underlying layers with rounded rock fragments; ***or*** 6. abrupt changes in colour not resulting from pedogenesis; ***or*** 7. marked differences in size and shape of resistant minerals between superimposed layers (as shown by micro-morphological or mineralogical methods).
RC	reducing conditions	Reducing conditions show one or more of the following: 1. a negative logarithm of the Hydrogen partial pressure (rH) of less than 20; ***or*** 2. the presence of free Fe^{2+}, as shown on a freshly broken and smoothed surface of a field-wet soil by the appearance of a strong red colour after wetting it with a 0.2% α,α,dipyridyl solution in 10% acetic acid; ***or***. 3. the presence of iron sulphide; ***or*** 4. the presence of methane.
SL	secondary carbonates	The term secondary carbonates refer to lime, precipitated in place from the soil solution rather than inherited from a soil parent material. As a diagnostic property, it should be present in significant quantities. Secondary carbonates may be present in soil fabric, forming masses, nodules, concretions, or spheroidal aggregates (*white eyes*) that are soft and powdery when dry, or may

be present as soft coatings in pores, on structural faces or on the undersides of rock or cemented fragments. If present as coatings, secondary carbonates cover 50% or more of the structural faces and are thick enough to be visible when moist. If present as soft nodules, they occupy 5% or more of the soil volume.

ST stagnic colour pattern

Soil materials develop a stagnic colour pattern if they are, at least temporarily, saturated with surface water (or were saturated in the past, if now drained) for a period long enough that allows *reducing conditions* to occur (this may range from a few days in the tropics to a few weeks in other areas). A stagnic colour pattern shows mottling in such a way that:

1. the surfaces of the peds (or parts of the soil matrix) are lighter (at least one Munsell value unit more) and paler (at least one chroma unit less), ***and***
2. the interiors of the peds (or parts of the soil matrix) are more reddish (at least one hue unit) and brighter (at least one chroma unit more) than the non-redoximorphic parts of the layer, or than the mixed average of the interior and surface parts.

VE vertic properties

The term vertic properties is used in connexion with clayey soils that have one or both of the following:

1. 30% or more clay throughout a thickness of 15 cm or more and one or both of the following:
   a) slickensides or wedge-shaped aggregates; ***or***
   b) cracks that open and close periodically and are 1 cm or more wide; ***or***
2. a COLE of 0.06 or more averaged over a depth of 100 cm from the soil surface.

VI vitric properties

Vitric properties apply to layers with volcanic glass and other primary minerals derived from volcanic ejecta and which contain a limited amount of short-range-order minerals or organo-metallic complexes.

Vitric properties require:

1. 5% or more (by grain count) volcanic glass, glassy aggregates and other glass-coated primary minerals, in the fraction between 0.05-2 mm, ***or*** in the fraction between 0.02- 0.25 mm; ***and***
2. an Al_{ox} + ½Fe_{ox} value of 0.4% or more; ***and***
3. a phosphate retention of 25% or more; ***and***
4. do not meet one or more of the criteria of the *andic* properties; ***and***
5. has less than 25% (by mass) organic carbon.

3.3 Diagnostic materials

Diagnostic materials (IUSS 2006, 2007) are intended to reflect original parent materials, in which pedogenetic processes have not yet been very active so that they have only slightly influenced the soil and have not yet lead to significant changes.

AF artefacts

Artefacts are solid or liquid substances that have:

1. one or both of the following:
   a) created or substantially modified by humans as part of an industrial or artisanal manufacturing process; *or*
   b) brought to the surface by human activity from a depth where they were not influenced by surface processes, with properties substantially different from the environment where they are placed; *and*
2. substantially the same properties as when first manufactured, modified or excavated (e.g. pieces of bricks, pottery, glass, garbage, etc.).

CO calcaric material

Soil material that show strong effervescence with 10% HCl in most of the fine earth. It applies to soil material that contains 2% or more calcium carbonate equivalent.

CU colluvic material

Colluvic material is formed by sedimentation through human- induced erosion. It normally accumulates in footslope positions, in depressions or above hedge walls. The erosion may have taken place since Neolithic times. Many colluvic materials have *artefacts* such as pieces of bricks, ceramics and glass, and may have a *lithological discontinuity* at its base.

FL fluvic material

Fluvic material refers to fluviatile, marine and lacustrine sediments that receive fresh materials at regular intervals, or have received it in the recent past. It shows one or both of the following:

1. stratification in at least 25% of the soil volume over a specified depth;
2. stratification may also be evident from an organic carbon content decreasing irregularly with depth, or remaining above 0.2% to a depth of 100 cm from the mineral soil surface. Thin strata of sand may have less organic carbon if the finer sediments below meet the latter requirement.

GP gypsiric material

Gypsiric material is mineral soil material that contains 5% or more gypsum (by volume).

LN limnic material

Limnic materials occur as subaquatic deposits (at the surface after drainage). Four types are distinguished; coprogenous earth or sedimentary peat, diatomaceous earth, marl and gyttja. Limnic material includes both organic and mineral material that are:

1. deposited in water by precipitation or through action of aquatic organisms, such as diatoms on other algae; *or*
2. derived from underwater and floating aquatic plants and subsequently modified by aquatic animals.

MR mineral material

In mineral material the soil properties are dominated by mineral components. Mineral material has one or both of the following:

1. less than 20% organic carbon in the fine earth (by mass), if saturated with water for less than 30 consecutive days in most years without being drained ; ***or***
2. one or both of the following:
   a) less than [12+(clay% of the mineral fraction x0.1)]% organic carbon in the fine earth (by mass); ***or***
   b) less than 18% organic carbon in the fine earth (by mass), if the mineral fraction has 60% or more clay.

OR organic material

Organic material has one or both of the following:

1. 20% or more organic carbon in the fine earth (by mass); ***or***
2. if saturated with water for 30 consecutive days or more in most years (unless drained) one or both of the following:
   a) [12+(clay% of the mineral fraction x 0.1)]% or more organic carbon in the fine earth fraction (by mass); ***or***
   b) 18% or more organic carbon in the fine earth fraction (by mass).

ON ornitho genic material

Ortnithogenic material is material with strong influence of bird excrement. It often has a high content of gravel that has been transported by birds. Ortnithogenic material has:

1. remnants of birds or bird activity (bones, feathers, sorted gravel of similar size); ***and***
2. a P_2O_5 content of 0.25% or more in 1% citric acid.

SF sulphidic material

Sulphidic material is a waterlogged deposit containing sulphur, mostly in the form of sulphides, and only moderate amounts of calcium carbonate. Sulfidic materials has:

1. a pH (1:1 in water) of 4.0 or more and 0.75% or more sulphur (dry mass) and less than three times as much calcium carbonate equivalent as S; ***or***
2. a pH (1:1 in water) of 4.0 or more that, if the material is incubated as a layer 1 cm thick, at field capacity at room temperature, drops 0.5 or more units to a pH of 4.0 or less (1:1 in water) within 8 weeks.

TR technic hard rock

Technic hard rock is non-natural material created by humans. It is defined as consolidated material resulting from industrial processes, with properties substantially different from those of natural materials.

TP tephric material

Tephric material consists either of tephra, i.e. unconsolidated, non- or only slightly weathered pyroclastic products of volcanic eruptions (including ash, cinders, lapilli, pumice, pumice-like vesicular pyroclastics, blocks or volcanic bombs), or of tephric deposits, i.e. tephra that has been reworked and mixed with material from other sources. This includes tephric loess, tephric blown sand and volcanogenic alluvium. Tephric soil material has:

1. 30% or more (by grain count) volcanic glass, glassy aggregates and other glass-coated primary minerals in the fraction 0.02 - 2 mm; ***and***
2. no *andic* or *vitric* properties.

3.4 Key to Reference Soil Groups with prefix and suffix qualifiers

The classification of the soil according to the Reference Soil Group (RSG) and subsequent subdivision is done in two steps: expression, thickness and depth of horizons are checked against the requirements of **WRB diagnostic horizons, properties and materials**, which are defined in terms of morphological characteristics and/or analytical criteria. The key of the WRB-RSG is compared with the described combination of diagnostic horizons, properties and materials to key out **the Reference Soil Group**. For the second level of WRB classification, **prefix** and **suffix qualifiers** are used from the priority list provided with each RSG (for definitions see Annex 3.5). **Specifiers** are only used in combination with **suffix** qualifiers. However, subdivisions of prefix qualifiers listed in 3.5, may be used to substitute that prefix qualifier, i.e. Epipetric instead of Petric.

Key to the Reference Soil Groups	**Prefix qualifiers**		**Suffix qualifiers**	
		(cont.)		(cont.)
Soils having *organic* material, *either* 1. 10 cm or more thick starting at the soil surface and immediately overlying ice, *continuous rock*, or fragmental materials, the interstices of which are filled with *organic* material; ***or*** 2. cumulatively within 100 cm of the soil surface either 60 cm or more thick if 75% (by volume) or more of the material consists of moss fibres *or* 40 cm or more thick in other materials and starting within 40 cm of the soil surface. **HISTOSOLS...(HS)**	Folic Limnic Lignic Fibric Hemic Sapric Floatic Subaquatic Glacic Ombric	Rheic Technic Cryic Hyper- skeletic Leptic Vitric Andic Salic Calcic	Thionic Ornithic Calcaric Sodic Alcalic Toxic Dystric Eutric Turbic Gelic	Petrogleyic Placic Skeletic Tidalic Drainic Transportic Novic
Other soils having *either* 1. a *hortic*, *irragric*, *plaggic* or *terric* horizon 50 cm or more thick; ***or*** 2. an *anthraquic* horizon and an underlying *hydragric* horizon with a combined thickness of 50 cm or more. **ANTHROSOLS...(AT)**	Hydragric Irragric Terric Plaggic Hortic Escalic Technic	Fluvic Salic Gleyic Spodic Ferralic Stagnic Regic	Sodic Alcalic Dystric Eutric Oxyaquic Arenic	Siltic Clayic Novic

Key to the Reference Soil Groups	Prefix qualifiers		Suffix qualifiers	
		(cont.)		(cont.)
Other soils having 1. 20% or more (by volume, by weighted average) *artefacts* in the upper 100 cm from the soil surface or to *continuous rock* or a cemented or indurated layer, whichever is shallower; ***or*** 2. a continuous, very slowly permeable to impermeable, constructed geo-membrane of any thickness starting within 100 cm of the soil surface; ***or*** 3. *technic hard rock* starting within 5 cm of the soil surface and covering 95% or more of the horizontal extent of the soil. **TECHNOSOLS[1]...(TC)** 1 Buried layers occur frequently in this RSG and can be indicated with the specifier thapto- followed by a qualifier or a RSG	Ekranic Linic Urbic Spolic Garbic Folic Histic Cryic Leptic Fluvic Gleyic Vitric	Stagnic Mollic Alic Acric Luvic Lixic Umbric	Calcaric Toxic Reductic Humic Oxyaquic Densic Skeletic Arenic	Siltic Clayic Drainic Novic
Other soils having 1. a *cryic* horizon starting within 100 cm of the soil surface; ***or*** 2. a *cryic* horizon starting within 200 cm of the soil surface *and* evidence of cryoturbation[1] in some layer within 100 cm of the soil surface. **CRYOSOLS...(CR)** 1 Evidence of cryoturbation includes frost heave, cryogenic sorting, thermal cracking, ice segregation, patterned ground, etc.	Glacic Turbic Folic Histic Technic Hyper-skeletic Lithic Leptic Natric	Salic Vitric Spodic Mollic Calcic Umbric Cambic Haplic	Gypsiric Calcaric Ornithic Dystric Eutric Reductaquic Oxyaquic Thixotropic	Aridic Skeletic Arenic Siltic Clayic Drainic Transportic Novic
Other soils having 1. one of the following: a. limitation of depth by *continuous rock* within 25 cm of the soil surface; ***or*** b. less than 20% (by volume) fine earth averaged over a depth of 75 cm from the soil surface or to *continuous rock*, whichever is shallower; ***and*** 2. no *calcic*, *gypsic, petrocalcic ,petrogypsic or spodic* horizon **LEPTOSOLS...(LP)**	Nudilithic Lithic Hyper-skeletic Rendzic Folic Histic Technic Vertic	Salic Gleyic Vitric Andic Stagnic Mollic Umbric Cambic Haplic	Brunic Gypsiric Calcaric Ornithic Tephric Protothionic Humic Sodic Dystric Eutric	Oxyaquic Gelic Placic Greyic Yermic Aridic Skeletic Drainic Novic

Key to the Reference Soil Groups	Prefix qualifiers		Suffix qualifiers	
Other soils having 1. a *vertic* horizon starting within 100 cm of the soil surface; ***and*** 2. after the upper 20 cm have been mixed, 30% or more clay between the soil surface and the *vertic* horizon throughout; ***and*** 3. cracks[1] that open and close periodically. **VERTISOLS...(VR)** 1) A crack is a separation between big blocks of soil. If the surface is self-mulching, or if the soil is cultivated while cracks are open, the cracks may be filled mainly by granular materials from the soil surface but they are open in the sense that the blocks are separated; it controls the infiltration and percolation of water. If the soil is irrigated, the upper 50 cm has a COLE of 0.06 or more.	Grumic Mazic Technic Endoleptic Salic Gleyic Sodic Stagnic Mollic	..(cont.) Gypsic Duric Calcic Haplic	Thionic Albic Manganiferric Ferric Gypsiric Calcaric Humic Hyposalic	..(cont.) Hyposodic Mesotrophic Hypereutric Pellic Chromic Novic
Other soils having 1. *fluvic* material starting within 25 cm of the soil surface and continuing to a depth of 50 cm or more *or* starting at the lower limit of a plough layer and continuing to a depth of 50 cm or more; ***and*** 2. no *argic, cambic, natric, petroplinthic* or *plinthic* horizon starting within 50 cm of the soil surface; ***and*** 3. no layers with *andic* or *vitric* properties with a combined thickness of 30 cm or more within 100 cm of the soil surface *and* starting within 25 cm of the soil surface. **FLUVISOLS[1]...(FL)** 1 Buried layers occur frequently in this RSG and can be indicated with the specifier thapto- followed by a qualifier or a RSG.	Subaquatic Tidalic Limnic Folic Histic Technic Salic Gleyic Stagnic Vertic	Mollic Gypsic Calcic Umbric Haplic	Thionic Anthric Gypsiric Calcaric Tephric Petrogleyic Gelic Oxyaquic Humic Sodic Dystric Eutric	Greyic Takyric Yermic Aridic Densic Skeletic Arenic Siltic Clayic Drainic Transportic
Other soils having 1. a *natric* horizon starting within 100 cm of the soil surface. **SOLONETZ...(SN)**	Technic Vertic Gleyic Salic Stagnic Mollic Gypsic Duric	Petrocalcic Calcic Haplic	Glossalbic Albic Abruptic Colluvic Ruptic Magnesic Humic Oxyaquic	Takyric Yermic Aridic Arenic Siltic Clayic Transportic Novic

Key to the Reference Soil Groups	Prefix qualifiers		Suffix qualifiers	
		..(cont.)		..(cont.)
Other soils having 1. a *salic* horizon starting within 50 cm of the soil surface; ***and*** 2. no *thionic* horizon starting within 50 cm of the soil surface. **SOLONCHAKS…(SC)**	Petrosalic Hypersalic Puffic Folic Histic Technic	Vertic Gleyic Stagnic Mollic Gypsic Duric Calcic Haplic	Sodic Aceric Chloridic Sulphatic Carbonatic Gelic Oxyaquic Takyric	Yermic Aridic Densic Arenic Siltic Clayic Drainic Transportic Novic
Other soils having 1. within 50 cm of the mineral soil surface a layer 25 cm or more thick, that has *reducing conditions* in some parts and a *gleyic colour pattern* throughout; ***and*** 2. no layers with *andic* or *vitric* properties with a combined thickness of ***either*** a. 30 cm or more within 100 cm of the soil surface *and* starting within 25 cm of the soil surface; ***or*** b. 60% or more of the entire thickness of the soil when *continuous rock* or a cemented or indurated layer is starting between 25 and 50 cm from the soil surface. **GLEYSOLS…(GL)**	Folic Histic Anthraquic Technic Fluvic Endosalic Vitric Andic Spodic Plinthic Mollic Gypsic Calcic	Alic Acric Luvic Lixic Umbric Haplic	Thionic Abruptic Calcaric Tephric Colluvic Humic Sodic Alcalic Alumic Toxic Dystric Eutric Petrogleyic	Turbic Gelic Greyic Takyric Arenic Siltic Clayic Drainic Novic
Other soils having 1. one or more layers with *andic* or *vitric* properties with combined thickness of ***either*** a. 30 cm or more within 100 cm of the soil surface *and* starting within 25 cm of the soil surface; ***or*** b. 60% or more of the entire thickness of the soil when *continuous rock* or a cemented or indurated layer is starting between 25 and 50 cm from the soil surface; ***and*** 2. no *argic*, *ferralic*, *petroplinthic*, *pisoplinthic*, *plinthic* or *spodic* horizon (unless buried deeper than 50 cm). **ANDOSOLS[1]…(AN)** 1 Buried layers occur frequently in this RSG and can be indicated with the specifier thapto- followed by a qualifier or a RSG.	Vitric Aluandic Eutrosilic Silandic Melanic Fulvic Hydric Folic Histic Technic Leptic Gleyic Mollic Gypsic	Petroduric Duric Calcic Umbric Haplic	Anthric Fragic Calcaric Colluvic Acroxic Sodic Dystric Eutric Turbic Gelic Oxyaquic Placic Greyic Thixotropic	Skeletic Arenic Siltic Clayic Drainic Transportic Novic

Key to the Reference Soil Groups	Prefix qualifiers		Suffix qualifiers	
		(cont.)		(cont.)
Other soils having 1. a *spodic* horizon starting within 200 cm of the mineral soil surface. **PODZOLS...(PZ)**	Placic Ortsteinic Carbic Rustic Entic Albic Folic Histic Technic	Hyper- skeletic Leptic Gleyic Vitric Andic Stagnic Umbric Haplic	Hortic Plaggic Terric Anthric Ornithic Fragic Ruptic Turbic	Gelic Oxyaquic Lamellic Densic Skeletic Drainic Transportic Novic
Other soils having ***either*** 1. a *plinthic*, *petroplinthic* or *pisoplinthic* horizon starting within 50 cm of the soil surface; ***or*** 2. a *plinthic* horizon starting within 100 cm of the soil surface and, directly above, a layer 10 cm or more thick, that has in some parts *reducing conditions* for some time during the year and in half or more of the soil volume, single or in combination a. a *stagnic colour pattern*; ***or*** b. an *albic* horizon. **PLINTHOSOLS...(PT)**	Petric Fractipetric Pisoplinthic Gibbsic Posic Geric Vetic Folic Histic Technic	Stagnic Acric Lixic Umbric Haplic	Albic Manganiferric Ferric Endoduric Abruptic Colluvic Ruptic Alumic Humic Dystric	Eutric Oxyaquic Pachic Umbri- glossic Arenic Siltic Clayic Drainic Transportic Novic
Other soils having 1. a *nitic* horizon starting within 100 cm of the soil surface; ***and*** 2. gradual to diffuse[1] horizon boundaries between the soil surface and the *nitic* horizon; ***and*** 3. no *ferric*, *petroplinthic*, *pisoplinthic*, *plinthic* or *vertic* horizon starting within 100 cm of the soil surface; ***and*** 4. no *gleyic* or *stagnic colour pattern* starting within 100 cm of the soil surface. **NITISOLS...(NT)** [1] as defined in FAO (2006).	Vetic Technic Andic Ferralic Mollic Alic Acric Luvic Lixic Umbric Haplic		Humic Alumic Dystric Eutric Oxyaquic Colluvic Densic Rhodic Transportic Novic	

Key to the Reference Soil Groups	**Prefix qualifiers**		**Suffix qualifiers**	
Other soils having 1. a *ferralic* horizon starting within 150 cm of the soil surface; ***and*** 2. no *argic* horizon that has, in the upper 30 cm, 10% or more water-dispersible clay unless the upper 30 cm of the *argic* horizon has one or both of the following: a. *geric* properties; ***or*** b. 1.4% or more organic carbon. **FERRALSOLS...(FR)**	Gibbsic Posic Geric Vetic Folic Technic Andic Fractiplinthic Petroplinthic	(cont.) Pisoplinthic Plinthic Mollic Acric Lixic Umbric Haplic	Sombric Manganiferric Ferric Colluvic Humic Alumic Dystric Eutric	(cont.) Ruptic Oxyaquic Densic Arenic Siltic Clayic Rhodic Xanthic Transportic Novic
Other soils having 1. an *abrupt textural change* within 100 cm of the soil surface and, directly above or below, a layer 5 cm or more thick, that has in some parts *reducing conditions* for some time during the year and in half or more of the soil volume, single or in combination a. *stagnic colour pattern*; ***or*** b. an *albic* horizon; ***and*** 2. no *albeluvic tonguing* starting within 100 cm of the soil surface. **PLANOSOLS...(PL)**	Solodic Folic Histic Technic Vertic Endosalic Plinthic Endogleyic Mollic Gypsic	Petrocalcic Calcic Alic Acric Luvic Lixic Umbric Haplic	Thionic Albic Manganiferric Ferric Geric Ruptic Calcaric Sodic Alcalic Alumic	Dystric Eutric Gelic Greyic Arenic Siltic Clayic Chromic Drainic Transportic
Other soils having 1. within 50 cm of the mineral soil surface in some parts *reducing conditions* for some time during the year and in half or more of the soil volume, single or in combination, a. a *stagnic colour pattern*; ***or*** b. an *albic* horizon; ***and*** 2. no *albeluvic tonguing* starting within 100 cm of the soil surface. **STAGNOSOLS...(ST)**	Folic Histic Technic Vertic Endosalic Plinthic Endogleyic Mollic Gypsic	Petrocalcic Calcic Alic Acric Luvic Lixic Umbric Haplic	Thionic Albic Manganiferric Ferric Ruptic Geric Calcaric Ornithic Sodic Alcalic Alumic	Dystric Eutric Gelic Greyic Placic Arenic Siltic Clayic Rhodic Chromic Drainic

Key to the Reference Soil Groups	Prefix qualifiers	(cont.)	Suffix qualifiers	(cont.)
Other soils having 1. a *mollic* horizon; ***and*** 2. a Munsell chroma, moist, of 2 or less from the soils surface to a depth of 20 cm or more, or having this chroma directly below any plough layer that is 20 cm or more deep; ***and*** 3. a *calcic* horizon, or concentrations of *secondary carbonates* starting within 50 cm below the lower limit of the *mollic* horizon and, if present, above a cemented or indurated layer; ***and*** 4. a base saturation (by 1 *M* NH_4OAc) of 50% or more from the soil surface to the *calcic* horizon or the concentrations of *secondary carbonates* throughout. **CHERNOZEMS...(CH)**	Voronic Vermic Technic Leptic Vertic Endofluvic Endosalic Gleyic Vitric Andic Stagnic	Petrogypsic Gypsic Petroduric Duric Petrocalcic Calcic Luvic Haplic	Anthric Glossic Tephric Sodic Pachic Oxyaquic Greyic Densic Skeletic Arenic Siltic Clayic Novic	
Other soils having 1. a *mollic* horizon; ***and*** 2. a *calcic* horizon, or concentrations of *secondary carbonates* starting within 50 cm below the lower limit of the *mollic* horizon and, if present, above a cemented or indurated layer; ***and*** 3. a base saturation (by 1 *M* NH_4OAc) of 50% or more from the soil surface to the *calcic* horizon or the concentrations of *secondary carbonates* throughout. **KASTANOZEMS...(KS)**	Vermic Technic Leptic Vertic Endosalic Gleyic Vitric Andic Stagnic Petrogypsic	Gypsic Petro duric Duric Petrocalcic Calcic Luvic Haplic	Anthric Glossic Tephric Sodic Oxyaquic Greyic Densic Skeletic	Arenic Siltic Clayic Chromic Novic
Other soils having 1. a *mollic* horizon; ***and*** 2. a base saturation (by 1 *M* NH_4OAc) of 50% or more throughout to a depth of 100 cm or more from the soil surface or to *continuous rock* or a cemented or indurated layer, whichever is shallower. **PHAEOZEMS...(PH)**	Vermic Greyic Technic Rendzic Leptic Vertic Endosalic Gleyic Vitric Andic Ferralic	Stagnic Petrogypsic Petroduric Duric Petrocalcic Calcic Luvic Haplic	Anthric Albic Abruptic Glossic Calcaric Tephric Sodic Pachic Oxyaquic	Densic Skeletic Arenic Siltic Clayic Chromic Novic

Key to the Reference Soil Groups	Prefix qualifiers		Suffix qualifiers	
		(cont.)		(cont.)
Other soils having 1. a *petrogypsic* horizon starting within 100 cm of the soil surface; *or* 2. a *gypsic* horizon starting within 100 cm of the soil surface *and* no *argic* horizon unless the *argic* horizon is permeated with gypsum or calcium carbonate. **GYPSISOLS...(GY)**	Petric Hypergypsic Hypogypsic Arzic Technic Hyper-skeletic Leptic Vertic Endosalic	Endogleyic Petroduric Duric Petrocalcic Calcic Luvic Haplic	Ruptic Sodic Hyperochric Takyric Yermic Aridic Skeletic	Arenic Siltic Clayic Transportic Novic
Other soils having 1. a *petroduric* or *duric* horizon starting within 100 cm of the soil surface. **DURISOLS...(DU)**	Petric Fractipetric Technic Leptic Vertic Endogleyic	Gypsic Petrocalcic Calcic Luvic Lixic Haplic	Ruptic Sodic Takyric Yermic Aridic Hyperochric	Arenic Siltic Clayic Chromic Transportic Novic
Other soils having 1. a *petrocalcic* horizon starting within 100 cm of the soil surface; *or* 2. a *calcic* horizon starting within 100 cm of the soil surface *and* no *argic* horizon unless the *argic* horizon is permeated with calcium carbonate. **CALCISOLS...(CL)**	Petric Hypercalcic Hypocalcic Technic Hyper skeletic Leptic Vertic	Endosalic Endogleyic Gypsic Luvic Lixic Haplic	Ruptic Sodic Takyric Yermic Aridic Hyperochric Densic Skeletic	Arenic Siltic Clayic Chromic Transportic Novic
Other soils having 1. an *argic* horizon starting within 100 cm of the soil surface with *albeluvic tonguing* at its upper boundary. **ALBELUVISOLS...(AB)**	Fragic Cutanic Folic Histic Technic Gleyic Stagnic	Umbric Cambic Haplic	Anthric Manganiferric Ferric Abruptic Ruptic Alumic Dystric Eutric Gelic	Oxyaquic Greyic Densic Arenic Siltic Clayic Drainic Transportic Novic

Key to the Reference Soil Groups	Prefix qualifiers		Suffix qualifiers	
		(cont.)		(cont.)
Other soils having 1. an *argic* horizon, which has a CEC (by 1 *M* NH_4OAc) of 24 cmolc kg^{-1} clay or more throughout or to a depth of 50 cm below its upper limit, whichever is shallower, either starting within 100 cm of the soil surface, or within 200 cm of the soil surface if the *argic* horizon is overlain by loamy sand or coarser textures throughout; ***and*** 2. a base saturation (by 1 *M* NH_4OAc) of less than 50% in the major part between 50 and 100 cm. **ALISOLS...(AL)**	Hyperalic Lamellic Cutanic Albic Technic Leptic Vertic Fractiplinthic Petroplinthic Pisoplinthic	Plinthic Gleyic Vitric Andic Nitic Stagnic Umbric Haplic	Anthric Fragic Manganiferric Ferric Abruptic Ruptic Alumic Humic Hyperdystric Epieutric Turbic Gelic Oxyaquic	Greyic Profondic Hyperochric Nudiargic Densic Skeletic Arenic Silltic Clayic Rhodic Chromic Transportic Novic
Other soils having 1. an *argic* horizon that has a CEC (by 1 *M* NH_4OAc) of less than 24 cmolc kg^{-1} clay in some part to a maximum depth of 50 cm below its upper limit, either starting within 100 cm of the soil surface, or within 200 cm of the soil surface if the *argic* horizon is overlain by loamy sand or coarser textures throughout; ***and*** 2. a base saturation (by 1 *M* NH_4OAc) of less than 50% in the major part between 50 and 100 cm. **ACRISOLS...(AC)**	Vetic Lamellic Cutanic Technic Leptic Fractiplinthic Petroplinthic Pisoplinthic Plinthic Gleyic	Vitric Andic Nitic Stagnic Umbric Haplic	Anthric Albic Fragic Sombric Manganiferric Ferric Abruptic Ruptic Alumic Humic Hyperdystric Epieutric Oxyaquic Greyic	Profondic Hyperochric Nudiargic Densic Skeletic Arenic Siltic Clayic Rhodic Chromic Transportic Novic

Key to the Reference Soil Groups	Prefix qualifiers		Suffix qualifiers	
Other soils having 1. an *argic* horizon with a CEC (by 1 *M* NH_4OAc) of 24 cmolc kg^{-1} clay or more throughout or to a depth of 50 cm below its upper limit, whichever is shallower, either starting within 100 cm of the soil surface or within 200 cm of the soil surface if the *argic* horizon is overlain by loamy sand or coarser textures throughout. **LUVISOLS…(LV)**	Lamellic Cutanic Albic Escalic Technic Leptic Vertic Gleyic Vitric (cont)	(cont) Andic Nitic Stagnic Calcic Haplic	Anthric Fragic Manganiferric Ferric Abruptic Ruptic Humic Sodic Epidystric Hypereutric Turbic Gelic Oxyaquic Greyic (cont)	(cont) Profondic Hyperochric Nudiargic Densic Skeletic Arenic Siltic Clayic Rhodic Chromic Transportic Novic
Other soils having 1. an *argic* horizon, either starting within 100 cm of the soil surface or within 200 cm of the soil surface if the *argic* horizon is overlain by loamy sand or coarser textures throughout. **LIXISOLS…(LX)**	Vetic Lamellic Cutanic Technic Leptic Gleyic Vitric Andic Fractiplinthic Petroplinthic	Pisoplinthic Plinthic Nitic Stagnic Calcic Haplic	Anthric Albic Fragic Manganiferric Ferric Abruptic Ruptic Humic Epidystric Hypereutric Oxyaquic Greyic Profondic	Hyperochric Nudiargic Densic Skeletic Arenic Siltic Clayic Rhodic Chromic Transportic Novic

Key to the Reference Soil Groups	Prefix qualifiers		Suffix qualifiers	
		(cont.)		(cont.)
Other soils having 1. an *umbric* or *mollic* horizon. **UMBRISOLS...(UM)**	Folic Histic Technic Leptic Fluvic Endogleyic Vitric Andic	Ferralic Stagnic Mollic Cambic Haplic	Anthric Albic Brunic Ornithic Thionic Glossic Humic Alumic Hyperdystric Endoeutric Pachic Turbic	Gelic Oxyaquic Greyic Laxic Placic Densic Skeletic Arenic Siltic Clayic Chromic Drainic Novic
Other soils having 1. a weighted average texture of loamy sand or coarser, if cumulative layers of finer texture are less than 15 cm thick, either to a depth of 100 cm from the soil surface or to a *petroplinthic*, *pisoplinthic*, *plinthic* or *salic* horizon starting between 50 and 100 cm from the soil surface; ***and*** 2. less than 40% (by volume) of gravels or coarser fragments in all layers within 100 cm of the soil surface or to a *petroplinthic*, *pisoplinthic*, *plinthic* or *salic* horizon starting between 50 and 100 cm from the soil surface; ***and*** 3. no *fragic*, *irragric*, *hortic*, *plaggic* or *terric* horizon; ***and*** 4. no layers with *andic* or *vitric* properties with a combined thickness of 15 cm or more. **ARENOSOLS...(AR)**	Lamellic Hypoluvic Hyperalbic Albic Rubic Brunic Hydrophobic Protic Folic Technic Endosalic Endogleyic	Fractiplinthic Petroplinthic Pisoplinthic Plinthic Ferralic Endostagnic Haplic	Ornithic Gypsiric Calcaric Tephric Hyposalic Dystric Eutric Petrogleyic Turbic Gelic Greyic Placic Hyperochric	Yermic Aridic Transportic Novic

Key to the Reference Soil Groups	Prefix qualifiers		Suffix qualifiers	
		(cont.)		(cont.)
Other soils having 1. a *cambic* horizon starting within 50 cm of the soil surface and having its base 25 cm or more below the soil surface or 15 cm or more below any plough layer; ***or*** 2. an *anthraquic*, *hortic*, *hydragric*, *irragric*, *plaggic* or *terric* horizon; ***or*** 3. a *fragic*, *petroplinthic*, *pisoplinthic*, *plinthic*, *salic, thionic* or *vertic* horizon starting within 100 cm of the soil surface; ***or*** 4. one or more layers with *andic* or *vitric* properties with a combined thickness of 15 cm or more within 100 cm of the soil surface. **CAMBISOLS…(CM)**	Folic Anthraquic Hortic Irragric Plaggic Terric Technic Leptic Vertic Thionic Fluvic Endosalic Endogleyic Vitric	Andic Fractiplinthic Petroplinthic Pisoplinthic Plinthic Ferralic Fragic Gelistagnic Stagnic Haplic	Manganiferric Ferric Ornithic Colluvic Gypsiric Calcaric Tephric Alumic Sodic Alcalic Humic Dystric Eutric Laxic Turbic Gelic Oxyaquic	Greyic Ruptic Pisocalcic Hyperochric Takyric Yermic Aridic Densic Skeletic Siltic Clayic Rhodic Chromic Escalic Transportic Novic
Other soils. **REGOSOLS…(RG)**	Folic Aric Colluvic Technic Leptic Endogleyic Thaptovitric Thaptandic	Gelistagnic Stagnic Haplic	Brunic Ornithic Gypsiric Calcaric Tephric Humic Hyposalic Sodic Dystric Eutric Turbic Gelic Oxyaquic Vermic	Hyperochric Takyric Yermic Aridic Densic Skeletic Arenic Siltic Clayic Escalic Transportic

3.5 Definitions of formative elements for second-level units of the WRB

The definitions of the formative elements for the second-level units relate to the Reference Soil Group (RSG), diagnostic horizons, properties and materials, and to attributes such as colour, chemical conditions, texture, etc. They reference to the RSGs defined in Annex 3.4 and the diagnostic features listed in Annex 3.1, 3.2 and 3.3 are given in italics.

Usually, only a limited number of combinations will be possible; most of the definitions are mutually exclusive.

Abruptic (ap)

Having an *abrupt textural change* within 100 cm of the soil surface.

Aceric (ae)

Having a pH (1:1 in water) between 3.5 and 5 and jarosite mottles in some layer within 100 cm of the soil surface (*in Solonchaks only*).

Acric (ac)

Having an *argic* horizon that has a CEC (by 1 *M* NH_4OAc) of less than 24 $cmol_c$ kg^{-1} clay in some part to a maximum depth of 50 cm below its upper limit, either starting within 100 cm of the soil surface or within 200 cm of the soil surface if the *argic* horizon is overlain by loamy sand or coarser textures throughout, and a base saturation (by 1 *M* NH_4OAc) of less than 50% in the major part between 50 and 100 cm from the soil surface.

Acroxic (ao)

Having less than 2 $cmol_c$ kg^{-1} fine earth exchangeable bases plus 1 *M* KCl exchangeable Al^{3+} in one or more layers with a combined thickness of 30 cm or more within 100 cm of the soil surface (*in Andosols only*).

Albic (ab)

Having an *albic* horizon starting within 100 cm of the soil surface.

> **Hyperalbic (ha)**
>
> Having an *albic* horizon starting within 50 cm of the soil surface and its lower boundary at a depth of 100 cm or more from the soil surface.
>
> **Glossalbic (gb)**
>
> Showing tonguing of an *albic* into an *argic* or *natric* horizon.

Alcalic (ax)

Having a pH (1:1 in water) of 8.5 or more throughout within 50 cm of the soil surface or to *continuous rock* or a cemented or indurated layer, whichever is shallower.

Alic (al)

Having an *argic* horizon that has a CEC (by 1 *M* NH_4OAc) of 24 $cmol_c$ kg^{-1} clay or more throughout or to a depth of 50 cm below its upper limit, whichever is shallower, either starting within 100 cm of the soil surface or within 200 cm of the soil surface if the *argic* horizon is overlain by loamy sand or coarser textures throughout, and a base saturation (by 1 *M* NH_4OAc) of less than 50% in the major part between 50 and100 cm from the soil surface.

Aluandic (aa)

Having one or more layers, cumulatively 15 cm or more thick, with *andic* properties and an acid oxalate (pH 3) extractable silica content of less than 0.6%, and an Al_{py}/Al_{ox} of 0.5 or more, within 100 cm of the soil surface *(in Andosols only)*.

> **Thaptaluandic (aab)**
>
> Having one or more buried layers, cumulatively 15 cm or more thick, with *andic* properties and an acid oxalate (pH 3) extractable silica content of less than 0.6%, or an Al_{py}/Al_{ox} of 0.5 or more, within 100 cm of the soil surface.

Alumic (au)

Having an Al saturation (effective) of 50% or more in some layer between 50 and 100 cm from the soil surface.

Andic (an)

Having within 100 cm of the soil surface one or more layers with *andic* or *vitric* properties with a combined thickness of 30 cm or more (in *Cambisols* 15 cm or more), of which 15 cm or more (in *Cambisols* 7.5 cm or more) have *andic* properties.

Thaptandic (ba)

Having within 100 cm of the soil surface one or more buried layers with *andic* or *vitric* properties with a combined thickness of 30 cm or more (in *Cambisols* 15 cm or more), of which 15 cm or more (in *Cambisols* 7.5 cm or more) have *andic* properties.

Anthraquic (aq)

Having an *anthraquic* horizon.

Anthric (am)

Having an *anthric* horizon.

Arenic (ar)

Having a texture of loamy fine sand or coarser in a layer, 30 cm or more thick, within 100 cm of the soil surface.

Epiarenic (arp)

Having a texture of loamy fine sand or coarser in a layer, 30 cm or more thick, within 50 cm of the soil surface.

Endoarenic (arn)

Having a texture of loamy fine sand or coarser in a layer, 30 cm or more thick, between 50 and 100 cm from the soil surface.

Aric (ai)

Having only remnants of diagnostic horizons, disturbed by deep ploughing.

Aridic (ad)

Having *aridic* properties without a *takyric* or *yermic* horizon.

Arzic (az)

Having sulphate-rich groundwater in some layer within 50 cm of the soil surface during some time in most years and containing 15% or more gypsum averaged over a depth of 100 cm from the soil surface or to *continuous rock* or a cemented or indurated layer, whichever is shallower (*in Gypsisols only*).

Brunic (br)

Having a layer, 15 cm or more thick, which meets criteria 2–4 of the *cambic* horizon but fails criterion 1 and does not form part of an albic horizon, starting within 50 cm of the soil surface.

Calcaric (ca)

Having *calcaric* material between 20 and 50 cm from the soil surface or between 20 cm and *continuous rock* or a cemented or indurated layer, whichever is shallower.

Calcic (cc)

Having a *calcic* horizon or concentrations of *secondary carbonates* starting within 100 cm of the soil surface.

Pisocalcic (cp)

Having only concentrations of secondary carbonates starting within 100 cm of the soil surface.

Cambic (cm)

Having a *cambic* horizon, which does not form part of an albic horizon, starting within 50 cm of the soil surface.

Carbic (cb)

Having a *spodic* horizon that does not turn redder on ignition throughout (*in Podzols only*).

Carbonatic (cn)

Having a *salic* horizon with a soil solution (1:1 in water) with a pH of 8.5 or more and [HCO_3^-] > [SO_4^{2-}] >> [Cl^-] (*in Solonchaks only*).

Chloridic (cl)

Having a *salic* horizon with a soil solution (1:1 in water) with [Cl^-] >> [SO_4^{2-}] > [HCO_3^-] *(in Solonchaks only)*

Chromic (cr)

Having within 150 cm of the soil surface a subsurface layer, 30 cm or more thick, that has a Munsell hue redder than 7.5 YR or that has both, a hue of 7.5 YR and a chroma, moist, of more than 4.

Clayic (ce)

Having a texture of clay in a layer, 30 cm or more thick, within 100 cm of the soil surface.

Epiclayic (cep)

Having a texture of clay in a layer, 30 cm or more thick, within 50 cm of the soil surface.

Endoclayic (cen)

Having a texture of clay in a layer, 30 cm or more thick, within 50 and 100 cm of the soil surface.

Colluvic (co)

Having *colluvic* material, 20 cm or more thick, created by human-induced lateral movement.

Cryic (cy)

Having a *cryic* horizon starting within 100 cm of the soil surface or a *cryic* horizon starting within 200 cm of the soil surface with evidence of cryoturbation in some layer within 100 cm of the soil surface.

Cutanic (ct)

Having clay coatings in some parts of an *argic* horizon either starting within 100 cm of the soil surface or within 200 cm of the soil surface if the *argic* horizon is overlain by loamy sand or coarser textures throughout.

Densic (dn)

Having natural or artificial compaction within 50 cm of the soil surface to the extent that roots cannot penetrate.

Drainic (dr)

Having a *histic* horizon that is drained artificially starting within 40 cm of the soil surface.

Duric (du)

Having a *duric* horizon starting within 100 cm of the soil surface.

Endoduric (nd)

Having a *duric* horizon starting between 50 and 100 cm from the soil surface.

Hyperduric (duh)

Having a *duric* horizon with 50% or more (by volume) durinodes or fragments of a broken-up *petroduric* horizon starting within 100 cm of the soil surface.

Dystric (dy)

Having a base saturation (by 1 *M* NH_4OAc) of less than 50% in the major part between 20 and 100 cm from the soil surface or between 20 cm and *continuous rock* or a cemented or indurated layer, or in a layer, 5 cm or more thick, directly above *continuous rock,* if the *continuous rock* starts within 25 cm of the soil surface.

Endodystric (ny)

Having a base saturation (by 1 *M* NH_4OAc) of less than 50% throughout between 50 and 100 cm from the soil surface.

Epidystric (ed)

Having a base saturation (by 1 *M* NH_4OAc) of less than 50% throughout between 20 and 50 cm from the soil surface.

Hyperdystric (hd)

Having a base saturation (by 1 *M* NH_4OAc) of less than 50% throughout between 20 and 100 cm from the soil surface, and less than 20% in some layer within 100 cm of the soil surface.

Orthodystric (dyo)

Having a base saturation (by 1 *M* NH_4OAc) of less than 50% throughout between 20 and 100 cm from the soil surface.

Ekranic (ek)

Having *technic hard rock* starting within 5 cm of the soil surface and covering 95% or more of the horizontal extent of the soil *(in Technosols only)*.

Endoduric (nd)

See Duric.

Endodystric (ny)

See Dystric.

Endoeutric (ne)

See Eutric.

Endofluvic (nf)

See Fluvic.

Endogleyic (ng)

See Gleyic.

Endoleptic (nl)

See Leptic.

Endosalic (ns)

See Salic.

Entic (et)

Not an *albic* horizon and a loose *spodic* horizon (*in Podzols only*).

Epidystric (ed)

See Dystric.

Epieutric (ee)

See Eutric.

Epileptic (el)

See Leptic.

Episalic (ea)

See Salic.

Escalic (ec)

Occurring in human-made terraces.

Eutric (eu)

Having a base saturation (by 1 *M* NH_4OAc) of 50% or more in the major part between 20 and 100 cm from the soil surface or between 20 cm and *continuous rock* or a cemented or indurated layer, or in a layer, 5 cm or more thick, directly above *continuous rock,* if the *continuous rock* starts within 25 cm of the soil surface.

> **Endoeutric (ne)**
>
> Having a base saturation (by 1 *M* NH_4OAc) of 50% or more throughout between 50 and 100 cm from the soil surface.
>
> **Epieutric (ee)**
>
> Having a base saturation (by 1 *M* NH_4OAc) of 50% or more throughout between 20 and 50 cm from the soil surface.
>
> **Hypereutric (he)**
>
> Having a base saturation (by 1 *M* NH_4OAc) of 50% or more throughout between 20 and 100 cm from the soil surface and 80% or more in some layer within 100 cm of the soil surface.
>
> **Orthoeutric (euo)**
>
> Having a base saturation (by 1 *M* NH_4OAc) of 50% or more throughout between 20 and 100 cm from the soil surface.

Eutrosilic (es)

Having one or more layers, cumulatively 30 cm or more thick, with *andic* properties and a sum of exchangeable bases of 15 $cmol_c$ kg^{-1} fine earth or more within 100 cm of the surface (*in Andosols only*).

Ferralic (fl)

Having a *ferralic* horizon starting within 200 cm of the soil surface *(in Anthrosols only)*, or *ferralic* properties in at least some layer starting within 100 cm of the soil surface *(in other soils)*.

> **Hyperferralic (flh)**
>
> Having *ferralic* properties and a CEC (by 1 *M* NH_4OAc) of less than 16 $cmol_c$ kg^{-1} clay in at least some layer starting within 100 cm of the soil surface.
>
> **Hypoferralic (flw)**
>
> Having in a layer, 30 cm or more thick, starting within 100 cm of the soil surface a CEC (by 1 *M* NH_4OAc) of less than 4 $cmol_c$ kg^{-1} fine earth and a Munsell chroma, moist, of 5 or more or a hue redder than 10 YR (*in Arenosols only*).

Ferric (fr)

Having a *ferric* horizon starting within 100 cm of the soil surface.

Hyperferric (frh)

Having a *ferric* horizon with 40% or more of the volume discrete reddish to blackish nodules starting within 100 cm of the soil surface.

Fibric (fi)

Having, after rubbing, two-thirds or more (by volume) of the *organic* material consisting of recognizable plant tissue within 100 cm of the soil surface (*in Histosols only*).

Floatic (ft)

Having *organic* material floating on water *(in Histosols only)*.

Fluvic (fv)

Having *fluvic* material in a layer, 25 cm or more thick, within 100 cm of the soil surface.

Endofluvic (nf)

Having *fluvic* material in a layer, 25 cm or more thick, between 50 and 100 cm from the soil surface.

Folic (fo)

Having a *folic* horizon starting within 40 cm of the soil surface.

Thaptofolic (fob)

Having a buried *folic* horizon starting between 40 and 100 cm from the soil surface.

Fractipetric (fp)

Having a strongly cemented or indurated horizon consisting of fractured or broken clods with an average horizontal length of less than 10 cm, starting within 100 cm of the soil surface.

Fractiplinthic (fa)

Having a *petroplinthic* horizon consisting of fractured or broken clods with an average horizontal length of less than 10 cm, starting within 100 cm of the soil surface.

Fragic (fg)

Having a *fragic* horizon starting within 100 cm of the soil surface.

Fulvic (fu)

Having a *fulvic* horizon starting within 30 cm of the soil surface.

Garbic (ga)

Having a layer, 20 cm or more thick, starting within 100 cm of the soil surface, with 20% or more (by volume, by weighted average) *artefacts* containing 35% or more (by volume) organic waste materials (*in Technosols only*).

Gelic (ge)

Having a layer with a soil temperature of 0 °C or less for two or more consecutive years starting within 200 cm of the soil surface.

Gelistagnic (gt)

Having temporary water saturation at the soil surface caused by a frozen subsoil.

Geric (gr)

Having *geric* properties in some layer starting within 100 cm of the soil surface.

Gibbsic (gi)

Having a layer, 30 cm or more thicker, containing 25% or more gibbsite in the fine earth fraction starting within 100 cm of the soil surface.

Glacic (gc)

Having a layer, 30 cm or more, containing 75% (by volume) or more ice starting within 100 cm of the soil surface.

Gleyic (gl)

Having within 100 cm of the mineral soil surface a layer, 25 cm or more thick, which has *reducing conditions* in some parts and a *gleyic colour pattern* throughout.

Endogleyic (ng)

Having between 50 and 100 cm from the mineral soil surface a layer, 25 cm or more thick, that has *reducing conditions* in some parts and a *gleyic colour pattern* throughout.

Epigleyic (glp)

Having within 50 cm of the mineral soil surface a layer, 25 cm or more thick, which has *reducing conditions* in some parts and a *gleyic colour pattern* throughout.

Glossalbic (gb)

See Albic.

Glossic (gs)

Showing tonguing of a *mollic* or *umbric* horizon into an underlying layer.

Molliglossic (mi)

Showing tonguing of a *mollic* horizon into an underlying layer.

Umbriglossic (ug)

Showing tonguing of an *umbric* horizon into an underlying layer.

Greyic (gz)

Having Munsell colours with a chroma of 3 or less when moist, a value of 3 or less when moist and 5 or less when dry and uncoated silt and sand grains on structural faces within 5 cm of the mineral soil surface.

Grumic (gm)

Having a soil surface layer with a thickness of 3 cm or more with a strong structure finer than very coarse granular (*in Vertisols only*).

Gypsic (gy)

Having a *gypsic* horizon starting within 100 cm of the soil surface.

Gypsiric (gp)

Having a *gypsiric* material between 20 and 50 cm from the soil surface or between 20 cm and *continuous rock* or a cemented or indurated layer, whichever is shallower.

Haplic (ha)

Having a typical expression of certain features (typical in the sense that there is no further or meaningful characterization) and only used if none of the preceding qualifiers applies.

Hemic (hm)

Having, after rubbing, between two-thirds and one-sixth (by volume) of the *organic* material consisting of recognizable plant tissue within 100 cm from the soil surface (*in Histosols only*).

Histic (hi)

Having a *histic* horizon starting within 40 cm of the soil surface.

Thaptohistic (hib)

Having a buried *histic* horizon starting between 40 and 100 cm from the soil surface.

Hortic (ht)

Having a *hortic* horizon.

Humic (hu)

Having the following organic carbon contents in the fine earth fraction as a weighted average in *Ferralsols* and *Nitisols*, 1.4% or more to a depth of 100 cm from the mineral soil surface; in *Leptosols* to which the Hyperskeletic qualifier applies, 2% or more to a depth of 25 cm from the mineral soil surface; in all other soils, 1% or more to a depth of 50 cm from the mineral soil surface.

Hyperhumic (huh)

Having an organic carbon content of 5% or more as a weighted average in the fine earth fraction to a depth of 50 cm from the mineral soil surface.

Hydragric (hg)

Having an *anthraquic* horizon and an underlying *hydragric* horizon, the latter starting within 100 cm of the soil surface.

Hydric (hy)

Having within 100 cm of the soil surface one or more layers with a combined thickness of 35 cm or more, which have a water retention at 1500 kPa (in undried samples) of 100% or more *(in Andosols only)*.

Hydrophobic (hf)

Water-repellent, i.e. water stands on a dry soil for the duration of 60 seconds or more *(in Arenosols only).*

Hyperalbic (hb)

See Albic.

Hyperalic (hl)

Having an *argic* horizon, either starting within 100 cm of the soil surface, *or* within 200 cm of the soil surface if the *argic* horizon is overlain by loamy sand or coarser textures throughout, that has a silt to clay ratio of less than 0.6 and an Al saturation (effective) of 50% or more, throughout or to a depth of 50 cm below its upper limit, whichever is shallower (*in Alisols only*).

Hypercalcic (hc)

Having a *calcic* horizon with 50% or more (by mass) calcium carbonate equivalent and starting within 100 cm of the soil surface *(in Calcisols only)*.

Hyperdystric (hd)

See Dystric.

Hypereutric (he)

See Eutric.

Hypergypsic (hp)

Having a *gypsic* horizon with 50% or more (by mass) gypsum and starting within 100 cm of the soil surface *(in Gypsisols only)*.

Hyperochric (ho)

Having a mineral topsoil layer, 5 cm or more thick, with a Munsell value, dry, of 5.5 or more that turns darker on moistening, an organic carbon content of less than 0.4%, a platy structure in 50% or more of the volume, and a surface crust.

Hypersalic (hs)

See Salic.

Hyperskeletic (hk)

Containing less than 20% (by volume) fine earth averaged over a depth of 75 cm from the soil surface or to *continuous rock*, whichever is shallower.

Hypocalcic (wc)

Having a *calcic* horizon with a calcium carbonate equivalent content in the fine earth fraction of less than 25% and starting within 100 cm of the soil surface *(in*

Calcisols only).

Hypogypsic (wg)

Having a *gypsic* horizon with a gypsum content in the fine earth fraction of less than 25% and starting within 100 cm of the soil surface *(in Gypsisols only)*.

Hypoluvic (wl)

Having an absolute clay increase of 3% or more within 100 cm of the soil surface (*in Arenosols only*).

Hyposalic (ws)

See Salic.

Hyposodic (wn)

See Sodic.

Irragric (ir)

Having an *irragric* horizon.

Lamellic (ll)

Having clay lamellae with a combined thickness of 15 cm or more within 200 cm of the soil surface.

Laxic (la)

Having a bulk density of less than 0.9 kg dm^{-3}, in a mineral soil layer, 20 cm or more thick, starting within 75 cm of the soil surface.

Leptic (le)

Having *continuous rock* starting within 100 cm of the soil surface.

Endoleptic (nl)

Having *continuous rock* starting between 50 and 100 cm from the soil surface.

Epileptic (el)

Having *continuous rock* starting within 50 cm of the soil surface.

Lignic (lg)

Having inclusions of intact wood fragments, which make up one-quarter or more of the soil volume, within 50 cm of the soil surface *(in Histosols only)*.

Limnic (lm)

Having *limnic material*, cumulatively 10 cm or more thick, within 50 cm of the soil surface.

Linic (lc)

Having a continuous, very slowly permeable to impermeable constructed geomembrane of any thickness starting within 100 cm of the soil surface.

Lithic (li)

Having *continuous rock* starting within 10 cm of the soil surface (*in Leptosols only*).

Nudilithic (nt)

Having *continuous rock* at the soil surface (*in Leptosols only*).

Lixic (lx)

Having an *argic* horizon that has a CEC (by 1 *M* NH_4OAc) of less than 24 $cmol_c$ kg^{-1} clay in some part to a maximum depth of 50 cm below its upper limit, either starting within 100 cm of the soil surface or within 200 cm of the soil surface if the *argic* horizon is overlain by loamy sand or coarser textures throughout, and a base saturation (by 1 *M* NH_4OAc) of 50% or more in the major part between 50 and 100 cm from the soil surface.

Luvic (lv)

Having an *argic* horizon that has a CEC (by 1 *M* NH_4OAc) of 24 $cmol_c$ kg^{-1} clay or more throughout or to a depth of 50 cm below its upper limit, whichever is shallower, either starting within 100 cm of the soil surface or within 200 cm of the soil surface if the *argic* horizon is overlain by loamy sand or coarser textures throughout, and a base saturation (by 1 *M* NH_4OAc) of 50% or more in the major part between 50 and 100 cm from the soil surface.

Magnesic (mg)

Having an exchangeable Ca to Mg ratio of less than 1 in the major part within 100 cm of the soil surface or to *continuous rock* or a cemented or indurated layer, whichever is shallower.

Manganiferric (mf)

Having a *ferric* horizon starting within 100 cm of the soil surface in which half or more of the nodules or mottles are black.

Mazic (mz)

Massive and hard to very hard in the upper 20 cm of the soil (*in Vertisols only*).

Melanic (ml)

Having a *melanic* horizon starting within 30 cm of the soil surface (*in Andosols only*).

Mesotrophic (ms)

Having a base saturation (by 1 *M* NH_4OAc) of less than 75% at a depth of 20 cm from the soil surface (*in Vertisols only*).

Mollic (mo)

Having a *mollic* horizon.

Molliglossic (mi)

See Glossic.

Natric (na)

Having a *natric* horizon starting within 100 cm of the soil surface.

Nitic (ni)

Having a *nitic* horizon starting within 100 cm of the soil surface.

Novic (nv)

Having above the soil that is classified at the RSG level, a layer with recent sediments (new material), 5 cm or more and less than 50 cm thick.

Areninovic (anv)

Having above the soil that is classified at the RSG level, a layer with recent sediments (new material), 5 cm or more and less than 50 cm thick, which has a texture of loamy fine sand or coarser in its major part.

Clayinovic (cnv)

Having above the soil that is classified at the RSG level, a layer with recent sediments (new material), 5 cm or more and less than 50 cm thick, which has a texture of clay in its major part.

Siltinovic (snv)

Having above the soil that is classified at the RSG level, a layer with recent sediments (new material), 5 cm or more and less than 50 cm thick, which has a texture of silt, silt loam, silty clay loam or silty clay in its major part.

Nudiargic (ng)

Having an *argic* horizon starting at the mineral soil surface

Nudilithic (nt)

See *Lithic*.

Ombric (om)

Having a *histic* horizon saturated predominantly with rainwater starting within 40 cm of the soil surface (*in Histosols only*).

Ornithic (oc)

Having a layer 15 cm or more thick with *ornithogenic* material starting within 50 cm of the soil surface.

Ortsteinic (os)

Having a cemented *spodic* horizon (*ortstein) (in Podzols only)*.

Oxyaquic (oa)

Saturated with oxygen-rich water during a period of 20 or more consecutive days and not a *gleyic* or *stagnic colour pattern* in some layer within 100 cm of the soil surface.

Pachic (ph)

Having a *mollic* or *umbric* horizon 50 cm or more thick.

Pellic (pe)

Having in the upper 30 cm of the soil a Munsell value, moist, of 3.5 or less and a chroma, moist, of 1.5 or less (*in Vertisols only*).

Petric (pt)

Having a strongly cemented or indurated layer starting within 100 cm of the soil surface.

> **Endopetric (ptn)**
>
> Having a strongly cemented or indurated layer starting between 50 and 100 cm from the soil surface.
>
> **Epipetric (ptp)**
>
> Having a strongly cemented or indurated layer starting within 50 cm of the soil surface.

Petrocalcic (pc)

Having a *petrocalcic* horizon starting within 100 cm of the soil surface.

Petroduric (pd)

Having a *petroduric* horizon starting within 100 cm of the soil surface.

Petrogleyic (py)

Having a layer, 10 cm or more thick, with an oximorphic colour pattern[19] and of which 15% or more (by volume) is cemented (*bog iron*), within 100 cm of the soil surface.

Petrogypsic (pg)

Having a *petrogypsic* horizon starting within 100 cm of the soil surface.

Petroplinthic (pp)

Having a *petroplinthic* horizon starting within 100 cm of the soil surface.

Petrosalic (ps)

Having within 100 cm of the soil surface, a layer, 10 cm or more thick, which is cemented by salts more soluble than gypsum.

Pisocalcic (cp)

See *Calcic*

Pisoplinthic (px)

Having a *pisoplinthic* horizon starting within 100 cm of the soil surface.

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[19] As defined in the *gleyic colour pattern*.

Placic (pi)

Having within 100 cm of the soil surface, an iron pan, between 1 and 25 mm thick, that is continuously cemented by a combination of organic matter, Fe and/or Al.

Plaggic (pa)

Having a *plaggic* horizon.

Plinthic (pl)

Having a *plinthic* horizon starting within 100 cm of the soil surface.

Posic (po)

Having a zero or positive charge (pH_{KCl} - $pH_{water} \geq 0$, both in 1:1 solution) in a layer, 30 cm or more thick, starting within 100 cm of the soil surface (*in Plinthosols and Ferralsols only*).

Profondic (pf)

Having an *argic* horizon in which the clay content does not decrease by 20% or more (relative) from its maximum within 150 cm of the soil surface.

Protic (pr)

Showing no soil horizon development (*in Arenosols only*).

Puffic (pu)

Having a crust pushed up by salt crystals (*in Solonchaks only*).

Reductaquic (ra)

Saturated with water during the thawing period and at some time of the year *reducing conditions* above a *cryic* horizon and within 100 cm of the soil surface (*in Cryosols only*).

Reductic (rd)

Having *reducing conditions* in 25% or more of the soil volume within 100 cm of the soil surface caused by gaseous emissions, e.g. methane or carbon dioxide (*in Technosols only*).

Regic (rg)

Not having buried horizons (*in Anthrosols only*).

Rendzic (rz)

Having a *mollic* horizon that contains, or immediately overlies *calcaric* materials or calcareous rock containing 40% or more calcium carbonate equivalent.

Rheic (rh)

Having a *histic* horizon saturated predominantly with groundwater or flowing surface water starting within 40 cm of the soil surface (*in Histosols only*).

Rhodic (ro)

Having within 150 cm of the soil surface a subsurface layer, 30 cm or more thick, with a Munsell hue of 2.5 YR or redder, a value, moist, of less than 3.5 and a value, dry, no more than one unit higher than the moist value.

Rubic (ru)

Within 100 cm of the soil surface a subsurface layer, 30 cm or more thick, with a Munsell hue redder than 10 YR or a chroma, moist, of 5 or more (*in Arenosols only*).

Ruptic (rp)

Having a *lithological discontinuity* within 100 cm of the soil surface.

Rustic (rs)

Having a *spodic* horizon in which the ratio of the percentage of acid oxalate (pH 3) extractable iron to the percentage of organic carbon is 6 or more throughout (*in Podzols only*).

Salic (sz)

Having a *salic* horizon starting within 100 cm of the soil surface.

Endosalic (ns)

Having a *salic* horizon starting between 50 and 100 cm from the soil surface.

Episalic (ea)

Having a *salic* horizon starting within 50 cm of the soil surface.

Hypersalic (hs)

Having an EC_e of 30 dS m^{-1} or more at 25 °C in some layer within 100 cm of the soil surface.

Hyposalic (ws)

Having an EC_e of 4 dS m^{-1} or more at 25 °C in some layer within 100 cm of the soil surface.

Sapric (sa)

Having, after rubbing, less than one-sixth (by volume) of the *organic* material consisting of recognizable plant tissue within 100 cm of the soil surface (*in Histosols only*).

Silandic (sn)

Having one or more layers, cumulatively 15 cm or more thick, with *andic* properties and an acid oxalate (pH 3) extractable silica (Si_{ox}) content of 0.6% or more, or an Al_{py} to Al_{ox} ratio of less than 0.5 within 100 cm of the soil surface (*in Andosols only*).

Thaptosilandic (snb)

Having one or more buried layers, cumulatively 15 cm or more thick, with *andic* properties and an acid oxalate (pH 3) extractable silica (Si_{ox}) content of 0.6% or more, or an Al_{py} to Al_{ox} ratio of less than 0.5 within 100 cm of the soil surface.

Siltic (sl)

Having a texture of silt, silt loam, silty clay loam or silty clay in a layer, 30 cm or more thick, within 100 cm of the soil surface.

Endosiltic (sln)

Having a texture of silt, silt loam, silty clay loam or silty clay in a layer, 30 cm or more thick, within 50 and 100 cm of the soil surface.

Episiltic (slp)

Having a texture of silt, silt loam, silty clay loam or silty clay in a layer, 30 cm or more thick, within 50 cm of the soil surface.

Skeletic (sk)

40% or more (by volume) gravel or other coarse fragments averaged over a depth of 100 cm from the soil surface or to *continuous rock* or a cemented or indurated layer, whichever is shallower.

Endoskeletic (skn)

Having 40% or more (by volume) gravel or other coarse fragments averaged over a depth between 50 and 100 cm from the soil surface.

Episkeletic (skp)

Having 40% or more (by volume) gravel or other coarse fragments averaged over a depth of 50 cm from the soil surface.

Sodic (so)

Having 15% or more exchangeable Na, or Na plus Mg>Ca on the exchange complex, within 50 cm of the soil surface throughout.

Endosodic (son)

Having 15% or more exchangeable Na or Na plus Mg>Ca on the exchange complex between 50 and 100 cm from the soil surface throughout.

Hyposodic (sow)

Having 6% or more exchangeable Na on the exchange complex in a layer, 20 cm or more thick, within 100 cm of the soil surface.

Solodic (sc)

Having a layer, 15 cm or more thick within 100 cm of the soil surface, with the columnar or prismatic structure of the *natric* horizon, but lacking its sodium saturation requirements.

Sombric (sm)

Having a *sombric* horizon starting within 150 cm of the soil surface.

Spodic (sd)

Having a *spodic* horizon starting within 200 cm of the mineral soil surface.

Spolic (sp)

Having a layer, 20 cm or more thick within 100 cm of the soil surface, with 20% or more (by volume, by weighted average) *artefacts* containing 35% or more (by volume) of industrial waste (mine spoil, dredgings, rubble, etc.) (*in Technosols only*).

Stagnic (st)

Having within 100 cm of the mineral soil surface in some parts *reducing conditions* for some time during the year and in 25% or more of the soil volume, single or in combination, a *stagnic colour pattern* or an *albic* horizon.

Endostagnic (stn)

Having between 50 and 100 cm from the mineral soil surface in some parts *reducing conditions* for some time during the year and in 25% or more of the soil volume, single or in combination, a *stagnic colour pattern* or an *albic* horizon.

Epistagnic (stn)

Having within 50 cm of the mineral soil surface in some parts *reducing conditions* for some time during the year and in 25% or more of the soil volume, single or in combination, a *stagnic colour pattern* or an *albic* horizon.

Subaquatic (sq)

Being permanently submerged under water not deeper than 200 cm.

Sulphatic (su)

Having a *salic* horizon with a soil solution (1:1 in water) with [SO_4^{2-}] >> [HCO_3^-] >[Cl^-] (*in Solonchaks only*).

Takyric (ty)

Having a *takyric* horizon.

Technic (te)

Having 10% or more (by volume, by weighted average) *artefacts* in the upper 100 cm from the soil surface or to *continuous rock* or a cemented or indurated layer, whichever is shallower.

Tephric (tf)

Having *tephric* material to a depth of 30 cm or more from the soil surface or to *continuous rock*, whichever is shallower.

Terric (tr)

Having a *terric* horizon.

Thaptandic (ba)

See Andic.

Thaptovitric (bv)

See Vitric.

Thionic (ti)

Having a *thionic* horizon or a layer with *sulphidic* material, 15 cm or more thick, starting within 100 cm of the soil surface.

> **Hyperthionic (tih)**
>
> Having a *thionic* horizon starting within 100 cm of the soil surface and a pH (1:1 in water) less than 3.5.
>
> **Orthothionic (tio)**
>
> Having a *thionic* horizon starting within 100 cm of the soil surface and a pH (1:1 in water) between 3.5 and 4.0.
>
> **Protothionic (tip)**
>
> Having a layer with *sulphidic* material, 15 cm or more thick, starting within 100 cm of the soil surface.

Thixotropic (tp)

Having in some layer within 50 cm of the soil surface material that changes, under pressure or by rubbing, from a plastic solid into a liquefied stage and back into the solid condition.

Tidalic (td)

Being flooded by tidewater but not covered by water at mean low tide.

Toxic (tx)

Having in some layer within 50 cm of the soil surface toxic concentrations of organic or inorganic substances other than ions of Al, Fe, Na, Ca and Mg.

Anthrotoxic (atx)

Having in some layer within 50 cm of the soil surface sufficiently high and persistent concentrations of organic or inorganic substances to markedly affect the health of humans who come in regular contact with the soil.

Ecotoxic (etx)

Having in some layer within 50 cm of the soil surface sufficiently high and persistent concentrations of organic or inorganic substances to markedly affect soil ecology, in particular the populations of the mesofauna.

Phytotoxic (ptx)

Having in some layer within 50 cm of the soil surface sufficiently high or low concentrations of ions other than Al, Fe, Na, Ca and Mg, to markedly affect plant growth.

Zootoxic (ztx)

Having in some layer within 50 cm of the soil surface sufficiently high and persistent concentrations of organic or inorganic substances to markedly affect the health of animals, including humans, that ingest plants grown on these soils.

Transportic (tn)

Having at the surface a layer, 30 cm or more thick, with solid or liquid material that has been moved from a source area outside the immediate vicinity of the soil by intentional human activity, usually with the aid of machinery, and without substantial reworking or displacement by natural forces

Turbic (tu)

Having cryoturbation features (mixed material, disrupted soil horizons, involutions, organic intrusions, frost heave, separation of coarse from fine materials, cracks or patterned ground) at the soil surface or above a *cryic* horizon and within 100 cm of the soil surface.

Umbric (um)

Having an *umbric* horizon.

Umbriglossic (ug)

See Glossic.

Urbic (ub)

Having a layer, 20 cm or more thick within 100 cm of the soil surface, with 20% or more (by volume, by weighted average) *artefacts* containing 35% or more (by volume) of rubble and refuse of human settlements (*in Technosols only*).

Vermic (vm)

Having 50% or more (by volume, by weighted average) of worm holes, casts, or filled animal burrows in the upper 100 cm of the soil or to *continuous rock* or a cemented or indurated layer, whichever is shallower.

Vertic (vr)

Having a *vertic* horizon or *vertic* properties starting within 100 cm of the soil surface.

Vetic (vt)

Having an ECEC (sum of exchangeable bases plus exchangeable acidity in 1 *M* KCl) of less than 6 $cmol_c\ kg^{-1}$ clay in some subsurface layer within 100 cm of the soil surface.

Vitric (vi)

Having within 100 cm of the soil surface one or more layers with *andic* or *vitric* properties, with a combined thickness of 30 cm or more (in Cambisols 15 cm or more), of which 15 cm or more have *vitric* properties

Thaptovitric (bv)

Having within 100 cm of the soil surface one or more buried layers with *andic* or *vitric* properties, with a combined thickness of 30 cm or more (in Cambisols 15 cm or more), of which 15 cm or more have *vitric* properties.

Voronic (vo)

Having a *voronic* horizon (*in Chernozems only*).

Xanthic (xa)

Having a *ferralic* horizon that has in a subhorizon, 30 cm or more thick within 150 cm of the soil surface, a Munsell hue of 7.5 YR or yellower and a value, moist, of 4 or more and a chroma, moist, of 5 or more.

Yermic (ye)

Having a *yermic* horizon, including a desert pavement.

Nudiyermic (yes)

Having a *yermic* horizon without a desert pavement.

3.5.1 Specifiers

The following specifiers may be used to indicate depth of occurrence, or to express the intensity of soil characteristics. Their code is always added after the qualifier code. The specifiers are combined with other elements into one word, e.g. Endoskeletic. A triple combination, e.g. Epihyperdystric, is allowed.

Bathy (..d)

The criteria of the qualifier are full filled for the required thickness somewhere between 100 and 200 cm from the soil surface.

Cumuli (..c)

Having a repetitive accumulation of material with a cumulative thickness of 50 cm or more at the soil surface (e.g. cumulinovic and cumulimollic).

Endo (..n)

The criteria of the qualifier are full filled for the required thickness somewhere starting between 50 and 100 cm from the soil surface.

Epi (..p)

The criteria of the qualifier are full filled for the required thickness somewhere starting within 50 cm of the soil surface.

Hyper (..h)

Having a strong expression of certain features.

Hypo (..w)

Having a weak expression of certain features.

Ortho (..o)

Having a typical expression of certain features (typical in the sense that no further or meaningful characterization is made).

Para (..r)

Having a resemblance to certain features (e.g. Paralithic).

Proto (..t)

Indicating a precondition or an early stage of development of certain features (e.g. Protothionic).

Thapto (..b)

Having a buried layer relating to diagnostic horizon, properties or materials starting within 100 cm of the surface (e.g. Thaptomollic).

Annex 4 Legends

4.1 Guidelines for constructing small-scale map legend using the World Reference Base for Soil Resources

Addendum to the World Reference Base for Soil Resources (IUSS 2006, 2007).

These guidelines are based on the following considerations:
- The soil units and their ranking in the FAO-UNESCO Legend and Revised Legend of the Soil Map of the World (SMW).
- The occurrence and significance of soil properties in other classification systems.
- The relevance of differentiation characteristics for environmental and management functions.
- The availability of soil information (legacy and modern).
- The mapability of soil characteristics at scales of 1:250 000 and smaller.

For every Reference Soil Group (RSG), the qualifiers are given that can be used to construct small-scale map units and map legends. They are divided into lists of main map unit qualifiers and optional map unit qualifiers. The main map unit qualifiers are ranked and have to be used in the given order. The optional map unit qualifiers are listed alphabetically and may be added according to the need of the user. The following rules apply:
- A map unit consists either of the dominant soil only or of the dominant soil plus a co-dominant soil or one or more associate soils; dominant soils represent 50% or more of the soil cover, co-dominant soils 25% or more, and associated soils are mentioned only if they represent 5% or more of the soil cover or are of high relevance in the landscape ecology; instead of one dominant soil, a combination of at least two co-dominant soils is also possible; if co-dominant or associated soils are indicated, the words 'dominant:', 'co-dominant:' and 'associated:' are written before the name of the soil; the soils are separated by semicolons.
- The number of qualifiers specified below refers to the dominant soil; for co-dominant or associated soils, smaller numbers of qualifiers (or even no qualifier) may be appropriate.
- For map scales of 1 : 5 000 000 and smaller, either the Reference Soil Group (RSG) name or the RSG name plus the first applicable qualifier of the main list is used; the qualifier is placed before the RSG name.
- For map scales from 1 : 1 000 000 to 1 : 5 000 000, the RSG name plus the first two applicable qualifiers of the main list is used; the qualifiers are placed before the RSG name; the first applicable qualifier stands closest to the RSG name.
- For map scales from 1 : 250 000 to 1 : 1 000 000, the RSG name plus the first three applicable qualifiers of the main list is used; the qualifiers are placed before the RSG name; the first applicable qualifier stands closest to the RSG name, the second one stands in the middle.
- Additional qualifiers of the main list or qualifiers of the optional list may be used in brackets behind the Reference Soil Group name; if two or more qualifiers behind the RSG are used, the following rules apply: (a) the qualifiers are separated by commas, (b) the additional qualifiers from the main list are placed first and out of them the first applicable qualifier stands first, (c) the sequence of qualifiers from the optional list is according to the preference of the soil scientist making the map.
- In case two or more main map unit qualifiers are listed separated by a slash (/), only the dominant one is used.
- If there are less qualifiers applying than described above, the smaller number is used.
- Redundant qualifiers (the characteristics of which are included in a previously used qualifier) are not added; the qualifier Haplic cannot be used in combination with other qualifiers before the RSG name.

– The use of the specifiers Epi- (the qualifier applies only between 0 and 50 cm from the mineral soil surface) and Endo- (the qualifier applies only between 50 and 100 cm from the mineral soil surface) is encouraged, where applicable.

These guidelines are based on the understanding that satisfactory (quality) data are necessary to determine the elements of the map units.

Reference Soil Groups (RSG) with legend qualifiers for small scale maps.

RSG	**Main map unit qualifiers** (in front of the soil name)	**Optional map unit qualifiers** (in brackets behind the soil name)	
			cont.
ACRISOLS	Leptic	Abruptic	Lamellic
	Fractiplinthic / Petroplinthic /	Alumic	Nitic
AC	Pisoplinthic / Plinthic	Andic	Novic
	Gleyic	Anthric	Nudiargic
	Stagnic	Clayic	Oxyaquic
	Umbric	Cutanic	Profondic
	Albic	Densic	Ruptic
	Manganiferric / Ferric	Epieutric	Skeletic
	Arenic / Siltic	Fragic	Sombric
	Humic	Greyic	Technic
	Rhodic / Chromic	Hyperdystric	Transportic
	Haplic	Hyperochric	Vetic
		cont.	Vitric
ALBELUVISOLS	Gleyic	Abruptic	Fragic
	Stagnic	Anthric	Gelic
AB	Folic / Histic	Arenic	Greyic
	Umbric	Cambic	Novic
	Manganiferric / Ferric	Clayic	Oxyaquic
	Alumic	Cutanic	Ruptic
	Dystric / Eutric	Densic	Siltic
		Drainic	Technic
			Transportic

RSG	Main map unit qualifiers (in front of the soil name)	Optional map unit qualifiers (in brackets behind the soil name)	
			cont.
ALISOLS	Leptic / Skeletic	Abruptic	Hyperochric
	Fractiplinthic / Petroplinthic /	Alumic	Lamellic
AL	Pisoplinthic / Plinthic	Andic	Nitic
	Gleyic	Anthric	Novic
	Stagnic	Clayic	Nudiargic
	Umbric	Cutanic	Oxyaquic
	Albic	Densic	Profondic
	Manganiferric / Ferric	Epieutric	Ruptic
	Arenic / Silltic	Fragic	Technic
	Humic	Gelic	Transportic
	Rhodic / Chromic	Greyic	Turbic
	Haplic	Hyperalic	Vertic
		Hyperdystric	Vitric
ANTHROSOLS	Hydragric / Irragric / Terric/	Alcalic	Oxyaquic
	Plaggic / Hortic	Arenic	Regic
AT	Dystric / Eutric	Clayic	Salic
		Escalic	Siltic
		Ferralic	Sodic
		Fluvic	Spodic
		Gleyic	Stagnic
		Novic	Technic
ANDOSOLS	Vitric	Acroxic	Gypsic
	Aluandic / Silandic	Anthric	Hydric
AN	Melanic / Fulvic	Arenic	Novic
	Leptic	Calcaric	Oxyaquic
	Gleyic	Clayic	Placic
	Folic / Histic	Colluvic	Siltic
	Mollic / Umbric	Drainic	Skeletic
	Petroduric / Duric	Eutrosilic	Sodic
	Calcic	Fragic	Technic
	Dystric / Eutric	Gelic	Thixotropic
		Greyic	Transportic
			Turbic

RSG	Main map unit qualifiers (in front of the soil name)	Optional map unit qualifiers (in brackets behind the soil name)	
			cont.
ARENOSOLS **AR**	Fractiplinthic / Petroplinthic / Pisoplinthic / Plinthic Gleyic Salic Folic Albic Ferralic Hypoluvic / Lamellic Rubic / Brunic Protic Gypsiric / Calcaric Dystric / Eutric	Aridic Gelic Greyic Hydrophobic Hyperalbic Hyperochric Novic Ornithic Petrogleyic Placic Stagnic	Technic Tephric Transportic Turbic Yermic
CALCISOLS **CL**	Petric Hyperskeletic / Leptic Luvic / Lixic Arenic Haplic	Aridic Chromic Clayic Densic Endogleyic Endosalic Gypsic Hypercalcic Hyperochric Hypocalcic	Novic Ruptic Siltic Skeletic Sodic Takyric Technic Transportic Vertic Yermic
CRYOSOLS **CR**	Glacic Turbic Folic / Histic Hyperskeletic / Leptic Mollic / Umbric Spodic Reductaquic / Oxyaquic Haplic	Arenic Aridic Calcaric Calcic Cambic Clayic Drainic Dystric Eutric	Gypsiric Natric Novic Ornithic Salic Siltic Skeletic Thixotropic Transportic Vitric

RSG	**Main map unit qualifiers** (in front of the soil name)	**Optional map unit qualifiers** (in brackets behind the soil name)	
			cont.
CAMBISOLS	Leptic / Skeletic	Alcalic	Laxic
	Fractiplinthic / Petroplinthic /	Alumic	Manganiferric
CM	Pisoplinthic / Plinthic	Anthraquic	Novic
	Vertic	Aridic	Ornithic
	Thionic	Clayic	Oxyaquic
	Gleyic	Colluvic	Pisocalcic
	Gelistagnic / Stagnic	Densic	Plaggic
	Salic	Escalic	Ruptic
	Vitric / Andic	Ferric	Siltic
	Ferralic	Folic	Sodic
	Fluvic	Fragic	Takyric
	Gypsiric / Calcaric	Gelic	Technic
	Rhodic / Chromic	Greyic	Tephric
	Dystric / Eutric	Hortic	Terric
		Humic	Transportic
		Hyperochric	Turbic
		Irragric	Yermic
CHERNOZEMS	Voronic	Andic	Oxyaquic
	Glossic	Anthric	Pachic
CH	Petrocalcic	Clayic	Petroduric
	Vertic	Densic	Petrogypsic
	Arenic	Duric	Siltic
	Gleyic	Endofluvic	Skeletic
	Luvic	Endosalic	Sodic
	Calcic	Greyic	Stagnic
	Haplic	Gypsic	Technic
		Leptic	Tephric
		Novic	Vermic
			Vitric
DURISOLS	Petric / Fractipetric	Aridic	Ruptic
	Petrocalcic / Calcic	Chromic	Siltic
DU	Luvic / Lixic	Clayic	Sodic
	Arenic	Endogleyic	Takyric
	Haplic	Gypsic	Technic
		Hyperochric	Transportic
		Leptic	Vertic
		Novic	Yermic

RSG	Main map unit qualifiers (in front of the soil name)	Optional map unit qualifiers (in brackets behind the soil name)	
			cont.
FERRALSOLS	Gibbsic	Alumic	Manganiferric
	Posic / Geric	Andic	Novic
FR	Fractiplinthic / Petroplinthic /	Arenic	Oxyaquic
	Pisoplinthic / Plinthic	Clayic	Ruptic
	Folic	Colluvic	Siltic
	Mollic / Umbric	Densic	Sombric
	Acric / Lixic	Dystric	Technic
	Humic	Eutric	Transportic
	Rhodic / Xanthic	Ferric	Vetic
	Haplic		
FLUVISOLS	Subaquatic/ Tidalic	Anthric	Humic
	Thionic	Arenic	Limnic
FL	Skeletic	Aridic	Oxyaquic
	Salic	Calcic	Petrogleyic
	Gleyic	Clayic	Siltic
	Stagnic	Densic	Sodic
	Vertic	Drainic	Takyric
	Folic/ Histic	Gelic	Technic
	Mollic/ Umbric	Greyic	Tephric
	Calcaric	Gypsic	Transportic
	Dystric / Eutric	Gypsiric	Yermic
GLEYSOLS	Thionic	Abruptic	Humic
	Folic / Histic	Acric	Lixic
GL	Mollic / Umbric	Alcalic	Luvic
	Pisoplinthic / Plinthic	Alic	Novic
	Gypsic	Alumic	Petrogleyic
	Calcic / Calcaric	Andic	Siltic
	Arenic	Anthraquic	Sodic
	Dystric / Eutric	Clayic	Spodic
		Colluvic	Takyric
		Drainic	Technic
		Endosalic	Tephric
		Fluvic	Toxic
		Gelic	Turbic
		Greyic	Vitric

RSG	Main map unit qualifiers (in front of the soil name)	Optional map unit qualifiers (in brackets behind the soil name)	
			cont.
GYPSISOLS	Petric	Aridic	Petroduric
	Hyperskeletic / Leptic	Arzic	Ruptic
GY	Petrocalcic / Calcic	Clayic	Siltic
	Luvic	Duric	Skeletic
	Arenic	Endogleyic	Sodic
	Haplic	Endosalic	Takyric
		Hypergypsic	Technic
		Hyperochric	Transportic
		Hypogypsic	Vertic
		Novic	Yermic
HISTOSOLS	Cryic	Alcalic	Ornithic
	Thionic	Calcaric	Petrogleyic
HS	Folic	Calcic	Placic
	Fibric / Hemic / Sapric	Drainic	Salic
	Technic	Floatic	Skeletic
	Hyperskeletic / Leptic	Gelic	Sodic
	Vitric / Andic	Glacic	Subaquatic
	Dystric / Eutric	Lignic	Tidalic
	Rheic / Ombric	Limnic	Toxic
		Novic	Transportic
			Turbic
KASTANOZEMS	Petrogypsic / Gypsic / Petroduric / Duric / Petrocalcic	Andic	Novic
		Anthric	Oxyaquic
KS	Vertic	Chromic	Siltic
	Arenic	Clayic	Skeletic
	Gleyic	Densic	Sodic
	Luvic	Endosalic	Stagnic
	Calcic	Glossic	Technic
	Haplic	Greyic	Tephric
		Leptic	Vermic
			Vitric

RSG	Main map unit qualifiers (in front of the soil name)	Optional map unit qualifiers (in brackets behind the soil name)	
			cont.
LEPTOSOLS	Nudilithic/ Lithic	Andic	Ornithic
	Hyperskeletic	Aridic	Oxyaquic
LP	Rendzic	Brunic	Placic
	Folic/ Histic	Calcaric	Protothionic
	Mollic/ Umbric	Cambic	Salic
	Dystric/ Eutric	Drainic	Skeletic
		Gelic	Sodic
		Gleyic	Stagnic
		Greyic	Technic
		Gypsiric	Tephric
		Humic	Vertic
		Novic	Vitric
			Yermic
LIXISOLS	Leptic	Abruptic	Lamellic
	Fractiplinthic / Petroplinthic /	Andic	Nitic
LX	Pisoplinthic / Plinthic	Anthric	Novic
	Gleyic	Clayic	Nudiargic
	Stagnic	Cutanic	Oxyaquic
	Albic	Densic	Profondic
	Calcic	Epidystric	Ruptic
	Manganiferric / Ferric	Fragic	Skeletic
	Arenic / Siltic	Greyic	Technic
	Rhodic / Chromic	Humic	Transportic
	Haplic	Hypereutric	Vetic
		Hyperochric	Vitric

RSG	**Main map unit qualifiers** (in front of the soil name)	**Optional map unit qualifiers** (in brackets behind the soil name)	
			cont.
LUVISOLS	Leptic / Skeletic	Abruptic	Hyperochric
	Gleyic	Andic	Lamellic
LV	Stagnic	Anthric	Nitic
	Albic	Clayic	Novic
	Vertic	Cutanic	Nudiargic
	Calcic	Densic	Oxyaquic
	Manganiferric / Ferric	Epidystric	Profondic
	Arenic / Siltic	Escalic	Ruptic
	Rhodic / Chromic	Fragic	Sodic
	Haplic	Gelic	Technic
		Greyic	Transportic
		Humic	Turbic
		Hypereutric	Vitric
		cont.	
NITISOLS	Mollic / Umbric	Alumic	Oxyaquic
	Ferralic	Andic	Technic
NT	Alic / Acric / Luvic / Lixic	Colluvic	Transportic
	Humic	Densic	Vetic
	Rhodic	Novic	
	Dystric / Eutric		
PHAEOZEMS	Greyic	Abruptic	Novic
	Rendzic	Albic	Oxyaquic
PH	Leptic / Skeletic	Andic	Pachic
	Petrocalcic	Anthric	Petroduric
	Vertic	Arenic	Petrogypsic
	Gleyic	Chromic	Siltic
	Luvic	Clayic	Sodic
	Calcaric	Densic	Stagnic
	Haplic	Duric	Technic
		Endosalic	Tephric
		Ferralic	Vermic
		Glossic	Vitric

RSG	Main map unit qualifiers (in front of the soil name)	Optional map unit qualifiers (in brackets behind the soil name)	
			cont.
PLANOSOLS	Solodic	Albic	Gelic
	Folic / Histic	Alcalic	Geric
PL	Mollic / Umbric	Alumic	Greyic
	Gypsic	Calcaric	Manganiferric
	Petrocalcic / Calcic	Chromic	Plinthic
	Alic / Acric / Luvic / Lixic	Clayic	Ruptic
	Vertic	Drainic	Sodic
	Arenic / Siltic	Endogleyic	Technic
	Dystric / Eutric	Endosalic	Thionic
		Ferric	Transportic
PLINTHOSOLS	Petric / Fractipetric	Abruptic	Lixic
	Pisoplinthic	Acric	Manganiferric
PT	Albic	Alumic	Novic
	Stagnic	Clayic	Oxyaquic
	Folic / Histic	Colluvic	Pachic
	Umbric	Drainic	Posic
	Arenic	Endoduric	Ruptic
	Dystric / Eutric	Ferric	Siltic
		Geric	Technic
		Gibbsic	Transportic
		Humic	Umbriglossic
			Vetic
PODZOLS	Carbic / Rustic	Anthric	Ortsteinic
	Albic / Entic	Densic	Oxyaquic
PZ	Gleyic	Drainic	Placic
	Stagnic	Fragic	Plaggic
	Folic / Histic / Umbric	Gelic	Ruptic
	Hyperskeletic / Leptic	Hortic	Skeletic
	Vitric / Silandic / Aluandic	Lamellic	Technic
	Haplic	Novic	Terric
		Ornithic	Transportic
			Turbic

RSG	**Main map unit qualifiers** (in front of the soil name)	**Optional map unit qualifiers** (in brackets behind the soil name)	
			cont.
REGOSOLS **RG**	Leptic / Skeletic Gleyic Gelistagnic / Stagnic Thaptovitric / Thaptandic Tephric Colluvic Gypsiric / Calcaric Dystric / Eutric	Arenic Aric Aridic Brunic Clayic Densic Escalic Folic Gelic Humic Hyperochric	Hyposalic Ornithic Oxyaquic Siltic Sodic Takyric Technic Transportic Turbic Vermic Yermic
SOLONCHAKS **SC**	Petrosalic Gleyic Stagnic Mollic Gypsic Duric Calcic Sodic Arenic Haplic	Aceric Aridic Carbonatic Chloridic Clayic Densic Drainic Folic Gelic Histic	Hypersalic Novic Oxyaquic Puffic Siltic Sulphatic Takyric Technic Transportic Vertic Yermic
SOLONETZ **SN**	Gleyic Stagnic Mollic Salic Gypsic Petrocalcic/ Calcic Haplic	Abruptic Albic Arenic Aridic Clayic Colluvic Duric Glossalbic Humic	Magnesic Novic Oxyaquic Ruptic Siltic Takyric Technic Transportic Vertic Yermic

RSG	Main map unit qualifiers (in front of the soil name)	Optional map unit qualifiers (in brackets behind the soil name)	
			cont.
STAGNOSOLS	Folic / Histic	Alcalic	Greyic
	Mollic / Umbric	Alumic	Manganiferric
ST	Vertic	Arenic	Ornithic
	Alic / Acric / Luvic / Lixic	Calcaric	Placic
	Albic	Chromic	Plinthic
	Gleyic	Clayic	Rhodic
	Gypsic	Drainic	Ruptic
	Petrocalcic / Calcic	Endosalic	Siltic
	Dystric / Eutric	Ferric	Sodic
		Gelic	Technic
		Geric	Thionic
TECHNOSOLS	Ekranic	Acric	Leptic
	Linic	Alic	Lixic
TC	Urbic / Spolic / Garbic	Arenic	Luvic
	Cryic	Calcaric	Mollic
	Toxic	Clayic	Novic
	Dystric / Eutric	Densic	Oxyaquic
		Drainic	Reductic
		Fluvic	Siltic
		Folic	Skeletic
		Gleyic	Stagnic
		Histic	Umbric
		Humic	Vitric
UMBRISOLS	Leptic / Skeletic	Alumic	Glossic
	Gleyic	Andic	Humic
UM	Stagnic	Anthric	Hyperdystric
	Folic / Histic	Brunic	Laxic
	Mollic	Cambic	Novic
	Albic	Chromic	Ornithic
	Greyic	Clayic	Oxyaquic
	Arenic	Densic	Pachic
	Haplic	Drainic	Placic
		Endoeutric	Siltic
		Ferralic	Technic
		Fluvic	Thionic
		Gelic	Turbic
			Vitric

RSG	Main map unit qualifiers (in front of the soil name)	Optional map unit qualifiers (in brackets behind the soil name)	
			cont.
VERTISOLS	Sodic	Albic	Hyposalic
	Salic	Calcaric	Hyposodic
VR	Gypsic	Duric	Manganiferric
	Petroduric	Endoleptic	Mazic
	Petrocalcic/Calcic	Ferric	Mesotrophic
	Pellic	Gleyic	Mollic
	Chromic	Grumic	Novic
	Haplic	Gypsiric	Stagnic
		Humic	Technic
		Hypereutric	Thionic
		cont.	

4.2 FAO soil unit codes according to the Revised Legend of the SMW

FAO Soil unit code (FAO 1988, 1990).

FL	FLUVISOLS		**AR**	ARENOSOLS	
	FLe	Eutric Fluvisols		**ARh**	Haplic Arenosols
	FLc	Calcaric Fluvisols		**ARb**	Cambic Arenosols
	FLd	Dystric Fluvisols		**ARi**	Luvic Arenosols
	FLm	Mollic Fluvisols		**ARo**	Ferralic Arenosols
	FLu	Umbric Fluvisols		**ARa**	Albic Arenosols
	FLt	Thionic Fluvisols		**ARc**	Calcaric Arenosols
	FLs	Salic Fluvisols		**ARg**	Gleyic Arenosols
GL	GLEYSOLS		**AN**	ANDOSOLS	
	Gle	Eutric Gleysols		**ANh**	Haplic Andosols
	GLk	Calcic Gleysols		**ANm**	Mollic Andosols
	GLd	Dystric Gleysols		**ANu**	Umbric Andosols
	GLa	Andic Gleysols		**ANz**	Vitric Andosols
	GLm	Mollic Gleysols		**ANg**	Gleyic Andosols
	GLu	Umbric Gleysols		**ANi**	Gelic Andosols
	GLt	Thionic Gleysols	**VR**	VERTISOLS	
	GLi	Gelic Gleysols		**VRe**	Eutric Vertisols
RG	REGOSOLS			**VRd**	Dystric Vertisols
	Rge	Eutric Regosols		**VRk**	Calcic Vertisols
	RGc	Calcaric Regosols		**VRy**	Gypsic Vertisols
	RGy	Gypsic Regosols	**CM**	CAMBISOLS	
	RGd	Dystric Regosols		**CMe**	Eutric Cambisols
	RGu	Umbric Regosols		**CMd**	Dystric Cambisols
	RGi	Gelic Regosols		**CMu**	Humic Cambisols

LP	LEPTOSOLS			**CMc**	Calcaric Cambisols
	LPe	Eutric Leptosols		**CMx**	Chromic Cambisols
	LPd	Dystric Leptosols		**CMv**	Vertic Cambisols
	LPk	Rendzic Leptosols		**CMo**	Ferralic Cambisols
	LPm	Mollic Leptosols		**CMg**	Gleyic Cambisols
	LPu	Umbric Leptosols		**CMi**	Gelic Cambisols
	LPq	Lithic Leptosols	**PH**	PHAEOZEMS	
	LPi	Gelic Leptosols		**PHh**	Haplic Phaeozems
CL	CALCISOLS			**PHc**	Calcaric Phaeozems
	CLh	Haplic Calcisols		**PHl**	Luvic Phaeozems
	CLl	Luvic Calcisols		**PHj**	Stagnic Phaeozems
GY	GYPSISOLS		**GR**	GREYZEMS	
	GYh	Haplic Gypsisols		**GRh**	Haplic Greyzems
	GYk	Calcic Gypsisols		**GRg**	Gleyic Greyzems
	GYl	Luvic Gypsisols	**LV**	LUVISOLS	
	GYp	Petric Gypsisols		**LVh**	Haplic Luvisols
SN	SOLONETZ			**LVf**	Ferric Luvisols
	SNh	Haplic Solonetz		**LVx**	Chromic Luvisols
	SNm	Mollic Solonetz		**LVk**	Calcic Luvisols
	SNk	Calcic Solonetz		**LVv**	Vertic Luvisols
	SNy	Gypsic Solonetz		**LVa**	Albic Luvisols
	SNj	Stagnic Solonetz		**LVj**	Stagnic Luvisols
	SNg	Gleyic Solonetz		**LVg**	Gleyic Luvisols
SC	SOLONCHAKS		**PL**	PLANOSOLS	
	SCh	Haplic Solonchaks		**PLe**	Eutric Planosols
	SCm	Mollic Solonchaks		**PLd**	Dystric Planosols
	SCk	Calcic Solonchaks		**PLm**	Mollic Planosols

	SCy	Gypsic Solonchaks		**PLu**	Umbric Planosols
	SCn	Sodic Solonchaks		**PLi**	Gelic Planosols
	SCg	Gleyic Solonchaks	**PD**	PODZOLUVISOLS	
	SCi	Gelic Solonchaks		**PDe**	Eutric Podzoluvisols
KS	KASTANOZEMS			**PDd**	Dystric Podzoluvisols
	KSh	Haplic Kastanozems		**PDj**	Stagnic Podzoluvisols
	KSl	Luvic Kastanozems		**PDg**	Gleyic Podzoluvisols
	KSk	Calcic Kastanozems		**PDi**	Gelic Podzoluvisols
	KSy	Gypsic Kastanozems	**PZ**	PODZOLS	
CH	CHERNOZEMS			**PZh**	Haplic Podzols
	CHh	Haplic Chernozems		**PZb**	Cambic Podzols
	CHk	Calcic Chernozems		**PZf**	Ferric Podzols
	CHl	Luvic Chernozems		**PZc**	Carbic Podzols
	CHw	Glossic Chernozems		**PZg**	Gleyic Podzols
	CHg	Gleyic Chernozems		**PZi**	Gelic Podzols
LX	LIXISOLS		**FR**	FERRALSOLS	
	LXh	Haplic Lixisols		**FRh**	Haplic Ferralsols
	LXf	Ferric Lixisols		**FRx**	Xanthic Ferralsols
	LXp	Plinthic Lixisols		**FRr**	Rhodic Ferralsols
	LXa	Albic Lixisols		**FRu**	Humic Ferralsols
	LXj	Stagnic Lixisols		**FRg**	Geric Ferralsols
	LXg	Gleyic Lixisols		**FRp**	Plinthic Ferralsols
AC	ACRISOLS		**PT**	PLINTHOSOLS	
	ACh	Haplic Acrisols		**PTe**	Eutric Plinthosols
	ACf	Ferric Acrisols		**PTd**	Dystric Plinthosols
	ACu	Humic Acrisols		**PTu**	Humic Plinthosols
	ACp	Plinthic Acrisols		**PTa**	Albic Plinthosols

	ACg	Gleyic Acrisols			
AL	ALISOLS		**HS**	HISTOSOLS	
	ALh	Haplic Alisols		**HSl**	Folic Histosols
	ALf	Ferric Alisols		**HSs**	Terric Histosols
	ALu	Humic Alisols		**HSf**	Fibric Histosols
	ALp	Plinthic Alisols		**HSt**	Thionic Histosols
	ALj	Stagnic Alisols		**HSi**	Gelic Histosols
	ALg	Gleyic Alisols	**AT**	ANTHROSOLS	
NT	NITISOLS			**ATa**	Aric Anthrosols
	NTh	Haplic Nitisols		**ATc**	Cumulic Anthrosols
	NTr	Rhodic Nitisols		**ATf**	Fimic Anthrosols
	NTu	Humic Nitisols		**ATu**	Urbic Anthrosols

Annex 5 Hierarchy of land use

Adapted from Remmelzwaal (1990); used to characterize the land use at the site of representative profile at time of profile description.

A Agriculture

Land used for cultivation of crops.

AA Annual field cropping

One or more crops harvested within one year. Land under temporary crops.

AA1 Shifting cultivation

Agricultural systems that involve an alternation between cropping for a few years on selected and cleared plots and a lengthy period when the soil is rested. The land is cultivated for less than 33% of the years.

AA2 Fallow system cultivation

Agricultural systems that involve an alternation of cropping- and fallow periods. The land is cultivated between 33 and 67% of the growing seasons; bush or grass fallow are typical.

AA3 Ley system cultivation

Several years of arable cropping are followed by several years of grass and legumes utilized for livestock production.

AA4 Rainfed arable cultivation

Agricultural systems where the land is cultivated in more than 67% of the growing seasons.

AA5 Wet rice cultivation

Annual field cropping system for the production of wetland rice. Paddies with or without controlled water supply and drainage system. Plots are inundated during at least some part of the cropping period.

AA6 Irrigated cultivation

Annual field cropping system with an artificial supply of water, in addition to rain.

AP Perennial field cropping

Land under perennial crops. Crops harvested more than one year after planting. Examples of perennial field crops are sugar-cane, bananas, pineapples and sisal.

AP1 Non-irrigated cultivation

AP2 Irrigated cultivation

AT Tree and shrub cropping

Crops harvested annually or perennially; trees or shrubs produce more than one crop. Examples of tree crops are oil-palm, rubber, cacao, coconuts and cloves; typical shrub crops are coffee and tea.

AT1 Non-irrigated tree crop cultivation

AT2 Irrigated tree crop cultivation

AT3 Non-irrigated shrub crop cultivation

AT4 Irrigated shrub crop cultivation

H **Animal husbandry**

Animal products.

HE Extensive grazing

Grazing on natural or semi-natural grassland or savannah vegetation.

HE1 Nomadism

Systems in which the animal owners do not have a permanent place of residence. No regular cultivation practices. People move with herds.

HE2 Semi-nomadism

Animal owners have a permanent place of residence where supplementary cultivation is practiced. Herds are moved to distant grazing areas.

HE3 Ranching

Grazing within well-defined boundaries, movements less distant and higher management level as compared to semi-nomadism.

HI Intensive grazing

Stationary animal husbandry. Grazing on permanent/semi-permanent improved grassland systems.

HI1 Animal production

HI2 Dairying

F **Forestry**

Activities related to the production of wood. Exploitation of forest for wood, with reforestation. A commercial activity.

FN Exploitation of natural forest and woodland

Wood is extracted from natural forest and woodland for commercial purpose.

FN1 Selective felling

Only selected species are removed from the natural vegetation.

FN2 Clear felling

All natural vegetation is cleared after which the area is reforested. This land use system develops into a plantation forestry system.

FP Plantation forestry

Forested areas. Relatively high management level. Homogeneous tree stands.

M **Mixed farming**

Activities concerning cropping and forestry or animal husbandry are mixed.

MF Agro-forestry

Combination of agriculture and forestry (with reforestation).

MP Agro-pastoralism

Combination of agriculture and animal husbandry, also called transhumance (farmers with a permanent place of residence send their herds, tended by herdsman, for long periods of time to distant grazing areas).

E Extraction/collecting

Extraction of products from the environment.

EV Exploitation of natural vegetation

Land used for extraction of wood or other products from the vegetation; for domestic use.

EH Hunting and fishing

Extraction of animals or fish from ecosystem.

P **Nature protection**

No, or low intensity of use, but under management system; low level of interference with natural environment or ecosystem.

PN Nature and game preservation

PN1 Reserves

PN2 Parks

PN3 Wildlife management

PD Degradation control

Degradation of land, in most cases further degradation, is not desirable and the land is protected.

PD1 Non-interference

All uses of the land are prohibited.

PD2 Interference

The land is managed. Works are implemented in order to stop degradation and limit the degradation risk.

S **Settlement/industries**

Residential, industrial use.

SR Residential use

Cities.

SI Industrial use

Industries.

ST Transport

Roads, railways etc.

SC Recreation

In use for recreation.

SX Excavations

Land used for excavations, quarries.

SD Disposal sites

Y **Military area**

O **Other land areas**

U **Unused**

Not used and not managed.

Annex 6 Hierarchy of vegetation

After Unesco (Unesco 1973).

I Closed forest

Formed by trees at least 5 m tall with their crowns interlocking.

IA Mainly evergreen forest

The canopy is never without green foliage. However, individual trees may shed their leaves.

IA1 Tropical ombrophilous forest (tropical rain forest)

Consisting mainly of broad-leaved evergreen trees, neither cold nor drought resistant. Truly evergreen, i.e. the forest canopy remains green all year though individual trees may be leafless for a few weeks.

IA2 Tropical and subtropical evergreen seasonal forest

Consisting mainly of broad-leaved evergreen trees. Foliage reduction during the dry season noticeable, often as partial shedding of leaves.

IA3 Tropical and subtropical semi-deciduous forest

Most of the upper canopy trees deciduous or drought-resistant; many of the under storey trees and shrubs evergreen and more or less sclerophyllous[20].

IA4 Subtropical ombrophilous forest

Forest with a dry season and more pronounced temperature differences between summer and winter than tropical ombrophilous forest.

IA5 Mangrove forest

Composed almost entirely of evergreen sclerophyllous broad-leaved trees/shrubs with either stilt roots or pneumatophores.

IA6 Temperate and subpolar evergreen ombrophilous forest

Consisting mostly of truly evergreen hemi-sclerophyllous trees.

IA7 Temperate evergreen seasonal broad-leaved forest

Consisting mainly of hemi-sclerophyllous evergreen trees and shrubs, rich in herbaceous undergrowth.

IA8 Winter-rain evergreen broad-leaved sclerophyllous forest (Mediterranean forest)

Consisting mainly of sclerophyllous evergreen trees and shrubs, most of them showing rough bark. Herbaceous undergrowth almost lacking.

IA9 Tropical and subtropical evergreen needle-leaved forest

Consisting mainly of needle-leaved evergreen trees. Broad-leaved trees may be present.

[20] Sclerophyllous: thick, hard leaves.

IA10 Temperate and subpolar evergreen needle-leaved forest

Consisting mainly of needle-leaved or scale-leaved evergreen trees, but broad-leaved trees may be admixed.

IB Mainly deciduous forest

Majority of trees shed their foliage simultaneously in connection with the unfavourable season.

IB1 Tropical and subtropical drought-deciduous forest

Unfavourable season mainly characterized by drought, in most cases winter-drought. Foliage is shed regularly every year. Most trees with relatively thick, fissured bark.

IB2 Cold-deciduous forest with evergreen trees (or shrubs)

Unfavourable season mainly characterized by winter frost. Deciduous broad-leaved trees dominant, but evergreen species present.

IB3 Cold-deciduous forest without evergreen trees

Deciduous trees absolutely dominant.

IC Extremely xeromorphic forest

Dense stand of xeromorphic phanerophytes such as bottle trees, tuft trees with succulent leaves and stem succulents. Undergrowth with shrubs of similar xeromorphic adaptations.

IC1 Sclerophyllous-dominated extremely xeromorphic forest

Predominance of sclerophyllous trees.

IC2 Thorn forest

Species with thorny appendices predominate.

IC3 Mainly succulent forest

Tree-formed and shrub-formed succulents.

II Woodland

Composed of trees at least 5 m tall with crowns not usually touching but with a coverage of at least 40%.

IIA Mainly evergreen woodland

The canopy is never without green foliage.

IIA1 Evergreen broad-leaved woodland

Mainly sclerophyllous trees and shrubs.

IIA2 Evergreen needle-leaved forest

Mainly needle-leaved or scale-leaved.

IIB Mainly deciduous woodland

Majority of trees shed their foliage simultaneously in connection with the unfavourable season.

IIB1 Drought deciduous woodland

Unfavourable season mainly characterized by winter-drought. Foliage is shed regularly every year. Most trees with relatively thick, fissured bark.

IIB2 Cold-deciduous woodland with evergreen trees

Unfavourable season mainly characterized by winter frost. Deciduous broad-leaved trees dominant, but evergreen species present.

IIB3 Cold-deciduous woodland without evergreen trees

Deciduous trees absolutely dominant.

IIC Extremely xeromorphic woodland

Open stand of xeromorphic phanerophytes such as bottle trees, tuft trees with succulent leaves and stem succulents. Undergrowth with shrubs of similar xeromorphic adaptations.

IIC1 Sclerophyllous-dominated extremely xeromorphic woodland

Predominance of sclerophyllous trees.

IIC2 Thorn woodland

Species with thorny appendices predominate.

IIC3 Mainly succulent woodland

Tree-formed and shrub-formed succulents

III Scrub *(shrubland and/or thicket)*

Mainly composed of woody plants of 0.5 to 5 m tall. Subdivisions:

- Shrubland: most of the individual shrubs not touching each other; often grass undergrowth.
- Thicket: individual shrubs interlocked.

IIIA Mainly evergreen scrub

The canopy is never without green foliage. However, individual shrubs may shed their leaves.

IIIA1 Evergreen broad-leaved shrubland (or thicket)

Mainly sclerophyllous shrubs.

IIIA2 Evergreen needle-leaved and microphyllous shrubland (or thicket)

Mainly needle-leaved or scale-leaved shrubs.

IIIB Mainly deciduous scrub

Majority of shrubs shed their foliage simultaneously in connection with the un-favourable season.

IIIB1 Drought-deciduous scrub with evergreen woody plants admixed

IIIB2 Drought-deciduous scrub without evergreen woody plants admixed

IIIB3 Cold-deciduous scrub

IIIC Extremely xeromorphic (subdesert) shrubland

Very open stands of shrubs with various xerophytic adaptations, such as extremely scleromorphic or strongly reduced leaves, green branches without leaves, or succulents stems, etc., some of them with thorns.

IIIC1 Mainly evergreen subdesert shrubland

In extremely dry years some leaves and shoot portions may be shed.

IIIC2 Deciduous subdesert shrubland

Mainly deciduous shrubs, often with a few evergreens

IV Dwarf-scrub and related communities

Rarely exceeding 50 cm in height. Subdivisions:

- Dwarf-scrub thicket: branches interlocked.
- Dwarf-shrubland: individual dwarf-shrubs more or less isolated or in clumps.

IVA Mainly evergreen dwarf-scrub

Most dwarf-scrubs evergreen.

IVA1 Evergreen dwarf-scrub thicket

Densely closed dwarf-scrub cover, dominating the landscape.

IVA2 Evergreen dwarf-shrubland

Open or more loose cover of dwarf-shrubs.

IVA3 Mixed evergreen dwarf-shrub and herbaceous formation

IVB Mainly deciduous dwarf-scrub

Most dwarf-scrubs deciduous.

IVB1 Facultatively drought-deciduous dwarf-thicket (or dwarf-shrubland)

Foliage is shed only in extreme years.

IVB2 Obligatory, drought-deciduous dwarf-thicket (or dwarf-shrubland)

Densely closed dwarf-shrub stands which loose all or at least part of their leaves in the dry season.

IVB3 Cold-deciduous dwarf-thicket (or dwarf-shrubland)

Densely closed dwarf-shrub stands which loose all or at least part of their leaves at the beginning of a cold season.

IVC Extremely xeromorphic dwarf-shrubland

More or less open formations of dwarf-shrubs, succulents and other life forms adapted to survive or to avoid a long dry season. Mostly subdesertic.

IVC1 Mainly evergreen subdesert dwarf-shrubland

In extremely dry years some leaves and shoot portions may be shed.

IVC2 Deciduous subdesert dwarf-shrubland

Mainly deciduous dwarf-shrubs, often with a few evergreens.

IVD Tundra

Slowly growing, low formations, consisting mainly of dwarf-shrubs and graminoids beyond the subpolar tree line.

IVD1 Mainly bryophyte tundra

Dominated by mats or small cushions of mosses (bryophytes).

IVD2 Mainly lichen tundra

Mats of lichen dominating.

IVE Mossy bog formations with dwarf-shrub

Oligotrophic peat accumulations formed by *Sphagnum* or other mosses.

IVE1 Raised bog

By growth of Sphagnum species raised above the general ground-water table.

IVE2 Non-raised bog

Not or not very markedly raised above the mineral-water table of the surrounding landscape.

V Herbaceous vegetation

VA Tall graminoid vegetation

Dominant graminoids over 2 m tall. Forb[21] coverage less than 50%.

VA1 Tall grassland with a tree synusia[22] covering 10-40%

More or less like a very open woodland.

VA2 Tall grassland with a tree synusia covering less than 10%

VA3 Tall grassland with a synusia of shrubs

VA4 Tall grassland with a woody synusia consisting mainly of tuft plants (usually palms)

VA5 Tall grassland practically without woody synusia

VB Medium tall grassland

VB1 Medium tall grassland with a tree synusia covering 10-40%

VB2 Medium tall grassland with a tree synusia covering less than 10%

VB3 Medium tall grassland with a synusia of shrubs

VB4 Medium tall grassland with an open synusia of tuft plants (usually palms)

VB5 Medium tall grassland practically without woody synusia

VC Short grassland

The dominant graminoid growth forms are less than 50 cm tall. Forbs cover less than 50%.

VC1 Short grassland with a tree synusia covering 10-40%

VC2 Short grassland with a tree synusia covering less than 10%

VC3 Short grassland with a synusia of shrubs

VC4 Short grassland with an open synusia of tuft plants (usually palms)

VC5 Short grassland practically without woody synusia

VC6 Short to medium tall mesophytic grassland

VC7 Graminoid tundra

VD Forb vegetation

Mainly forbs, graminoid cover less than 50%.

VD1 Tall forb communities

Dominant forb growth forms are more than 1 m tall.

VD2 Low forb communities

Dominant forb growth forms are less than 1 m tall.

VE Hydromorphic fresh-water vegetation

VE1 Rooted fresh-water communities

VE2 Free floating fresh-water communities

VI No vegetation, bare soil or vegetation less than 5%

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21 Forb: non-graminoid/non-woody vegetation.

22 Synusia: layer.

Annex 7 ISO country codes

Country codes according to ISO-3166 (ISO, 2006)

AF	Afghanistan
AX	Åland Islands
AL	Albania
DZ	Algeria
AS	American Samoa
AD	Andorra
AO	Angola
AI	Anguilla
AQ	Antarctica
AG	Antigua and Barbuda
AR	Argentina
AM	Armenia
AW	Aruba
AU	Australia
AT	Austria
AZ	Azerbaijan
BS	Bahamas
BH	Bahrain
BD	Bangladesh
BB	Barbados
BY	Belarus
BE	Belgium
BZ	Belize
BJ	Benin
BM	Bermuda
BT	Bhutan
BO	Bolivia
BA	Bosnia and Herzegovina
BW	Botswana
BV	Bouvet Island
BR	Brazil
IO	British Indian Ocean Territory
BN	Brunei Darussalam
BG	Bulgaria
BF	Burkina Faso
BI	Burundi
KH	Cambodia
KY	Cayman Islands
CF	Central African Republic
TD	Chad
CL	Chile
CN	China, mainland
CX	Christmas Island
CC	Cocos (Keeling) Islands
CO	Colombia
KM	Comoros
CG	Congo, Republic of the
CD	Congo, The Democratic Republic of the
CK	Cook Islands
CR	Costa Rica
CI	Côte d'Ivoire
HR	Croatia
CU	Cuba
CY	Cyprus
CZ	Czech Republic
DK	Denmark
DJ	Djibouti
DM	Dominica
DO	Dominican Republic
EC	Ecuador
EG	Egypt
SV	El Salvador
GQ	Equatorial Guinea
ER	Eritrea
EE	Estonia
ET	Ethiopia
FK	Falkland Islands
FO	Faroer Islands
FJ	Fiji
FI	Finland
FR	France
GF	French Guiana
PF	French Polynesia
TF	French Southern Territories
DE	Germany
GH	Ghana
GI	Gibraltar
GR	Greece
GL	Greenland
GD	Grenada
GP	Guadeloupe
GU	Guam
GT	Guatemala
GN	Guinea
GW	Guinea-Bissau
GY	Guyana
HT	Haiti
HM	Heard Island and McDonald Islands
HN	Honduras
HK	Hong Kong
HU	Hungary
IS	Iceland
IN	India
ID	Indonesia
IR	Iran, Islamic Republic of
IQ	Iraq
IE	Ireland
IL	Israel
IT	Italy
JM	Jamaica
JP	Japan
JO	Jordan
KZ	Kazakhstan
KE	Kenya
KI	Kiribati
KP	Korea, Democratic People's Republic of
KR	Korea, Republic of
KW	Kuwait
KG	Kyrgyzstan
LA	Lao People's Democratic Republic
LV	Latvia

CM	Cameroon
CA	Canada
CV	Cape Verde
LY	Libyan Arab Jamahiriya
LI	Liechtenstein
LT	Lithuania
LU	Luxembourg
MO	Macao
MK	Macedonia, The Former Yugoslav Republic of
MG	Madagascar
MW	Malawi
MY	Malaysia
MV	Maldives
ML	Mali
MT	Malta
MH	Marshall Islands
MQ	Martinique
MR	Mauritania
MU	Mauritius
YT	Mayotte
MX	Mexico
FM	Micronesia, Federated States of
MD	Moldova, Republicof
MC	Monaco
MN	Mongolia
MS	Montserrat
ME	Montenegro
MA	Morocco
MZ	Mozambique
MM	Myanmar
NA	Namibia
NR	Nauru
NP	Nepal
NL	Netherlands
AN	Netherlands Antilles
NC	New Caledonia
NZ	New Zealand
NI	Nicaragua
NE	Niger
GA	Gabon
GM	Gambia
GE	Georgia
OM	Oman
PK	Pakistan
PW	Palau
PS	Palestinian Territory, Occupied
PA	Panama
PG	Papua New Guinea
PY	Paraguay
PE	Peru
PH	Philippines
PN	Pitcairn
PL	Poland
PT	Portugal
PR	Puerto Rico
QA	Qatar
RE	Réunion
RO	Romania
RU	Russian Federation
RW	Rwanda
SH	Saint Helena
KN	Saint Kitts and Nevis
LC	Saint Lucia
VC	Saint Vincent and the Grenadines
PM	Saint-Pierre and Miquelon
WS	Samoa
SM	San Marino
ST	São Tomé and Príncipe
SA	Saudi Arabia
SN	Senegal
CS	Serbia
SC	Seychelles
SL	Sierra Leone
SG	Singapore
SK	Slovakia
SI	Slovenia
SB	Solomon Islands
LB	Lebanon
LS	Lesotho
LR	Liberia
SD	Sudan
SR	Suriname
SJ	Svalbard and Jan Mayen
SZ	Swaziland
SE	Sweden
CH	Switzerland
SY	Syrian Arab Republic
TW	Taiwan (Republic of China)
TJ	Tajikistan
TZ	Tanzania, United Republic of
TH	Thailand
TL	Timor-Leste
TG	Togo
TK	Tokelau
TO	Tonga
TT	Trinidad and Tobago
TN	Tunisia
TR	Turkey
TM	Turkmenistan
TC	Turks and Caicos Islands
TV	Tuvalu
UG	Uganda
UA	Ukraine
AE	United Arab Emirates
GB	United Kingdom
US	United States
UM	United States Minor Outlying Islands
UY	Uruguay
UZ	Uzbekistan

NG	Nigeria	SO	Somalia
NU	Niue	ZA	South Africa
NF	Norfolk Island	GS	South Georgia and the South Sandwich Islands
MP	Northern Mariana Islands	ES	Spain
NO	Norway	LK	Sri Lanka

Annex 8 Analytical methods

Attribute	AM_ID	Analytical method description
Bulk density	BD–	Not measured (Bulk density)
	BD01	Core sampling (pF rings)
	BD02	Clod samples
	BD03	Replacement method (with spherical plastic balls; Avery & Bascomb, 1974)
	BD04	Auger-hole method (Zwarich & Shaykewich, 1969)
	BD05	Clod samples, oven-dry (USDA method 4A1h)
	BD06	drying and weighting of 100-ml sample (Schlichting *et al.* 1995)
	BD99	Unspecified methods
Base saturation	BS–	Not measured (Base saturation)
	BS01	Sum of bases as percentage of CEC (method specified above)
	BS99	Unspecified methods
$CaCO_3$	CA–	Not measured ($CaCO_3$)
	CA01	Method of Scheibler (volumetric)
	CA02	Method of Wesemael
	CA03	Method of Piper
	CA04	Calcimeter method (volumetric after addition of dilute acid)
	CA05	Gravimetric (Richards 1954), Hdbk 60
	CA06	H_3PO_4 acid at 80C, conductometric in NaOH (Schlichting & Blume, 1966)
	CA07	Pressure calcimeter (Nelson, 1982)
	CA08	Bernard calcimeter (Total $CaCO_3$)
	CA09	Carbonates: H3PO4 treatment at 80 deg. C and CO2 measurement like TOC (OC13), transformation into $CaCO_3$ (Schlichting *et al.* 1995)
	CA99	Unspecified methods
CEC	CE–	Not measured (CEC, sum of bases)
	CE01	Sum of exch. Ca, Mg, K and Na, plus exchangeable aluminium (in 1M KCl) *
	CE02	Sum of exch. Ca, Mg, K and Na, plus exchangeable Al (according to method EA02)
	CE03	Sum of exch. Ca, Mg, K and Na, plus exchangeable H+Al (in 1M KCl)
	CE04	Sum of exch. Ca, Mg, K and Na (in NH_4Cl at pH 7/0), plus exchangeable H+Al (in 1M KCl)
	CE05	CEC and exchangeable cations with $BACl_2$ (after extracting water soluble cations, measurement by AAS); Schlichting *et al.* 1995
	CE99	Unspecified methods
CES	CS–	Not measured (CEC soil)
	CS01	CEC in 1M NH_4OAc buffered at pH 7
	CS02	CEC in 1M $BaCl_2$ buffered at pH 8.1
	CS03	CEC in 1M NH_4OAc buffered at pH 8.2 (Bascomb)
	CS04	CEC in 1M Na_4OAc buffered at pH 8.2
	CS05	CEC in Silver Thiourea (AgTU)
	CS06	CEC as sum of bases (NH_4OAc at pH 7) + extr. acidity in $BaCl_2$-TEA at pH 8.2
	CS07	CEC determined in 0.5 M LiCl buffered at pH 8 with TEA (after Peech, 1965)

	CS08	CEC in 1 M KCl at pH of soil
	CS09	Sum of exch. cations (Brasil)
	CS10	CEC in Li-EDTA at pH7; treat. with K-EDTA solution at pH 10
	CS11	CEC in 1M $BaCl_2$ at pH 8.4
	CS12	CEC by saturation with NH_4OAc and percolation with 10% NaCl + 4 cc conc. HCl/L
	CS13	CEC determined in 0.2 M NH_4Cl at approximately field pH (Rusell, 1973)
	CS14	CEC determined in 0.5N BaOAc at pH 8.2-8.4 after washing
	CS15	CEC determined according to Oosterbeek (NL) method
	CS16	CEC Mehlich; Ba_2+ retained from $BaCl_2$, TEA at pH 8.2
	CS17	CEC with 0.1 M Li-EDTA, buffered at pH 8.0
	CS18	CEC acc. Schollenberger/Shmuck/Pfeffer depend on initial pH and salt content
	CS19	CEC in NH_4OAc at pH7 and NaO_4Ac at pH 8.2 dep. on initial pH and salt content
	CS20	CEC in 1M Na-acetate (after Herrmann 2005)
	CS98	Other methods (buffered at pH of about 8)
	CS99	Other methods (buffered at pH of about 7)
Exchange acidity	EA–	Not measured (Exchangeable acidity)
	EA01	Exchangeable acidity (H+Al) in 1 M KCl
	EA02	Exch. acidity in 1 M KCl estimated from soluble Al in 2:1 v/v 0.02 M $CaCl_2$
	EA03	Extractable acidity in NH_4OAc, formaldehyde and BaCl2; acid. by titration at pH 11 (Mados, 1943)
	EA04	Ca-acetate 1 M at pH 7 (Brasil)
	EA05	Exch. acidity in 0.1 N NH_4Cl extract
	EA06	Extractable acidity in 1 M $BaCl_2$ and TEA
	EA07	Exch. acidity in NaCl extract
	EA08	Exhangeable Ha and Ala (pH measurement in in Ca-acetate pH 7.2); Schlichting *et al.* 1995
	EA99	Unspecified methods
EC	EL–	Not measured (Electo-conductivity)
	EL01	Elec. conductivity at 1:1 soil/water ratio
	EL02	Elec. conductivity at 1:2.5 soil/water ratio
	EL03	Elec. conductivity at 1:5 soil/water ratio
	EL04	Elec. conductivity at 1:2 soil/water ratio
	EL05	Elec. conductivity at 1:10 soil/water ratio
	EL99	Unspecified methods
ES	ES–	Not measured (Electo-conductivity saturated paste)
	ES01	Elec. conductivity in saturated paste (ECe)
	ES99	Unspecified method
Exchangeable bases	EX–	Not measured (Exchangeable bases)
	EX01	Various methods with no apparent differences in results
	EX99	Unspecified methods
Gypsum	GY–	Not measured (Gypsum)
	GY01	Dissolved in water and precipitated by acetone
	GY02	Differ. between Ca-conc. in sat. extr. and Ca-conc. in 1/50 s/w solution
	GY03	Calculated from conductivity of successive dilutions
	GY04	In 0.1 M Na_3-EDTA; turbidimetric (Begheijn, 1993)
	GY05	Gravimetric after dissolution in 0.2 N HCl (USSR-method)
	GY06	Total-S, using LECO furnace, minus easily soluble $MgSO_4$ and Na_2SO_4

	GY07	Schleiff method, electrometric
	GY99	Unspecified methods
Hydraulic Conductivity	HC–	Not measured (Hydraulic conductivity)
	HC01	Double ring method
	HC02	Bore hole method
	HC03	Inverse bore hole method
	HC04	Permeability in cm/hr determined in column filled with fine earth fraction
	HC99	Unspecified methods
Moisture Content	MC–	Not measured (Moisture content)
	MC01	Sand/silt baths and porous plates, undisturbed samples (pF rings)
	MC02	Ceramic plate extractors, dist. samples in 10x50mm rings; after L.A. Richards 1965
	MC99	Unspecified methods
Organic Carbon	OC–	Not measured (Organic Carbon)
	OC01	Method of Walkley-Black (1934) (Org. matter = Org. C x 1.72)
	OC02	Loss on ignition (NL)
	OC03	Method of Allison
	OC04	Method of Kurmies
	OC05	Method of furnace combustion (e.g., LECO analyzer)
	OC06	Method of Kalembass and Jenkinson (1973); acid dichromate; Org. matter = Org. C x 1.72)
	OC07	Wet oxidation according to Tinsley (1950)
	OC08	Wet oxidation according to Anne(1945) (Org. matter = Org. C x 1.7)
	OC09	Method of Tiurin (oxid. with K-dichr.)
	OC10	Wet oxidation by Chromic acid and gravimetric determination of CO_2 (Knopp)
	OC11	Total carbon (no-carbonates present) using VarioEL CNS-analyzer
	OC12	Dry combustion using a CN-corder and cobalt oxide or copper oxide as an oxidation accelerator (Tanabe and Araragi, 1970)
	OC13	Dry combustion at 1200 deg. C and coulometric CO_2 measurement (Schlichting *et al.* 1995)
	OC99	Unspecified methods
pH CaCl	PC–	Not measured (pH_$CaCl_2$)
	PC01	pH in 1:1 soil/1 M $CaCl_2$ solution
	PC02	pH in 1:2.5 soil/1 M $CaCl_2$ solution
	PC03	pH in 1:5 soil/1 M $CaCl_2$ solution
	PC04	pH in 1:2 soil/0.01 M $CaCl_2$ solution
	PC05	pH in 1:2.5 soil/0.01 M $CaCl_2$ solution
	PC06	pH in 1:2.5 soil/0.1 M $CaCl_2$ solution
	PC07	pH in 1:5 (w/v) soil/0.01 M $CaCl_2$ solution for mineral soils; 1/10 for organic soils
	PC99	Unspecified methods
pH water	PH–	Not measured (pH-water)
	PH01	pH in 1:1 soil/water solution
	PH02	pH 1:2.5 soil/water solution
	PH03	pH 1:5 soil/water solution
	PH04	pH in 1:2 soil/water solution
	PH05	pH in water saturated extract
	PH06	–
	PH99	Unspecified methods

pH KCl	PK–	Not measured (pH-KCl)
	PK01	pH in 1:1 soil/ M KCl solution
	PK02	pH in 1:2.5 soil/ M KCl solution
	PK03	pH in 1:5 soil/ M KCl solution
	PK04	pH in 1:2 soil/0.01 M KCl solution
	PK99	Unspecified methods
P available	PA–	Not measured (P-available)
	PA01	Method of Bray I (dilute HCl/NH_4F)
	PA02	Method of Olsen (0.5 M bicarbonate extraction at pH 8.5)
	PA03	Method of Truog (dilute H_2SO_4)
	PA04	Method of Morgan (Na-acetate/acetic acid)
	PA05	Method of Saunders and Metelerkamp (anion-exch. resin)
	PA06	Method of Bray II (dilute HCl/NH_4F)
	PA07	Modified after ISFEI method, A.H. Hunter (1975)
	PA08	Method of Nelson (dilute HCl/H_2SO_4)
	PA09	ADAS method (NH_4 acetate/acetic acid)
	PA10	Spectrometer (Brasil)
	PA11	North Carolina (0.05 M HCl, 0.025 N H_2SO_4)
	PA12	0.02 colorimetric in N H_2SO_4 extract, molybd. blue method
	PA13	Method of Olsen, modified by Dabin(1967) - ORSTOM
	PA14	Method of Kurtz-Bray I (0.025 M HCl + 0.03 M NH_4F)
	PA15	Complexation with citric acid (van Reeuwijk)
	PA16	NH_4-lactate extraction method (KU-Leuven)
	PA17	Bray-I (acid soils) resp. Olsen (other soils)
	PA18	Ambic1 method (ammonium bicarbonate) (South Africa)
	PA99	Unspecified methods
Total carbon	TC–	Not measured (Total Carbon)
	TC01	Total Carbon (USDA-NRCS method 6A2d)
Particle size distribution	TE–	Not measured (texture)
	TE01	Pipette method, with appropriate dispersion treatment (c< 0.002 <si< 0.05 <sa< 2mm)
	TE02	Pipette method, without dispersion treatment (c< 0.002 <si< 0.05 <sa< 2mm)
	TE03	Hydrometer method, with dispersion treatment (c< 0.002 <si<0.05 <sa< 2mm)
	TE04	Hydrometer, without dispersion treatment (c< 0.002 <si< 0.05 <sa< 2mm)
	TE05	Pipette method, with appropriate dispersion treatment (c<0.002 <si< 0.02 <sa< 2mm)
	TE06	Pipette method, without dispersion treatment (c<0.002 <si< 0.02 <sa< 2mm)
	TE07	Hydrometer method, with dispersion treatment (c<0.002 <si< 0.02 <sa< 2mm)
	TE08	Hydrometer, without dispersion treatment (c<0.002 <si< 0.02 <sa< 2mm)
	TE09	Pipette method, with appropriate dispersion treatment (c< 0.002 <si< 0.06 <sa< 2mm)
	TE10	Pipette method, without dispersion treatment (c< 0.002 <si< 0.06 <sa< 2mm)
	TE11	Hydrometer method, with dispersion treatment (c< 0.002 <si< 0.06 <sa< 2mm)
	TE12	Hydrometer, without dispersion treatment (c< 0.002 <si< 0.06 <sa< 2mm)
	TE13	Hydrometer method, with dispersion treatment (c< 0.005 <si< 0.05 <sa< 1mm)
	TE14	Beaker method of sedimentation, with dispersion treatment (c< 0.002 <si< 0.06 <sa< 2mm)
	TE15	Pipette method, full dispersion (c<.001<si<0.05<sa<1mm; USSR method)
	TE16	Sieve and pipette method after H_2O_2 extraction, and dispersion (Schlichting *et al.* 1995)
	TE97	Other methods (c< 0.002 <si< 0.06 <sa< 2mm)

	TE98	Other methods (c< 0.002 <si< 0.05 <sa< 2mm)
	TE99	Other methods (c< 0.002 <si< 0.05 <sa< 2mm)
Total N	TN–	Not measured (Total N)
	TN01	Method of Kjeldahl
	TN02	Element analyzer (LECO analyzer)
	TN03	Total N (Bremner, 1965, p. 1162-1164)
	TN04	Dry combustion using a CN-corder and cobalt oxide or copper oxide as an oxidation accelerator (Tanabe and Araragi, 1970)
	TN99	Unspecified methods
Total P	TP–	Not measured (Total-P)
	TP01	Total P; colorimetric in H_2SO_4-Se-Salicylic acid digest
	TP99	Unspecified methods
Soluble salts	SS–	Not measured (soluble salts)
	SS01	Na, flame photometry
	SS02	Ca , precipitation Ca oxalate (Hdb 60)
	SS03	Ca , EDTA titration
	SS04	Ca , Atomic absorption spectrophotometry (AAS)
	SS05	Mg, precipitation Mg ammonium phosphate
	SS06	Mg, Atomic absorption spectrophotometry (AAS)
	SS07	K, flame photometry
	SS08	Cl, titration with $AgNO_3$ (Hdb60)
	SS09	Cl, colorimetric by Clor-O-counter Cl titrator
	SS10	Cl, ion chromatography
	SS11	SO_4, precipitation Ca sulphate (Hdb60)
	SS12	SO_4, precipitation Ba sulphate with turbidimetry
	SS13	SO_4, ion chromatography
	SS14	SO_4, other
	SS15	HCO_2 and CO_3, titration with acid (Hdb60)
	SS16	HCO_2 and CO_3, potentiometric titration with HCl
	SS99	Unspecified methods
Fe	FE–	Not measured (Fe)
	FE01	Fe, dithionite–citrate extraction (‘free iron’)
	FE02	Fe, acid oxalate extraction (‘active’)
	FE03	Fe, pyrophosphate extraction (organic bound Fe)
Al	AL–	Not measured (Al)
	AL01	Al, dithionite–citrate extraction (‘free aluminium)
	AL02	Al, acid oxalate extraction (‘active’)
	AL03	Al, pyrophosphate extraction (organic bound Al)

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