INVESTIGATION OF ENVIRONMENTAL FACTORS FOR LAND MANAGEMENT IN LITEMBO VILLAGE, MBINGA DISTRICT, TANZANIA

Didas N. Kimaro
Joel L. Meliyo
Balthazar M. Msanya
Juvent P. Magoggo
Juma M. Wickama
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Department of Soil Science
Faculty of Agriculture
Sokoine University of Agriculture
P.O. Box 3008,
Morogoro, Tanzania

Ministry of Agriculture
National Soil Service
A.R.I. Mlingano
P.O. Box 5088,
Tanga, Tanzania

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EXECUTIVE SUMMARY

Mbinga district is one of the areas in Tanzania facing tremendous land pressure due to increasing population. The district was under natural forest i.e. Afromontane rain and undifferentiated forest in the highlands and *Miombo* woodland forest in the low hills. The natural vegetation has been cleared by arable land uses (e.g. fuel wood harvesting and shifting cultivation for crop production particularly in the densely populated mountain areas. Due to the nature of these practices particularly the practice of shifting cultivation, deforestation of these areas resulted into serious ecological hazards like gully erosion and other ecological imbalances in natural resources.

Several villages have been selected for detailed studies in Mbinga district. The selected villages will form sample areas and nuclei of technology transfer in the district. The studies which are currently taking place include socio-economy, technological studies and natural resources.

This report describes the natural resources study of Litembo village as part of the continuing project on the assessment of the natural resources of Mbinga district. The study covers measurements of terrain elements, soil physical and chemical properties, land use systems including farming and production systems and an appraisal of the ecological potential and constraints of the village natural resources.

Climatic resources

There are no specific climatic records for Litembo village. The rainfall pattern is monomodal, starting in November and ending in May with an estimated mean annual precipitation of about 1200 mm. The rest of the year is cool and dry. The average annual temperatures for Mbinga district range from about 13°C in the Matengo highlands to 30°C on the shores of Lake Nyasa. The study area is in the Matengo highland with mean annual temperatures between 13°C and 20°C. Seasonal variations in temperature exist whereby the dry season (May to September) is cooler than the rainy season.

Geology and landform

The study area is underlain by igneous *granitic* rocks with *hornblende* and/or *biotite* in the western part and gneissic metamorphic rocks rich in ferromagnesian minerals (*migmatised* and *hornfelsed granulite, charnockite* and *amphibolite)* in the eastern part of the village. The village is characterized by four major landscapes generally corresponding to altitudes levels. The plateau predominantly occupies the highest elevation in the area; the mid-altitude areas are hillands; and the piedmonts are primarily colluvial (depositional) landscapes but are also secondary denudational sites. The river valleys comprise the lowest lying landscape. These form the sink sites for material eroded from the higher landscapes.

Vegetation and land use

In Litembo village, natural vegetation has been cleared. Only remnants in some catchment areas are left comprising Afromontane rain and undifferentiated forest. The dominant grasses include *Imperata cylindrica, Tegetes minuta, Hyparrhenia sp., Coryza sp., and Ferns*. There are two categories of land use in Litembo village i.e. improved traditional agriculture (Ngoro and/or ridge cultivation systems with mainly annual crops and coffee/*Grevillea* agroforestry), and fallow/grazing. Few tree species (*Eucalyptus, Cypress and black wattle)* are planted.

Soils

Nine mapping units were distinguished in the area and their distribution and extent are shown on the soil map which is presented at the scale of 1:25,000. The soils of Litembo village are broadly categorized into the following types:

(a) - mainly rock outcrops and inselbergs with pockets of very shallow to moderately deep, well to excessively drained, dark brown, sandy clay loams in the hill summits and plateaux.

(b) - very deep, well to somewhat excessively drained, red, extremely gravelly clays, with thick gravelly clay loam topsoils, mainly in the plateaux.

(c) - very deep, well to somewhat excessively drained, reddish, clays with thick to very thick dark brown sandy clay loam to clay loam topsoils in the steep hill slopes and piedmonts. Rock outcrops (in some places about 40 - 50 %) are common.

(d) - very deep, poorly drained, strong brown, stratified and mottled gravelly sandy clay loams to sand clays. These soils are found in the river valleys.

The soils of the plateaux hillslopes and hill summits were classified as **Dystric Leptosols (Lithic Ustorthents)**, **Humic Acrisols (Ustic Kanhaplohumults)** and **Halpic Acrisols (Acrustoxic Kandiustults).**

The soils of the piedmonts were classified as **Rhodic Ferralsols (Rhodic Kanhaplustults), Ferric Acrisols (Kanhaplic Haplustults), Haplic Ferralsols (Typic Haplustox), Ferric Lixisols (Ustic Kandihumults) and Humic Acrisols (Ustic Haplohumults).**

The soils of the river valleys were classified as **Umbric Fluvisols (Aeric Tropic Fluvaquents)**.

There are significant differences in bulk densities of topsoils and subsoils. The bulk densities of most topsoils are relatively lower than those of subsoils ranging from 1.0 to 1.2 g/cc. The bulk densities of subsoils are 1.4 g/cc except for the soils of the plateau where bulk densities are 1.6 g/cc. Total porosity ranges from about 55 to 70 percent in the topsoils and from 40 to 50 percent in the subsoils. Available water holding capacity of the soils are between 125 to 177 mm per meter of soil.

The soils are generally poor in major nutrients such as nitrogen, phosphorus and potassium. The C/N ratios range from 10 to 12, which indicate good quality of organic matter. The soil reaction is very strongly acid to strongly acid. Most of the basic cations i.e. Ca^{++}, Mg^{++} and K^{+} are generally low to medium. The overall capacity of the soils to retain nutrients against leaching is low.

In general the agricultural productivity in the village is limited by soil depth in the steep slopes and summits, and the ever declining natural soil fertility with time due to continuous cultivation as a result of population pressure. At present the land can not optimally support the growing population. Recommendations on the improvement of the farming system have been restricted by a lack of climatic information which is required to be able to establish planting dates and advise on various land utilization types. A comprehensive study on climatic elements i.e. rainfall intensity, distribution and rainfall pattern is thus recommended.

1. INTRODUCTION

Land data obtained through systematic land resource inventory and characterization are a pre-requisite when sound interpretation towards land use potentials are to be made. Such data are important in the assessment of ecological potentials and constraints for various land uses and permit the development of sound environmental conservation strategies.

In Tanzania available information on natural resources is inadequate (Msanya and Magoggo, 1993). The available information on land resources covers only a small part of the country and at details that are not sufficient for sound land use planning and management. Most areas which have not been covered have potential for agricultural production and at the same time face serious land degradation due to increasing population. It is generally known that among these areas, the named **big four** regions including Iringa, Mbeya, Rukwa and Ruvuma have high potential for cash and food crop production but land information is inadequate or in some cases lacking.

In order to provide a starting point the *Miombo* Woodland Research Project (MWRP) was initiated at Sokoine University of Agriculture and Mbinga district in Ruvuma region was selected as an area of research aimed at studying the biophysical as well as socio-economic conditions with the aim of developing packages for proper land use planning, land management and conservation of the environment. It was also envisaged that through this project methodologies for extrapolation of technologies into other areas of similar ecological conditions in the country would be developed.

Mbinga district is one of the areas in Tanzania facing tremendous land pressure due to increasing population. The district was under natural forest i.e. Afromontane rain and undifferentiated forest in the highlands and *Miombo* woodland forest in the low hills. The natural vegetation has been cleared by arable land uses (e.g. fuel wood harvesting and shifting cultivation for crop production) particularly in the densely populated mountain areas. Due to the nature of these practices particularly shifting cultivation, deforestation of these areas has resulted into serious ecological hazards like gully erosion and other ecological imbalances in natural resources.

Several villages have been selected for detailed studies in Mbinga district. The villages will form sample areas and nuclei of technology transfer in the district. The studies are currently focussing on socio-economy, natural resources and indigenous technologies.

The current study was mainly aimed to research on environmental factors of Litembo village as part of the continuing project on the assessment of the natural resources of Mbinga district. The study covers measurements of terrain elements, soil physical and chemical properties, land use systems (including farming and production systems) and an appraisal of the ecological potential and constraints of the village natural resources.
The specific objectives of the study were:

(a) to identify and characterize the soils and terrain elements of Litembo village;
(b) to map the spatial distribution of the existing pedological entities in the village;
(c) to classify the soils of Litembo village using the two international systems adopted in Tanzania (i.e. the FAO legend of the soil map of the world and the United States Department of Agriculture [USDA] Soil Taxonomy system) in order to enable correlation with other areas in the country and international transfer of soil technology;
(d) to link the properties of the land resources above to ecological requirements of the existing land use systems in order to provide a basis for quantification of their potential and constraints to the use of land in the village;
(e) to provide a land information system (LIS) to both researchers and land use planners in the area that will guide activities related to management of land resources.

2. MATERIALS AND METHODS

2.1. Pre-field work

The activities executed during this phase includes literature search, collection of available data and preliminary study of the materials listed below:

- Geological map at the scale of 1:125,000 Litembo-South C36/QIV (degree sheet 85 Manda, S.E. Quarter). *Geological Survey of Tanganyika, 1957.*
- Topographic map at the scale of 1:50,000, Mbinga, map sheet 297/4. *Ministry of Lands, Survey and Mapping Division*, 1972.
- Aerial photographs at the scale of 1:10,000 and 1:50,000. *Geosurvey International Limited. August/September 1990.*
- SPOT imagery: False colour composite (FCC)
- A report on the identification of indigenous tree species and shrubs for agroforestry use and suggestion of boundary for the forest reserve in Mpepo Division, Mbinga district, Tanzania. *Mwihomeke, S.T., C.K. Ruffo and C.K. Mabula*, 1991.
- Pedological investigations and land resources characterization in Lupilo village, Mbinga district, Tanzania. *Msanya, B.M., D.N. Kimaro and J.P. Magoggo,* 1995.
- Pedological investigations of sites for slash and burn experiment in Lupilo village and soil erosion studies in Tukuzi village, Mbinga District, Tanzania. *Kimaro, D.N., B.M. Msanya and J.P. Magoggo*, 1995.
- Annual Progress report: 1994/1995 Miombo Woodland Agroecological Research Project, FoA/SUA-KU/JICA.
- Environmental profile for agricultural production and development of conservation strategies in Mahenge village, Mbinga district, Tanzania. *Magoggo, J.P., B.M. Msanya and D.N. Kimaro, 1996.*

The systematic stereoscopic interpretation of static and dynamic photo elements (landform, geology, lineaments, drainage patterns, vegetation, land use and drainage conditions) was carried out as an initial step of mapping pedological entities in the field. The delineated polygons on the aerial photographs were converted into photo interpretation map which was used as a basis for execution of activities in field.

2.2. Field work

Hand auger borings were used to study the soils in the field. Aerial photo interpretation map was used to select transects, for planning observations sites and sampling points in the field. At each observation site data on pedological (soil morphological) characteristics, landform, elevation, slope gradient, parent material (lithology), vegetation and land use/crops were collected. Soils were studied by description of mini-pits plus auger hole boring and/or soil profile pits. In total 12 mini-pits and 9 soil profile pits were studied and described. Description of the soils and landforms was done following standard procedures as outlined in the FAO (1990) guidelines and USDA Soil Taxonomy (Soil Survey Staff, 1990).

Correlations of the described soil augerings enabled soils similar in characteristics and in arrangement of soil horizons to be singled out and mapped. In this way nine soil mapping units (section 3.2.5) were confirmed on the photo interpretation map. Soil samples were collected from the field for laboratory analysis as follows:

- disturbed soil samples for routine physico-chemical analysis

- undisturbed soil samples for determination of bulk density and soil moisture characteristics

2.3. Post-field work

The activities carried out at this stage included cartographic generalization of the topographic base map to reduce thematic details and enlarging the scale to 1:25,000, transfer of the polygons delineated on the photo-interpretation map onto the enlarged topographic base map and copying of the field and laboratory analytical data recorded on the analogue forms into the national digital soil data base management system (*SISTAN*). Appendix 1 presents the soil profile descriptions and their corresponding laboratory analytical data. Appendix 2 provides a guide to general evaluation of soil chemical and physical properties.

2.3.1. Laboratory and office work

The following determinations on soil chemical and physical properties were made:
pH was measured potentiometrically in water and in 1M KCl at the ratio of 1/2.5 soil-water and soil-KCl respectively. Organic carbon was determined by the wet oxidation method of Walkley and Black (Nelson and Sommers, 1982). Total nitrogen was determined by Kjeldahl method (Bremner and Mulvaney, 1982). Phosphorus was extracted by Bray and Kurtz-1 method (Bray and Kurtz, 1945) and determined spectrophotometrically (Murphy and Riley, 1962; Watanabe and Olsen, 1965). The cation exchange capacity and exchangeable bases were extracted by saturating soil with neutral 1M NH_4OAc (Thomas, 1982) and the absorbed NH_4^+ displaced by K^+ using 1M KCl and then determined by Kjeldal distillation method for the estimation of CEC of soil. The bases Ca^{2+}, Mg^{2+}, Na^+, and K^+, displaced by NH_4^+ were measured by atomic absorption spectrophotometer. Exchangeable acidity i.e. aluminium and hydrogen ions were titrimetrically determined after extraction by 1N KCl (Baize, 1993).

Texture was determined by hydrometer method after dispersing soil with sodium hexametaphosphate (calgon). Bulk density was determined using core sample method (Blake, 1965). Soil moisture characteristics were determined using pressure plate and membrane apparatus (Klute, 1986).

2.3.2. Preparation and presentation of soil map and legend

The soil map polygons were delineated on the basis of the following hierarchy of elements: land-forms, relative position in the landscape, slope classes and soil properties. The soil mapping legend is presented on the map given in the back cover of this report.

In the legend and on the map every mapping unit has a symbol referring to the landform. Further subdivision is based on slope, parent material and soil characteristics and is indicated by a number following the capital letter. The column "soil description" in the legend gives the main characteristics of the soil types i.e. soil depth, drainage, colour, texture, and other diagnostic characteristics that separate each soil type from other soils.

2.3.3. Soil classification and data processing

Using both field and laboratory data the identified soil types were classified by the FAO-Unesco legend (FAO, 1988) at two levels and USDA Soil Taxonomy legend to subgroup level (Soil Survey Staff, 1990). This information is also included in the description of map units. Data processing and report writing was done using *SISTAN* and other computer softwares.

3. RESULTS AND DISCUSSION

3.1. Physical environment

3.1.1. Location

Mbinga district is located between longitudes 34° 24'E and 35° 28'E and latitudes 10° 15'S and 11° 34'S. Litembo village is located in the western part at the Matengo highlands at an average elevation of about 1800 meters a.s.l. The approximate geographical coordinates are 34^0 50' E and $10^0$59 S (Figure 1) shows the location of the study area.

3.1.2. Climate

There are no specific climatic records for Litembo village. The climatic information available in Mbinga town was used to estimate the climatic conditions of the village. The average annual temperatures for Mbinga district are reported to range from about 13°C in the Matengo highlands to about 30°C on the shores of Lake Nyasa (Mchau, 1993). The study area is in the Matengo highland with mean annual temperatures between 13°C and 20°C. Seasonal variations in temperature exist whereby the dry season (May to September) is cooler than the rainy season.

The study area falls in a relatively higher and wetter part of Mbinga district and is estimated to receive a total annual rainfall of over 1200 mm (Mchau, 1993). The rainfall pattern is monomodal, starting in November to May. The rest of the year is essentially dry. Table 1 shows some rainfall data obtained from the district authorities.

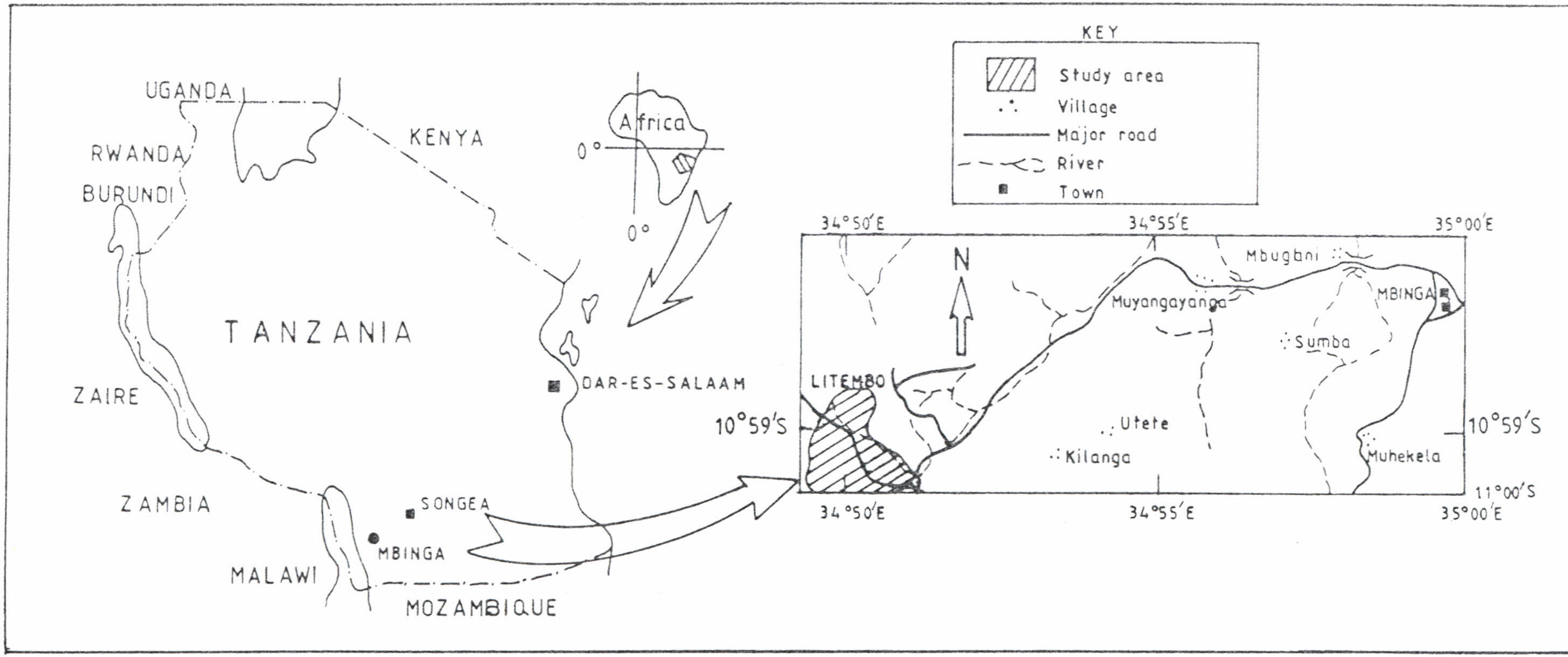

Figure 1. *Location of the study area*

Table 1. Rainfall distribution (mm) during the period 1988/89 - 1993/94 at Mbinga

Month Year	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Total
1988/89	-	56.0	70.1	179.2	198.3	110.1	253.7	139.9	35.0	-	-	-	1024.3
1989/90	-	-	82.0	200.0	149.9	188.5	166.4	137.3	15.5	-	-	-	939.6
1990/91	4.7	-	18.2	47.5	314.0	126.2	199.0	164.8	2.6	-	-	-	877.0
1991/92	-	-	79.4	182.6	218.5	179.3	151.5	65.5	64.4	-	-	-	941.2
1992/93	-	-	107.9	95.0	266.2	319.1	479.1	154.5	36.1	-	-	-	1457.9
1993/94	-	-	5.2	54.5	21.5	325.0	324.5	300.5	94.6	-	-	-	1125.8

Source: Rutatora *et al.* (1995)

3.1.3. Geology and landforms

The underlying geology of Mbinga district is essentially comprising *hornblende-biotite* and *garnet gneisses, granulites* and *charnockites* of the Ubendian system (Ministry of Commerce and Industries 1967). The study area is underlain by Igneous granitic rocks with *hornblende* and/or *biotite* in the western part and Gneissic metamorphic rocks rich in ferromagnesian minerals (*migmatised* and *hornfelsed granulite, charnockite* and *amphibolite)* in the eastern part of the village (Geological Survey Department, 1956).

The village is characterized by four major landscapes generally corresponding to altitudes levels. The plateau predominantly occupies the highest elevation in the area, the mid-altitude areas are hillands and the piedmonts are primarily colluvial (depositional) landscapes but are also secondary denudational sites. The river valleys comprise the lowest lying landscape. These form the sink sites for material eroded from the higher landscapes.

The present landscape in Litembo village has been shaped by faulting. Two major faults have been identified. To the east the village boundary follows the Luunei river, which marks a major fault line. This fault more or less follows the boundary between the metamorphic rocks in the east and the granitic basement complex to the west. The faulting has resulted in long piedmonts (footslopes) sloping from the **Mandekendeke** plateau with renewed mass movement of colluvial sediment. The other, less prominent fault lines, are marked by the course of the streams running perpendicular to river Luunei.

As a result of the above geomorphic processes, Litembo village is characterized by a highly dissected and denudated plateau (mean elevation 1900 m asl) and piedmonts (mean elevation 1500 - 1600 m asl) landscapes with many rock outcrops and inselbergs and narrow drainage ways and river valleys. The hill tops, which stand out to an altitude of about 1800 m, commonly have rock outcrops. The slopes are between 2 and 45%. Most of the low lying lands (streams and tributaries of the Luunei and Luhali rivers) are found at altitudes between 1500 and 1600 m. asl.

During the rains water infiltrates into the soil and underlying parent rock and seeps slowly down the hill slopes and into the valleys. This seepage water continues to flow throughout a major part of the dry season and contributes to the perennial streams in the valleys.

3.1.4. Vegetation and land use

The relationship between landforms, soils, vegetation and land use is given in Table 2.
In Litembo village, natural vegetation has been cleared. Only remnants in some catchment areas are left comprising Afromontane rain and undifferentiated forest. Dominant tree and grass species include *Imperata cylindrica, Tegetes minuta, Hyparrhenia sp., Coryza sp.* and ferns.

There are two major kinds of land use in Litembo village i.e. improved traditional agriculture and fallow/grazing land use systems. These land use systems are mostly practiced in the piedmonts and river valleys. The main production systems are *ngoro* and/or *ridge* cultivation systems, with annual crops such as maize, beans and wheat. Maize is planted in November/December and harvested in July/August. Beans are planted in February and harvested in May. In the river valleys maize and beans are planted in August on residual moisture and harvested in February. Coffee/*Grevillea* agroforestry as perennial crops are grown on bench terraces on steep slopes (hilland) and some are intercropped with other crops such as banana and maize. Fallow and grazing is mainly practiced on the plateaux and other areas waiting for crop rotation cycles. Few trees (*Eucalyptus*, cypress and black wattle) are planted to serve social needs and to conserve the land. Other minor land use systems are cultivation of sweet potatoes, vegetables during dry season in valley bottoms. Ngoro drainage ditches are also practiced in poorly drained areas.

3.2. Soils

3.2.1. Landforms, soils, vegetation and land use

The map showing the spatial distribution of the soils of Litembo village is included in the back cover of this report. The relationship between landforms, soils and vegetation/land use is shown in Table 2.

Table 2. Landforms, soils, vegetation and land use in Litembo village

MAP SYMBOL	LANDFORM CHARACTERISTICS	DOMINANT SLOPE (%)	AREA Ha	AREA %	SOIL DESCRIPTION	LAND USE
DISSECTED PLATEAU (L), mean elevation 1900 m above sea level						
L1	Rock outcrops and inselbergs		97	13	Rocky land	
L2	Undulating to rolling slopes	2 - 15	54	7	Very deep, well drained to somewhat excessively drained, red, extremely gravelly, clays with thick, dark brown gravelly clay loam topsoils; developed on granitic rocks. The soil classify as **Humic Acrisols (Ustic Kanhaplohumults)**	Improved traditional agriculture (Ngoro cultivation) with wheat and maize as the main crops; sunflower is grown with maize as an intercrop.
HILLLAND (H), mean elevation 1600 to 1800 m above sea level						
H1	Hill summits and upper slopes	2 - 45	38	5	Mainly rock outcrops with pockets of shallow to moderately deep, excessively drained, dark brown, sandy clay loams. The soils classify as **Dystric Leptosols (Lithic Ustorthents)**	Planted forest mainly Eucalyptus and black wattle.
H2	Steeply dissected hill slopes	15 - 35	72	10	Very deep, well drained, red, sandy clay loams to sandy clays, with very thick dark brown to reddish brown, sandy clay loam topsoils; developed on colluvium derived from mixed metamorphic rocks mainly gneisses. The soils classify as **Haplic Acrisols (Acrustoxic Kandiustults)**	Coffee/Grevillea agroforestry and maize cultivation.
DISSECTED PIEDMONT (P), mean elevation 1550 - 1650 m above sea level						
P1	Undulating to rolling piedmont slopes	10 - 20	41	5	Very deep, well drained, dark red, clays, with thick dark brown, clay loam topsoils; developed on colluvium derived from mixed metamorphic rocks mainly gneisses. The soils classify as **Rhodic Ferralsols (Rhodic Kanhaplustults)**	Improved traditional agriculture (Ngoro cultivation system). The main crops are maize, wheat and beans on Ngoro and Coffee/Grevillea agroforestry on bench terraces.

P2	Moderately to steeply dissected piedmont slopes	10 - 45	132	17	Association of rocks outcrops (40 to 50 %) and Very deep, well drained, red to dark reddish brown, clays with very thick, dark reddish brown sandy clay topsoils; developed on colluvium derived from granitic rocks. The soils classify as **Humic Acrisols (Ustic Haplohumults)**	Natural forest has been cleared. Coffee/Grevillea agroforestry. Grevillea covers about 20% of the land surface.
P3	Undulating to rolling piedmont slopes	5 - 20	131	17	Very deep, well drained, red, clays with very thick, dark reddish brown to reddish brown, sandy clay to sandy clay loam topsoils; developed on colluvium derived from granitic rocks; in the profile occurs a layer of gravels mixed with angular rocks at variable depth (stone line) ranging from 50 to 150 cm., few scattered rock outcrops are common. The soils classify as **Haplic Ferralsols (Typic Haplustoxs)** and **Ferric Lixisols (Ustic Kandihumults)**	Ngoro and ridge cultivation systems, Fallow and Coffee/Grevillea agroforestry and grazing are common land uses systems.
P4			50	7	Very deep, well drained, yellowish red, clays, with very thick, dark reddish brown, sandy clay topsoils; developed on colluvium derived from granitic rocks. Few scattered rock outcrops are common. The soils classify as **Ferric Acrisols (Kanhaplic Haplustults)**	Fallow and Ngoro cultivation system; with maize, wheat and beans on Ngoro and few Coffee/Grevillea agroforestry.

RIVER VALLEY (V), elevation 1550 to 1600 m above sea level

V	Gently undulating to undulating river slopes	0 - 8	146	19	Very deep, very poorly drained, pink, strong brown and yellowish red, stratified and mottled, gravelly, sandy clay loams with dark reddish brown, sandy clay loam topsoils; developed on mixed alluvial-colluvium of diverse origin. The soil classify as **Umbric Fluvisols (Aeric Tropic Fluvaquents)**	Maize, beans, sweet potatoes and vegetables are grown on improved drainage conditions.

Table 3. Selected physical properties of soils of Litembo village

Profile no.	Depth (cm)	Textural class	Bulk density (g/cc)	Total porosity (%)	Available water capacity (% vol)	AWC (mm/m)
LTP-1	0-35	CL	1.0	61.5	18	
	35-50	C	1.5	44.3	16	137
	50-95	C	1.6	40.2	10	
	95-100	C	1.6	40.2	10	
LTP-2	0-25	CL	1.0	63.1	16	
	25-50	C	1.4	50.8	14	125
	50-100	C	1.4	50.3	10	
LTP-3	0-30	SC	1.2	56.9	17	
	30-60	SC	1.2	55.4	18	176
	60-95	C	1.3	53.2	15	
	95-100	C	1.3	53.0	15	
LTP-4	0-40	SC	1.2	57.0	16	
	40-60	C	1.2	55.4	15	146
	60-100	C	1.4	47.6	13	
LTP-7	0-30	SC	0.98	72.2	24	
	30-80	C	1.0	61.6	15	177
	80-120	C	1.3	51.6	15	
LTP-9	0-20	SCL	1.0	62	17	
	20-45	SCL	1.1	53	22	153
	80-100	SC	1.3	49	10	

3.2.2. Physical properties

Soil physical properties are important for agricultural land management. Soil physical conditions such as moisture storage capacity, rootability and retention of plant nutrients are related to physical soil properties. In this report, four main soil physical properties, i.e. texture, bulk density, porosity (Table 3) and water retention characteristics (Figure 2) are presented and discussed.

Soil texture, bulk density and total porosity

The relative size of the soil particles is expressed by the term *texture* which refers to the fineness, or coarseness of the soil. The texture more specifically refers the relative proportions of sand, silt and clay. The rate and extent of many important physical and chemical reactions in soils are governed by texture because it determines the amount of surface on which the reactions occur.

The dominant soil textures in the study area are sandy clay loams to clay loams in the topsoils and clays in subsoils. Topsoils textures indicate that the soils are well aerated and well drained, and hence they pose no physical limitations for crop with shallow roots.

Bulk density and total porosity of the soils are mainly influenced by texture, compaction and to some extent by the organic matter content of the soils. The bulk densities of most topsoil are relatively lower than those of the subsoils. The topsoils bulk density range between 0.99 and 1.2 g/cc and those of the subsoils from 1.3 to 1.4 g/cc, except profile LTP-1 with bulk density ranging from 1.5 to 1.6 g/cc. In general there is a tendency for bulk densities of the soils to increase with depth. The effects of *ngoro* cultivation practices that lead to accumulation of high organic matter resulted low bulk densities in the topsoils. In general increases in soil bulk density impose many stresses such as mechanical resistance, poor aeration and reduced permeability on a plant rooting system. Total porosity ranges from 56 - 72% in the topsoils and from 40 to 53% in the subsoils. These values indicate that there is no compaction limitations particularly in the topsoils.

Moisture characteristics (water retention and available water capacity)

Figure 2 and Table 3 present the moisture characteristics of three soil depths (surface horizon, intermediate horizon and subsoil) of the studied soils. The soils are mainly clayey in texture. Therefore they have relatively high matric potential throughout the suction ranges which decreases with increasing suction. Available water capacity is the amount of water held in the soil between field capacity and wilting point. The available water capacity of most topsoils range between 15 and 25 percent by volume which is fairly high. The available water capacity of intermediate horizons and subsoils range between 10 and 18 percent by volume. The volume fraction of water in the surface layer is generally higher than that in the intermediate layer and subsoils. This can be explained by the fact that organic matter levels and porosity in the topsoils are higher than in the subsoils. The overall available water capacity per meter range from 125 to 177 mm/m which is medium to high.

3.2.3. Chemical properties

Tables 4 and 5 present the chemical properties of the soils of Litembo. The following chemical parameters are discussed:

Soil reaction

The term soil reaction is used to denote the degree of acidity or alkalinity of a moist soil. This is indicated by the hydrogen ion concentration in the soil moisture. The soil reaction is measured and presented as the pH value, which equals the negative logarithm of the H-ion concentration (EUROCONSULT, 1989). Most plants thrive well in soils of a pH 6.5 to 7.5 (Baize, 1993). In the study area the pH of most topsoils is very strongly acid to strongly acid with values between 4.5 to 5.5. The exchangeable hydrogen ion values range between 0.1 and 0.2 cmol(+)/kg of soil (Table 4). The low pH values could be attributed to the leaching of bases as indicated by low percent base saturation percentage (Table 4).

Organic matter and nitrogen

Organic matter contents are generally medium to high corresponding to organic carbon levels between 1.3 to 3.7 percent in topsoils. The levels of organic matter in subsoils are very low (less than 0.2 percent organic carbon). The high levels of organic matter in the topsoils are attributed to the *ngoro* farming practice. In most soils absolute nitrogen levels are generally low (less than 0.2 percent). Nitrogen is a dynamic plant nutrient, which in most cases needs replenishment, either as an organic manure or as mineral fertilizer. The C/N ratios are between 10 and 12 in topsoils. For many soils the C/N ratios are in the optimal range showing good quality organic matter.

Available phosphorus

The available phosphorus for most soils is low. Average phosphorus levels of more than 7 mg P/kg are considered to be optimum below which P-deficiency symptoms are likely to occur in many crops. The low phosphorus content in these soils is attributed to the low pH values probably due to fixation by oxides and hydroxides of iron, aluminium and manganese.

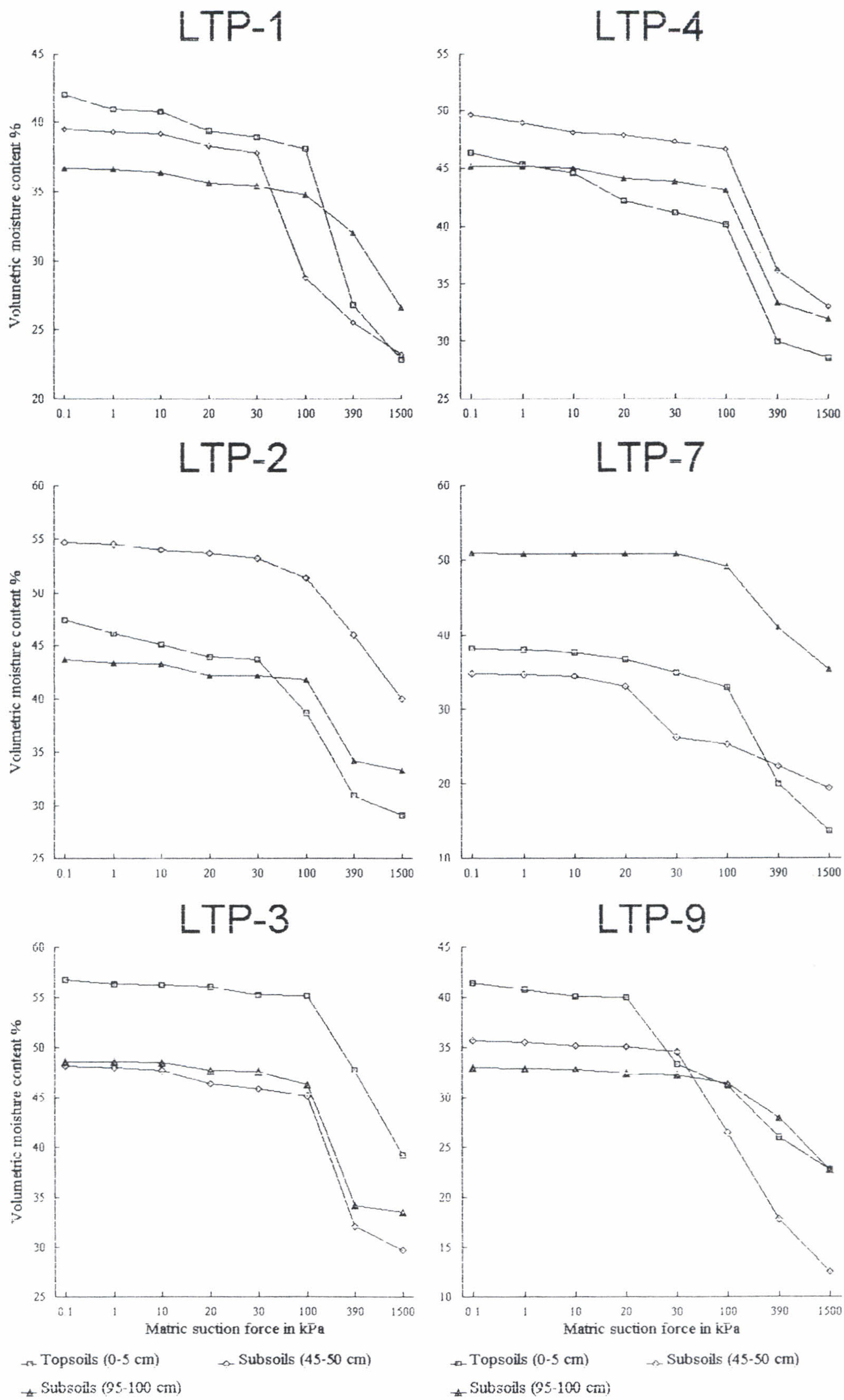

Figure 2. Soil moisture release curves for selected profiles of Litembo village

Cation exchange capacity (CEC)

The CEC reflects the capacity of the soil to retain nutrients against leaching. CEC values of most topsoils are medium to high ranging from 13 to 30 cmol(+)/kg soil. In the subsoils CEC values are low to very low (less than 10 cmol(+)/kg). The high CEC values in the topsoils could be explained by high organic matter contents.

Exchangeable Calcium (Ca^{2+}), Magnesium (Mg^{2+}) and Potassium (K^{1+})

Table 5 presents the topsoil and subsoil exchangeable cations (Ca^{2+}, Mg^{2+}, and K^{1+}) levels of Litembo soils. In most soils calcium levels are medium (1.4 to 6.0 cmol(+)/kg) except for the soils of the hilland where calcium levels are low. The levels of exchangeable magnesium and potassium are low to very low.

Nutrient balance

The availability of nutrients for uptake by the plant depends not only upon absolute levels but also on nutrient balances. In most of the studied soils there was a general trend indicating Ca levels are greater than Mg levels and Mg levels greater than K levels. Although this trend indicate a common nutrient balance in soils, it is important to consider the individual nutrient ratios i.e. Ca/Mg, Mg/K and K/total exchangeable bases (TEB) which are indicators of nutrients uptake.

The established Ca/Mg ratios in Litembo soils are above optimal range. The optimum range for Ca/Mg ratios are between 2 and 4 which is considered favourable for most crops. The Mg/K ratios for most soils is lower than unity (< 1). The recommended range is between 1 and 4. The Mg/K ratio of less than 1 inhibit magnesium uptake by most crops. The overall K/TEB (total exchangeable bases) ratios for most soils is above 2 percent which is said to be favourable for most tropical crops.

3.2.4. Soil classification

Table 6 gives a summary of the salient soil morphological and other diagnostic features used in classifying the soils. Table 7 gives the soil names according to the two systems of classification i.e. FAO-Unesco classification system (FAO, 1988) and USDA Soil Taxonomy (Soil Survey Staff, 1990).

Table 4. Chemical analytical data of soils of Litembo village

Profile No.	Depth	pH (H2O)	Org. C (%)	Total N (%)	C/N	Avail.P (mg/kg)	CEC (cmol(+)/kg)	Exchangeable acidity Al^{3+} (cmol(+)/kg)	Exchangeable acidity H^{+} (cmol(+)/kg)	Base saturation (%)
LTP-1	Topsoil	5.4	3.1	0.30	10	6	19.5	-	0.2	39
	Subsoil	5.3	0.4	0.09	4	10	11.5	0.3	0.1	21
LTP-2	Topsoil	5.2	1.3	0.26	5	9	15.0	-	0.2	23
	Subsoil	6.0	0.3	0.08	6	1	7.5	-	0.1	60
LTP-3	Topsoil	5.1	2.1	0.19	11	7	13.0	0.2	0.1	19
	Subsoil	6.0	0.5	0.08	6	1	10.0	-	0.1	23
LTP-4	Topsoil	5.0	1.7	0.17	10	4	14.5	0.3	0.1	18
	Subsoil	5.7	0.3	0.06	6	1	5.0	-	0.1	50
LTP-5	Topsoil	5.4	2.2	0.18	12	11	17.5	0.1	0.1	16
	Subsoil	5.9	0.3	0.07	5	2	9.5	-	0.1	23
LTP-6	Topsoil	5.4	1.8	0.17	11	7	19.5	0.1	0.1	15
	Subsoil	5.8	0.3	0.06	6	2	9.5	-	0.1	20
LTP-7	Topsoil	5.4	3.7	0.30	12	32	29.5	-	0.1	45
	Subsoil	5.9	0.6	0.11	6	3	14.5	-	0.1	63
LTP-8	Topsoil	4.4	2.3	0.16	14	2	13.4	-	0.01	7
	Subsoil	4.4	1.3	0.10	13	3	13.7	-	0.04	29
LTP-9	Topsoil	4.9	2.8	0.14	20	1	13.5	-	0.05	15
	Subsoil	4.8	0.6	0.05	13	1	5.9	-	0.02	15

Table 5. Interpretation ratings for exchangeable cations of Litembo soils

		Exchangeable Calcium (cmol(+)/kg)		Exchangeable Magnesium (cmol(+)/kg soil)		Exchangeable Potassium (cmol(+)/kg soil)		Percent Aluminum saturation	
Profile No.	Map Unit	Topsoil (0-20cm)	Subsoil (30-150cm)	Topsoil (0-20cm)	Subsoil (30-150cm)	Topsoil (0-20cm)	Subsoil (30-150cm)	Topsoil (0-20cm)	Subsoil (30-150cm)
LTP-1	L2	High (4.1-5.9)	Low (<2.0)	High (1.5)	Low (0.2)	Low (0.1)	Low (0.04)	Nil	Low (15%)
LTP-2	P1	Medium (2.1)	Medium (2.1-3.3)	Low (0.4)	Medium (0.5-1)	Low (0.25)	very to low (0.07-0.15)	Nil	Nil
LTP-3	P4	Medium (1.9)	Medium (1.5-2.0)	Low (0.3)	Low (0.3-0.4)	Low (0.2)	Low (0.1-0.17)	Low (2%)	Nil
LTP-4	P31	Medium (1.4)	Medium (1.4-2.0)	Low (0.4)	Low (0.3-0.6)	Low (0.14)	Very low (0.04-0.05)	Nil	Low (12%)
LTP-5	P32	Medium (2.1)	Medium to high (1.6-5.5)	Low (0.4)	Low (0.4)	Low (0.2)	Low (0.1-0.6	Low (2%)	Nil
LTP-6	V	Medium (2.2)	Low to medium (1.5-2.2)	Low (0.3)	Low (0.2-0.4)	Medium (0.26)	very low to low (O.08-0.15)	Nil	Nil
LTP-7	P2	Very high (7)	Medium to high (3.9-5.0)	Medium (1.9)	Low (0.6-0.8)	Medium (0.33)	Very low to medium (0.07-0.29)	Nil	Nil
LTP-8	H1	Very low (0.6)	Low (1.4)	Low (0.3)	Very high (2.6)	Very low (0.06)	Very low (0.02)	Nil	Nil
LTP-9	H2	Low (1.3)	Very low (0.6 - 0.7)	Low (0.5)	Low to very low (0.1 - 0.3)	Low (0.17)	Very low (0.05 - 0.06)	Nil	Nil

Table 6. Summary of salient morphological and other diagnostic features of the studied representative soils

Profile	Diagnostic horizons	Other diagnostic features
LTP-1	*ochric A (ochric epipedon); *argic B (argillic horizon)	*strongly humic, ustic SMR; thermic STR
LTP-2	*ochric A (ochric epipedon); *ferralic B (argillic horizon)	*ferric properties, ustic SMR; thermic STR; (*small textural gradient in the B horizon)
LTP-3	*umbric A (umbric epipedon); *argic B (argillic horizon)	*ferric properties, ustic SMR; thermic STR
LTP-4	*ochric A (ochric epipedon); *ferralic B (oxic horizon)	ustic SMR; thermic STR
LTP-5	*ochric A (ochric epipedon); *argic B (argillic horizon)	*ferric properties, ustic SMR; thermic STR
LTP-6	*umbric A (umbric epipedon)	*gleyic and stagnic properties (aquic SMR); thermic STR, *fluvic properties, *ferric properties
LTP-7	*umbric A (umbric epipedon); *argic B (argillic horizon)	ustic SMR; thermic STR; *ferric properties, *strongly humic, (*abrupt textural gradient in the B horizon)
LTP-8	*ochric A (ochric epipedon)	ustic SMR; thermic STR
LTP-9	*ochric A (ochric epipedon); *argic B (kandic horizon)	ustic SMR; thermic STR

NB. * terminology used particularly in the FAO-Unesco Classification; those without * are mostly used in USDA System.

Table 7. Classification of the studied representative soils

Profile	FAO-Unesco legend classification		USDA Soil Taxonomy			
	level 1	*level 2*	*order*	*suborder*	*greatgroup*	*subgroup*
LTP-1	Acrisol (AC)	Humic Acrisol (ACh)	Ultisol	Humult	Kanhaplohumult	Ustic Kanhaplohumult
LTP-2	Ferralsol (FR)	Rhodic Ferralsol (FRr)	Ultisol	Ustult	Kanhaplustult	Rhodic Kanhaplustult
LTP-3	Acrisol (AC)	Ferric Acrisol (ACf)	Ultisol	Ustult	Haplustult	Kanhaplic Haplustult
LTP-4	Ferrasol (FR)	Haplic Ferrasol (FRh)	Oxisol	Ustox	Haplustox	Typic Haplustox
LTP-5	Lixisol (LX)	Ferric Lixisol (LXf)	Ultisol	Humult	Kandihumult	Ustic Kandihumult
LTP-6	Fluvisol (FL)	Umbric Fluvisol (FLu)	Entisol	Aquent	Fluvaquent	Aeric Fluvaquent
LTP-7	Acrisol (AC)	Humic Acrisol (ACu)	Ultisol	Humult	Haplohumult	Ustic Haplohumult
LTP-8	Leptosol (LP)	Dystric Leptosol (LPd)	Entisol	Orthent	Ustorthent	Lithic Ustorthent
LTP-9	Acrisol (AC)	Haplic Acrisol (ACh)	Ultisol	Ustult	Kandiustult	Acrustoxic Kandiustult

3.2.5. Mapping unit description

Each mapping unit is described in a defined order. The first paragraph outlines the setting (landform and vegetation cover) of the unit. The second paragraph describes the field characteristics of the soil profile; the major soils horizons are described in terms of colour, texture, structure and thickness or depth range of the horizons. Soil names according to the FAO-Unesco legend of the soil map of the world are given, together with USDA Soil Taxonomy in brackets. Physical properties (drainage, effective rooting depth, bulk density, available water capacity) are discussed in the third paragraph. The fourth paragraph concerns the chemical properties of the soils. Physical and chemical properties are described in relative terms. Absolute values are presented under the chapters discussing the physical and chemical properties respectively.

Mapping unit L1

Rocky land (rock outcrops and inselbergs).

Mapping unit L2

Very deep, well drained to somewhat excessively drained, red, extremely gravelly, clays with thick, dark brown gravelly clay loam topsoils; developed on granitic rocks.

Setting:

The landform is undulating to rolling slopes. The unit has 50 percent rock outcrops (boulders) with a complex slope pattern. The dominant slopes are between 2 and 15 percent and the mean elevation is at about 1900 m asl. The soils are gravelly throughout the profile; the surface is bouldery and stony. The lands are planted with Eucalyptus and black wattle. Grasses on this mapping unit include *Tegetes minuta, Imperata cylindrica, Coryza spp*. and Ferns. The main land use type is improved traditional agriculture (Ngoro cultivation system) with maize/sunflower intercrop and wheat.

Soil profile characteristics:

The topsoil is very thick (23 to 35 cm), brown to dark brown, very friable, gravelly clay loam and moderately structured. The subsoil to a depth of 50 cm is strong brown, friable, weak to moderate structured. Below a depth of 50 cm the subsoil is friable, red, extremely gravelly clay, weak to moderate structure. This soil classifies as **Humic Acrisol (Ustic Kanhaplohumult)** and profile **LTP - 1** is representative.

Soil physical properties:

The soil is well to excessively drained and the rooting depth is over 140 cm. Bulk density increases with depth from 1.0 g/cc in the topsoil to 1.6 g/cc in the subsoil. The available water capacity is medium (135 mm/m). The soil is gravelly to extremely gravelly from the topsoil to subsoil. The soil has many fresh and weathered primary minerals and rock fragments of quartz and granite. The topsoil texture is clay loam and gravelly clay in the subsoil.

Soil chemical properties:

The major plant nutrients nitrogen, phosphorus and potassium are generally low to very low. Nitrogen levels in the topsoil are medium (0.3 %) and decline with depth to very low levels (0.07 %). The topsoil has medium amounts of organic matter (O.C 3.1 %). The soil reaction is strongly acid and has low levels of exchangeable bases. The soil has high Ca/Mg ratio of 6 which is not favourable for nutrient uptake for most tropical crops. Generally the soil potential to supply nutrient is poor.

Mapping unit H1

Mainly rock outcrops with pockets of shallow to moderately deep, excessively drained, dark brown, sandy clay loams.

Setting:

This unit is on the hill summits and shoulder (convex slopes) of the hills. It occupies the highest positions in the hilland landscape. The slopes are between 2 and 45 percent at mean elevation of about 1600 - 1800 m asl. The lands are rocky with 80 percent rock outcrops. Farming practices are limited by soil depth and rockiness of the area. Forestry mainly with Eucalyptus and black wattle is practised.

Soil profile characteristics:

The topsoil is thick (20 cm) and is dark brown, sandy clay loam. The subsoil is dark brown sandy clay loam. The soil classifies as **Dystric Leptsol (Lithic Ustorthent)** and **LTP-8** is a representative.

Soil physical properties:

The soil is excessively drained, the root zone extends to a depth of 60 cm. Available water capacity is 142 mm/m. Bulk density is 0.99 g/cc in the topsoil and 1.3 g/cc in the subsoil. Total porosity is high about 64 % in the topsoil and 49 % in subsoil. Generally the profile is porous.

Soil chemical properties:

The soil has an overall low potential to supply plant nutrients. The major nutrients like nitrogen, phosphorus are very low. The soil in general has medium levels of organic matter. The C/N ratio is 14 and 13 which is slightly unfavourable for plant residue decomposition. The levels of calcium and potassium are very low. The soil reaction is extremely acid throughout the profile with pH values of 4.4. The soil has very low to medium capacity to retain nutrients.

Mapping unit H2

Very deep, well drained, red, sandy clay loams to sandy clays, with very thick dark brown to reddish brown, sandy clay loam topsoils; developed on colluvium derived from mixed metamorphic rocks mainly gneisses.

Setting:

The unit comprises hill slopes with dominant slopes between 15 and 20 percent. The mean elevation range between 1600 - 1700 m asl. The unit has potential soil erosion hazards. Presently it has been checked by ngoro farming practice. The main agricultural activities are maize cultivation and coffee/grevillea agroforestry on ngoro and bench terraces respectively.

Soil profile characteristics:

The topsoil is very thick (40 cm thick) and it is dark brown to a detph of 20 cm. Below a depth of 20 to 45 cm it is red brown. It is sandy clay loam and weakly to moderately structured. The subsoil to a depth of 45 cm and below is very friable, red, sandy clay and it is moderately structured. The soil classifies as **Haplic Acrisol (Acrustoxic Kandiustult)** and profile **LTP - 9** is representative.

Soil physical properties:

The soil is well drained with a rooting depth of more than 200 cm. The available water capacity is 153 mm/m. Bulk density for topsoil is 1 g/cc and that of subsoil is 1.4 g/cc.

Soil chemical properties:

In this soil phosphorus and nitrogen levels are low to very low from surface down the profile. Organic carbon is medium in topsoil and decreases progressively with depth from 2.8 % in topsoil to 0.2 % in subsoil. The bases (Ca, Mg, K) are very low (Table 4 and 5). Nutrient balance is unfavourable for most crops, Ca/Mg being very wide so suppress Mg uptake by plants. Soil reaction is very strongly acid to strongly acid with pH values between 4.8 and 5.2. The cation exchange capacity is low also declining with depth from 13.5 cmol(+)/kg soil in topsoil to 3.1 cmol(+)/kg in subsoil.

Mapping unit P1

Very deep, well drained, dark red, clays, with thick dark brown, clay loam topsoils; developed on colluvium derived from mixed metamorphic rocks mainly gneisses.

Setting:

The unit occupies the strongly dissected piedmont slopes on the gneissic landscape. The dominant slopes are between 10 and 20 percent with rolling to hilly topography and the mean elevation is about 1500-1600 m asl. In this unit Ngoro is the main cultivation system including maize, wheat and beans as the main crops. Coffee/Grevillea agroforestry is established on bench terraces, few bananas and mango trees are also grown. This piedmont landscape is separated from the granitic plateau in the west by a fault line running from south to north along river Luunei.

Soil profile characteristics:

The topsoil is thick to very thick (15 to 25 cm thick). It is dark brown, very friable, slightly sticky and slightly plastic, clay loam and weakly structured. The subsoil to a depth of over 190 cm is friable, sticky and plastic, dark red to red, clay and it is moderately structured. The subsoil shows diffuse textural and colour gradient with many Mn-Fe-Clay nodules of different shapes increasing with depth. The soil classifies as **Rhodic Ferralsol (Rhodic Kanhaplustult)** and profile **LTP-2** is a representative.

Soil physical properties:

The soil is well drained, the root zone extends to a depth of 190 cm and deeper. Available water capacity is medium (125 mm/m). Bulk density is medium (1.0 g/cc) in the topsoil and is 1.4 g/cc in the subsoil. Total porosity is high about 60% in the topsoil and 50% in subsoil.

Soil chemical properties:

The soil has overall medium potential to supply nutrients. Nitrogen and phosphorus levels are medium (Table 4). The soil has medium levels of organic matter. The C/N ratio is narrow suggesting the presence of good quality organic matter. The soil reaction is strongly acid in the topsoil with pH values of 5.2, and strongly to medium acid in the subsoil (pH values 5.9 - 6.0). Exchangeable bases (magnesium and potassium) levels are low (Table 5). The soil has medium CEC in topsoil (15 cmol(+)/kg soil) and very low CEC in subsoil (5 cmol (+)/kg soil). Generally, the soil has low to medium capacity to retain nutrients.

Mapping unit P2

Association of rock outcrops (40 to 50 %) and very deep, well drained, red to dark reddish brown, clays with very thick, dark reddish brown sandy clay topsoils; developed on colluvium derived from granitic rocks.

Setting:

This unit occupies the moderately and steeply dissected piedmont slopes between *Mandekendeke* plateau and river Luhali. The dominant slopes are between 15 and 20 percent towards Luhali river. The mean elevation is about 1600 m asl. The rock outcrops occupy 50 % of the mapping unit. Improved traditional agriculture is the main land use with coffee/grevillea/banana agroforestry farming system in between rock outcrops.

Soil profile characteristics:

The topsoil is very thick (30 cm), dark reddish brown, sandy clay very friable, and is moderately structured. The subsoil to a depth of 120 cm and deeper is dark reddish brown to red, friable, clay with moderate structure. Concretion nodules of clay and iron of different shapes and sizes are many throughout the profile. This soil classifies as **Humic Acrisol (Ustic Haplohumult)** and profile **LTP-7** is representative.

Soil physical properties:

The soil is well drained, with a rooting depth of more than 180 cm. The available water capacity is high (177 mm/m). Bulk densities are low with values between 0.98 g/cc in the topsoil to 1.3 g/cc in the subsoil. The soil is porous with total porosity of 72 % in topsoil and about 50% in the subsoil.

Soil chemical properties:

The soil can be said to be relatively fertile in the topsoil. It has medium levels of nitrogen, phosphorus and organic matter in the topsoil with C/N ratio of 12. The soil reaction is strongly acid in the topsoil to medium acid in the subsoil with pH values between 5.4 and 5.9. The calcium levels are medium. The soil has overall poor supply of other bases (magnesium and potassium) that are essential plant nutrients. The CEC of the soil is high in the topsoil and medium in the subsoil. The soil has moderate capacity to retain nutrients.

Mapping unit P3

Very deep, well drained, red, clays with very thick, dark reddish brown to reddish brown, sandy clay to sandy clay loam topsoils; developed on colluvium derived from granitic rocks; in the profile occurs a layer of gravels mixed with angular rocks at variable depth (stone line) ranging from 50 to 150 cm., few scattered rock outcrops are common.

Setting:

The unit occupies the rolling to undulating piedmont slopes in the middle part of the village. The slopes are between 6 and 8 percent and the mean elevation is about 1570 m asl. The land is mainly agricultural with ridge and ngoro cultivation as main cultivation systems. The unit at present is under fallow and scattered Grevillea/Coffee agroforestry farms.

Soil profile characteristics:

The topsoil is very thick (30 to 40 cm), dark reddish brown, sandy clay. It is very friable and weakly structured. The subsoil is friable, red, clay and moderately structured. The soil classifies as **Haplic Ferralsol (Typic Haplustox)** and profile **LTP-4** is representative.

Soil physical properties:

The soil is well drained. The rooting depth extends beyond 180 cm from the surface, but there is a root restricting gravelly layer below depth of 100 to 130 cm. Available water capacity is medium, 146 mm/m. Bulk density is medium (1.2 g/cc) throughout the profile.

Soil chemical properties:

The soil has overall low supply of plant nutrients. Phosphorus and nitrogen are low and very low in the topsoil and subsoil respectively (Table 4). Organic carbon contents is medium in topsoil and very low in subsoil (Table 4). The C/N ratio of the soil is 10 and declines progressively with depth. The soil reaction is strongly acid in the topsoil (5.0 to 5.2) and medium acid in the subsoil (5.7). The topsoil has low levels of aluminum saturation (aluminum saturation of 14.5 percent). The levels of the bases calcium, magnesium and potassium are very low (Table 5). The soil also has very wide Ca/Mg ratio which is likely to causes nutrient imbalances. In general these soils have low capacity to retain nutrients.

Mapping unit P4

Very deep, well drained, yellowish red, clays, with very thick, dark reddish brown, sandy clay topsoils; developed on colluvium derived from granitic rocks. Few scattered rock outcrops are common.

Setting:

The topography of this unit is undulating to rolling with slopes between 14 and 16 percent. The mean elevation is 1600 m asl. The land is presently fallow. The farming activities are maize/wheat/beans which are grown on Ngoro. There are few coffee/grevillea agroforestry plots. Scattered planted trees such as *Eucalyptus camadulensis, Grevillea spp. and Black wattle* are common. Over 50 percent of the land is covered by grasses *mainly, Imperata cylindrica, Tegetes minuta, Coryza spp,* and ferns. The unit has about 5 percent rock outcrops.

Soil profile characteristics:

The topsoil is very thick (25 to 30 cm), reddish brown, gravelly clay loam and is very friable and weakly structured. The subsoil is friable, moderately structured, red, clays. The soil classifies as **Ferric Lixisol (Ustic Kandihumult)** and profile **LTP - 3** is representative.

Soil physical properties:

The soil is well drained. The rooting depth is beyond 160 cm. Available water capacity is high (176 mm/m). Bulk density in topsoil is medium (1.2 g/cc) and high (1.4g/cc) in subsoil. The upper 100 cm of the profile shows high biological activities (bioturbation).

Soil chemical properties:

The soil has overall low supply of nitrogen and phosphorus (Table 4). The topsoil has medium levels of soil organic matter with moderate quality as indicated by a narrow C/N ratio. The soil reaction is strongly acid in the topsoil associated with low levels of aluminum saturation (aluminum saturation of 15 percent). The levels of the magnesium and potassium are very low. Calcium levels are medium (Tables 5). The Ca/Mg ratio in topsoil is very wide, which is likely to affect Mg uptake by plants. Mg/K ratio is within the recommended level for most tropical crops. The soil has low capacity to retain nutrients.

Mapping unit V

Very deep, very poorly drained, pink, strong brown and yellowish red, stratified and mottled, gravelly, sandy clay loams with dark reddish brown, sandy clay loam topsoils; developed on mixed alluvial-colluvium of diverse origin.

Setting:
The unit represents the gently undulating to undulating river slopes of the low lying drainage ways and river courses in Litembo village. The slopes are between 0 and 8 percent. In some places the unit is covered with dense bamboo and elephant grass. Ridge and *ngoro* cultivation systems are practiced with maize, beans, sweet potatoes and vegetables during dry season. Ngoro and drainage ditches are constructed to control waterlogging condition.

Soil profile characteristics:
The topsoil is very thick (35 to 43 cm), dark reddish brown, friable, gravelly sandy clay loam and weakly structured. The subsoil is yellowish red, strong brown, and pink. It is layered, mottled and massive. Angular, spherical, fresh and weathered rock fragments are common in the profile. This soil classifies as **Umbric Fluvisol (Aeric Tropic Fluvaquent)** and profile **LTP-6** is representative.

Soil physical properties:
The soil is poorly drained. The rooting depth extends to a depth of 130 cm but may be limited by waterlogging conditions. Bulk density is medium ($<$ 1.20 g/cc) in the topsoil and high (1.4 g/cc) in the subsoil.

Soil chemical properties:
The soil has overall low supply of phosphorus and nitrogen (Table 4). The topsoil has medium level of organic matter. The soil reaction is strongly acid in the topsoil and medium acid in the subsoil. Calcium levels are medium; whereas magnesium and potassium levels are low (Table 5). There is a wide Ca/Mg ratio which indicates nutrient imbalances. Generally the soil has low nutrient supply potential.

4. CONCLUDING REMARKS AND RECOMMENDATIONS

The lands of Litembo village have a high potential for soil erosion. The hazards of soil erosion in these lands can be attributed to the steep slopes and weak structure of the topsoils. However, the seriousness of soil erosion in the area has been reduced by the *ngoro* farming practice.

Soil depth is the most limiting land quality in the summits and upper slopes of the hills. Most of these lands are bare with rock outcrops and surface stones which are signs of serious soil erosion. The consequences of soil erosion are initially felt as land degradation and decline of land productivity as a result of nutrient loss.

Climatic information in the area such as rainfall intensity and distribution, potential evaporation, temperature records and relative humidity are not available which could be used to advise farmers on various farming systems, land management and development of sound conservation strategies.

All the lands in the village are intensively used. They are continuously used for settlements and cultivation of both annual and perennial crops. The lands are also used for planting exotic trees (Eucalyptus, Grevillea and black wattle) and livestock keeping including pigs, few cattle and goats. The intensive land use can be explained by the high population density estimated at 120 persons per square kilometer which is the highest in the district. The effects of continuous land cultivation for a long time without proper management leads to physical and chemical land degradation.

The soils of the village have overall poor fertility. The major nutrients for crops i.e. nitrogen, phosphorus and potassium are very low. Most of the soils have very low to low exchangeable calcium and magnesium. The bases are also in unfavourable proportions for nutrients uptake by plants. The Ca/Mg ratios in most cases are very small which results into Mg unavailability to plants.

The low soil fertility in Litembo village is due to the high degree of weathering of the soils, this include leaching and lateral movement of nutrients along the steep slopes into drainage streams.

In order to protect lands from further physical and chemical degradation and protecting the catchment areas, afforestation should be employed in sloping lands and hilly areas. Also *ngoro* farming practice should be encouraged because it has proved to be efficient in soil erosion control, improvement of organic matter contents in topsoils and also improves soil water holding capacity. Moreover, research on making *ngoro* less labour intensive should be carried out. Also other means of land conservation such as *fanya juu fanya chini* and *grass strips* should be researched on as an alternative to *ngoro.* Farming and agroforestry systems should be encouraged which will protect the lands from further degradation and also facilitate nutrient cycling.

Due to lack of enough climatic information in the survey area, it is important to research on the following: rainfall onsets, rainfall pattern and distribution, rainfall intensity and effective rainfall. It is also recommended to carry out research on planting dates, growing periods, and water balance for various crops grown in the area. The climatic research should also address the effects of humidity to farming systems.

Due to the consequences of high population density, research on other land use alternative such as zero grazing should be carried out. This land use type will introduce improved pastures that will not only feed the animals but also avail manures that will improve physical-chemical properties of the soils. The pasture will also protect the land from erosion.

Due to poor fertility of these soils, most soils are likely to respond to mineral and organic fertilizers. Research to determine rates and types of mineral fertilizers and organic manures should be carried out. The economics and social implications of both fertilizers should be investigated.

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Appendix 1. Soil profile description and analytical data

Profile number : LTP-1 Mapping unit: L 2 Agro-ecol. zone:
Region : Ruvuma
District : Mbinga
Map sheet no. : 297/4
Coordinates : 34°49.456'E /11°00.2990' S
Location : Mandekendeke, 3 km West of Litembo village head office
Elevation : 1920 m asl. Parent material: Granite (felsic igneous) rocks. Landform: plateau; undulating. Slope: 4 %; straight
Surface characteristics : Outcrops boulders: 50 % Erosion: None or slight (checked by ngoro). Deposition: none. Natural drainage class : well drained to somewhat excessive
Described by D.N. Kimaro, G.J. Nkondola, J.L. Meliyo and B.M. Msanya on 22/11/15

Ap 0 - 23/35 cm: brown (7.5YR5/2) dry, dark brown (7.5YR3/4) moist; gravelly clay loam; soft dry, very friable moist, slightly sticky and slightly plastic wet; moderate medium and fine granular; common medium and many fine pores; frequent small angular fresh and weathered quartz fragments; many fine and very fine roots; abrupt wavy boundary to

Bt1 23/35 - 50 cm: brown (7.5YR5/4) dry, brown (7.5YR4/6) moist; gravelly clay; slightly hard dry, friable moist, sticky and plastic wet; weak to moderate subangular blocks; patchy moderately thick clay cutans;medium and many fine pores; frequent small angular fresh and weathered quartz fragments; very fine roots; diffuse smooth boundary to

Bt2 35/50 - 90 cm: red (2.5YR4/3) dry, red (2.5YR4/3) moist; extremely gravelly clay; hard dry, friable moist, sticky and plastic wet; weak to moderate coarse and medium subangular blocks; patchy moderately thick clay cutans; many fine and very fine pores; frequent small and medium angular, round fresh and weathered quartz and granite fragments; diffuse smooth boundary to

Bt3 90 - 140 cm: red (2.5YR4/8) dry, red (2.5YR4/3) moist; extremely gravelly clay; hard dry, friable moist, sticky and plastic wet; weak to moderate coarse and medium subangular blocks; patchy moderately thick clay cutans; many fine and very fine pores; frequent small, medium angular, round , fresh weathered quartz and granite fragments; diffuse smooth boundary to

SOIL CLASSIFICATION: FAO legend: 1988:Humic Acrisol (ACu)
USDA Soil Taxonomy: 1990:Ustic Kanhaplohumult

ANALYTICAL DATA FOR PROFILE LTP-1

Horizon		Ap	Bt1	Bt2	Bt3
Depth (cm)		0-23/35	23/35-50	35/50- 90	90 - 140
Clay	%	39	49	61	55
Silt	%	16	13	10	18
sand	%	45	38	29	27
Texture class		CL	C	C	C
pH H_2O	1:2.5	5.4	5.4	5.3	5.3
pH KCl	1:2.5	5.3	4.7	4.8	4.8
EC mS/cm	1:2.5	0.04	0.02	0.01	0.01
Organic C	%	3.1	1.1	0.4	0.2
Total N	%	0.30	0.20	0.10	0.07
C/N		10	6	4	3
Available P	mg/kg	6	2	7	10
CEC NH40Ac	cmol(+)/kg	19.5	11.5	10.0	9.5
Exch. Ca	cmol(+)/kg	5.9	2.1	2.5	2.3
Exch. Mg	cmol(+)/kg	1.5	0.2	0.5	0.5
Exch. K	cmol(+)/kg	0.10	0.05	0.04	0.04
Exch. Na	cmol(+)/kg	0.08	0.07	0.07	0.07
Exch. H	cmol(+)/kg	0.20	0.10	0.10	0.10
TEB	cmol(+)/kg	7.6	2.4	3.1	2.9
Base saturation	%	39	21	31	31
CECclay	cmol(+)/kg	50	23	16	17

Profile number : LTP-2   Mapping unit: P 1   Agro-ecol. zone:
Region : Ruvuma
District : Mbinga
Map sheet no. : 297/4
Coordinates : 10° 58.904.9' S / 34° 50.118'E
Location : Nang'ombe, 2 km East of Litembo mission Hospital
Elevation : 1570 m a.s.l. Parent material: colluvium derived from gneissic rocks. Landform: piedmont plain; undulating to rolling slopes.
Slope: 14 %; straight
Surface characteristics : Erosion: none or slight. Deposition: none.
Natural drainage class : well drained
Described by B.M. Msanya, D.N. Kimaro, G.J. Nkondola and J.L. Meliyo on 24/11/95

Ap 0 - 15/25 cm: brown (7.5YR4/4) dry, dark brown (7.5YR3/4) moist; clay loam; soft dry, very friable moist, slightly sticky and slightly plastic wet; weak fine subangular blocks; few medium and many very fine pores; many fine and very fine roots; abrupt wavy boundary to

Bt1 15/25 - 50 cm: yellowish (5YR4/6) dry, reddish brown (5YR4/4) moist; clay; hard dry, friable moist, sticky and plastic wet; moderate medium and fine angular and subangular blocks; few medium and many fine pores; frequent medium and small angular, irregular and spherical hard clay and iron nodules; few coarse and many fine roots; diffuse smooth boundary to

Bt2 50 - 100 cm: red (2.5YR4/6) dry, dark red (2.5YR3/6) moist; clay; hard dry, friable moist, sticky and plastic wet; moderate medium and fine angular and subangular blocks; many fine and very fine pores; very frequent large, medium and small angular, irregular and spherical hard clay and iron nodules; few medium and common very fine roots; diffuse smooth boundary to

Bt3 100 - 140 cm: red (2.5YR4/6) dry, dark red (2.5YR3/6) moist; clay; hard dry, friable moist, sticky and plastic wet; moderate medium and fine angular and subangular blocks; many fine and very fine pores; very frequent large, medium and small angular, irregular and spherical hard clay and iron nodules; very fine roots; diffuse smooth boundary to

Bt4 140 - 190 cm: red (2.5YR4/6) dry, dark red (2.5YR3/6) moist; clay; hard dry, friable moist, sticky and plastic wet; moderate medium and fine angular and subangular blocks; many fine and very fine pores; very frequent large, medium and small angular, irregular and spherical hard clay and iron nodules; very fine roots

SOIL CLASSIFICATION: FAO legend: 1988:Rhodic Ferralsol (FRr)
USDA Soil Taxonomy: 1990:Rhodic Kanhaplustult

ANALYTICAL DATA FOR PROFILE LTP-2

Horizon		Ap	Bt1	Bt2	Bt3	Bt4
Depth (cm)		0-15/25	15/25- 50	50 - 100	100 - 140	140 - 190
Clay	%	35	63	63	63	61
Silt	%	18	15	14	15	18
Sand	%	47	22	23	22	21
Texture class		CL	C	C	C	C
pH H_2O	1:2.5	5.2	5.8	5.9	5.9	6.0
pH KCl	1:2.5	5.0	5.6	5.6	5.6	5.6
EC mS/cm	1:2.5	0.05	0.02	0.02	0.01	0.02
Organic C	%	1.3	0.8	0.4	0.3	0.1
Total N	%	0.26	0.11	0.08	0.05	0.04
C/N		5	7	5	6	3
Available P	mg/kg	9	1	1	1	1
CEC NH4OAc	cmol(+)/kg	15.0	10.0	10.0	7.5	5.0
Exch. Ca	cmol(+)/kg	2.1	2.1	2.1	3.3	2.1
Exch. Mg	cmol(+)/kg	0.4	0.5	0.7	1.0	0.4
Exch. K	cmol(+)/kg	0.25	0.15	0.10	0.10	0.10
Exch. Na	cmol(+)/kg	0.70	0.07	0.08	0.10	0.08
Exch. H	cmol(+)/kg	0.20	0.10	0.10	0.10	-
TEB	cmol(+)/kg	3.5	2.8	3.0	4.5	2.7
Base saturation	%	23	28	30	60	54
CECclay	cmol(+)/kg	43	16	16	12	8

Profile number : LTP-3 Mapping unit: P4 Agro-ecol. zone:
Region : Ruvuma
District : Mbinga
Map sheet no. : 297/4
Coordinates : 10° 59.380' S / 34° 50.208' E
Location : Kitupi - 1.5 km North of the village head office; 100m west of road
Elevation : 1600 m asl. Parent material: colluvium derived from granite (felsic igneous rocks).
Landform: piedmont plain; undulating. Slope: 14 %; straight
Surface characteristics : Outcrops: 5 % Erosion: none or slight. Deposition: none.
Natural drainage class : well drained
Described by J.L. Meliyo, D.N. Kimaro, B.M. Msanya and G.J. Nkondola on 24/11/95

Ap 0 - 30/50 cm: dark reddish grey (5YR4/2) dry, dark reddish brown (5YR3/2) moist; slightly gravelly sandy clay; soft dry, very friable moist, slightly sticky and slightly plastic wet; weak medium subangular blocks; few medium and many very fine pores; frequent medium and small angular fresh quartz fragments; few small spherical hard clay and iron nodules; common medium and many fine roots; abrupt wavy boundary to

Bt1 30/50 - 60 cm: yellowish red (5YR4/6) dry, reddish brown (5YR4/4) moist; clay; soft dry, friable moist, sticky and plastic wet; moderate medium and fine subangular blocks; few medium and many fine pores; few small angular fresh quartz fragments; few small irregular and spherical hard clay and iron nodules; common medium and many fine roots; crotovinas filled with topsoil material; gradual smooth boundary to

Bt1 60 - 95 cm: yellowish red (5YR5/8) dry, yellowish red (5YR5/6) moist; clay; slightly hard dry, friable moist, sticky and plastic wet; moderate medium and fine subangular blocks; many fine and very fine pores; few small angular fresh quartz fragments; frequent large, medium and small spherical and irregular hard clay and iron nodules; common fine and very fine roots; crotovinas filled with topsoil material; diffuse smooth boundary to

Bt2 95 - 160 cm: yellowish red (5YR5/8) dry, yellowish red (5YR5/6) moist; clay; hard dry, friable moist, sticky and plastic wet; moderate medium and fine subangular blocks; many fine and very fine pores; frequent small angular fresh quartz fragments mixed in the nodules; frequent large, medium and small angular hard clay and iron nodules; few fine and very fine roots; crotovina filled in by topsoil materials

SOIL CLASSIFICATION: FAO legend: 1988:Ferric Acrisol (ACf)
USDA Soil Taxonomy: 1990:Kanhaplic Haplustult

ANALYTICAL DATA FOR PROFILE LTP-3

Horizon		Ap	Bt1	Bt2	Bt3
Depth (cm)		0-30/50	30/50-60	60 - 95	95 - 160
Clay	%	39	48	53	63
Silt	%	12	9	9	7
Sand	%	49	43	38	30
Texture class		SC	C	C	C
pH H_2O	1:2.5	5.1	5.2	5.4	6.0
pH KCl	1:2.5	4.6	4.7	5.0	5.4
EC mS/cm	1:2.5	0.02	0.01	0.01	0.01
Organic C	%	2.1	0.8	0.5	0.4
Total N	%	0.19	0.12	0.08	0.07
C/N		11	7	6	6
Available P	mg/kg	7	3	2	1
CEC NH4OAc	cmol(+)/kg	13.0	10.0	10.0	10.0
Exch. Ca	cmol(+)/kg	1.9	2.0	1.6	1.5
Exch. Mg	cmol(+)/kg	0.3	0.4	0.4	0.3
Exch. K	cmol(+)/kg	0.20	0.10	0.20	0.10
Exch. Na	cmol(+)/kg	0.07	0.07	0.07	0.08
Exch. H	cmol(+)/kg	0.10	0.20	-	-
TEB	cmol(+)/kg	2.5	2.6	2.3	2.0
Base saturation	%	19	26	23	20
CECclay	cmol(+)/kg	33	21	19	16

Profile number : LTP-4 Mapping unit: P3 Agro-ecol. zone:
Region : Ruvuma
District : Mbinga
Map sheet no. : 297/4
Coordinates : 10° 59.643' S / 34° 50.621' E
Location : Kigangi, 1km NE of Kigangi Pr. School
Elevation : 1570 m asl. Parent material: felsic igneous rocks. Landform: piedmont plain; (rolling towards the valley).
Slope : 7 %; straight
Surface characteristics : Outcrops: 10 % Erosion: none or slight. Deposition: none.
Natural drainage class : well drained
Described by D.N. Kimaro, B.M. Msanya, G.J. Nkondola and J.L. Meliyo on 25/11/95

Ap 0 - 30/40 cm: reddish brown (5YR5/4) dry, dark reddish brown (5YR3/4) moist; sandy clay; soft dry, very friable moist, slightly sticky and slightly plastic wet; weak medium and fine subangular blocks; common medium and many fine and very fine pores; very few small angular fresh quartz fragments; few small spherical soft clay nodules; few coarse and many medium, fine and very roots; clear wavy boundary to

Bt1 30/40 - 60 cm: red (2.5YR5/6) dry, red (2.5YR4/6) moist; clay; slightly hard dry, friable moist, sticky and plastic wet; moderate medium and fine subangular blocks; many fine and very fine pores; few small and medium angular fresh and weathered quartz fragments; few small spherical soft clay nodules; few coarse and many fine and very roots; gradual smooth boundary to

Bt2 60 - 100 cm: red (2.5YR4/6) dry, red (2.5YR4/8) moist; clay; slightly hard dry, friable moist, sticky and plastic wet; moderate and strong fine angular and subangular blocks; many fine and very fine pores; frequent small and medium angular weathered and fresh quartz and granite fragments; frequent small and medium spherical, angular and irregular hard clay and iron nodules; few fine and very fine roots; abrupt smooth boundary to

2CB 100 - 130 cm: red (10R5/8) dry, red (10R4/8) moist; extremely gravelly clay; hard dry, friable moist, sticky and plastic wet; weak medium subangular blocks; common fine and very fine pores; angular rocks (weathered granite and fresh quartz) angular fresh quartz and weathered granite gavels; very few medium and fine roots; abrupt smooth boundary to

2Bt 130 - 180 cm: red (2.5YR5/6) dry, red (2.5YR5/6) moist; sandy clay (clay); hard dry, friable moist, sticky and plastic wet; moderate coarse and medium subangular blocks; continuous moderately thick clay and iron cutans; many fine and very fine pores; frequent small and medium angular weathered and fresh quartz and granite fragments; frequent small and medium spherical, angular and irregular hard clay and iron nodules; very few very fine roots

SOIL CLASSIFICATION: FAO legend: 1988 :Haplic Ferralsol (FRh)
USDA Soil Taxonomy: 1990 :Typic Haplustox

ANALYTICAL DATA FOR PROFILE LTP-4

Horizon		Ap	Bt1	Bt2	2CB	2Bt
Depth (cm)		0 -30/40	30/40 - 60	60 - 100	100 - 130	130 - 180
Clay	%	40	44	61	61	53
Silt	%	10	9	10	9	18
Sand	%	50	47	29	30	29
Texture class		SC	C	C	C	C
pH H_2O	1:2.5	5.0	5.2	5.4	5.7	5.7
pH KCl	1:2.5	4.7	4.9	5.0	5.3	5.4
EC mS/cm	1:2.5	0.30	0.01	-	-	-
Organic C	%	1.7	0.7	0.5	0.3	0.2
Total N	%	0.17	0.09	0.06	0.05	0.03
C/N		10	8	8	6	7
Available P	mg/kg	4	2	1	1	1
CEC NH4OAc	cmol(+)/kg	14.5	10.0	5.0	5.0	5.0
Exch. Ca	cmol(+)/kg	1.4	1.6	1.9	1.4	2.0
Exch. Mg	cmol(+)/kg	0.4	0.4	0.6	0.3	0.4
Exch. K	cmol(+)/kg	0.14	0.05	0.04	0.05	0.05
Exch. Na	cmol(+)/kg	0.07	0.08	0.07	0.08	0.07
Exch. H	cmol(+)/kg	0.10	0.10	0.10	0.10	0.10
TEB	cmol(+)/kg	2.0	2.1	2.6	1.8	2.5
Base saturation	%	14	21	52	37	50
CECclay	cmol(+)/kg	36	23	8	8	9

Profile number : LTP-5 Mapping unit: P3 Agro-ecol. zone:
Region : Ruvuma
District : Mbinga
Map sheet no. : 297/4
Coordinates : 10° 59.824' S / 34° 50.536' E
Location : Kiganngi Pr. School
Elevation : 1590 m asl. Parent material: colluvium from granite rocks. Landform: piedmont plain; undulating-rolling towards the valleys.
Slope: 10 %; straight
Surface characteristics : Outcrops: 4 % Erosion: none or slight. Deposition: none.
Natural drainage class : well drained
Described by D.N. Kimaro, G.J. Nkondola, J.L. Meliyo and B.M. Msanya on 25/11/95

Ap 0 - 25/30 cm: reddish brown (5YR5/4) dry, reddish brown (5YR4/4) moist; clay loam; soft dry, very friable moist, slightly sticky and slightly plastic wet; weak medium subangular blocks; many fine and very fine pores; frequent small spherical hard clay nodules; many medium, fine and very fine roots; abrupt wavy boundary to

Bt1 25/30 -40/50 cm: red (2.5YR4/6) dry, red (2.5YR4/6) moist;clay; soft dry, friable moist, sticky and plastic wet; moderate medium and fine subangular blocks; patchy thin clay cutans; many fine and very fine pores; few small angular fresh quartz fragments; frequent small spherical hard clay nodules; common fine and very fine roots; gradual wavy boundary to

Bt2 40/50 - 90 cm: red (2.5YR4/8) dry, red (2.5YR4/6) moist; clay; slightly hard dry, friable moist, sticky and plastic wet; moderate medium and fine subangular blocks; patchy thin clay cutans; many fine and very fine pores; few small angular fresh quartz fragments, (angular rocks and weathered granite); frequent large and small spherical hard clay nodules; very fine roots; diffuse smooth boundary to

Bt3 90 - 160 cm: red (2.5YR5/6) dry, red (2.5YR4/6) moist; clay; hard dry, friable moist, sticky and plastic wet; moderate to strong medium and fine subangular blocks; patchy thin clay cutans; many fine and very fine pores; few small angular fresh quartz fragments; frequent large spherical hard clay and iron nodules; very fine roots; angular rocks, weathered granite, quartz and granite gavels below a depth of 150 cm.

SOIL CLASSIFICATION: FAO legend: 1988:Ferric Lixisol (LXf)
USDA Soil Taxonomy: 1990:Ustic Kandihumult

ANALYTICAL DATA FOR PROFILE LTP-5

Horizon		Ap	Bt1	Bt2	Bt3
Depth (cm)		0 -25/30	25/30-40/50	40/50-90	90 - 160
Clay	%	39	47	55	63
Silt	%	14	13	12	8
Sand	%	45	40	33	29
Texture class		CL	C	C	C
pH H2O	1:2.5	5.4	5.5	5.8	5.9
pH KCl	1:2.5	4.7	4.9	5.4	5.4
EC mS/cm	1:2.5	0.01	0.01	0.03	0.01
Organic C	%	2.2	0.9	0.3	0.3
Total N	%	0.18	0.13	0.07	0.50
C/N		12	7	4	1
Available P	mg/kg	11	4	3	2
CEC NH4OAc	cmol(+)/kg	17.5	14.5	9.5	9.5
Exch. Ca	cmol(+)/kg	2.1	5.5	1.8	1.6
Exch. Mg	cmol(+)/kg	0.4	1.4	0.5	0.4
Exch. K	cmol(+)/kg	0.21	0.15	0.16	0.10
Exch. Na	cmol(+)/kg	0.07	0.07	0.07	0.07
Exch. H	cmol(+)/kg	0.10	0.10	0.10	0.10
TEB	cmol(+)/kg	2.8	7.1	2.5	2.2
Base saturation	%	16	49	27	23
CECclay	cmol(+)/kg	45	32	17	15

Profile number : LTP-6 Mapping unit: V Agro-ecol. zone:
Region : Ruvuma
District : Mbinga
Map sheet no. : 297/4
Coordinates : 10° 59.811' S / 34° 50.244' E
Location : Mbugani along river Luhali, 500 m south of Litembo village office.
Elevation : 1570 m asl. Parent material: alluvium from granite rocks. Landform: alluvial/flood plain; flat or almost flat. Slope: 2 %
Surface characteristics : Erosion: none or slight. Deposition: none.
Natural drainage class : poorly drained
Described by B.M. Msanya, D.N. Kimaro, J.L. Meliyo and G.J. Nkondola on 27/11/95

Apg 0 - 35/43 cm: dark reddish brown (5YR3/2) moist; slightly gravelly sandy clay loam; common medium faint diffuse mottles; friable moist, slightly sticky and plastic wet; weak medium and fine subangular blocks; common very fine and fine pores; few small angular fresh quartz fragments; few coarse and many very fine roots; abrupt wavy boundary to

2Cg 35/43 - 53/60 cm: yellowish red (5YR4/6) moist; very gravelly sandy clay loam; common coarse distinct clear (7.5YR3/2) mottles; slightly sticky and slightly plastic wet; massive, common very fine and fine pores; frequent medium and small angular and spherical fresh and weathered granite and quartz fragments; common very fine and fine roots; gradual wavy boundary to

3Cg 53/60 - 72/90 cm: strong brown (7.5YR5/8) moist; slightly gravelly sandy clay loam; many coarse prominent sharp (2.5YR2.5/2) mottles; slightly sticky and slightly plastic wet; massive; many very fine and fine pores; few small angular weathered and fresh granite and quartz fragments; few medium and small spherical soft clay and iron nodules; common very fine and fine roots; the structure of 2cg - 4cg is massive; clear wavy boundary to

4Cg 90 - 130 cm: pink (7.5YR8/4) moist; slightly gravelly sandy clay loam; many medium distinct clear (10R3/6) mottles; sticky and plastic wet; massive; frequent medium and small irregular weathered granite and quartz fragments; frequent medium and small spherical soft clay and iron nodules; few very fine and fine roots.

SOIL CLASSIFICATION:

FAO legend: 1988 :Umbric Fluvisol (FLu)
USDA Soil Taxonomy: 1990 :Aeric Tropic Fluvaquent

ANALYTICAL DATA FOR PROFILE LTP-6

Horizon		Apg	2Cg	3Cg	4Cg
Depth (cm)		0 - 43	43 - 60	60 - 90	90 - 130
Clay	%	31	28	32	26
Silt	%	16	17	15	13
Sand	%	53	55	53	61
Texture class		SCL	SCL	SCL	SCL
pH H2O	1:2.5	5.4	5.4	5.8	5.7
pH KCl	1:2.5	4.7	50.0	50.0	5.5
EC mS/cm	1:2.5	0.01	0.01	0.01	0.07
Organic C	%	1.8	0.4	0.3	0.2
Total N	%	0.17	0.08	0.06	0.05
C/N		11	5	5	4
Available P	mg/kg	7	5	5	2
CEC NH4OAc	cmol(+)/kg	19.5	14.5	9.5	9.5
Exch. Ca	cmol(+)/kg	2.2	2.1	2.2	1.5
Exch. Mg	cmol(+)/kg	0.3	0.3	0.4	0.2
Exch. K	cmol(+)/kg	0.26	0.15	0.14	0.10
Exch. Na	cmol(+)/kg	0.11	0.10	0.10	0.10
Exch. H	cmol(+)/kg	0.20	0.10	0.10	0.10
TEB	cmol(+)/kg	2.9	2.7	2.8	1.9
Base saturation	%	15	18	30	20
CECclay	cmol(+)/kg	63	52	30	37

Profile number : LTP-7 Mapping unit: P2 Agro-ecol. zone:
Region : Ruvuma
District : Mbinga
Map sheet no. : 297/4
Coordinates : 10° 59.841' S / 34° 49.874' E
Location : Ugenini, 1.5 km west of Litembo village head office along the truck road
Elevation : 1630 m asl. Parent material: colluvium from granite (felsic igneous) rocks.
Landform: piedmont plain; rolling. Slope: 15 %; straight
Surface characteristics : Outcrops: 50 % Erosion: none or slight. Deposition: none.
Natural drainage class : well drained
Described by D.N. Kimaro, G.J. Nkondola, J.L. Meliyo and B.M. Msanya on 27/11/95

Ap1 0 - 30 cm: reddish grey (5YR5/2) dry, dark reddish brown (5YR3/3) moist; sandy clay loam; soft dry, very friable moist, slightly sticky and slightly plastic wet; very weak medium subangular blocks; many fine and very fine pores; frequent medium and small spherical and angular weathered granite and quartz fragments; frequent small spherical hard clay and iron nodules; few coarse and many fine and very fine roots; abrupt smooth boundary to

Ap2 30 - 80 cm: dark reddish brown (2.5YR3/4) moist; sandy clay; friable moist, sticky and plastic wet; moderate medium and fine subangular blocks; many fine and very fine pores; frequent medium and small angular weathered granite and quartz fragments; frequent large, medium and small spherical and irregular hard clay and iron nodules; few coarse and common very fine roots; a piece of angular granite rock seen; gradual smooth boundary to

Bt1 80 - 120 cm: dark reddish brown (2.5YR3/4) moist; clay; friable moist, sticky and plastic wet; moderate medium and fine subangular blocks; many fine and very fine pores; frequent medium and small angular and irregular weathered granite and quartz fragments; frequent large, medium and small spherical and irregular hard clay and iron nodules; few fine and very fine roots; gradual smooth boundary to

Bt2 120 - 180 cm: red (10R4/8) moist; clay; friable moist, sticky and plastic wet; moderate medium and fine subangular blocks; many fine and very fine pores; frequent medium and small angular and irregular weathered granite and quartz fragments; frequent large, medium and small spherical and irregular hard clay and iron nodules; very few very fine roots

SOIL CLASSIFICATION: FAO legend: 1988:Humic Acrisol (ACu)
USDA Soil Taxonomy: 1990:Ustic Haplohumult

ANALYTICAL DATA FOR PROFILE LTP-7

Horizon		Ap1	Ap2	Bt1	Bt2
Depth (cm)		0 - 30	30 - 80	80 - 120	120 - 180
Clay	%	38	65	65	63
Silt	%	14	11	12	13
Sand	%	48	24	23	24
Texture class		SC	C	C	C
pH H20	1:2.5	5.4	5.9	5.6	5.9
pH KCl	1:2.5	4.9	4.9	4.9	5.5
EC mS/cm	1:2.5	0.05	0.02	0.02	0.01
Organic C	%	3.7	0.9	0.6	0.3
Total N	%	0.30	0.14	0.11	0.05
C/N		12	6	5	6
Available P	mg/kg	32	7	5	3
CEC NH4OAc	cmol(+)/kg	29.5	19.5	14.5	9.5
Exch. Ca	cmol(+)/kg	7.0	4.7	5.0	3.9
Exch. Mg	cmol(+)/kg	1.9	0.8	0.7	0.6
Exch. K	cmol(+)/kg	0.33	0.29	0.23	0.10
Exch. Na	cmol(+)/kg	0.10	0.10	0.10	0.10
Exch. H	cmol(+)/kg	0.10	0.10	0.10	0.05
TEB	cmol(+)/kg	9.3	5.9	6.0	4.7
Base saturation	%	32	30	42	49
CECclay	cmol(+)/kg	78	30	22	15

Profile : LTP-8 Mapping unit: H1
Survey project : Litembo village
Region : Ruvuma
District : Mbinga
Map sheet no. : 297/4
Coordinates : 34° 50' 56.8" E / 10° 58' 25.7" S
Location : Nalioba hill
Elevation : 1770 m asl. Parent material: weathered mafic metamorphic rock. Landform: hill; hilly. Slope: 2 %; convex
Surface characteristics : Outcrops: 80 % Erosion: none or slight. Deposition: none.
Natural drainage class : somewhat excessively drained

Described by D.N. Kimaro, J.P. Magoggo and B.M. Msanya on 09/08/95

Soil: Mainly rock outcrops with pockets of very shallow soils. Minor pockets of moderately deep soil.

Ah 0 - 20 cm: brown (7.5YR4/2) dry, dark brown (7.5YR3/4) moist; sandy clay loam

Bw 20 - 60 cm: brown to dark brown (7.5Y4/4) moist; clay loam

SOIL CLASSIFICATION: FAO legend: 1988:Dystric Leptosol (LPd)
USDA Soil Taxonomy: 1990:Lithic Ustorthent

ANALYTICAL DATA FOR PROFILE LTP-8

Horizon		Ah	Bw
Depth (cm)		0 - 20	30 - 50
Clay	%	25	24
Silt	%	13	11
Very fine sand	%	12	13
Fine sand	%	30	33
Medium sand	%	15	15
Coarse sand	%	3	3
Very coarse sand	%	2	1
Total sand	%	-	-
Texture class		SCL	SCL
pH H2O	1:2.5	4.4	4.4
pH KCl	1:2.5	3.9	4.0
EC mS/cm	1:2.5	0.04	0.02
Organic C	%	2.3	1.3
Total N	%	0.16	0.10
C/N		14	13
Available P	mg/kg	2	3
CEC NH4OAc	cmol/kg	13.4	13.7
Exch. Ca	cmol/kg	0.6	1.4
Exch. Mg	cmol/kg	0.3	2.6
Exch. K	cmol/kg	0.06	0.02
Exch. Na	cmol/kg	0.03	0.02
Exch. H	cmol/kg	0.01	0.04
TEB	cmol/kg	1.0	4.0
Base saturation	%	7	29
CECclay	cmol/kg	54	57

Profile : LTP-9 Mapping unit: H2
Survey project : Litembo village
Region : Ruvuma
District : Mbinga
Map sheet no. : 297/4
Coordinates : 34° 51' 31.7" E / 10° 58' 54.1" S
Location : About 100 m north of village office
Elevation : 1650 m asl. Parent material: mixed colluvial material. Landform: hill; hilly.
Slope: 17 %; straight
Surface characteristics : Erosion: none or slight. Deposition: none.
Natural drainage class : well drained

Described by B.M. Msanya, D.N. Kimaro and J.P. Magoggo on 11/08/95

Soil: Very deep, well drained red clays.

Ap1	0 - 20 cm:	dark brown (7.5YR4/4) dry, dark brown (7.5YR3/4) moist; clay loam; soft dry, very friable moist, slightly sticky and slightly plastic wet; weak medium subangular blocks; many fine pores; many fine roots; clear smooth boundary to
Ap2	20 - 45 cm:	reddish brown (5YR4/4) moist; clay; very friable moist, sticky and plastic wet; moderate medium subangular blocks; many fine pores; many fine and medium roots; gradual smooth boundary to
Bw	45 - 60 cm:	red (2.5YR4/6) moist; clay; very friable moist, sticky and plastic wet; moderate medium subangular blocks; patchy thin clay cutans; many fine pores; few nodules; few fine and common medium roots; gradual smooth boundary to
Bt1	60 - 120 cm:	red (2.5YR4/6) moist; clay; very friable moist, sticky and plastic wet; moderate medium and fine subangular blocks; broken thin clay cutans; many fine pores; frequent nodules; few fine roots; diffuse smooth boundary to
Bt2	120 - 200 cm:	red (10R4/8) moist; clay; very friable moist, sticky and plastic wet; moderate medium and fine subangular blocks; broken thin clay cutans; many fine pores; frequent nodules; few fine roots

SOIL CLASSIFICATION: FAO legend: 1988:Haplic Acrisol (ACh)
USDA Soil Taxonomy: 1990:Acrustoxic Kandiustult

ANALYTICAL DATA FOR PROFILE LTP-9

Horizon		Ap1	Ap2	Bw	Bt1	Bt2
Depth (cm)		0 - 20	20 - 45	45 - 60	80 - 100	160 - 180
Clay	%	25	31	26	40	46
Silt	%	17	13	10	14	8
Very fine sand	%	10	9	12	9	9
Fine sand	%	29	26	31	22	21
Medium sand	%	14	17	16	11	12
Coarse sand	%	4	3	4	3	3
Very coarse sand	%	1	1	1	1	1
Total sand	%	-	-	-	-	-
Texture class		SCL	SCL	SCL	SC	SC
pH H2O	1:2.5	4.9	5.2	4.8	4.9	5.0
pH KCl	1:2.5	4.1	4.4	4.1	4.3	4.3
EC mS/cm	1:2.5	0.01	0.03	0.02	0.01	0.01
Organic C	%	2.8	1.4	0.6	0.4	0.2
Total N	%	0.14	0.10	0.05	0.03	0.02
C/N		20	14	12	13	10
Available P	mg/kg	1	7	1	-	-
CEC NH4OAc	cmol/kg	13.5	5.0	5.9	3.1	3.1
Exch. Ca	cmol/kg	1.3	1.3	0.7	0.6	0.7
Exch. Mg	cmol/kg	0.5	0.4	0.1	0.2	0.3
Exch. K	cmol/kg	0.17	0.06	0.05	0.06	0.07
Exch. Na	cmol/kg	0.02	0.04	0.01	0.04	0.01
Exch. H	cmol/kg	0.05	0.06	0.05	0.10	0.02
TEB	cmol/kg	2.0	1.8	0.9	0.9	1.1
Base saturation	%	15	36	15	29	35
CECclay	cmol/kg	54	16	23	8	7

Appendix 2. Guide to general evaluation of some soil chemical and physical properties

Compiled from Baize (1993), EUROCONSULT (1989) and Landon (1991)

1. Organic matter and total nitrogen

	Very low	Low	Medium	High	Very high
Organic matter %	<1.0	1.0-2.0	2.1-4.2	4.3-6.0	> 6.0
Organic C %	<0.60	0.60-1.25	1.26-2.50	2.51-3.50	> 3.50
Total N %	<0.10	0.10-0.20	0.21-0.50	> 0.50	

C/N ratios give an indication of the quality of the organic matter:
C/N 8 - 13 : good quality
C/N 14 - 20: moderate quality
C/N > 20 : poor quality

2. Soil reaction

Soil reaction (pH H_2O) is classified as follows:

extremely acid	pH below 4.5
very strongly acid	pH 4.5 to 5.0
strongly acid	pH 5.1 to 5.5
medium acid	pH 5.6 to 6.0
slightly acid	pH 6.1 to 6.5
neutral	pH 6.6 to 7.3
mildly alkaline	pH 7.4 to 7.8
moderately alkaline	pH 7.9 to 8.4
strongly alkaline	pH 8.5 to 9.0
very strongly alkaline	pH above 9.0

3. Available phosphorus

mg/kg	Low	Medium	High
Avail. P (Bray-Kurtz I)	<7	7-20	>20
Avail. P (Olsen)	<5	5-10	>10

Available phosphorus is determined by the Bray-Kurtz I method if the pH H_2O of the soil is less than 7.0. In soils with a pH H_2O of more than 7.0 the Olsen method is used.

4. Cation exchange capacity (CEC)

me/100 g	Very low	Low	Medium	High	Very high
CEC	<6.0	6.0-12.0	12.1-25.0	25.0-40.0	>40.0

CEC is determined using 1M ammonium acetate in soils with pH less than 7.5. In soils with pH greater than 7.5 CEC is determined using 1M sodium acetate.

5. Exchangeable calcium

me/100 g	Very low	Low	Medium	High	Very high
Ca (clayey soils rich in 2:1 clays)	<2.0	2.0-5.0	5.1-10.0	10.1-20.0	>20.0
Ca (loamy soils)	<0.5	0.5-2.0	2.1-4.0	4.1-6.0	>6.0
Ca (kaolinitic and sandy soils)	<0.2	0.2-0.5	0.6-2.5	2.6-5.0	>5.0

6. Exchangeable magnesium

me/100 g	Very low	Low	Medium	High	Very high
Mg (clayey soils)	<0.3	0.3-1.0	1.1-3.0	3.1-6.0	>6.0
Mg (loamy soils)	<0.25	0.25-0.75	0.75-2.0	2.1-4.0	>4.1
Mg (sandy soils)	<0.2	0.2-0.5	0.5-1.0	1.1-2.0	>2.0

The desired saturation level of exchangeable Mg is 10 to 15 percent; for sandy and kaolinitic soils 6 to 8 percent Mg saturation is still sufficient.
Ca/Mg ratios of 2 to 4 are favorable.

7. Exchangeable K

me/100 g	Very low	Low	Medium	High	Very high
K (clayey soils)	<0.20	0.20-0.40	0.41-1.20	1.21-2.00	>2.00
K (loamy soils)	<0.13	0.13-0.25	0.26-0.80	0.81-1.35	>1.35
K (sandy soils)	<0.05	0.05-0.10	0.11-0.40	0.41-0.70	>0.70

The desired saturation level of exchangeable K is 2 to 7 percent.
Favorable Mg/K ratios for most crops are in the range of 1 to 4.

8. Exchangeable sodium

me/100 g	Very low	Low	Medium	High	Very high
Na	<0.10	0.10-0.30	0.31-0.70	0.71-2.00	>2.00

More important than the absolute level of exchangeable Na is the exchangeable sodium percentage ESP) calculated by dividing exchangeable Na by CEC (x 100). ESP values are a measure of the sodicity of the soil.

9. Soil sodicity

	Non-sodic	Slightly sodic	Moderately sodic	Strongly sodic	Very strongly sodic	Extremely sodic
ESP %	<6	6-10	11-15	16-25	26-35	>35

ESP <15% -up to 50 percent yield reduction of sensitive crops (maize, beans)
ESP 16-25% -up to percent yield reduction of semi-tolerant crops (rice, wheat, sorghum, sugarcane)
ESP 35% -up to 50 percent yield reduction of tolerant crops (barley, cotton)

10. Basic infiltration rate (IR)

IR <0.1 cm/h	extremely slow
IR 0.1-0.3 cm/h	very slow
IR 0.3-0.5 cm/h	slow
IR 0.5-2.0 cm/h	moderately slow
IR 2.0-6.5 cm/h	moderate
IR 6.5-12.5 cm/h	moderately rapid
IR 2.5-25.0 cm/h	rapid
IR >25.0 cm/h	very rapid

Basic infiltration rate is the constant rate at which water enters the (pre-wetted) soil and which develops after 3 to 5 hours of infiltration.

11. Available water capacity (AWC)

AWC	<25 mm/m	extremely low
AWC	25-50 mm/m	very low
AWC	50-100 mm/m	low
AWC	100-150 mm/m	medium
AWC	150-200 mm/m	high
AWC	>200 mm/m	very high

Available water capacity is the capacity of the soil to store water that is readily available for uptake by plant roots; usually expressed in millimeters of water per meter depth of soils; technically the difference between the percentage of soil water at field capacity (normally taken as the water content at pF 2.2) and the percentage at wilting point (taken as the water content at pF 4.2).

12. Aluminium saturation

	very low	low	medium	high	very high
Al saturation %	< 10	10 - 30	31 - 50	51 - 80	> 80

Aluminium saturation as a measure of toxicity is calculated by dividing exchangeable Al by the sum of exchangeable bases and exchangeable Al.