SOTER database for Southern Africa

(SOTERSAF)

TECHNICAL REPORT

J.A. Dijkshoorn

ISRIC

INTERNATIONAL SOIL REFERENCE AND INFORMATION CENTRE

Wageningen 2003

Table of contents

List of figures

List of tables

Acknowledgements

The compilation of this material has taken over three years and did involve the active cooperation of the national soil institutes of the countries, as mentioned in the list of participating institutes on page four of this report, the technical expertise of the International Soil Reference and Information Centre (ISRIC) and the financial support of UNEP for the Zimbabwe study.

This compilation would not have been possible without the wealth of soil survey information gathered over the years through the cooperation of the national soil institutes and the FAO field programme.

A large number of soil experts have particularly contributed to the collection of the material or the preparation of the SOTER database and are herewith gratefully acknowledged (in alphabetical order):

Beernaert, Frank (FAO, Namibia and Angola)
Coetzee Marina (Ministry of Agriculture, Water and Rural Development,Windhoek: Namibia)
De Pauw, Eddy (FAO, Tanzania and Namibia)
De Wit, Paul (FAO, Botswana)
Dijkshoorn, Koos (ISRIC, SOTER compilation)
Eschweiler, Hans (FAO, Tanzania)
Masuku, B.S. (Ministry of Agriculture and Cooperation, Mbabane: Swaziland)
Moganane, Buago (Soil Survey, Land Utilization Division, Gaborone: Botswana).
Mushambi, C.F. (Chemistry and Soil Research Institute, Harare: Zimbabwe)
Nyaki, A.S. (Agricultural Research Institute Mlingano, Tanga: Tanzania)
Nachtergaele, Freddy (FAO, Botswana; SOTER Coordination)
Remmelzwaal Arie (FAO, Botswana, South Africa and Swaziland)
Souirjii, Abdelghani (FAO, Mozambique)
Pinto Ricardo (Instituto Superior de Agronomia, Portugal: Angola)
Samadi, Massoud (Institute for Soil, Climate and Water, Pretoria: South Africa)
Uaiene Rafael (INIA, Maputo: Mozambique)
Van Engelen, Vincent (ISRIC, SOTER Coordination)
Van Waveren, Erik (FAO, Swaziland)
Zanetti, Marina (FAO, GIS Coordination)

1 Introduction

The compilation of a Soil and Terrain digital database for the South-African region forms a part of the ongoing activities of the Food and Agriculture Organisation of the United Nations (FAO) and the International Soil Reference and Information Centre (ISRIC) to update the world's baseline information on natural resources. The updating of world soil resources, using the Soil and Terrain (SOTER) digital database methodology, is part of a global SOTER programme and intended to replace the FAO/Unesco 1:5 million scale Soil Map of the World (1971-1981). The African sheet of this map was published in 1973 and has been compiled on basis of information and data available at that time. It is understandable that a substantial part does not reflect the present state of knowledge of the soils in that region. The national institutes, responsible for the natural resources inventories, have been collecting a wealth of new information on the distribution and occurrence of soils in their region, which has resulted in updating their national soil maps mostly at scale 1:1 million, often applying the Revised Legend (FAO, UNEP, ISRIC, 1988) for the description of the mapping units. The International Union of Soil Science (IUSS) adopted an important change in the classification used for the map by introducing lower levels of subunits of the World Reference Base for Soil Resources (IUSS, FAO, ISRIC, 1998). This, together with the new soil data available at national level, justified such an update of the soil resources for the Southern African region.

An agreement between FAO and ISRIC to compile a SOTER database for Southern Africa (SOTERSAF) was signed in 2001. The agreement included the compilation and harmonization of SOTER databases for seven countries, viz. Botswana, Mozambique, Namibia, South Africa, Swaziland, Tanzania and Zimbabwe at an equivalent scale of 1:2 Million. A separate agreement was signed in 2002 for the compilation of a SOTER database of Angola.

The present SOTERSAF database has been compiled by joining all eight national SOTER databases into one overall database. This was possible because national SOTER databases have been compiled for Tanzania (1998) and Namibia (2001). Recently, the national institutes of South Africa and Zimbabwe have completed their own national SOTER and made them available for the SOTERSAF database. No SOTER database existed for Botswana, Swaziland and Mozambique. These have been compiled by ISRIC, using the available data from the national soil maps at scale 1:1 million, the national soil databases and available reports. Most of this information has been obtained through FAO (AGLL). A SOTER-like database existed for Angola, with two separate GIS layers for landforms and soils. These have been integrated into one SOTER layer and appended to SOTERSAF database.

A Digital Elevation Model, Gtopo30 DEM (USGS, 1996) validated in Europe with a DEM of higher resolution (King et al., 2002), has been used to support the delineation of SOTER units for Mozambique and was further consulted for the harmonization of the SOTER maps of the other countries. The soil map of Mozambique lacked sufficient detailed information on landforms needed to adjust the soil-mapping units into SOTER units.

After completion, the eight national SOTER databases have been joined into one SOTERSAF attributes database and GIS file (ARC/Info). Draft regional thematic maps were printed, displaying discrepancies between countries, not only differences attributed to scale causing substantial differences in detail, but also differences in level of distinction of attributes e.g. in landform, parent materials or soils. Through database harmonisation many of theses differences in level of distinction could be smoothed out, particularly for landforms. This was not possible for parent materials and for a number of SOTER units this attribute is only characterized at a higher and general level.

Differences in dominant soils (according to the Revised Legend, 1988 and WRB, 1998) existed for SOTER units occurring on both sides of a national border, having identical landform and parent material. A number of these differences on dominant soils could be corrected, but some remained as no additional information was obtained to justify a decision in favour of one of them. This still has to be followed up by the national institutes. For better harmonisation some additional SOTER units have been created. In a few SOTER units the dominant soil were only specified at soil group level, while subunit levels are mandatory. Most have been corrected.

A striking difference in resolution occurs in the SOTER database for South Africa where SOTER units are based on a scale of 1:250,000 compared to the other countries, which have been mapped at 1:1,000,000 scale or smaller. A generalisation of this large-scale database is required to comply not only with the mapping criteria, but also to obtain a "balanced" database with more equal resolution of land resources data. This could not properly be done for the South African database for reasons explained in paragraph 10.

A list of participating and contributing institutes is given in the box below.

Angola:	A soil and terrain database obtained through FAO (AGLL). Additional geographical and attribute data of Angola obtained in a cooperation with the Centro de Estudos de Pedologia (CEP) of the Instituto de Investigação Científica Tropical, Lisbon, Portugal
Botswana:	Data obtained through FAO (AGLL) and partly from ISRIC. Information originates from Soil Survey Section, Land Utilization Division, Ministry of Agriculture, Gaborone in cooperation with FAO Mapping and Advisory Services Project: BOT/085/11.
Mozambique:	Data obtained through FAO (AGLL). Information originates from Dept. Terra e Agua, Instituto Nacional de Investigação Agronomica (INIA), Maputo. Data collected in cooperation with FAO (MOZ/86/010) and other projects.
Namibia:	SOTER database obtained trough FAO (AGLL). Data source is the Agro-ecological Zoning Programme, Directorate of Agricultural Research and Training, Ministry of Agriculture, Water and Rural Development, Windhoek
South Africa:	SOTER database obtained from the Institute of Soil Climate and Water (ISCW), Agricultural Research Council, Ministry of Agriculture, Pretoria.
Swaziland:	Data obtained through FAO (AGLL). Information originates from the Land Use Planning Section, Ministry of Agriculture, Mbabane, in cooperation with FAO project: SWA 89/001.
Tanzania:	SOTER database obtained through FAO (AGLL). Information source is the National Soil Service (NSS), Mlingano in cooperation with FAO and other projects.
Zimbabwe:	SOTER database obtained from the Chemistry and Soils Research Institute (CSRI), Department of Research and Specialist Services (DR&SS), Harare. The CRSI compiled the SOTER database as part of a larger project for the United Nations Environment Programme (UNEP). FP/1300-96-75-22d.

2 Methodology

The SOTER methodology is a land resources information system based on the relation between the physiography (landform), parent materials and soils within a certain area. Compared to the traditional physiographic soil mapping, SOTER puts more emphasis on the relationships between landform, parent materials and soils, integrating these into one unit, the SOTER unit. The guiding principle for SOTER is the identification of areas of land with a distinctive and often repetitive pattern of landform, slope, parent material and soils. The highest level of distinction is the physiography, characterized by the dominant slope of the landform and its relief intensity. The broad mapping units obtained in such way are further refined separating new units on basis of different parent material and ultimately on differences in soils. Uniform expanses of land distinguished in such a way are called SOTER units. Each SOTER unit thus represents one unique combination of terrain and soil characteristics. The SOTER units should be sufficient large to be depicted on the map at its intended scale; this should be kept in mind when delineating the SOTER units. The present working scale 1:2 million does not allow to map all the differences presented on the 1:1 million soil maps. However these differences, which are not displayed on the map, can still be distinguished in the database by creating subdivisions of the SOTER unit. These are the terrain components and soil components.

Figure 1 gives an example of a SOTER map with polygons that have been mapped at a certain level of differentiation and shows the representation of a SOTER unit in the attribute database.

At the highest level, SOTER requires a spatial distinction in physiography. Often detailed information on the national physiography or landforms is lacking, or it is insufficiently described to suit the proper SOTER criteria. For that reason often information from various sources has been used. Sometimes the information on landforms can partly be found on the soil maps itself, provided the legends have a physiographic base. In such cases landforms and terrain components are partly inferred from the soil mapping unit and the description given at that level. Other sources with attribute data on landforms are geomorphological maps, land system maps, etc. from which SOTER attributes can be inferred. More modern techniques are explored nowadays, such as Digital Elevation Models (DEMs) to define the landform units, from which additional information can be obtained to describe the terrain attributes.

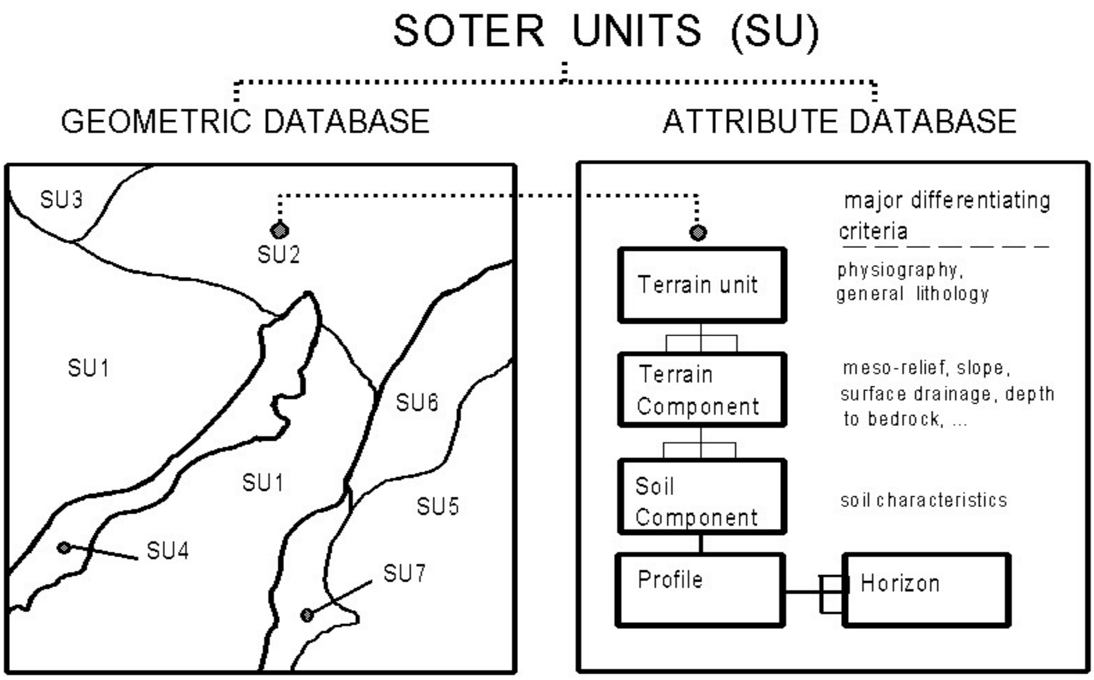

Figure 1 - Representation of a SOTER unit in the database and on a map (source: Van Engelen & Wen, 1995).

The guidelines for the compilation of a SOTER database can be found in the SOTER manual: “Global and National Soil and Terrain Digital Database” (van Engelen and Wen, 1995). The manual gives a number of discriminating criteria to delineate SOTER units and characterize them. For filling the SOTER attribute database a number of criteria and rules are given.
No further explication on the guidelines is given here, as it is expected that one is familiar with its procedures. For consultation of the manual one is referred to http://www.isric.org/index.cfm?mode=&menuid=2&menuitemid=8&submenuid=48

Table 1. Non-spatial attributes of a SOTER unit (source: Van Engelen & Wen, 1995)

TERRAIN

1 SOTER unit_ID
2 year of data collection
3 map_ID
4 minimum elevation
5 maximum elevation
6 slope gradient
7 relief intensity
8 major landform
9 regional slope
10 hypsometry
11 dissection
12 general lithology
13 permanent water surface

TERRAIN COMPONENT

14 SOTER unit_ID
15 terrain component number
16 proportion of SOTER unit
17 terrain component data_ID

TERRAIN COMPONENT DATA

18 terrain component data_ID
19 dominant slope
20 length of slope
21 form of slope
22 local surface form
23 average height
24 coverage
25 surface lithology
26 texture group non-consolidated parent material
27 depth to bedrock
28 surface drainage
29 depth to groundwater
30 frequency of flooding
31 duration of flooding
32 start of flooding

SOIL COMPONENT

33 SOTER unit_ID
34 terrain component number
35 soil component number
36 proportion of SOTER unit
37 representative profile_ID
38 number of reference profiles
39 position in terrain component
40 surface rockiness
41 surface stoniness
42 types of erosion/deposition
43 area affected
44 degree of erosion
45 sensitivity to capping
46 rootable depth
47 relation with other soil components.

SOILS

48 SOTER unit_ID
49 terrain component number
50 soil component number
51 reference profile_ID

PROFILE

52 representative profile_ID
53 profile database_ID
54 latitude
55 longitude
56 elevation
57 sampling date
58 laboratory_ID
59 drainage
60 infiltration rate
61 surface organic matter
62 WRB classification
63 WRB specifier
64 FAO classification
65 FAO classification version
66 FAO phase
67 national classification
68 Soil Taxonomy

HORIZON (* = mandatory)

69 profile_ID*
70 horizon number*
71 diagnostic horizon*
72 diagnostic property*
73 horizon designation
74 lower depth*
75 distinctness of transition
76 moist colour*
77 dry colour
78 grade of structure
79 size of structure elements
80 type of structure*
81 abund. coarse fragments*
82 size of coarse fragments
83 very coarse sand
84 coarse sand
85 medium sand
86 fine sand
87 very fine sand
88 total sand*
89 silt*
90 clay*
91 particle-size class
92 bulk density*
93 moisture content at various tensions
94 hydraulic conductivity
95 infiltration rate
96 pH H_2O*
97 pH KCl
98 electrical conductivity
99 soluble Na^+
100 soluble Ca^{++}
101soluble Mg^{++}
102 soluble K^+
103 soluble Cl^-
104 soluble SO_4^{--}
105 soluble HCO_3^-
106 soluble CO_3^{--}
107 exchangeable Ca^{++}
108 exchangeable Mg^{++}
109 exchangeable Na^+
110 exchangeable K^+
111 exchangeable Al^{+++}
112 exchangeable acidity
113 CEC soil*
114 total carbonate equivalent
115 gypsum
116 total organic carbon*
117 total nitrogen
118 P_2O_5
119 phosphate retention
120 Fe dithionite
121 Al dithionite
122 Fe pyrophosphate
123 Al pyrophosphate
124 clay mineralogy

Note: Table SOILS has a new addition; the WRB classification has been added to the profile table.

SOTER adheres to rigorous data entry formats necessary for the construction of a universal terrain and soil database. As a result of this approach the attribute data accepted by the database will be standardized and will have the highest achievable degree of reliability (van Engelen and Wen, 1995). The SOTER database structure for SOTERSAF is conform the structure given for the 1:1 million SOTER database. In total of 124 attributes can be described in the database as presented in table 1.

3 Procedures and conventions

The discrimination between undulating and rolling land deviates from the present SOTER guidelines (1995) and has been set at 10% in accordance with the Guidelines for Soil Description (FAO, ISRIC, 1990). This change in percentage from the previously 8 % to the present 10% should change the delineation of SOTER units in already existing databases. More land will fall in the category "level land". However it is assumed that this change has not affected the delineation of these SOTER units of the SOTERSAF database to a large extend. This was confirmed by the classification of slopes from the DEM. In Tanzania and Namibia the 8 % criteria has been used.

The SOTER manual states 15% as minimum for the proportion of the terrain and soil components in the SOTER units, but for SOTERSAF a minimum of 10% has been accepted. This implies that different soil-mapping units agglomerated into a new SOTER unit and thus similar soils have been combined into one soil component, unless there are reasons that these similar soils occurred in different terrain components.

As a general rule soils covering less than 10% of the SOTER unit are not listed in the database and are added to the soil component with a similar classification at major soil group level within the same terrain component. As an example, Calcic Luvisols (e.g. occupying 6%) have been combined to Haplic Luvisols (e.g. occupying 9%) and listed as one soil component Haplic Luvisols 15%. Note that in such a case another member of the major soil group e.g. Chromic Luvisols could well be dominant, e.g. occupying 35%.

In general soil components covering less than 10% and having no equivalent soil component at soil group level (no soil component with equivalent major soil group) have been omitted and the percentage added proportionally to the remaining soil components. In some exceptional cases inclusions of Leptosols and Regosols have sometimes been combined into one soil component, the dominant soil component occupying a minimum percentage of 10%. Note that for the harmonization at soil component level the Revised Legend (FAO, UNEP, ISRIC, 1988) has been used as a reference base for comparison.

The tables in the SOTERSAF database are related by their "primary key 'fields. For the tables, terrain, terrain component and soil component, these are the ISO country code (ISOC) and SOTER unit_ID (SUID), combined in the column LINK. The terrain component data table is relational to the terrain component table by its terrain component data_ID (TCDC).
The table profile and representative horizon values are linked by their profile_ID (PRID). This profile_ID also links these tables to the soil component table and thus forming a relational to the terrain and terrain component tables.

The SOTERSAF-GIS map has been drawn following the principle of geographic coordinates in decimal degrees and in the Lambert Equal Area Azimuthal Projection with the Central Meridian 20^0 East and Reference Latitude 5^0 North. The Digital Chart of the World was used as topographic base. Most countries used ARC/Info software or the ILWIS programme for digitising their SOTER map. Data has been stored in a relational database system using the MS Access programme following the SOTER input software version 3.20.

4 Outputs

The outputs for the SOTERSAF project are formulated as follows:
A generalized digital 1:2 million Soil and Terrain database for Southern Africa (SOTERSAF) on CD-ROM.

The project has a total of 4,250 SOTER mapping units divided over 6,074 polygons. These have been further subdivided in 9,004 terrain components and 15,937 soil components. In total 1328 representative profiles with 4795 horizons have been included.

Still many gaps exist in the database, as not all attribute information has been available. Particularly attributes describing the representative horizons in detail are lacking. Most of the physical data on bulk density, moisture content at various tensions, hydraulic conductivity and infiltration rate are also lacking. Only a few profiles have information on soluble salts, as this is only relevant for saline soils and therefore not included in most standard analyses.

Table 2. Details per country on SOTER units and their components

Country	Area (10^3 $km^{2)}$)	SOTER units	Terrain components	Soil components	Profiles
Angola	1,252	238	322	887	150
Botswana	578	94	145	404	60
Mozambique	788	225	325	641	127
Namibia	826	92	118	269	52
Tanzania	976	169	297	687	54
South Africa	1,251	3,039	7,006	11,822	328
Swaziland	17	19	32	72	14
Zimbabwe	392	143	200	294	156
Total	6,080	4,019	8,445	15,076	941

5 Conclusions and recommendations

The SOTER database for Southern Africa (SOTERSAF) has been compiled by joining the national databases of eight countries. These national databases, being compiled by different institutes displayed large differences in resolution and attribute data between countries. Particular striking has been the difference in resolution between South Africa database (SASOTER) and the other countries of SOTERSAF. The SASOTER database maintained the many units of the Land Type database at a scale of 1:250,000. Despite an attempt to generalize in the database by eliminating small terrain and soil components still the South African dataset maintains a high number of units and is considered to have limitations in its use, because no generalization was made to reduce the number of small SOTER units. Therefore the database is considered being not “well-balanced” and not having equal resolution of land resources data over the SOTERSAF mandate area, causing differences in quality of the dataset.

Some general conclusions and recommendations are:

1. Continuing SOTER units occurring in bordering countries have been harmonized as much as possible and many differences have been smoothed out. However, not all differences between countries could be resolved. Still discrepancies occur in e.g. soils between Botswana - Zimbabwe and Namibia - Angola. This should still get a follow up by the national institutes responsible for the natural resources inventories.
Almost no harmonisation of the SASOTER database with the neighbouring countries has been done, as a too large difference in resolution exists.

2. A future generalisation of the SASOTER should be considered to improve the quality of the SOTERSAF database and its use. This is only possible when one can dispose of the Land Type database. Not only the number of terrain and soil components has to be reduced further, but also the number of SOTER units by generalizing the units on the SOTER map. Many small SOTER units can probably included as terrain component in a larger SOTER unit.

3. In order to fill the existing gaps in the attribute data, additional soil profiles have to be included in the SOTERSAF database to replace synthetic and virtual profiles. It has to be realized that fully described and analysed typical profiles are needed to complete the representative profiles in the database. Particular attention should be given to collect profiles with soil physical data. It is hoped that the national soil survey organisations will contribute to this need by releasing additional soil profile data suitable for filling the present gaps and, for future updating of the SOTERSAF database.

6 References

FAO, ISRIC, 1990. Guidelines for Soil Profile Description. FAO, Rome.

FAO, UNEP and ISRIC 1988. Revised Legend, Soil Map of the World.

FAO-Unesco, 1971-1981. Soil Map of the World. Vol. I-X. Unesco, Paris.

IUSS, FAO and ISRIC 1998. World Reference Base for Soil Resources. FAO, Rome.

King, D., Saby, N., Le Bas, C., Nachtergaele, F., Van Engelen, V.W.P., Eimberck, M., Jamagne, M., Lambert, J. J., Bridges M., Hartwich, R., Montanarella, L.,, 2002. A method for generalization of a soil geographical database: The example of the transfer of the European database EUSIS at 1:1 M to the World SOTER program at 1:5M. Transactions of the 17th World Congress of Soil Science, August 2002, Bangkok. (on CD-rom, p 495/1-495/9).

USGS, 1996. Gtopo30 DEM, Eros Data Centre, Sioux Falls.

Van Engelen V.W.P. and Wen T.T. (editors), 1995. Global and National Soils and Terrain Digital Databases (SOTER), Procedures manual. International Soil Reference and Information Centre, Wageningen .

Annexes: Country Reports

I Angola

I.1 Base map and attribute information

The present SOTER database of Angola has been based on the digital Soil and Terrain map / database for Angola (Beernaert, 1997). This database has been obtained through FAO (AGLL). The main source of information for this soil and terrain map and database has been the "Carta Generalizada dos Solos de Angola", 3 rd approximation (Missão de Pedologia de Angola, 1965). For the present SOTER database, additional cartographic and attribute information has been obtained from the Centro de Estudos de Pedologia (CEP) of the Instituto de Investigação Científica Tropical (IICT), Lisbon, Portugal. Most of the profile data, which has been the base for the soil map and the present database, has been collected before the period of civil war.
The database of Angola has been compiled in a separate agreement, finalized in April 2003 and appended to the SOTERSAF database.

The digital Soil and Terrain map/database (Beernaert, 1997) consists of two separate GIS layers with its databases. One layer represents the soil map of Angola, displaying the dominant soils and soil associations according to the Revised Legend (FAO, 1988) at a scale of 1:2,500,000. The other layer, called the terrain unit map, at equal scale, gives the dominant landforms of the country, according to the commonly used "Major Land Regions" of Angola. A further subdivision of the landscapes of these Major Land Regions resulted in this terrain unit map or first version of a SOTER map. The landforms of this terrain unit map, although given the SOTER nomenclature, follow largely a geomorphologic subdivision and not the proper SOTER criteria for major landforms. Moreover, the accompanying soil and terrain database do not fully comply to the SOTER concept, as the terrain units of the first SOTER version in many cases do not coincide with the presented soil-mapping units. This has been a major constraint and reason to build a new SOTER database for Angola using the information of the terrain and soil layers of the first version. The present SOTER database has been compiled by integrating landforms and soils, taking into account lithology, resulting in more detail than the first version.

The revision of the Soil and Terrain (SOTER) database of Angola opened also the possibility to include available up to data information on the soils of Angola. The Centro de Estudos de Pedologia (CEP) of the Instituto de Investigação Científica Tropical (IICT), Lisbon, contributed to the SOTER database by making available the draft version of the "Carta Generalizada dos Solos de Angola", 4th approximation (Centro de Estudos de Pedologia, 1997).
The mapping units of this soil map, at scale 1:1 million, have been defined according to FAO's Revised Legend (1988), giving not only information on dominant soils, soil association and inclusions, but also on textural and topographical classes. Moreover in CEP's database vegetation and climate have been linked to the present soil-mapping units. This national soil map has been derived from a number of partial soil studies executed in Angola, covering provinces and districts at scales varying between 1:500,000 and 1:1,000,000. The legend has been compiled by correlation of the Portuguese Overseas Soil Classification (MPAM, 1965) into the Revised Legend (FAO, 1988)

Compared to the 3rd, the 4th approximation showed also a number of new soil units. Not all this new soil information could be incorporated into the new version of the SOTER database, although as much as possible has been entered in the terrain and soil components. Only in a number of cases, when soil or landform is significantly different, they have been incorporated in the SOTER map.

The delineation of landforms has been based partly on the terrain units as defined by Beernaert, (1997). In a number of cases however, the given terrain units appeared to have too much variation in slope or relief intensity and consisted of two or more landforms, e.g. plateaus with slopes from 0 to 15 percent. In such case SOTER will show this difference in a two SOTER units or, if one of the new units is too small or too irregular to be shown on the map, in two different terrain components. A Digital Elevation Model (DEM) of Angola (USGS, 1996) has been used to confirm the delineation of the landforms of the SOTER unit, according to a methodology developed by Huting (per. comm.). For this purpose the Gtopo30 DEM with a 1 km grid has been used. In order to decide on landform and to arrive at the required attribute data the soil and terrain unit maps have been used as overlays on this DEM.
Per SOTER unit the attribute data, such as elevation and slope classes have been estimated using the ArcView Spatial Analyst. The interpretative estimates from the DEM for some of these attributes in the database must only be seen as indicative until more accurate and reliable DEM become available. Despite all this information from the DEM the reliability on the landforms and most attributes is only moderate and need further improvement by calibration from actual topographic data. A major difference of the present SOTER compared to the original version is that a much smaller part of the landform turns out to be plateaus.

CEP also contributed a number of representative profiles (about 140) to the present SOTER database. However, no proper profile data could be obtained for soil components characterized as Leptosols, Fluvisols, Gleysols, Eutric Planosols and Humic Plinthosols. Furthermore the mapping unit “rocky terrain” has been divided into soil components Lithic Leptosols and partly into the miscellaneous component “bare rock” (AO-RO), conform the actual legend of the soil map and at the same time harmonizing to the rocky area in Namibia. Also a miscellaneous component “dunes” or “shifting sands” (AO-DU) has been created, which correspond with a similar component in Namibia. Dunes are in the WRB legend classified as Protic Arenosols. Note that 50 percent of SOTER unit 11 is open water.

The classification of the selected profiles according to the Revised Legend (FAO, 1988) and WRB (FAO, 1998) has posed some problems as diagnostic horizons and properties are sometimes difficult to indicate. Most soil descriptions were made in the fifties and sixties, not all attributes have been documented according to present-day standards. Lacking is e.g. the horizon designation, which is an indication for the observed diagnostic horizons and properties in the field. Morphological attributes like structure and clay illuviation were often not well described. Much attention has been given to the chemical analyses and mineralogical composition of the individual horizons, e.g. molecular ratios of silica and sesquioxides to define the fersialic and ferralic properties of the soils. It should be kept in mind that missing attribute data in the descriptions create often some uncertainty in the classification following the Revised Legend and WRB. The correlation of the “Portuguese Overseas Soil Classification” (MPAM, 1965) to the present FAO classification according to the Revised Legend, as given by CEP, and the correlation tables presented in the first SOTER version (Beernaert, 1997) have been used to arrive at the present FAO Revised Legend and WRB classifications. A particular problem is the justification of Calcisols, when having only secondary lime accumulation, is indicated in the description.

I.2 SOTER database of Angola

The terrain attributes, dominant slope and relief intensity have been estimated from the given slope classes in the legend of the soil map of Angola, from topographic descriptions of the profiles representative for the mapping units (partial studies) and from the DEM of Angola. The highest and lowest elevations could also be estimated from the contours of the DEM after overlaying it with the SOTER map.

The river valleys occurring in the northeast of the country (North Lunda province) have been steeply incised, and have cut through the Kalahari sand sheet into the Basement Complex forming complex landforms. Therefore, these have been classified as CV, valleys with a composite landform.
The dominant parent material (general lithology) has been given at type level using mainly the information from the first SOTER version and from a number of (partial) soil survey studies. The meta-sediments ("xisto-gresoso") are mainly classified as metamorphic rock, but depending on the source of this information sometimes could also be classified as sedimentary rock.
For the terrain components no data about meso-relief, depth to bedrock and depth to groundwater has been provided, as this information is generally not available.

The presented SOTER database for Angola contains 238 SOTER units, compared to 98 in the old version. The SOTER units are further subdivided into 322 terrain components and 887 soil components. A total of 150 representative profiles represent the soil components with 760 horizons. No proper profile data could be obtained for soil components characterized as Leptosols, (Eutric, Lithic, Calcaric subgroups), Fluvisols (Eutric, Thionic, Salic subgroups), Gleysols (Eutric, Dystric subgroups), Eutric Planosols and Humic Plinthosols.

Generally no attribute information is given on diagnostic horizons and properties, as well as horizon designations as this information has not been collected during profile descriptions in the field. Also a number of Munsell colours are still missing; these data will be delivered by CEP later and can be included in a next version.

All soil information has been collected before 1975, following the soil descriptions methods of the former Angolan Soil Survey Department (Missão de Pedologia de Angola and Moçambique, MPAM) and analysed by the laboratory of the present Centro de Estudos de Pedologia (CEP-IICT) Lisbon. It has to be noted that, although of high standard, a number of analytical methods used to characterize the attributes of the Angolan soils can deviate from present-day SOTER standards. This should be kept in mind when using the profile attribute data and when comparing these values with attributes of other profiles outside Angola.

This is e.g. the case for the particle size classes that follow different upper and lower limits. The sand and silt fractions do not fit in the USDA particle size classes and therefore can best be used as a total sand fraction. In the database for Angola the limits are for coarse sand (2-0.2 mm) and fine sand (0.2-0.02 mm), compared to USDA fractions; (2 -0.25 mm) for coarse and (0.25-0.05 mm) for fine sand. The silt fraction (0.02 - .002 mm) contains only fine silt, with the common limit for the clay fraction, particles smaller than 0.002 mm. Coarse silt form thus part of the fine sand fraction. It means also that the particle size class as given in the database has not been read from the conventional textural triangle, but from an adjusted one. (Gomes and Silva, 1962; Franco, 1986).

Deviating from the standard methods is also the cation exchange capacity determination (CEC). The barium chloride method, buffered with triethanolamine at pH 8.1, has been used for all samples of Angola. This higher pH of 8.1 compared to pH 7.0 for the standard ammonium acetate method, causes a higher exchange capacity through pH variable charge of the soil and thus higher CEC. The variable charge is relatively high for organic matter and clay minerals with a high exchange capacity. The difference in CEC between both methods will be smallest, when kaolinite is the dominant clay mineral, which possesses a low CEC. Hence, care should be taken to use the CEC of the Angolan soils directly and compared them to the rest of the database without being corrected for a somewhat too high CEC.
Note that the given P_2O_5 contents for Angola are the total phosphate contents.

References

Documentation:

Beernaert, F.R., 1997. Development of a soil and terrain map /database for Angola, Food and Agriculture Organization of the United Nations, Rome, and the Institute for Land and Water Management, Catholic University of Leuven.

Diniz, A. Castanheira, 1973. Características Mesológicas de Angola. Missão de Inquerítos Agrícolas de Angola, Nova Lisboa, Angola.

Franco, E.P. Cardoso, 1986. Um novo diagrama textural para uso com a escala international. Garcia de Orta, Lisboa, 13 (1-2): 1-7.

Gomes, M. Pereira and Silva, A. Antunes, 1962. Um novo diagrama triangular para a classificação básica da textura do solo. Garcia da Horta, Lisboa, 10 (1): 171-179.

Missão de Pedologia de Angola e Moçambique, e Centro de Estudos de Pedologia Tropical. 1965. Carta Generalizada dos Solos de Angola (3a approximação); Ministério do Ultramar, Memórias da Junta de Investigações do Ultramar No 56 (2da Série) ; Lisboa, 341 pp.

Missão de Pedologia de Angola e Moçambique (MPAM) e Centro de Estudos de Pedologia Tropical (CEPT), presently called the Centro de Estudos de Pedologia(CEP) do Instituto de Investigação Científica Tropical (IICT), Lisboa, published the following soil survey reports (Memórias da Junta de Investigações do Ultramar) nowadays Memórias do Instituto de Investigação Científica Tropical:
Carta Geral dos Solos de Angola - 1. Distrito de Huíla, 1959
Carta Geral dos Solos de Angola - 2. Distrito de Huambo, 1961
Carta Geral dos Solos de Angola - 3. Distrito Moçâmedes, 1963
Carta Geral dos Solos de Angola - 4. Distrito de Cabinda, 1968
Carta Geral dos Solos de Angola - 5. Distritos de Uíge e Zaire, 1972
Carta Geral dos Solos de Angola - 6. Distrito de Benguela, 1981
Carta Geral dos Solos de Angola - 7. Província de Cuanza Sul, 1985
Carta Geral dos Solos de Angola - 8. Distrito de Malanje, 1995
Carta Geral dos Solos de Angola - 9. Província de Bié, 2002

Maps:

Carta Generalizada dos Solos de Angola, (3a approximação), 1965. Missão de Pedologia de Angola e Moçambique e Centro de Estudos de Pedologia Tropical, Ministério do Ultramar, Junta de Investigações do Ultramar, Lisboa.

Carta Generalizada dos Solos de Angola, (4a approximação), 1997. Centro de Estudos de Pedologia do Instituto de Investigação Científica Tropical, Ministério da Cíencia e da Tecnologia, Lisboa

Databases:

Beernaert, 1997. Digital Soil and Terrain database of Angola, scale 1:2.5,000,000

II Botswana

II.1 Base map and attribute information

The Land Systems Map of the Republic of Botswana, 1990, at scale 1:2 million has been digitised and served as base map for the physiography and the delineation of the SOTER units. Attribute data on landforms have been taken from: "Explanatory Note on the Land Systems Map of Botswana" (de Wit and Bekker, 1990) and earlier studies (Bawden and Stobbs, 1963). From these sources interpretative estimates were made for the attributes general slope and relief intensity for defining the SOTER units. This information was compared to slope information obtained from the Gtopo30 DEM with a 1 km grid (USGS, 1996).
Information on parent material has partly been deducted from the legend of the mentioned land system map, with additional information taken from the Geological Map of Botswana (1973). Both served to discriminate further on parent material for refining the SOTER units.

The terrain components have been inferred from the description of the land systems and accompanying maps from de Wit and Bekker (1990) and for the eastern part of the country from Bawden and Stobbs (1963). The latter gives valuable information on land units and soils, which was used to distinguish terrain components.

The Soil Map of the Republic of Botswana, (De Wit and Nachtergaele, 1990a), at scale 1:1 million, served as basis for distinguishing the soil components within the SOTER units. The mapping units are described according to the Revised Legend of the Soil Map of the World, (FAO, 1988) and are composed of soil associates and inclusions. The digital format of the soil map allowed for a "weighted" calculation of each soil component within the SOTER unit on basis of the percentage of the soils given in the legend.

Most of the geo-referenced profiles were taken from the Explanatory Note on the Soil Map of Botswana with typifying pedons and analytical data (de Wit and Nachtergaele, 1990b). These profiles have been selected as representative for the soil units occurring in Botswana and are stored in digital format in the Soil Database of Botswana (SDB-B). All soil attributes of SDB-B have been recoded to the SOTER codes, before transferring them into the database.
Some additional profiles have been extracted from the SDB-B and so far this has been the only source of pedon data used for the Botswana SOTER. No profiles could be found in the SDB-B for the soil components characterized as Lithic Leptosols (LPq) and Ferralic Cambisols (CMo) petric phase.

On the Soil Map of Botswana most rock outcrops are classified as Lithic Leptosols (LPq) combining the very shallow soils and bare rock in one soil component. For the Aha hills in western Botswana a soil component was created with profile "BW-rock" to harmonize with the soils classified as bare rock in Namibia ("NA-rock").

In eastern Botswana, at the meeting point of the Zimbabwe, South Africa and Botswana borders, the soil map of Botswana gives as dominant soil Eutric Regosols, lithic phase. For harmonization with the dominant soil component in Zimbabwe these soils have been classified as Eutric Leptosols.

The WRB classification has been inferred from the given 1988 FAO classification and from profile information in the database. However most of the representative profiles had already a third level name that has been verified to fit the present WRB classification.

II.2 SOTER database Botswana

A total of 94 SOTER units at a scale of 1:2 million have been identified on basis of landform, parent materials and soils. These units are further subdivided in the database into 145 terrain components and 404 soil components. For the characterization of the soil components 60 representative profiles are stored (with 265 horizons). For the delineation of SOTER units on basis of soil differences the Botswana SOTER database has not been used to its full extent. Particularly the soil map of eastern Botswana shows a high resolution on soils and many soil units. No large differences in landforms at terrain component level could be inferred from the Land System Map and for that reason it has been preferred to subdivide the SOTER unit into soil components on basis of its "recurrent soil pattern".

Slope gradient and relief intensity are estimates and taken from various sources, available maps and legends (land system and soil map), DEM and from consulted reports. The upper limit of 10% for level land was applied according to the Guidelines for Soil Profile Description (FAO, ISRIC, 1990). The interpretative estimates from the DEM for some of these attributes must only be seen as indicative until more accurate and reliable data become available.
The same holds for the description of the terrain components such as dominant slope and length of slope in the terrain component table. No data are provided for the meso-relief forms, depth to bedrock and depth of groundwater as such data could not be obtained from the available data.

The information on the surface characteristics of the individual soil components are taken from the representative pedons and the soil profile descriptions found in the SDB-Botswana. Also other attribute data, such as surface stoniness, rockiness, and observable erosion, are taken from point data (profile descriptions) assuming that what holds true for the representative profile also holds for the entire soil component.
The representative profiles are geo-referenced and most have documented elevations. Soil classification is provided according to the Revised Legend (FAO, 1988) and was, in almost all cases, taken from the given classification. New in the SOTER database is an entry for classification at subunit level according to WRB. Most representative profiles for Botswana could tentatively be classified at this lower level with the help of the given 1988 FAO classification in which most third level units have already been indicated. Nevertheless some changes in the classification at subunit level have been made on basis of the now final morphological and analytical differentiation criteria in WRB.

No distinction could be made in the SOTER database for some analytical methods. For the particle size determination of the representative profiles, both the hydrometer as well as the pipette method has been used during the same period. These differences given at profile level cannot be given in the present version of SOTER. The same applies for electrical conductivity that in most cases is measured in 1: 2.5 soil/water solutions.

References

Documentation:

Bawden, M.G., Stobbs A.R. 1963. The Land Resources of Eastern Bechuanaland, Forestry and Land Use Section, Directorate of Overseas Surveys, Surrey, England.

De Wit, P.V., Nachtergaele, F. O., 1990a. Explanatory Note on the Soil Map of the Republic of Botswana, FAO Soil Mapping and Advisory Services, Ministry of Agriculture, Gaborone. BOT/85/011, Field document 30.

De Wit, P.V., Bekker, R.P., 1990. Explanatory Note on the Land System Map of Botswana, FAO Soil Mapping and Advisory Services, Ministry of Agriculture, Gaborone. BOT/85/011, Field document 31.

De Wit, P.V., Nachtergaele, F. O., 1990b. Explanatory Note on the Soil Map of the Republic of Botswana, Typifying Pedons and Soil Analytical Data, FAO Soil Mapping and Advisory Services, Ministry of Agriculture, Gaborone. BOT/85/011, Field document 30, Annex I.

Maps:

Land Systems Map of the Republic of Botswana 1990. de Wit, P., Bekker, R., FAO Soil Mapping and Advisory Project, Ministry of Agriculture, Gaborone . BOT/85/011.

Soil Map of the Republic of Botswana, 1990a. de Wit, P., Nachtergaele, F., FAO Soil Mapping and Advisory Service, Ministry of Agriculture, Gaborone. BOT/85/011.

Geological Map of Botswana, 1973. Geological Survey and Mines Department, Lobatse.

Databases:

FAO, 1991. Soil database of Botswana.

FAO, 1991. Digital Soil Map of Botswana.

III Mozambique

III.1 Base map and attribute information

The digital Soil and Terrain database of Mozambique (STD-M), scale 1:1million (Souirji, 1997), has been the base for the present SOTER database and map of Mozambique at scale 1:2,000,000. The compilation of this STD-M had been possible using data from the 1:1 million-scale soil map of Mozambique (DTA, 1994). This soil map and legend served as basis for the soil layer in the STD-M database. As mentioned in the report of Souirji the compilation of this soil map took place during the period of civil war, which made large areas inaccessible and field checking and collecting additional data impossible. Moreover, the resolution of data is not equally divided over Mozambique. Large areas in the North are only known at exploratory level or from satellite imagery interpretation without proper ground check, while in the southern part of the country soil mapping has been executed at semi-detailed level for the provinces Maputo and Gaza. Therefore large areas in Central and Northern Mozambique have low reliability.

The structure of the soil and terrain database for Mozambique (STD-M) follows an earlier SOTER database structure as is used in the Soils and Physiography Database of East Africa (FAO, 1993). The STD-M has several GIS layers, apart from soils also layers of parent material, landform and vegetation can be displayed using the legend conform the SEA publication. Not only the structure of STD-M is different from the present SOTER database, but also a number of attribute classes and coding, especially those of landform and parent material. Nevertheless the STD-M database and maps are used as basis for the present SOTER map.

The SEA legend allows for combinations of landforms and usually combines several, e.g. one legend unit is given as mountain/hill/mountain foot ridges/plateaus. Without further information it is almost impossible to decide what is the dominant landform for the SOTER unit, what are the terrain components and what is their proportion of the SOTER unit. Similar problems occur for parent materials. In order to define the physiographic basis of the SOTER units the present criteria for the SEA landscape units had to be refined.

A Digital Elevation Model (Gtopo30 DEM) with a 1 km grid has been used for this purpose. In order to decide on the landform and to arrive at the required attribute data the soil map has been used as overlay on the DEM. Per SOTER unit the attribute data of elevation and slope classes has been estimated using the ArcView Spatial Analyst. The interpretative estimates from the DEM for some of these attributes must only be seen as indicative until more accurate and reliable data becomes available. Apart from these estimates from the DEM, also the geo-morphological map of Mozambique (Mininisterio dos Recursos Minerais, 1983) has been consulted to verify the delineation of SOTER units.

The delineation of the final SOTER unit has been the combination of landform, parent materials and soils. The SOTER map has been derived from the soil map (STD-M) by digitising in ARC/Info. As the final scale of publication of the SOTERSAF will be 1:2 million, small soil mapping units have been combined into one SOTER unit as long as these fit into the landform units. Small soil mapping units, which are combined into one SOTER unit, will form often terrain and/or soil components within the SOTER database. E.g. inselberg areas with Leptosols, when large enough, are indicated on the soil map as small mapping units. However, when they are not mappable but occupy more than 10 percent of the SOTER unit, they are indicated as different terrain (and soil) component. Units smaller than 10% are discarded.

A substantial area between the rivers Limpopo and Save up to the Buzi river forms a extensive (gently) undulating plain of "Mananga" deposits, which is displayed as one SOTER unit. These are Pleistocene sediments, which form an up to 20 m thick layer and consist often of hard, difficult to penetrate and partly sodic soils. Mostly they are covered by a thin sand cover, which can reach a thickness of over 1 meter. These sediments are called "Mananga" by local farmers and are avoided for cultivation. The parent material of these "Mananga" soils is classified as unconsolidated colluvial. These soils classify as (Haplic) Solonetz and (Eutric) Planosols, and when sufficiently thick sand cover is present, as Arenosols. However, the proportional distribution of these three soils is insufficiently known, reason why they have been put together in one large SOTER unit.

The legend of the national soil map is built on the soil classification key with most important differentiating criteria: geomorphology, parent materials, topography, soil depth, soil texture, drainage, colour, cation exchange capacity (oxic units) and base saturation (dystric units). The soil classification key does not take into account most of the genetic (diagnostic) horizons as differentiating criteria. Therefore mapping units might be very heterogeneous and not consistent in terms of soil units as defined in the Revised Legend and WRB. On basis of the classification key no differentiation can be made between e.g. Luvisols, Lixisols and Cambisols as all these are reddish brown soils with a texture finer than loamy sand. But if an argic or a cambic horizon is present cannot be concluded from the national classification key, but only from the proper profiles in the SDB of Mozambique.

It has been a major problem to correlate the legend of the national soil map to the FAO classification according to the Revised Legend and WRB. This problem was also encountered during the compilation of the STD-M (Souirji, 1997). The selected profiles from the SDB of Mozambique (SDB-M) for representing the soil component had to be checked firstly on the presence of diagnostic horizons and properties. This is only possible if fully described and analysed profiles have been entered into SDB-M, which has not been standard practice. Profiles in the SDB-M often lack sufficient detail or have incomplete descriptions and analyses to decide on their diagnostic criteria, making the classification of most soils difficult.

Despite the many profiles in the database relatively few are from the northern provinces. Thus, many profiles from detailed studies in the south have been used as representative profiles for the soil components in the northern provinces to fill up these gaps. This is allowed as long as the legend of the national soil map indicates similar soil components in the mapping units, but as mentioned before mapping units can be very heterogeneous. This results in different soils between north and south Mozambique, when applying the Revised Legend, although the national legend indicates similar mapping units and soils. Therefore it has been tried as much as possible to find suitable (typical) soil profiles located in or near the SOTER unit.

III.2 SOTER database of Mozambique

The terrain attributes, dominant slope and relief intensity have been estimated from the given slope classes of the National Soil map, from regional slope data of profiles in the STD-M database and from the DEM, until more accurate data become available.
The dominant parent material (general lithology) has been given at type level. The parent material of the Mozambique belt, described as poorly metamorphized granite and granitic gneiss, has all been coded as gneiss (MA2).

The stoniness and rockiness in the soil component table are inferred from the key of the National Soil Legend, in which the estimated class values are given. No data are provided for the meso-relief, depth to bedrock and depth of groundwater as such data are not standard available for the profiles in the SDB-M.

The correlation given by Souirji (1997) between the Mozambican national soil legend and the Revised Legend (1988) has been the basis to identify representative (typical) profiles for the soil components. In his correlation no typical profiles have been found for 35 of the soil-mapping units of the STD-M (out of 117). This is a rather high percentage and therefore additional typical profiles were selected. Some of the lacking profiles have been added from the SDB-M, others from field documents and ISIS profiles (ISRIC, 1993; ISRIC Soil Information System), the latter fully described and analysed. For ten soil components no typical profile has been found.

For Mozambique 222 SOTER units have been identified. These SOTER units are further subdivided into 322 terrain components and 637 soil components. The soil components are represented by 164 typical profiles with 538 horizons. As mentioned for 10 soil components no typical pedons have been identified. These profiles are easy to recognize in the database as their coding consists of the ISO country code and their expected FAO soil classification (1988 version). In a few cases the initial national soil classification is maintained in the coding. This is done to indicate an uncertainty in the FAO classification or an expected difference with an already selected typical profile from a different region.
The WRB unit and subunit names are given. It has to be considered as a first approximate based on the morphology and often, incomplete analytical data. As mentioned previously the correlation between the key for the Mozambican national classification and the FAO Revised Legend and WRB is often weak. As much as possible typical profiles with a full description and analytical data have been selected. Nevertheless many typical profiles lack attribute data and even some profiles lack complete analysis.

References

Documentation:

DTA, 1993. Os solos das províncias Maputo e Gaza. Nota explicativa dos mapas de solos. Escales 1 :50.000 e 1:250.000, Dept. Terra e Agua, INIA, Maputo.

DTA, 1995. Land Resources Appraisal Report, District Xai-Xai . Dept. Terra e Agua, INIA, Maputo.

DTA, 1995. Legenda da Carta Nacional de Solos, escala 1:1.000.000. Dept. Terra e Agua, INIA, Maputo.

ISRIC, 1993. Soil Reference Profiles of Mozambique, Wageningen.

Souirji, 1997. Soils and Terrain database for Mozambique, scale 1:1.000.000. FAO consultant report.

Internal documents of the Dept. Terra e Agua.

Maps:

Carta de Solos de Moçambique, 1994. escala 1:1.000.000. Dept. Terra e Agua, Maputo.

Carta de Solos das Províncias Maputo e Gaza (parte Sul) 1993. escala 1:250.000, Dept. Terra e Agua, Maputo.

Ministerio dos Recursos Minerais, 1983. Carta Geomorfologica de Moçambique , 1:2.000.000.

Databases:

FAO, 1997. Digital Soil and Terrain database of Mozambique, scale 1:1.000.000

FAO, 1993. Digital Soil Map of East Africa, scale 1:1.000.000

IV Namibia

IV.1 Base map and attribute information.

NAMSOTER, the SOTER database for Namibia was compiled as part of the National Agro-Ecological Zoning Programme of the Ministry of Agriculture, Water and Rural Development (MAWRD). The compilation of NAMSOTER has been possible, because of a recent, nationwide project collecting natural resources data (Coetzee, 2001). The collected data has been described and coded according to the Guidelines for Soil Profile Description (FAO, ISRIC, 1990); this makes them suitable for the SOTER database.
From 1998 until 2000 the MAWRD carried out phase I of a National Soil Survey as one of the projects of the Agro-Ecological Zoning Programme. Although much attention was given to northern Namibia, with a more favourable climate and thus higher agricultural potential (mapping at 1:250,000), the programme also included a Pedo-Morphological mapping at scale 1:1,000,000 for the remainder of the country. This mapping served as basis for the Namibian SOTER map and the collected data as input in the attribute database. The report (Coetzee, 2001) gives a complete description of the methodology and of the materials used for the NAMSOTER database. Only minor changes have been made to the database and GIS coverage to harmonize with the databases of Botswana and South Africa.

The SOTER map shows three areas, which were excluded from phase I of the National Soil Survey. These are the Etosha National Park, the Skeleton Coast in the northwest, and the Diamond area in southwest of Namibia. It is aimed to include those areas in phase II of the National Soil Survey and update the NAMSOTER at the same time (Coetzee, 2001)

IV.2 SOTER database Namibia

The NAMSOTER database has been linked to the SOTER database of Botswana and South Africa requiring only minor changes in the northeast to harmonize the SOTER units at the Botswana border. One modification in the SOTER map has been made (unit NA14) and two polygons have been relabelled and given them a new SOTER unit_ID. One of these changes was made to differentiate the main course of the perennial Okavango and Chobe rivers (NA92) from their seasonal tributaries (NA27).

More changes have been made in the NAMSOTER attribute database. The original database contained class intervals for the attributes dominant slope and relief intensity. As SOTER requires only single values for these attributes, these have been estimated on basis of comparing the "dominant slope class" with the "regional slope". In the original database the dominant slope has been given as less than 10%, with a regional slope "gently undulating". Making use of this information the dominant slope, which has been entered in the present database, is estimated at 3 %. The estimated dominant slopes for other combinations is as follows:

Dominant slope given	Regional slope SOTER manual		Estimated dominant slope
< 10 %	0 – 2	flat	2%
< 10 %	0 – 2	flat, wet	1%
< 10 %	2 – 5	gently undulating	3%
< 10 %	5 – 10	undulating	8%
10-30%	10 –15	rolling	15%

10-30%	15 –30 moderately steep	25%
> 30%	30 - 60 steep	45%
> 30%	>60 very steep	60%

When the major landform is expected to have a different slope gradient adaptations were made. This information comply better with the SOTER criteria and must be seen as estimates, which has to be corrected when accurate data are available.

The eastern part of Namibia has been classified as plateau lands. In order to harmonise with the "elevated plains" of Botswana and South Africa, most of the plateaus have been redefined as plains. The parent material has been classified up to major lithologic group level (acid igneous rock) and not to type (granite) level. For the present scale this is sufficient and no further refining has been made.

Both slope gradient and slope length in the terrain component table have also been given as class intervals. SOTER requires these values as a percentage; therefore the slope has been estimated in the same way as in the terrain table, while slope length has been estimated from the given units. These estimates have to be refined and corrected in future.

In total 92 SOTER units have been identified, composed of 118 terrain components and subdivided in 269 soil components. The NAMSOTER database holds 56 representative, geo-referenced profiles. All representative profiles have been classified according to WRB 1998 and the Revised Legend (FAO, 1988). Harmonization on soils with Botswana and Angola is based on the soils classified according to the Revised Legend. Included in the database, as representative profiles are four "synthetic" profiles, which have only an indicative name and contain no attribute data. At present there are no suitable pedons available to represent these four profiles; in future these can easily be replaced.

One of these profiles represents those areas with "bare rock" at the surface and no soil development. It is entered in the database as "NA-Rock" and has not been given a soil classification according to the Revised Legend (1988). Also "Active Sand" has been entered as dunes according to the Revised Legend (FAO, 1988) and as Protic Arenosols for the WRB (FAO, 1998). The other two profiles are entered as Leptosol, Solonchak and have respectively been classified as LPe and SCh.

References

Documentation:

Coetzee, M.E., 2001. NAMSOTER, A SOTER database for Namibia, Agro-ecological Zoning Programme, Directorate of Agricultural Research and Training, Ministry of Agriculture, Water & Rural Development, Republic of Namibia.

Databases:

NAMSOTER, the SOTER map of Namibia, 2001.

Digital SOTER database, 2001.

V South Africa

V.1 Base map and attribute information

The SOTER database for South Africa (SASOTER) has been compiled by the ARC- Institute for Soil, Climate and Water (ISCW) of the National Department of Agriculture, Pretoria. A first draft of the SASOTER database was received in July 2002. The database contained many details from the original Land Type database. It appeared also that errors occurred in the proportion of the soil components, the sum of percentages exceeding 100% of the SOTER unit. Because of these shortcomings the ISCW was requested to generalize the database and correct the proportion of the soil components. Due to manpower and financial constraints ISCW could not generalize the database. However, they made a commitment to correct the percentages of the soil components. The corrected database has been received early November 2002, leaving little time for harmonization with the other SOTERSAF countries. Nevertheless some database harmonization of the South African part was made.

The SASOTER database has been built on the existing Land Type database of ISCW, which is based on 1:250.000 scale maps of the land type series, the land classification of South Africa. The land type resembles partly a SOTER unit, in that the land type is subdivided in terrain units and subsequently in soil series. However, the criteria used to distinguish land type units differ in a number of aspects from the definitions used in SOTER methodology.

In order to maintain the link between the original Land Type database and the SASOTER database ISCW did not generalize to the intended scale. This implies an unwanted detail of the map when used at a scale of 1:2 million. From the SOTER methodology point of view generalization of the SOTER map and database is still needed. However, without disposing of the data of the Land Type database such a generalization is impossible and cannot be done by ISRIC.

The present database contains more than 3200 SOTER units. This outnumbers the total of the SOTER units in the other 7 countries and creates an imbalance in resolution of the map and data. The SASOTER map has a much higher resolution than the other countries; the database is very detailed at soil component level, displaying many soil components covering much less than 10 % of the unit. This is not conform the SOTER methodology and suggests a precision, which is unrealistic and not relevant for this scale.

Except for minor corrections nearly all the mapping units of the Land Type series map can be found back on the SOTER map, being now the SOTER units. Each SOTER unit has been assigned the attribute data available in the Land Type database. The criteria to define the land type are different from the landform criteria used for SOTER. Therefore additional attributes to classify the landforms have been derived from a DEM with a 400 m grid.
By using computer programming, ISCW analyzed the DEM and differentiated the landforms automatically following a fixed set of criteria. The first step in analyzing the DEM is to differentiate on slope, next to differentiate the DEM data further into second level landform units as plains, plateaus, valley floors, medium-gradient mountains, hills, etc, using the cross-sections of the Land Type series. How this was done and what algorithm has been used is not yet published.

In order to select a DEM, which identifies well the SOTER landforms, tests with DEM's of various resolutions have been compared for the Barberton area bordering to Swaziland. The selected DEM with a 400 m grid appeared the most suitable. In this test area the chosen DEM appeared to give fairly accurate results regarding the first delineation of terrain units based on its slopes.

The major landforms are given in the database together with the regional slope class, which has been derived from the 400-meter grid DEM. Although the first trials with this DEM showed good results, in the final output the slope classes of this DEM appeared to be underestimated in a number of cases. Also the attributes of slope gradient and relief intensity, criteria to classify the landform, were missing in the terrain table and thus could not be used for adjustments. Therefore a visual comparison was made between the given landforms and a DEM (Gtopo30) based on a 1km grid, corrected for slopes at ISRIC. This revealed a good correspondence of the general pattern of major landforms in the SASOTER database and the derived slope map based on this DEM. On basis of this comparison no changes have been made.

Despite this good correspondence some major landforms occurred too frequently as might be expected from the landscape conditions, such as valley floors and dissected plains. The valley floors covered very extensive units, which in SOTER methodology will classify as plain. This shortcoming in the landform classification using the DEM has been corrected for a major part by re-assigning valley floors to plains, based on the extension and shape of the polygon, compared to the surrounding area and using a topographic map scale 1:1 million. Valley floors are generally expected to have elongated polygons. In this way the percentage of valley floor units has been decreased from 30% to less than 8% of the SASOTER database. Also a few high gradient valley units have been re-assigned to both high and medium gradient hills based on their polygon shape and surrounding area.

Some harmonization of the SOTER database has been made in the areas bordering to neighboring countries. Particular this is done for the attributes major landforms and parent material to display a corresponding general picture. Still many polygons on the South African side do not continue in a similar unit on the other side of the border. It is obvious that some further harmonization has to be done.

Lesotho has not been covered in the SASOTER database.

V.2 SOTER database generalization

The attribute description of the SOTER units at terrain level follows the dominant terrain unit of the dominant land type in the Land Type database. The attribute description for the terrain components has been taken from all terrain units of the dominant land type. Most SOTER units have four terrain components, which correspond with the terrain units. This can be crest, scarp, midslope, footslope and valley bottom. Scarps and some other terrain subunits are less frequent.

The original database contained more than 12,000 terrain components of which many (about 30%) are smaller than 10% of the unit. All those terrain components smaller than 10% have been joined and allocated to larger units according to the following rules:

- All terrain components with number 5 (TC5) less than 10% have been allocated to terrain component number 4 and continue as TC4, while TC5 larger than 10% remained as terrain component. For the attribute data of the joined TC4 and TC5 those of the TC4 is maintained. This decision is based on the assumption that the small TCs are usually valley bottoms and footslopes, which can be joined as one terrain component.

- Similar this has been done for TC1 and TC2. All TC2 less than 10% have been allocated to TC1 and continue as TC1, under the assumption that scarps can best be added to the crests.
- All SOTER units with four or more terrain components and with a TC3 less than 10% are allocated to TC4. After joining the TCs, the attribute data of the remaining TC is kept and those of the discarded TC are deleted.
- A number of SOTER units have more than five terrain components. All TC6 and TC7 smaller than 10% have been joined and allocated to the largest TC usually this is TC1.
- The last step is to eliminate all remaining TCs smaller than 10 % and to allocate them to the largest TC of the SOTER unit. This resulted in 7,580 terrain components.

The original database contained more than 70,000 soil components of which more than 50 % are smaller than 10 % of the unit. To reduce the large number of soil components in a sound way, the following steps have been taken:

- All soil components (SCs) belonging to the eliminated TC have been joined to SCs of their new TC.
- All soil components with a similar WRB classification occurring in one TC have been joined and added to the largest SC with the same WRB classification (subunit level), discarding the smallest SC.
- All SCs within a TC and with a similar WRB reference soil group (highest level) smaller than 6% has been added to the largest SC reference soil group in the TC, e.g. Rhodic Cambisols (2%), Calcaric Cambisols (3%) and Eutric Cambisols (7%) will become Eutric Cambisols (12 %). Condition is that the terrain component is larger than 10% of the SOTER unit.

These steps have reduced the number of soil components to 29,052.

Still a considerable number of soil components within the SOTER unit are smaller than 10 %. Reason that they remained in the SOTER unit is, because the SCs belong to different major soil groupings of the FAO Revised Legend (1988), e.g. 1% ARh, 1% RGe and 5% LPe.
The following decisions have been taken to agglomerate these small SCs.
- For each TC, soils of different soil components smaller than 10 % have been agglomerated into one of the following three groups of soils.
 a.) “ wet soils” with major soil groupings HS, VR, FL, GL, PT, PL, SN.
 b.) soils with “no or little soil developments” LP, SC, GY, CL, CM, RG.
 c.) “upland soils”, mostly “ well developed soils” AR, FR, CH, KS, PH, NT, AL, AC, LV, LX, PZ.
- Is one of the three newly formed groups within the TC smaller than 5% than this group is joint with the largest group in the TC without considering its composition. The smallest possible SC is now 5% of the TC.
- Soil components in the remaining groups, together larger than 5% (two or more SCs) are added to the largest SC of each of the three groups, e.g. 1% GL, 1%FL, 1% HS and 3% VR become 6 % VR. In case of equal percentages of the largest SCs in the group, the adding is done to the first ranked, largest of the group. In this way the number of soil components has been reduced to 12,712. Re-labeling identical SOTER units (similar attribute description and soil components) made a further reduction to 11,822 soil components.

V.3 SOTER database for South Africa

The SOTER database of South Africa, which has been included into the SOTERSAF, contained a reduced number of terrain and soil components as compared to the original SASOTER database.

Still the number of SOTER units, terrain and soil components of SASOTER outnumbers those of the other countries in the database.
In total there are now 3039 SOTER units in SASOTER, 7,006 terrain components and 11,822 soil components. These are represented by 328 geo-referenced profiles in the database and many virtual profiles, the latter having only a WRB classification and a textural class.

A few changes have been made in the database to harmonize landforms in the border areas with Namibia, Swaziland and Mozambique particularly on landforms. At the border with Swaziland some additional units have been classified as plateaus, harmonizing with the units in the southwestern part of Swaziland. Changes have also been made in the landforms of the SOTER units along the Orange River harmonizing the border area to Namibia. A harmonization at soil component level has been made to correlate with the soils of Swaziland. In consultation with ISCW a few SOTER units have been split up and additional profiles added.
A number of virtual profiles with no WRB classes are actually " miscellaneous land classes" for which there is no WRB classification. In the database these are coded with one single letter. These miscellaneous land classes can be interpreted as follow:

R Rocks and rocky area, generally classified as Leptosols.
S Stream beds
W Dunes
T Coarse deposits
P Pans
M Marshes
H Reclaimed land
E Erosion
A Other

References

Dept. of Agriculture and Water Supply, 1987. Land Types of the Maps Rustenburg (2526) and Pretoria (2528). Memoirs on the Agricultural Natural Resources of South Africa No. 8.

VI Swaziland

VI.1 Base map and attribute information

The physiographic map of Swaziland, scale 1:750,000 (Remmelzwaal, 1993) served as base map for the delineation of the SOTER units. The map shows the major physiographic zones and includes also the second level landforms, based on topography and altitude. In order to comply to the SOTER criteria, and in consultation with Remmelzwaal, some refinements have been made to this map to delineate the SOTER units. These are based on a subdivision of second level landforms, which satisfy best the differences in dominant soils. The subdivision of the second level landforms was mainly made in the Upper Middleveld, in the Highveld and Lebombo range.

The report, "Physiographic Map of Swaziland", (Remmelzwaal, 1993) supplied the attribute data for the major landforms. These have been compared to the DEM and adjusted when necessary. The report did not only give attribute data on landforms, but also information on parent material and on the dominant "soil sets" of the physiographic units. These soil sets and series, also known as "Murdock series", refer to the study "Soils and Land Capability in Swaziland " (Murdock, 1970). In this study the soil sets and series are briefly characterized and analytical data of "average values" for top and subsoil given. However, these data of "average values" are insufficient for proper differentiation on soils according to the Revised Legend (FAO, 1988).

Fortunately 10 representative profiles could be obtained from the Swaziland database (Remmelzwaal & Masuku, 1994), four others are from an erosion study in the Upper Middleveld (Scholten, 1997).

VI.2 SOTER database for Swaziland

Swaziland has only 19 SOTER units. These units are subdivided into 32 terrain components and 72 soil components. The terrain components are based on the second and third level subdivision made in the physiographic map of Swaziland. These subdivisions represent different terrain conditions (mainly slope) and cannot be shown on the SOTER map (Remmelzwaal & van Waveren, 1994). The report also gives the dominant and subdominant soil series according to Murdock and their proportion within the physiographic unit. Using this key the proportion of the soil component per SOTER unit could be obtained. Soil components covering less than 10 % are excluded, the percentage is added to the most related soil series. The final step has been to correlate the Murdock's series to the FAO classification according to the Revised Legend (1988) and to the WRB classification (1998). This is tentatively done for those series lacking representative profiles and which are only based on the descriptions of Murdock. The different Murdock series (soil components) in the database are characterized by 14 different soil profiles. No representative profiles have been obtained for 11 soil components.

Not all attribute data has been obtained, e.g. no data were found for depth to groundwater and depth to bedrock. Also no attribute data existed for observed erosion and for the flooding frequency.

References

Documentation:

Murdock, G., 1970. Soils and land Capabilityin Swaziland. Ministry of Agriculture, Swaziland.

Remmelzwaal, A., 1993. Physiographic Map of Swaziland. Land Use Planning Section, Ministry of Agrriculture (in cooperation with FAO/SWA/89/001), Mbabane.

Remmelzwaal, A. and B.S. Masuku, 1994. Characterization and Correlation of the Soils of Swaziland. Land Use Planning Section, Ministry of Agrriculture (in cooperation with FAO/SWA/89/001), Mbabane.

Remmelzwaal, A. and E.J. van Waveren, 1994. Agro-Ecological analysis of Swaziland. Part A. Land Resources: The Agro-Ecological Map. Land Use Planning Section, Ministry of Agrriculture (in cooperation with FAO/SWA/89/001), Mbabane.

Scholten, 1997. Genese und Erosiensanfällifkeit von Boden-Saprolit-Komplexen aus Kristallingesteinen in Swaziland. Justus-Liebig-Universität Giessen, Germany.

Maps:

FAO, 1994. Agro-Ecological map of Swaziland (including the physiography), Mbabane.

VII Tanzania

VII.1 Base map and attribute information

A SOTER database of Tanzania, scale 1:2,000,000 have been available since 1998 (Eschweiler, 1998). The main source of information for this SOTER database has been the earlier work of de Pauw (1984). His map “Soils and Physiography” (1983) at scale 1:2 million and report on “Soils, Physiography and Agro-Ecological Zones of Tanzania” served as basis for the delineation of the SOTER units. The map displays the land units within their broader physiographic zones and describes a.o. for each unit the dominant parent material, slope and hypsometry. The report also gives the relation between the landform unit and the generalized soil pattern (position of the soils in the landscape) and the distribution of dominant and subdominant soils. This information formed the basis of the SOTER database for Tanzania (Eschweiler, 1998). Representative profile information has been taken from the SDB of Tanzania (1998).

The procedures followed for the Tanzanian SOTER database have been somewhat different from the other SOTERSAF databases. It has followed the guidelines developed for the SOTER database at scale 1:2,5 million (Batjes and Van Engelen, 1997). Although derived from the Global and National Soil and Terrain Digital Database, scale 1:1 million (Van Engelen and Wen, 1995), this database has a restricted number of attributes. As a consequence of smaller scale, the number of attributes has been reduced from 124 in the original database to 74. This was justified because of most discarded attributes no data are available.

The GIS database included about 100 polygons, which on the Pauw’s map had been classified as miscellaneous landforms, such as undifferentiated rocky terrain, rocky hills, escarpments, slopes, canyons, etc. These had not been further specified in the original SOTER database for Tanzania. However for the SOTERSAF, these have been redefined and regrouped in a number of SOTER units. Depending on the physiographic zone in which the polygons occur, and with the additional information of a DEM with 1km grid (Gtopo30), they have been classified in 14 new SOTER units, ranging between medium-gradient hills, escarpments and high-gradient mountains. Some (small) polygons, often inselberg areas, have been erased from the map and in the database added as terrain components to the SOTER unit in which they occurred.

Missing terrain attributes in the Tanzanian database are maximum, minimum elevation, dominant slope gradient, relief intensity and dissection. Also at terrain component and soil component level some less important attributes have been omitted, such as depth to bedrock, depth to groundwater, frequency of flooding and flooding periods; omitted for the soil component are the attributes describing the observed erosion, and sensitivity to capping.

Not easily available attributes in the profile and representative horizon table, such as soluble salts, hydraulic conductivity, etc. have also been omitted. Also attributes considered important in SOTER, but which are not available in the SDB of Tanzania such as those for diagnostic horizon and properties, pH (KCl), exchangeable acidity, gypsum, bulk density and moisture content at various tensions have also been left out. As the SOTER of Tanzania has been incorporated into SOTERSAF database, these attributes remain empty for a larger part, except in those cases where additional soil and terrain data has been consulted to make amendments and corrections for the harmonisation of the database.

VII.2 SOTER database for Tanzania

The SOTER database of Tanzania included a few units with major landform "dissected plateau" (SL), a newly defined major landform with slopes between 10 and 30 % and relief intensity of more than 50 m/slope unit (Eschweiler, 1998). Because "dissected plateau" is not an accepted landform in the SOTER hierarchy, it has been redefined into dissected plain (SP), for SOTER units 128,129, and into medium gradient hills (SH) for units 112, 127.

In the original database the upper limit of level land was set at 8% (Batjes and Van Engelen, 1997). The database makes also a difference in unconsolidated calcareous and non-calcareous parent materials according to the differentiation made in the 1:2.5 million database

To redefine the miscellaneous landforms given by de Pauw, some difficulty was encountered for the South-western Highlands, as very little additional information was found in support of the differentiation of these landforms in steep hills, escarpment and medium gradient hilly areas. Also the DEM indicated a large variation in slope and altitude not coinciding fully with the given SOTER units.

The dominant slope for the terrain component has been given as class intervals identical to the regional slopes given in the terrain table. As SOTER requires numeric values for these gradients, they have been estimated according to following rules:

Wet	(W)	dominant slope gradient	0 %
Flat	(F)	,,	1 %
Gently undulating	(G)	,,	4 %
Undulating	(U)	,,	7 %
Rolling	(R)	,,	12 %
Moderately steep	(S)	,,	25 %
Steep	(T)	,,	45 %
Very steep	(V)	,,	60 %

A number of terrain and soil components did not add up to 100 percent (entry errors) and have been corrected to the full coverage of the SOTER unit. Some adjustments were made to harmonize with the SOTER database of Mozambique along the national border.

A major difficulty has been to convert the profiles with a given 1988 FAO soil classification into the new WRB (1998) soil classification. It appeared that often some essential information is missing in the database to decide on its third level. For that reason most of the WRB entries are similar to the 1988 Revised Legend. Nevertheless some WRB classification could be made up to the third level.
The SOTER database of Tanzania contains in total 169 SOTER units subdivided into 297 terrain components and 687 soil components. These are characterized by 89 representative profiles of which only 54 have analytical data. For the remaining 35 no suitable representative profiles have been found.

References

Documentation:

De Pauw, E. 1984. Soils, Physiography and Agro-Ecological Zones of Tanzania. Crop Monitoring and Early Warning Systems Project, FAO. GCPS/URT/047/NET, Ministry of Agriculture, Dar es Salaam.

Eschweiler, J.A., 1998. SOTER database Tanzania, FAO, AGLL Working Paper No 8.

Maps:

De Pauw, 1983, Soils and Physiography. Crop Monitoring and Early Warning Systems Project, FAO. GCPS/URT/047/NET, Ministry of Agriculture, Dar es Salaam.

Databases:

FAO, 1998. SOTER database Tanzania. Eschweiler, J.A.

VIII Zimbabwe

VIII.1 Base map and attribute information source

The Chemistry and Soil Research Institute (CSRI), within the Department of Research and Specialist Services of the Ministry of Lands, Agriculture and Water Development, Harare, Zimbabwe, has compiled a SOTER database at scale 1:1 million. The database compilation formed part of a larger, UNEP funded, project titled: "The Impact of Desertification on Food Security in Southern Africa: a case study for Zimbabwe". This project has been jointly undertaken by UNEP, ISRIC and CSRI. The project continues with studies of the interpretation of the SOTER database. The database was compiled between 2001 and mid 2002.

A first differentiation in the compilation of the SOTER unit map has been based on the 1:250,000 scale topographic maps with additional information of aerial photographs, parent materials and the existing soil maps o.a. of the Communal Land Areas at scale 1:500 000. After the delineation of the SOTER units attribute data on terrain and soils have been added to the database. Without making changes for scale the original SOTER map and database at 1:1 million has been used for the 1:2 million scale of the SOTERSAF database.

Most of the soil profile data comes from the Inventory of the Communal Lands of Zimbabwe, for which the surveys have been undertaken between 1985 and 1991 (Anderson et al., 1993).

VIII.2 SOTER database for Zimbabwe

The SOTER database of Zimbabwe contains 143 SOTER units, which have been subdivided into 200 terrain components and 295 soil components. In total there are 213 entries for representative profiles, but only 156 are actually geo-referenced, described and analysed. For the missing profiles 57 "synthetic" profiles has been created for which at least the FAO and WRB classification have been given.

A few additional SOTER units have been created for harmonization with the units along the borders with Botswana and Mozambique. Particularly at the eastern border with Mozambique differences in resolution created harmonization problems, which has been partly solved by re-labelling some SOTER units. In Zimbabwe much more detailed information has been available compared to Mozambique. The border harmonization has not resolved all the discrepancies in landform, particularly not in the central mountain region in the eastern part of the country. This still has to get a follow up by the national institutes responsible for the natural resources inventories.

The harmonisation between Zimbabwe and Botswana on dominant soils, according to the Revised Legend (FAO, 1988), could only partly be resolved; a.o. Lithic Regosols in northeast Botswana have been provisionally converted into Eutric Leptosol to harmonize with the Eutric Leptosols in Zimbabwe. Not all differences along the border could be solved and still need further follow up by the national institutes; e.g. no harmonization could be made between the Arenosols in Botswana and the Lixisols in Zimbabwe in the Kalahari Sandveld region.

References

Documentation:

Anderson et al., 1993. Physical Resource Inventory of the Communal Lands of Zimbabwe, An overview, NRI Bulletin 60. Natural Resources Institute, Chatham, UK.

Nyamapfene, Kingston, 1991. Soils of Zimbabwe. Nehanda Publishers, Harare, Zimbabwe

Databases:

CSRI (unpublished). SOTER database of Zimbabwe at scale 1:1 million.