INVESTIGATION OF THE ENVIRONMENTAL ATTRIBUTES FOR AGRICULTURAL DEVELOPMENT IN KITANDA VILLAGE, MBINGA DISTRICT, TANZANIA

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EXECUTIVE SUMMARY

Mbinga district like most of Tanzania lacks soils information at sufficient detail for proper land use planning and management. The district falls under the *Miombo* woodlands zone of Tanzania which are areas that are or were formerly under *Miombo* woodlands. These areas have been under natural vegetation for a long time but are now being encroached by arable land uses. The resultant changes in land cover are liable to disturb the ecological equilibrium of the natural resources. Studies to assess the land resources have not been done adequately in these areas.

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

This report describes the study of environmental attributes of Kitanda village as part of the continuing project on the assessment of the natural resources of Mbinga district. The study involved measurements of terrain elements, quantitative investigations of soil properties, inventory of land use systems and an assessment of the ecological potential and constraints as determined from a balance sheet analysis of resources and land use requirements.

Climatic resources

Kitanda village has no specific climate records. The rainfall pattern in Kitanda and the surroundimg areas is monomodal. The rains start in November ending in May. It is estimated that the mean annual precipitation in the village and the nearby areas is slightly less than 1000 mm. In the rainy season there is enough moisture in the soil to sustain crop production without irrigation. 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. Kitanda village is expected to be in between with mean annual temperatures between 20°C and 25°C. The dry season (May to September) is cooler than the rainy season. Research on climatic aspects is necessary.

Geology and landform

Kitanda village is underlain by mixed intermediate and mafic metamorphic rocks. These are the major parent materials for soils in the study area. The hilland forms the upper part of the village, and includes backslopes and slope facet complexes. Following the hilland are the piedmonts which are primarily colluvial (depositional) sites but are also secondary denudational sites. The lowest-lying parts are the river valleys. These form the ultimate sink for all materials eroded from the higher-lying land.

Vegetation and land use

In Kitanda village *miombo* woodland is the major natural vegetation. This vegetation occupies mainly the hillands and the piedmonts. The dominant tree species are *Brachystegia spp*. (Myombo), *Parinari curatelifolia* (Mbuni), *Uapaka kirikiana* (Msuku). Others include *Diplorhynchus candylocarpon* (Mtomoni) and *Cussonia arborea* (Mtumbitumbi). The *miombo* woodlands normally have grasses (*Hyparrhenia spp*. and *Brycharia spp*.) as undergrowth. The major categories of land use in Kitanda village are shifting cultivation (known as slash and burn) with finger millet as the main crop, and *ngoro* and/or *ridge* cultivation with maize and beans as the dominant crops.

Soils

Six 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 Kitanda area are:

(a) very shallow to shallow, well to excessively drained, yellowish red to dark red, gravelly clays, with thin dark reddish brown, gravelly sandy clay loam topsoils in the major part of the hilland. Here rock outcrops and surface stones are common.

(b) very deep, well to somewhat excessively drained, dark red clays, with thin dark reddish brown to black sandy clay loam to sandy clay topsoils.

(c) very deep, very poorly drained, very dark grey, sand clay loam to clay loams, with thick dark reddish brown to very dark brown sandy clay loam topsoils. The soils are stratified and mottled.

The soils of the hillands were classified as **Umbric Leptosols (Lithic Ustorthents)**, **Eutric Leptosols (Lithic Ustorthents)**, and **Ferric Acrisols (Ustic Kandihumults** and **Typic Kanhaplustults)**; those of the piedmonts as **Ferric Lixisols (Ustic Kandihumults)** and **Rhodic Ferralsols (Rhodic Kanhaplustults)**; and those of the river valleys as **Dystric Fluvisols (Aeric Fluvaquents)**.

The bulk densities of most topsoils are relatively lower than those of the subsoils, ranging from 0.8 to 1.2 g/cc (topsoils) and 1.2 to 1.5 g/cc (subsoils). Total porosity ranges from 56 to 72 percent in the topsoils and from 46 to 58 percent in the subsoils. Available water holding capacities of the soils are between 131 and 176 mm per meter of soil.

The soils have overall poor supply of the major nutrients i.e. nitrogen and phosphorus. The average C/N ratios range from 16 for topsoils to 18 for subsoils. This ratios indicate moderate quality of organic matter. Most of the basic cations e.g. Ca^{++}, Mg^{++} and K^{+} are low to medium. The overall capacity of the soils to retain nutrients against leaching is medium (CEC values range between 12 and 25 cmol(+)/kg).

Generally the soils in the village were found to have seriuos limitations in depth for hillands and low fertility in the piedmonts and river valleys. This calls for research on fertilizer use, afforestation and proper soil management. Intergrated farming systems research e.g inclusion of livestock in the village land utilization types is recommended.

1. INTRODUCTION

Tanzania is largely covered by *Miombo* woodlands (Kimaro *et al.,* 1995a & b; Msanya *et al.,* 1995a & b). These lands which have been under natural vegetation for a long time are now being encroached by arable land uses. The resultant changes in land cover are liable to disturb the ecological equilibrium of the natural resources. However, studies to assess the land resources in the Miombo woodlands have not been done adequately to allow present and potential land users to utilize their land resources sustainably.

Information on the soil and other land resources normally gathered by systematically identifying, grouping and delineating different soils according to their genesis, physico-chemical characteristics and overall ecological conditions is a pre-requisite when sound interpretations towards land use potential are to be made. Fertilizer and other agronomic trials carried out on uncharacterized soils are not very useful because their results are specific to the trial site and hence they have low transferability to other areas (Msanya *et al.*, 1995c). When site selection and soil characterization are properly done it is possible then to extend research results to a large number of farmers.

Recently, a project called Miombo Woodland Research Project (MWRP) was initiated between the Sokoine University of Agriculture Tanzania, and Kyoto University, Japan. This project is aimed at studying land resources, ecological aspects, and related socio-economic issues in Ruvuma which is largely covered by *Miombo* woodlands. Mbinga district is a pilot area selected for this project. The land resources in Mbinga are representative of the typical conditions found in a large part of *Miombo* woodland areas of Tanzania. The MWRP is presently concentrating its efforts in some selected villages of Mbinga to serve as nuclei for technological transfer. Some villages like Lupilo (Msanya *et al.*, 1995a) and Tukuzi (Kimaro *et al.,* 1995a), have had their soils characterized.

The study in Kitanda village is part of the on-going activities of the MWRP focussing on the inventory and assessment of the natural resources of Mbinga district. Emphasis is laid on terrain attributes, soils, vegetation and land use systems. Information generated by this and other studies in the project will form a base for the development of the soil information system for Tanzania (*SISTAN*) and its linkage to computerized land evaluation systems and geographic information systems (GIS). It is also foreseen that the data generated in this study will provide information on natural resources to other research teams of the MWRP working in Mbinga district.

The general objective of this study was therefore to investigate the environmental attributes for agricultural development in Kitanda village.
The specific objectives of the study were thus:

(a) to identify and characterize the soils and terrain elements of Kitanda village;

(b to map the spatial distribution of the existing pedological entities in the village;

(c) to classify the soils of Kitanda village using the two international systems adopted in Tanzania (i.e. 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 to permit 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

This phase included literature search, collection of available data and preliminary study of the materials listed below:

- Geological map at the scale of 1:125,000 quarter degree sheet 298 (86-Songea S.W.). *Geological Survey of Tanganyika, 1956.*
- Topographic map at the scale of 1:50,000, Kigonsera, map sheet 298/3. *Ministry of Lands, Survey and Mapping Division, 1972.*
- Aerial photographs at the scale of 1:50,000, runs 8404, 8405, 8406 and 8407. *Photomap International, August/September, 1990.*
- SPOT imagery: False colour composite (FCC)
- Pedological investigations and land resources characterization of Lupilo village, Mbinga District. *Msanya, B.M., D.N. Kimaro, and J.P. Magoggo, 1995a.*
- Characteristics of two pedons and their implications for environmental management in parts of Mbinga District, Tanzania. *Msanya, B.M., D.N. Kimaro and J.P. Magoggo, 1995b.*
- 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 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, 1995a.*
- Considerations of some land qualities in relation to land management in Lupilo village, Mbinga District, Tanzania. *Kimaro D.N., B.M. Msanya and J.P. Magoggo, 1995b.*
- Annual progress report 1994/1995 (draft). *Miombo Woodland Research Project (SUA), 1995.*
- 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.*

Before mapping the soils, aerial photo interpretation was carried out to identify mappable features useful for the study e.g. landforms, drainage patterns, vegetation and land use patterns. The delineated features on the aerial photographs were then converted into photo interpretation map which formed the basis for planning the field mapping.

2.2. Field work

Free survey technique was used using aerial photo interpretation map to select observation and sampling points. Data was collected on pedological characteristics, landforms, elevation, slope gradients, parent materials (lithology), vegetation and land use/crops. Soils were studied by description of mini-pits plus auger hole borings and soil profile pits. In total, 14 mini-pits and 7 soil profile pits were studied and described. Soils and landforms were described according to standard procedures as outlined in the FAO guidelines and USDA Soil Taxonomy. The data collected were recorded on standard analogue field forms. Soil auger descriptions were used to identify similar soils that could form mapping units.

Disturbed soil samples were collected for physico-chemical analysis while undisturbed samples were collected for determination of bulk density and soil moisture characteristics.

2.3. Post-field work

Post-field activities included cartographic generalization of the topographic base map to reduce thematic details, and enlargement of the scale to 1:25,000, transfer of the polygons delineated on the photo-interpretation map onto the enlarged topographic base map and digitization of the field and laboratory analytical data into the national soil/land data base management system (*SISTAN*).

Appendix 1 presents the soil profile descriptions and their corresponding laboratory data. Appendix 2 provides a guide to general evaluation of soil chemical and phyisical properties.

2.3.1. Laboratory and office work

Soils were analysed as follows:
The pH was measured potentiometrically in water and in 1M KCl at the ratio of 1/2.5 soil-water and soil-KCl respectively (Peech 1965). 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 Kjeldahl 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.

Texture was determined by the hydrometer method after dispersing soil with sodium hexametaphosphate (calgon). Bulk density was determined using the core sample method (Blake, 1965). Soil moisture characteristics were determined by use of 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 landforms, relative position in the landscape, slope classes and soil properties. The soil mapping legend is given in Table 2.

In the legend and on the map every mapping unit was given a symbol referring to the topography. Further subdivision is based on slope and soil characteristics and is indicated by an arbitrary numbers following the capital letter. The column "soil description" in the legend gives the main characteristics of the soil types i.e. soil depth, drainage, color, texture, and other diagnostic characteristics that distinguish each soil type from others.

2.3.3. Soil classification and data processing

Soil types were classified to level-2 of the FAO-Unesco (1988) legend of the soil map of the world and up to subgroup level of the USDA Soil Taxonomy (Soil Survey Staff, 1990). This information is also included in the description of mapping units. Data processing and report writing was done using *SISTAN* and other computer software.

3. RESULTS AND DISCUSSION

3.1. Physical environment

3.1.1. Location

Mbinga district is located within longitudes 34° 24'E and 35° 28'E and latitudes 10° 15'S and 11° 34'S. Kitanda village is situated in the Kigonsera low hills and footslopes. The approximate geographical coordinates are 35° 06' 44.1" E and 10° 55' 24.6" S. The location of the village is shown in Figure 1.

3.1.2. Climate

Climatic records for Mbinga town have been used to deduce the climatic conditions in Kitanda as there are no specific records for the village. The rainfall distribution in Mbinga district is monomodal starting in November and ending in May. During this period rainfed crop production is feasible. The rest of the year is dry. Kitanda village falls in a relatively drier part of Mbinga district and is estimated to receive a total annual rainfall of slightly less than 1000 mm compared to the average range of between 1,200 to 1,500 mm as reported by Mchau (1993) for Mbinga district in general. Table 1 shows some rainfall data obtained from District authorities for Mbinga town covering a period of 6 years.

The average annual temperatures for Mbinga district range from about 13°C in the Matengo highlands to about 30°C on the shores of Lake Nyasa (Mchau, 1993). Kitanda village has mean annual temperatures between 20°C and 25°C. Minor seasonal variations in temperature exist whereby the dry season (May to September) is cooler than the rainy season.

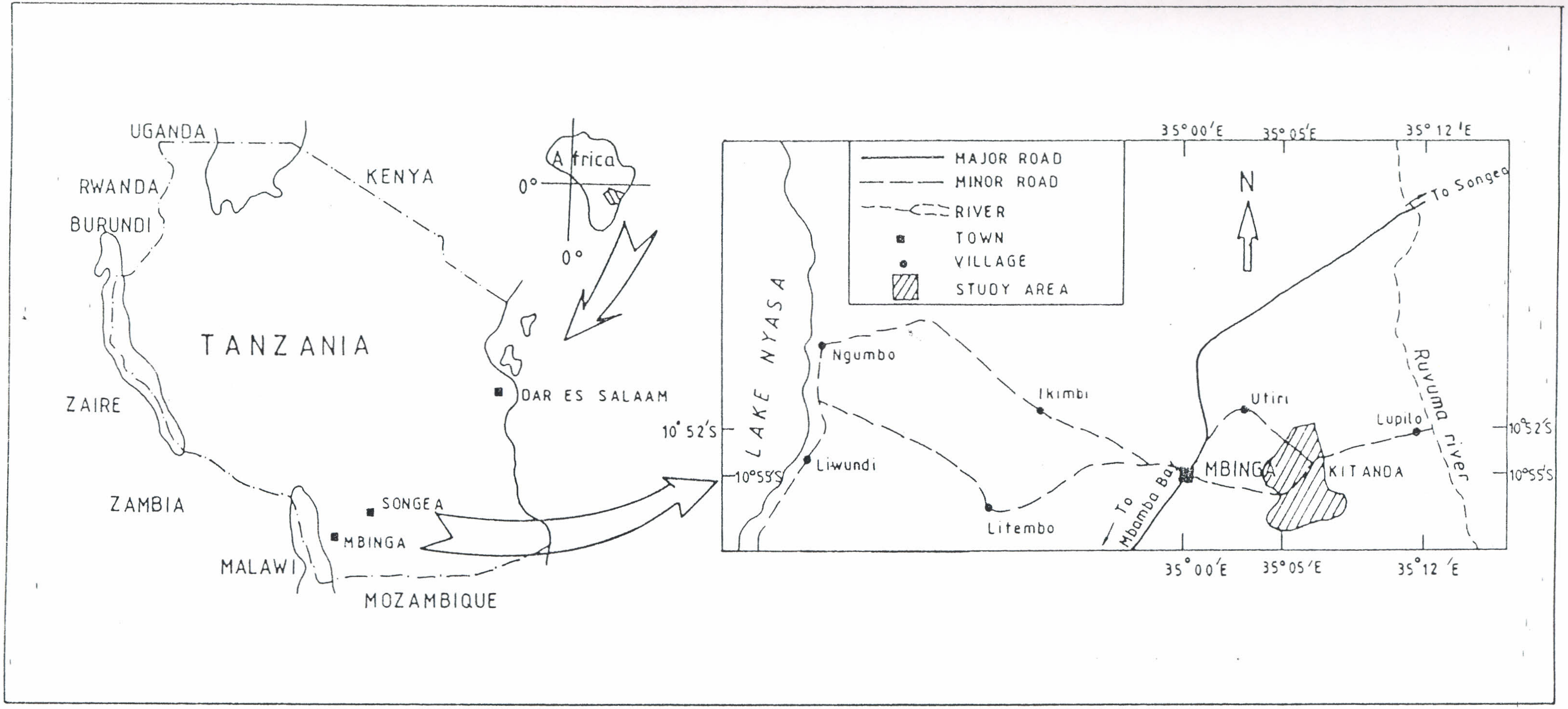

Figure 1. *Location of the study area*

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 geology of Kitanda village comprises garnet-sillimanite-cordierite-granulite and cordieritised amphibolites (Geological Survey Department, 1956). The village has three major landscapes corresponding to altitude. The high areas are predominantly hilly, the mid-altitude areas are piedmonts adjacent to the hilly landscape. The river valleys comprise the lowest-lying landscape. The topography of the area consists of very steep slopes (dominantly 25 - 50%) in the hilly landscapes, becoming gentler in the piedmont landscapes (mainly around 2 -35%). The river valleys are generally flat (0 - 5%).

As it was earlier observed by Msanya *et al.* (1995) in the neighbouring village of Lupilo, the hilly landscape in Kitanda village is dominated by processes of denudation. The products resulting from weathering of the lithological materials are removed relatively quickly due to the high relief intensity and steep slopes. These materials are subsequently deposited as colluvium on the piedmonts. The valley landscape forms the ultimate sink of all materials denudated laterally from the higher landscapes as well as longitudinally along the courses of the drainage ways and rivers.

3.1.4. Vegetation and land use

Miombo woodland is still the major natural vegetation covering the village. Despite the relatively recent occupation of the village lands (about 15 years), presently the miombo vegetation is found in the hillands and to a little extent in the piedmonts. This indicates a high rate of clearing the woodlands which is feared to be detrimental to other environmental attributes in the area. The dominant *Miombo* tree species include *Brachystegia spp.* (Myombo), *Parinari curatelifolia* (Mbuni) and *Uapaka kirikiana* (Msuku). Others include *Diploryhchus candylocarpon* (Mtomoni) and *Cussonea arborea* (Mtumbitumbi). The dominant grasses which appear as undergrowth in the *Miombo* woodlands include *Hyparrhenia spp.* and *Brycharia spp.*

In Kitanda village, like it was observed by Msanya *et al.* (1995a) in the neighbouring village of Lupilo it was noted that human influence in the *miombo* woodland environment e.g. fuel wood harvesting, land claering for food production, livestock keeping etc. plays a major role in the ecological balance. This vegetation type contributes to a certain degree to the fertility of the soils. Clearing of this vegetation which has poor regeneration, leads to a drastic fall in soil fertility due to increased degradation of the soil and other enviromental factors. Consequently, a system of shifting cultivation of *'slash and burn'* has evolved in these areas.

The major part of the piedmonts and river valleys in Kitanda village are used for cultivation. Two dominant types of land use are practiced in the village:

(a) *Ridge and/or Ngoro cultivation system*

The main crops on the ridges and ngoros are maize and beans which are planted in November/December and February respectively. Harvesting of maize and beans takes place in July/August and May respectively. The ridge/ngoro cultivation system is practiced on the piedmonts. Compared to the Matengo highlands, ngoros are not as predominant as ridges in Kitanda village. The ridges are more liked because they are simpler to prepare.

(b) *Shifting cultivation (slash and burn)*

This land use type is particularly used for fingermillet production. Virgin or fallowed land is cleared by slashing and burning existing vegetation before sowing the seeds. Fingermillet is planted in November/December and harvested in April/May. Shifting cultivation is widespread in the piedmonts. Other minor land use systems include flat cultivation of fruit crops like pineapples, mangoes and bananas on the piedmonts; flat cultivation of off-season maize and vegetables including tomatoes, cabbages and spinach, in the river valleys; and flat cultivation of coffee and grevillea on the piedmonts. Livestock keeping is very minor and includes goats, sheep and pigs.

Allocation of crops to the available land by the farmer is affected by labour and soil conditions. Coffee was observed to be closer to the homes because of its high labour demand, while fingermillet is grown on virgin or fallowed fields because such fields have favourable soil conditions for the crop. Similar observations were made in Lupilo and other villages in Mbinga district (Msanya *et al.*, 1995a; Temu and Bisanda, 1994).

3.2. Soils

3.2.1. Landforms, soils, vegetation and land use

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

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

MAP SYMBOL	LANDFORM CHARACTERISTICS	DOMINANT SLOPE (%)	AREA		SOIL DESCRIPTION	VEGETATION/LAND USE
			ha	%		
HILLAND (H), elevation 1200 to 1500 m above sea level						
H1	Hill summits and upper slopes	0-2	711	13	Shallow to moderately deep, well to somewhat excessively drained, yellowish red, very gravelly clays, with dark redish brown, very gravelly sand clay loam topsoils; developed on mixed partially metamorphosed granitic rocks. In places rock outcrops, boulders, stones and gravels occur on/at the surface. The soils classify as **Umbric Leptosols (Lithic Ustorthents).**	Natural forest; mainly *Miombo* woodland: *Brachystegia spp.* (Myombo), *Parinari curatelifolia* (Mbuni), *Uapaka kirikiana* (Msuku), *Cussonia arborea* (Mtumbitumbi), *Diplorhynchus candylocarpon* (Mtomoni). Grasses mainly *Hyperrhenia rufa, Brycharia spp.* as undergrowth. Farming systems include few *ridge* and *ngoro cultivation* used mainly for maize production.
H2	moderately dissected steep hill slopes	25-50	258	5	Very shallow to shallow, well to excessively drained, dark red gravelly clays, with dark reddish brown, sandy clay loam topsoils; developed on mixed partially metamorphosed granitic rocks. In places rock outcrops and boulders occur.The soils classify as **Eutric Leptosols (Lithic Ustorthents).**	Natural forest; mainly *Miombo* woodland: *Brachystegia spp., Parinari curatelifolia.* Grasses mainly *Hyperrhenia rufa* and Brycharia spp. Farming systems include few *ridge and ngoro cultivation* used mainly for maize production.
H3	steep and strongly dissected slope facet complex	25-50	1885	34	Very deep, well to somewhat excessively drained, dusky red clays, with thin dark reddish brown, sandy clay topsoils; developed on colluvial material derived from mixed partially metamorphosed granitic rocks. The soils classify as **Ferric Acrisols (Ustic Kandihumults** and **Typic Kanhaplustults)**	Natural forest; mainly *Miombo* woodland: *Brachystegia spp., Parinari curatelifolia.* Grasses mainly *Hyperrhenia rufa, Brycharia spp., Themeda triandra.* Farming systems include *ridge and ngoro* cultivation with beans and maize as main crops. Coffee-Grevillea agroforestry, cultivation of bananas, mangoes are also practiced.

PIEDMONTS (P), elevation 1100 to 1400 m above sea level

P1	gently undulating and strongly dissected very steep slopes with narrow interfluves sloping towards the streams	2-35	416	7	Very deep, well drained, dark red clays, with thin, black to dark reddish brown, sandy clay loam topsoils; developed on colluvium derived from mixed partially metamorphosed granitic rocks. The soils classify as **Ferric Lixisols (Ustic Kandihumults)**.	Coffee-Grevillea agroforestry and fruit crops (mangoes and bananas). *Ngoro* and *ridge* cultivation for maize and beans are practiced on the steep slopes towards drainage valleys. The unit has few miombo trees on the steep slopes such as *Brachystegia spp*. and *Parinari spp.*
P2	Moderately dissected slopes, with broad interfluves and short steep slopes towards drainage streams	5-25	2047	37	Very deep, well drained, dark red clays, with thin, black to dark reddish brown sandy clay loam topsoils; developed on colluvium derived from mixed partially metamorphosed granitic rocks. The soils classify as **Rhodic Ferralsols (Rhodic Kanhaplustults).**	*Ridge* cultivation with beans and maize; and coffee-grevillea agroforestry. There is also a natural forest of miombo trees such as *Brachystegia spp* and *Parinari spp.* Small scale cultivation of pineappless is also practiced.

RIVER VALLEYS (V), elevation 1200 to 1250 m above sea level

V	Flat to almost U-shaped river floors	0-5	246	4	Very deep, very poorly drained, very dark gray, layered and mottled sandy clay loams to clay loams, with thick, dark reddish brown to very dark brown, sandy clay loam topsoils; developed on alluvial-colluvial material of diverse origin. The soils classify as **Dystric Fluvisols (Aeric Fluvaquents).**	Flat, *ridge* and *ngoro* cultivation with maize and beans as main crops. Natural *miombo* woodland trees and grasses in waterways are common. Bamboo, *Hyperrhenia spp.* and *napia* grasses are common.

3.2.2. *Physical properties*

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

Soil texture is the most stable physical characteristic of the soil which influences a number of other soil properties such as structure, consistence, soil moisture regime, permeability, infiltration rate, runoff rate, erodibility, workability, root penetration and fertility (Landon, 1984). In Kitanda village most topsoils have a sandy clay loam texture, with an exception of profiles KTP-3 and KTP-6 which have a sandy loam texture. The subsoils of most profiles are clayey except profile KTP-4 with predominantly sandy clay loam texture. The bulk densities of most topsoils are relatively lower than those of the subsoils; ranging from 0.8 to 1.2 g/cc in the topsoils and 1.2 to 1.5 g/cc in the subsoils. Profile KTP-1 has higher bulk densities (1.5 g/cc) in the deeper subsoils while profile KTP-3 has the lowest bulk densities (1.1 - 1.2 g/cc). Total porosity ranges from 56 - 72% in the topsoils and from 46 - 59% in the subsoils. Bulk density and total porosity of the soils are mainly influenced by texture and to some extent by organic matter content of the soils.

Water retention and available water capacity

Moisture retention characteristics for three depths (surface 0 - 15 cm, intermediate 45 - 50 cm and subsoil 95-100 cm) of four profiles (KTP-1, KTP-2, KTP-3 and KTP-7) are presented in Figure 2. There is a steady but slow decrease of available water capacity with increased suction for the four studied profiles. This behaviour is reported by Landon (1984) as being characteristic of most clayey soils. The available water capacity for the soils seems to increase with soil depth as does the clay content. Similar observations were made by *Msanya et al.* (1995a) in Lupilo village. A positive correlation between clay content and available water capacity in soils of the tropics has been reported by van Wambeke (1991). Generally the available water capacity per meter of soil depth ranges from high (150 - 200 mm/m) for KTP-1, KTP-2 and KTP-7, to medium (100 - 150 mm/m) for KTP-3. The magnitude of the available water capacity is in the order of KTP-1>KTP-7>KTP-2>KTP-3.

3.2.3. *Chemical properties*

The analytical data of the studied soil profiles are given in Appendix 1. Tables 4 and 5 present the chemical analytical data of Kitanda soils. The following chemical properties are presented and discussed:

Table 3. Selected soil physical properties of Kitanda village

Profile No.	Depth (cm)	Textural class	Bulk density (g/cc)	Total porosity (%)	Available water capacity (% vol.)	Available water capacity (mm/m)
KTP-1	0-10	SCL	1.2	56	14	
	33-70	C	1.5	46	17	176
	70-120	C	1.3	51	20	
KTP-2	0-15	SCL	1.1	61	10	
	40-80	C	1.2	55	17	164
	80-120	C	1.2	56	19	
KTP-3	0-15	SL	0.8	72	9	
	35-80	C	1.2	58	13	131
	80-120	C	1.1	59	18	
KTP-7	0-22	SCL	1.0	63	10	
	40-80	C	1.2	56	17	157
	80-130	C	1.3	55	18	

C=clay SCL=sandy clay loam SC=sandy clay SL=sandy loam

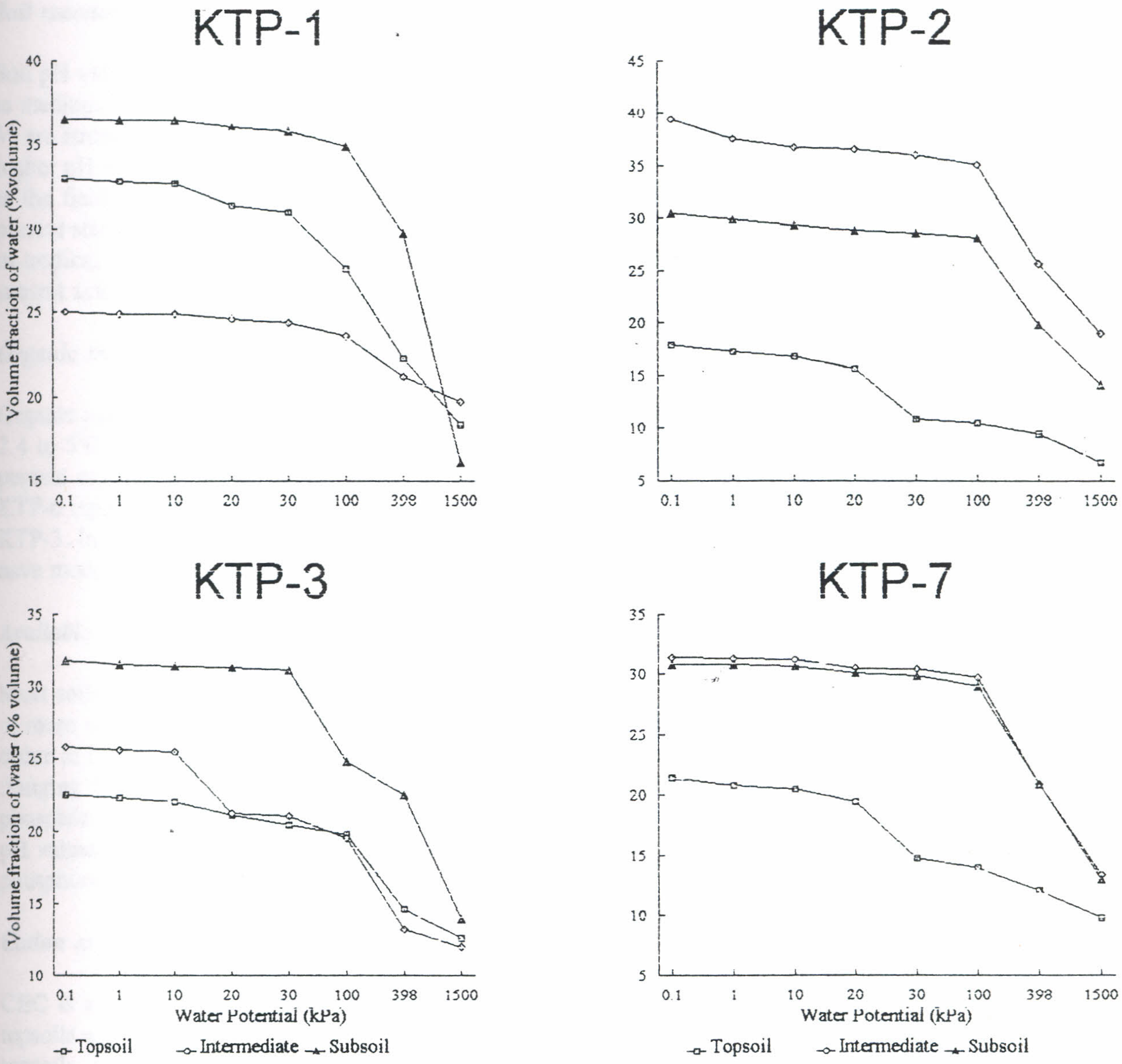

Figure 2. Soil moisture release curves for some selected profiles of Kitanda village

Soil reaction

Soil pH values are medium acid in most topsoils ranging from 5.6 to 6.1. The subsoils are strongly acid to medium acid with pH values ranging from 5.0 to 5.8. The pH values of profile KTP-4 (mapping unit V) are strongly acid in the topsoil and very strongly acid in the subsoil. In general nearly all topsoils have higher pH values than subsoils. In view of the local practices of burning vegetation and spreading ashes in the fields while preparing the land for agriculture, the soil pH values are likely to remain in their present status or rise temporarily with repeated burning. Such observations have been reported elsewhere in tropical soils by Sanchez (1976). However, if the topsoils are eroded the deleterious effects of the subsoil acidity will be a serious limitation to crop production.

Organic matter and nitrogen

Organic matter contents are generally medium to high corresponding to organic carbon levels between 2.4 to 5.0 percent in topsoils. The levels of organic matter in the subsoils are very low (less than 0.6 percent organic carbon) except for profile KTP-4 representing the river valleys and profiles KTP-5 and KTP-6 representing the hillands. Lowest levels of organic carbon were observed in the subsoils of profile KTP-3. In most soils nitrogen levels are low (less than 0.2 percent). However, the topsoils of these soils have moderate to good quality organic matter (C/N ratios between 10 and 18).

Available phosphorus

Most soils have low levels of available phosphorus (less than 7 mg P/kg). An average phosphorus level of more than 7 mg P/kg is considered to be optimum below which P-deficiency symptoms are likely to occur in many crops. The topsoils of profile KTP-1, KTP-3 and KTP-5 have high levels of phosphorus (ranging from 20 to 45 mg P/kg). The topsoils of the remaining soils have low levels of available phosphorus (less than 6 mg P/kg) except profile KTP-6 which has medium levels of phosphorus. The low pH values in Kitanda village imply a possibility of high phosphate fixation capacity by the soils. Future phosphorus fertilizer recommendations in the study area must put this into consideration.

Cation exchange capacity (CEC)

CEC is a measure of the capacity of soil to retain nutrients (against leaching). CEC values of most topsoils are medium ranging from 12 to 25 cmol(+)/kg soil. The relatively high CEC values in the topsoils can be attributed to the higher values of OC content. The CEC values in most subsoils are low (CEC (6-12 cmol(+)/kg). Values of CEC clay of subsoils are generally low and indicate that the soils are highly weathered.

Exchangeable Calcium (Ca), Magnesium (Mg) and Potassium (K)

Table 5 presents the levels of topsoil and subsoil exchangeable cations (Ca, Mg and K) in Kitanda soils. It shows that the levels of exchangeable Ca, Mg and K are medium to high in most topsoils while subsoil levels are very low to low. The low values of these basic cations indicates that most of the soils are highly weathered.

Table 4. Chemical analytical data of soils of Kitanda village

Profile No.	Depth	pH (H_2O)	Org. C (%)	Total N (%)	C/N	Available P (mg/kg)	CEC (cmol(+)/kg soil)	Base saturation (%)
KTP-1	Topsoil	6.1	4.0	0.24	17	30	24	67
	Subsoil	5.7	0.1	0.04	3	1	6	52
KTP-2	Topsoil	5.6	2.4	0.18	13	6	18	53
	Subsoil	5.4	0.2	0.04	5	1	6	51
KTP-3	Topsoil	5.2	3.7	0.23	16	24	13	34
	Subsoil	5.7	0.2	0.02	10	1	7	59
KTP-4	Topsoil	5.3	3.9	0.25	16	5	14	39
KTP-5	Topsoil	6.0	2.9	0.16	18	46	20	67
	Subsoil	5.9	0.4	0.06	13	3	8	63
KTP-6	Topsoil	5.7	5.5	0.32	18	11	24	46
	Subsoil	5.3	2.4	0.16	15	6	16	48
KTP-7	Topsoil	5.7	3.4	0.22	15	3	17	53
	Subsoil	5.3	0.4	0.01	40	1	6	40

Table 5. Interpretation ratings for exchangeable cations of Kitanda soils

Profile No.	Map Unit	Exchangeable Calcium (cmol(+)/kg soil)		Exchangeable Magnesium (cmol(+)/kg soil)		Exchangeable Potassium (cmol(+)/kg soil)	
		Topsoil (0-20cm)	Subsoil (30-150cm)	Topsoil (0-20cm)	Subsoil (30-150cm)	Topsoil (0-20cm)	Subsoil (30-150cm)
KTP-1	H3	High (10.6)	Low (2.6-1.7)	High (3.52)	Medium (0.7-1.64)	High (1.8)	Medium (0.48-0.98)
KTP-2	P1	Medium (6.6)	Low (2.2-3.9)	Medium (1.4)	Low-Medium (0.4-1.3)	High (1.52)	Very low-Low (0.17-0.21)
KTP-3	P2	Low (3.5)	Low (2.5-3.7)	Low (0.6)	Low (0.6-0.8)	Low (0.3)	Very low-Low (0.10-0.30)
KTP-4	V	Low (4.0)	Low to medium (3.7-5.6)	Medium (1.2)	Low (0.6-0.9)	Low (0.2)	Very low to low (0.07-0.19)
KTP-5	H2	Medium (10.0)	Very low (0.6)	Medium (2.10)	Low (0.6)	High (1.21)	Very low (0.40)
KTP-6	H1	Medium (7.8)	Medium (4.6)	Low (2.3)	Low (0.9)	Medium (0.85)	Low (0.34)
KTP-7	H3	Medium (5.2)	Low-Medium (1.8-5.2)	Low (2.2)	V.low to Low (0.1-0.8)	High (1.61)	Very low (0.06-0.32)

Nutrient balance

The availability of nutrients for uptake by plants depends not only upon absolute levels but also on relative amounts of individual elements. In most of the studied soils, calcium, magnesium and potassium are well balanced with calcium higher than magnesium and magnesium higher than potassium. Although the general trend of the individual nutrients indicates a good balance what is also important are the individual nutrient ratios i.e. Ca/Mg, Mg/K and K/TEB (total exchangeable bases Ca, Mg, K and Na). The Ca/Mg ratios in the topsoils are 3 to 5 which are considered to be optimal for most crops. The Ca/Mg ratios in the subsoils are 4 to 6. These are not favourable for deep-rooted crops. The Mg/K ratios are 3 to 6. The optimal range is normally between 1 and 4 for most crops; hence the observed ratios may pose slight limitation related to K-deficiency. The K/TEB ratios for most of the soils are more than 2% which is considered favourable for most tropical crops. In some of the soils the ratios are less than 2% indicating problems of K-deficiency.

3.2.4. Soil classification

The salient morphological and other diagnostic features of the studied soils used in classification are presented in Table 6 while the soil names are given in Table 7. The soils are classified as **Acrisols** (KTP-1, KTP-7), **Lixisol** (KTP-2), **Ferralsol** (KTP-3), **Fluvisol** (KTP-4) and **Leptosols** (KTP-5, KTP-6) according to the FAO-Unesco classification system. These correspond to **Ultisols** (KTP-1, KTP-2, KTP-3 and KTP-7) and **Entisols** (KTP-4, KTP-5 and KTP-6) in the USDA Soil Taxonomy.

Table 6. Summary of diagnostic features of the studied representative soils

Profile	Diagnostic horizons	Other diagnostic features
KTP-1	*ochric A (ochric epipedon); *argic B (argillic horizon)	ustic SMR; isohyperthemic STR *ferric properties; abrupt textural change to B horizon
KTP-2	*ochric A (ochric epipedon); *argic B (kandic horizon)	ustic SMR; isohyperthermic STR; *ferric properties
KTP-3	*ochric A (ochric epipedon); *ferrallic B (kandic horizon)	ustic SMR; isohyperthermic STR; *ferric properties
KTP-4	*ochric A (ochric epipedon)	*gleyic properties (aquic SMR); isohyperthermic STR; *fluvic properties (irregular decrease of OC with depth)
KTP-5	*ochric A (ochric epipedon)	ustic SMR; isohyperthermic STR; rudic phase; limited depth
KTP-6	*umbric A (umbric epipedon)	ustic SMR; isohyperthermic STR; limited depth; rudic phase
KTP-7	*ochric A (ochric epipedon); *argic B (argillic horizon)	ustic SMR; isohyperthermic STR; *ferric properties

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*
KTP-1	Acrisol	Ferric Acrisol (ACf)	Ultisol	Humult	Kandihumult	Ustic Kandihumult
KTP-2	Lixisol	Ferric Lixisol (LXf)	Ultisol	Humult	Kandihumult	Ustic Kandihumult
KTP-3	Ferralsol	Rhodic Ferralsol (FRr)	Ultisol	Ustult	Kanhaplustult	Rhodic Kanhaplustult
KTP-4	Fluvisol	Dystric Fluvisol (FLd)	Entisol	Aquent	Fluvaquent	Aeric Fluvaquent
KTP-5	Leptosol	Eutric Leptosol (LPe)	Entisol	Orthent	Ustorthent	Lithic Ustorthent
KTP-6	Leptosol	Umbric Leptosol (LPu)	Entisol	Orthent	Ustorthent	Lithic Ustorthent
KTP-7	Acrisol	Ferric Acrisol (ACf)	Ultisol	Ustult	Kanhaplustult	Typic Kanhaplustult

3.2.5. Description of soil mapping units

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

Mapping unit H1

Shallow to moderately deep, well to somewhat excessively drained, yellowish red, very gravelly clays, with dark redish brown, very gravelly sand clay loam topsoils; developed on mixed partially metamorphosed granitic rocks. In places rock outcrops, boulders, stones and gravels occur on/at the surface

Setting:
This unit is on the summits of the hills. It occupies the highest positions in the hilland landscape. The slopes are between 0 and 2 percent at mean elevation of about 1500 m asl. The lands are occupied with natural forest mainly *Miombo* woodland: *Brachystegia spp.* (Myombo), *Parinari curatelifolia* (Mbuni), *Uapaka kirikiana* (Msuku), *Cussonia arborea* (Mtumbitumbi), *Diplorhynchus candylocarpon* (Mtomoni). The common grasses include *Hyperrhenia rufa, Brycharia spp.* as undergrowth. Farming systems include few *ridge* and *ngoro* cultivation with maize as main crop.

Soil profile characteristics:
The topsoil (about 10 cm thick) is dark brown, friable, sandy clay loam and it is moderately structured. The subsoil to a depth of 35 cm is friable, dark reddish brown, gravelly clay loam and it is moderately structured. The soil classifies as **Umbric Leptosol- rudic phase (Lithic Ustorthent)** and profile **KTP-6** is representative.

Soil physical properties:
The soil is well to somewhat excessively drained and the rooting depth is limited at 35 cm. The available water capacity is low owing to the limitation in depth. The surface conditions are limited by rock outcrops, boulders, stones and gravels.

Soil chemical properties:
Nitrogen levels are medium in the topsoils. The available phosphorus is medium. Organic matter contents are high. The soil pH is medium acid. This soil has low to medium levels of exchangeable bases. The overall capacity of the soil to retain nutrient is medium.

Mapping unit H2

Very shallow to shallow, well to excessively drained, dark red gravelly clays, with dark reddish brown, sandy clay loam topsoils; developed on mixed partially metamorphosed granitic rocks. In places rock outcrops and boulders occur.

Setting:
The unit occupies the backslopes (very steep linear slopes) of the hills. The dominant slopes are between 30 and 50 percent and the mean elevation is at about 1300-1400 m asl. Typically the soil surface is rocky, bouldery and stony. The lands are occupied by natural forest; mainly *Miombo* woodland: *Brachystegia spp., Parinari curatelifolia*. The grasses as undergrowth include *Hyperrhenia rufa* and *Brycharia spp*. Farming systems include few *ridge and ngoro cultivation with maize as main crop.*

Soil profile characteristics:
The topsoil (less than 10 cm thick), is dark reddish brown, very gravelly, sandy clay loam and weakly to moderately structured. The subsoil to a depth of 35 cm is friable, very gravelly, dark red, clay and is moderately to strongly structured. The soil classifies as **Eutric Leptosol- lithic phase (Lithic Ustorthent)** and profile **KTP-5** is representative.

Soil physical properties:
The soil is well to excessively drained and the rooting depth is less than 35 cm. The available water capacity is low due to its shallow depth. In places surface rock outcrops, boulders and stones are common.

Soil chemical properties:
In this soil nitrogen levels are low. Levels of phosphorus are high (46 mg/kg of soil). The topsoil has moderate quality organic matter. The soil is medium to slightly acid. The soil has low to medium levels of exchangeable bases. The capacity of the soil to retain nutrients is medium.

Mapping unit H3

Very deep, well to somewhat excessively drained, dusky red clays, with thin dark reddish brown, sandy clay topsoils; developed on colluvial material derived from mixed partially metamorphosed granitic rocks.

Setting:
The unit occupies the steep and strongly dissected slope facet complex of the hilland. The slopes are between 25 and 40 percent with hilly topography. The mean elevation is at about 1300-1350m asl. The lands are covered with patches of natural forest; mainly *Miombo* woodland: *Brachystegia spp., Parinari curatelifolia*. Grasses mainly *Hyperrhenia rufa, Brycharia spp., Themeda triandra.* Farming systems include *ridge and ngoro* cultivation with beans, maize, coffee-Grevillea agroforestry, bananas, and mangoes.

Soil profile characteristics:
The topsoil (about 10-20 cm thick) is dark reddish brown to dark brown, sandy clay loam. The soil is friable and it is moderately structured. The subsoil to a depth of 150 cm and deeper is dusky red to red, friable, clay, with moderate structure. Small and hard irregular iron and manganese nodules are common. This soil classifies as **Ferric Acrisol (Ustic Kandihumult and Typic Kanhaplustult)** for profiles **KTP-1** and **KTP-7** respectively.

Soil physical properties:
The soil is well drained. The rooting depth is more than 165 cm. The available water capacity ranges from 157-176 mm/m which is high. Bulk densities are medium with values ranging between 1.1 g/cc in the topsoil to 1.5 g/cc in the subsoil. The porosity of the topsoil varies from 57-63% and about 46-55% in the subsoil.

Soil chemical properties:
The soil has medium levels of nitrogen in the topsoil but very low in the subsoil. Phosphorus levels are low to high in the topsoil but low in the subsoil.The soil has overall moderate quality organic matter. Exchangeable bases are medium to high in the topsoil but low in the subsoil. The soil reaction is slightly acid in the topsoil and medium to strongly acid in the subsoil. The soil has medium capacity to retain nutrients in the topsoil and low in the subsoil.

Mapping unit P1

Very deep, well drained, dark red clays, with thin, black to dark reddish brown, sandy clay loam topsoils; developed on colluvium derived from mixed partially metamorphosed granitic rocks.

Setting:
The unit occupies the gently undulating and strongly dissected piedmont slopes. The dominant slopes are between 5 and 10 percent on the piedmont. The slopes become very steep (35%) with narrow interfluves and very steep slopes towards the streams. The mean elevation is at about 1100 -1400 m asl. In this unit coffee-Grevillea agroforestry and fruit crops (mangoes and bananas) are grown. On the steep slopes towards drainage streams, maize cultivation is done on *ngoro* and *ridges*. The unit has few miombo trees on the steep slopes such as *Brachystegia spp*. and *Parinari spp*.

Soil profile characteristics:
The topsoil (15 cm thick) is dark reddish brown, friable, sandy clay loam and moderately structured. The subsoil to a depth of 190 cm and more is friable, dusky red, clay and it is moderately structured. The subsoil show gradual to diffuse textural and colour gradient with many Mn-Fe-Clay nodules increasing with depth. The soil classifies as **Ferric Lixisol (Ustic Kandihumult)** and profile **KTP-2** is representative.

Soil physical properties:
The soil is well drained with effective soil depth of 190 cm and deeper. Available water capacity is high (164 mm/m). Bulk density is medium around 1.1 g/cc in the topsoil and 1.2 g/cc in the subsoil. Total porosity is about 61% in the topsoil decreasing to 56% in the subsoil.

Soil chemical properties:
The soil has overall poor supply of major nutrients i.e. nitrogen and phosphorus. Potassium levels are high in the topsoil and low in the subsoil. The soil reaction is medium acid in the topsoil and strongly acid in the subsoil. The soil has medium levels of organic matter in the topsoil but very low in the subsoil. Calcium and magnesium levels are medium. The soil has medium capacity to retain nutrients in topsoil but low in the subsoil.

Mapping unit P2

Very deep, well drained, dark red clays, with thin, black to dark reddish brown sandy clay loam topsoils; developed on colluvium derived from mixed partially metamorphosed granitic rocks.

Setting:
The unit occupies the moderately dissected piedmont slopes of Kitanda hills. The slopes are between 10-15 percent and the mean elevation is at about 1300 m asl. Ridge cultivation with beans and maize is extensively practised in this unit as is coffee-grevillea agroforestry. There is also a natural forest of miombo trees such as *Brachystegia spp.*, and *Parinari spp.* Small scale

cultivation of pineappless is also practiced.

Soil profile characteristics:
The topsoil (15cm thick) is brown, and friable, sandy clay loam. The subsoil is clayey throughout. The structure is moderate in the topsoil and weak in the subsoil. The soil classifies as **Rhodic Ferralsol (Rhodic Kanhaplustult)** and the profile **KTP-3** is representative.

Soil physical properties:
The soil is well drained. The rooting depth extends to a depth of 165 cm and deeper. Available water capacity is medium (131 mm/m). Bulk density is low (0.8 g/cc) in the topsoil and medium (1.1 to 1.2 g/cc) in the subsoil.

Soil chemical properties:
The topsoil has overall medium supply of nitrogen. Phosphorus is high in the topsoil and very low in the subsoil. Topsoil has moderate quality of organic matter. The soil reaction is strongly acid. Potassium levels are low to very low in the top and subsoil respectively. Calcium and magnesium levels are low in both top and subsoil. The topsoil has medium capacity to retain nutrients but the capacity is low to very low in the subsoil.

Mapping unit V

Very deep, very poorly drained, very dark gray, layered and mottled sandy clay loams to clay loams, with thick, dark reddish brown to very dark brown, sandy clay loam topsoils; developed on alluvial-colluvial material of diverse origin.

Setting:
This unit represents the river valleys in Kitanda village. The slopes are between 0 and 2 percent. The unit is covered with dense mixed vegetation including, scattered *miombo* woodland, *bamboo* trees, and grasses (*Hyparrhenia* and *Napia* grass). Ridge and flat cultivation systems are the main land use system in this unit for the growing of off season crops like maize, beans and vegetables.

Soil profile characteristics:
The topsoil (20 cm thick) is dark reddish brown, friable, sandy clay loam. The subsoil is dark reddish brown and dark grey, firm, sandy clay loam to clay with a massive structure. The profile has partially decomposed fibrous materials and classifies as **Dystric Fluvisol (Aeric Fluvaquent)** for which profile **KTP-4** is representative.

Soil physical properties:
The soil is very poorly drained, layered and mottled, the rooting depth extends to a depth of 150 cm.

Soil chemical properties:
Nitrogen is medium in the topsoil and very low in the subsoil. The soil has overall very low supply of phosphorus. The topsoil has medium quality organic matter. The soil reaction is strongly acid in the topsoil and very strongly acid in the subsoil. Potassium levels are low to very low. Calcium and magnesium levels are generally low. This soil has medium capacity to retain nutrients.

4. CONCLUDING REMARKS AND RECOMMENDATIONS

The available climatic data for Kitanda and other villages are not sufficient to give recommendations on the onset and distribution pattern of rainfall, proper planting dates and water balance for various crops in these areas. There is a serious need to research more on these aspects to permit sound planning on the use of the available land resources.

For most part of the village the soils offer good aeration and rooting conditions except on the hillands (summits and the steep hill slopes) where soil depth, steep slopes and surface stoniness are major limitations for deep rooted crops and mechanized agricultural implements. The practice of clearing the hillands is accelarating soil erosion and as a consequence these areas are losing both soils and plant nutrients. These lands should best be left intact and protected as catchment areas. Bush fires should be controlled and afforestation of already cleared hillands should be done. In areas where agriculture is already firmly established under the *ngoro* and *ridge* farming systems, studies should be carried out to determine their effectiveness in land conservation. Research on agroforestry should also be encouraged in these areas.

Soil conditions on the piedmonts allow both good rooting and aeration. However, most soils have poor fertility and low capacity to retain nutrients. The low fertility in Kitanda village is mainly due to high degree of weathering of the soils. Clearing of vegetation is also responsible for further decline in fertility through loss of topsoils by erosion and nutrient mining. This unit can only be utilized optimally if good soil management practices are adopted including crop rotation, replenishment of organic matter by incorporating crop residues into the soil when preparing the fields, soil erosion control, agroforestry etc. Use of inorganic N, P and K fertilizers will be necessary as the levels of these nutrients are generally low in most of the soils. The low pH levels in most of the soils imply possibilities of P-fixation problems, hence P-fertilizer recommendations should take this factor into consideration. Use of non-acidifying inorganic fertilizers should be preferred.

Livestock keeping is still a minor land use in Kitanda village. There is room for development of this land use as there is ample land. Since the benefits related to livestock keeping are numerous including improved nutrition, provision of farm yard manure, animal power etc., it is hereby recommended that suitable ways of establishing livestock be looked into, putting into consideration livestock types, pastures, animal health and general management aspects. To avoid soil and land degradation, zero-grazing as opposed to extensive grazing would probably be the most plausible.

5. REFERENCES

Baize, D. 1993. Soil science analyses. A guide to current use. John Wiley & Sons Ltd. West Sussex.

Blake, G.R. 1964. Bulk density. In: Methods of Soil Analysis, part 1 (eds. C.A Black, D.D. Evans, J.L. White, L.E. Ensminger and F.E. Clark), pp. 374-390. ASA, Madison, Wisconsin.

Bray, R.H. and L.T. Kurtz, 1945. Determination of total, organic and available forms of phosphorus in soils. Soil Sci: 59:39-45.

Bremner, J.M. and C.S. Mulvaney, 1982. Total nitrogen. In: Methods of Soil Analysis, part 2, 2nd edit. (eds. A.L. Page, R.H. Miller and D.R. Keeney), pp. 595-624. ASA, SSSA Monograph no. 9, Madison, Wisconsin.

Day, P.R. 1965. Particle fractionation and particle size analysis. In: Methods of Soil Analysis, part 1, (eds. C.A. Black, D.D. Evans, J.L. White, L.E. Ensminger and F.E. Clark), pp. 545-566. ASA, Madison, Wisconsin.

EUROCONSULT, 1989. Agricultural compendium for rural development in the tropics and subtropics. Elsevier Science Publishers, Amsterdam. 740 pp.

FAO, 1990. Guidelines for soil description 3rd edition (Revised). Soil Resource Management and Conservation Service, Land and Water Development Division, FAO, Rome. 70 pp.

FAO-Unesco, 1989. Soil map of the world, revised legend. International Soil Reference and Information Centre, Wageningen. 138 pp.

Geological Survey Department, 1956. Geology of Tanganyika: Songea 86-S.W. Quarter degree sheet 298. Dodoma.

Kimaro, D.N., B.M. Msanya and J.P. Magoggo, 1995a. Pedological investigations of sites for slash and burn experiment in Lupilo village and soil erosion studies in Tukuzi village, Mbinga District, Tanzania. Miombo Woodland Research Project, Natural Resources Study Team, Technical Report 2. National Soil Service, Agricultural Research Institute, Mlingano, Tanga and Sokoine University of Agriculture, Morogoro, Tanzania.

Kimaro, D.N., B.M. Msanya and J.P. Magoggo, 1995b. Considerations of some land qualities in relation to land Management in Lupilo village, Mbinga District, Tanzania. Paper presented at the First Annual Faculty of Agriculture Research Conference. August 28-30th, 1995. Sokoine University of Agriculture, Morogoro, Tanzania.

Klute, A. 1986. Water retention. In: A. Klute (ed.), 1981. Methods of soil analysis part 1, physical and mineralogical methods. 2nd edition. pp. 635-662.

Landon, J.R., 1984 (ed.). Booker Tropical Soil Manual. A handbook for soil survey and agricultural land evaluation in the tropics and subtropics. Longman Inc., New York.

Landon, J.R., 1991 (ed.). Booker Tropical Soil Manual. A handbook for soil survey and agricultural land evaluation in the tropics and subtropics. Longman Scientific & Technical Publishers, Essex.

Magoggo, J.P., B.M. Msanya and D.N. Kimaro, 1996. Environmental profile for agricultural production and development of conservation strategies in Mahenge village, Mbinga District, Tanzania. Miombo Woodland Research Project, Natural Resources Study Team, Technical Report 3. Ministry of Agriculture, National Soil Service, Agricultural Research Institute, Mlingano, Tanga and Department of Soil Science, Faculty of Agriculture, Sokoine University of Agriculture, Morogoro, Tanzania.

Mchau, J.M.J., 1993. Evaluation of agroforestry adoption in Mbinga district, Tanzania. M.Sc. thesis. University College of North Wales, Bangor.

Ministry of Commerce and Industries, 1967. Geology of Tanzania. Mining and Geology Division. Government of United Republic of Tanzania.

Miombo Woodland Research Project (SUA), 1995. Annual Progress Report (draft) 1994/1995. Faculty of Agriculture, Sokoine University of Agriculture. Morogoro. Tanzania.

Msanya, B.M. and J.P. Magoggo, 1993. Review of soil surveys (soil resource inventories) in Tanzania. Ecology and Development Paper No. 6. Published by The Ecology and Development Programme, The Agricultural University of Norway, ISSN 0804-2144, A^0s, Norway.

Msanya, B.M., D.N. Kimaro, and J.P. Magoggo, 1995a. Pedological investigations and land resources characterization in Lupilo village, Mbinga District, Tanzania. Miombo Woodland Research Project, Natural Resources Study Team, Technical Report 1. Department of Soil Science, Faculty of Agriculture, Sokoine University of Agriculture, Morogoro and Ministry of Agriculture, National Soil Service, Agricultural Research Institute, Mlingano, Tanga, Tanzania.

Msanya, B.M., D.N. Kimaro and J.P. Magoggo, 1995b. Characteristics of two pedons and their implication for environmental management in parts of Mbinga District, Tanzania. Paper presented at the First Annual Faculty of Agriculture Research Conference. August 28-30th 1995. Sokoine University of Agriculture, Morogoro, Tanzania.

Msanya, B.M., D.N. Kimaro and A.J. Shayo-Ngowi, 1995c. Soils of Kitulanghalo Forest Reserve Area, Morogoro district, Tanzania. Department of Soil Science, Sokoine University of Agriculture, Morogoro, Tanzania.

Munsell Color Company, 1975. Munsell Soil Color Charts. Munsell Color Co. Inc. Baltimore.

Murphy, J. and J.P. Riley, 1962. A modified single solution method for determination of phosphate in natural waters. Anal. Chim. Acta 27:31-36.

Mwihomeke, S.T., C.K. Ruffo and C.K. Mabula, 1991. 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.

Nelson, D.W. and L.E. Sommers, 1982. Total carbon, organic carbon and organic matter. In: Methods of Soil Analysis, part 2, 2nd edit. (eds. A.L. Page, R.H. Miller and D.R. Keeney), pp. 539-579. ASA, SSSA Monograph no. 9, Madison, Wisconsin.

Nieuwolt, S., 1973. Rainfall and evaporation in Tanzania. Bureau of Resource Assessment and Land Use Planning (BRALUP) Research Paper No. 24. University of Dar es Salaam.

Olsen, S.R. and L.E. Sommers, 1982. Phosphorus. In: Methods of Soil Analysis, part 2. Agronomy monograph No. 9 (Edited by A.L. Page, R.H. Miller, and D.R. Keeney). American Society of Agronomy. Madison, Wisconsin. pp. 403-430.

Peech, M., 1965. Hydrogen-ion activity. In: Methods of Soil Analysis, part 2. Edited by C.A. Black. Agronomy Monograph No. 9, 1st edition. Soil Science Society of America. Madison, Wisconsin. pp. 914-925.

Peters, D.B., 1965. Determination of field capacity. In: Methods of Soil Analysis, part 1. Edited by C.A Black. Agronomy Monograph No.9. American Society of Agronomy. Madison, Wisconsin. pp. 281.

Regional Development Director-Ruvuma, 1982. Ruvuma Regional Intergrated Development Plan. RDD-Ruvuma. Songea. 535 pp.

Rutatora, D.F., J. Rugambisa and D. Mwaseba, 1995. Report on participatory rural appraissal (PRA) activities carried out by the Socio-economic Studies Team (SEST) of the Miombo Woodland Research Project for the period between 20/10/94 and 18/10/94 in some selected villages of Mbinga District-Ruvuma Region. Sokoine University of Agriculture, Morogoro, Tanzania.

Sanchez, P.A., 1976. Properties and management of soils in the tropics. John Wiley & Sons, Inc. New York. 618 pp.

Soil Survey Staff, 1975. Soil Taxonomy. United States Department of Agriculture. Soil conservation Services Agriculture Handbook no. 436. Virginia Polytechnic Institute and State University. 754 pp.

Soil Survey Staff, 1990. Keys to Soil Taxonomy. Agency for International Development, United States Department of Agriculture. Soil Management Support Services Technical Monograph no. 19. Virginia Polytechnic Institute and State University. 422 pp.

Temu, A.E.M and S. Bisanda, 1994 (unpublished). Pit cultivation: An indigneous soil fertility and anti-erosion technique of the Matengo in the southern highlands of Tanzania. A Participatory Rural Appraisal report. MARTI-Uyole, Mbeya, Tanzania. 23 pp.

Thomas, G.W. 1982. Exchangeable cations. In: Methods of Soil Analysis part 2, 2nd edit. (eds. A.L. Page, R.H. Miller and R.D. Keeney), pp. 159-165. ASA, SSSA Monograph no. 9, Madison, Wisconsin.

Van Wambeke, A. 1982. Calculated soil moisture and temperature regimes of Africa. Soil Management Support Service (SMSS) Technical Monograph No. 3. Compilation of soil climatic regimes calculated by using a mathematical model developed by F. Newhall (Soil Conservation Service, USDA, 1972). Agency for International Development. Ithaca, New York.

Watanabe, F.S. and S.R. Olsen, 1965. Test of ascorbic acid method for determining phosphorus in water and $NaHCO_3$ extracts from soil. Soil Sci. Soc. Am. Proc. 29:677-678.

Appendix 1: Soil profile description and analytical data

Profile number : KTP-1 Mapping unit: H3
Agro-ecol. zone:
Region : Ruvuma
District : Mbinga
Map sheet no. : 298/3
Coordinates : 35° 8' 16.4" E/10° 36' 14.8" S
Location : Kiblang'oma area (near chairman's farm)
Elevation : 1240 m asl. Parent material: metamorphic rocks.
Landform: hill; steeply dissected. Slope: 25 %; straight
Surface characteristics : Erosion: severe. Deposition: none.
Natural drainage class : well drained
Described by B.M. Msanya, J.M. Wickama, D.N. Kimaro and J.L. Meliyo on 18/12/95

Soil: Very deep, well drained, dark reddish brown to dusk red, clays, with thin dark reddish brown, sandy clay loam topsoils; developed on colluvium derived from mixed metamorphic rocks. The mapping unit is a slope facet complex characterized by rolling to steeply dissected slopes with very deep red soils.The unit has agricultural potential coupled with soil conservation i.e ridges and ngoro soil conservation systems. The unit has very deep V-shaped drainage streams (dendritic) with permanent water flow which follow fault lines. Presently there is mismanagement of catchments through grazing and burning.

Ah 0 - 9 cm: dark reddish brown (5YR3/2) dry, dark reddish brown (5YR3/2) moist; sandy clay loam; slightly hard dry,friable moist, sticky and plastic wet; moderate medium and fine subangular blocks; many fine and very fine pores; few coarse and many fine roots; clear smooth boundary to

Bt1 9 - 33 cm: dark reddish brown (2.5YR3/4) dry, dark reddish brown (2.5YR3/4) moist; clay; hard dry, friable moist, sticky and plastic wet; moderate coarse angular blocks and strong medium subangular blocks; patchy thin clay + iron (hydr)oxide cutans; many fine and very fine pores; few small angular fresh quartz fragments; frequent small spherical hard Fe & Mn nodules; few coarse and common fine roots; gradual smooth boundary to

Bt2 33 - 70 cm: dusky red (10R3/4) dry, dusky red (10R3/4) moist; clay; hard dry, friable moist, sticky and plastic wet;moderate coarse angular blocks and strong medium subangular blocks; patchy thin clay + iron (hydr)oxide cutans; many fine and very fine pores; frequent small spherical hard Fe & Mn nodules; medium and few fine roots; diffuse smooth boundary to

Bt3 70 - 120 cm: dusky red (10R3/4) dry, dusky red (10R3/4) moist; clay; hard dry, friable moist, sticky and plastic wet; moderate coarse angular blocks and strong medium subangular blocks; many fine and very fine pores; frequent small spherical hard Fe & Mn nodules; coarse and fine roots; gradual smooth boundary to

Bt4 120 - 190 cm: dark red (2.5YR3/6) dry, dark red (2.5YR3/6) moist; clay; hard dry, friable moist, sticky and plastic wet; moderate coarse angular blocks and strong medium subangular blocks; many fine and very fine pores; frequent medium spherical hard Fe & Mn nodules; coarse and fine roots

SOIL CLASSIFICATION: FAO legend: Ferric Acrisol
USDA-Soil Taxonomy: Ustic Kandihumult

ANALYTICAL DATA FOR PROFILE KTP-1

Horizon		Ah	Bt1	Bt2	Bt3	Bt4
Depth (cm)		0-9	9-33	33-70	70-120	120-190
Clay	%	26	48	64	62	64
Silt	%	8	18	12	12	12
Sand	%	66	34	24	26	24
Texture class		SCL	C	C	C	C
pH H_2O 1:2.5		6.1	5.9	5.7	5.6	5.7
pH KCl 1:2.5		5.6	5.4	5.0	5.0	5.1
EC mS/cm 1:2.5		0.11	0.02	0.02	0.01	0.01
Organic C	%	4.0	1.1	0.9	0.7	0.1
Total N	%	0.24	0.07	0.05	0.03	0.04
C/N		17	16	18	23	3
Avail. P mg/kg		30	7	6	1	-
CEC cmol(+)/kg		24	10	8	7	6
Ca cmol(+)/kg		10.6	3.6	2.6	1.6	1.7
Mg cmol(+)/kg		3.5	1.6	0.9	0.7	0.9
K cmol(+)/kg		1.80	0.65	0.62	0.98	0.48
Na cmol(+)/kg		0.06	0.02	0.16	0.02	0.02
TEB cmol(+)/kg		15.96	5.41	4.28	3.3	3.11
Base sat.	%	67	59	54	47	52
CECclay cmol(+)/kg		92	21	13	11	9

Profile number : KTP-2 Mapping unit: P1

Agro-ecol. zone:
Region : Ruvuma
District : Mbinga
Map sheet no. : 298/3
Coordinates : 35° 8' 31.6" E/10° 55' 50.9" S
Location : Kiblang'oma area
Elevation : 1180 m asl. Parent material: metamorphic rocks.
Landform: footslope (undefined); undulating.Slope: 5 %; straight
Surface characteristics : Erosion: moderate. Deposition: none.
Natural drainage class : well drained
Described by D.N. Kimaro, J.L. Meliyo, B.M. Msanya and J.M. Wickama on 18/12/95

Soil: Very deep, well drained, dark red to dusky red, clays, with moderately thick, dark reddish brown sandy clay loam topsoils; developed on colluvium derived from mixed metamorphic rocks. The profile was located in a site which was a coffee farm in the near past.

Ap 0 - 15 cm: dark reddish brown (5YR3/2) moist; sandy clay loam; friable moist, slightly sticky and slightly plastic wet; moderate medium and fine subangular blocks; few fine and many fine pores; few small spherical hard nodules; many fine and very fine roots; krotovina, termites and insect nests seen; clear wavy boundary to

Bt1 15 - 40 cm: dark reddish brown (5YR3/3) dry, dark reddish brown (5YR3/3) moist; clay; hard dry, friable moist, sticky and plastic wet; moderate medium and fine subangular blocks; few medium and many fine pores; common fine and very fine roots; gradual smooth boundary to

Bt2 40 -80 cm: dark reddish brown (2.5YR3/4) dry, dark reddish brown (2.5YR2.5/4) moist; clay; slightly hard dry, friable moist, sticky and plastic wet; moderate coarse subangular blocks and medium subangular blocks; many fine and very fine pores; frequent medium spherical hard nodules; few coarse and common fine roots; gradual smooth boundary to

Bt3 80 - 120 cm: dusky red (10R3/4) dry, dusky red (10R3/4) moist; clay; slightly hard dry, friable moist, sticky and plastic wet; moderate coarse and medium subangular blocks; many fine and very fine pores; very few small angular fresh quartz fragments; frequent medium spherical soft Fe & Mn nodules; very fine roots; diffuse smooth boundary to

Bt4 120 - 190 cm: dusky red (10R3/4) dry, dusky red (10R3/4) moist; clay; soft dry, friable moist, sticky and plastic wet; moderate coarse and medium subangular blocks; many fine and very fine pores; frequent small spherical soft Fe & Mn nodules; very fine roots

SOIL CLASSIFICATION: FAO legend: Ferric Lixisol
USDA-Soil Taxonomy: Ustic Kandihumult

ANALYTICAL DATA FOR PROFILE KTP-2

Horizon		Ap	Bt1	Bt2	Bt3	Bt4
Depth (cm)		0-15	15-40	40-80	80-120	120-190
Clay	%	34	52	54	56	60
Silt	%	20	10	14	12	10
Sand	%	46	38	32	32	30
Texture class		SCL	C	C	C	C
pH H_2O 1:2.5		5.6	5.6	5.7	5.4	5.4
pH KCl 1:2.5		5.2	5.2	5.3	4.9	4.9
EC mS/cm 1:2.5		0.12	0.03	0.02	0.12	0.01
Organic C	%	2.4	1.2	0.5	0.3	0.2
Total N	%	0.18	0.10	0.06	0.06	0.04
C/N		13	12	8	5	5
Avail. P mg/kg		6	2	1	-	-
CEC cmol(+)/kg		18	16	10	6	6
Ca cmol(+)/kg		6.6	6.2	3.9	2.7	2.2
Mg cmol(+)/kg		1.4	2.1	1.3	0.4	0.5
K cmol(+)/kg		1.52	0.37	0.21	0.17	0.30
Na cmol(+)/kg		0.02	0.14	0.04	0.02	0.05
TEB cmol(+)/kg		9.54	8.81	5.45	3.29	3.05
Base sat.	%	53	55	55	55	51
CECclay cmol(+)/kg		53	31	18	11	10

Profile number : KTP-4 Mapping unit: V
Agro-ecol. zone:
Region : Ruvuma
District : Mbinga
Map sheet no. : 298/3
Coordinates : 35° 6' 46.8" E/10° 5' 32.6" S
Location : River Mbangamao valley about 1km west of village centre.
Elevation : 1250 m asl. Parent material: unconsolidated mixed material. Landform: alluvial/flood plain; flat or almost flat. Slope: 1 %; straight
Surface characteristics : Outcrops: 2 % Erosion: moderate. Deposition: none.
Natural drainage class : Very poorly drained
Described by B.M. Msanya, J.M. Wickama, D.N. Kimaro and J.L. Meliyo on 19/12/95

Soil: Very deep, very poorly drained, dark grey to dark reddish brown, stratified, mottled, loams and sandy clay loams with thick, dark reddish brown sandy loam topsoils; developed on alluvial-colluvium derived from highly weathered mixed metamorphic rocks. The mapping unit is in a valley bottom landscape.

Apg 0 - 20 cm: dark reddish brown (5YR3/2) moist; sandy clay loam; common medium faint clear 5YR5/6 yellowish red mottles; sticky and plastic wet; weak medium and coarse subangular blocks; many medium and fine roots; fresh and partly decomposed fibres present; gradual smooth boundary to

2Cg 20 - 45 cm: dark reddish brown (5YR3/2) moist; sandyclay loam; many medium distinct clear 7.5YR6/8 reddish yellow mottles; sticky and plastic wet; many medium and fine roots; fresh and partly decomposed fibrous materials present; clear smooth boundary to

3Cgr 45 - 60 cm: dark grey (5YR4/1) moist; sandy clay loam; few fine faint diffuse 7.5YR4/6 strong brown mottles; sticky and plastic wet; few medium and fine roots; fresh and partly decomposed fibrous materials present; clear smooth boundary to

4Cgr 60 - 80 cm: very dark grey (5YR3/1) moist;sandy clay loam; many fine faint diffuse 7.5YR4/4 brown mottles; sticky and plastic wet;; partly decomposed fibrous materials present; clear smooth boundary to

5Cgr 80 - 100 cm: very dark grey (5YR3/1) moist; clay loam; common medium distinct clear 7.5YR4/6 strong brown mottles; sticky and plastic wet; partly decomposed fibrous materials present; clear smooth boundary to

6Cgr 100 - 120 cm: dark grey (7.5YR4/6) moist; sandy clay; few fine faint diffuse 7.5YR4/6 strong brown mottles; sticky and plastic wet; partly decomposed fibrous materials present; gradual smooth boundary to

7Cr 120 - 150 cm: dark grey (7.5YR4/6) moist; clay; sticky and plastic wet;; partly decomposed fibrous materials present

SOIL CLASSIFICATION: FAO legend: Dystric Fluvisol
USDA-Soil Taxonomy: Aeric Fluvaquent

ANALYTICAL DATA FOR PROFILE KTP-4

Horizon		Apg	2Cg	3Cgr	4Cgr	5Cgr	6Cgr	7Cr
Depth (cm)		0-20	20-45	45-60	60-80	80-100	100-120	120-150
Clay	%	28	21	21	32	38	40	44
Silt	%	18	16	14	8	20	14	14
Sand	%	54	63	65	60	42	46	42
Texture class		SCL	SCL	SCL	SCL	CL	SC	C
pH H_2O 1:2.5		5.3	5.1	4.8	5.0	5.1	5.1	5.0
pH KCl 1:2.5		4.9	4.6	4.5	4.6	4.7	4.6	4.6
EC mS/cm1:2.5		0.03	0.03	0.03	0.02	0.01	0.02	0.02
Organic C	%	3.9	3.5	3.9	3.1	2.0	2.10	2.0
Total N	%	0.25	0.21	0.26	0.17	0.12	0.13	0.12
C/N		16	17	15	18	17	16	17
Avail. P mg/kg		5	3	1	6	3	4	5
CEC cmol(+)/kg		14	14	16	16	18	18	12
Ca cmol(+)/kg		4.0	5.6	3.8	3.8	3.9	3.9	3.7
Mg cmol(+)/kg		1.2	0.8	0.9	0.8	0.6	0.8	0.7
K cmol(+)/kg		0.20	0.13	0.12	0.26	0.18	0.14	0.20
Na cmol(+)/kg		0.03	0.02	0.02	0.02	0.04	0.03	0.02
TEB cmol(+)/kg		5.43	6.56	4.84	4.81	4.72	4.87	4.62
Base sat.	%	39	47	30	31	26	27	39
CECclay (cmol(+)/kg)		50	67	76	50	47	45	27

Profile number : KTP-5   Mapping unit: H2
Agro-ecol. zone:
Region   : Ruvuma
District   : Mbinga
Map sheet no. : 298/3
Coordinates   : 35° 6' 49.0" E/10° 56' 16.4" S
Location   : Muungano area
Elevation   : 1380 m asl. Parent material: metamorphic rocks.
Landform: hill; steeply dissected. Slope: 47 %; straight
Surface characteristics : Outcrops: 1 % Stones: 1 %
Erosion: moderate. Deposition: none.
Natural drainage class : somewhat excessively drained
Described by B.M. Msanya, J.L. Meliyo, D.N. Kimaro and J.M. Wickama on 19/12/95

Soil: Very shallow to shallow, excessively drained, dark red, extremely gravelly clays with very thin, dark reddish brown, sandy clay loam topsoils; developed on mixed metamorphic rocks. In places occur rock outcrops. The soils are very young and limited by depth.

Ap 0 - 15 cm: dark reddish brown (5YR3/2) moist; sandy clay loam; friable moist, sticky and plastic wet; weak medium and fine subangular blocks; many fine and very fine pores; frequent large angular fresh quartz fragments; many fine and very fine roots; clear smooth boundary to

BA 15 - 25 cm: dark reddish brown (5YR3/3) moist; very gravelly sandy clay loam; friable moist, sticky and plastic wet; weak medium and fine subangular blocks; many fine and very fine pores; frequent medium angular fresh quartz fragments; many fine and very fine roots; clear smooth boundary to

BC/CB 25 - 90 cm: red (2.5YR4/6) dry, dark red (2.5YR3/6) moist; gravelly clay; hard dry, friable moist, sticky and plastic wet; weak medium and fine subangular blocks; few medium and many fine pores; frequent medium angular fresh quartz fragments; common fine and few medium roots

SOIL CLASSIFICATION: FAO legend: Eutric Leptosol
USDA-Soil Taxonomy: Lithic Ustorthent

ANALYTICAL DATA FOR PROFILE KTP-5

Horizon		Ap	BA	BC/CB
Depth (cm)		0 - 15	15 - 25	25 - 90
Clay	%	22	30	44
Silt	%	16	16	14
Sand	%	62	54	42
Texture class		SCL	SCL	C
pH H_2O	1:2.5	6.0	6.1	5.9
pH KCl	1:2.5	5.4	5.4	5.6
EC mS/cm	1:2.5	0.12	0.03	0.01
Organic C	%	2.9	1.7	0.4
Total N	%	0.16	0.10	0.03
C/N		18	17	13
Avail. P mg/kg		46	6	3
CEC cmol(+)/kg		20	20	8
Ca cmol(+)/kg		10	9.6	4.0
Mg cmol(+)/kg		2.1	1.4	0.6
K cmol(+)/kg		1.21	0.56	0.40
Na cmol(+)/kg		0.02	0.07	0.02
TEB cmol(+)/kg		13.33	11.63	5.03
Base sat.	%	67	58	63
CECclay cmol(+)/kg		91	66	18

Profile number : KTP-6   Mapping unit: H1
Agro-ecol. zone:
Region : Ruvuma
District : Mbinga
Map sheet no. : 298/3
Coordinates : 35° 5' 8.5" E/10° 53' 56.4" S
Location : Msenga area (near the border with Utiri village)
Elevation : 1460 m asl. Parent material: metamorphic rocks.
Landform: hill summit; flat or almost flat.Slope:1%; convex
Surface characteristics : Outcrops: 1 % Stones: 10 %
Erosion:moderate. Deposition: none.
Natural drainage class : well drained
Described by D.N. Kimaro, B.M. Msanya, J.M. Wickama and J.L. Meliyo on 20/12/95

Soil: Moderately shallow, well to somewhat excessively drained, yellowish red, gravelly sandy clays with thin black, gravelly clay loam topsoils; developed on mixed metamorphic rocks. In places rock outcrops, boulders, stones and gravel appear at or near the surface. The mapping unit has potential for aforestation coupled with other soil conservation measures. The soil is limited in depth.

Ah 0 - 10 cm: dark reddish brown (5YR3/2) moist; very gravelly sandy loam; friable moist, slightly sticky and slightly plastic wet; weak medium and fine subangular blocks; many fine and medium pores; frequent large angular fresh quartz fragments; many medium and few coarse roots; clear smooth boundary to

AC 10 - 20 cm: dark reddish brown (5YR3/3) moist; very gravelly sandy clay loam; friable moist, slightly sticky and plastic wet; weak medium and fine subangular blocks; many fine and medium pores; frequent large angular fresh quartz fragments; many medium and few coarse roots gradual wavy boundary to

C 20 -35 cm: yellowish red (5YR4/6)moist;very gravelly sandy clay loam; friable moist, sticky and plastic wet; weak medium and fine subangular blocks; few medium and many fine pores; frequent medium angular fresh quartz fragments; few coarse and medium roots;

SOIL CLASSIFICATION: FAO legend: Umbric Leptosol
USDA-Soil Taxonomy: Lithic Ustorthent

ANALYTICAL DATA FOR PROFILE KTP-6

Horizon		Ah	AC	C
Depth (cm)		0 - 10	10 - 20	20 - 35
Clay	%	15	24	26
Silt	%	8	6	18
Sand	%	77	70	56
Texture class		SL	SCL	SCL
pH H_2O	1:2.5	5.7	5.3	5.1
pH KCl	1:2.5	5.2	4.9	4.6
EC mS/cm	1:2.5	0.08	0.04	0.02
Organic C	%	5.5	2.4	1.0
Total N	%	0.32	0.16	0.06
C/N		18	15	17
Avail. P mg/kg		11	6	2
CEC cmol(+)/kg		24	16	18
Ca cmol(+)/kg		7.8	6.8	4.6
Mg cmol(+)/kg		2.3	0.6	0.9
K cmol(+)/kg		0.85	0.22	0.34
Na cmol(+)/kg		0.06	0.02	0.1
TEB cmol(+)/kg		11.01	7.64	5.86
Base sat.	%	46	48	33
CECclay cmol(+)/kg		160	67	69

Profile number : KTP-7 Mapping unit: H3
Agro-ecol. zone:
Region : Ruvuma
District : Mbinga
Map sheet no. : 298/3
Coordinates : 35° 5" 51.0' E/10° 53" 10.3' S
Location : Rudisha-Msenga (Border with Utiri village)
Elevation : 1340 m asl. Parent material: metamorphic rocks.
Landform: hill; hilly. Slope: 42 %; straight
Surface characteristics : Stones: 2 % Erosion: moderate.
Deposition: none.
Natural drainage class : well drained
Described by B.M. Msanya, D.N. Kimaro, J.L. Meliyo and J.M. Wickama on 20/12/95

Soil: Very deep, well drained, dark reddish brown to red, clays, with thin dark reddish brown, sandy clay loam topsoils; developed on colluvium derived from mixed metamorphic rocks. The mapping unit is a slope facet complex characterized by rolling to steeply dissected slopes with very deep red soils. The mappimg unit is steeply dissected hilland. It has good agricultural potential if soil conservation and management are practiced.
The mappimg unit is a steep and strongly dissected hilland.

Ah 0 - 22 cm: very dark brown (10YR2/2) moist; sandy clay loam; friable moist, sticky and plastic wet; weak medium and fine subangular blocks; coarse and many medium pores; few small spherical soft nodules; many medium and fine roots; many crotovinas present high biological activity; clear smooth boundary to

BA 22 - 40 cm: dark reddish brown (5YR3/4) moist; clay; very friable moist, slightly sticky and plastic wet; weak medium and fine subangular blocks; many medium and few coarse pores; very few small irregular weathered quartz fragments;few medium irregular hardnodules; few medium and many fine roots; many crotovinas and high biological activity present; gradual smooth boundary to

Bt1 40 - 80 cm: red (2.5YR2/8) dry, dark red (2.5YR3/6) moist; clay; slightly hard dry, friable moist, sticky and plastic wet; moderate medium angular blocks and coarse subangular blocks; continuous thin clay cutans; few medium and many fine pores; few medium irregular weathered quartz fragments; few medium irregular soft nodules; coarse and medium roots; many crotovinas present and high biological activity; diffuse smooth boundary to

Bt2 80 - 130 cm: red (10R4/8) dry, red (10R4/6) moist; clay; slightly hard dry, friable moist, sticky and plastic wet; moderate medium and coarse subangular blocks; continuous thin clay cutans; few medium and many fine pores; few small spherical fresh granite fragments; few medium spherical soft nodules; very fine and coarse roots; many crotovinas present and high biological activity present; diffuse smooth boundary to

Bt3 130 - 200 cm: red (10R4/8) dry, red (10R4/8) moist; clay; slightly hard dry, friable moist, sticky and plastic wet; moderate medium and fine subangular blocks; continuous thin clay cutans; few medium and many very fine pores; frequent small spherical fresh quartz fragments; frequent medium spherical soft nodules; coarse and fine roots; many crotovinas and high biological activity present.

SOIL CLASSIFICATION: FAO legend: Ferric Acrisol
USDA-Soil Taxonomy: Typic Kanhaplustult

ANALYTICAL DATA FOR PROFILE KTP-7

Horizon		Ah	BA	Bt1	Bt2	Bt3
Depth (cm)		0 - 22	22 - 40	40- 80	80-130	130-200
Clay	%	24	44	54	54	54
Silt	%	12	14	12	14	14
Sand	%	64	42	34	32	32
Texture class		SCL	C	C	C	C
pH H_2O 1:2.5		5.7	5.1	4.9	5.1	5.3
pH KCl 1:2.5		5.1	4.6	4.5	4.8	5.0
EC mS/cm 1:2.5		0.04	0.02	0.01	-	-
Organic C	%	3.4	1.3	0.6	0.2	0.4
Total N	%	0.22	0.11	0.06	0.02	0.01
C/N		15	12	10	10	40
Avail. P mg/kg		3	2	2	-	-
CEC cmol(+)/kg		17	9	8	6.0	6.0
Ca cmol(+)/kg		5.2	3.2	2.0	1.8	2.1
Mg cmol(+)/kg		2.2	0.8	0.1	0.5	0.2
K cmol(+)/kg		1.61	0.32	0.13	0.06	0.07
Na cmol(+)/kg		0.02	0.07	0.02	0.02	0.02
TEB cmol(+)/kg		9.03	4.00	2.25	2.38	2.39
Base sat.	%	53	49	28	39	40
CECclay cmol(+)/kg		71	20	15	11	11

Appendix 2. Guide to general evaluation of some 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 < 4.5	neutral	pH 6.6 to 7.3
very strongly acid	pH 4.5 to 5.0	mildly alkaline	pH 7.4 to 7.8
strongly acid	pH 5.1 to 5.5	moderately alkaline	pH 7.9 to 8.4
medium acid	pH 5.6 to 6.0	strongly alkaline	pH 8.5 to 9.0
slightly acid	pH 6.1 to 6.5	very strongly alkaline	pH > 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)

cmol(+)/kg	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

cmol(+)/kg	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

cmol(+)/kg	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 favourable.

7. Exchangeable K

cmol(+)/kg	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.
Favourable Mg/K ratios for most crops are in the range of 1 to 4.

8. Exchangeable sodium

cmol(+)/kg	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 metre depth of soils; technically the difference between the percentage of soil water at field capacity (normally taken as the water content at pF 2.0) and the percentage at wilting point (taken as the water content at pF 4.2). This is applicable for most tropical soils.

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.