**AGLS Working Paper Nr. 8**

# SOTER DATABASE

# TANZANIA

by

J.A. Eschweiler

**Food and Agriculture Organization of the United Nations**

**1998**

## TABLE OF CONTENTS

## ACKNOWLEDGEMENTS

The author wishes to thank the following persons/institutions for their assistance in carrying out the assignment:

- National Soil Service - Tanzania (Mlingano);
  Clarification on laboratory methods used, conversion of UTM to GRID references and additional information with regard to the distribution of Luvisols, Lixisols, Acrisols and Alisols in Tanzania.
- TANRIC (Tanzania Resource Information Center of the University of Dar es Salam)
  Making available digital version of the Soils and Physiography map of Tanzania.
- Mr. V. van Engelen and K. Dijkshoorn (ISRIC, Wageningen);
  General assistance and advise with regards to the compilation of a SOTER database and for providing relevant SOTER data from Kenya (Tanzania-Kenya cross-border correlation).
- Mr. E. de Pauw (ICARDA, Aleppo);
  Making available a listing and distribution of soil classification units according to the old (FAO, 1974) and revised FAO soil classification system (FAO, 1990) by land and soil units (as indicated in the legend of the Soils and Physiography Map of Tanzania - de Pauw, 1984).
- Mr. A. van Kekem (SC-DLO, Wageningen);
  Making available a coloured version of the Soils and Physiography Map of Tanzania (de Pauw, 1983) and a recompiled/regrouped legend.

# 1. INTRODUCTION

FAO (AGLS) has embarked on the preparation of a Soil and TERrain (SOTER) database for Tanzania as part of an ongoing activity to compile Land and Water Digital Media Series which will include a Soil and Terrain Database for Southern Africa. The attributes and procedures for the compilation of such a database have been described by van Engelen and Wen (1995).

To this effect, towards the end of 1997 a Letter of Agreement was signed between the FAO and the National Soil Service (NSS) of Tanzania for the provision of a computerised Soil Database of Tanzania (using SDB software; FAO, 1995) incorporating all of the soil units occurring on the Soils and Physiography Map of Tanzania at a scale of 1:2 million, compiled by de Pauw (1984). The soil classification units were to be reclassified according to the new FAO/UNESCO Soil Classification System of 1990 (originally the FAO/UNESCO Soil Classification System of 1974 was used).

The information became available in June 1998. The Soil Database for Tanzania contains data for 96 representative soils; 57 soils are unique, the remainder being either duplicates or, in a few cases, triplicates. Representative soil profiles were selected by the NSS and for each soil profile a full set of soil descriptive, physical and chemical data was provided in accordance with the FAO Guidelines for Soil Profile Description (FAO, 1990) and entered into a database following the attributes and procedures described in the Multilingual Soil Database (FAO/ISRIC/CSIC, 1995).

The original map (at a scale of 1:2 million) with accompanying extensive legends and report describing the Soils and Physiography of Tanzania (de Pauw, 1984) and the Soil Database provided by the NSS (1998) together with additional information obtained from various sources (see Acknowledgements and List of References) provided the basis for the compilation of the SOTER unit Map of Tanzania and the input data for the database (FAO Authors Contract No. 144127). The map completed with data base entry is annexed to this Working Paper in a digital form.

# 2. METHODOLOGY

## 2.1 SOTER mapping approach

SOTER is a land resources information system comprising two components: terrain and soils. In many respects the SOTER mapping approach resembles physiographic soil mapping, often applied in traditional soil mapping. However, SOTER emphasises the relationships between terrain and soil. The guiding principle is the identification of areas of land with a distinctive and often repetitive pattern of landform, slope, general lithology and soils. Uniform expanses of land distinguished in this manner are called SOTER units. SOTER units can be delineated in various ways depending on the type of source material available.

The procedures followed in this study are conform the guidelines produced by Batjes and van Engelen (1997) for the compilation of a SOTER database at a scale of 1:2.5 million (see Appendix 1). These guidelines have been derived from the more elaborate procedures for the compilation of a Global and National SOTER Database at a typical scale of 1:1 million (van Engelen and Wen, 1995). As a consequence of smaller scale Batjes and van Engelen (1997) reduced the number of attributes to be incorporated in the 1:2.5 million scale database from 118 to a total of 74.

Each SOTER database consists of two elements:

- geometric database (containing information on location, extent and topology of each SOTER unit
- attribute data base (containing tabular information about attributes of the terrain unit, terrain and soil components)

Spatial data (SOTER unit map) is handled within a Geographic Information System, while attribute data (SOTER Database) is handled by a Relational Database Management System.

Main source for the compilation of input data for the SOTER Database of Tanzania has been the map (at a scale of 1:2 million) and report on Soils and Physiography of Tanzania (de Pauw, 1984) and the digital Soil Database of Tanzania (NSS, 1998). The resulting SOTER unit map at a scale of 1:2 million contains 154 mapping units. Unavailability of data for some of the 74 attributes listed by Batjes and van Engelen (1997) and the incorporation of some other attributes thought to be of importance resulted in a total number of 65 attributes incorporated in the SOTER Database for Tanzania (see 2.2, Table 1).

## 2.2 Database structure

The database structure of the SOTER Database for Tanzania is conform the one described by Batjes and van Engelen (1997) except for:

- Individual soil components are described using a maximum of two representative soil profiles rather than only one.
- The list of attributes is 65 (see Table 1) as compared to 74. Due to unavailability of data the following attributes listed in Batjes and van Engelen (1997) were deleted (original attribute numbers by Batjes and van Engelen are presented in brackets):

* <u>Terrain component</u>

- depth to bedrock (13)
- depth to groundwater (16)
- frequency of flooding (17)
- duration of flooding (18)

* Profiles

- infiltration rate (36)
- national classification (39)

* Horizon representative profile

- diagnostic horizon (44)
- diagnostic property (45)
- pH (KCL) (56)
- exchangeable acidity (63)
- gypsum (68)
- bulk density (69)
- moisture content at various tensions (70-74)

while the following ones, all related to the horizon representative profile, were added:

- structure grade
- structure size
- consistence wet
- consistence dry
- consistence moist
- size of coarse fragments
- percentage base saturation
- available phosphorus

SOTER attribute data were inputted using SOTER data management software (1:2.5 million).

The inputs were done for:

- Terrain unit (see sample Form1, Appendix 2)
- Terrain component (see sample Form1, Appendix 2)
- Soil component (see sample Form2, Appendix 2)
- Profiles (see sample Form3, Appendix 2)
- Horizon representative profile (see sample Form3b, Appendix 2)

**TABLE 1:** Non-spatial attributes of a SOTER unit for Tanzania.

**Terrain unit**

| | | |
|---|---|---|
| 1 | *SOTER UNIT-ID* | (1) |
| 2 | year of data collection | (2) |
| 3 | *map ID* | (3) |
| 4 | major landform | (4) |
| 5 | regional slope | (5) |
| 6 | hypsometry | (6) |
| 7 | general lithology | (7) |

**Terrain component**

| | | |
|---|---|---|
| 8 | *SOTER UNIT-ID* | (8) |
| 9 | terrain component number | (9) |
| 10 | prop. of TC in SOTER unit | (10) |
| 11 | dominant slope | (11) |
| 12 | local surface form | (12) |
| 13 | parent material | (14) |
| 14 | surface drainage | (15) |

**Soil component**

| | | |
|---|---|---|
| 15 | *SOTER unit-ID* | (19) |
| 16 | *terrain component number* | (20) |
| 17 | *soil component number* | (21) |
| 18 | prop. of SC in SOTER unit | (22) |
| 19 | *profile ID* | (23) |
| 20 | position in terrain component | (24) |
| 21 | surface rockiness | (25) |
| 22 | surface stoniness | (26) |
| 23 | rootable depth | (27) |

**Profile**

| | | |
|---|---|---|
| 15 | *profile ID* | (28) |
| 16 | *profile database ID* | (29) |
| 17 | latitude | (30) |
| 18 | longitude | (31) |
| 19 | elevation | (32) |
| 20 | sampling date | (33) |
| 21 | *lab-ID* | (34) |
| 22 | drainage | (35) |
| 23 | FAO classification (1990) | (37) |
| 24 | FAO phase (1990) | (38) |

**Horizon**

| | | |
|---|---|---|
| 34 | *profile ID* | (40) |
| 35 | *horizon number* | (41) |
| 36 | upper depth | (42) |
| 37 | lower depth | (43) |
| 38 | horizon designation | (46) |
| 39 | moist colour | (47) |
| 40 | dry colour | (48) |
| 41 | structure grade | - |
| 42 | structure size | - |
| 43 | structure type | (49) |
| 44 | consistence wet | - |
| 45 | consistence dry | - |
| 46 | consistence moist | - |
| 47 | abundance of coarse fragments | (50) |
| 48 | size of coarse fragments | - |
| 49 | sand | (51) |
| 50 | silt | (52) |
| 51 | clay | (53) |
| 25 | particle size class (USDA) | (54) |
| 26 | pH (H2O) | (55) |
| 27 | electrical conductivity | (57) |
| 28 | exch. Ca++ | (58) |
| 29 | exch. Mg++ | (59) |
| 30 | exch. Na+ | (60) |
| 31 | exch. K+ | (61) |
| 32 | exch. Al+++ | (62) |
| 33 | CEC soil | (64) |
| 34 | percentage base saturation | - |
| 35 | total org. carbon | (65) |
| 36 | total nitrogen | (66) |
| 37 | available phosphorus | - |
| 38 | total carbonate equiv. | (67) |

Numbers in brackets refer to attribute numbers used by Batjes and van Engelen, 1997)
Primary keys are in italics

### 2.3 Delineation of SOTER mapping units

SOTER mapping units have been derived from the Soils and Physiography map of Tanzania at a scale of 1:2 million (de Pauw, 1984). De Pauw's mapping units are primarily land units grouped according to the prevailing dominant physiography. The land units are described in terms of landform, topography, altitude range and parent material in which the soils were formed. For each land unit the distribution (in percentage) of the constituting soil units is presented and their relative occurrence in relation to the landscape is shown in a schematic cross-section. Soil units are classified in accordance with the FAO/UNESCO Soil Classification System of 1974.

At the highest level, SOTER units are also mapped based on major landform, regional slope, hypsometry and general lithology. Hence, it was concluded that de Pauw's mapping units can in fact be considered as SOTER units provided they meet the criteria of the latter.

A somewhat simplified version (Samki, 19??) of the Soils and Physiography Map of Tanzania showing the dominant soil unit per land unit was used as a (transparent) basis. Reason for this is that the author had obtained a digital version of the latter from TANRIC - Tanzania (Resource Information Center, Univ. of Dar es Salam). By overlay, cross-checking was done with de Pauw's original map. This revealed that both maps were almost identical as far as the delineation of mapping units was concerned: in the case of Samki's map part of de Pauw's smaller units had been deleted, some mapping units had been incorporated into others and some errors were detected in the delineation of unit boundaries (possibly due to incorrect map digitization). Hence it was found to be easier to adjust the existing digital version (Samki's map) rather than digitizing de Pauw's original map.

Following the SOTER criteria each mapping unit was checked and only for a few units on de Pauw's original map further adjustments/subdivisions appeared necessary based on landform and hypsometry. A cross-check was also done with the Draft Physiographic Map of Africa (based on the SOTER mapping system: Eschweiler, 1993). For this purpose the original scale of this map (1:5 million) had been enlarged to 1:2 million and printed on transparent paper to facilitate map overlay. Few alterations were made. Furthermore, de Pauw's land unit "Very steep ash, lava and cinder cones" (main Physiographic unit "Volcanoes") could be further differentiated based on i) landform, i.e., the occurrence in association with stony lava slopes or large volcanic craters and ii) hypsometry. An overlay was also done with the Geological Map of Tanzania (the most recent map that could be obtained at a scale of 1:2 million is from 1959) to cross-check lithology but no major differences were found (obviously the same map must have been consulted by de Pauw when he delineated his land units). A comparison of slope/topography was straight forward as both de Pauw's and SOTER slope classes are in accordance with those presented in the FAO Guidelines for Soil Profile Description (FAO, 1997, revised 1990).

Cross-border correlation has been carried out only with Kenya - the only neighbouring country for which a SOTER unit map (at a scale of 1:1 million) and associated database is currently available (FAO, 1998). Although correlation of terrain units and terrain components were of little difficulty - only minor adjustments of SOTER unit boundaries were necessary - correlation of soil components turned out to be more troublesome. Hence, additional SOTER units were created along the border with Kenya to allow for correlation with the SOTER unit map of Kenya (these alterations relate only to the soil component composition). Apart from obvious differences in soil classification another reason could be that the SOTER unit map of Kenya is at a more detailed scale and may therefore show more accurate information.

As a rule of thumb the minimum size of a mapping unit has been set at at least 0.5 $cm^2$, possibly with the exception of narrow and elongated units such as valleys and floodplains which, incidentally, might be smaller. However, almost all SOTER units are much larger.

The resulting draft SOTER unit map of Tanzania (at a scale of 1:2 million on transparent) has been attached to this report for final digitization. The map contains 152 SOTER units and two miscellaneous units, i.e. W - Open Water (lakes) and R - undifferentiated rocky terrain.

**2.4 Terrain units and terrain components**

The terrain unit file lists the main, unique features of a SOTER unit. The terrain component file specifies attribute data by terrain component and gives its relative area as a percentage of the terrain unit.

As mentioned before and at the highest level SOTER units have been identified based on major landform, regional slope, hypsometry and general lithology conform the guidelines in Batjes and van Engelen (1997) (see Appendix 1). Therefore, each landscape is defined into unique areas (broad mapping units) termed terrain units. Although fairly homogeneous in their characteristics at the highest level, typical combinations of surface form, mesorelief, parent material and soils may be recognized and hence providing the basis for further subdivision of the landscape into terrain and associated soil components. However, these entities are not mapped at this scale.

Subdivision of the terrain unit into terrain components has been done using mainly the schematic cross-sections, occurrence of particular soil units within the land unit and the proportion taken up by each soil unit: see Part 1 (land units and soil distribution), and Part 2 (soil units) of de Pauw's legend and his Table 1 (estimated proportions of soil units per mapping unit).

Due to its common occurrence in Tanzania and considering it to be a conspicuous feature in the landscape, one extra major landform has been created under the category sloping land, i.e. dissected plateau (SL) with a gradient of 8-30% and a relief intensity of >50m/slope unit.

Each SOTER unit has been given a unique code consisting of the country ISO code (TZ) and a number ranging from 001 to 159 (note there are no SOTER unit 39, 144-149) and the sequence of SOTER units has been determined by the original sequence of de Pauw's legend on the Soils and Physiography map of Tanzania (de Pauw, 1984). Note that number 150-159 relate to SOTER units created to facilitate cross-border correlation with the (more detailed) SOTER unit map of Kenya.

Terrain components have been differentiated based on dominant slope, parent material and surface drainage. Individual terrain components within a terrain unit are numbered in sequence from one to a maximum of three starting with the most extensive component. Often only two terrain components have been identified, i.e. the upper and middle terrain components and those found in the lower and lowest positions in the landscape. At times those found at upper, middle and lower positions have been separated completely if quite different soil components were found.

Due to lack of data some of the attributes suggested for incorporation in the 1:2.5 million database guidelines (Batjes and van Engelen, 1997) had to be deleted (see 2.2). Although it is commonly known in Tanzania that the "wet" terrain components (usually occupied by Fluvisols, Gleysols and Histosols) are prone to flooding and waterlogging and have high groundwater tables accurate information on their flooding characteristics (as required for incorporation in the SOTER database) is frequently lacking.

In Appendix 2, samples of the data entry forms with the attributes of the terrain unit and terrain component(s) (Form 1) are presented.

**2.5 Soil components**

The soil component file specifies the relative area of the constituting soil components and provides information with regard to the position in the terrain component, surface rockiness and stoniness and rootable depth.

As is the case with the Soils and Physiography map of Tanzania, the terrain components correspond with soil associations or complexes. Hence, soil components (maximum of six) were identified for each terrain component. The soil components have been derived from de Pauw's report (de Pauw, 1984) where a listing and description is provided of soil units occurring within each land unit and where an indication is given (in percentage) of the proportion of the land unit occupied by each soil unit. Schematic cross-sections show the particular location of a soil unit within the terrain unit. "Average" surface rockiness and stoniness has been based on expert judgement rather than having been obtained from the NSS Soil Database. Rootable soil depth was obtained mainly from Table 6 (estimated depths for different soil units) in de Pauw's report and to a limited extent was based on expert judgement.

In de Pauw's legend one soil unit may consist of one up to a maximum of six soil classification units (using the FAO/UNESCO Soil Classification System of 1974) and one land unit may consist of one dominant soil unit (occupying >50% of the mapping unit), up to five associated soil units (occupying 15-50% of the mapping unit) and several inclusions (occupying >15% of the mapping unit). Hence, the total number of soil classification units that may be found in one SOTER unit can be considerable. Following the SOTER guidelines only soils occupying >15% of the SOTER unit should be incorporated. Therefore frequently arbitrary decisions had to be made in determining which soil classification units were to be incorporated in the SOTER database, applying the rule that i) not more than six soil components (equivalent to soil classification units) can make up a SOTER unit (or terrain component), ii) each unit must at least occupy 15% of the SOTER unit and iii) that the total percentage of all constituting soil components add up to 100%. This has resulted in soils belonging to different soil units but to the same major soil grouping having been incorporated under the name of the dominant soil unit, i.e., in the case where none of the constituting soil classification units reached up to 15% of the mapping unit e.g., a Rhodic Ferralsol (occupying 7%) and a Haplic Ferralsol (occupying 5%) will have been listed under soil component only as a Rhodic Ferralsols occupying 15% of the SOTER unit (as this one is the dominant Ferralsol). Soil classification units occupying less than 5% were usually ignored.

As is the case with terrain components, soil components are not mappable at the applied scale. Soil components are only characterized in the attribute data base. Soil components within each terrain component are also numbered sequentially up to a maximum of six to a terrain component; the one occupying the largest extent is listed first (in decreasing order).

In Appendix 2, samples of the data entry forms with the attributes of the terrain unit and terrain component(s) (Form 2) are presented (see also 2.2, Table 1).

### 2.6 Soil profile data

The profile file contains the common attributes of the representative profile such as its location, elevation, sampling date, soil drainage and 1990 FAO/UNESCO soil classification (soil unit and phase).

Soil profile data has been compiled from the Soil Database prepared by the NSS - Tanzania under a separate FAO contract. A digital soil database of a total of 57 unique and dominant soil profiles (classified according to the 1990 FAO/UNESCO Soil Classification System) were provided in accordance with procedures and guidelines specified in the FAO Guidelines for Soil Profile Description (FAO, 1990) and the Multilingual Soil Database (FAO/ISRIC/CSIC, 1995). The database also contains another 39 soil profiles being either duplicates or triplicates of the former ones derived from different places. The type of soil profiles to be provided by the NSS was mainly guided by the report of de Pauw which lists a total of 48 different soil classification units for Tanzania based on the FAO/UNESCO Soil Classification System of 1974.

Converting the old (1974) classification system into the new one of 1990 created a problem for a number of soils. Luvisols and Acrisols under the new soil classification system can be either Luvisols and/or Lixisols and Acrisols can be Acrisols and/or Alisols depending on CEC and Base Saturation. In de Pauw's report values range just around these differentiating criteria. Therefore, it was not possible to provide a reliable solution. Both Mr. de Pauw and the NSS were kind enough to provide guidance on this but unfortunately their views were often contradicting:

> *A comparison was made between the two sources of information for 18 (land) mapping units with soils thought to occupy at least 15% of the mapping unit according to the NSS. Only in 4 cases this was confirmed by de Pauw's information, in 5 cases there was some agreement (but with an extent of usually far less than 7%) and in 9 cases there was no match at all.*

The rather common former Pellic Vertisols can be either Dystric, Eutric or even Calcic Vertisols under the new classification system. Part of the (Ferralic) Cambisols are now believed to be (Ferralic) Arenosols (according to de Pauw) while Xerosols no longer occur in the 1990 system at all. Differences in soil classification (and soil classification conversions) are also thought to be a main reason for the mismatch in soil units along the border between Tanzania and Kenya rather than those soils being entirely different from those of the rest of the country.

The author has mainly followed the guidance provided by Mr. de Pauw who made available a complete listing of old and new FAO/UNESCO soil classification units together with their representation in each of his soil and land units. This also contributed to the fact that for a number of commonly occurring soil profiles (i.e., Haplic Solonetz, Chromic Luvisols, Humic Nitisols, Histosols and Vitric Andosols) and some less frequent soil units (i.e., Mollic Solonetz, Thionic and Calcaric Fluvisols, Haplic Calcisols, Luvic Calcisols, Gleyic Solonetz, Humic Andosols, Mollic Andosols, Calcic Chernozems, Haplic Solonchak, Rendzic Leptosols) no soil profile descriptions are currently provided. Furthermore almost all former Lithosols are now indicated as Eutric Leptosols, however, a large part of them may in fact be Lithic Leptosols while Dystric Leptosols are also thought to occur.

It must be noted that the NSS Soil Database also provides soil profile descriptions and analytical data for a number of soil units that have not been incorporated in the SOTER database, due to their limited extent within a given SOTER unit (i.e. occupying less than 5% ). These soil units are: Umbric Fluvisols, Mollic Gleysols, Dystric Leptosols, Haplic and Gleyic Arenosols, Gleyic Phaeozems, Eutric and Dystric Planosols, Gleyic Lixisols, Plinthic and Gleyic Acrisols, Ferric and Plinthic Alisols, Geric Ferralsols and Eutric Plinthosols.

In Appendix 2, samples of the data entry forms with the attributes of the soil profiles (Form 3) are presented (see also 2.2).

### 2.7 Horizon representative profile

The horizon file holds the morphological, physical and chemical data by individual horizon (for a listing of all attributes see Table 1 in 2.2).

All profile data was extracted from the material provided by the NSS. Data was also put into the SOTER format which required in one case conversion of units (i.e., from minutes latitude/longitude to decimal degrees) and in other cases conversion of the applied coding system. Selection of attributes from the Soil Database for incorporation into the SOTER database was primarily guided by the work of Batjes and van Engelen (1997). However a number of attributes thought to be of importance were added (see 2.2). Soil consistence is not listed as an attribute of SOTER. Hence the applied attribute coding conventions are conform those used in the Multilingual Soil Database (FAO/ISRIC/CSIC, 1995) (see also Appendix 1).

In Appendix 2, samples of the data entry forms with the attributes of the soil profiles (Form 3b) are presented.

**2.8 Miscellaneous data**

A data entry form for general information concerning the source map is attached as Appendix 2 (form 4). Latitude/longitude of the area covered is entered, type of map (M=Morpho-pedological map or soil-landscapes) map title, year of production and scale of the source map are indicated.

Data pertaining to laboratory and analytical methods is also filled in on form 4 (Appendix 2). The number of the method of analysis (number before the dash (-)) corresponds with the number of the relevant attribute, while a slash (/) in the number indicates that the method applies to more than one attribute (i.e., method of analysis ID 51/3-1 applies to attributes 51, 52 and 53). The description of the analytical methods has been provided by the NSS - Tanzania. Note that the date when a particular method was introduced (attribute 4) is unknown and has been left blank.

**2.9 Data entry**

Data entry can be done directly from the annexed completed data entry sheets which have been organised according to the five files and two miscellaneous files described in the foregoing chapters (Appendix 3). Alternatively a conversion programme can be used to convert attribute data from the Soil DataBase of Tanzania to the SOTER database (apparently ISRIC has an interface for this but note that the SDB for Tanzania has been compiled in Excel, not in Dbase).

It is suggested that the numbering of the attributes is revised when creating the data base to delete attribute numbers that have not been used and to renumber the retained attributes in sequential order as indicated in Table 1.

Note that the attributes 44 (diagnostic horizon) and 45(diagnostic property) (numbering according to Batjes and van Engelen, 1997, see Appendix 1) have been deleted for each soil profile (mandatory by Batjes and van Engelen). This type of information is not required nor included in the Soil Database and therefore not available. However, if to be incorporated in the SOTER database of Tanzania, it is suggested that this should be requested from those responsible for the classification of the soils, i.e. the NSS - Tanzania.

**LIST OF REFERENCES**

**Batjes N.H., and V.W.P. van Engelen** (eds) (1997); Guidelines for the Compilation of a 1:2.5 million SOTER Database (SOVEUR Project), draft for discussion, ISRIC, Wageningen.

**De Pauw, E.** (1984); Soils, Physiography and agroecological zones of Tanzania, MinAg/FAO Project GCPS/URT/047/NET, Dar es Salam.

**Eschweiler, J.A.** (1993); A Draft Physiographic Map of Africa, Working Paper (draft) Internal Document, FAO, Rome.

**FAO/UNESCO** (1974); Soil Map of the World 1:5 million, Volume I, Legend, Rome.

**FAO/UNESCO** (1990); Soil Map of the World - Revised Legend, Rome.

**FAO** (1990); Guidelines for Soil Profile Description, AGLS, Rome.

**FAO/ISRIC/CSIC** (1995); Multilingual Soil Database, World Soil Resources Reports No. 81, Rome.

**FAO** (1998); The soil and terrain database for northeastern Africa and Crop Production System Zones of the IGAD subregion, FAO - Land and Water Digital Media Series nr. 2
.

**National Soil Service - Tanzania** (1998); A Soil Profile Database for Tanzania, Techn. report FAO contract CMT 132036, Mlingano/Rome.

**van Engelen V.W.P. and T.T. Wen** (eds) (1995); Global and National Soils and Terrain Digital Databases (SOTER) - Procedures Manual (rev. version) UNEP/ISSS/ISRIC/FAO, Wageningen.

# APPENDICES

- Appendix 1: Attribute coding conventions

- Appendix 2: Sample data entry forms for the compilation of a 1:2 million SOTER database:

  - Form 1  :  Terrain units and terrain components
  - Form 2  :  Soils components
  - Form 3  :  Soil profile information
  - Form 3b:  Representative soil profile data

- SOTER unit map of Tanzania (scale 1:2 million) (in digital form)

## APPENDIX 1: ATTRIBUTE CODING CONVENTIONS

The attribute coding conventions of Batjes and van Engelen (1997) are reproduced on the following pages. Note that some of these attributes have been deleted while others were added (see 2.2). For those added the coding conventions are as follows (numbers refer to those listed under the column “new numbers” on form 3b of the sample data entry forms):

47) **structure grade**

Conform van Engelen and Wen (1995), i.e.:

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

47) **structure size**

Conform van Engelen and Wen (1995), i.e.:

Size classes of structure elements of various types (in mm, Soil Survey Staff 1951; FAO 1990)

| Size classes | Ranges of size of structure elements | | | | |
|---|---|---|---|---|---|
| | platy | prismatic/columnar | (sub)ang.blocky | granular | 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 | |

48) **consistence wet**

Conform Multilingual Soil Database (FAO/ISRIC/CSIS, 1995) coding conventions for stickiness and plasticity, i.e.:

| | | | |
|---|---|---|---|
| NST | non sticky | NPL | non plastic |
| SST | slightly sticky | SPL | slightly plastic |
| ST | sticky | PL | plastic |
| VST | very sticky | VPL | very plastic |
| SS | slightly sticky to sticky | SP | slightly plastic to plastic |
| SV | sticky to very sticky | PV | plastic to very plastic |

49) **consistence dry**

Conform Multilingual Soil Database (FAO/ISRIC/CSIC, 1995), i.e.:

| | |
|---|---|
| LO | loose |
| SO | soft |
| SHA | slightly hard |
| HA | hard |
| VHA | very hard |
| EHA | extremely hard |
| SSH | soft to slightly hard |
| SHH | slightly hard to hard |
| HVH | hard to very hard |

49) **consistence moist**

| | |
|---|---|
| LO | loose |
| VFR | very friable |
| FR | friable |
| FI | firm |
| VFI | very firm |
| EFI | extremely firm |
| VFF | very friable to friable |
| FRF | friable to firm |
| FVF | firm to very firm |

50) **size of coarse fragments**

Conform van Engelen and Wen (1995), i.e.:

Size of dominant rock or mineral fragments in classes (FAO, 1990):

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

63) **percentage base saturation**

The extent to which the adsorption complex of a soil is saturated with exchangeable cations other than hydrogen and aluminium, expressed as a percentage of the total CEC (percentage between 0-100).

66) **available phosphorus**

Available phosphorus content in ppm.

The numbers of the attributes in the following coding conventions of Batjes and van Engelen (1997) are corresponding to the attribute numbers on the data entry sample forms (on form 3b the column “old” numbers apply).

**TERRAIN UNIT**

1. *SOTER unit_ID*

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

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

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

2. *year of data collection*

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

**3** *map_ID*

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

**4** *major landform*

Landforms are described foremost by their morphology and not by their genetic origin, or processes responsible for their shape. The regionally dominant slope class is the most important differentiating criterion, followed by the relief intensity. The relief intensity is normally given in m/km, but for distinction between hills and mountains it is more practical to use two kilometer intervals (see Table 2).

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

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

TABLE 2
**Hierarchy of major landforms**

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

Notes: Water bodies are coded by the letter W

## 5 *regional slope*

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

a) Simple landforms

**1** (W) 0-2 % flat, wet*

**2** (F) 0-2 % flat

**3** (G) 2-5 % gently undulating

**4** (U) 5-8 % undulating

**5** (R) 8-15 % rolling

**6** (S) 15-30 % moderately steep

**7** (T) 30-60 % steep

**8** (V) ≥ 60 % very steep

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

b) Complex landforms**

**CU** Cuesta-shaped

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

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

**6** *hypsometry*

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

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

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

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

| | | |
|---|---|---|
| **6** | < 200 m | low (hills etc.) |
| **7** | 200-400 m | medium |

| | | |
|---|---|---|
| **8** | ≥ 400 m | high |

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

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

**7** *general lithology*

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

TABLE 3
**Hierarchy of lithology**

| Major class | | Group | | Type | |
|---|---|---|---|---|---|
| **I** | igneous rock | **IA** | acid igneous | **IAI**<br>**IA2**<br>**IA3**<br>**IA4** | granite<br>grano-diorite<br>quartz-doprite<br>rhyolite |
| **"** | | **II** | intermediate igneous | **II1**<br>**II2** | andesite, trachyte, phonolite<br>diorite-syenite |
| **"** | | **IB** | basic igneous | **IB1**<br>**IB2**<br>**IB3** | gabbro<br>basalt<br>dolerite |
| **"** | | **IU** | ultrabasic igneous | **IU1**<br>**IU2**<br>**IU3** | peridotite<br>pyroxenite<br>ilmenite, magnetite, ironstone, serpentine |
| **M** | metamorphic rock | **MA** | acid metamorphic | **MA1**<br>**MA2** | quartzite<br>gneiss, magmatite |
| **"** | | **MB** | basic metamorphic | **MB1**<br>**MB2**<br>**MB3**<br>**MB4** | slate, phyllite (pelitic rocks)<br>schist<br>gneiss rich in ferro-magnesian minerals<br>metamorphic limestone (marble) |
| **S** | sedimentary rock | **SC** | clastic sediments | **SC1**<br>**SC2**<br>**SC3**<br>**SC4** | conglomerate, breccia<br>sandstone, greywacke, arkose<br>siltstone, mudstone, claystone<br>shale |
| **'** | | **SO** | organic | **SO1**<br>**SO2**<br>**SO3** | limestone, other carbonate rocks<br>marl and other mixtures<br>coals, bitumen and related rocks |
| **"** | | **SE** | evaporites | **SE1**<br>**SE2** | anhydrite, gypsum<br>halite |
| **U** | unconsolidated | **UF** | Fluvial | **UF1**<br>**UF2** | Calcaresous<br>Non-calacreous |
| | | **UL** | Lacustrine | **UL1**<br>**UL2** | Calcareous<br>Non calcareous |
| | | **UM** | Marine | **UM1**<br>**UM2** | Calcaresous<br>Non-calacreous |
| | | **UC** | Colluvial | **UC1**<br>**UC2** | Calcareous<br>Non calcareous |
| | | **UE** | Eolian | **UE1**<br>**UE2** | Calcaresous<br>Non-calcacreous |
| | | **UG** | Glacial | **UG1**<br>**UG2** | Calcareous<br>Non calcareous |
| | | **UP** | Pyroclastic | **UP1**<br>**UP2** | Non-acid<br>Acid |
| | | **UO** | organic | **UO1**<br>**UO2** | Calcareous<br>Non-calcareous |

**8** *SOTER unit_ID*

See SOTER unit_ID under Terrain unit.

**9** *terrain component number*

The sequential number of the terrain component in the terrain. The largest terrain component in the SOTER unit comes first, followed by the second in size, and so on. The combination SOTER unit_ID and terrain component number (e.g. RU2034/1) would refer to the first, thus spatially dominant, terrain component in SOTER unit "RU2034".

**10** *proportion of SOTER unit*

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

**Example**

| | |
|---|---|
| SOTER unit_id = RU2034 | SOTER unit_id = RU2034 |
| Terrain component number = 1 | Terrain component number = 2 |
| Proportion within SU = 70% | Proportion within SU = 30% |

**11** *dominant slope*

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

**12** *local surface form*

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

| | | |
|---|---|---|
| **H** | hummocky | very complex pattern of slopes extending from somewhat rounded depressions or kettleholes of various sizes to irregular conical knolls or knobs. There is a general lack of concordance between knolls or depressions. Slopes ranges are large and vary generally between 4 % and 70 %. |
| **M** | mounded | coverage (at least 5 %) by isolated mounds more than 2.5 m high |
| **K** | towered | coverage (at least 5 %) by isolated steep sided karst towers more than 2.5 m high. |
| **R** | ridged | coverage (at least 5 %) by parallel, sub-parallel or intersecting usually sharpcrested ridges (elongated narrow elevations) more than 2.5 m high. |
| **T** | terraced | level areas (less than 2 % slope) bounded on one side by a steep slope more than 2.5 m high with |
| **G** | gullied | Coverage (at least 5 %) by steep-sided gullies more than 2.5 m deep. |
| **S** | strongly | areas with a drainage density of more than 25 km $km^{-2}$, the depth |

| | | |
|---|---|---|
| | (dissected) | dissected of the drainage lines being at least 2.5 m |
| **D** | dissected | areas with a drainage density of more than 10 km $km^{-2}$, the depth of the drainage lines being at least 2.5 m |
| **L** | slightly (dissected) | areas with a drainage density of less than 10 km $km^{-2}$, the depth of the dissected drainage lines being at least 2.5 m. |

**14** *parent material*

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

**15** *surface drainage*

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

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

## SOIL COMPONENT

**19** *SOTER unit_ID*

The SOTER unit_ID under the section *Terrain unit*.

**20** *terrain component number*

See terrain component number under section *Terrain component*.

**21** *soil component number*

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

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

**22** *proportion of SC in SOTER unit*

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

**23** *profile_ID*

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

**24** *position in terrain component*

The relative position of the soil component within the terrain component is characterized by one of the following descriptions:

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

**25** *surface rockiness*

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

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

**26** *surface stoniness*

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

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

**27** *rootable depth*

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

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

**PROFILE**

**28** *profile_ID*

Same as profile_ID in under soil component

**29** *profile database_ID*

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

**30** *latitude*

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

**31** *longitude*

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

**32** *elevation*

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

**33** *sampling date*

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

**34** *lab_ID*

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

**35** *drainage*

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

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

**37** *classification*

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

**38** *phase (FAO, 1990)*

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

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

**HORIZON DATA**

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

All mandatory attributes are clearly marked in Table 1.

**40** *profile_ID* (mandatory)

Same as profile_ID under profile.

**41** *horizon number* (mandatory)

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

**42** *upper depth* (mandatory)

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

**43** *lower depth* (mandatory)

**46** *horizon designation*

Master horizon with subordinate characteristics according to the rules given below (for more details see FAO, 1990a).

a) Master horizons

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

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

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

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

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

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

**B** B horizon. A B horizon has formed below an A, E, O or H horizon, and has as dominant feature the obliteration of all or much of the original rock structure, together with one or a combination of the following:
illuvial concentration, alone or in combination, of silicate clay, iron, aluminium, humus, carbonates, gypsum or silica;

- evidence of removal of carbonates
- coating of sesquioxides that make the horizon conspicuously lower in value, higher in chroma, or redder in hue than overlying
- alteration that forms silicate clay or liberates oxides or both and that forms a granular, blocky or prismatic structure if volume changes accompany the changes in moisture content, or
- brittleness

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

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

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

b) Subordinate properties

Subordinate distinctions and features within master horizons are indicated with lower case letters used as suffixes. The following subordinate properties may be used (see FAO, 1990a for more details).

**b** buried genetic horizon

**c** concretions or nodules

**f** frozen soil

**g** strong gleying

**h** accumulation of organic matter

**j** jarosite mottling

**k** accumulation of carbonates

**m** cementation or induration

**n** accumulation of sodium

**o** residual accumulation of sesquioxides

**p** ploughing or other disturbance

**q** accumulation of silica

**r** strong reduction

**s** illuvial accumulation of sesquioxides

**t** accumulation of silicate clay

**v** occurrence of plinthite

**w** development of colour or structure

**x** fragipan character

**y** accumulation of gypsum

**z** accumulation of salts more soluble than gypsum

**47** *moist colour* (mandatory)

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

**48** *dry colour*

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

**49** *type of structure* (mandatory)

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

**50** *abundance of coarse fragments* (mandatory)

| | | |
|---|---|---|
| **N** | None | 0% |
| **V** | Very few | 0-2% |
| **F** | Few | 2-5% |
| **C** | Common | 5-15% |
| **M** | Many | 15-40% |
| **A** | Abundant | 40-80% |
| **D** | Dominant | ≥ 80% |

**51** *total sand* (mandatory)

Weight % of particles 2.0-1.0 mm in fine earth fraction (USDA standard (Soil survey Staff, 1993); *if other class limit are used this should be indicated clearly under the laboratory methods*. The total sand fraction, either as an absolute value, or as the sum of the sub-fraction.

**52** *silt* (mandatory)

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

**53** *clay* (mandatory)

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

**54** *particle size class*

The particle size as derived, with the aid of figure 9, from the particle size analysis results

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

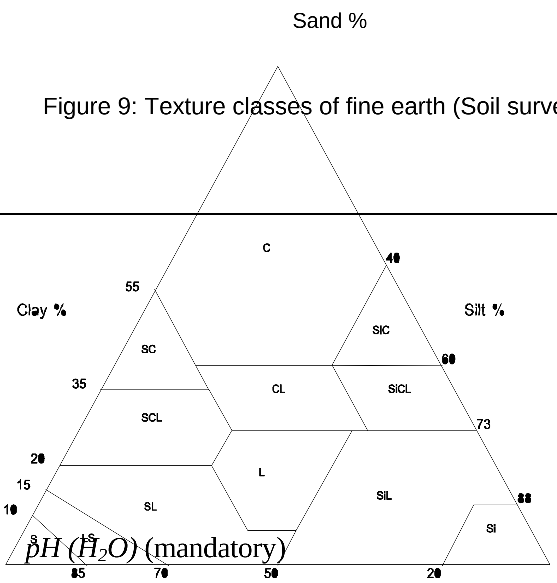


Figure 9: Texture classes of fine earth (Soil survey Staff 1993)

**55** *pH ($H_2O$)* (mandatory)

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

**57** *electrical conductivity ($EC_e$)*

The electrical conductivity of saturation extract, dS/m, only mandatory if the soil contains salts.

**58** *exchangeable $Ca^{++}$*

The exchangeable Ca in cmol(+) $kg^{-1}$ (= meq/100 g fine earth) measured in 1 *M* $NH_4Oac$, buffered at pH7.

**59** *exchangeable $Mg^{++}$*

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

**60** *exchangeable $Na^{+}$*

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

**61** *exchangeable $K^{+}$*

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

**62** *exchangeable $Al^{+++}$*

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

**64** *CEC soil* (mandatory)

The cation exchange capacity of the soil at pH 7.0, measured in 1 *M* $NH_4Oac$, in $cmol_{c\ Kg}{}^{-1}$.

**65** *total organic carbon* (mandatory)

The content of total organic carbon in g $kg^{-1}$

**66** *total nitrogen*

The content of total N in g $kg^{-1}$.

**67** *total carbonate equivalent*

The content of carbonates, as $CaCO_3$ in g $kg^{-1}$.

**Form 1**

**APPENDIX 2: SOTER Data Base Input Forms (Tanzania)**

**SOTER** data entry sheet (1:2.0 million database)

---

**TERRAIN COMPONENT**

1 *SOTER unit-ID* |T|Z| + |0|_|_|_|

*2* year of data collection |1|9|8|3|

*3* map_id |T|Z|-|d|e|P|a|u|w|'|8|4|

4 major landform |_|_|

*5* regional slope |_|

6 hypsometry |_|

7 general lithology |_|

---

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

---

**TERRAIN COMPONENT**

8 *SOTER unit_id* |T|Z| + |0|_|_|_|

9 *terrain component number* |_| |_| |_|

10 Proportion of TC in SOTER unit |_||_| |_||_| |_||_|

11 Dominant slope |_||_| |_||_| |_||_|

12 Local surface form |_| |_| |_|

*13 Depth to bedrock (m) |_||_| |_||_| |_||_|

14 Surface drainage |_||_||_| |_||_||_| |_|

15 Parent material |_| |_| |_||_|

*16 Depth to groundwater |_||_| |_||_| |_|

*17 Frequency of flooding |_| |_| |_|

*18 Duration of flooding |_| |_| |_|

---

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

*deleted

**Form 2**

**SOTER** data entry sheet (1:2.0 million database)

**SOIL COMPONENT**

<table>
<tr><td>19</td><td>SOTER unit-ID</td><td>|T|Z| + |0|_|_|_|</td><td></td><td></td></tr>
<tr><td>20</td><td>terrain component number</td><td>|_|</td><td></td><td></td></tr>
<tr><td>21</td><td>soil component number (SC)</td><td>|_|</td><td>|_|</td><td>|_|</td></tr>
<tr><td>22</td><td>prop. of SC in SOTER unit</td><td>|_||_||_|</td><td>|_||_||_|</td><td>|_||_||_|</td></tr>
<tr><td>23</td><td>profile-ID</td><td>|_||_||_||_||_||_||_||_||_||_||_||_|</td><td>|_||_||_||_||_||_||_||_||_||_||_||_|</td><td>|_||_||_||_||_||_||_||_||_||_||_||_|</td></tr>
<tr><td>24</td><td>position in terrain component</td><td>|_|</td><td>|_|</td><td>|_|</td></tr>
<tr><td>25</td><td>surface rockiness</td><td>|_|</td><td>|_|</td><td>|_|</td></tr>
<tr><td>26</td><td>surface stoniness</td><td>|_|</td><td>|_|</td><td>|_|</td></tr>
<tr><td>27</td><td>rootable depth</td><td>|_|</td><td>|_|</td><td>|_|</td></tr>
</table>

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

**SOIL COMPONENT**

<table>
<tr><td>19</td><td>SOTER unit_id</td><td>|T|Z| + |0|_|_|_|</td><td></td><td></td></tr>
<tr><td>20</td><td>terrain component number</td><td>|_|</td><td></td><td></td></tr>
<tr><td>21</td><td>soil component number (SC)</td><td>|_|</td><td>|_|</td><td>|_|</td></tr>
<tr><td>22</td><td>prop. of SC in SOTER unit</td><td>|_||_||_|</td><td>|_||_||_|</td><td>|_||_||_|</td></tr>
<tr><td>23</td><td>profile-ID</td><td>|_||_||_||_||_||_||_||_||_||_||_||_|</td><td>|_||_||_||_||_||_||_||_||_||_||_||_|</td><td>|_||_||_||_||_||_||_||_||_||_||_||_|</td></tr>
<tr><td>24</td><td>position in terrain component</td><td>|_|</td><td>|_|</td><td>|_|</td></tr>
<tr><td>25</td><td>surface rockiness</td><td>|_|</td><td>|_|</td><td>|_|</td></tr>
<tr><td>26</td><td>surface stoniness</td><td>|_|</td><td>|_|</td><td>|_|</td></tr>
<tr><td>27</td><td>rootable depth</td><td>|_|</td><td>|_|</td><td>|_|</td></tr>
</table>

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

**Form 3**

**SOTER** data entry sheet (1:2.0 million database)

## SOIL COMPONENT

| | | |
|---|---|---|
| 28 | profile_ID | \|_\|_\|_\|\|_\|\|_\|\|_\|\|_\|\|_\|\|_\|\|_\|\|_\|\|_\|\|_\| |
| 29 | profile database_ID | \|_\|\|_\|\|_\|\|_\|\|_\| |
| 30 | latitude (dec. degrees*)* | \|_\|\|_\|\|_\|\|_\|\|_.\|\|_\|\|_\| |
| 31 | longitude (dec. degrees) | \|_\|\|_\|\|_\|\|_\|\|_.\|\|_\|\|_\| |
| *32* | elevation | \|_\|\|_\|\|_\|\|_\| |
| 33 | sampling data | \|_\|\|_\|\|/\|\|_\|\|_\| |
| 34 | lab_ID | \|_\|\|_\|\|_\|\|_\|\|_\| |
| 35 | drainage | \|_\| |
| *36 | infiltration rate | \|_\| |
| 37 | FAO classification (1990) | \|_\|\|_\|\|_\| |
| 38 | FAO hase (1990) | \|_\|\|_\| |
| *39 | National classification | \|_\|\|_\|\|_\|\|_\|\|_\|\|_\|\|_\|\|_\|\|_\|\|_\|\|_\|\|_\|\|_\|\|_\| |

* Use Form 3b forcorresponding horizon data.
* deleted

**Form 3b**

**SOTER** data entry sheet (1:2.0 million database)

Horizon representative profile

Old/new number

<table>
<tr><td>40</td><td>40</td><td>profile_ID</td><td>|T|Z|-||_||_||_||_||_||_||_|</td><td></td><td></td><td></td><td></td></tr>
<tr><td>41</td><td>41</td><td>horizon number</td><td>|_|</td><td>|_|</td><td>|_|</td><td>|_|</td><td>|_|</td></tr>
<tr><td>42</td><td>42</td><td>upper depth</td><td>|_||_||_|</td><td>|_||_||_|</td><td>|_||_||_|</td><td>|_||_||_|</td><td>|_||_||_|</td></tr>
<tr><td>43</td><td>43</td><td>lower depth</td><td>|_||_||_|</td><td>|_||_||_|</td><td>|_||_||_|</td><td>|_||_||_|</td><td>|_||_||_|</td></tr>
<tr><td>46</td><td>44</td><td>horizon des</td><td>|_||_||_||_||_|</td><td>|_||_||_||_||_|</td><td>|_||_||_||_||_|</td><td>|_||_||_||_||_|</td><td>|_||_||_||_||_|</td></tr>
<tr><td>47</td><td>45</td><td>moist colour</td><td>|_||_||_||_||_||_||_||_||_|</td><td>|_||_||_||_||_||_||_||_||_|</td><td>|_||_||_||_||_||_||_||_||_|</td><td>|_||_||_||_||_||_||_||_||_|</td><td>|_||_||_||_||_||_||_||_||_|</td></tr>
<tr><td>48</td><td>46</td><td>dry colour</td><td>|_||_||_||_||_||_||_||_||_|</td><td>|_||_||_||_||_||_||_||_||_|</td><td>|_||_||_||_||_||_||_||_||_|</td><td>|_||_||_||_||_||_||_||_||_|</td><td>|_||_||_||_||_||_||_||_||_|</td></tr>
<tr><td>(49)</td><td>47</td><td>structure type</td><td>|_||_||.||_||_|.||_||_|</td><td>|_||_||.||_||_|.||_||_|</td><td>|_||_||.||_||_|.||_||_|</td><td>|_||_||.||_||_|.||_||_|</td><td>|_||_||.||_||_|.||_||_|</td></tr>
<tr><td>-</td><td>48</td><td>consistence wet</td><td>|_||_||_||.||_||_||_|</td><td>|_||_||_||.||_||_||_|</td><td>|_||_||_||.||_||_||_|</td><td>|_||_||_||.||_||_||_|</td><td>|_||_||_||.||_||_||_|</td></tr>
<tr><td>-</td><td>49</td><td>consistence dry</td><td>|_||_||_||.||_||_||_|</td><td>|_||_||_||.||_||_||_|</td><td>|_||_||_||.||_||_||_|</td><td>|_||_||_||.||_||_||_|</td><td>|_||_||_||.||_||_||_|</td></tr>
<tr><td>(50)</td><td>50</td><td>abundance + size</td><td>|_||.||_||_||_|</td><td>|_||.||_||_||_|</td><td>|_||.||_||_||_|</td><td>|_||.||_||_||_|</td><td>|_||.||_||_||_|</td></tr>
<tr><td>51</td><td>51</td><td>sand</td><td>|_||_||_|</td><td>|_||_||_|</td><td>|_||_||_|</td><td>|_||_||_|</td><td>|_||_||_|</td></tr>
<tr><td>52</td><td>52</td><td>silt</td><td>|_||_||_|</td><td>|_||_||_|</td><td>|_||_||_|</td><td>|_||_||_|</td><td>|_||_||_|</td></tr>
<tr><td>53</td><td>53</td><td>clay</td><td>|_||_||_|</td><td>|_||_||_|</td><td>|_||_||_|</td><td>|_||_||_|</td><td>|_||_||_|</td></tr>
<tr><td>54</td><td>54</td><td>USDA size class</td><td>|_||_||_||_|</td><td>|_||_||_||_|</td><td>|_||_||_||_|</td><td>|_||_||_||_|</td><td>|_||_||_||_|</td></tr>
<tr><td>55</td><td>55</td><td>pH (H20)</td><td>|_||_||.||_|</td><td>|_||_||.||_|</td><td>|_||_||.||_|</td><td>|_||_||.||_|</td><td>|_||_||.||_|</td></tr>
<tr><td>57</td><td>56</td><td>electricalc conduct</td><td>|_||_||.||_|</td><td>|_||_||.||_|</td><td>|_||_||.||_|</td><td>|_||_||.||_|</td><td>|_||_||.||_|</td></tr>
<tr><td>58</td><td>57</td><td>exch. Ca</td><td>|_||_||.||_|</td><td>|_||_||.||_|</td><td>|_||_||.||_|</td><td>|_||_||.||_|</td><td>|_||_||.||_|</td></tr>
<tr><td>59</td><td>58</td><td>exch. Mg</td><td>|_||_||.||_|</td><td>|_||_||.||_|</td><td>|_||_||.||_|</td><td>|_||_||.||_|</td><td>|_||_||.||_|</td></tr>
<tr><td>60</td><td>59</td><td>exch. Na</td><td>|_||_||.||_|</td><td>|_||_||.||_|</td><td>|_||_||.||_|</td><td>|_||_||.||_|</td><td>|_||_||.||_|</td></tr>
<tr><td>61</td><td>60</td><td>exch. K</td><td>|_||_||.||_|</td><td>|_||_||.||_|</td><td>|_||_||.||_|</td><td>|_||_||.||_|</td><td>|_||_||.||_|</td></tr>
<tr><td>62</td><td>61</td><td>exch. Al</td><td>|_||_||.||_|</td><td>|_||_||.||_|</td><td>|_||_||.||_|</td><td>|_||_||.||_|</td><td>|_||_||.||_|</td></tr>
<tr><td>64</td><td>62</td><td>CEC soil</td><td>|_||_||_||.||_|</td><td>|_||_||_||.||_|</td><td>|_||_||_||.||_|</td><td>|_||_||_||.||_|</td><td>|_||_||_||.||_|</td></tr>
<tr><td>-</td><td>63</td><td>% base saturation</td><td>|_||_||_|</td><td>|_||_||_|</td><td>|_||_||_|</td><td>|_||_||_|</td><td>|_||_||_|</td></tr>
<tr><td>65</td><td>64</td><td>total org. carbon</td><td>|_||_||.||_|</td><td>|_||_||.||_|</td><td>|_||_||.||_|</td><td>|_||_||.||_|</td><td>|_||_||.||_|</td></tr>
<tr><td>66</td><td>65</td><td>total nitrogen</td><td>|_||_||.||_||_|</td><td>|_||_||.||_||_|</td><td>|_||_||.||_||_|</td><td>|_||_||.||_||_|</td><td>|_||_||.||_||_|</td></tr>
<tr><td>-</td><td>66</td><td>avail. Phosphorus</td><td>|_||_||.||_|</td><td>|_||_||.||_|</td><td>|_||_||.||_|</td><td>|_||_||.||_|</td><td>|_||_||.||_|</td></tr>
<tr><td>67</td><td>67</td><td>total carbonate eq.</td><td>|_||_||.||_|</td><td>|_||_||.||_|</td><td>|_||_||.||_|</td><td>|_||_||.||_|</td><td>|_||_||.||_|</td></tr>
<tr><td></td><td>68</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>69</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>70</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

* Old numbers are those used by Batjes and Van Engelen, 1997: Guidelines for the compilation of a 1:2.5 million SOTER Databases (ISRIC Report 97/06)