MINISTRY OF LANDS, NATURAL RESOURCES AND ENVIROMENTAL PROTECTION

SOIL CARBON STOCK INVENTORY AND MONITORING:

TRAINING AND FIELD MANUAL FOR SOIL SAMPLING

Sesele B. Sokotela

UN-REDD PROGRAMME AND ILUA II PROJECT

Forestry Department

LUSAKA

September, 2012

Contents

Contents ... 3
ACKNOWLEDGEMENT ... 5
ACRONYMS ... 6
1.0 INTRODUCTION ... 1
1.1 Objective for measurement of organic carbon ... 1
1.2 Soil manual presentation ... 1
1.3 Sampling design for soil carbon survey ... 2
1.4 Focused sampling for the determination of soil organic carbon ... 3
2.0 FIELD SOIL SAMPLING METHODOLOGY ... 4
2.1 Integration and stratification with the ILUA forestry biophysical sampling ... 4
2.2 Location of soil sampling pit ... 5
3.0 COLLECTION OF SOIL SAMPLES ... 7
3.1 Soil sampling ... 7
Soil pit digging ... 7
3.2 Soil description ... 8
Photograph ... 8
Soil colour assessment ... 8
Field soil texture assessment ... 9
Soil structure ... 11
3.3 Soil sampling for bulk density ... 11
3.4 Organic carbon variable soil samples ... 14
Composite soil sampling ... 14
Surface plant litter sampling ... 15
Samples handling ... 15
Labels for soil and litter samples ... 16
Bulk density core rings ... 16
4.0 References ... 17
ANNEX I ... 18
UN-REDD AND ILUA SOIL FIELD OBSERVATION RECORD FORM ... 18
Form SDS_1: Soil Pit Site Description ... 18

Form SDS -2: Soil Pit Horizons Description 20
ANNEX II 22
GENERAL PROCEEDURES FOR SOIL SAMPLING 22
Composite Samples 22
Soil Survey Samples 23
Preparation of the soil sample in the laboratory 23
ANNEX III 24
LABORATORY SOIL ANALYTICAL METHODS 24
Carbon and Organic Matter Determination by the Walkley – Black Method 24
General Guidelines on Soil Sampling and Soil Analysis 25
Determination of Soil pH 25
Bulk Density Core Method 26
ANNEX IV 30
SOME EQUIPMENT NECESSARY FOR FIELD WORK 30
ANNEX V 31
GLOSSARY OF TERMS 31

ACKNOWLEDGEMENT

The author is grateful for the support, co-operation and team work exhibited and accorded by all who were involved in the preparation of this manual. Of critical importance were both the technical and administrative guidance provided by the Project Management Unit (PMU) at the Forestry Department, Ministry of Lands, Natural Resources and Environmental Protection, Lusaka, and the FAO and UN-REDD Programme technical team. The encouragement received from all the colleagues in the work place at the National Soil Surveys Programme, Zambia Agricultural Research Institute, Ministry of Agriculture and Livestock is gratefully acknowledged. Thanks are also due to the participants of the field testing and training teams whose feed-back comments and suggestions were incorporated to complete the writing of the soils manual to its current form.

SBDS.

ACRONYMS

C	Carbon
Ca	Calcium
CEC	Cation Exchange Capacity
EC	Electrical Conductivity
FAO	Food and Agricultural Organization of the United Nations
GHG	Greenhouse Gas
ILUA	Integrated land Use Assessment
IPCC	Intergovernmental Panel on Climate Change
K	Potassium
Mg	Magnesium
MRV	Measurement, Reporting and Verification
N	Nitrogen
Na	Sodium
P	Phosphorus
pH	potential Hydrogen concentration
REDD+ mechanism	Reduction in Emissions from Deforestation and forest Degradation framework mechanism
S	Sulphur
SOC	Soil Organic Carbon
UNFCCC	United Nations Framework Convention on Climate Change
UN-REDD	United Nations Reduction in Emissions from Deforestation and forest Degradation Programme
ZFD	Zambia Forestry Department

1.0 INTRODUCTION

1.1 Objective for measurement of organic carbon

This manual contains guide lines for field soil description, soil samples collection methods with the main objective of undertaking the assessment of soil organic carbon (SOC) stock in Zambia. It is presented in a simplified format and is intended for use by personnel who may not be experts in the subject of soil science. In this regard the manual is not designed to provide a comprehensive soil taxonomic coverage in relation with the subject of soil description, classification and land evaluations. Users with interest in detailed pedological classification and soil nomenclature may refer to the FAO Guidelines for Soil Description (FAO, 2006).

However, it sets out the procedural protocol to be followed for consistency in the inventory of soil organic carbon stocks covering the entire country in Zambia, and the content of this manual requires rigorous adherence by all participating personnel and institutions.

The first part of the manual is developed as part of the soil survey design and methodology to serve as an instructional guideline and practical application tool for use in the field for soils and landscape description, and sampling.

Part II of the manual provides an outline to guide laboratory soil samples analysis for soil organic carbon, and is developed for distribution to research laboratory facilities charged with the task to do soil samples analysis for soil organic carbon measurement.

Central to the objective for the preparation of this manual on soil survey design and methodology development is to address the measurement of soil organic carbon in accordance with the measurement reporting and verification (MRV) framework for reducing emissions from deforestation and forest degradation (REDD + mechanism). In order to effectively implement the REDD + mechanism it is required that forest and carbon monitoring systems are transparent, accurate, complete, consistent and comparable. The data generated by the use and application of the methodologies must be accurate, consistent and internationally comparable on the quantification of greenhouse gas (GHG) emissions. This is essential for the international community to take the appropriate action and measures to mitigate climate change and ultimately achieve the objective of the United Nations Framework Convention on Climate Change (UNFCCC). Strict adherence will be observed to follow the Intergovernmental Panel on Climate Change (IPCC) Guidelines for Agriculture, Forestry and Land Use (IPCC, 1996; 2003; 2006; 2007).

1.2 Soil manual presentation

The presentation of the manual begins with an outline of the UN-REDD and ILUA framework for forestry biophysical sampling design. The soil site identification and description or characterization process is covered, followed by the sitting, digging, describing and sampling of the soil pit. Special attention is drawn to the discerning of the soil horizons, the identification of the soil layers from which soil samples are collected for soil carbon analysis. Distinction is made between the procedure to obtain undisturbed core soil samples for the measurement of bulk density, and the collection of soil samples for the determination of soil organic carbon. A technique for collection of surface plant litter, the packaging and handling of all sampled materials (soils, litter, etc.) is also included. Laboratory sample registration, sample preparation and analytical methods pertaining to soil organic carbon quantification are given. In order to guide survey teams in making adequate preparations for field work, a list of some required equipment is provided in Annex II. A glossary of commonly used terms is also outlined.

1.3 Sampling design for soil carbon survey

The aim of undertaking the nation-wide soil carbon inventory is the provision of unbiased estimates of the soil carbon stock and stock changes. Thus relevant issues under consideration must include, 1) sampling intensity (the number of study sites and rules to locate the study sites) –ILUA land tracts, referred as clusters in the manual, 2) sampling interval (decadal or five year intervals) –a five year repetitive cycle may be preferred if resources are permitting, but sampling within and around the same plots every ten years is strongly recommended, 3) soil layers to be studied, in accordance with the IPCC guidance, are to comprise the 0 – 10 cm, 10 – 20 cm and 20 – 30 cm depths from within and around the soil pit, and 4) the location of sample points and numbers at the study sites (the location of the soil pit), and subsequent variable composite soil sub-samples within the established sampling plots is considered critical.
Efficiency in the sampling can be improved by stratification with available prior information of variation of target variables. Soil layers selection to be studied are guided by known sensitivity of the different layers caused by human induced disturbance, soil erosion or other factors including accumulation of organic and other materials. The IPCC guidelines recommend the use of 0-30 cm as default layers. Further to the collection of soil samples for measurement of soil organic carbon, surface organic plant litter samples are to be taken. The next section of the manual outlines instruction details to follow before, during and after the soil and litter samples are collected.

1.4 Focused sampling for the determination of soil organic carbon

Presently the determination of initial soil carbon pools across the Republic of Zambia is of primary importance, and will focus sampling on the determination of soil organic carbon quantity. Therefore, for this purpose the only variable under consideration are laboratory tested organic carbon percent (Org. % C), and the bulk density (BD) of the soil materials. Soil pH will be measured solely as an indicative parameter of the soil reaction condition that might imply a requirement to explain or understand certain content underlying trends in soil carbon quantities variation between study sites. This will help to gather baseline data on which to build the basis for applications of suitable soil carbon model calculations and simulation of soil carbon cycling over future study periods. Actual soil carbon calculations will provide the results for use in soil carbon budget in the form of the pool of soil carbon, changes in the pool of soil carbon over time, and emissions of carbon dioxide from soil.

In Zambia, soil samples obtained during the first soil carbon survey are to include soil organic carbon, soil pH, bulk density, and variables to be measured *in-situ* from the soil pit by field assessment techniques shall comprise soil texture, structure, drainage, soil colour, and other morphological features. In the future, and when needs arise, other variables, such as exchangeable bases cations (Ca, Mg, K, Na), soil Cation Exchange Capacity (CEC), soil Electrical Conductivity (EC), Nitrogen (N), Phosphorus (P), Sulphur (S) and others, including assessment of heavy metals, micronutrient elements, or elemental isotopes for experimental studies to help understand greater in-depth environmental circumstances may all be assessed depending on actual demanding needs for data application and use. Thus, for that reason the archiving of soil samples into safe storage for at least five years after the initial laboratory tests were conducted is necessary.

Finally, it is of critical importance that sampling procedural consistency is highly maintained by strict adherence to instruction guidelines provided in this manual. Soil sample field collection, samples preparation, and procedures of the chemical analysis methodologies must be the same across all research institutions and personnel involved; if different, serious systematic errors can be introduced on soil carbon estimates, as such resulting carbon stock estimates will be biased and change estimates inaccurate. Equally, for the soil organic carbon inventory and monitoring sample plots, it is essential to record the land use category, natural land features, human activities, natural vegetation type and soil types. Procedures used to select and sample plots must be consistent across all the clusters, districts, provinces and the whole country.

2.0 FIELD SOIL SAMPLING METHODOLOGY

2.1 Integration and stratification with the ILUA forestry biophysical sampling

The soil sampling methodology will be linked to the Integrated Land Use Assessment (ILUA) phase I field inventory sites, where the sample density and distribution in Zambia is a systematic grid set of a cluster of sampling plots positioned over the country selected at an intersection of every 30 minutes on the latitude/longitude grid, resulting into an inclusion of a total of 248 tracts nation-wide (ZFD/FAO, 2009). These are to represent the first phase sampling scheme and will comprise the potential permanent sampling clusters. Of these original 248 clusters, 221 of the clusters were accessible. During the ILUA II biophysical forest resources inventory, there will be a total of about 1300 new clusters, of which at least 10 % will be included as additional soil sampling sites. Thus, new sample sites will bring the total up to about 350 clusters for soil and litter sampling across the country.

The stratification procedure takes into account several factors, including vegetation type, land cover and vegetation canopy cover obtained through Google Earth imagery interpretations at all potential sampling cluster sites (Forestry Department, personal communication). In ILUA II, all ILUA I plots will be revisited, and a predefined number of samples within strata will be collected. The design shows the location of clusters and sampling plots in the country, in a province or a given district. The primary reporting area in the inventory design is a province.

As a rule each cluster consists of a 1 km by 1km land quadrate, in which sampling plots are spatially distributed as illustrated in a schematic diagram (Figure 1).

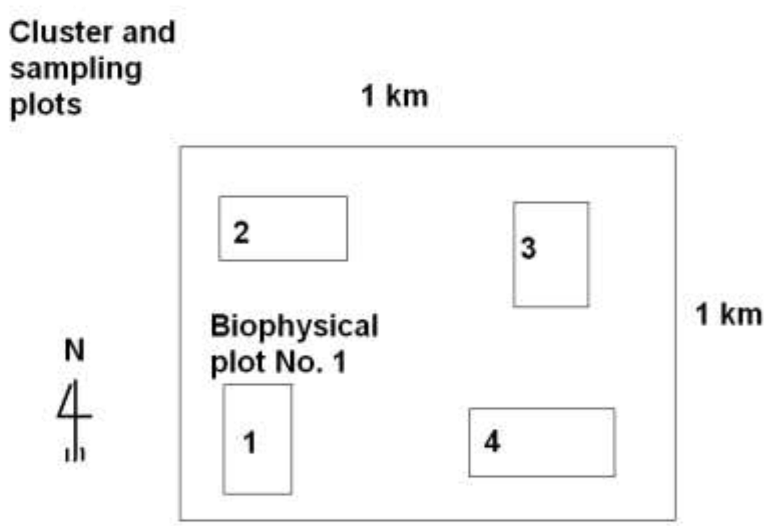


Figure 1: Cluster schematic diagram with spatial positions of sample plots (1, 2, 3,4)

In each one of these plots, (the sampling plots) the position and geographical location will be determined in the field by precise co-ordinates measured with the help of the GPS (global positioning system) receivers. Each sampling plot will measure 50 m long and 20 m wide.

2.2 Location of soil sampling pit

When arriving at the starting point of the sampling plot within the Cluster, the team establishes a marker pin and starting point by following guidance of the biophysical field data manual.

The position of the soil pit will always be placed 5 m to the northern edge of the biophysical inventory sampling Plot 1 (Figure 2). This is done to avoid undue disturbance in the sampling plots. In the initial year of sampling the soil pit and collection field soil samples will be made from the Biophysical inventory plot designated as No. 1 Plot. Thereafter, the subsequent sampling regimes to follow will rotate clockwise (i.e. Year 0 at No.1, Year 5 at No.2, Year 10 at No.3 and Year 15 at No.4).

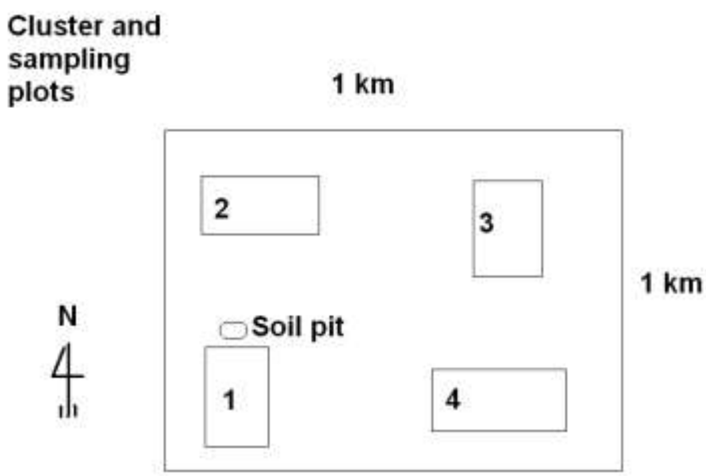


Figure 2: Diagrammatic representation of a Cluster, Biophysical sampling plots and Soil pit position

Plot ending point coordinates will work as reference coordinates for the soil pit location. It must be collected together with a point description of the location of the soil pit in order to enable soil samples relocation in the future. The exact geographical location coordinates of the soil pit are determined with the help of GPS (average position). Once the soil pit has been dug a photograph will be taken of the soil pit with a graduated scale in cm placed against the wall of the exposed face to be sampled in the pit (0 – 10 cm, 10 – 20 cm and 20 – 30 cm).

If it is not practical for the soil pit to be located in the prescribed position due to certain physical obstacles (such as termite mounds, termitaria, river, surface rocks, buildings, roads, or other construction works, etc.) being encountered, a reasonable alternative pit position should be determined and found. This is done by moving in a clock-wise direction to the side of the plot measured directly from the plot center due east at 90 degrees fron the north-axis line.

As a rule there will be no plot to be left abandoned on account of obstacles or what so ever reason in the course of undertaking the soil sampling procedure. Any alternative changes made in the defined procedure should be recorded and reported in the respective data entry sheet provided as ‘the Soil Site Description Form SDS – 1’, by marking in the space provided for additional observations, remarks/notes (ANNEX I)

3.0 COLLECTION OF SOIL SAMPLES

3.1 Soil sampling

At the soil pit study site three types of soil samples will be taken firstly, the undisturbed core ring sample will be collected from the soil pit at 0 – 10 , 10 – 20 cm and the 20 – 30 cm layers, respectively. Secondly, from the same layers in the soil pit, disturbed soil samples are collected for the measurement of soil organic carbon in the laboratory. Thirdly, composite soil samples are prepared having been collected using a soil auger from several sub samples targeting the top soil (0 – 10 cm), and sub soil (10 – 20 – 30 cm depths) from within the sampling plot.

Soil pit digging

The soil pit dimensions will conform to a mini-pit measuring 50 cm wide, 60 cm in length and 40 cm depth. The soil pit is dug or excavated using hand tools like a hoe, pick or mattock and a spade. The width and length of the pit are just adequate to permit personnel to carry out soil morphological descriptions, collect the required soil samples for measurement of soil organic carbon. The orientation of the pit will be such that maximum light illumination falls on the vertical face of the pit prepared for description and sampling. The opposite side to this face will have a step-in stair-case-like arrangement of steps for the convenience of the soil sampler (Figure 3).

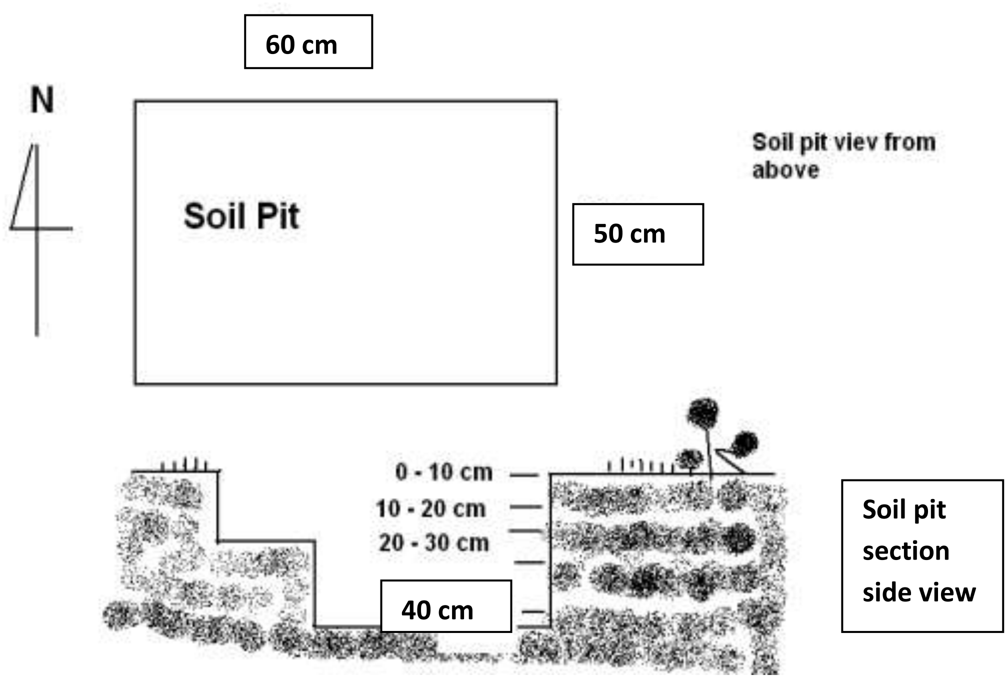


Figure 3: Schematic soil pit diagram illustration

3.2 Soil description

The site description information will include location, vegetation type, land use, farming system, crops, land forms and land elements, meso and micro relief, soil erosion, stoniness, rockiness, slope and site position on slope and soil drainage condition. The information should be recorded on the soil pit description sheet provided (Form SDS –1 Annex I). To complete the description of landform and topographic position, visually inspect the area surrounding the plot and select the appropriate categories provided on the field recording sheet and the major landform designation.

Note that for pits dug during the morning time of the day, the profile face will be made on the western direction to face and permit maximum sunlight illumination and visual observation of soil horizons and other soil morphological features, whilst the opposite will be the case for soil pits dug and sampled in afternoon times. The ground surface on top of the pit vertical face must be left clear of any excavation materials from the pit and must be undisturbed as Figure 3 illustrates.

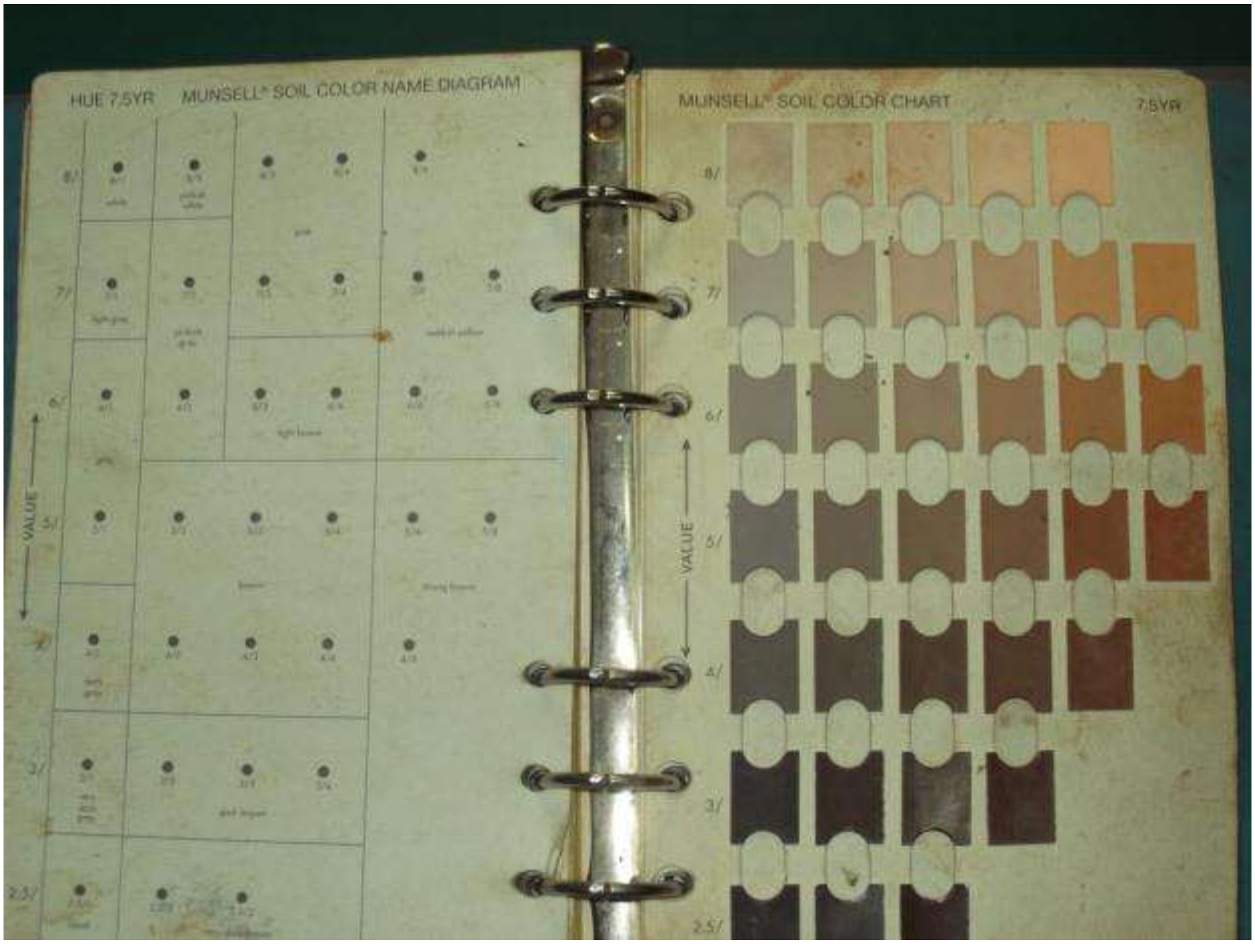
Photograph

Once the soil pit is dug and the soil layers (0-10, 10-20, 20-30) are measured and marked using a clearly graduated tape or ruler, before sampling take a 'flash ' photograph with a depth scale tape and identification plate at the soil surface.

Soil colour assessment

Soil colour reflects the composition as well as the past and present oxidation-reduction conditions of the soil. It is generally determined by coatings of very fine particles of humified organic matter (dark), iron oxides (yellow, brown, orange and red), manganese oxides (black) and others, or it may be due to the colour of the parent rock.

The colour of the soil matrix of each horizon should be recorded in the moist condition (or both dry and moist conditions where possible) using the notations for hue, and chroma values as given in the Munsell Soil Color Charts (Figure 4). Hue is the dominant spectral colour (red, yellow, green, blue or violet), value is the lightness or darkness of colour ranging from 1 (dark) to 8 (light), and chroma is the purity or strength of colour ranging from 1 (pale) to 8 (bright). Where there is no dominant soil matrix colour, the horizon is described as mottled and two or more colours are given. In addition to the colour notations, the standard Munsell colour names may be given.



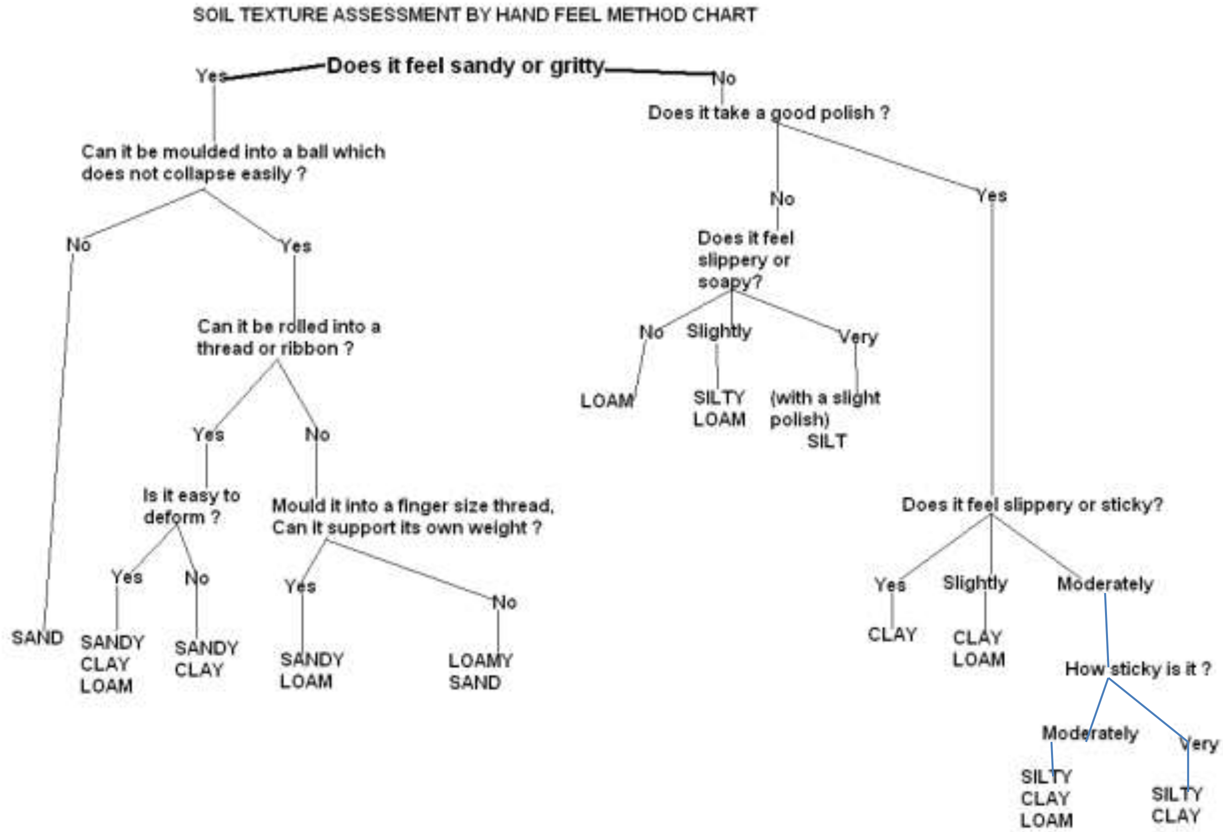
Source: Munsell Color, 1994 (Revised edition)

Figure 4: Munsell Soil Color Charts

Field soil texture assessment

Soil texture refers to the proportion of the various particle-size classes (or soil separates, or fractions) in a given soil volume and is described as soil textural class. The names for the particle-size classes correspond closely with commonly used standard terminology. The textural class can be estimated in the field by simple field tests and feeling the constituents of the soil (Hand Feel Flow Chart Method –see Figure 5); take a well mixed soil sample 2- 3 table spoon size in the hand. The soil sample must be in a moist to weak wet state with water. Gravel and other constituents > 2 mm must be removed. The constituents have the following feel: Clay: soils fingers, is cohesive (sticky), is formable, has a high plasticity and has a shiny surface after squeezing between fingers, Silt: soils fingers, is non-sticky, only weakly formable, has a rough and ripped surface after squeezing between fingers and feels very floury (like talcum powder), and Sand: cannot be formed, does not soil fingers and feels very grainy.

Assessment of Soil Texture in the Field



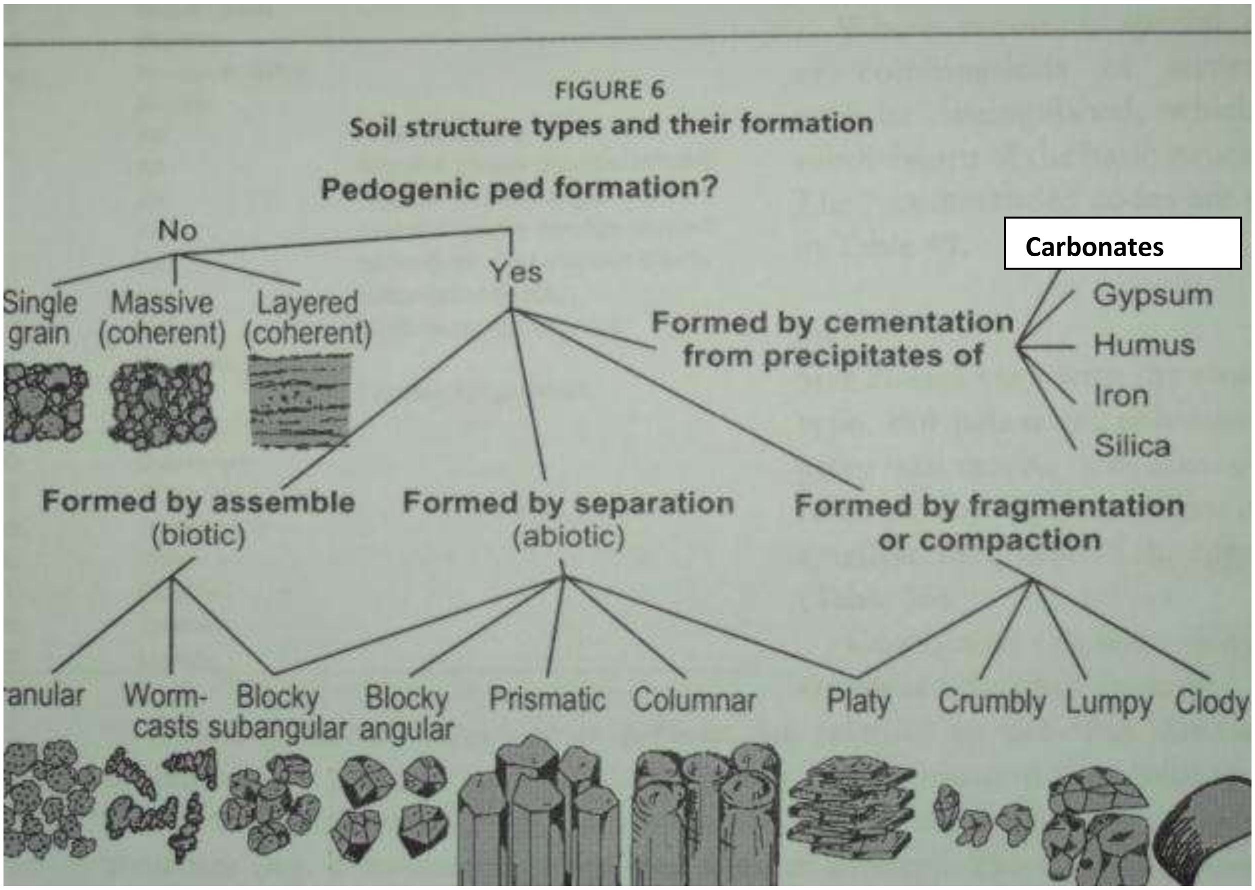
Source: Woode, 1988

Figure 5: Flow Chart Method –a hand feel assessment of soil texture

---

Soil structure

Soil structure refers to the natural organization of soil particles into discrete soil units (aggregates or peds) that result from pedogenic processes. The aggregates are separated from each other by pores or voids (Figure 6). It is preferred to describe the structure when the soil is dry or slightly moist. In moist or wet conditions, it is advisable to leave the description of structure to a later time when the soil has dried out. For the description of soil structure, a large lump of the soil should be taken from the profile, from various parts of the horizon if necessary, rather than observing the soil structure *in situ*. Soil structure is described in terms of grade, size and type of aggregates. Where a soil horizon contains aggregates of more than one grade, size or type, the different kinds of aggregates should be described separately and their relationship indicated.



Source: FAO, 2006

Figure 6: Soil structure assessment

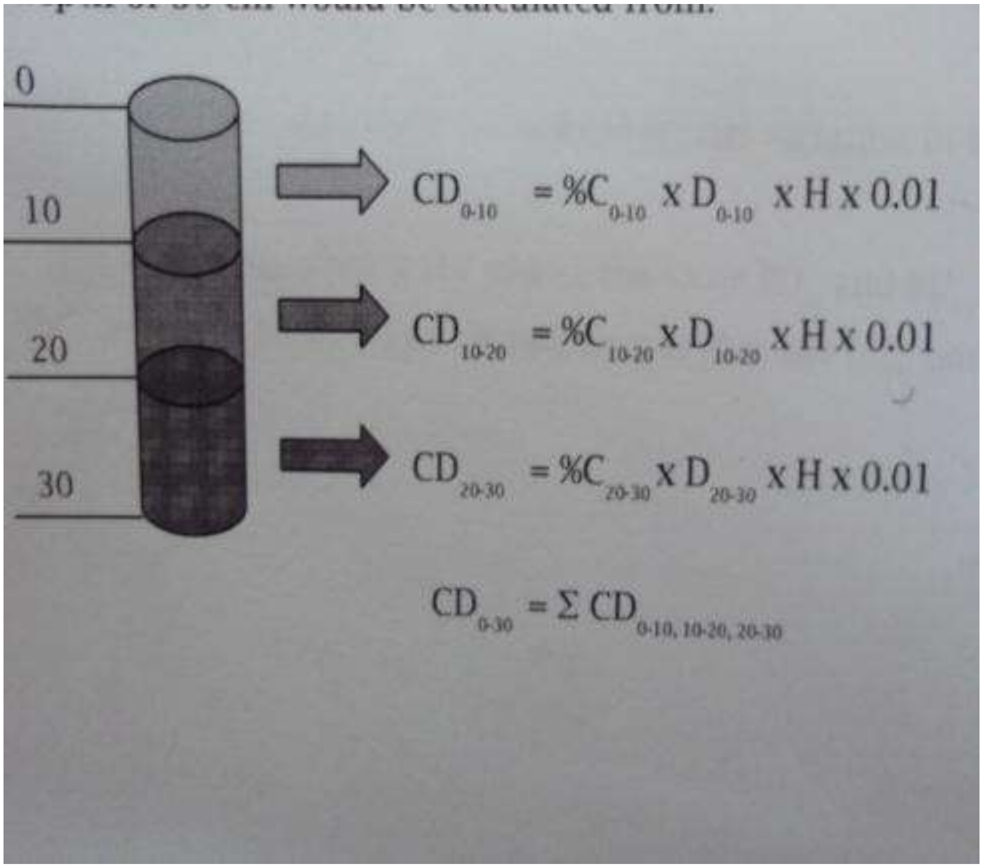
3.3 Soil sampling for bulk density

It must be noted that all bulk density samples will be taken in duplicate, that is, to comprise two core ring samplers collected per soil layer from the soil pit.

Bulk density is defined as the mass of a unit volume of dry soil (105 °C). This volume includes both solids and pores and, thus, bulk density reflects the total soil porosity. Low bulk density values (generally below 1.3 kg dm^{-3}) generally indicate a porous soil condition. Bulk density is an important parameter for the description of soil quality and ecosystem function. High bulk density values indicate a poorer environment for root growth, reduced aeration, and undesirable changes in hydrologic function, such as reduced water infiltration. There are several methods of determining soil bulk density. One method is to obtain a known volume of soil, dry it to remove the water, and weigh the dry mass. Another uses a special coring instrument (cylindrical metal device –soil core ring method-as illustrated in Figure 7), to obtain a sample of known volume without disturbing the natural soil structure, and then to determine the dry mass (see ANNEX III (3).

For surface horizons, a simple method is to dig a small hole and fill it completely with a measured volume of sand. Field determinations of bulk density may be obtained by estimating the force required to push a knife into a soil horizon exposed at a field moist pit wall.

The undisturbed mineral soil samples are taken from the vertical side face of the pit.
The 10 cm depth intervals soil core rings are used to sample, in duplicate, the upper 30 cm mineral soil about 15 cm from the pit vertical side, using a thick hard wood plank and short handled rubber hammer to insert the soil core vertically without side-ways movements or wobbling to avoid underestimate of bulk density, or an overestimate.



Source: Livesley, 2010

Figure 7: soil core ring method of soil bulk density

In a soil without stones and minimal coarse roots soil carbon is calculated from a core sampled at 0 -10 cm (CD 0-10) by the expression below

$M/V=D_{0-10}$

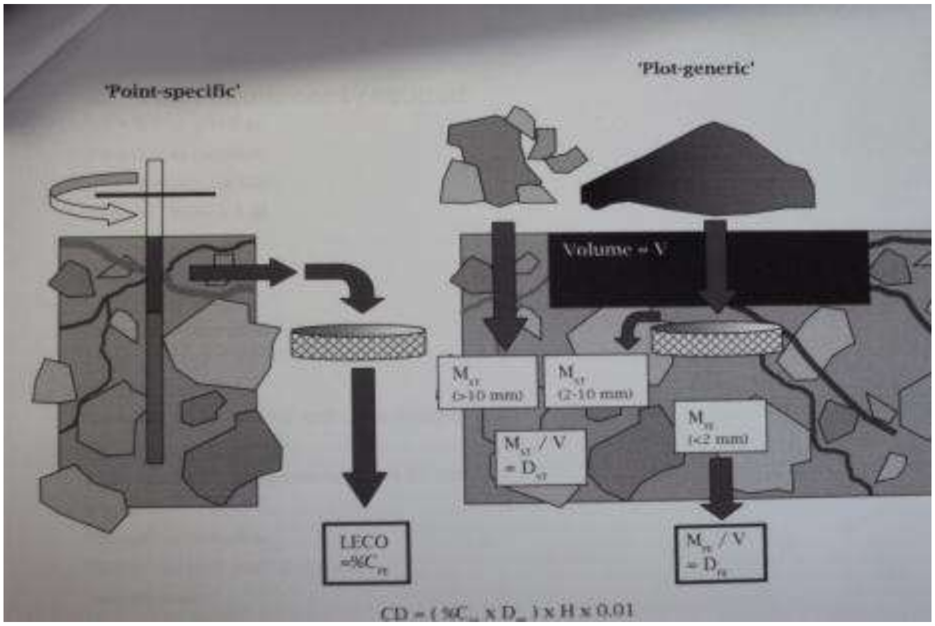
LECO 2000 %C;

$CD_{0-10} = \% C_{0-10} * D_{0-10} * H * 0.01$

Where, M=Oven dry (105 degrees Celcius) mass total soil sample; V=volume of the soil core (cubic meter);D= soil Bulk Density (kg /cubic meter) for that depth, H=the sampled depth interval (m), and % C 0-10 is the %C concentration the sieved soil material; LECO 2000 %C is quantitative carbon content measured by the dry combustion method.

It is important to note that procedures for gravelly and stony soils for defining the fine earth and stony earth mass, where soils with large stones or boulders are encountered require a more complex sampling, for instance, the use of disturbed cores/gouge augers, or the point specific, or ‘plot generic’ pit excavation illustrated in Figure 8) may be applied.

Estimating soil bulk density in more complex situations takes into account the separation of the course earth materials from fine earth by sieving through a > 10 mm and < 2 mm mesh, determining the material mass of both a known volume, either from a 'point specific or plot generic approach.



Source: Livesley,2010

Figure 8: estimating soil bulk density in more complex situations

3.4 Organic carbon variable soil samples

Composite soil sampling

Composite soil samples are to comprise disturbed soil samples collected in two ways, one from each of the soil pit layers sampled for bulk density, and another from within the sampling plot obtained from several spots collected at two levels, one topsoil (0 – 10 cm) and another, subsoil (10 – 20 – 30 cm) depths using the soil auger. These will be taken, beginning by identifying the center of the sampling plot. By means of an auger sample a number of points representative of the plot. Five (5) soil samples will be obtained from the centre of the sampling plot, then five meters to the north, east, west and south, as illustrated in Figure 9. Sample the surface or topsoil separately and place in clearly marked container or bucket. Samples from the topsoil are combined and thoroughly mixed, from which a 'grab' sample, the composite sample is taken. This is about 500 g to 700 g soil material that is then placed into a clean sample bag, labeled according to location, depth for transportation to the laboratory. In a separate bucket the same procedure is repeated for the sub sample.

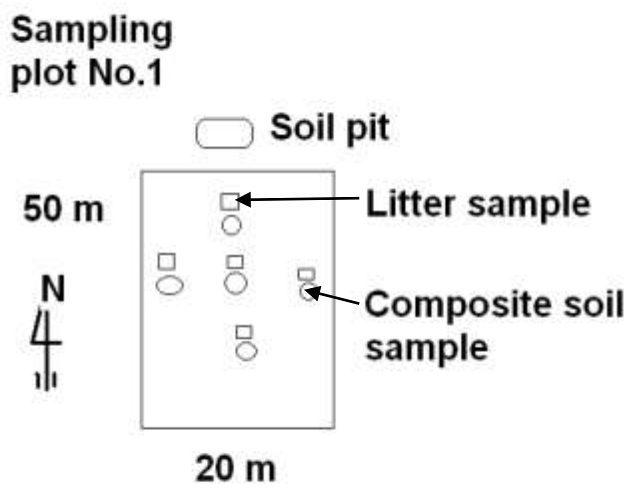


Figure 9: Illustration of location of Composite soil and Litter samples in the sampling plot

---

Surface plant litter sampling

Surface plant litter samples will be collected one meter to the north of the composite soil sample. Use a 0.5 m x 0.5 m quadrate, and collect all the plant litter material debris within the square, weigh using an electronic balance and record the reading on the field record sheet. After each weight is taken, the materials from all the five positions are thoroughly mixed on a ground sheet, from which a 'grab' sample weighing approximately 1.0 kg is obtained, bagged, and labeled according to plot and cluster for transportation to the laboratory to determine the dry matter weight.

Samples handling

All soil samples should be double plastic bagged, clearly labeled and stored in a dark cool stout box for transportation for laboratory analysis. Profile wall soil core rings are to be capped on both sides, and stored in the carry box for transport to the laboratory for processing.

All litter samples should remain in staple-sealed paper bags, stored in large plastic containers for storage with lids to prevent ripping and water damage during transportation. Ensure the litter bags can 'breath' to prevent mould and water damage. This is done by perforating sample bags with a paper perforator.

Upon delivery to the laboratory the samples should be checked and assigned a unique laboratory identifier at the soil receiving centre or bay. It is essential the samples are passed from field records to laboratory records, where laboratory numbers are assigned at this stage. Soil samples should be air-dried at room temperature for at least five days, then crushed and sieved (< 2mm mesh) to obtain the fine earth samples, and sub-divided immediately (10 – 20 g) for respective laboratory analyses for the organic carbon variable, and pH measurements.

After the soil samples have been air dried crushed and sieved to fine earth and sub-sampled for the appropriate analysis, the remaining soil material should be archived to safe storage for repeat analyses whenever required in the future.

All data obtained from the various laboratory tests should be recorded, entered into a spread sheet and stored in a database.

Labels for soil and litter samples

Soil carbon variable disturbed and composite soil samples collected at the depth o – 10, 10 – 20 and 20 – 30 cm are to be labeled by Province, District, Cluster, Sampling Plot, Pit No. and Depth of the sampling layer, with the Date and name of the Sampler. Labels may be pre-printed prior to field work, with the required information details to be completed whilst in the field. (see sample label details format). Each sample must have a set of two labels written. One will be placed on the inside between the two double bagged sample bag, while the other will be placed, or tied to the outside of the bag for easy identification and sorting of samples.

Litter samples are treated similarly, except the soil layer depth space or position will be marked ”N/A” (Not Applicable). No blank spaces are permitted, so all spaces provided on the label should be filled and completed.

Bulk density core rings

The Bulk Density core rings will in addition to label details provided for the composite and litter samples, which will be placed inside of the metallic carry box, each core ring sample should be marked with adhesive label directly placed on the outside of the upper lid cap.

Sample Label Details Format

SAMPLE TYPE ID	
PROVINCE ID	
DISTRICT ID	
CLUSTER ID	
SOIL PIT ID	
SAMPLE No.	
SOIL LAYER DEPTH	
DATE SAMPLED	
SAMPLER NAME	

4.0 References

Cheatle, R J and R. van't Klooster, 1984. Methods of Soil Analysis. Technical Guide No 16. Soil Survey Unit, Department of Agriculture, Chilanga.

FAO, 2006. Guidelines for Soil Description. Food and Agriculture Organisation of the United Nations, Rome.

IPCC, 1996. Climate Change 1995. Working Group 1, Cambridge University Press, Cambridge –U.K.

IPCC, 2003. Penman J, Gystarsky M,Hiraishi T,Kruger D,Pipatti R, Buendia L,Miwa K, Ngara T, Tanabe K, Wagner F (eds.). Good practice guidance for land-use change and forestry. Institute for Global Environmental Strategies (IGES), Hayama, Japan.

IPCC, 2006. Guidelines for national greenhouse gas Inventories. IPCC National Greenhouse Gas Inventories Programme, Kanagawa, Japan.

IPCC, 2007. IPCC Fourth Assessment Reort: Climate Change 2007. http://www.ch/ipccreports/assessments.htm

Livesley S, 2010. Soil sampling for site characterization and carbon stock Field and Laboratory Manual (2nd Draft).. Deepartment of Sustainable and Environment, University of Melbourn pp25

Munsell Color, 1994. Munsell Colour Charts. Revised Edition.Macbeth Division of Kollmorgen Instruments Corporation, New Windsor, New York.

Woode P, 1988. Field Guide for Soil Surveyors. Technical Guide No. 18. Soil Survey Unit, Research Branch, Department of Agriculture, Chilanga -–Zambia

ZFD/FAO, 2009. Intergrated Land Use Assessment (ILUA) Zambia 2005 – 2008. Zambia Foretry Department and Food and Agriculture Organisation of the United Nations, Ministry of Tourism,Environment and Natural Resources, Lusaka.

ANNEX I

UN-REDD AND ILUA SOIL FIELD OBSERVATION RECORD FORM

Form SDS_1: Soil Pit Site Description

1a. **Cluster Number**		**Soil Pit Number.**				**Brief Terrain Description (Drawing sketch)**
1b. **ILUA I Number**						
A. Cluster Location						
2. Province		6. ILUA I cluster [Y/N]				
3. District		7. Soil sampling cluster [Y/N]				
4. Township		8. UTM Zone	34	35	36	
5. Village/Locality						

B. Authors			
Name	**Address**	**Phone Number**	**Role**
			9. Team Leader
			Assistant TL
			10. Enumerator

C. Equipment Used	**F. Soil Pit Geographical Location**
11. GPS (Name, model)	
12. High-precision GPS [Y/N]	Pit position coordinates
	13. UTM E (X)
	14. UTM N (Y)

D. Vegetation type (circle choice number)		**G. Farming System**	
1 *Cryptosepalum* forest	11 *Munga* woodland	1 Shifting axe and hoe cultivation	6 Commercial
2 *Baikiaea* Dry Dec. forest	12 Kalahari woodland	2 Semi-permanent hoe	7 Other farming
3 Itigi Dry Forest	13 Thickets	3 Semi-perm. Hoe/ ox Plough	(Specify)
4 *Parinari* Dry Evergreen	14 Grassland *Dambo*	4 Fishing and semi-perm. Hoe cult	
5 *Riparian* Forest	15 Grassland	5 Semi- commercial ox and tractor cult	
6 Swamp forest	16 Sedges- papyrus/Reeds-	**H. Crops**	
7 Kalahari sand *Chipya*	17 *Terminaria*	1 Maize	5 Groundnut
8 Lake Basin *Chipya*		2 Sorghum	6 Soya bean
9 *Miombo* woodland	18 Other vegetation	3 Millet	7 Other crop
10 *Mopane* woodland	(Specify)	4 Beans	(Specify)

E. Land use				
1 Urban	3 Improved pastures		5 Protected Forest Reserve	7 Natural vegetation
2 Cropland	4 Natural grazing		6 Afforestation	8 Other (specify)

J Land form			
Hills and Mountain	Escarpment	Rift Valley	Degraded Plateau
Aggraded Plateau	Flood plains, Flats and Swamps	Narrow river/stream valley	Erosion gulley
Rock outcrops	Sink-hole depression	Laterite out crop	Erosion Rills
Sand dunes	Micro-relief surface features (gilgai, stool mounds, etc.)	Termite mounds	Moss
Mine waste dump	Animal burrows	Contour ridges/bunds	Other (Specify)

K. Land Surface Features present

	Water logging	**Erosion**	**Stoniness**	**Slope**
Degree of severity				
None				
Slight				
Moderate				
Severe				

Additional observation Remarks/Notes:

____

____

____

____

____

____

____

____

____

Form SDS -2: Soil Pit Horizons Description

Soil Morphology Feature	Description	Co des					Horizon Designation (enter code)			
1 Layer		1	2	3	4	5	Soil pit layers			Other Notes
2 Horizon	Mineral Soil	A	AB	BA	B	C				
	Organic Soil	H	O							
3 Depth	Measured in pit (cm)						0-10	10-20	20-30	
4 Boundary	Distinct	Smooth	Wavy	irregular	Broken					
	Topography (Shape)	Sharp	Clear	Gradual	Diffuse					
5 Coarse material	Abundance	None	Very	Few	Common	Many				
	Size	Fine Gravel	Medium	Coarse	Stones	Boulders				
	Shape	Flat	Angular	Sub-round	Rounded					
	Nature (Rock type)	Sand stone	Granite	Gneiss	Diorite	Gabbro				
	Other (specify)									
6 Colour (Matrix)	Dry (Munsell charts)									
	Moist									
7 Mottles	Matrix colouration	None	Faint	Distinct	Prominent					
8 Texture	Estimate proportions of content of clay, silt, sand	S LS	SL SCL	SiL SiCL CL	L SC SiC	C HC				
9 Structure	Grade	Structure less	Massive	Weak	Moderate	strong				
	Size	Fine	Medium	Coarse	Very coarse					
	Type	Single grain	Sub angular blocky	Angular Blocky	Granular					
10 Consistence	Dry	Loose	Soft	Slight Hard	hard	Very Hard				
	Moist	Loose	Very friable	Friable	Firm	Very Firm				

	Wet stickiness	**Non-sticky**	**Slight**	**Sticky**	**Very Sticky**				
	Wet plasticity	**Non-plastic**	**Slight**	**Plastic**	**Very plastic**				
11 Moisture	**Condition**	**Dry**	**Moderate Dry**	**Moist**	**Wet**				
12 Compactness	**Detection of special formation or cementation**	**Non-compact**	**Slight**	**Moderate**	**Compact**				
13 Voids	**Size**	**Fine**	**Medium**	**Coarse**	**Very coarse**				
	Abundance	**None**	**Few**	**Common**	**Many**				
	Type	**Interstitial**	**Vesicles**	**Vughs**	**Channels**				
14 Roots	**Size**	**Fine**	**Medium**	**Coarse**	**Very coarse**				
	Abundance	**Few**	**Common**	**Many**	**Abundant**				
	Orientation	**Random**	**Vertical**	**Horizontal**					
15 Reactions (CO_3 Test) - Optional	**Intensity of effervescence in weak HCl**	**-**	**+-**	**+**	**++**				
16 Sample	**ID – Number of soil material sample collected for lab test**	**Org.C**	**Variables**						
		BD	**Bulk**	**Density**	**(BD)**				

NB: Simplified compilation adapted from Guidelines for soil Description (FAO, 2006)

Key to codes:-

H	Organic soil layer dominated by organic material formed from accumulations of undecomposed or partially decomposed organic material at the soil surface, which may be under water.
O	Organic soil horizon layer dominated by organic material consisting of undecomposed or partially decomposed organic litter, such as leaves, needles, twigs, moss, and lichens that has accumulated on the surface; they may be on top of either mineral or organic soils.
A	Surface mineral soil layer (usually rich in humified plant organic matter and dark in colour)
AB	Transitional mineral soil layer immediately below the surface layer with dominant features resembling the A horizon
BA	Similar to AB, but B Horizon features dominating
B	Subsuface mineral soil layer, substantially altered in colour, and well-formed structure
C	Subsurface mineral or/and organic soil material forming the parent materials of the soil (may comprise decayed and weathering geological rock materials- *saprolite*, alluvium or other depositions from which soil materials would have derived origin)
BD	Bulk Density of the soil

S=sand; LS=loamy sand; SL=sandy loam; SCL=sandy clay loam; SC=sandy clay; C=clay; HC=heavy clay; Cl=clay loam; SiCl=silty clay loam; SiC=silty clay

GENERAL PROCEEDURES FOR SOIL SAMPLING

The purpose for which the soil is required determines the method of sampling. Where the sample is to be representative of a given area of land, it is necessary to take a number of samples scattered uniformly over the field or block to be examined. Such composite samples are required in sampling experimental plots, but for general soil survey purposes, they are of little value for soil profiles descriptions and no attempt should be made to secure a mixed sample representative of a given area, unless require for soil classification purposes.

Composite Samples

By means of an auger or cylindrical borer, sample number of sites representative of the plot or area to be investigated. Sample the surface much separately from the rest of the soil. Take the remaining samples from different depths as desired. Combine the soil from the appropriate depth in each hole and mix thoroughly on a piece of clean plastic or paper. From this material take a 'grab sample'; that is, spread the material into a layer, then take small portions of soil, at random, so that the sample taken is representative of the original material. Place the sample in a light bag, label with the location and depth and transport to the laboratory.

Soil Survey Samples

Carefully choose the site of the pit, taking into consideration all other factors likely to affect the soil in comparison with the normal type it is intended to represent. By means of suitable bearings, fix the position of the depth of the pit on the map. As far as possible dig the pit and the depth of the pit will vary with soil type and sampling requirements. Clear one face of the pit carefully with spade and note the succession and, depth of each horizon. Take the first sample to represent the whole of the surface horizon, to the depth of the first distinct change in colour or texture. Sample each horizon below this by cutting steps in the pot face and remove a portion of the layer, typical of the horizon, without attempting to include its full depth. By discarding about four cm at the junctions of the horizon the transitional phases are affectively excluded from the sample.

Place each sample, together with a slip of paper identifying the soil, in a numbered plastic bag for transport to the laboratory.

Preparation of the soil sample in the laboratory

When the sample reaches the laboratory, break up any larger lumps and spread it out in a suitable clean tray to become air – dry. When air – dry, grind the main sample in a mortar to pass the desired size of sieve depending on the analysis. It is considered to work with laboratory numbers than with field number; therefore, enter samples into a “Soil Reception Ledger”, and accord a laboratory number. Store samples in a dust free cupboard.

ANNEX III

LABORATORY SOIL ANALYTICAL METHODS

Carbon and Organic Matter Determination by the Walkley – Black Method

The term "soil organic matter" embraces the whole non-material fraction of soil. Organic matter contributes to the physical condition of a soil by holding moisture and by affecting structure. It is a direct source plant nutrient element, the release of which depends upon microbial activity and by affecting the cation exchange capacity; organic matter is directly involved in the availability of nutrient elements. In many forested soils, the organic matter is synonymous with soil fertility.

Vegetable and animal matter added to soil contains more carbon than nitrogen and as long as this carbonaceous material persists in the soil, very little nitrogen will be released. As the row organic matter decomposes, carbon is lost as carbon dioxide and the C/N ratio gradually narrows. It is generally considered that for most soils the ratio eventually stabilizes at about 10.1. If soil temperature and microbiological activity are high, the ratio may narrow even more. As mineralization of organic matter and immobilization by micro-organisms occur simultaneously in soil, the C/N ratio is one way of expressing the balance at any particular time.

The ecological importance of the content of organic matter as determined by analysis varies widely with climatic factors, nature of the soil and the specific requirements of trees. Under certain conditions rapidly growing forest stands of for example, hard pines can be found on soils with a low content of organic matter. In the great majority of cases, however, a reasonably satisfactory growth of even the least exacting species is confined to soils with a minimum content of 0.7 per cent of organic matter. On the other hand, exacting hardwoods produce their best growth on soils with content of organic matter exceeding 3.5 percent. Under normal conditions economic production of nursery stock requires soil with at 2 percent of organic matter.

Total organic matter in the soils is estimated as a routine from measurements of its organic carbon content. The most popular method used is the Walkley – Black. This uses potassium dichromate to oxidize the organic matter in the soil. The reaction is facilitated by the heat generated by the addition of sulphuric acid.

General Guidelines on Soil Sampling and Soil Analysis

1. Before any samples of soil are taken contact should be made with the laboratory doing the analysis.
2. Agreement must be reached about when and how many samples are required, and the sampling and labeling procedure to be followed.

Determination of Soil pH

When "Soil pH value" is referred to, what is meant is the pH value of a soil-water system, the composition of which is variable according to circumstances.

The pH was defined by Sorenson (1909) as the negative Logarithm of the hydrogen ion concentration, i.e.

$$\text{pH} = \frac{1}{\text{activity of } H^+ \text{ ion}}$$

and $$\text{pH} = \text{Log of activity of } H^+ \text{ ion}$$

Where H^+ represents the activity of hydrogen ion.

Further information on how to derive the above equations and their use is the measurement of pH can be found in appropriate literature (Cheatle and van't Klooster, (1984).

The main value of a pH measurement is not that it shows a soil to be acid or alkaline but the information it gives about associated soil properties such as phosphorus availability, base status, and lime potential and so on.

Most agricultural soils have pH values lying between 4 and 8. In Zambia most of our forest soils have a pH values of 5.0 – 1. More acid soils are usually peaty in nature and often contain a high proportion of sulfur or aluminium. Strongly alkaline soils, i.e. pH 9 and above, are found in the arid regions of the world.

The more acid a soil the more mobile will become such elements as ion, manganese, zinc, copper and other minor elements. Thus at very low pH value, below pH 4, a soil may contain toxic qualities of certain elements which may be responsible for poor plant growth rather than acidity per se. For example, aluminium becomes toxic at low pH values and causes, inter alia, stunted and deformed roots. The usual method of counteracting aluminium toxicity is to raise the pH value of a soil can induce minor element deficiencies.

Another important soil property depending upon pH status is that of microbial activity. Many micro-organisms, and is in particular the nitrifies, are inhibited by acidity; other require a low pH in order to function effectively.

1. Let suspension stand for about 30 minutes to allow most of the suspended clay to settle out from the suspension.

2. Decant into a 25ml beaker.

3. Read the pH value of the soil suspension using instructions in the operation manual. Record the pH as "soil pH measured in 0.01M CaCl2".

Bulk Density Core Method

In trying to talk about density, it is more realistic first to define other related terms of porosity terms of porosity and particle density of soils.

Porosity

The portion of a given volume of soil which is unfilled with solid matter is termed pore space. The proportion of a soil occupied by spore space and depends on both the texture and structure of the soil and on the shape of the particles. A high content of organic matter leads to much pore space. In sandy soils the total of pore space is small even though the individual spaces are large.

The amount of pore space in a soil is expressed as a percentage of the total soil volume. The term porosity refers to the total pore space in a soil rather than to the size of the individual pores. The amount of pore space in given volume of soil greatly influences its weight.

Particle Density of soil

In determination of the particle density of soil consideration is given to the solid particle only. Thus, the particle density of any soil is a constant and does not vary with the amount of space between the particles. It is defined as the weight per unit volume of soil particles (soil solids) and is frequently expressed as grams per cubic centimeter. It does not vary a great deal for different soils unless there is considerable variation in content of organic matter or mineralogical composition. For most mineral soils the particle density will average about 2.65 grams per cubic centimeter.

Determination of Bulk Density of Soil

In determining bulk density of soil, consideration is given to the pore space as well as to the solid particles. Bulk density of a given soil is, accordingly, a variable because the volume of pore space varies. It is calculated by dividing the dry weight of a given volume of soil, in its natural structural condition, by its volume. When expressed in terms of grams per cubic centimeters, the bulk density of fine-textured soils may range from 1.1 to 1.6, and of sandy soils from 1.3 to 1.7.

Bulk density varies with structural condition of the soil, particularly that related to parking. For this reason it is often used as a measure of soil structure.

Bulk density is a widely used value. It is needed for converting water percentage by weight to content by volume, and for calculating porosity when the particle density is known, and for estimating the weight of a volume of soil too large to weigh conveniently, such as the weight of a furrow slice, of an acre-foot. It is also very important in the determination of the nutrient content and other chemical properties of soils.

Analysis of soil provides result expressed in terms of percentages of different nutrient elements or compounds found in pulverized soils on a weight basis. Such results do not give the actual amount of nutrients found in soil until they are recalculated on the basis of bulk density of the plow layer or of different soil horizons. Similarly, the knowledge that a certain soil material has 0.2 percent of total nitrogen or 100 ppm of available potassium is meaningless unless the weight per unit volume of this particular material in its natural state is known.

Apparatus: Core samplers

Procedure:

1. Drive or press the sampler into either a vertical or horizontal soil surface far enough to fill the sampler (but not so far as to compress the soil).

2. Carefully remove the sampler and its contents so as to preserve the natural structure and packing of the soil as nearly as possible. Use the shovel, of possible, so as to remove the sampler without disturbance.

3. Trim the soil extending beyond each end of the sample holder flush with each end with a straight edge knife. The soil sample volume is thus established to be the same as the volume of the sampler holder.

4. Transfer the soil to a container, place it in an oven at 105^0 C until constant weight is reached, and weigh it. The bulk density is the oven-dry mass of the sample divided by the sample volume.

Thus:-

Wt of core samples = X

Wt of core samples + soil = Y

Wt of soil = Y – X

Volume of soil = volume of core samples = V

$$\therefore \quad D_b = \frac{(Y - X)}{V} \qquad B_p = \frac{\text{mass (dry)}}{V}\ \text{g/cm}^3$$

Where Db is the bulk density in grams
Per cubic centimeter

Calculation of porosity can be determined from the bulk density and particle density. If both are expressed in the same units of measurement as particle density is assumed to be about the same for most soils, a bulk-density determination is all that is required for the calculation of total spore space.

The following formula will give the percentage of the soil which is solid particles.

$$\frac{\text{(Bulk density)}}{\text{(Particle density)}} \times 100 = \%\ \text{solids}$$

This percentage, taken from the total volume (100 percent) will
Give the percentage of pore space, hence the formula

$$100\% - \frac{\text{(Bulk density)}}{\text{(Particle density)}} = \%\ \text{pore space}$$

$$\text{Thus,}\quad 100 - \frac{\text{(Bulk density)}}{\text{(Particle density)}} = e\%$$ IS PORE SPACE

ANNEX IV

SOME EQUIPMENT NECESSARY FOR FIELD WORK

1 Field Recording Sheets

2 Munsell Colour Charts Book

3 Sample bags: Sturdy plastic bags, tussle paper bags

4 Labels, cm graduated vertical scale,

5 Hand hoe, Pick axe, Mattock, Hammer Mixing Trowel

6 Core ring sample cylinders

7 GPS unit, Digital Camera

8 Soil Augers

9 Clinometer

10 Calculator

11 Soil map

12 Field note book

13 Colour markers, pencils and pens

14 Ruler

15 Wash bottle with Water

16 Bottle weak Hydrochloric acid (if possible)

17 Two sample buckets

18 One Small ground sheet

19 Folders and box file, paper perforator

20 Measuring tape (3 m)

21 Small back pack bag

22 First aid kit (if possible)

23 Prismatic compass (if possible)

24 X10 Hand lens (if possible)

26 Field Guide Manuals (vegetation, geology, etc)

27 Clip board

28 Writing Boards

29 Training and Field Manual for Soil Sampling

GLOSSARY OF TERMS

The purpose of this glossary is to help personnel with unfamiliar words or terms. In addition to terms used in this manual some other commonly used words in soils are included, as well as definitions of a few geological terms often associated with soil surveying.

Acidity	The Hydrogen ion activity in a solution, expressed as a pH value.
Acid soil	A soil with a pH less than 7.0 (measured in water) or less than 6.5 (measured in calcium chloride).
Aeration	The process by which atmospheric air enters the soil. The rate and amount of aeration depends on the size and continuity of pore space and the degree of waterlogging or saturation.
Aggregate	A cluster of soil particles forming a *ped*
Aggregation	The process by which particles form aggregates
Aerobic	Condition having a continuous supply of oxygen
Alkaline soil	A soil with a pH greater than 7.0 (measured in water) or more than 6.5 (measured in calcium chloride)
Alluvium	Sediment deposited by streams and varying widely in particle size. The stones and boulders when present are usually rounded or sub-rounded. Some of the most fertile soils are derived from alluvium of medium or fine texture.
Anaerobic	Condition that is free from oxygen. In soils this is usually caused by excessive wetness
Anion	An electrically charged element or group of elements carrying a negative electrical charge.

Arable land	Land suitable for use on a long term economic basis for annual or semi-perennial cultivated crops
Auger	A tool used for boring into the soil and withdrawing small samples for field or laboratory examinations
Available Water Capacity	The weight percentage of water which a soil can store in a form available to plants. It is equal to the moisture content at field capacity minus that at the wilting point.
Basic Rocks	Quartz free igneous rocks containing feldspars. The term does not mean basic or alkaline in the chemical sense.
Beacon	A reference mark established so that a given point can be found in the future. On soil and land capability surveys beacons usually consist of a long stick supported by three other sticks acting as legs.
Boulders	Rock or mineral fragments with a diameter greater than 25 cm.
Catena	A sequence of soils of about the same age, derived from similar parent materials and occurring under similar climatic conditions but having different characteristics due to variations in topography and drainage.
Cation	An electrically charged element or group of elements carrying a positive charge.
Cation Exchange	The sum total of exchangeable *cation* that a soil can adsorb expressed in *cent-mole* charge per kilo gramme soil (NB used to be expressed as milli-equivalents per 100 grams of soil (similarly, -ppm –parts per million), and conventions can be made for the desired unit)
Cemented	See Indurated.
Chroma	The relative purity or strength of a colour.
Clastic	Composed of broken fragments of rocks and minerals.
Clay	The mineral fraction of a soil with a particle size of less than 0.02 mm diameter.

Clay minerals	Those constituents of clay which give it its plastic properties. They are produced by wearing of silicates. There are four main groups: kaolinite, illite, montmorillonite and vermiculite.
Clinometer	A small hand held instrument that gives a direct reading of percentage slopes.
Cohesive	Sticking together.
Colloid	Organic and inorganic matter with very small particle size and a correspondingly large surface area per unit of gravitational action.
Colluvium	A deposit of rock fragments and soil material accumulated at the base of steep slopes as a result of gravitational action.
Compass magnetic	An instrument to determine bearings by means of a magnetized needle or card that always points towards magnetic north.
Contour	An imaginary line joining together points of equal elevation above sea level.
Creep	Slow mass movement of soil and material down steep slopes. The process takes place due to gravity, facilitated by saturation with water.
Crest	The top of the ridge
Dambo	A low lying, gently sloping treeless tract of country which is seasonally waterlogged by seepage from surrounding high ground assisted by rainfall, and which frequently contains the natural drainage channel for the removal of excess surface run-off.
Degrees (of arc)	If a full circle is divided into 360 equal segments, the angle between two adjacent divisions is one degree of arc.

Drainage	A measure of the frequency and duration of periods when a soil is free of saturation (especially water).
Drift (Soil)	Deposits of gravel, sand, alluvium etc. having been transported from another place.
Elevation	The height of a point or area above sea level.
Evaluation	The removal of soil material in suspension or solution from a layer of the soil; annually the loss of material in solution is referred to as "leaching".
Erosion	The wearing away of the land surface by running water wind, or other agents.
Gully erosion	The erosion process whereby water accumulates in narrow channels and, over short periods, removes the soil form this narrow area to considerable depths.
Rill erosion	An erosion process in which numerous small channels of only several centimeters in depth are formed.
Sheet erosion	The removal of a fairly uniform layer of soil from the land surface by runoff water.
Erosion class	Visible evidence of erosion at or in the vicinity of the sampling point is assessed as slight, moderate or severe.
Evaporation	The conversion of a liquid into a vapour, without necessarily reaching the boiling point.
Fertility	The ability of a soil to provide the proper nutrients in the proper amounts for the growth of plants.
Field capacity	The amount of water held in a soil after gravitational water has drained away.
Gravel	Rock particles measuring from 0.2cm to 7.5cm in diameter
Grazing land	Land unsuitable for the long-term production of arable crops, but suitable for grazing cattle.
Grid north	The direction from a point of a line parallel to the vertical grid lines on a map of that area.

Grid reference	A method of defining the position of a point on a map. Vertical and horizontal grid lines are numbered. By quoting the numbers of the lines which intersect at the point, an accurate reference of the position of that point is given.
Hue	The dominant spectral (rainbow) colour of a soil e.g. red, yellow, etc.
Illuvial horizon	A horizon that receives material in solution or suspension from some other part of the same soil.
Inclusions	Soils which cover less than 20% of the area of a mapping unit.
Indurated	Soil material cemented into a hard mass that will not soften on wetting.
Infiltration rate	The maximum rate at which water can enter a soil.
Ion	Electrically charged atom or group of atoms.
Iron stone	Another name for laterite.
Irrigability	The suitability of an area of land for the production of crops under irrigation.
Irrigation	The artificial application of water to an area to replace or supplement rainfall.
Land capability classification	The system used in Zambia to indicate the relative suitability of the land for rainfed medium and large scale ox or tractor cultivation under a high level of management.
Laterite	A highly weathered material rich in secondary oxides of iron, aluminium or both. Silicates, but it may contain large amounts of quartz and kaolinite. It is either hard or capable of hardening on exposure to wetting and drying
Latitude	A distance around the world, measured in degrees of arc north or south from the equator .

Leaching	The removal of material in solution from the soil.
Legend	An explanation of symbols on a map
Limestone	A sedimentary rock composed primarily of calcium carbonate. If dolomite (magnesium coabonate) is present in appreciable quantities it is called a dolomitic limestone.
Limiting materials	Rock, Laterite, gravel, hardpan, etc which is limiting to crop root development
Loam	The textural class name for soil having a moderate amount of sand, silt, and clay
Longitude	A distance around world measured in degrees of arc east from a line joining the north pole and south pole and passing through Greenwhich in London, U.K.
Magnetic declination	The difference between magnetic north (the direction of a compose points) and true north (the direction of the north pole), or between magnetic north and grid north (the direction of the vertical grid lines on topographic maps).
Magnetic north	The direction in which a compass needle points at any place.
Map reference	See grid reference
Marginal arable land	Land that will not support long term intensive use for arable crops without great risk of poor yields, limited freedom of choice of crops, or much environmental control
Matrix	Material within which large particles are embedded
Mica	A transparent rock with a perfect cleavage, producing flakes that are flexible and elastic.
Miombo woodland	A two-storeyed woodland with an open partially closed canopy of semi-evergreen trees 15-20m

	high, characterized by species of Brachystegia , Isoberlinia, Julbernardia, and Marquesia. The forest floor is covered by a more or less dense cover. Most Miombo woodland is secondary regrowth.
Mottling	Sports of different colour or shades of colour interspersed with the dominant soil colour.
Munsell colour	A system of different coloured papers in a loose-leaf book. Each chip is indentified by numbers and letters representing the hue value, and chroma of the colour. Soil colours may be determined by comparison of a moist fragment of soil with the colour chips.
Neutral soil	A soil with a pH of 7.0 (measured in water) or 6.5 (measured in calcium chloride).
Oxidation	Chemical combustion with oxygen, or the removal of hydrogen from a system.
Parent material	The unconsolidated more or less chemically weathered mineral or organic matter from whicsoil is developed.
Ped	An individual natural soil aggregate such as a crumb, prism, or block, in contrast to a clod, which is a mass of soil brought about by digging or other disturbance.
Percolation	The process where by water moves through the soil in response to the force of gravity and the downward pull of soil pores.
pH	A measure of the acidity or alkalinity of the soil.
Physiographic	Position within the relief of an area.
Plateau	A relatively flat area of high elevation underlain by essentially horizontal strata.
Pores	The spaces between the mineral or oganic particles in a soil.
Potential evaporation	The amount of water, measured in millimeters, that it is estimated is lost from the soil by
Reaction	

Reduction	evaporation and transportation each month.
Relief	The degree of acidity or alkalinity of a soil, usually expressed as pH value.
	The removal of chemically combined oxygen from or the addition of hydrogen to a system.
Rock	
Rusty root channels	The irregularity of a land surface; the difference in elevation between the highest and lowest points in an area.
	Any naturally form mass of mineral matter forming an essential part of the earth's crust.
Salinity	
Sand	A deposition of red oxidized iron across an area and within root channels in a soil. It is indication of water logging.
Sandstone	The presence of soluble salts in a soil.
Scale	A soil particle between 0.05mm and 2.00mm in diameter.
	A sedimentary rock consisting of consolidated sand.
Sedimentary	
Sediment	The ratio of a distance measured on a map or air photo, and the corresponding distance measured on the ground.
Shale	Formed by the accumulation of sediments.
Silt	Material that has been deposited by settling from a transportation agent such as water or air.
Siltstone	Thinly layered sedimentary rock composed of consolidated mud, clay, or silt.
Slate	A soil separate consisting of particles between o.o5mm and 0.002mm in diameter.

Slope class	A sedimentary rock consisting primarily of consolidated silt particles (a type of shale).
	Finely layered, compact metamorphic rock which splits readily into sheets.
Soil	
	The Steepness of the slope at a soil observation site is measured, and according to the percentage slope is classified as an A, B, C, D. or E slope.
Soil colour	The collection of natural bodies occupying parts of the earth' surface that support plants and that have properties due to the integrated effect of climate and living matter, acting upon parent material, as conditioned by relief, over material, as conditioned by relief, over periods of time.
Soil horizon	
	The dominant colour of the soil in any given horizon, measured on Munsell standard colour charts. For land capability classification the colour is taken of moist soil at 50cm deep.
Soil map	
Soil profile	A layer of soil, approximately parallel to the soil surface, with distinct characteristics produced by soil forming processes.
Soil Survey	A map showing the distribution of soil types. A soil map and the two should not be confused.
Soil type	A vertical section of the soil through all its horizons.
	The systematic examination, description, classification, and mapping of soils in an area.
Sour soil	
Stones	The lowest unit in the soil classification, being soils alike in all characteristics including the texture of the surface horizon.
Strike	A popular term used by farmers to refer to strongly acid soils.
Stricture	Rock fragments measuring 7.5cm to 25cm diameter.
	The direction of the general trend or run of geological or topographic features.

Subsoil	
Sweet soil	The combination of primary soil particles into units or peds, which are classified on the basis of shape, size and distinctness.
Texture	That part of soil below the plough layer.
Topography	A popular term used by farmers to to near neutral soils.
Topsoil	The relative proportions of different sized groups of soil grains.
	A map showing the physical features of an area, especially the relief and contours of the map.
True north	
Tussocks	The upper 20-25cm of the soil profile, with a concentration of living and dead organic matter. (may be thinner if erosion is severe).
Unsuitable land	The direction of the north pole at any point.
UTM coordinates	
	Land with too severe limitations for either arable cropping or grazing.
Valley	
Value	Grid references given in the Universal Transverse Mercator system, as used on the 1:50,000 topographic maps used in Zambia
Water logged	A generally elongated depression of the land surface which contains a stream.
Water table	The relative lightness of a colour.
Weathering	Saturated with water.
	The upper surface of ground water or that level below which the soil is saturated with water.

Weathering medium	
Weathering rock	All physical and chemical changes produced in rocks, at or near the earth's surface, by atmospheric agents.
Wetness	The medium within weathering is taking place.
	Soft, partly decomposed rock encountered at depth in a soil profile.
Wilting point	The degree of wetness within the rooting range during the rainy season (the growing season). A poorly drained soil will remain fully or partially waterlogged in the root region for long periods. This restricts the amount of air around the roots, and results in poor crop growth. Four wetness classes are defined in the land capability system.
	The percentage of water in the soil when permanent wilting of plants occurs.
Stricture	The combination of primary soil particles into units or peds, which are classified on the basis of shape, size and distinctness.
Subsoil	That part of soil below the plough layer.
Sweet soil	A popular term used by farmers to refer to near neutral soils.
Texture	The relative proportions of different sized groups of soil grains.
Topographic map	A map showing the physical features of an area, especially the relief and contours of the map.
Topsoil	The upper 20-25cm of the soil profile, with a concentration of living and dead organic matter. (may be thinner if erosion is severe).
True north	The direction of the north pole at any point.

Tussocks	Collection of a tuft, or a thick assemblage of soil materials forming around the base of growing bunch of grasses, sedges or other plant forms, signifying occurrence of sheet soil erosion
Unsuitable land	Land with too severe limitations for either arable cropping or grazing.
UTM coordinates	Grid references given in the Universal Transverse Mercator system, as used on the 1:50,000 topographic maps used in Zambia
Valley	A generally elongated depression of the land surface which contains a stream.
Value	The relative lightness of a colour.
Water logged	Saturated with water.
Water table	The upper surface of ground water or that level below which the soil is saturated with water.
Weathering	All physical and chemical changes produced in rocks, at or near the earth's surface, by atmospheric agents.
Weathering medium	The medium within weathering is taking place.
Weathering rock	Soft, partly decomposed rock encountered at depth in a soil profile.
Wetness	The degree of wetness within the rooting range during the rainy season (the growing season). A poorly drained soil will remain fully or partially waterlogged in the root region for long periods. This restricts the amount of air around the roots, and results in poor crop growth. Four wetness classes are defined in the land capability system.
Wilting point	The percentage of water in the soil when permanent wilting of plants occurs.