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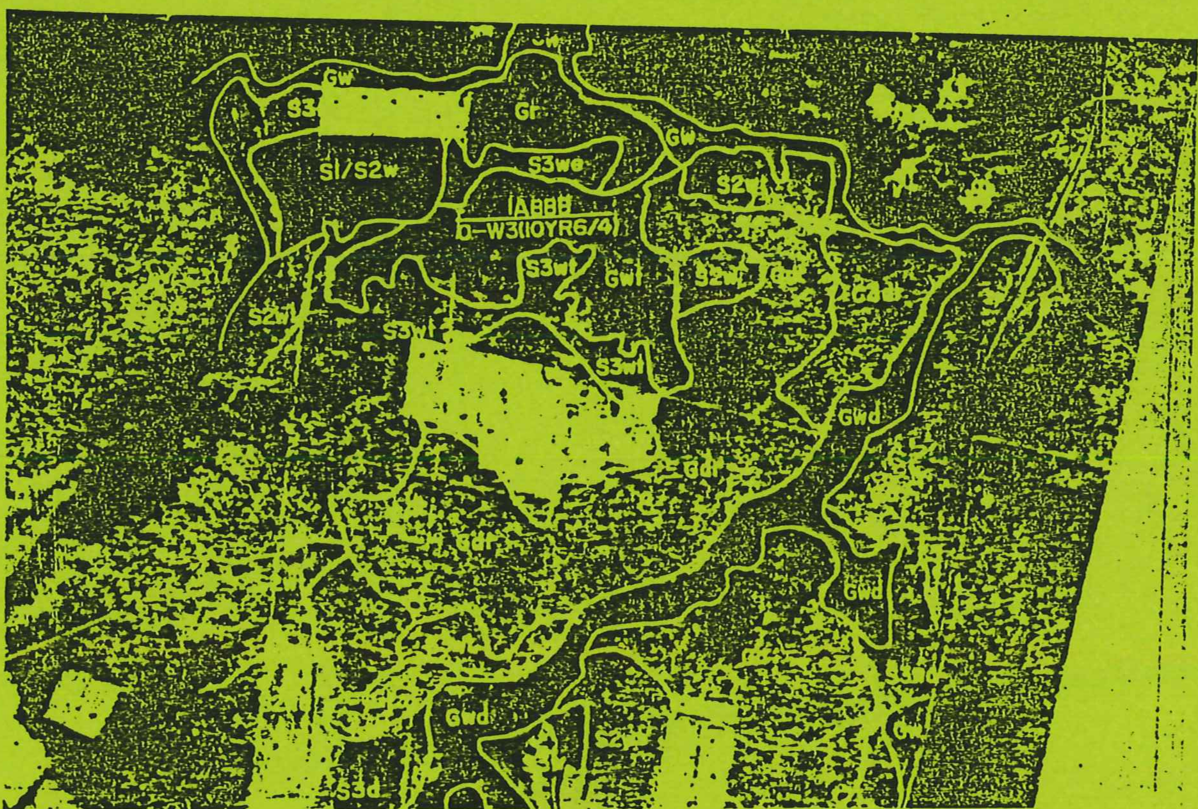
TECHNICAL GUIDE No. 13

SOIL SURVEY GUIDE



SOIL SURVEY UNIT
LAND USE BRANCH
DEPARTMENT OF AGRICULTURE

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TECHNICAL GUIDE No. 13
SOIL SURVEY

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Contents

Preface

The text is an updating of Technical Guides numbers 1 to 6 written by H. Brammer during 1973. They have been revised and new ideas added. The aim of this Technical Guide is to standardize the output of the Soil Survey Unit. Its purpose is not to prescribe in detail how soil surveyors should execute their surveys. Land evaluation is only dealt with as far as its requirements with respect to soil survey are concerned.

In chapter 4 particular reference is made to the Guidelines for soil profile description" (FAO. 1979). This chapter should be seen as a kind of appendix to these "Guidelines". Technical Guide No. 13 is intended to evolve into a Soil Survey Manual for Zambia after some years of testing. Comments and proposals for further revisions are therefore always welcome, and should be directed to the Soil Correlator at Mount Makulu.

This text was written by W.J. Veldkamp and Wen Ting-tiang. A. Commissaris, R.J. Chestle, D.B. Dalal-Clayton, R. Magai, C. English (Soil Survey Unit) and M.C. Daly (Geological Survey Department) made useful additions and comments. The senior author acted as final editor.

1. INTRODUCTION

1.1 General

Soil survey is the process of distinguishing, describing, characterizing, classifying and mapping soils, as well as predicting their behaviour under, and adaptability to certain kinds of management. Soil survey is thus directed to land-use purposes, which are mainly of an agricultural or sylvicultural nature. Hence the main users of soil maps are farmers, foresters, planners and other involved in land development. They want to know what soils occur in a certain area and are especially interested in the general characteristics of these soils, their differences, and how they compare to soils elsewhere. Above all they want to know the limitations of the soils, enabling them to assess their suitability for farming or forestry in general, and for crops in particular. Conversely, they may be interested in pinpointing areas or sites with soils which are known to be suitable for certain crops. While surveying, these purposes should be kept in mind all the time.

1.2 Land and physiography

Land and soil are different terms. Soil is part of the earth's surface that supports plants and that has properties due to the integrated effect of climate, man, animals, plants, parent material, topography and time. Land includes soils, but also the underlying rock or deposit , the (micro) climate, the vegetation, in fact everything on, above or below the surface of the earth. Description of land includes the landforms. Each landform has its own particular set of characteristics amongst which the soil. On each landform different elements exert their influence on soil formation, such as the underlying rock, the slope, the vegetation, the hydrology, etc.

The delimitation and description of landforms is called physiography. Physiographic units are often very suitable for making an initial gross division among units of land, followed by units of soil. Therefore, the physiography is an appropriate differentiating factor in soil map legends. There exists a danger, however, that especially small scale maps are rather more physiographic maps than soil maps. This should be avoided as much as possible.

1.3 Accuracy and Scale

The scale of the map shows for two given points the relationships between their distance as measured on the map and their actual distance on the ground. The smaller the relation, i.e. the less these two distances differ, the larger the scale.

Detailed or very detailed maps are large scale maps, usually covering relatively small areas; small scale maps on the other hand, show large areas, provinces or even a whole country. Reconnaissance or exploratory maps are examples of small scale maps. An intermediate scale is semi-detailed. Table II shows this division in scales.

The accuracy of a survey is determined by the density of observations per cm^2 map surface. A density of 0.5 observation per cm^2 map surface can be taken as an acceptable accurate value. In Table I this value is worked out for the various scales, while some useful additional data have been included. This table should not be interpreted too rigidly but should rather be seen as indicating the order of magnitude of some useful survey values.

Table I.

Density of observation in relation to scale, and application of soil survey elements and aerial photography (based on 0.5 obs/cm^2 map surface).

Scale:	1:1,000,000	1:250,000	1:100,000	1:50,000	1:30,000	1:20,000	1:10,000	1:5,000
Name	exploratory	-----reconnaissance	------semi-detailed		-------detailed	-----	very detailed	
observations per km^2 field	0.005	0.08	0.5	2	5.6	12.5	50	200
hectares per observations	20,000	1,250	200	50	18	8	2	0.5
time required office:- preparation week (month)	-	2	1.5	0.5	0.3	0.2	0.1	0.1
report writing (month)		4	3	1.2	0.5	0.5	0.3	0.[illegible]
hectares per month per team	600.00	150,000	60,000	20.000	9.000	5000	1500	500
distance between traverses (m)	nr	nr	2,000	1.000	600	400	200	100
distance between augerholes on traverse (m)	nr	nr	nr	1,600	500	200	100	50
Surface (ha) of smallest map unit on final map	2,500	156	25	6.25	2.25	1	0.25 (2500 m^2)	0.0625 (625m2)
width (m) of narrowest map unit on final map	2,000	500	200	100	50	40	20	10
soil survey elements	broad associations	-----	associations of series	-------series	----series+ phases	---	phases---	phases + subphases
aerial photo interpretation	extensive (rough)	----- intensive	---------	base map	------------------			base map or only general picture of surroundings

nr: not relevant, as for these cases a free survey is used.

Table II.

Division in scales.

Exploratory	less than 1:250,000
Reconnaissance	1:50,000 to 1:250,000 (incl.)
Semi-detailed	1:20,000 to 1:50,000 (incl.)
Detailed	1:5,000 to 1:20,000 (incl.)
Very detailed	more than 1:5,000

The most common type of soil map in Zambia is one that has a semi-detailed scale, When mapping the soils of a (relatively) large area the scale to be used depends on the expected variation in soils and the required accuracy. Furthermore the time available for each survey is limited since a soil surveyor cannot spent a long time on just one survey. This would cause a severe reduction in the number of the surveys carried out in one year. So a compromise between a reliable map on the one hand and limited time on the other hand has to be made. Hence, in view of the usually large workload of the provincial teams, semi-detailed surveys are the most common type of survey in Zambia.

Detailed surveys are reserved for small farms, or sections of farms which for instance will be put under irrigation. Very detailed surveys are rarely carried out by the Soil Survey Unit. They are too time consuming in relation to the area surveyed. Such surveys are particularly appropriate for scientific soil research such as exploring the genesis of soils along a slope (catena, toposequence) or to study the variability within soil complexes. They are also suited for special purposes like the mapping of depth to gravelly layers for citrus plantations. The field map for both detailed and very detailed surveys is usually composed of a fixed grid system of traverses. This is drawn on a clean sheet of paper on which features like roads, streams and compounds have been sketched as accurately as possible.

Apart from the more detailed soil surveys, reconnaissance and exploratory soil mapping form a different category of survey. For such kind of mapping a different approach is used. Normally a temporary legend is made first, based on physiography and geology. Secondly remote sensing and photography are used to delineate mapping units.

Field work is mainly aimed at checking the photo interpretation and to determine the appropriate name of each mapping unit, using the provisional legend. Little field work is required to study soils within mapping units, apart from some verification needed to revise the legend. The composition of soils within a mapping unit may already be known from sample areas or former surveys. Of course in new areas, unknown soils may be encountered. A more in-depth study is then required, although time spent on such work should be limited to the study of some well chosen profile pits. In small scale mapping it is important to find a compromise between the available time and the production of a useful soil map. It is always very tempting to go into detail, but this may hinder the progress of the survey severely. A certain degree of flexibility on the part of the surveyor (made possible through his experience) is needed to complete the map. It must be remembered that each map needs up-dating after 10 to 20 years, as continuous progress is made in soil science research. It is usually better (in small scale surveys) to have a completed medium quality map than a half finished high quality map.

The soil map in the report (publication map) is different from the field map. Preferably the publication map should be a reduced map from the field so as to decrease the size and number of errors of the map. Normally a 70% reduction is applied, as to reduce the field map to half its size. It is often very useful to use existing topographical maps or aerial photographs as base maps because more detail of land features can be shown, compared to maps with a drawn background of roads, rivers, etc. However, there are several limitations to each type (or scale) of map.

When using aerial photographs as base map either one photograph is enlarged or a photomosaic is composed, depending on the size of the area and the scale of the survey. Aerial photographs are uncontrolled. In photomosaics, because they are made from aerial photographs, the error will be bigger the more photographs are involved in its composition. It is advised only to use a photomosaic as base map for areas 3 to 3,000 ha, or less. It should be noted that aerial photographs loose quality if enlarged more than three times.

Most parts of Zambia are covered by topographic maps at scale 1:50,000. These are compiled from aerial photographs, but have the advantage that they are controlled. Their scale makes them more useful for the relatively small scale surveys.

Transfer of soil boundaries from the field map onto the photomosaic or topographic map is done by sketchmaster. Preferably the soil surveyor should do this.

The following kinds of background are suggested for the various scales of soil maps:

- Very detailed soil map. Aerial photographs are not suitable if they have to be enlarged many times. Although an enlarged photograph is preferred, usually a sheet of paper with accurately sketched features as roads, rivers and field boundaries is taken as background.

- Detailed soil map. For such a map either enlarged or original aerial photographs or photomosaic, composed of a few photographs, are used. Detailed surveys normally involve areas up to 2 to 3,000 ha e.g. farms, schemes, etc. Therefore small photomosaics are especially suitable, the more when recent photographs are utilised.

- Semi-detailed soil map. For relatively small areas of up to 3,000 ha a photomosaic is suited. Photographs with a small scale might have to be enlarged somewhat. Normally, however, the original photographs are used. For relatively larger survey areas unreduced (scale 1:50,000) topographic maps are ideal. A special category of maps involve large areas mapped at scale 1:30,000 to 1:40,000 (e.g. state farms). For this kind of maps enlarged topographic maps are unsuitable. Therefore photomosaics are the only possible way. In order to improve the quality of such a large photomosaic the cartographic section should try to use as many photographs as possible and whenever feasible apply photogrammetry methods (e.g. slotted-templed) to make the mosaic more or less controlled.

- Reconnaissance soil map. A topographic map (1:50,000) or a reduction (to 1:100,000) is best suited as background. For smaller scale maps see exploratory soil map.

Exploratory soil map. For such a map a new base map showing the infrastructure has to be made. Satellite imagery might be useful. On these maps climatic data might also be superimposed on the soil boundaries.

2. LEGEND AND CLASSIFICATION; SOIL SERIES AND PHASES.

At the start of a survey, the first augerhole is most important as it determines the first series and is used as reference for subsequent soil observations. At the second hole the surveyor wonders whether to classify the soil there and the one at the first hole as one and the same, or differently. This is the combined process of setting up soil series, phases and a legend, and of soil correlation and soil classification. There exists some confusion about the actual meaning of these terms. This chapter tries to explain how the different subjects are to be dealt with and why.

2.1 Setting up of series and phases; soil classification.

After the surveyor has finished examining the second augerhole, a decision has to be made whether or not the soil at this augerhole is similar to the soil at the first augerhole. Firstly the soil surveyor ponders about the mutual relationship of the two soils, i.e. about their similarities and differences. This is soil correlation at its most elementary level. Having done this, he/she decides whether or not to put the two soils into one class. This, basically, is soil classification.

At a higher level soil classification is the process of setting up a general system of discrete units that cater for all the soils in the survey area. Soil correlation is here also involved since every time a new soil class is being considered comparisons have to be made (e.g. between different parts of the area, between the findings of different surveyors, or with already established classes), in a manner similar to what was done at the second augerhole. When a small scale map is being compiled from larger scale maps, soil correlation again precedes soil classification.

Soil classification also pertains to the process of assigning soils to established classes. Thus, although soil classification and soil correlation seem to be quite similar processes, they differ in that soil classification aims at or uses a rigid system, whereas in soil correlation the rigidity of the system itself is the subject of investigation.

The soil series is normally the basic element in soil classification. Therefore, the distinction between soil seri is the most important part of a soil survey. The general characteristics of a series can be used later for extrapolati to new areas, while the placement of a soil in an already established series means that most of the characteristics (ne to assess the suitability for agriculture) are familiar and on need to be verified if necessary. In short, this is the who meaning of soil classification.

A soil series can be defined as a group of soils having soil horizons similar in differentiating characteristics and arrangement in the soil profile, as well as being developed f a particular type of parent material. The soils within a se are essentially homogeneous in most soil profile characterist except in such features as slope, stoniness, degree of erosio topographic position and depth to bedrock, where these feat do not modify greatly the kind and arrangements of the soil horizons.

A soil series by itself is only occasionally used as a mapping unit in soil surveys in Zambia. It is not sufficient homogeneous in most characteristics to meet the objectives of most detailed soil surveys, and it rarely occurs alone in a large enough to serve as a unit of mapping on more generali maps. The series name, however, remains the key to the majority of the soil characteristics even when, e.g. in detail mapping, classification is at phase level. The series brings units of mapping together in an organized manner to help us remember soil properties and the relationships among soils (Soil Survey Manual 1951, page 280).

Besides soil series other forms of classifying or group soils are used. A soil variant is a new born series, which come into existence without having been recognised as a new yet. As long as it is on the waiting list, it is called a The term variant, however, is not much used. It is easier include it as a peculiar one in the list of profiles belongi to one series. When many profile data exist for one variant, it may be decided to either extend the range of characteristics of the soil series in such a way that the characteristics of the variant are included or to narrow the range of some or all the characteristics, excluding the variant and thus seperating a new series.

A soil phase is part of a soil series; it is used to separate soils from the main series concept on the basis of usually one characteristic, e.g. slope, soil depth, etc. Important features of the phase - it will be used all the time - are the applicability in soil survey (i.e. it should be mappable) and the significance for further interpretation of the soils data (e.g. for land evaluation purposes). Characteristics like pH or CEC cannot be mapped easily and are not used to separate phases within the soil series concept. The question when a difference in a characteristic should be reflected in the classification at series or phase level can only be decided when enough data are available.

A new proposed name, the sub-phase, is to be used for those differentiating characteristics which are not mappable but are thought too important to be excluded from the series concept. The sub-phase is especially important with respect to detailed land evaluation. The range in fertility characteristics is usually so wide within one series that sub-phases on basis of each of such characteristics can be formed. When laboratory data are available a rough assessment of the occurrence of sub-phases within a series can be made.

Association and complex are terms used for any combination of series. Their definitions according to the Soil Survey Manual (1951) are as follows:" a soil association is a group of defined and named taxonomic soil units (series), regularly geographically associated in a defined proportional pattern. A soil complex is a soil association, the taxonomic members of which cannot be separated individually in a detailed soil survey because of the complexity of occurrence". An association is used in the smaller scale surveys (exploratory, reconnaissance and sometimes semi-detailed) where it is not the intention to separate these series due to the scale of survey. A complex is used in large scale survey (detailed, very detailed) where one is unable to separate these series due to their complexity within an area. Each association or complex is composed of two or more series;

the proportion of each series within the association or complex is assumed to be stable. Each member of the soil association or complex needs to be fully described as well as proportions of their occurrence (in %) and where they occur in relation to other soils.

Other terms like family, groups, etc. are classification terms which are not appropriate here. They belong to international classification systems which are discussed in section 2.2.

2.2 International soil classification.

Classification, being the process of dividing a phenomenon into specific classes, has been already mentioned in section 2.1. What is usually meant by soil classification is the application of international soil classification systems, e.g. Soil Taxonomy. Normally the correlation between the locally used soil names and internationally accepted soil names is included in soil reports. The USDA Soil Taxonomy is a real soil classification system, whereas the FAO/UNESCO system is in theory a legend but can actually be considered a summarised version of the Soil Taxonomy in many respects. Both systems are used for international soil classification purposes.

Classification of the local Zambian soil series and phases in terms of Soil Taxonomy and FAO Legend is a process to be carried out as the last stage of reporting. When all data are available one may be able to classify a soil into the Soil Taxonomy system (from order level down to family level); the FAO-legend is simpler and uses soil units and phases only. To facilitate the classification of soils according to the main international systems, as many criteria of those systems as possible should be incorporated in the key to the soil series or in the general legend (cf. section 2.3). But it is not obligatory to use these criteria in exactly the same way. For instance a subgroup or a family of the Soil Taxonomy or FAO-Legend might be split up into the two series in the key to Zambian soil series.

2.3 Legend

The legend is a systematic summary of the mapping units or, in some cases, the elements of the mapping units. A map is explained by way of a legend indicating which colour or symbol on the map represents which mapping unit. For the convenience of the user a brief description of the mapping unit is usually given apart from the name or symbol representing it. This description should consist of statements on the major characteristics of the soil(s) forming each mapping unit. A copy of the legend must always be included in the report.

Effort should be made to standardize the presentation of the legends as much as possible. Physiography and geology, in combination or ranked, normally provide the most suitable way of dividing the mapping units at the highest level (see also section 1.2). Further divisions depend very much on the characteristics of the survey area. Soil drainage is usually an important characteristic of the soils in conjuction with physiography. Other characteristics often used are slope, texture, colour and soil depth. Their order of importance depends on the area, scale of mapping, etc., and must therefore be decided by the surveyor. In relative detailed surveys texture and colour are very suited for a first separation of the soils, followed by slope and soil depth. Usually the latter two are used at phase level. Only in relatively small scale surveys or in survey areas with clear relief, slope and soil depth may be more important and it may be decided to employ one or both characteristics at higher level in the legend, if large enough mapping units can be distinguished by them. Colour and texture are then mentioned at a lower level.

A legend can be in a descriptive form or in a tabulated form. Both forms are acceptable, as long as they conform more or less to a common standard. Rather than explaining in detail how such a standard legend should be structured specimens of each type have been given in table III (a and b).

It is not allowed to include in a legend tables with symbols related to selected soil features, and use these symbols in the many possible combinations that may occur in order to denote the mapping units (i.e. legends must be closed). Thus, the LUB code cannot serve as a symbol for a mapping unit on soil maps. Furthermore each delineation (a map area surrounded by a single continuous line) should, as far as possible, be identified by a single symbol only, and not by a compound symbol (i.e. legends should be controlled) To take the specimen legends as an example, only if it is a very minor mapping unit can the combination of symbols 3b and 3c (Hanson series, gently sloping and gravelly phase) be used.

Table III. Example of a legend.

(a) Tabulated legend

UNIT	Slope (%)	Soil depth	drainage	colour at 50cm	texture	Other remarks
STEEP HILLS AND MOUNTAINS						
a1 Johnson series	more than 13, often more than 25	moderately shallow	well	reddish brown	gravelly clay	often eroded, many (50%) granite rock outcrops
1b (mod. deep phase)	13-25	mod. deep	well	reddish brown	slightly gravelly-clay	slightly eroded if bare, common 25%) rock outcrops
FOOTSLOPES OF HILLS						
2 Peterson series	8-13	mod. deep to deep	well	yellowish red	sandy clay loam over	some (10%) rock outcrops
PLATEAU						
3a Hanson series	0-5	deep	well	yellowish brown	sandy loam over sandy clay loam to clay	major series of survey area (covering 55%)
3b (gentle sloping phase)	5-8	mod. deep	well	yellowish red to yellowish brown	sandy clay loam over sandy clay	at transition to foot slopes (unit 2)
3c.(gravelly phase)	0-8	deep	well	yellowish brown	gravelly clay subsoil, sandy loam & loam topsoil and upper subsoil	found scattered near rock outcrops; gravel is used for road hardening

LOWER SLOPES DAMBO FRINGES						
4a Erikson series	0-3	deep	mod. well	yellowish brown	sandy loam or loamy sand over sandy clay loam	transition of unit 3 to unit 5. groundwater within 1.0m during rainy season.
4b (imperfectly drained phase)	0-3	deep	imper-fect	yellowish brown to greyish brown	sandy loam over sandy clay loam	local depressions of wetter places due to stagnation of groundwater
DAMBO						
5a Classon series	0-1	deep	imper-fect	greyish brown	loamy sand over sandy loam	groundwater within 50 cm throughout the rainy season; waterlogging during several weeks.
5b (very poorly) drained loamy phase)	0-1	deep	very poor	dark grey-ish brown over very light brown	loamy sand over sandy loam	often waterlogging in rainy season; groundwater around 1.0m depth during dry season.
5c (very poorly drained clayey phase)	0	deep	very poor	dark greyish brown over pale brown	muck sandy loam over sandy clay loam	located at centre of dambo having thick dark coloured top-soil; very wet during most of the year.

(b) Descriptive legend

Steep hills and mountains.

1a Moderately shallow, well drained, reddish brown, gravelly clay soils on relatively steep (13% or more) slopes (Johnson series)

1b Moderately deep, well drained, reddish brown, slightly gravelly clay soils on moderately steep (13-25%) slopes (Johnson series - mod. deep phase)

Footslopes

2. Moderately deep, well drained, yellowish red, sandy clay loam over clay soils on gentle (8-13%) slopes (Peterson series)

Plateau

3a Deep, well drained, yellowish brown, sandy loam over sandy clay loam to clay soils on very gentle (0-5%) slopes (Hanson series)

3b Moderately deep to deep, well drained, yellowish red to yellowish brown, sandy loam over sandy clay soils on gentle (5-8%) slopes (Hanson series - gentle sloping phase).

3c Deep, well drained, yellowish brown, gravelly sandy (clay) loam over clay soils on very gentle and gentle (0-8%) slopes (Hanson series - gravelly phase)

Lower slopes and dambo fringes.

4a Deep, moderately well drained, yellowish brown, sandy loam/loamy sand over sandy clay loam soils on very gentle (0-3%) slopes (Erikson series)

4b Deep, imperfectly drained, yellowish brown to greyish brown, sandy loam over sandy clay loam soils on very gentle (0-3%) slopes (Erikson series - imperfectly drained phase).

Dambo

5a Deep, poorly drained, greyish brown, loamy sand over sandy loam soils on nearly level (0-1%) slopes (Classon series)

5b Deep, very poorly drained, dark greyish brown over very light brown, loamy sand over sandy loam soils on nearly level (0-1%) slopes (Classon series - very poorly drained, loamy phase).

5c Deep, very poorly drained, dark greyish brown over pale brown, sandy loam over sandy clay loam soils on level slopes (Classon series - very poorly drained; clayey phase).

If it occurs over a wide area or in several delineations a new mapping unit, represented by its own symbol (e.g. 3d), must be created.

The symbols themselves can be made up of figures and letters. For large scale surveys a combination as is shown in the specimen legends (a figure for the higher level division and a letter for the lower level division) is most suited. For surveys at the reconnaissance or exploratory level the legend can be made open to a certain extent by including some specific information in the final part of the symbol. A symbol then consists of two elements, one identifying the series and one giving the phase. For instance 4-5b stands for an association of Erikson and Classon series (4-5), imperfectly to poorly drained phase (b). Alternatively, if it is possible to achieve enough distinction, units from the FAO/UNESCO legend may be used together with an appropriate figure to indicate the phase; Bc3 then being a chromic Cambisol moderately shallow phase. However, in order to remain intelligible, a symbol should never consist of more than 3 or 4 characters.

It is not necessary to repeat specifications (e.g. soil depth, slope classes etc) throughout the legend. In case of repetition, it is better to list the specifications separately and use them in the legend without further explanation.

In the survey report, a description of the mapping units is always required besides the presentation of the legend. In this description the LUB code and the land capability class should be mentioned, as planners are especially interested in this part of the report. In other words, it would be wrong to give an extensive legend as a table in the report without a further description.

A more general legend, possibly one for each scale, can be compiled when the data of many surveys have become available. In such a legend the characteristics of the soils in a large area are combined into a single key. The names of all soil series are given in the key followed by a description of each series and its phases and sub-phases.

Using such a legend the surveyor at his first augerhole decides which unit fits the augered soil best. Instead of giving a new name he/she should decide whether or not to use an accepted series (and phase) name. Correlation in that case might be needed to avoid creating too wide a range in characteristics of a series or to make changes in the general legend. The exact definition of series is thus a never ending process between the surveyors and the soil correlator.

An important aspect of the general legend is that the surveyor is able to use existing information of the soil series during the survey. He may extrapolate the conclusions of former research to his survey area, without having the trouble of sampling etc. If he is sure of the classification, he also knows the suitability for agricultural purposes, provided it has been worked out and possibly tested on the particular soil series, phase or sub-phase.

2.4 Differentiating and diagnostic criteria.

To give an indication of what criteria might be used for distinction between soil series, phases and sub-phases, the following list (table IV) may be useful. The establishment of boundaries in the key to the soil series is a matter to be centralized at Mt. Makulu by the Soil Correlator to maintain consistency and applicability.

Differentiating criteria are used, as has been explained before, for differentiating soil series and (sub)phase ; they must be mentioned in the legend. When one or more characteristics are unique to one or a few soil series or (sub)phases, they are called diagnostic criteria. These can be mentioned in the description of the mapping units, but should not appear in the legend. For instance, the occurrence of a plough pan in a certain series or (sub)phase might be used as a diagnostic criteria. In distinguishing between series at least two differentiating criteria should be used; for phases and subphases one is sufficient.

Table IV. List of characteristics applicable in distinguishing between soil series, phases and sub-phases:

Climate	- agro-ecological zone, length of growing period, climatic zone (FAO World Soil Resources Report No. 48)
	- soil moisture regime (Soil Taxonomy)
	- soil temperature regime (Soil Taxonomy)
Geology	- parent material
	- rock outcrops and type of rock

Physiography
- elevation (altitude)
- landform
- topography
- slope

Hydrology
- groundwater soil drainage (wetness classes)
- level (season and yearly fluctuation)

Ecology
- natural vegetation
- land use (virgin land, chitemene, permanent cultivation)
- management (irrigation, use of fertilizer, tillage, mechanization, conservation measures)
- presence of anthills
- particle size class (clay, silt and sand content)
- water dispersable clay
- texture pattern (clay increase with depth)
- abrupt textural changes
- texture topsoil (0-20 cm depth)
- texture subsoil, possibly subdivided into 20-40 40-60, 60-90 cm.
- soil colour of upper 18cm (mixed)
- soil colour of upper B-horizon or at 50 cm depth
- mottling
- occurrence of plinthite
- soil consistence
- presence of gravelly or stony fragments
- presence of concretions, free carbonate or gypsum
- porosity
- rooting depth
- presence and abundance of biological features
- cementation
- weathering stage of rock
- soil depth to layer impenetrable to roots or hard bedrock
- occurrence of an ironpan (sheet laterite)
- petroferric contact (very many ironstone concretions)
- buried horizon(s)
- diagnostic surface horizons (mollic, umbric, histic, ochric epipedon)

	- diagnostic subsurface horizons (argillic, natric, cambic, oxic, spodic B-horizons, albic, calcic horizons)
	- gilgai
	- occurrence of slickensides
Physics	- bulk density
	- available water holding capacity (pF 2.0-pF 4.2)
	- erodibility
	- initial or basic infiltration rate
	- permeability
Chemistry	- CEC (NH_4OAc pH 7) (per 100g soil or clay).
	- average CEC over upper 50 cm (per 100g soil)
	base saturation (acc. to CEC NH_4OAc pH 7)
	- exchangeable calcium, magnesium, potassium, sodium
	- sum of cations
	- exchange acidity (Al+H)
	- exchangeable aluminium
	- effective CEC (sum of cations + exchange acidity per 100g soil or clay)
	- base saturation (acc. to effective CEC)
	- aluminium saturation of the exchange complex
	- pH (H_2O)
	- pH ($CaCl_2$ or KCL)
	- organic C content
	- average organic C over upper 50 cm
	- total N
	- C/N ratio
	- available P
	- total P
	- total S
	- CEC of the clay fraction; possibly corrected for organic C
	- electrical conductivity EC_e (salinity)
	- exchangeable sodium percentage ESP (alkalinity)
	- total SiO_2, Fe_2O_3, Al_2O_3
	- free Fe (dithionite)
	- $CaSO_4$ (gypsum)
	- trace elements, available Mn, Cu, B, Zn, Mo, Fe
Mineralogy	- clay mineralogy (DTA, X-ray)
	- sand fraction mineralogy (light and heavy fraction (by microscope)
	- roundness of sand grains

Micro-morphology	-	cutans (illuviation, stress)
	-	other features
Others	-	other characteristics mentioned in Soil Taxonomy, applicable to soils of Zambia.

2.5 Soil Correlation.

In a soil survey, new series and phases are set up. For each new area, other symbols or names are used. Afer many surveys have been undertaken a lot of names and symbols occur which, by systematic approach, need to be selected into series, phases and possibly sub-phases. This is the basic idea of soil correlation. On the other hand, comparisons between series can be made in order to check whether two or mores series can be combined. If two series resemble each other in many ways, but differ in one characteristic, it may be decided to make one of the series a phase of the other. Usually the series with a small extent is in such a way included into the series with a large extent. At phase level correlation is hardly possible, as the characteristics used at this level normally follow a rigid system (e.g. FAO guidelines); correlation thus concerns itself exclusively with soil series.

To facilitate comparison of soil series a correlation box filled with peds of the main horizons can be very useful. These boxes should be used in case of unidentified soil series. The location of sampling site and profile number should be mentioned clearly on the box (not on the cover).

3. LAND EVALUATION

A separate technical guide on land evaluation will be prepared in due course, but some remarks will be made here with respect to the influence of advanced land evaluation methodology on the distinction of mapping units (associations, complexes, series, phases, sub-phases). As stated in chapter 2, one of the main factors in distinguishing soil series and phases is their significance to land evaluation. The requirements for land evaluation should determine which distinctions should be made between soils. But during a soil survey some of these distinctions may prove difficult to map, while others, not relevant for land evaluation, can be mapped very easily. So, both surveyor and land evaluator should work together at the same time to produce general legends, which are applicable for both soil survey and land evaluation.

4. DESCRIPTION OF PROFILE SITE, SOIL PROFILE AND SAMPLING

4.1 General

Soil profile descriptions form one of the most important elements of a soil survey. The concepts formed during routine observations on the differences in soils in the survey area can be verified by describing soil pits. Consequently, the description of soil profiles should be started as soon as a picture, no matter how limited, on the distribution and relation between the soils begins to emerge, and should not be postponed until the end of the survey. Routine field observations and detailed profile descriptions supplement each other: no soil survey is complete without soil profile descriptions while conversely it is not possible to produce a proper soil map on the basis of a selected number of profile descriptions only.

A further reason for making soil profile descriptions is to record and transfer information on soils. In particular the correlation between soils of different areas, or studied by different persons, is very much dependent on sound profile descriptions and their analytical data.

It is thus imperative that great care should be taken to produce clear and complete, yet concise soil profile descriptions. In order to standardize soil profile descriptions certain guidelines exist, of which those published by the FAO are best known. The Soil Survey Unit has hitherto adhered to these FAO Guidelines (1977) and will continue to do so. However, some additions and amendments have become necessary to adopt these guidelines to the Zambian situation. These amendments are all explained below: they are in keeping with accepted international practices and terminology (Soil Survey Manual, Soil Taxonomy, FAO/UNESCO Soil Map of the World Legend, ISM Soil description sheets) with respect to soil survey, soil classification and land evaluation.

The use of abbreviations in the final text should be avoided as much as possible. Where abbreviations are required to shorten descriptions considerably, they must be explained clearly in the report.

To enhance the usefulness of the Zambian Land Use Planning Guide, and make its method of soil coding fully convertible with the FAO Guidelines for Soil Profile Description, it will become necessary in future to modify the former.

4.2 Siting of soil profile pits

Every major soil mapping unit should be represented by at least one soil profile description. If some of the mapping units include widely ranging characteristics, a "typical" profile should be chosen rather than an "ideal" one in which the characteristics are expressed most clearly. Mapping units occupying 20% or more of the area should (if this area is of sufficient size) be represented by at least two profile descriptions.

If possible, pits should be 1.50 to 2.0 m deep. It is often very instructive to auger for another metre in the bottom of the pit if the material allows (in such a case the description must mention the depth of pit and of the subsequent augering separately). Description of pits should be done as soon as possible after the pit is dug, preferably on a face orientated towards the sun. The spoil of the pit is deposited on either side of this face.

The description must mention the locality of the pit, the topographic sheet number and UTM grid as accurate as possible.

4.3 Profile description heading

Above each profile description a number of lines must be devoted to general information on the site and the soil. The following sequence of features is recommended for routine soil profile descriptions. For descriptions of profiles considered to be representative for a particular series a more extensive list of general information has to be given.

Profile number:	
Soil name	"unnamed series" if not yet determined
Int. classification:	FAO/UNESCO legend and Soil Taxonomy (USDA) classification; the remark "tentative" can be added if necessary.
Date of description:	-
Described by :	-
Location:	give name of area or form, and either the longitude and latitude or the UTM grid number
Elevation:	in meters above sea level
Land form:	this item must include physiographic position, topography and microtopography, if any (c.f. 4.4.1-3), and the slope (expressed in percent.)

Vegetation and land-use:	includes remarks on anthills (cf 4.4.5)
Climate*:	general climate, annual rainfall and distribution, max. and min. temperatures
Parent material*	if not in situ, indicate where the material came from and how it was deposited (cf. 4.5.1)).
Soil depth:	cf 4.4.4
Drainage:	cf 4.5.2
Permeability:	if necessary and "when dry" or "when wet"
Moisture state:	if the profile is moist or wet because of recent rains, indicate so
Groundwater:	give as much information as possible, like "in nearby well", "during rainy season", and give duration of the level at a certa depth if known.
Surface stones:	includes gravel
Rock outcrops:	-
Erosion:	Never state "none" but rather state "no visible evidence", "none detected" etc.
Human influence:	includes remarks on burning, cultivation practices, presence of brick fragments etc.
LUB code:	-
Land capability classification:-	
Remarks:	includes notes on cracking, occurence of salt and alkali, slaking etc.

Features marked by an* are optional, they can be deleted if they are more or less uniform for the whole of the survey area, and a description of them is given elsewhere in the report.

4.4 <u>General information on the site sampled.</u>

4.4.1 <u>Physiographic position</u>: Slope is to be divided into either upper, middle or lower slope. Lower slope, toe slope or foot slope (only in mountainous terrain) are considered similar terms. A slope or part of the slope can be convex, straight or concave. Other descriptive terms are : plateau (former peneplain surface), dissected plateau, summit, escarpment (scarp, crest), inselberg, piedmont slope, terrace, dissected terrace, valley bottom, plain, depression, floodplain, levee, backswamp, cut-off channel (old meander), dambo, valley dambo, upland "head" dambo, hanging dambo, drainage [illegible]

This list is not comprehensive. Later a complete list will be published together definitions of the various landforms.

4.4.2 Topography. FAO Guidelines should be followed, with the refinement as mentioned below.

The flat or almost flat topography is divided into

- flat: steepest slopeless than 0-5%
- almost flat: steepest slope between 0.5 and 2%

The undulating topography is divided into

- gently undulating: steepest slope between 2 and 5%
- undulating: steepest slope between 5 and 8%

4.4.3 Slope on which profile is sited. Use slope classes as mentioned below (based on the Land Use Planning Guide).

level of nearly level	(O):	0 - 1%
very gently sloping	(A):	1 - 3%
gently sloping	(B):	3 - 5%
moderately sloping	(C):	5 - 8%
moderately steep	(D):	8 -12%
steep	(E):	more than 12%

Where appropriate, slopes can be subdivided into simple and complex slopes

4.4.4 Soil depth: The soil depth is not stated in the FAO Guidelines. The following depth classes are used:

shallow	:	Less than 30 cm
moderately shallow	:	30 - 60 cm
moderately deep	:	60 - 90 cm
deep	:	90 - 120 cm
very deep	:	More than 120 cm

4.4.5 Vegetation/Land Use: describe as extensive as possible; mention fertiliser use, crop rotation, etc.

4.5 General Information on the soil

4.5.1 Parent material: Describe the parent material of the soil as clear as possible. Geological maps are of course useful, but own observations should be added. Different descriptions to be used in Zambia can be found in table V.

table V **Rock types in Zambia**

IGNEOUS		METAMORPHIC		SEDIMENTARY
Plutonic	Volcanic	Gneisses	Schists	
Pegmatite, Aplite Quartz rich granitoids K/Na Alkali-feldspar granite ↓ Granite Granodiorite Na/Ca Tonalite	Rhyolite Quartz porphyry Granophyre	All plutonic terms with suffix Gneiss Quartzofeldspathic Gneiss Psammite Charnockite	Quartzofeldspathic Schist Psammatic schist	Quartzitic sandstone Arkosic sandstone Siltstone Greywacke Quartz conglomerate
K/Na Alkali-feldspar granite ↓ Quartz syenite Quartz monzonite Na/Ca Quartz diorite	Dacite Lamprophyre	All plutonic terms with suffix Gneiss Biotite gneiss Hornblende gneiss Charnockite Enderbite	Quartz mica schist Pelitic schist Phyllite Slate	Siltstone Shale Mudstone(argillite)
K/Na Syenite ↓ Monzonite Na/Ca Diorite	Andesite	All plutonic terms with suffix Gneiss	Mica schist Talc schist Calc silicate schist	Calcareous siltstone Calcareous mudstone Calcareous sandstone
Dolorite Gabbro Norite Carbonatite	Basalt	Amphibolite Marble	Amphibolite	Limestone Dolomite
Picrite Perodotite Dunite Kimberlite		Hornblendite Pyroxenite Serpentanite Metaperidotite		

The material in which the profile is formed does not always result from the weathering of the underlying rock, but may have been derived from elsewhere (where the same or a different rock prevails) through colluviation and/or alluviation. Even in cases where the parent material is the same as that of nearby in-situ developed soils, the soil will be different, as colluviation usually results in a darker soil (mixture with organic material) and alluviation in a browner or yellower soil (goethite instead of hematite being the main Fe mineral). Signs of any of those processes having taken place should therefore be mentioned, e.g. colluviated clay from limestone, alluvial deposit mainly derived from nearby granite hills, etc.

4.5.2 Soil drainage.

The correct determination of wetness class of Zambian soils, or, even better, the groundwater regime from which the wetness class can be derived, is still full of pitfalls. Ideally, the wetness class should give information on the height, duration and fluctuation of the groundwater level, but no such data are as yet available in Zambia. Likewise, knowledge of oxidation and reduction processes and of iron mobility and its influence on soil colour is still too scanty to enable some of the information on groundwater movements to be extracted from soil morphological phenomena. For the time being the soil drainage class will therefore have to be estimated from profile, physiographic and environmental features in accordance with the flow chart in Technical Guide No. 11. In the meantime every soil surveyor should try to obtain as much information on groundwater levels as possible, either by monitoring it in groundwater tubes, by personal observation, or by asking the inhabitants of the area, and try to relate the information so gathered to the soil morphology.

4.6 Description of individual soil horizons

4.6.1 Horizon designation

Horizon designation is performed according to the rules given by the International Society of Soil Science. The system underlying these rules differs fundamentally from the system as given in the Soil Survey Manual. Soil Surveyors not fully conversant with the new international system can find a full explanation and definition of horizon designations in any of the following publications:

FAO Guidelines for Soil Profile Description (1977)
FAO/Unesco Soil Map of the World, Legend (1974)
Soil Survey of England and Wales, Soil Survey Field
Handbook (1974)

The notation of horizons in Zambian soils will thus be in accordance with this international system. When this leads to a conflict with established usage, preference should be given to the international system.

So although rust root channels are considered indicative enough of wetness to classify a soil's land use capability class Bw, such a horizon can in general not be considered an Ag horizon because it lacks mottles with low chromas. Similarly, a horizon can only be regarded as argillic when it meets the requirements as given in the Soil Map of the World Legend or in the Soil Taxonomy (which are more or less the same).

To solve problems of this nature, horizons which do not qualify for one of the diagnostic horizons can be given the suffix "u". This lower case letter, which stands for "unspecified" makes it possible to denote a horizon as a master horizon and subdivide it without committing oneself to the exact nature of the horizon. E.g. a mottled horizon can not be called a Bg or Bw horizon when it does not have low chromas, but may still be subdivided into Bu1, Bu2 etc.

Some remarks on special problems:

- A vertisol is considered to have a B horizon, since the formation of wedge shaped aggregates etc. is consequent upon a certain amount of pedogenesis. The soil profile is thus made up of an A, Bw, C sequence.

- Horizons rich in (nodular) laterite are considered as B horizons, rather than C horizons. But they should not automatically be regarded as 2B. A numerical prefix must, as usual, only be added when there are clear indications of a discontinuity in parent material. Such horizons will normally thus be designated Bcs, or when the laterite is indurated, Bms.

4.6.2. <u>Colour, mottles and plinthite.</u>

Soil colour is a convenient feature to characterize the soil and therefore plays an important role in the description and classification of soils. Both the Munsell Colour Chart ...

differences in some of the colours between these two sets of charts, soil surveyors are advised to stick to one or the other during a survey, and to indicate which one has been used in their report.

In order to standardize the determination of soil colour, the soil must be moist when a soil clod is compared with the colour chips. For dark A horizons, which may qualify as a mollic or umbric epipedon, the air-dry colour of the soil must be given as well. Dry colours of the subsoil are also required for soils with an argillic horizon that may be accommodated in a rhodic great group of the alfisols or ultisols. When a soil clod is so mottled as to make it difficult to determine the colour of the matrix, the rubbed colour can be given, but this must be clearly stated (e.g. 2.5Y 6/4, moist and rubbed). In such a case a full description of the mottles is required too.

The colour of mottles does not necessarily have to be accurately determined, but may be given in more general terms like reddish brown, dark brown etc. This does not hold, however, for mottles with a low chroma. For classification purposes it is necessary to determine the colour of such mottles as exactly as possible, even to the extent of using half chroma units (e.g. 7.5YR 3/1½) Otherwise it will seldom be necessary to determine the colour so precise, although from time to time there may be cases where one clearly distinguishes a difference without being able to express it in full chroma or value units. In such cases in interpolation of the colour chips may be warranted. For example: A 10YR 3/3, AB 10YR 3/3½ and B 10YR 3/4 or Bt1 7.5YR 5/8, Bt2 5 to 7.5YR 5/8 and C 5YR 5/8. Before one resorts to such a degree of detail, however, it is advisable to lay clods from the horizons involved side by side on a white sheet of paper to make sure the differences are real.

To enable comparison of colours determined during bright weather and during overcast weather, soil colours must always be determined out of the direct sunlight, i.e. in light reflected from the sky. This can be best accomplished by facing away from the sun when comparing the sample clod with the colour chips. Care must also be taken that soil colours are not determined in an environment with a strong reflection of coloured light, e.g. inside a soil pit or under a close tree canopy, or even very early or very late in the day, when the sky is red.

A special form of mottles is called plinthite. Plinthite is an iron-rich, humus-poor mixture of clay with quartz and other diluents. Plinthite general forms in a horizon that is saturated with water at certain times in the rainy season. Redistribution of iron then forms soft more or less clayey, red or dark red mottles which usually are in a platy, polygonal or reticulate pattern. The mottles are not considered plinthite unless there has been enough accumulation of iron to permit irreversible hardening on exposure to wetting and drying. Plinthite in the soil usually is firm or very firm when moist and hard when dry. In a moist soil, plinthite is soft enough that it can be cut with a spade. After irreversible hardening, it is no longer considered plinthite out is called ironstone (see section 4.5.8).

4.6.3 Soil Structure

Generally speaking the structural development of Zambian soils is rather subdued. As a result, the determination of structural parameters (grade, type and class) is difficult and easily liable to different interpretations, making it hard to maintain a consistent and uniform approach among soil surveyors.

Structure is most strongly expressed when the soil is dry, the structure being much weaker, and thus harder to discern, when the soil is moist. This should be borne in mind when determining the soil structure. Fortunately, most of our fieldwork is done during the dry season, so there should normally not be much of a problem.

The following remarks are offered to assist with the determination of the soil structure (see also the Soil Survey Manual for a good elucidation of the soil structure determinations).

Grade of structure This refers to the degree of development and durability of structure. It can be assessed from the ease with which the structural elements can be distinguished in the pit as well as from the amount of smaller (broken) peds and unaggregated material that is produced when the soil (or a big clod of soil) is disturbed. A soil horizon with a strong structure is almost entirely made up by peds of uniform size (e.g. in a vertisol) while in a horizon with a weak structure there appear to be peds of many sizes, and often also a great amount of non-pedal material.

When the structure is ill-defined in a dry pit the grade of structure is either weak or structureless. To make sure which of the two is applicable, clods of soil should be broken with the hands. When they break along preferential faces of weakness the soil has weak structure grade, otherwise it is structureless. The word preferential is emphasized, since structureless soils often seem to break along faces of weakness as well. When these faces occur in nearly every direction, depending on the direction in which the hands apply force to the clods, then they cannot be considered to be preferential, hence the horizon must be described as structureless. Only when but a few faces of weakness are prevalent can the horizon be regarded as having some structural development.

Normally a massive structure is more likely to occur in sandier soils than in clayey soils, the latter more easily forming peds, especially if there is a 2:1 clay component. It should be noted that the occurrence of clay cutans other than in root channels or animal burrows and a structureless grade of structure are mutually exclusive. This is not to say that no argillic horizon can occur in structureless soils, but it only means that there are no traces of clay translocation visible in such soils.

The Guidelines for Soil Description recognizes only two types of structureless grades: single grain and massive, which in the Zambian context is highly unsatisfactory. Therefore, the IBM scheme has been adopted which distinguishes between single grain, porous massive and massive. For the sake of clarity the qualification "compact" can be added to massive. A compact massiv structural grade is then reserved for massive material that has a very slow permeability or is altogether impermeable. A furthe subdivision of porous massive is to be made by adding one of the following qualifications: weakly coherent, moderately coherent and strongly coherent. A structureless grade is thus divided into the following subgrades:

single grain

porous massive, weakly coherent

porous massive, moderately coherent

porous massive, strongly coherent

compact massive.

Pedon 32 in the Soil Taxonomy gives an example of how these terms are to be used.

Soil coherence and consistence are closely related features, so that it generally will be possible to derive the coherence from the consistence. The following tentative conversion table is given as a first approach, later a revision will be necessary after some field testing.

Consistence when dry	consistence when moist	coherence
extremely hard	not relevant	strong
very hard	extremely firm, very firm firm, friable, very friable	strong moderate
hard	extremely firm very firm, firm, friable very friable	strong moderate weak
slightly hard	extremely firm very firm firm, friable, very friable	moderate weak
soft	not relevant	weak

<u>Type of structure</u> Most of the Zambian soils on the plateau areas have a weak subangular blocky structure. If the structure is intermediate between angular and subangular it should be described as angular to subangular rather than angular and subangular, as this refers to a compound structure. A crumb structure only occurs in surface horizons (usually sandy) and is unlikely to be of a strong grade.

Compound structures may occur in a horizon with a strong or moderate structural grade. They should not be confused with weak structures, where the peds readily and randomly disintegrate into smaller elements. Compound structures can be described as e.g. "strong coarse subangular blocky, parting into fine subangular blocky", or "compound moderate very coarse prismatic and weak medium subangular blocky". Alternatively, when one type of structure dominates, yet a second structural type can vaguely be discerned as well, it may be described as for instance "moderate coarse subangular blocky tending to weak very coarse prismatic".

<u>Class of structure</u> Class sizes for each type of ped are given in the FAO Guidelines for Profile Description too. Sometimes peds are very much larger than the lower limit of the biggest class mentioned in the Guidelines. In such a case it is recommended that the approximate size of the peds is given, as for instance in a "strong very coarse (15-25 cm) angular blocky (wedge shaped)" vertical horizon.

4.5.4 <u>Soil consistence</u>.

The FAO Guidelines for Soil Profile Description treat the determination of consistence fairly extensive, so there is little need for further elucidation or amendments.

It is not necessary to determine the consistence of a horizon always at all three moisture states; it can be restricted in most cases to those moisture states that have practical implications for agriculture. E.g. the determination of the wet consistence of a Kalahari sand will serve little purpose, while on the other hand the wet consistence may be very important parameter in a dambo soil. Generally speaking, the following consistence grades should definitely be determined:

dry	A horizon(s)
moist	all horizons
wet	clayey horizons

Although the terms used to describe the consistence at different moisture levels are unique, it is nevertheless common practice to add the moisture state between brackets behind the consistence qualification, like in "very hard (dry), firm(moist), slightly sticky and slightly plastic (wet)".

Soil material which is very hard when dry often appears to be cemented. A cemented layer, however, retains its consistence under all soil moisture conditions, whereas the consistence of un-cemented material varies with the moisture content.

4.6.5 Pores

It is not necessary to describe pores as detailed as is suggested in the Guidelines for Soil Profile Description. The following characteristics should be mentioned: diameter (micro can be left out, as they can hardly be seen with the naked eye, or even with a handlens), abundance, inped or exped (the latter mostly occurring in surface horizons) and continuity.

4.6.6 Cutans

Cutans should of course be mentioned when seen in the profile. When in doubt add the word "probable". When not observed, mention so. Illuviation cutans are formed by selective translocation and should not be confused with deposits of material that has been washed down wholly along cracks, as for instance can sometimes be observed in vertisols.

Normally if the word cutan is used on its own, it is understood to refer to (ferri-)argillans (iron-clay cutans). If any other type of cutan is meant it should be specifically be mentioned, like stress-cutans. The colour of cutans must be given when it contrasts clearly with the colour of the matrix.

4.6.7 Krotovinas.

Infillings of animal burrows by material derived from overlying horizons are known by the Russian work "krotovina". They are especially common in soils with a high termite activity. Krotovinas should be described in terms of abudance and size. The same abudance and size classes can be used as those given for mineral nodules in the Guidelines for Soil Profile Description, with an extra size class "very large" for krotovinas with a smallest dimension of 2 cm or more.

4.6.8 Nodules

The word concretion can be used instead of nodule when it has a more or less concentric fabric. Full description of the hodules must always be given (see Guidelines for Soil Profile Description). It is advisable to use the qualification "well rounded" instead of just "sperical" when they are so round that they may have acquired their shape by intensive abrasion. Ironstone is a convenient term for hard sperical nodules which consist mainly of iron. As a small amount of manganese can readily impart a blackish colour to mottles and nodules, such accretions should not be described as consisting merely of manganese, but as iron-manganese (Fe/Mn). Sometimes it is not clear whether we are dealing with a mottle or nodule. The expression nodular mottle or concretionary mottle may then be used, but usually it will be better to regard it as a soft nodule.

4.7 Sampling

Laboratory determinations are needed to supply chemical and physical soil data in addition to data collected in the field. They are used in soil classification and in farm managem specifications. Chemical and physical data form an intrinsic pa of the characterization of the soil. Their significance in this respect is as important as that of the field data. The usual soil sample we take is but a very small part of the soil it represents. Suppose one, 1.5m deep, pit represents a mapping unit of 1 ha and has six horizons, then the samples from these six horizons together represent only 0.0006% of the mapping unit (assuming each sample weighs 2kg). Therefore great care is needed to make sure the sample we send to the laboratory not only represents the described pit but also the mapping unit. So it is important in sampling to select representative pits within the mapping units.

What makes a sample representative? A sample is representative when no big errors are found later in the characterization of the mapping unit. For instance, if the laborator data indicate certain toxicities and the farmer applies the recommended improvement without result, then the sample happens to be a non-representative one, provided the recommendation was a sound one. In soil classification a wrong sample may lead to mistakes in land use planning, because certain limitations are not determined or land might prove to be much better than indicated by the sample.

Ideally we should sample as much as possible of the surveyed mapping units. However, there are limitations. Firs we limit the number of pits in order to avoid duplication. O good pit is enough to describe a mapping unit of normal exte

Other pits may be digged and described, but for the report the best one is selected, while the data of the remaining pits are kept in the provincial records but will not be published. Secondly we limit the number of horizons in a soil profile. It is useless to identify ten horizons, if five cover the composition of the soil profile. In case the horizon thickness exceeds 50 cm more then one sample should be collected. Also special samples might be taken to determine e.g. clay increase within a short distance (as required for international soil classification).

In the laboratory the samples are dried, sieved through a 2 mm sieve and stored in a box. From this box samples ("sub-samples") are taken for each laboratory determination. Here again the problem of taking representative samples comes up. The soil in the box should be well mixed to avoid sub-sampling errors. Apart from the sub-sampling, analytical determinations are not 100 % consistent and accurate and here too an error is made. All in all the final laboratory data of the soils are subject to all kinds of errors. From experience we know that the sampling in the field contributes most to the error. Sub-sampling and analytical errors are reduced as much as possible by the laboratory personel, as they are well aware of this problem. So should the surveyor be, and keep this in mind whenever samples are to be taken.

Topsoil samples form a different category of samples. As the topsoil is the most important part of the soil with respect to agriculture it is not enough to take a sample from just one point, but a composite sampe needs to be collected from this part of the soil. The more sites in the vicinity of the pit can be sampled (in a random way) the better. A number of 25 sites is recommended. These 25 samples are placed in a heap, from which 1 to 2 kg is taken after thorough mixing.

The following rules should be followed when sampling:

1. Select the most representative face of the pit, being the same one as used to describe the profile. In selecting a position for sampling the objective is the identification of uniform material seemingly from a visual point of view

representative of the horizon. Any special features likely to produce analytical aberration such as lined termite galleries should be avoided, and where such features are exposed upon sampling a new site should be chosen. Where features occur that should be drawn to the attention of laboratory personnel such as soft nodular material in the matrix a note should be made to report this in the laboratory data sheets. In this example it is clear that crushing of nodules and incorporation of them into the sub-sample material may result in determinations that suggest conditions out of line with actual field conditions.

2. Sample from the base of the pit upwards. This approach avoids the possibility of contamination by spillage that can occur when sampling is from the surface downwards.

3. Where a horizon has depth greater than 50 cm it should be split into equal sections for sampling such that no single section is deeper than 50 cm.

4. Each horizon should be sampled throughout its entire depth. A rectilinear channel should be cut into the pit face, the material being carefully removed and placed in a plastic bag directly. As it is desirable to collect about 1-2 Kg of material the dimensions of the channel will very from horizon to horizon but for each horizon the two boundaries parallel to the soil surface should be of similar size.

5. Always take samples from freshly exposed uncontaminated pit faces except in the case of composite topsoil samples and never collect samples near auger holes.

6. Samples should be collected one by one and each packed immediately. Two labels should be provided, one placed inside the bag and one tied to the outside. On the labels should be recorded a unique profile number, a horizon identification recorded by making the upper and lower horizon depths, the name of the collector and the date of collection.

7. Samples should be despatched to the laboratory as soon as possible accompanied by a profile description and three prepared copies of the laboratory data sheet. In cases where it is necessary to store samples for a while these should be unpacked, spread on a clean surface, air-dried and repacked at the earliest opportunity. This action will reduce the rate of change due to microbiological and other reactive activity.

5. SURVEY REPORT

5.1. Content of survey reports

A standard soil survey report consists of the following chapters:

Summary (and recommendations).

Acknowledgements

1. Introduction
2. Environment

   2.1 Location

   2.2 Communication, population, infrastructure

   2.3 Climate

   2.4 Geology

   2.5 Physiography, hydrology

   2.6 Vegetation and land use

3 Survey methods

   3.1 Office methods

   3.2 Field methods

4. Description of mapping units

   4.1 General (incl. legend)

   4.2 Description of individual mapping units

   4.3 Classification and correlation

5. Land capability and crop suitability

   5.1 Land capability

   5.2 Irrigability classification

   5.3 Crop suitability

   5.4 General remarks or management and productivity

References

Appendices 1 - Profile description and analytical data.

(other standard appendices will be taken care of at Mount Makulu).

5.2 Content of the chapters.

Some more remarks can be made on what each chapter should contain. The first page of a standard soil survey report is the title page. On this page the following text is required: Republic of Zambia, Ministry of Agriculture and Water Development. Number of survey report, Name of survey (title), province, Author(s), Soil Survey Unit, Year of publication, Nature of report in case it is preliminary or interim and Address where the report can be obtained. In the summary the main facts of the report are summarized in half page or less. Clear recommendations may be included. The acknowledgements are needed to thank all those involved, especially higher authorities and other people outside the Soil Survey Unit.

In the introduction, which should have a length of 2 pages or less, the reason why the survey was carried out, the dates of the survey, the scale used in the field and the scale of the final maps are to be mentioned.

In environment six sections are to be written. For standard reports each section should be not more than one, preferably half a page of text. In some cases one of the sections may be longer if interesting features can be mentioned. The use of figures in this part of the report is recommended, especially in geology and physiography.

In survey methods the specific methods and details about the way the survey was carried should be mentioned. Keep this chapter short.

In description of mapping units the main body of the repor is given and thus a lot of effort should go into this chapter. It may begin with some statements about previous work on soil survey in the area and on the genesis (history of formation) of the soils. In the next section simple descriptions of the mapping units are given, consisting of the main concept of the mapping unit and the range of characteristics. Profile descriptions and summarized forms of them should not be inclu It is especially important to be clear about the differences between the mapping units; a special table showing the differences is therefore often helpful. The extent of each mapping unit can either be mentioned with each description or given as a table. The classification of the soils according to the Zambian soil classification system (in progress) is imperative. Classification according to FAO/UNESCO and Soil Taxonomy is recommended. This chapter is often the most boring part of the report. Try to put a personal touch to the description of the mapping units. Mention particulars about them, even if you are not sure whether they really have a meaning. Remember that you have been some time in the area and before another person will see the same phenomena it may take many years.

In land capability and crop suitability the land evaluation according to the present system is presented. Do not give the methodology as it will be given as a standard appendix. In this chapter the land capability class of each mapping unit is to be identified together with the suitability of crops. However it is not enough to stop this chapter at this point. You should try to get an overview of the potential land use of the survey area. Having studied the soils and with some knowledge about crops and agriculture in the region it must be possible to give information about possibilities. These suggestions will then be studied by the planners.

In references you give the literature as mentioned in the text. In reports with only few references this can be done by using footnotes.

Appendices. Appendix 1 is always the profile descriptions and the analytical data. Appendix 2 is a standarized appendix on methods of analysis. Appendix 3 is a standarized appendix on the interpretation of analytical data. Appendix 4 is a standarized appendix on land capability. Appendix 5 is a standarized appendix on irrigability classification, which will only be included if relevant. More appendices may be added, e.g. tables used in land evaluation, specific phenomena in the study area. The last standarized appendix, without a number, is list of survey reports published sofar. This appendix will be provided by Mt. Makulu, together with the other standarized appendices.

Optional is a glossary. We have to keep in mind the persons who will read the report. It would be better to avoid terms which need explanation. If this is impossible, we use a footnote. Also optional is a table showing the correlation between the soils of the current report with others.

Following the content page a list of tables, figures and maps should be given. Especially figures enlighten a report remarkably. A pencil drawn sketch is often sufficient for the draughtsman to make a useful figure. The number of each map accompaning the report should be mentioned in the list of maps. A location map (often as a figure), a soil map and a land capavility map are imperative in each report. The legend of each map should be simple and clear. In the description of the mapping units the inclusion of the legend makes the description more clear and is recommended. The soil map and the land capability map may only be combined if delineations are similar and mapping units are large enough for the symbols.

5.2 General remarks on writing survey reports

1. Do not make long and boring texts: use simple terms; write short sentences.
2. Do not lecture on textbook issues. Be factual
3. Use paragraphs as much as possible
4. Type draft at double spacing
5. Write page numbers only by pencil
6. Use figures wherever possible; mention location of figures and tables on the side of the page; number figures and tables per chapter (fig. 5.1, 5.2); give tables and figures on separate sheets.
7. Do most of the writing in the field while camping, your memory is fresher and forcing oneself to write the findings of the day makes the survey of the next day more pleasant and clear.

5.3 Editing of survey reports.

In order to get some consistency in content and presentation of survey reports the soil correlator will act as editor and take care of comformity, correlation, text editing and reproduction.

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