THE SOTER MANUAL

PROCEDURES FOR SMALL SCALE DIGITAL MAP AND DATABASE COMPILATION OF SOIL AND TERRAIN CONDITIONS

Editors:
V.W.P. van Engelen
J.H.M. Pulles

4th Edition
May 1991

INTERNATIONAL SOIL REFERENCE AND INFORMATION CENTRE

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PREFACE

At the initiative of the International Society of Soil Science (ISSS) a workshop of international experts on soils and related disciplines was convened in Wageningen, the Netherlands, to discuss the Structure of a Digital International Soil Resources Map annex Data Base (ISSS, 1986a). Based on the findings and recommendations of this workshop a project proposal was written for *SOTER*, a World **SO**ils and **TER**rain Digital Data Base at a scale of 1:1 million (ISSS, 1986b).

A small international committee was appointed to develop a 'universal' map legend dataset 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 soil change, irrigation suitability, agro-ecological zonation, and risk of droughtiness. An initial list of attributes was compiled. The SOTER approach was further endorsed at the ISSS Congress in Hamburg, FRG, August 1986.

A second meeting sponsored by the United Nations Environment Programme (UNEP) was held in Nairobi, Kenya, in May 1987 to discuss the application of the SOTER database 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 to develop guidelines for a World Soils and Terrain Digital Database at 1:1 million scale, to propose general legend concepts and definitions, to prepare an attribute file structure, and to draft a tentative outline of a Procedures Manual (ISSS, 1987).

As a follow-up of the Nairobi meeting, UNEP contracted ISRIC to compile a global map on the status of human-induced soil degradation at a scale of 1:10-15 million, and to have it accompanied by a first pilot area at 1:1 million scale in Latin America where both status and risk of soil degradation would be assessed on the basis of a digital soil and terrain database at 1:1 million scale. ISRIC subcontracted the preparation of a first approach of a Procedures Manual for the 1:1 million pilot study area to the Land Resource Research Centre, Agriculture Canada.

The first draft of a 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 (ISSS, 1988). The proposed methodology was then tested in a first pilot area, covering parts of Argentina, Brazil and Uruguay. Soils and terrain data were collected by the soil survey teams of the participating countries in order to assess the workability of the procedures proposed in the manual. During two correlation meetings and field trips minor changes were suggested while also at the workshop that concluded the data collection stage modifications were recommended. These were incorporated in the January 1989 version of the Procedures Manual (Shields and Coote, 1989).

Application of the SOTER methodology in central Brazil, as well as in an area along the border between the USA and Canada revealed some shortcomings in the first version of the manual. Also, the first tentative interpretations of the data from Latin America as well as the integration of the attribute data within a Geographic Information System demonstrated the need for modifications.

A third revised version of the manual was compiled by the SOTER staff (ISRIC, 1990a) and circulated for comments amongst a broad spectrum of soil scientists and potential users of the database. A workshop on Procedures Manual Revisions was held at ISRIC, Wageningen to discuss the revised legend concepts and definitions (ISRIC, 1990b).

Based on the recommendations of this workshop, the proposed modifications were further elaborated and comments were included, resulting in the current version of the Procedures Manual.

The manual consists of three parts. The first section is dealing with the terrain and soil characteristics, while the second one treats the land use in a summary way until a more comprehensive land use database becomes available (from other organizations). In the third part, information on related files and climatic data needed for SOTER applications are described. In each section definitions and descriptions of the attributes to be coded are given while in the first section also an explanation of the mapping approach is provided.

In contrary to the 1988 and 1989 versions, the current manual does not elaborate on the soil degradation assessment as this is considered an interpretative part. Such interpretations will be part of forthcoming publications.

The technical specifications (viz. table definitions, primary keys, table contraints, etc.) and the rules for management of the database (input and backup procedures, etc.) will be part of an forthcoming SOTER publication.

The editors hope that this revised edition will form a solid base for further work with SOTER. Comments are welcomed, and should be sent to the SOTER project[1].

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editors

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PART I SOILS AND TERRAIN

1 Introduction

The aim of the SOTER project is to utilize current and emerging information technology to produce a world soils and terrain digital database containing digitized map unit boundaries and their attribute data (ISSS, 1986b). The database will be used for improved mapping and monitoring of changes of world soils and terrain resources, and the development of an information system capable of delivering accurate, useful, and timely information about soils and terrain resources to decision- and policy-makers.

The database will:

a) have a general average scale or accuracy of 1:1 million,
b) be compatible with global databases of other environmental resources,
c) be amenable to updating and purging of obsolete and/or irrelevant data,
d) be accessible to a broad array of international, regional, and national decision-makers and policy-makers to provide them with interpretative maps and tabular information essential for development, management, and conservation of environmental resources, and
e) be transferable to and useable by developing countries for national database development at larger scales.

As can be deducted from these characteristics the SOTER procedures manual should translate the overall objectives into a workable set of arrangements for the collection (from existing sources, or, if necessary, through new field surveys or remote sensing), coding and storing of soils and terrain data.

The manual is not intended as guidelines for survey procedures or any other methodology for the collection of field data. It does not present a methodology for the interpretation of remotely sensed data. Several handbooks on soil survey techniques are available on the market and any novice of soil survey methodologies should refer to these.

2 The SOTER mapping approach

When the general objectives of SOTER, as defined in chapter 1, are further elaborated it results in the following list of subjects to be discussed in the procedures manual:

a) the identification of the criteria for delineating areas with a homogeneous set of soil and terrain characteristics
b) the definion of soils and terrain parameters to be included in the database resulting in an adaptation of a universal set of data ("legend") for a world soils and terrain digital database with a resolution of 1:1,000,000
c) the development of a methodology that should be transferable to and useable by developing countries for national database development at the same or at larger scale (technology transfer).

2.1 Differentiating criteria

The mapping of soil and terrain characteristics as presented in this manual has evolved from the idea that land (in which terrain and soil occur) incorporates processes and systems of interrelationships between physical, biological (and social) phenomena evolving through time. This idea was initially developed in the USSR and Germany (landscape science) and was gradually accepted throughout the world. A similar integrated concept of land was used in the land systems approach developed in Australia (Christian and Stewart, 1953) and evolved further in time (McDonald et al, 1990, Gunn et al, 1990). SOTER has continued this development in viewing the land as natural divisions made up of terrain and soil individuals.

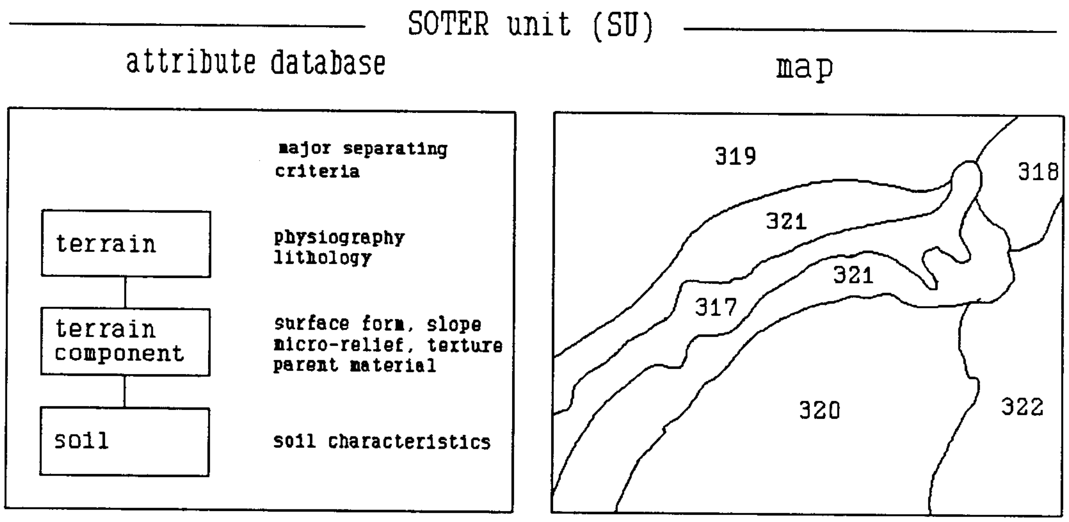


Figure 1 Relations between a SOTER Unit and their composing parts and major separating criteria.

Terrain

Basic in the SOTER approach is the mapping of areas with a distinctive, often repetitive pattern of landform, surface form, slope, parent material, and soils. The areas in this way delineated on the map, are named SOTER units (SU). Each SU thus represents area(s) with a unique combination of terrain and soil characteristics.

In fig. 1 the relations between the SU's and their composing parts are depicted. As can be seen from this figure, a SOTER unit on the map can consist of one or more map polygons, with each of these having identical attribute data except for the location.

The major differentiating criteria are applied in a step-by-step way. Physiography is the first separating criterion to differentiate between SU's. The form of the earth surface can be best described by denominating and quantifying as far as feasible the major landforms, their elevation and relief intensity. In this way a broad subdivision of an area can be made and delineated on a map (fig 2). The areas corresponding with the major landforms are further subdivided according to the lithology or parent material (fig. 3).

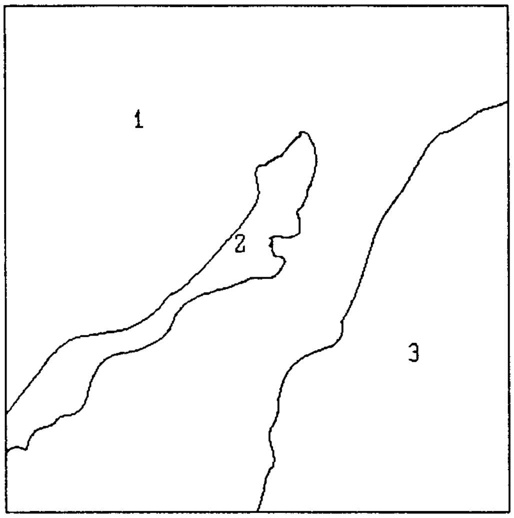


Figure 2 SOTER units after differentiating major landforms.

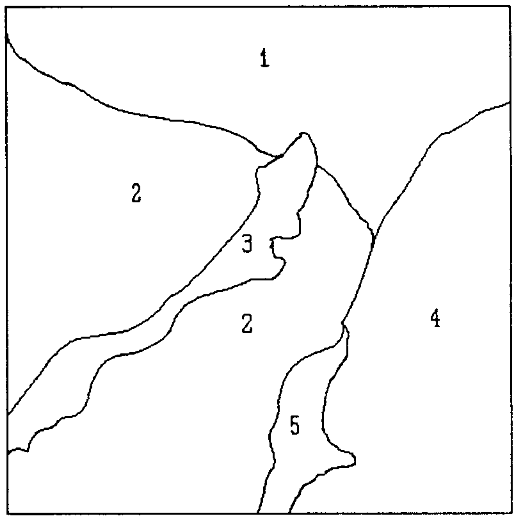


Figure 3 SOTER units after differentiating lithology.

This will lead to further fragmentation of the physiographic units. Terrain in the SU context is defined as an area with a particular combination of landform and lithology. It possesses also a typical combination/pattern of terrain surface forms and soils which will be described later. The major differentiating criteria concerning terrain are shown in fig. 1.

Terrain component

The next step is the identification of areas within the terrain with a particular (pattern of) surface form, slope, micro-relief and parent material aspects. This will result in a further partitioning of the terrain into terrain components (fig. 4 and 5). It is possible that the pattern of surface form and slope characteristics etc. is too intricate to be separated on a map at a 1:1 million scale. In that case the subdivisions cannot be made on the map, but only in the database. However, it still justifies the identification of terrain components. The major differentiating criteria for the terrain component are shown in fig. 1.

Soil

Each terrain component will have one or more soils which, depending of their size or complexity of their pattern, can again be delineated on the map (fig. 6) or only separated in the database.

Terrain data are linked to a soil profile database. Soil data are taken from a representative profile. In other words soil data are based on point observations viz. profile pits, and can be extrapolated to the SOTER unit for which they are considered representative. However, not all profile characteristics can be extrapolated to the same extent, and caution is necessary. For major soil characteristics it is assumed that extrapolation to the entire SOTER unit is justifiable. But for other soil attributes the spatial variability might be too great to do so indiscriminately.

The criteria for the distinction of soils are based on the differences in major soil characteristics, such as the thickness of the major layers/horizons, texture, pH, CEC and organic C. Differences in other characteristics, such as exchangeable K, usually do not justify the definition of a 'new' soil.

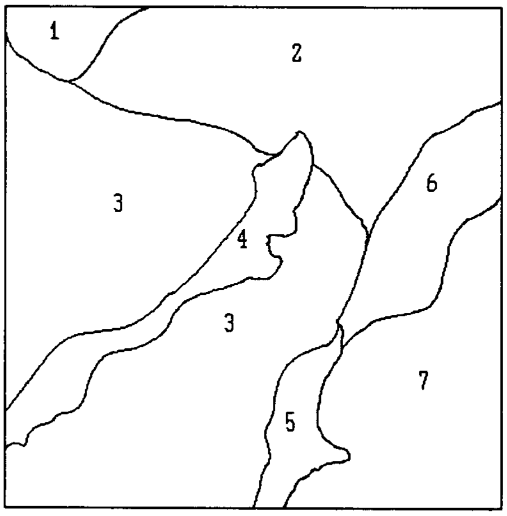


Figure 4 SOTER units after differentiating surface forms.

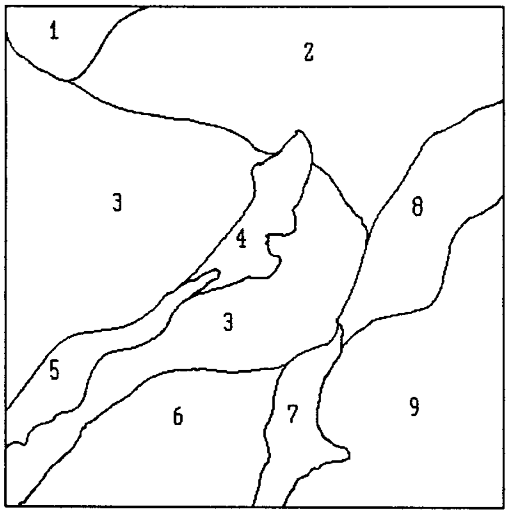


Figure 5 SOTER units after differentiating slope gradients.

In the case that existing soil information is used for the compilation of the SU's the following rule of thumb can be used whether soils are to be considered similar or dissimilar:

- If traditional mapping units are defined only till the second level of the FAO Legend (FAO-Unesco, 1974) or till the third level of Soil Taxonomy (Soil Survey Staff, 1975), i.e. great group, then separate entries have to be made for each soil within the terrain component.
- If the classification is given down to the equivalent of the Soil Taxonomy subgroup level or comparable, e.g. third level of FAO Legend plus phases (FAO, 1988), then reference to one entry elsewhere in the database is permissible.

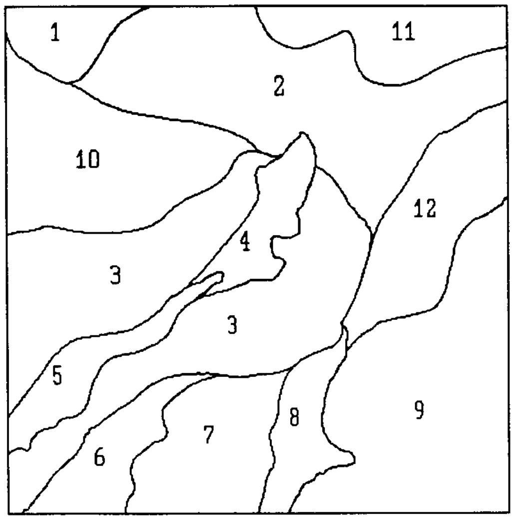


Figure 6 SOTER units after differentiating soils.

In the ideal situation, at least from the point of view of geo-referencing the data, the procedure will lead to homogeneous areas on the map (SU's) with one landform, one parent material and one soil. At the scale at which SOTER is used (1:1 million) it is unlikely that this situation will often occur. More commonly, patterns of surface form and soils will be too complex to be separated on the map. Therefore SU's will be most likely composed of a terrain with several terrain components and soils.

Although the splitting of the SU's into various terrain components and soils has the advantage of recording much information on the SU, it has one major disadvantage.While the relative position of the constituents of the SU and the percentage they occupy within it are recorded, their exact location within the SU cannot be. The subdivisions of the SOTER units, i.e. terrain components and soils, cannot be located precisely; they occur somewhere within the delineation of the SOTER unit.

This situation is similar to conventional soil mapping at small scales, where complexes occur frequently. The SOTER approach should be considered a compromise between the resolution of the small-scale map and the quantity of information that is available.

The disadvantage of non-precise location of terrain components and soils exists only when data of complex SU's are to be presented in a map format. It does not play a role when tabular output is generated.

2.2 Universal set of soils and terrain data

The major part of this manual is concerned with the definitions of the soil and terrain attributes, the non-spatial data, to be included in the database. Although the definitions are meant to be valid universally, our present experience is restricted to the application in a limited number of areas. As a consequence, the SOTER database structure is expected to evolve in time.

Definitions have been taken as far as possible from existing sources (Benzler et al.,1982; Day, 1983; FAO, 1977, 1986 and 1990; ISSS, 1986b; Remmelzwaal, 1990 and 1991; Soil Conservation Service, 1979, 1981 and 1986; Soil Survey Staff, 1975; Touber et al., 1989;

Unesco, 1975). Some definitions have been adapted to the SOTER requirements. Also new meanings have been given for those attributes that have not been universally defined. Precise definitions for all non-spatial soil and terrain attributes are given in chapter 4.

As no universally accepted definitions of major landforms and many other attributes in this manual have been agreed upon the list is rather provisional. However, the recent approval of some of the proposed criteria and meanings by global organisations and the incorporation of these in their guidelines (e.g. FAO, 1990), will certainly make these definitions more widely accepted.

As far as possible, a hierarchy of terms for the attributes is given. This was not always feasible as there are no well defined subdivisions for many of the attributes. E.g. subdivisions of landform, and surface form vary between many authors.

Attributes which can be derived from other data are in principle not recorded, e.g. base saturation, and C/N quotient. Soil texture class is an exception. It can be derived from the individual particle fractions but to speed up queries it is recorded separately. Soil classification as such is not recorded as an attribute in SOTER, but if required, it can be derived from several attributes in the database.

2.3 The SOTER approach at larger scales

The methodology as presented in this manual has been developed for applications at a scale of 1:1 million. The approach has been tested succesfully in several pilot areas (Latin America, Brazil, North America). Nevertheless, the methodology is also intended for use at larger scales for the development of national soils and terrain databases. A first atttempt was made in Sao Paulo State of Brazil at a scale of 1:100,000 (Oliviera and van de Berg, in prep.).

As expected, some modifications were necessary in the composing parts of a SOTER unit (structure of the attribute database) while the definitions of the attributes could be used more or less scale-independent. The changes will be resumed below.

Constituents of a SOTER unit

At small scales (up to 1:250,000) the structure as presented in figure 1 for the 1:1 million approach can be maintained. With increasing scales it is assumed that the highest level of the composing part of a SOTER unit (the terrain part) will gradually disappear. This does not mean that information on the terrain will be left out. It will be part of the information of the SOTER unit. The attributes of the terrain will be included in the nearest lower level (the terrain component). This will probably occur already at scales of 1:100,000 to 1:50,000.

At scales larger than 1:50,000 it is expected that also the terrain component part of a SOTER unit can be incorporated in the soils part. SOTER units will become delineations of soil entities.

Attributes

In order to apply the approach at various scales it is necessary to develop a hierarchy of terms for the attributes to be used at various scales. This is in particular the case for those attributes that concern an area. Contrarily, attributes of point observations are independent of scale. Examples of hierarchies of terms are given in this manual for lithology, land use and vegetation for which at each level a scale related set of classes exists (annexes 1, 2, and 3).

No such hierarchy could be given for hydrology and landform at the higher levels of the database. At the lower levels of the database, viz. at the soil level, a hierarchy of terms is not required as the data mainly refer to measurements at point observations.

The list of attributes for point data of soils (representative profiles) is restricted to those attributes for which it is assumed that an extrapolation can be made to the SU for which the point is considered representative. More attributes can certainly be collected but their spatial variability make their representativiness for an entire SU doubtful. This means that at larger scales more attributes per point observation can be recorded and used for interpretation.

Attributes which are not incorporated in the database are e.g. some which are related to the organic soil material (humus type) and detailed chemical properties (micro-nutrients, fractions of Nitrogen, etc.). Moreover, it might be necessary to introduce more detailed attributes for databases at larger scale.

3 SOTER database structure

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

1. geometric data; location and extent of an object are represented by a point, line or delineated area and topology (shapes, neighbours and hierarchy).

2. attribute data; characteristics of the object.

Also in SOTER these two forms are present. Soils and terrain information has a geometric component which indicates the location and the topology as well as an attribute part that describes the non-spatial characteristics. The geometry is stored in one part of the database (handled by Geographic Information System software, GIS) while the attribute data is stored in separate attribute files (handled by a DataBase Management System, DBMS). A unique label attached to both the geometric and the attribute data forms the link to connect these two types of information (see figures 7 and 8). In fig. 7 a part of a map has been visualized in a block diagram. Separation of the SOTER units has been made as far as the terrain component level. Fig. 8 exhibits also the soils within a SOTER unit.

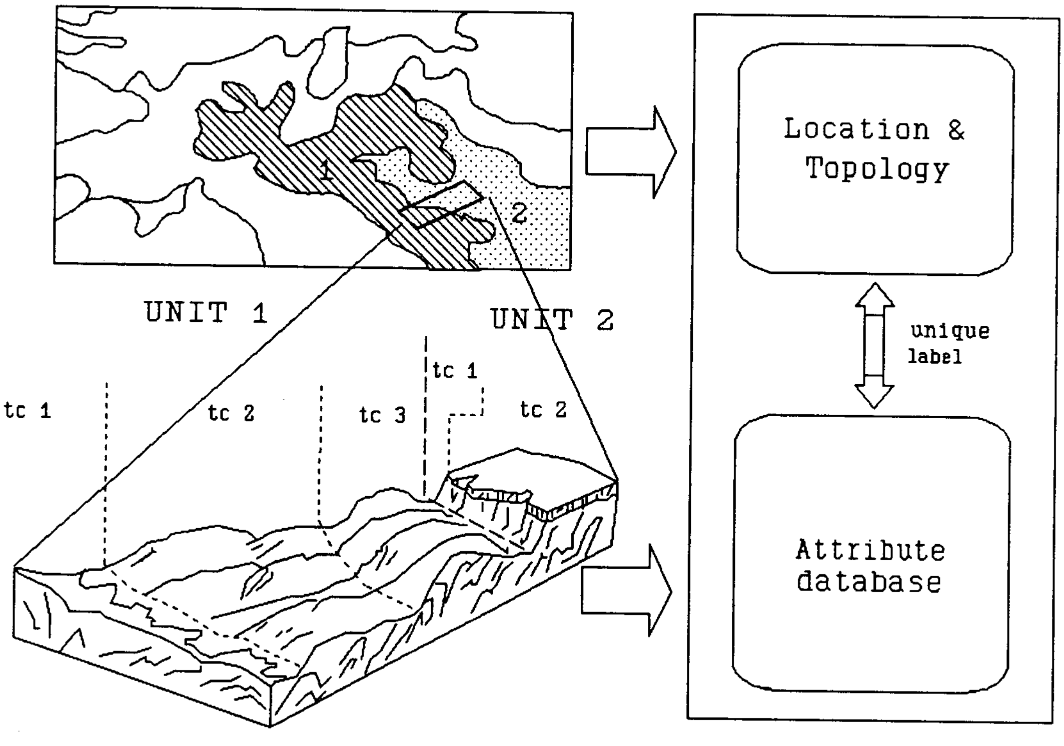


Figure 7 SOTER units, their terrain components (tc), attributes, and location.

The overall system (GIS plus DBMS) stores and handles both the geometric and attribute database. This manual limits itself to the attribute part of the database, in particular the structure of the attribute database and the definitions of the attributes.

To ensure the most effective storage and flexible management of the non-spatial attributes it was decided to use a relational database for SOTER (Pulles, 1988). The handling of the data is done by a relational database management system (RDBMS) in which the data is stored in tables, whose records are related to each other by the values of certain key fields (primary keys), e.g. the SOTER unit identifier.

The database structure for the non-spatial attributes of the SU's as shown in fig. 9 is derived from the scheme of the consituents of a SU (fig. 1). It is the result of a continuing process of creating the most efficient structure for data which describe areas and data related to a particular point observation, while it also leaves room for links with other point observations, viz. national soil profile databases.

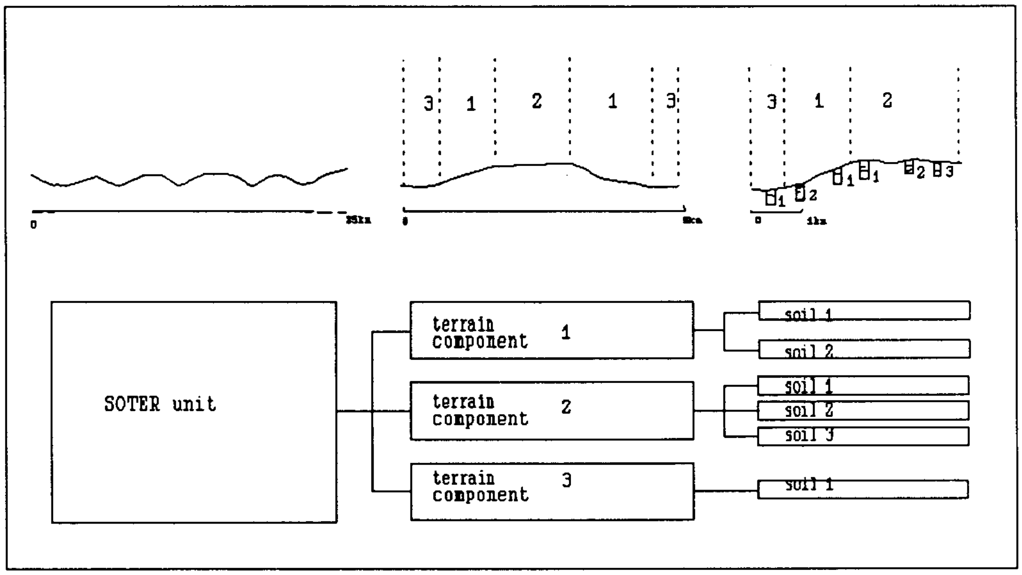


Figure 8 Schematic representation of a SOTER unit, with terrain, terrain components and soils.

For reasons of database efficiency several blocks of the composing parts of the SU have been split, resulting in two separations for the terrain components and three for the soils parts. Fig. 9 shows the complete scheme of the attribute database structure, while table 1 lists all attributes.

As terrain components and soils might occur in various SU's at the same time, it is efficient to store the data only once. Therefore the database structure differs slightly from the scheme of the SU. Changes are explained in the next paragraphs.

3.1 Terrain

At the SOTER unit level, the terrain is described in terms of major landform, relief, and incisions, amongst others. Note that the SOTER unit is not equal to a terrain or landform unit; as has been written in chapter 2, other criteria for delineating separate SOTER units are for example the surface form and soil characteristics.

3.2 Terrain component

When terrain components in different units share the same terrain component data, it is desirable to refer to each other, and enter the data only once. Therefore, the terrain component of the SU uses two tables:

1) a *terrain component* table with the proportion in its specific SOTER unit and a reference to a terrain component data set, and
2) a *terrain component data* table containing the specific attribute values.

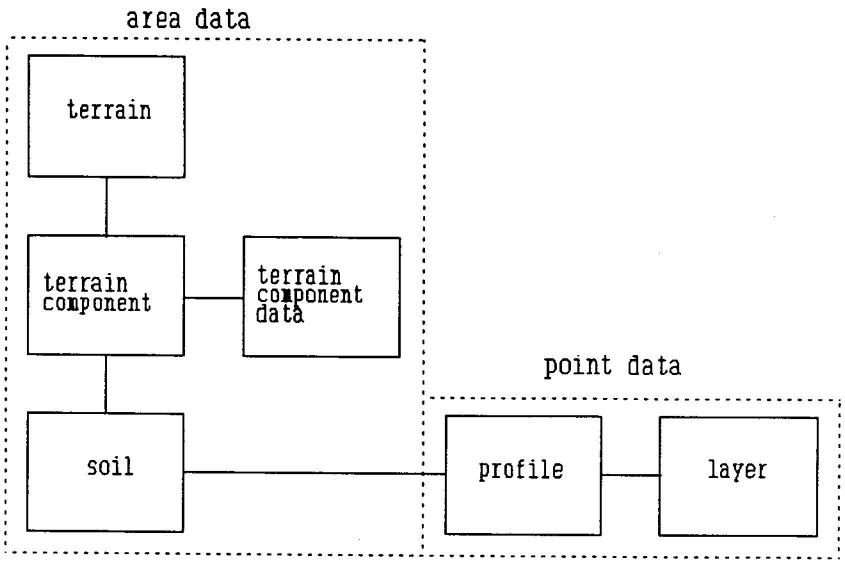


Figure 9 SOTER attribute database structure with area and point data.

A representation of the database structure is given in fig. 9. All blocks shown in it represent tables in the SOTER database. Data records are linked to each other through their unique identifiers.

For each set of terrain components with an identical terrain component data set, a unique identifier is generated by the DBMS for that data set. Attributes at the terrain component level cannot be mapped without some processing because one SOTER unit can consist of multiple terrain components and thus contain a range of values for an attribute.

Links between the tables are maintained through key fields, so-called primary keys: identification labels that occur throughout all tables. The link between the terrain and terrain component table goes through the SOTER unit ID, between terrain component and terrain component data through the SOTER unit and terrain component ID, etc. All primary key fields are printed in bold in table 1.

Part of the attribute data concerns an average value for the whole SU or its constituing parts. The dotted lines in fig. 9 show the tables which hold data valid for areas within the SU ('area data') and data related to a point observation ('point data'). The latter are extrapolated to (a part of) the SU.

The link with other point data (e.g. national soil profile databases) is explained in chapter 7.

3.3 Soil

The 'soil' of a SOTER unit is a part of a terrain component, and, as can be seen from figure 9, is not directly linked to the terrain component data. The proportion that the soil occupies, is expressed as a percentage of the SOTER unit instead of the terrain component. The 'soil' relates a given reference profile to one (or more) terrain components. In this way, profile data are stored only once, but can be referred to many times.

Table 1 Non-spatial attributes of a SOTER unit.

TERRAIN		
1 SOTER unit ID	6 relief intensity	11 permanent water surface
2 year of compilation	7 depth of incisions	12 map ID
3 regional landform	8 slope of incisions	
4 minimum elevation	9 coverage of incisions	
5 maximum elevation	10 general lithology	

TERRAIN COMPONENT	TERRAIN COMPONENT DATA	
13 SOTER unit ID	**17 terrain component data ID**	24 surface rockiness
14 terrain component number	18 slope gradient	25 surface stoniness
15 proportion of SU	19 length of slope	26 depth to parent rock
16 terrain component data ID	20 meso-relief	27 surface drainage
	21 micro-relief	28 frequency of flooding
	22 parent material	29 start of flooding
	23 texture group of non-consolidated parent material	30 duration of flooding
		31 high groundwater
		32 low groundwater

SOIL	LAYER	
33 SOTER unit ID	**54 profile ID**	80 EC_e
34 terrain component number	**55 layer number**	81 $CaCO_3$
35 soil number	56 lower depth	82 gypsum
36 proportion of SU	57 abruptness boundary	83 coarse fragments vol%
37 position in terrain component	58 moist colour	84 coarse fragments size
	59 dry colour	85 total sand%
38 rootable depth	60 form of structure	86 very coarse sand%
39 profile ID	61 size of structure	87 coarse sand%
40 number of reference pedons	62 grade of stucture	88 medium sand%
	63 carbon content	89 fine sand%
PROFILE	64 nitrogen content	90 very fine sand%
	65 P-total	91 silt%
41 profile ID	66 CEC-soil	92 clay%
42 latitude location	67 ECEC-soil	93 natural clay%
43 longitude location	68 AEC-soil	94 texture class
44 lab ID	69 exchangeable Ca	95 clay mineralogy
45 sampling date	70 exchangeable Mg	96 SM% at various pF
46 national profile database	71 exchangeable K	97 bulk density
47 internal drainage	72 exchangeable Na	98 hydraulic conductivity at various pF
48 infiltration	73 exchangeable Al	
49 soil development	74 Fe-dithionite	99 diagnostic horizon
50 thickness O.M./litter on surface	75 Al-dithionite	100 diagnostic property
	76 Fe-oxalate	
51 decomposition O.M.	77 Al-oxalate	
52 sensitivity to capping	78 pH-H_2O	
53 material below pedon	79 pH-KCl	

N.B. Primary keys are printed in bold.

The soil attributes can be divided into three parts:

1) the *soil* table holds information to link the soil to the terrain component and to the *profile* table; plus the proportion of the soil within the SOTER unit,
2) the *profile* table is carrying information valid for the whole soil profile, and
3) the *layer* table is holding information on the various soil profile layers.

The designation 'layer' has been used instead of horizon because the latter word is being used in a pure pedogenetic context.

At present, the SOTER database limits the maximum number of reference profiles per soil to 1.

4 Additional SOTER conventions

The various conventions described in this chapter form an addition to those characterized in chapter 2. They concern mainly rules governing the minimum size of a SU, both in absolute and in relative terms, as well as criteria determining the selection of representative profiles, relations with associated databases, type of data, missing data and the like.

SOTER database management procedures, such as date stamps and backup procedures, are not treated in this manual, but are to be describe in a separate paper.

4.1 SOTER unit codes

Each SOTER unit is assigned an identifying code that is unique for the database in question. When national databases are to be merged into a regional or global soils and terrain database, it is the responsibility of the system administrator to ensure that the codes are unique. At the national level, there is no need for concern of a globally unique code.

4.2 Minimum size of the SU

As a rule of thumb the minimum size of a single SOTER unit is 0.25 cm^2 on the map at 1:1 million, which equals 25 km^2 in the terrain. Mostly such tiny units will correspond with narrow elongated features and drainage patterns or strongly contrasting soil and terrain areas. By convention a minimum size of 0.25 cm^2 is considered as the smallest area that can be cartographically presented. In general, most map units will be larger.

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

The compiler of the map, should be very selective in choosing the terrain components and soils which are considered important for subsequent interpretations. Only a significant change in parent material, surface form and slope gradient can result in a different SU. It is important to remember that it is not advisable to describe more terrain components or soils than is necessary. Discretion at this point will save much time required for the coding and computer processing of extra data.

4.3 Number of components

Within a SU the terrain component can occupy any percentage of the terrain and the minimum size of an area holding one soil is also not restricted. That allows in theory for an unlimited number of terrain components, each with one soil component. In practice, this situation is very unlikely to occur as many terrain components or soil areas are not so small.

Most commonly the terrain of a SU will consist of 2 or 3 terrain components having 1 or 2 soils each, leading to 2 to 6 soils for one unit.

Parts of the SUs which cannot be allocated separately as terrain components should be joined with neighbouring components. The sum of the percentages of the terrain components as indicated in the attribute file should always be 100%.

4.4 Representative soil profiles

The representative profile used for the soils part is chosen from amongst a number of reference profiles with similar characteristics representative for the soil. SOTER will rely on the selection by the original surveyors. It is envisaged that reference profiles taken into account for the selection into the SOTER database should be stored in a national soil profile database e.g. FAO/ISRIC Soil Database format (FAO, 1989). A selection of these profiles will ultimately also be stored in a global soil profile database, the ISRIC Soil Information System (van Waveren and Bos, 1988a, 1988b). The SOTER database includes a key to the national databases.

The SOTER database includes also a code showing how many reference profiles were used for the selection of the representative profile. This is a first approach to incorporate information on spatial reliability of the data.

Pedogenetic master (layers) horizons of the profile are described. They are derived from the Legend of the FAO-Unesco's Soil Map of the World (1974 and 1988). Commonly each profile can be characterized using up to 4 master horizons. If necessary, more horizons can be used, but the general objective is that the total number of layers is kept to a minimum.

4.5 Attribute types

Different types of attributes can be distinguished based on their importance for interpretations on the database. Two types of attributes are then distinguished:

- mandatory attributes must be collected or estimated
- optional attributes; collection is considered advisable

For most numeric attributes of the layer file, expert estimates are desired when analytical values are missing. Some numeric attributes are defined as requiring a measured value in addition to being mandatory (e.g. sand %); for a certain set of attributes no estimates are accepted, such as the relation between soil moisture content and matric suction.

Where quantitative attribute data is available it will be entered as such in the database. In case of missing data expert estimates are considered adequate. The two types of data are labelled in the database, in particular in the layer file. Empty fields for the mandatory attributes are not permitted. Empty fields for the optional attributes are allowed. When values for quantitative attributes are derived from existing survey reports with classified attribute values, the average of class ranges can be used as an expert estimate.

There are two ways in which data can be available: in numeric and in descriptive (non-numeric) format. For numeric attributes the measured value is entered in the database file. For descriptive attributes the dominant quality is stored, usually by a connotative abbreviation of the attribute name.

4.6 Updating procedures

Although soil and especially terrain characteristics are thought to be rather stable over time, it might become necessary to update certain data. At present, there is no procedure for updates on the geographic data, such as the borders of the SOTER units.

When the attribute database needs to be updated, it can be because of *missing data* in the database, *incorrect data*, or *obsolete data*. If data was missing, the gaps can simply be filled up; when new data replaces incorrect data, the old data can be overwritten.

In contrary to this, when more up-to-date data becomes available, the old data remains correct for that moment in time and is **not** replaced. Instead, the old data are down-loaded to a database containing obsolete data. This database can then be used for the monitoring of changes. SOTER unit and profile data are unique in both space and time.

5 Attribute coding

Note that the names of the attributes given in table 1 or in the following paragraphs need not be identical to the identifiers/codes used in the SOTER database. The numbers preceding the attributes in table 1 are identical to the numbers of the attributes in this chapter.

5.1 Terrain

1 *SOTER unit_id*

The SOTER unit_id is the identification code of a SOTER unit on the map. It links the mapped area to the attributes in the database. SOTER units which have identical attributes thus carry the same SOTER unit_id. In other words the SOTER unit_id is similar to a code for a mapping unit on a conventional soil map.

For SOTER which is to become a global database, the code of every terrain unit must be unique for the world. Most GIS software can handle only numeric codes and SOTER is thus limited to numbers for its coding. As it seems impossible to foresee how many numbers will be needed, number will be given in first-come-first-served way.

However, for regional compilors of SOTER data it is sufficient to give only locally unique numbers, e.g. numbers in sequential order, which can be adjusted before entry in the central SOTER database.

2 *date of compilation*

The year in which the original terrain data were collected. The date on which the map was recompiled according to the SOTER procedures is not recorded separately as this date is generally very near the date of entry into the database (a date recorded by the RDBMS). It is assumed that the date of colllection of the terrain data also applies to the terrain component data.

3 *regional landform*

Landforms are described by their physiography (form) in contrast to their genetic origin or processes causing their shape. Landforms are determined by their dominant slopes and the relief intensity, which is defined as the median difference between high and low per unit length (m/km). These criteria have been proposed for a landform classification system to be used by FAO (Remmelzwaal, 1991). Three groups are proposed:

Landforms with steep slopes and a high relief:

M Mountains characteristic slopes > 30% and relief intensity > 600 m/2km.
In general with a restricted summit area, steep sides and an irregular shape. Major scarps, the relatively steep and straight cliff-like slopes of considerable linear extent separating surfaces such as plateaus lying at different levels, are also included in this landform.

Landforms with moderate slopes and moderate relief:

H Hills — characteristic slopes 10 - 30%, relief intensity > 50 m over characteristic slope unit. The characteristic slope may be > 30%, but then the relief intensity < 600m/2km.
Natural elevations rising prominently above the adjacent/surrounding plain and having a recognizably denser pattern of generally higher knolls or crest lines with an irregular or chaotic surface form composed of upper surface convexity and lower concavity.

V Valley — Same characteristics as hills but the valley is lower than the surrounding landform and has an elongated form.

Landforms with gentle slopes and low relief:

P Plain — overall slopes 0-10%, relief intensity less than 100 m/km; characteristic slope may be > 10% if the relief intensity < 50 m per characteristic slope unit.
Flat to gently undulating areas which have few or no prominent irregularities.

T Plateau — special type of plain, bounded on at least one side by an abrupt escarpment (Tableland).

B Basin — special type of plain: depressions/basins surrounded by mountains, hills or plateaus.

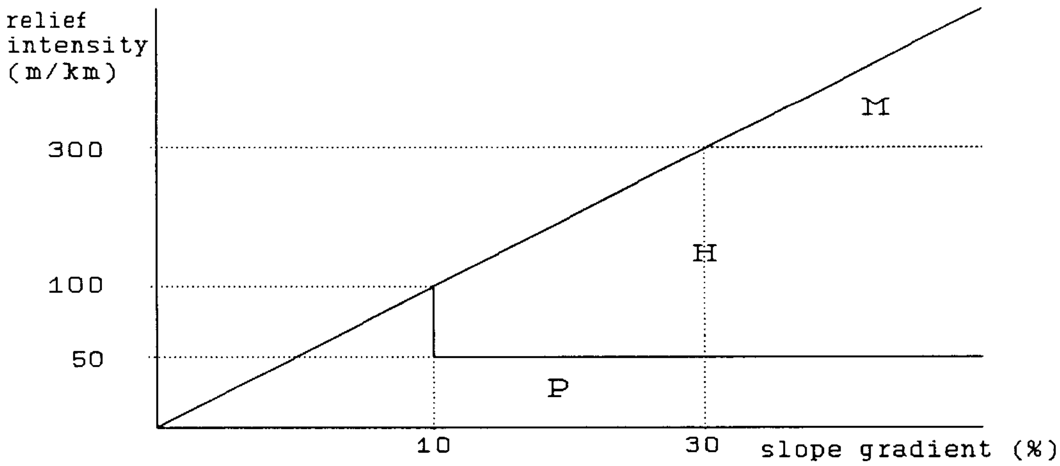


Figure 10 Major regional landforms as determined by relief intensity and slope gradient.

4 *minimum elevation*

Absolute minimum elevation of the SU, in meters above sea level. Both this attribute and the next one are easily read from a topographic map.

5 *maximum elevation*

Absolute maximum elevation of the SU, in meters above sea level.

6 *relief intensity*

The relief intensity is the difference between highest and lowest point within the terrain per unit length, m/km. Note that the relief intensity is given in m/km and not m/2km.

7 *depth of incisions*

The depth of dissection of the landform in meters (only for plains, plateaus, and basins).

8 *slope of incisions*

The characteristic slope % of the dissection (only for plains, plateaus or depressions).

9 *coverge of incisions*

The estimated area of the SU covered by the dissection, in %.

10 *general lithology*

Generalized description of the consolidated or unconsolidated surficial materials which occupy most of the terrain (Holmes, 1968). Major differentiating criteria are genesis and mineralogical composition. For a description of the hierarchy of terms, see ANNEX 1. The lithology should be specified to the group level at least.

Table 2 Hierarchy of lithology.

major class		group		type	
I	igneous rock	IA	acid igneous	IA1	granite
				IA2	grano-diorite
				IA3	quartz-diorite
				IA4	rhyolite
..		II	intermediate igneous	II1	andesite, trachyte, phonolite
				II2	diorite-syenite
..		IB	basic igneous	IB1	gabbro
				IB2	basalt
				IB3	dolerite
..		IU	ultrabasic igneous	IU1	peridotite
				IU2	pyroxenite
				IU3	ilmenite, magnetite, ironstone, serpentine
M	metamorphic rock	MA	acid metamorphic	MA1	quartzite
				MA2	gneiss, migmatite

..		MB	basic metamorphic	MB1	slate, phyllite (pelitic rocks)
				MB2	schist
				MB3	gneiss rich in ferro-magnesian minerals
				MB4	metamorphic limestone (marble)
S	sedimentary rock	SC	clastic sediments	SC1	conglomerate, breccia
				SC2	sandstone, greywacke, arkose
				SC3	siltstone, mudstone, claystone
				SC4	shale
..		SO	organic	SO1	limestone, other carbonate rocks
				SO2	marl and other mixtures
				SO3	coals, bitumen & related rocks
..		SE	evaporites	SE1	anhydrite, gypsum
				SE2	halite
U	unconsolidated	UF	fluvial		
		UL	lacustrine		
		UM	marine		
		UC	colluvial		
		UE	eolian		
		UG	glacial		
		UP	pyroclastic		
		UO	organic		

11 *permanent water surface*

Area of the SOTER unit that is a permanent water body, i.e. more than 10 months/year. When a water body is large enough, it should be delineated on the map. The area is expressed as a percentage.

12 *map_id*

The map number code from which the data were derived for the compilation of the SOTER units.

5.2 Terrain component

13 *SOTER unit_id*

See SOTER unit_id under paragraph 1.1 Terrain.

14 *terrain component number*

The sequence number of the terrain component in the terrain. The largest terrain component in the SU comes first, followed by the second in size, and so on.

Examples

SOTER unit_id = 2034,	SOTER unit_id = 2034
terrain component number = 1	terrain component number = 1
(proportion within SU = 70%	proportion within SU = 30%)

15 *proportion of SU*

Proportion that the terrain component occupies within the SU, in %. The sum of all terrain components should be 100% for each SOTER unit. If a terrain component is too small to be coded, its proportion should be included with an adjacent component.

16 *terrain component data_id*

Code for terrain component data_id. This code is identical to the combination terrain_id and terrain component number or when refering to an already described terrain component data_id, equal to that id.

Examples

case A (two terrain components, both not yet described in the attribute database)

SOTER unit_id = 2034,	SOTER unit_id = 2034
terrain component number = 1	terrain component number = 1
proportion within SU = 70%	proportion within SU = 30%
terrain component data_id= 2034_1	terrain component data_id= 2034_2

case B (two terrain components, one already described (marked with *), one not yet)

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

5.3 Terrain component data

17 *terrain component data_id*

See terrain component data_id under paragraph 1.2 Terrain component.

18 *slope gradient*

Dominant slope gradient, %

19 *length of slope*

Estimated dominant length of slopes, m.

20 *meso-relief*

The meso-relief or local surface form (Day, 1983; FAO, 1977; McDonald, 1990; Soil Survey Staff, 1951):

D	dissected	A dense pattern of drainage lines more than 5 m deep.
G	gullies	A well developed pattern of frequent, active gullies (more than 30 cm deep) providing external drainage for the area.
H	hummocky	A very complex sequence of slopes extending from somewhat rounded depressions or kettles of various sizes to irregular conical knolls or knobs. There is a general lack of concordance between knolls or depressions. Slopes are generally between 4 and 70%.
I	ridged	A long, narrow elevation of the surface, usually sharp crested with steep sides. The ridges may be parallel, subparallel or intersecting.
O	sloping	Uniform long slope with a gradient of more than 2%.
C	concave	Concave, lower slope, with decreasing slope gradient going downslope.
X	convex	Convex, upper slope, with decreasing slope gradient going slope upwards.
T	terraced	Scarp face and the horizontal or gently sloping surface above it. Slopes 2% or less.

21 *micro-relief*

The micro-relief of the surface form refers to the small-scale differences in height over short distances (FAO, 1986; McDonald, 1990).

A	absent	No micro-relief is present.
M	mounded	A pattern including distinct mounds of varying relief rising above a planar surface. The mounds must occupy at least 40% of the area. Examples are termite and ant mounds.
G	gilgai	A microrelief pattern consisting of enclosed micro-basins and micro-knolls less than 60 cm in nearly level areas or of micro-valleys and micro-ridges that run with the slope. The pattern occurs on clay soils with high coefficients of expansion and contraction with changes in moisture.
R	rills	A well developed pattern of frequent, active rills (less than 30 cm deep) providing external drainage for the area.
D	depositions	Overwash and overblow deposits, forming slight elevations above the original surface (micro-dunes, etc.).
P	frost polygons	Polygonal ridges, consisting of coarser material (mostly stones) than the inner part, slightly rising above the surface.

22 *parent material*

Generalized description of the consolidated or unconsolidated surficial materials which occupy most of the terrain component (Holmes, 1968; Strahler, 1969). These materials include the kinds of rockmass from which parent material is derived and other unconsolidated mineral or organic deposits.

A complete listing of the codes of lithology is given in ANNEX 1. Describe the parent material at least up to the type level. If the type level of parent material has already been given at the terrain level it is not necessary to specify it here again.

23 *texture group of non-consolidated parent material*

Texture group of particles < 2mm of the non-consolidated parent material or the material at 2 m if the soil is deeply developed.

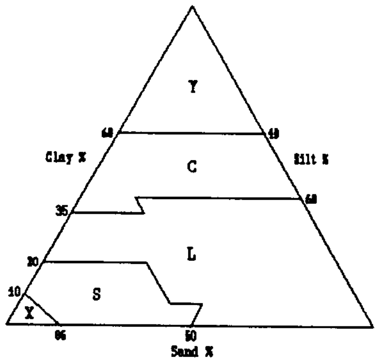


Figure 11 Texture groups of parent material.

Y	very clayey	More than 60% clay
C	clayey	Sandy clay, silty clay and clay texture classes (see fig. 5), up to 60% clay
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

24 *surface rockiness*

Rock outcrops, % coverage or exposure.

25 *surface stoniness*

Stoniness at surface, % coverage.

26 *depth to parent rock*

Depth to consolidated parent rock, m.

27 *surface drainage*

Surface drainage (Cochrane et.al., 1985; van Waveren, 1987).

E	extremely slow	Water ponds at the surface, and the soil is waterlogged for periods of a month or more
S	slow	Water drains slowly; the soil does not remain waterlogged for a period less than a month
M	medium	Water drains at a medium rate; the soil is not waterlogged for more than 48 hours at a time
R	rapid	Excess water drains rapidly, even during periods of prolonged rainfall
V	very rapid	Excess water drains very rapidly; the topsoil cannot supply adequate moisture for seed germination

28 *frequency of flooding*

The frequency of flooding, periods/year. E.g.: 0.2 = one period of flooding in five years

29 *start of flooding*

The day on which flooding of the terrain component generally starts.

30 *duration of flooding*

The average duration of flooding per period (days/period). In case of diurnal flooding, the duration of each period is 0.25.

31 *depth to ground water, high*

Mean highest ground water level over a number of years, cm.

32 *depth to ground water, low*

Mean lowest ground water level over a number of years, cm.

5.4 Soil

33 *SOTER unit_id*

See SOTER unit_id under paragraph 1.1 Terrain.

34 *terrain component number*

See terrain component_id under paragraph 1.2 Terrain component.

35 *soil number*

The sequence number of the soil within the terrain component. The most extensive soil in the terrain component is numbered first followed by the second in size, and so on.

36 *proportion of SU*

Proportion that the soil occupies within the SOTER unit, %.

37 *position in terrain component*

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

H	high	crest/higher part of terrain unit
M	medium	upper and middle slope/medium positions of terrain unit
L	low	lower slope/part of terrain unit
A	all	all positions within terrain unit

38 *rootable depth*

Depth in cm to which root growth is not restricted by any physical or chemical characteristics, such as an impenetrable or toxic layer. Strongly fractured rocks, e.g. shales may be considered as rootable.

39 *profile_id*

Code for representative profile. Any national code is permitted provided it is unique.

40 *number of reference profiles*

The number of reference profiles that were considered for the selection of the representative profile.

5.5 Profile data

41 *profile_id*

Code for representatitive profile.

42 *latitude location*

Latitude of location of reference profile in decimal degrees (e.g. -10.8050 = 10°48'30"S).

43 *longitude location*

Longitude of location of profile in decimal degrees (e.g. -97.2510 = 97°15'06"W).

44 *lab_id*

Code for the laboratory that analysed the samples.

45 *sampling date*

Date at which samples of the profile were taken.

46 *national profile database*

Name of national profile database where other pedons of the same SU can be found.

47 *internal drainage*

Internal drainage (FAO, 1977).

X excessive	Water is removed from the soil very rapidly in relation to supply. Excess water flows downward very rapidly if underlying material is pervious. There may be very rapid subsurface flow during heavy rainfall provided there is a steep gradient. Water source is precipitation.
R rapid	Water is removed rapidly. Excess water flows downward if underlying material is pervious. Subsurface flow may occur on steep gradients during heavy rainfall. Water source is precipitation.

W well	Water is removed from the soil readily. Excess water flows downward readily into underlying pervious material or laterally as subsurface flow. These soils commonly retain optimum amounts of moisture for plant growth after rains or addition of irrigation water.
I imperfect	Water is removed from the soil sufficiently slowly in relation to supply to keep the soil wet for a significant part of the growing season. Excess water moves slowly downward if precipitation is the major supply. If subsurface water or ground water, or both, is the main source, the flow rate may vary but the soil remains wet for a significant part of the growing season.
P poor	Water is removed so slowly in relation to supply that the soil remains wet for a comparatively large part of the time the soil is not frozen. Excess water is evident in the soil for a large part of the time. Subsurface flow or ground water flow, or both, in addition to precipitation are the main water sources; there may also be a perched water table.
V very poor	Water is removed from the soil so slowly that the water table remains at or on the surface for the greater part of the time the soil is not frozen. Ground water flow and subsurface flow are the major water sources. Precipitation is less important except where there is a perched water table.

48 *infiltration*

Infiltration or percolation, cm/hr.

49 *soil development*

The assumed soil forming process (ISSS, 1990) that has led to the present soil.

AD	andic	Weathering of volcanic material resulting in the formation of amorphous alumino-silicates
AN	anthric	Pronounced human influence
CA	calcic	Accumulation of calcium carbonate
CB	cambic	Weathering in situ reflected by a change in colour, texture or consistence without important translocations
CH	chernic	Surface accumulation of saturated organic matter
FA	ferralic	Residual accumulation of sesquioxides as a result of strong weathering
FL	fluvic	Absence of distinct attributes due to soil formation, but with sedimentary stratification

GL	gleyic	Reduction as a result of groundwater influence
GY	gypsic	Acculation of gypsum
LI	lixic	Illuvial accumulation of low activity clays
LU	luvic	Illuvial accumulation of high activity clays
MO	modic	Surface accumulation of desaturated organic matter
NI	nitic	Accumulation of clay (illuvial and/or residual) in the presence of low activity clays
OR	organic	Thick surface accumulation of non or only partial decomposed organic materials generally associated with waterlogging
PO	podzic	Illuvial accumulation of amorphous compounds of organic matter, often with iron and/or aluminium
PR	primic	Absence of distinct attributes due to soil formation, non-stratified
SA	salic	Accumulation of soluble salts
SO	sodic	Accumulation of sodium (and magnesium) leading to dispersed soil material
ST	stagnic	Reduction as a result of surface or subsurface waterlogging
VE	vertic	Churning of soil material as a result of swelling and shrinking

50 *thickness of litter/organic material on the surface*

Thickness in cm of litter layer/organic material on the soil surface.

51 *degree of decomposition*

Degree of decomposition of organic material/litter on the surface (Soil Survey Staff, 1975).

F	fibric	Weakly decomposed organic soil materials, fiber content >2/3 of volume
H	hemic	organic soil material that has a degree of decomposition that is intermediate between fibric and humic (fiber content between 1/6 and 2/3 of volume)
S	sapric	organic soil material has a high degree of decomposition; fiber content < 1/6th of volume.

52 *sensitivity to capping*

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

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

53 *material below pedon*

The material that occurs below the last described layer:

N	unconsolidated rock	unconsolidated rock / material
P	petroplinthite	irreversibly hardened plinthite
R	rock	unweathered hard rock
S	stones	stone line, stone bed or gravel bed
W	weathered rock	weathered or rotten rock
U	unknown	unknown, continuation of overlying layer

5.6 Layer data

54 *profile_id*

See profile_id under paragraph 5.4 Soil (attribute 39).

55 *layer number*

Sequence number for the master horizon of the reference profile. It is recommended to limit the number of layers to a maximum of 4.

56 *lower depth*

Depth of lower boundary of layer, cm.

57 *abruptness of boundary*

Abruptness of layer boundary to underlying horizon (FAO, 1990). For the deepest layer described, the abruptness need not be entered.

A	abrupt	less than 2 cm
C	clear	2 to 5 cm
G	gradual	5 to 15 cm
D	diffuse	15 cm or more

58 *moist colour*

Munsell hue, chroma and value for moist soil. Intermediate values in the Munsell Soil Color Charts are not accepted.

59 *dry colour*

Munsell hue, chroma and value for dry soil.

60 *form of structure*

Form or type of structure (FAO, 1990; Soil Survey Staff, 1951).

P	platy	Particles arranged around a plane, generally horizontal
R	prismatic	Prisms without rounded upper ends
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	Spheroidal or polyhedral, relatively non-porous
B	crumb	Spheroidal or polyhedral, porous
M	massive	No structure; massive
N	single grain	No structure; individual grains
W	wedge-shaped	Structure in horizons with intersecting slickensides, as in Vertisols.

61 *size of structure elements*

Table 3 Size classes for structure elements of various types. In mm's. (Soil Survey Staff, 1951; FAO, 1990).

Size classes	Ranges of size of structure elements (mm)				
	platy	prismatic/columnar	(sub)ang.blocky	granul.	crumb
V very fine	< 1	< 10	< 5	< 1	<1
F fine	1- 2	10 - 20	5 - 10	1- 2	1-2
M medium	2- 5	20 - 50	10 - 20	2- 5	2-5
C coarse	5-10	50 -100	20 - 50	5-10	
X very coarse	>10	>100	> 50	>10	

62 *grade of structure*

Grade or development of structure elements (FAO, 1977).

N	structureless	No observable aggregation or no orderly arrangement of natural lines of weakness (massive or single grain)
W	weak	Poorly formed indistinct peds, barely observable in place
M	moderate	Well-formed distinct peds, moderately durable and evident, but not distinct in undisturbed soil
S	strong	Durable peds that are quite evident in undisplaced soil, adhere weakly to one another, withstand displacement, and become separated when soil is disturbed

63 *carbon content*

Content of organic carbon in the fine earth, g/kg.

64 *nitrogen content*

total nitrogen, g/kg

65 *total P*

mg/kg

66 *CEC soil*

cmol(+)/kg at pH 7.0 (in NH_4OAc)

67 *ECEC soil*

Effective CEC soil, cmol(+)/kg in 1M KCl.

68 *AEC soil*

cmol(-)/kg

69 *exchangeable Ca*

cmol(+)/kg

70 *exchangeable Mg*

cmol(+)/kg

71 *exchangeable K*

cmol(+)/kg

72 *exchangeable Na*

cmol(+)/kg

73 *exchangeable Al*

cmol(+)/kg

74 *Fe, dithionite extractable*

weight %

75 *Al, dithionite extractable*

weight %

76 *Fe, acid oxalate extractable*

Extraction with a solution of ammonium oxalate at pH 3, weigth %.

77 *Al, acid oxalate extractable*

Extraction with a solution of ammonium oxalate at pH 3, weigth %.

78 *pH-H_2O*

pH is determined in the supernatant suspension of a 1:2.5 soil-water mixture

79 *pH-KCl*

pH is determined in the supernatant suspension of a 1:2.5 soil-1 M KCl mixture

80 *electrical conductivity (EC_e)*

Electrical conductivity of saturation extract, mS/m.

81 *$CaCO_3$*

Content of calciumcarbonate ($CaCO_3$), g/kg

82 *gypsum*

Content of gypsum ($CaSO_4.2H_2O$), g/kg

83 *Volume of coarse fragments*

Volume % of coarse fragments in soil matrix.

84 *Size of coarse fragments*

Size of dominant coarse fragments in cm. When the estimate is based on the classes gravel (0.2 to 7.5 cm), stones (7.5 to 25 cm) and boulders (> 25 cm) enter the average class value.

85 *total sand*

Weight % of particles 2.0 - 0.050 mm in the fine earth.

86 *very coarse sand*

Weight % of particles 2.0 - 1.0 mm in the fine earth.

87 *coarse sand*

Weight % of particles 1.0 - 0.5 mm in the fine earth.

88 *medium sand*

Weight % of particles 0.5 - 0.25 mm in the fine earth.

89 *fine sand*

Weight % of particles 0.25 - 0.10 mm in the fine earth.

90 *very fine sand*

Weight % of particles 0.10 - 0.05 mm in the fine earth.

91 *silt*

Weight % of particles 0.002 - 0.050 mm in the fine earth.

92 *clay*

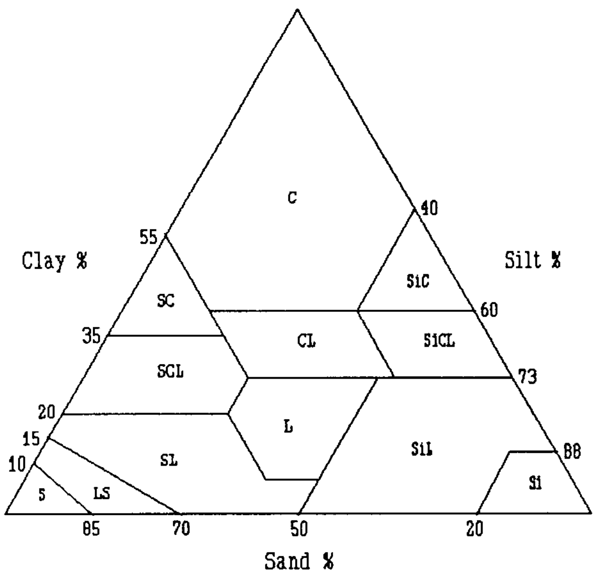
Weight % of particles < 0.002 mm in the fine earth.

93 *natural clay*

Weight % of particles < 0.002 mm in the fine earth, no pretreatment.

94 *texture class*

Texture class of the fine earth (Soil Survey Staff, 1951).



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 12 Texture classes of fine earth.

95 *clay mineralogy*

Dominant type of minerals in the clay fraction:

AL allophane

CH chloritic

IL illitic

IN interstratified or mixed

KA kaolinitic

MO montmorillonitic

SE sesquioxidic

VE vermiculitic

96 *moisture content at various pF values*

Volume % of soil moisture at various pF values. It is recommended to fill in data for at least two pF-values, preferably at field capacity and wilting point.

E.g.:

pF	1.0	1.3	2.0	2.4	2.7	3.4	4.2	6.0
soil moisture %	0.41	0.40	0.37	0.32	0.26	0.17	0.09	0.02

97 *bulk density*

kg/dm^3, or g/cm^3

98 *hydraulic conductivity at various pF values*

The hydraulic conductivity in cm/hr at various pF values. At least two values are required: one for the saturated conductivity and one for a non-saturated condition. See also the example of moisture content at various pF values above.

99 *diagnostic horizon*

Descriptions are taken from the Revised Legend of the FAO/Unesco Soil Map of the World (FAO, 1988). For more precise definitions refer to this publication.

HI histic — A horizon which is more than 25 cm but less than 40 cm thick. It can be more than 40 cm but less than 60 cm thick if it consists of 75 percent or more, by volume, of sphagnum fibres or has a bulk density when moist of less than 0.1 $kg.dm^{-3}$. A surface layer less than 25 cm thick qualifies as a histic horizon if, after having been mixed to a depth of 25 cm, it has 16% or more organic carbon and the mineral fraction contains more than 60% clay, or 8% or more organic carbon for intermediate contents of clay.

MO mollic

A horizon with the following properties for the upper 18 cm:
1) the soil structure is sufficiently strong that the horizon is not both massive and hard or very hard when dry. Very coarse prisms larger than 30 cm in diameter are included in the meaning of massive if there is no secondary structure within the prisms.
2) the chroma is less than 3.5 when moist, the value darker than 3.5 when moist and 5.5 when dry; the colour value is at least one unit darker than that of the C (both moist and dry). If a C horizon is not present, comparison should be made with the horizon immediately underlying the A horizon. If there is more than 40% finely divided lime, the limits of the colour value dry are waived; the colour value moist should then be 5 or less.
3) the base saturation is 50% or more
4) the organic carbon content is at least 0.6% throughout the thickness of mixed soil, as specified below. It is at least petrocalcic or a petrogypsic horizon or a petroferric phase.

FI fimic

A man made surface layer 50 cm or more thick which has been produced by long continued manuring with earthy mixtures. If a fimic horizon meets the requirements of the mollic or umbric horizon, it is distinguished from it by an acid-extractable P_2O_5 content which is higher than 250 mg/kg soil by 1 percent citric acid. Examples are the plaggen epipedon and the anthropic epipedon of Soil Taxonomy.

UM umbric

Comparable to mollic in colour, organic carbon and phosphorus content, consistency, structure and thickness. However, the base saturation is less than 50%.

OC ochric

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

AR argic

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

NA	natric	An argic horizon with 1) a columnar or prismatic structure in some part of the horizon, or a blocky structure with tongues of an eluvial horizon in which there are uncoated silt or sand grains extending more than 2.5 cm into the horizon, and 2) an exchangeable sodium percentage of more than 15% within the upper 40 cm of the horizon; or more exchangeable magnesium plus sodium than calcium plus exchange acidity within the upper 40 cm of the horizon if the saturation with exchangeable sodium is more than 15% in some subhorizon within 200 cm of the surface.
CB	cambic	An altered horizon lacking properties that meet the requirements of an argic, natric or spodic horizon; lacking the dark colours, organic matter content and structure of the histic horizon, or the mollic and umbric horizons. The texture is sandy loam or finer, with at least 8% of clay; the thickness is at least 15 cm with the lower depth at least 25 cm below the surface; soil structure is at least moderately developed or rock structure is absent in at least half the volume of the horizon; the CEC is more than 160 mmol(+)/kg clay, or the content of weatherable minerals in the 0.050 to 0.200 mm fraction is 10% or more; the horizon shows alteration in a) stronger chroma, redder hue, or higher clay content than the underlying horizon, or b) evidence of removal of carbonates, or c) if carbonates are absent in the parent material and in the dust that falls on the soil, the required evidence of alteration is satisfied by the presence of soil structure and the absence of rock structure in more than 50% of the horizon; shows no cementation, induration or brittle consistence when moist.
SP	spodic	A spodic horizon meets one of the following requirements below a depth of 12.5 cm: 1) a subhorizon more than 2.5 cm thick that is continuously cemented by a combination of organic matter with iron or aluminium or with both 2) a sandy or coarse-loamy texture with distinct dark pellets of coarse silt size or larger or with sand grains covered with cracked coatings which consist of organic matter and aluminium with or without iron. 3) one or more subhorizons in which a) if there is 0.1% or more extractable iron, the ratio of iron plus Al extractable by pyrophosphate at pH 10 to clay% is 0.2 or more, or if there is less than 0.1% extractable iron, the ratio of Al plus organic carbon to clay is 0.2 or more; and b) the sum of pyrophosphate-extractable Fe+Al is half or more of the sum of dithionite-citrate extractable Fe+Al; and c) the thickness is such that the index of accumulation of amorphous material in the subhorizons that meet the preceding requirements is 65 or more. This index is calculated by subtracting half the clay% from CEC at pH 8.2 mmol/kg clay and multiplying the remainder by the thickness of the subhorizon in centimeters. The results of all subhorizons are then added.
FA	ferralic	The ferralic horizon has a texture that is sandy loam or finer with at least 8% of clay; is at least 30 cm thick; has a CEC equal to or

		less than 160 mmol/kg clay or has an effective CEC equal to or less than 120 mmol/kg clay (sum of NH_4OAc exchangeable bases plus 1M KCl-exchangeable acidity); has less than 10% weatherable minerals in the 0.050 to 0.200 mm fraction; has less than 10% water-dispersible clay; has a silt-clay ratio which is 0.2 or less; does not have andic properties; has less than 5% by volume showing rock structure.
CA	calcic	A horizon of accumulation of calcium carbonate. The horizon is enriched with secondary calcium carbonate over a thickness of 15 cm or more, has a calcium carbonate content of 15% or more and at least 5% greater than that of a deeper horizon. The latter requirement is expressed by volume if the secondary carbonates in the calcic horizon occur as pendants on pebbles, or as concretions or soft powdery forms. If such a calcic horizon rests on very calcareous materials (40% or more calcium carbonate equivalent), the percentage of carbonates need not decrease with depth.
PC	petrocalcic	A continuous cemented or indurated calcic horizon, cemented by calcium carbonate and in places by calcium and some magnesium carbonate. Accessory silica may be present. The petrocalcic horizon is continuously cemented to the extent that dry fragments do not slake in water and roots cannot enter. It is massive or platy, extremely hard when dry so that it cannot be penetrated by spade or auger, and very firm to extremely firm when moist. Noncapillary pores are filled; hydraulic conductivity is moderately slow to very slow. It is usually thicker than 10 cm.
GY	gypsic	The gypsic horizon is enriched with secondary calcium sulphate ($CaSO_4.2H_2O$), is 10 cm or more thick, has at least 5% more gypsum than the underlying horizon, and the product of the thickness (cm) and the percent of gypsum is 150 or more.
PG	petrogypsic	A gypsic horizon that is so cemented with gypsum that dry fragments do not slake in water and roots cannot enter. The gypsum content usually exceeds 60%.
SU	sulphuric	The sulphuric horizon forms as a result of artificial drainage and oxidation of mineral or organic materials which are rich in sulphides. It is at least 15 cm thick and characterized by a pH-H_2O less than 3.5 and generally has jarosite mottles with a hue of 2.5Y or more and a chroma of 6 or more.
AL	albic	Clay and free iron oxides have been removed, or the oxides have been segragated to the extent that the colour of the horizon is determined by the colour of the primary sand and silt particles rather than by coatings of these particles. An albic horizon has a colour value moist of 4 or more, or a value dry of 5 or more, or both. If the value dry is 7 or more, or the value moist is 6 or more, the chroma is 3 or less. If the value dry is 5 or 6, or the value moist 4 or 5, the chroma is closer to 2 than to 3. If the parent materials have a hue of 5YR or redder, a chroma moist of 3 is permitted in the albic horizon where the chroma is due to the colour of uncoated silt or sand grains.

100 *diagnostic properties*

Diagnostic properties (FAO, 1989).

TC	abrupt textural change	A clay increase between two layers, which takes place over a distance of less than 5 cm, where the lower layer shows a clay content of twice the clay content of the overlying layer if the latter has more than 20% clay, or an increase of 20% or more if the latter has 20% clay or more.
AD	andic properties	Soil materials which meet one or more of the following requirements: 1) acid oxalate extractable Al plus 1/2 acid oxalate extractable Fe is 2.0% or more in the fine earth fraction; bulk density of the fine earth fraction, measured in the field moist state, is 0.9 kg/dm^3 or less; phosphate retention is more than 85%. 2) more than 60% by volume of the whole soil is volcani-clastic material coarser than 2 mm; acid oxalate extractable Al plus 1/2 acid oxalate extractable Fe is 0.40% or more in the fine earth fraction. 3) the 0.02 to 2.0 mm fraction is at least 30% of the fine earth fraction and meets one of the following: a) if the fine earth fraction has acid oxalate extractable Al plus 1/2 acid oxalate extractable Fe of 0.40% or less, there is at least 30% volcanic glass in the 0.02 to 2.0 mm fraction; or b) if the fine earth fraction has acid oxalate extractable Al plus 1/2 acid oxalate extractable Fe of 2.0% or more, there is at least 5% volcanic glass in the 0.02 to 2.0 mm fraction; or c) if the fine earth fraction has acid oxalate extractable Al plus 1/2 acid oxalate extractable Fe of between 0.40 and 2.0%, there is a proportional content of volcanic glass in the 0.02 to 2.0 mm fraction between 30 and 5%.
CO	calcareous	Soil material which shows strong effervescence with 10% HCl in most of the fine earth or which contains more than 2% calcium carbonate equivalent.
CA	calcaric	Soils which are calcareous throughout the depth between 20 and 50 cm.
RO	continuous hard rock	The underlying material is sufficiently coherent and hard when moist to make hand digging with a spade impractable. The material is continuous except for a few cracks produced in place without significant displacement of the pieces and horizontally distant to an average of 10 cm or more. The material considered here does not include subsurface horizons such as a duripan, a petrocalcic or a petrogypsic horizon or a petroferric phase.
FA	ferralic properties	The term 'ferralic properties' is used in connection with Cambisols and Arenosols which have a CEC of less than 240 mmol(+)/kg clay or less than 40 mmol(+)/kg soil in at least one subhorizon of the cambic horizon or the horizon immediately underlying the A horizon.

FI	ferric properties	Many coarse mottles with hues redder than 7.5YR or chromas more than 5 or both; discrete nodules, up to 2 cm in diameter, the exteriors of the nodules being enriched and weakly cemented or indurated with Fe and having redder hues or stronger chromas than the interiors (Luvisols, Alisols, Lixisols and Acrisols).
FL	fluvic properties	Fluviatile, marine and lacustrine sediments, which receive fresh materials at regular intervals, and which, unless empoldered, have one or both of the following properties: 1) an organic carbon content that decreases irregularly with depth or that remains above 0.20% to a depth of 125 cm. Thin strata of sand may have less organic carbon if the finer sediments below, exclusive of buried horizons, meet the requirement; 2) stratification in at least 25% of the soil within 125 cm of the surface.
GE	geric properties	Soil materials which have either: 1) 15 mmol(+)/kg or less of exchangeable bases (Ca, Mg, K, Na) plus unbuffered 1M KCl extractable Al and a pH (1M KCl) of 5.0 or more; or 2) a delta pH (pH KCl minus pH H_2O) of +0.1 or more.
GL	gleyic and stagnic properties	Soil materials which are saturated with water at some period of the year, or throughout the year, in most years, and which show evidence of reduction processes or of reduction and segregation of iron (see FAO/UNESCO Soil Map of the World).
GY	gypsiferous	Soil material which contains 5% or more gypsum.
IN	interfingering	Penetrations of an albic horizon into an underlying argic or natric horizon along ped faces, primarily vertical faces. The penetrations are not wide enough to constitute tonguing, but form continuous skeletans (ped coatings of clean silt or sand, more than 1 mm thick on the vertical ped faces).
NI	nitic properties	Soil material that has 30% or more clay, has a moderately strong angular blocky structure which falls easily apart into flat edged ('polyhedric' or 'nutty') elements which show shiny ped faces that are either thin clay coatings or pressure faces. This soil structure is apparently associated with the presence of significant amounts of active iron oxides and is indicative of a high effective moisture storage and favourable phosphate sorption - desorption properties.
OR	organic soil materials	Organic soil materials are: 1) saturated with water for long periods or are artificially drained and, excluding live roots, a) have 18% or more organic carbon if the mineral fraction is 60% or more clay, b) have 12% or more organic carbon if the mineral fraction has no clay, or c) have a proportional content of organic carbon between 12 and 18% if the clay content of the mineral fraction is less than 60%; or 2) never saturated with water for more than a few days and have 20% or more organic carbon.
PE	permafrost	Permafrost is a layer in which the temperature is perennially at or below 0°C.
PL	plinthite	Plinthite is an iron-rich, humus-poor mixture of clay with quartz and other diluents. It commonly occurs as red mottles, usually in

		platy, polygonal or reticulate patterns, and changes irreversibly to a hardpan or to irregular aggregates on exposure to repeated wetting and drying. In a moist soil, plinthite is usually firm but it can be cut with a spade. When irreversibly hardened the mnaterial is no longer considered plinthite. Such hardened material is shown as a petroferric or a skeletic phase.
SA	salic properties	The electric conductivity of the saturation extract is more than 15 dS/m within 30 cm of the surface, or more than 4 dS/m within 30 cm of the surface if the pH-H_2O exceeds 8.5.
SI	slickensides	Slickensides are polished and grooved surfaces that are produced by one mass sliding past another. Some of them occur at the base of a lsip surface where a mass of soil moves downward on a relatively steep slope. Slickensides are very common in swelling clays in which there are marked seasonal changes in moisture content.
SM	smeary consistence	Thixotropic soil material; it changes under pressure or by rubbing from a plastic solid into a liquefied stage and back to the solid condition. In the liquefied stage the material skids or smears between the fingers (Andosols).
SO	sodic properties	The exchangeable sodium percentage is 15% or more, or exchangeable sodium plus magnesium is 50% or more.
SL	soft powdery lime	Translocated authigenic lime, soft enough to be cut readily with finger nail, precipitated in place from the soil solution rather than inherited from a soil parent material. It should be present in a significant accumulation (coatings on pores or structural faces).
HU	strongly humic	Soil material with an organic carbon content of more than 14 g/kg fine earth as a weighted average over a depth of 100 cm from the surface. This calculation assumes a bulk density of 1.5 kg/dm^3.
SU	sulphidic materials	Sulphidic materials are waterlogged mineral or organic soil materials containing 0.75% or more sulphur (dry weight), mostly in the form of sulphides, having less than three times as much calcium carbonate equivalent as sulphur, and having a pH above 3.5. Sulphidic materials accumulate in a soil that is permanently saturated and having a pH above 3.5, generally with brackish water. If the soil is drained the sulphides oxidize to form sulphuric acid. The pH, which is normally near neutrality before drainage, drops below 3.5. At this point these materials become a sulphuric horizon. Sulphidic material differs from the sulphuric horizon in its reduced condition, its pH and the absence of jarosite mottles with a hue of 2.5Y or more or a chroma of 6 or more.

TO	tonguing	An albic horizon penetrates an argic horizon along ped surfaces, if peds are present. Tongues must have greater depth than width, have horizontal dimensions of 5 mm or more in fine textured argic horizons (clay, silty clay and sandy clay), 10 mm or more in moderately fine textured argic horizons, and 15 mm or more in medium or coarser textured argic horizons (silt loams, loams and sandy loams), and must occupy more than 15% of the mas of the upper part of the argic horizon.
VE	vertic properties	In connection with clayey soils which at some period in most years show one or more of the following: cracks, slickensides, wedge-shaped or parallelepiped structural aggregates, that are not in a combination, or are not sufficiently expressed, for the soils to qualify as Vertisols.
WM	weatherable minerals	Minerals included are those that are unstable in a humid climate relative to other minerals, such as quartz and 1:1 lattice clays, and that, when weathering occurs, liberate plant nutrients and iron or aluminium. They include: 1) clay minerals: all 2:1 lattice clays except aluminium-interlayered chlorite. Sepiolite, talc and glauconite are also included in the meaning of this group of weatherable clay minerals, although they are not always of clay size. 2) silt- and sand-size minerals: feldspars, feldspathoids, ferromagnesian minerals, glasses, micas, and zeolites.

PART II LAND USE AND VEGETATION

6 Land cover

In SOTER, land cover characteristics (vegetation and land use) are stored in two files that are separate from the soil and terrain properties. In contrast with the more stable attributes of the land which are covered in Part I of this manual, land cover is considered a more dynamic entity which can change quickly in time. Therefore there may be a frequent need for addition of more recent data. Moreover, third parties are working on global databases for land use (FAO) and for vegetation, or are planning to do so. At present, such databases are not available and therefore the need exists for incorporation of these data into SOTER.

For interpretative uses of the SOTER database there is a need for land cover data. A provisional system for such data is implemented for the SOTER database. In it, the land cover information is given at the level of the SOTER unit. By doing so, the effort of digitizing separate land cover boundaries is avoided and a simple link is possible between the soil and terrain data and the land cover.

6.1 Land use

The land use file contains only four attributes, of which the first two, viz. SOTER unit ID and date of observation, are the key attributes.

1 *SOTER unit_id*

Identification code of a SOTER unit (see 5.1 Terrain)

2 *date of observation*

Date of observation for the land use; stored in format YYMMDD

3 *land use*

Land use classes are defined in a hierarchical system (Remmelzwaal, 1990). At the highest level, classes are subdivided into subclasses and groupes on the basis of the type of land use, and the occurrence of input and/or output (animal products, crops). The codes for land use codes are given in the table 4, descriptions in annex 2.

4 *proportion of SU*

Proportion that the land use occupies within the SU, in %.

Table 4 Hierarchy of land use; land use orders, groups, and systems.

S	SETTLEMENT/INDUSTRIES	SR	residential use		
		SI	industrial use		
		ST	transport		
		SC	recreational		
		SX	excavations		
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	non-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
U	UNUSED				

6.2 Vegetation

The vegetation file contains four attributes, of which the first two, viz. SOTER unit ID and date of observation, are the key attributes.

1 *SOTER unit_id*

Identification code of a SOTER unit (see 5.1 Terrain)

2 *date of observation*

Date of observation for the native vegetation; stored in format YYMMDD.

3 *vegetation*

Generalized description of the physiognomy of the present native vegetation (Unesco, 1973). Table 5 gives the hierarchical classification of the vegetation to apply at the SOTER unit level. A full description of the classes is given in annex 3. Vegetation should be specified at least on the formation subclass level.

4 *proportion of SU*

Proportion that the vegetation occupies within the SU, in %.

Table 5 Hierarchical vegetation classes.

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	subdivisions as extremely xeromorphic forest (IC)	
III	scrub	**IIIA**	mainly evergreen scrub	**IIIA1**	evergreen broad-leaved shrubland (or thicket)
				IIIA2	evergreen needle-leaved and microphyllous shrubland
..		**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	mixzed 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	subdivisions as extremely xeromorphic (subdesert) shrubland (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%
				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-	VE1	rooted fresh-water

water vegetation		communities
	VE2	free-floating fresh-water communities

PART III MISCELLANEOUS FILES

7 Reference files

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

Table 6 Related tables.

MAP INFORMATION	LABORATORY	SOIL PROFILE DATABASE
1 map ID	**1 lab ID**	**1 soil profile database ID**
2 map title	2 laboratory name	2 name of institute
3 year		
4 scale	LABMETHODS	
5 minimum latitude		
6 minimum longitude	**3 lab ID**	
7 maximum latitude	4 date	
8 maximum longitude	5 characteristic	
9 type of map	6 method of analysis	
	METHODS	
	7 method of analysis	
	8 description	

7.1 Map information

In this file information on type of map, scale, location and date are stored. As the location in max and min X and Y-coordinates is recorded, the GIS can be used to overlay this information on the SOTER map. There exists a direct link (primary key 'map_id') between the terrain table and the map-info table. The attributes are shown in table 6.

1 *map_id*

The map number code from which the data were derived for the compilation of the SOTER units. See also map_id in chapter 1.1 Terrain.

2 *map title*

The citation of the map title.

3 *year*

The year of publication of the map.

4 *scale*

The 1:scale of the map.

5 *minimum latitude*

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

6 *minimum longitude*

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

7 *maximum latitude*

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

8 *maximum longitude*

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

9 *type of map*

The type of map:

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

7.2 Laboratory information

For every analysis method that has been applied in a particular laboratory separate entries in these tables should be made.

Laboratory

1 *lab_id*

Identification code for the laboratory that analyzed the reference soil profile. A country code with a sequential number is given. See list of country codes in annex 4.

2 *laboratory name*

Name of the laboratory, in full.

Labmethods

3 *lab_id*

Laboratory code (see attribute 1, lab_id).

4 *date*

Date at which the laboratory introduced a method for a given attribute. Format is YYMMDD.

5 *attribute*

Profile layer attribute that was analyzed. Same codes as in chapter 4.6 Layer data.

6 *method of analysis*

Code for the analysis method applied. Methods are described in a summary way, without going into detail on precise procedures.

Methods

7 *method of analysis*

Method code (see attribute 6).

8 *description*

A complete description of the method used.

7.3 Soil profile database

Information on the (national) soil profile database that has been consulted for the selection of the SOTER profile data can be found as an additional file. A code for the country (ISO code from annex 4) followed by a sequence number is given. Also the name of the organisation can be indicated.

1 *soil profile database_id*

The identification code for the owner, institute or organisation that holds (part of) the national soil profile database. The code consists of an ISO code for the country (see annex 4) and a sequence number.

2 *name*

Name (in full) of the owner, institute or organisation of the national soil profile database.

8 Climate

8.1 Introduction

Climatic data forms an inseparable part of the basic inventory of natural resources. Nevertheless, climate is treated separately from the SOTER database as the climate data are not directly linked to the SOTER units. Climate data are based on point observations only and the link with the soils and terrain information exists by means of the geographical location of these points. The SOTER climate files are intended for multiple applications of the soils and terrain database. Monthly data are considered sufficient for most of the (small scale) applications.

At the Workshop on Procedures Manual Revisions (ISRIC, 1990b), it was recommended that the attribute data for the climate database of SOTER should be derived, if possible, from existing computerized databases, e.g. WMO (CLICOM), FAO and CIAT. Data from these databases can be imported through an ASCII file interface. Care should be taken on the dimensions.

Data from point observations are extracted from meteorological data sets and consist of two major groupings: 1) climate station particulars, and 2) monthly climate data.

The files shown in table 7 are used to store the station particulars and the monthly and decade climatic data. Key fields in the station table are station code, in the monthly data table station code, kind of data first year and last year.

Table 7 Attribute list for climate station and climate data files.

STATION	CLIMATE DATA
1 station code	**6 station code**
2 station name	**7 kind of data**
3 latitude	8 source ID
4 longitude	9 first year
5 altitude	10 last year
	11 years of record
	12 jan
	..
	23 dec
	24 annual

8.2 Climate station

1 *station code*

The station code is given as a two-character ISO country code (according to annex 4) followed by a four digit sequential number.

2 *station name*

The name of the climate station is given. Up to 80 characters are permitted.

3 *latitude*

The latitude is stored in decimal degrees north; latitudes in the southern hemisphere are negative.

4 *longitude*

The longitude is stored in decimal degrees east; longitudes in the western hemisphere are negative.

5 *altitude*

The altitude above or below (negative) sea level, m.

8.3 Climate data

6 *station code*

Code for the climate station. See station code under Climate station.

7 *kind of data*

The various kinds of climatic data are treated in paragraph 8.4.

8 *source_id*

Code for the main source of the data for each separate kind of data. Codes are to be explained in a separate file.

9 *first year*

The first year of the observation period.

10 *last year*

The last year of the observation period.

11 *years*

The number of years of record in the observation period

12..23 *jan..dec*

The data values for each individual month. Average monthly value for the numbers of years recorded.

24 *annual*

The annual value (average or total).

8.4 Various climate characteristics

In this section various climate characteristics (attribute 8: 'kind of data') are arranged in several groups. The importance of the kind of data attribute is indicated by a letter (M = mandatory, D = desirable and O = optional). When a mandatory characteristic is missing, the station should not be included in the database.

rainfall

Data on rainfall is recorded in mm's. The amount of rainfall is a mandatory attribute; if it is missing, it is considered of no use to include the climate station in the database.

RAIN	M	precipitation total, mm
RDAY	D	number of rainy days; days with at least 1 mm of precipitation
RMAX	O	maximum 24-hour rainfall, mm
RR75	O	rainfall reliability; the amount of rainfall exceeded in 3 out of 4 years, mm

temperature

Temperature is stored in degrees centigrade (°C). Both minimum and maximum temperature are mandatory. The average temperature is optional because it can be derived from the minimum and maximum temperatures.

TEMP	O	mean temperature during 24-hour period
TMIN	M	minimum temperature during a 24 hour period
TMAX	M	maximum temperature during a 24 hour period

radiation/sunshine

Either radiation or sunshine hours is mandatory; the other is then optional. Radiation data is preferred.

RADI	M/O	total radiation, $MJ.m^{-2}.day^{-1}$
SUNH	O/M	hours of bright sunshine per day
CLOU	O	degree of cloudiness, octas

humidity

Either vapour pressure or relative humidity is mandatory. Vapour pressure is preferred above relative humidity.

VAPP	M/O	vapour pressure, mbar
HUMI	O/M	average relative humidity during 24 hour period, %
HMIN	O	minimum relative humidity during 24 hour period, %
HMAX	O	maximum relative humidity during 24 hour period, %

wind

Wind velocity in m/s.

WIND	D	mean wind velocity at 2 m during 24 hour period
WDAY	O	wind speed during day at 2m during 24 hour period
WNIG	O	wind speed during night at 2m during 24 hour period
WDIR	O	dominant wind direction at 2m during 24 hour period

risk or occurrence of adverse weather events

WRIS	O	risk or occurrence of adverse weather events like severe hailstorms, hurricanes and nightfrost. Indicated on a scale of 0 (never) to 1 (every year in the month under consideration). Intermediate values are used if the frequency is less than every year (for that month). E.g.: One occurrence every 5 years in the month of March = 0.2

evaporation

EPAN	O	class A pan evaporation, mm
ECOL	O	Colorado pan evaporation, mm
EPIC	O	evaporation, Piche, mm

evapotranspiration

Because evapotranspiration is a calculated characteristic, it is optional.

PETP	O	Penman potential evapotranspiration, mm
PETH	O	Hargreaves potential evapotranspiration, mm
PETT	O	Thornthwaite potential evapotranspiration, mm

8.5 Additional conventions

Data can be given for different categories of climate characteristics:

For Penman calculations, mandatory data are minimum and maximum temperature, irradiation, vapour pressure or relative humidity, wind speed, monthly rainfall, and number of rainy days.

When data are missing, some parameters can be estimated from others:
- relative humidity and vapour pressure can be estimated from each other
- radiation, sunshine hours, and cloudiness degree
- minimum and maximum temperature determine average temperature

STAT.	SR	DATA	F-YR	L-YR	YRS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
AR21	06	RAIN	1901	1980	80	141	148	139	146	131	127	97	99	143	189	134	149	1643
AR21	07	RDAY	1951	1980	30	9.6	9.3	9.3	8.3	8.3	9.6	9.3	9.3	11.0	10.6	7.6	8.6	110.8
AR21	01	TEMP	1951	1980	30	26.2	25.8	24.3	20.7	18.1	16.5	15.6	17.3	18.8	20.9	23.3	25.7	21.1
AR21	01	TMIN	1951	1980	30	19.7	19.4	18.2	14.8	12.5	11.5	10.0	11.0	12.8	14.7	16.5	18.8	15.0
AR21	01	TMAX	1951	1980	30	32.7	32.2	30.4	26.6	23.6	21.5	21.2	23.6	24.8	27.1	30.1	32.6	27.2
AR21	01	VAPP	1951	1980	30	24.2	24.5	32.0	19.3	17.5	15.9	14.2	14.7	16.5	18.5	19.7	21.8	19.2
AR21	01	WIND	1951	1980	30	1.5	1.7	1.5	1.5	1.7	1.7	2.0	2.0	2.0	2.0	1.7	1.7	1.8
AR21	01	PETP	1951	1980	30	149	125	105	69	45	32	41	63	74	107	138	161	1109

Figure 13 Example of various kinds of climatic data recorded for a climate station (Posedas, Argentina).

8.6 Related file

One related file to the climate database exists: the 'file of sources'. It contains one key field namely the source_id of the climate data file and one attribute: the full name of the source (published report, or name and address of the meteorological organisation holding the complete climate dataset).

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GLOSSARY OF TERMS

attribute data	Non-graphic information on elements in a GIS. In this manual: associated with SOTER units.
database	A computerized recordkeeping system.
database structure	The way in which data are organized in a database.
backup	A copy of a file or of a whole disk in case the original is lost/ damaged.
DBMS	Database Management System; a system for management and manipulation a database.
geo-referenced data	Information that has a precise location (coordinates).
GIS	Geographic(al) Information System = a system of hardware, software and procedures designated to support the capture, management, manipulation, analysis, modelling and display of spatially referenced data.
input	The process of entering data.
mapping unit	a set of areas (polygons) on a map that represent a well-defined feature or set of features; mapping units are described by the map legend.
polygon	delineated area on a map
primary key	attribute or combination of attributes that uniquely identify a record in a table/file.
RDBMS	Relational Database Management System; a computerized recordkeeping system in which the data are structured in sets of records so that relationships between data can be used for the management and manipulation. The data files are perceived as tables.
SOTER unit (SU)	special type of mapping unit; a set of areas (polygons) on a map that have a distinctive, often repetitive pattern of landform, surface form, parent material and soil.
topology	The way in which geographic elements are linked together (neighbouring elements, enclosed elements).

ANNEX 1. Hierarchy of lithology.

Adapted from Holmes (1968) and Strahler (1969).

I igneous rocks

Formed by solidification from a molten or partially molten state; major varieties include intrusive (plutonic) and extrusive (volcanic) rocks.

IA acid igneous rocks

Any igneous rock predominantly consisting of light-coloured materials, having low specific gravity and having more than 65% silica.

IA1 granite

Coarse-grained intrusive rock, composed essentially of a mixture of quartz, potassium feldspar, and mica.

IA2 grano-diorite

IA3 quartz-diorite

IA4 rhyolite

The lava (extrusive) that is similar in composition to granite.

II intermediate igneous rocks

II1 andesite, trachyte, phonolyte

Light-gray or pink on freshly broken surfaces. Andesite is extrusive.

II2 diorite-syenite

Intrusive rocks.

IB basic igneous rocks

Any igneous rock having a relatively low silica content, sometimes delimited arbitrarily as less than 54%. They are relatively rich in Fe-Mg minerals such as pyroxenes (augite), hornblend.

IB1 gabbro

IB2 basalt

Extrusive, dense black rock.

IB3 dolerite

IU ultrabasic igneous

Igneous rock, very rich in Fe-Mg minerals.

IU1 peridotite

IU2 pyroxenite

IU3 ilmenite, magnetite, ironstone, serpentine

M metamorphic rocks

Rock of any origin altered in mineralogical and/or chemical composition, or structure by heat, pressure and movement at depth in the earth's crust. Nearly all metamorphic rocks are crystalline.
Subdivided on mineralogy (acid, basic).

MA acid metamorph

Metamorphic rocks from acid environment.

MA1 quartzite

MA2 gneiss, migmatite

MB basic metamorph

Metamorphic rocks from basic environment.

MB1 slate, phyllite

MB2 schist

MB3 gneiss rich in ferro-magnesian minerals (E.g. hornblende gneiss)

MB4 metamorphic limestone (marble)

S Sedimentary rocks

A consolidated deposit of clastic particles, chemical precipitates and organic remains, accumulated at or near the surface of the earth under relatively low temperature and pressure conditions.

SC Clastic sediments

Rock derived from clastic sediments.

SC1 Conglomerate, breccia

SC2 Sandstone, greywacke, arkose

Sedimentary rock consisting of consolidated sands, grits, graywackes, and conglomerate.

SC3 Siltstone, mudstone, claystone

SC4 Shale

Sedimentary rock consisting of shales (clays/silts with fine stratification).

SO Organic sedimentary rock

SO1 Limestone and other carbonate rocks

Sedimentary rock consisting of limestone, coral reef limestones or travertines.

SO2 Marl and other mixtures

An earthy, unconsolidated deposit consisting chiefly of calcium carbonate mixed with clay in approximately equal proportions.

SO3 coals, bitumen and related rocks

SE Evaporites

Chemical sediments.

SE1 Anhydrite, gypsum

Calcium sulphate (anhydrite) and/or hydrous calcium sulphate (gypsum).

SE2 Halite

Rock salt, sodium chloride (halite).

U Unconsolidated materials

Unconsolidated mineral or organic deposits.

UF Fluvial

Sediment generally consisting of gravel and sand or silt and clay. The gravels are typically rounded and contain interstitial sand. Fluvial sediments are commonly moderately to well sorted and display stratification. Examples: channel deposits, overbank deposits, terraces, alluvial fans, deltas, and backswamps.

UC Colluvial

Massive to moderately well stratified, non-sorted to poorly sorted sediments with any range of particle sizes from clay to boulders that have reached their present position only by direct, gravity-induced movement (excepting snow-avalanches). Processes include slow displacements such as creep and solifluction and rapid movements such as earth flows, rockslides, avalanches, and falls.

UE Eolian

Sediment, generally consisting of medium to fine sand and coarse silt particle sizes, that is well sorted, poorly compacted, and may show internal structures such as cross bedding or ripple laminae, or may be massive. Individual grains may be rounded and show signs of frosting. These materials have been transported by wind action. Examples: dunes, shallow deposits of sand and coarse silt, and loess but not tuffs.

UG Glacial

(Morainal) sediment generally consisting of well-compacted material that is nonstratified and contains a heterogenous mixture of sand, silt and clay particles sizes in a mixture that has been transported beneath, beside, on, within, or in front of a glacier and not modified by any intermediate agent. Examples: basal till (ground moraine), lateral and terminal moraines, rubbly moraines of cirque glaciers, hummocky ice-desintegration moraines, and pre-existing, unconsolidated sediments reworked by a glacier so that their original character is largely or completely destroyed.
(Fluvioglacial) material moved by glaciers and subsequently sorted and deposited by streams flowing from the melting ice. The deposits are stratified and may occur in the form of outwash plains, deltas, kames, eskers, and kame terraces.

UL Lacustrine

Sediment generally consisting of either stratified fine sand, silt and clay deposited on the lake bed or moderately well sorted stratified sand and coarser materials that are beach and other nearshore sediments transported and deposited by wave action. These materials that either have settled from suspension in bodies of standing fresh water or have accumulated at their margins through wave action. Examples are lake sediments and beaches.

UM Marine

Unconsolidated deposits of clay, silt, sand, or gravel that are well to moderately well sorted and well to moderately well stratified (in some places containing shells). They have settled from suspension in salt or brackish water bodies or have accumulated at their margins through shoreline processes such as wave action and longshore drift. Non-fossiliferous deposits may be judged marine, if they are located in an area that might reasonably be considered to have contained salt water at the time the deposits were formed.

UP Pyroclastic

Deposits, produced by usually explosive, aerial ejection of clastic particles from a volcanic vent either on land or under water.

UO Organic

Organic materials known as peat, muck, bog or swamp, that are commonly saturated with water for prolonged periods. They contain 17% or more organic C by weight.

ANNEX 2. Hierarchy of land use.

Adapted from Remmelzwaal (1990).

S Settlement/industries

Rural, industrial use.

SR Residential use

Cities.

SI Industrial use

Industries.

ST Transport

Roads, railways etc.

SC Recreation

In use for recreation.

SX Excavations

Land is used for excavations, quarries.

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 periods and fallow periods. The land is cultivated between 33 and 67% of the growing seasons; bush or grass fallows 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 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 & 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 savanna 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 practised. 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.

U Unused

Not used and not managed.

ANNEX 3. Hierarchy of vegetation.

After 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 or drought resistant. Truly evergreen, i.e. the forest canopy remains green all year though a few individual tree 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.

IA3 Tropical and subtropical semi-deciduous forest

Most of the upper canopy trees drought-deciduous; many of the understorey trees and shrubs evergreen and more or less sclerophyllous[1].

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 stilts roots or pneumatophores.

IA6 Temperate and subpolar evergreen ombrophilous forest

Consisting mostly of truly evergreen hemi-sclerophyllous trees and shrubs. Rich in epiphytes and herbaceous ferns.

---

[1] Sclerophyllous: thick, hard leaves

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.

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 or thicket)

Mainly composed of woody plants 0.5 to 5 m tall. Subdivisions:
- Shrubland: most of the individual shrubs not touching each other; often grass under-growth
- 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 unfavourable 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[2] coverage less than 50%.

VA1 Tall grassland with a tree synusia[3] 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

---

[2] Forb: non-graminoid/non-woody vegetation

[3] Synusia: layer

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

The dominant graminoid growth forms are 50 cm to 2 m tall. Forbs cover less than 50%.

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

ANNEX 4. ISO country codes.

Afghanistan	AF
Albania	AL
Algeria	DZ
American Samoa	AS
Andorra	AD
Angola	AO
Anguilla	AI
Antarctica	AQ
Antigua and Barbuda	AG
Argentina	AR
Aruba	AW
Australia	AU
Austria	AT
Bahamas	BS
Bahrain	BH
Bangladesh	BD
Barbados	BB
Belgium	BE
Belize	BZ
Benin	BJ
Bermuda	BM
Bhutan	BT
Bolivia	BO
Botswana	BW
Bouvet Island	BV
Brazil	BR
British Indian Ocean Territories	IO
Brunei Darussalam	BN
Bulgaria	BG
Burkina Faso	BF
Burma	BU
Burundi	BI
Byelorussian SSR	BY
Cameroon	CM
Canada	CA
Cape Verde	CV
Cayman Islands	KY
Central African Republic	CF
Chad	TD
Chile	CL
China	CN
Christmas Island	CX
Cocos Islands	CC
Colombia	CO
Congo	CG
Cook Islands	CK
Costa Rica	CR
Cuba	CU
Cyprus	CY
Czechoslovakia	CS
Côte d'Ivoire	CI
Denmark	DK
Djibouti	DJ
Dominica	DM
Dominican Republic	DO
East Timor	TP
Ecuador	EC
Egypt	EG
El Salvador	SV
Equatorial Guinea	GQ
Ethiopia	ET
Falkland Islands	FK
Faroe Islands	FO
Fiji	FJ
Finland	FI
France	FR
French Guiana	GF
French Polynesia	PF
French Southern Territories	TF
Gabon	GA
Gambia	GM
Germany, Democratic Republic	DD
Germany, Federal Republic of	DE
Ghana	GH
Gibraltar	GI
Greece	GR
Greenland	GL
Grenada	GD
Guadeloupe	GP
Guam	GU
Guatemala	GT
Guinea	GN
Guinea-Bissau	GW
Guyana	GY
Haiti	HT
Heard + McDonald Island	HM
Honduras	HN
Hong Kong	HK
Hungary	HU
Iceland	IS
India	IN
Indonesia	ID
Iran, Islamic Republic of	IR
Iraq	IQ
Ireland	IE
Israel	IL
Italy	IT
Jamaica	JM
Japan	JP
Jordan	JO
Kampuchea, Democratic	KH
Kenya	KE
Kiribati	KI
Korea, Democratic Peoples Republic	KP
Korea, Republic of	KR
Kuwait	KW
Lao, Peoples Democratic Republic	LA
Lebanon	LB
Lesotho	LS
Liberia	LR
Libyan Arab Jamahiri	LY
Liechtenstein	LI
Luxembourg	LU
Macau	MO
Madagascar	MG
Malawi	MW
Malaysia	MY
Maldives	MV
Mali	ML
Malta	MT
Marshall Islands	MH
Martinique	MQ
Mauritania	MR
Mauritius	MU
Mexico	MX
Micronesia	FM
Monaco	MC
Mongolia	MN
Montserrat	MS
Morocco	MA
Mozambique	MZ
Namibia	NA
Nauru	NR
Nepal	NP
Netherlands	NL
Netherlands Antilles	AN
Neutral Zone	NT
New Caledonia	NC
New Zealand	NZ
Nigaragua	NI
Niger	NE
Nigeria	NG
Niue	NU
Norfolk Island	NF
North.Mariana Island	MP
Norway	NO
Oman	OM
Pakistan	PK
Palau	PW
Panama	PA
Papua New Guinea	PG
Paraguay	PY
Peru	PE
Philippines	PH
Pitcairn	PN
Poland	PL
Portugal	PT
Puerto Rico	PR
Qatar	QA
Reunion	RE
Romania	RO
Rwanda	RW
Saint Lucia	LC
Samoa	WS
San Marino	SM
Sao Tome + Principe	ST
Saudi Arabia	SA
Senegal	SN
Seychelles	SC
Sierra Leone	SL
Singapore	SG
Solomon Islands	SB
Somalia	SO
South Africa	ZA
Spain	ES
Sri Lanka	LK
St. Helena	SH
St. Kitts and Nevis	KN
St. Pierre + Miquelon	PM
St. Vincent + Grenadine	VC
Sudan	SD
Suriname	SR
Svalbard + Jan Mayen	SJ
Swaziland	SZ
Sweden	SE
Switzerland	CH
Syrian Arab Republic	SY
Taiwan,Province Chin	TW
Tanzania, United Republic of	TZ
Thailand	TH
Togo	TG
Tokelau	TK
Tonga	TO
Trinidad and Tobago	TT
Tunisia	TN
Turkey	TR
Turks + Caicos Islands	TC
Tuvalu	TV
US Minor Outl. Island	UM
USSR	SU
Uganda	UG
Ukrainian SSR	UA
United Arab Emirates	AE
United Kingdom	GB
United States	US
Uruguay	UY
Vanuatu	VU
Vatican City State	VA
Venezuela	VE
Viet Nam	VN
Virgin Islands UK	VG
Virgin Islands US	VI
Wallis + Futuna Island	WF
Western Sahara	EH
Yemen	YE
Yemen, Democratic Republic	YD
Yugoslavia	YU
Zaire	ZR
Zambia	ZM
Zimbabwe	ZW

ANNEX 5. SOTER data entry forms

SOTER data entry screen forms, version 4.0, May 1991.

Profile ID: ______
Date of sampl.: ______

Laboratory: ______
Soil Profile DB: ______

Point location:
latitude ______
longitude ______

Soil development: ______
Material below: ______
Litter layer:
thickness ______
decomposition ______

Capping: ______
Infiltration: ______
Int. drainage: ______

Figure 14 Profile form.

Profile ID: ______
Layer number: ______

Lower boundary:
depth ______
abruptness ______

Colour:
moist ________
dry ________

Structure:
form ______
size ______
grade ______

Texture class: ______

Clay mineralogy: ______

Diagnostics:
horizon ______
property ______

Figure 15 Layer form; descriptive characteristics.

Profile ID: ______
Layer number: ______

Carbon content: ______ _

Nitrogen cont.: ______ _

pH:
H2O ______ _
KCl ______ _

Soil exchange capacity:
CEC ______ _
Effective CEC ______ _
AEC ______ _

Exchangeable cations:
Ca ______ _
Mg ______ _
K ______ _
Na ______ _
Al ______ _

ECe: ______ _

Contents of (mg/g):
CaCO3 ______ _
gypsum ______ _

Phosphorus:
total ______ _

Dithionite extractable:
Al ______ _
Fe ______ _

Oxalate extractable:
Al ______ _
Fe ______ _

Figure 16 Layer form; chemical characteristics.

```
Profile ID:      _______
Layer number:    _______

Particle distribution:          Coarse fragments:           Bulk density:  _______
  sand, total     _______         volume        _______
  , very coarse   _______         size          _______
  , coarse        _______
  , medium        _______       Soil moisture content:      Hydraulic conductivity:
  , fine          _______             pF     vol%                  pF     k
  , very fine     _______         _______  _______ ↑          _______  _______ ↑
  silt            _______         _______  _______            _______  _______
  clay            _______         _______  _______            _______  _______
  natural clay    _______         _______  _______ ↓          _______  _______ ↓
```

Figure 17 Layer form; physical characteristics.

```
SOTER unit ID:  _______  | Landform:          _______   Incisions:
Date of comp.:  _______  |                                depth        _______
                         | Lithology:         _______     slope%       _______
Map ID:         _______  |                                coverage     _______
                         | Relief:
                         |   minimum alt.     _______   Water surface: _______
                         |   maximum alt.     _______
                         |   intensity        _______
```

Figure 18 Terrain form.

```
Terrain Components        | Terrain Component Data
                          |
SOTER ID    TcNo   Prop   | Parent material:              Surface:
_________   _____  ____ ↑ |   type            _______       rockiness     _______
_________   _____  ____   |   texture group   _______       stoniness     _______
_________   _____  ____   |   depth to rock   _______       drainage      _______
_________   _____  ____   |
_________   _____  ____   | Landform:                     Flooding periods:
_________   _____  ____   |   slope gradient  _______       frequency     _______
_________   _____  ____   |   slope length    _______       start         _______
_________   _____  ____   |   meso-relief     _______       duration      _______
_________   _____  ____   |   micro-relief    _______
_________   _____  ____   |
_________   _____  ____   | Groundwater:
_________   _____  ____   |   high            _______
_________   _____  ____ ↓ |   low             _______
```

Figure 19 Terrain components and data form.

SOTER unit ID: ______ Terrain comp.: ______ Soil number: ______	Proportion: ______ Position: ______ Rootable depth: ______	. Reference profile(s): total number ______ profile ID ______ ‡ ______ ↑ ______ ______ ______ ______ ↓

Figure 20 Soil form.