PEDOLOGICAL INVESTIGATIONS OF SITES FOR *SLASH AND BURN* EXPERIMENT IN LUPILO VILLAGE AND *SOIL EROSION* STUDIES IN TUKUZI VILLAGE, MBINGA DISTRICT, TANZANIA

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SUMMARY

The study area (Mbinga district) is under the Miombo Woodland zone of Tanzania which are areas that are or at one time were under Miombo Woodlands. Two villages namely Lupilo and Tukuzi were covered in the study at the request of other scientists interested to carry out experiments respectively on *"slash and burn"* type of agriculture and on *soil erosion*. Detailed characterization of two sites representative of the two villages was done including general ecological conditions, pedological measurements and soil clay mineralogy.

The climate of Mbinga district is generally characterized as having a monomodal rainfall pattern starting in November and ending in May. Lupilo is slightly drier receiving slightly less than 1000 mm mean annual rainfall, while Tukuzi, which is situated higher in the Matengo Highlands, receives slightly more than 1000 mm mean annual rainfall.

The soils have clayey textures (more than 45%) particularly in the subsoils. There is a clear increase of clay with depth from the topsoils to subsoils indicating that clay eluviation and illuviation are among the dominant pedogenic processes. The subsoil silt/clay ratios of both soils especially that of Tukuzi are low (less indicating that the soils are highly weathered. The clay mineralogical composition is dominantly kaolinitic with accessory amounts of sesquioxides, which is typical of highly weathered soils. Accessory amounts of illite were also detected. The chemical analytical data clearly show that the two soils are generally low in fertility and the little available fertility is limited to the upper 20 cm of the soil. Levels of nitrogen and phosphorus are low and there is a clear need for N and P fertilization. The base saturation is low (<50%) throughout the two profiles except for the topsoil of Tukuzi. The cation exchange capacities are generally low (< 12 cmol(+)/kg soil) in the subsoils which relates very well with the clay mineralogy.

Lupilo profile was classified as *Isohyperthermic, very deep, kaolinitic, Typic Rhodustult* or *Haplic Acrisol* and Tukuzi profile as *Isohyperthermic, very deep, kaolinitic, Ustic Haplohumult* or *Ferric Acrisol.*

It was concluded that the two soils represent fragile ecosystems that require careful management. In Lupilo emphasis should be on raising and maintaining soil fertility. It should be noted that the practice of *slash and burn* is not a stable management system since it eliminates the natural vegetation in a very short time. Apart from the fact that the original vegetation is not very contributive to soil fertility, once slashed in the early seasons it does not regenerate sufficiently quickly to be available for slashing in the following season(s). That means the practice cannot be continued on the same land. Therefore, experiments should include identification of alternative land management practices which are suitable for the area and that protect the land from further degradation. Such alternatives may ultimately save haphazard destruction of the *Miombo* woodland ecosystem.

In Tukuzi the *Ngoro* management system has shown to be effective in maintaining organic matter levels. However, the physical characteristics of the soils are poor. The poor, fluffy structure and low bulk density make these soils vulnerable to both wind and water erosion. It is recommended that erosion studies should go hand in hand with experiments into ways of improving the soil physical properties.

1 INTRODUCTION

Tanzania in general and Mbinga district specifically have a lack of soils information required for proper land use planning and management (Msanya *et al.,* 1995b; Msanya and Magoggo, 1993). A large part of Tanzania is covered by *Miombo* woodlands or was 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. A lot of scientists have been attracted to research in the *Miombo* Woodlands because of the uniqueness of the existing ecological conditions and that of the indigenous farming system practiced particularly in Mbinga district. In order to provide a starting point the *Miombo* Woodlands Research Project (MWRP) was initiated and Mbinga district was chosen as an area which could represent a large part of *Miombo* woodland areas of Tanzania.

This study is part of the continuing *Miombo* Woodlands Research Project on the assessment of the natural resources of Mbinga district with particular emphasis on terrain, soils, vegetation and land use systems. The Natural Resources Study team of the *Miombo* Woodlands Research Project at the Sokoine University of Agriculture, which carried out the current study, has, as one of its mandates, the responsibility of providing information on natural resources to other research teams of the MWRP working in Mbinga district, particularly the Technological Studies team, to guide them in their research activities. Lupilo and Tukuzi villages are among several villages earmarked by the MWRP as research sites. These two villages have been selected respectively for *slash and burn* experiment and *soil erosion* studies. This study was aimed mainly at the pedological characterization of the sites to provide the needed basic information on the soil and ecological conditions.

The specific objectives of the study were:

(a) to characterize the soils of Lupilo and Tukuzi villages in terms of their physical, chemical and mineralogical properties and terrain attributes;

(b) to classify the soils of the two villages 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 and to

(c) to provide basic soils information to researchers working in the study area that will guide activities related to the management of the existing land resources.

2 MATERIALS AND METHODS

2.1 Field methods

Selection of the sites was done using existing soil information, interpretation of aerial photographs and field observations on both landforms and soils. Homogeneity of soils was established using auger observations. Sites for representative soil profiles were then located. Soil profile pits were excavated, described and sampled following standard procedures (FAO, 1990; Munsell Color Company, 1975; Soil Survey Staff, 1951). Exact locations of the sites in terms of international coordinates were determined using Sony Global Positioning System Receiver. Table 1 gives the salient site features of the two areas studied. More detailed soil descriptions are presented in separate documents (Kiwale, 1995; Msanya *et al.,* 1995b; Mwasha, 1995; Temba, 1995; Wamara, 1995).

2.2 Routine laboratory methods

Chemical and physical analyses were done as follows: pH was measured potentiometrically in water and in 1N KCl at the ratio 1/2.5 soil-water and soil-KCl. Organic carbon was determined by wet oxidation method of Walkley and Black (Nelson and Sommers, 1982). Kjeldahl method (Bremner and Mulvaney, 1982) was employed to determine total nitrogen. 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 (CEC) and exchangeable bases were extracted by saturating soil with neutral 1M NH_4OAc (Thomas, 1982) and the adsorbed NH_4^+ displaced with K^+ using 1M KCl and then determined by Kjeldahl distillation method for the estimation of CEC of soil. The bases Ca^{++}, Mg^{++}, Na^+, and K^+, displaced by NH_4^+ were measured by atomic absorption spectrophotometer. Texture was determined by pipette method (Day, 1965) after dispersing soil with sodium hexametaphosphate. Bulk density was determined using core sample method (Blake, 1965). Soil moisture characteristics were determined using pressure plate and membrane apparatus (Klute, 1986).

Samples for clay mineralogical analysis were prepared as follows:
About 20 gm of fine-earth subsoil samples (from a depth of 50 cm) were first treated with 30% H_2O_2 in glass beakers to remove organic matter and the excess H_2O_2 evaporated on a hot plate. To each of the samples 1 ml of 1N NaOH (dispersing agent) and then 300 ml of deionized water were added. The samples were then shaken overnight in an end-over-end shaker to allow thorough dispersion and the suspensions were transferred to 1000 ml glass cylinders, their volumes made up to the mark and then allowed to settle. At appropriate time interval and depth, clay samples were siphoned out of the cylinders into glass beakers. The clay samples were mounted on glass slides for x-ray diffraction analysis. Five treatments were applied, namely Mg saturation, Mg + glycerol saturation, K saturation, K saturation + 300°C and K saturation + 550°C. X-ray diffractometer model Shimazu XD-D1 was used for the analysis and the x-ray diffractograms interpreted manually using information registered on the X-ray diffraction charts. Identification of clay mineral species was done using standard guidelines and books (Thorez, 1975; Brindley and Brown, 1980; Dixon and Weed, 1989).

2.3 Soil classification, data processing and interpretation

Using both field and laboratory data the representative soils were classified up to level 2-soil unit names of the FAO-Unesco (1989) and up to family level of the USDA Soil Taxonomy (Soil Survey Staff, 1990). Data processing and report preparation were done using computer software available at Sokoine University of Agriculture and the National Soil Service. Both field and laboratory data were stored in the national soil data base and information system (*SISTAN*) (Magoggo, 1992). Interpretation of both physical and chemical data was based on some standard guidelines (EUROCONSULT, 1989; Msanya *et al.,* 1995a).

3 RESULTS AND DISCUSSION

3.1 Physical environment

3.1.1 Location

Mbinga district in which the study was carried out is located within longitudes 34° 24'E and 35° 28'E and latitudes 10° 15'S and 11° 34'S. Lupilo village is situated in the Kigonsera low hills and footslopes, while Tukuzi forms part of the Matengo Highlands. The important site features of the studied areas are summarized in Table 1.

3.1.2 Climate

Climatic records specific for Lupilo village were not available. However, the rainfall pattern in Mbinga district is generally monomodal, starting in November and ending in May with an estimated mean annual precipitation of about than 1,000 mm. During this period crop production is feasible without irrigation. The rest of the year is virtually dry. The rainfall data available for Mbinga Meteorological Station (see table 2) are more representative for Tukuzi which is situated more on the highlands where the mean annual rainfall may be slightly more than 1,000 mm. 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 two study areas have conditions in between the two extremes with mean annual temperatures between 20°C and 25°C. However, due to differences in altitude Tukuzi is cooler than Lupilo. In both areas seasonal variations in temperature do exist whereby the dry season (May to September) is cooler than the rainy season.

3.1.3 Geology and landform

Lupilo area is underlain by mixed intermediate and mafic metamorphic rocks (Geological Survey Department, 1956). The higher-lying parts of the village form hilland which is essentially a denudational landscape. Immediately below and adjacent to the hilland are the piedmonts which are primarily colluvial (depositional) sites but are also secondary denudational areas. The lowest-lying parts are the valleys. These form the ultimate sink for all materials eroded from the higher-lying land.

Table 1 Site features of the studied areas

Soil profile no.	Location	Coordinates	Altitude	Landform	Slopes	Parent material	Soils
LP-1	Lupilo village,27 km from Mbinga town, 1.5 km east of Kitanda village office	35°8'48.1"E, 10°52'39"S	930 m asl	piedmont plain; rolling	11%	colluvium derived from mixed metamorphic rocks	very deep, well drained, dark reddish brown, sandy clays to clays with thin dark brown sandy clay loam topsoils
TP-1	Tukuzi village Arusha, 12 km from Mbinga town along road to Mbamba Bay	34°57'28.4"E, 11°1'20.6"S	1410 m asl	piedmont plain, rolling	15%	old colluvium derived from mixed metamorphic rocks	very deep, well drained, red clays with very thick dark yellowish brown clay topsoils. The topsoil is man-made (ngoro)

The general topography of the area comprises very steep slopes (dominantly 30 - 50%) in the hilly landscapes, becoming gentler in the piedmont landscapes (about 10%, rising to about 30% in some parts closer to the hillands). The valleys are generally flat, being river terraces or river floors. The studied soil profile represents the piedmonts.

The geology in Tukuzi is basically similar to that in Lupilo, being composed also of intermediate and mafic metamorphic rocks. The higher parts of the village form mountains which essentially are a structural landscape. Adjacent to the mountains are piedmonts (on which the study profile was dug) which are primarily old colluvial deposits derived from metamorphic rocks. The lowest parts of the landscape are the valleys which form the ultimate sink for the materials eroded from the higher-lying land.

3.1.4 Vegetation and land use

Most of the original vegetation (Miombo woodland) in Tukuzi has been cleared as a result of the intensive cultivation (*Ngoro* or "Matengo pits") practiced in the area since many years. The Miombo Woodland has been replaced to a very large extent by cultivation of maize, beans and wheat in a rotational system; and to a lesser extent by some exotic tree species including *Eucalyptus sp.* and *Grevillea sp.*

In Lupilo where land has been invaded for agriculture rather recently (less than 15 years), the Miombo Woodland vegetation prevails. Among the species identified at the site of study include *Brachystegia spp., Parinari curatelifolia, Uapaka kirikiana* and *Pterocarpus angolensis*. Grasses mainly *Hyparrhenia spp.* were also identified. A more comprehensive list of trees and shrubs found in the areas with intact native Miombo vegetation bearing both their botanical and local names is attached as appendix 3. The kind of agriculture being practiced in Lupilo and other newly opened areas is ridge cultivation with maize and beans; and slash and burn cultivation system involving finger millet.

Table 2 *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)

3.2 Soils

3.2.1 Physical properties

Table 3 presents a summary of the important physical properties of the studied soils. The soils at Lupilo have dark brown topsoils and red and dark red subsoils, while those at Tukuzi have yellowish brown topsoils and red and yellowish red subsoils. Generally speaking Tukuzi soils are redder than Lupilo soils. The texture of the soils of Lupilo is predominantly sandy clay loam in the topsoil and grades to sandy clay and clay textures in the subsoils. The texture of Tukuzi soils on the other hand, is clay throughout the profile. The subsoil silt/clay ratios of both profiles particularly the Tukuzi one are low; however, those of Tukuzi are relatively lower than those of Lupilo. Although both Lupilo and Tukuzi soil profiles have morphological features indicative of advanced pedogenesis, the soils of the Tukuzi are pedogenetically more developed than those of Lupilo, based on their more reddish colors, finer textures and lower silt/clay ratios.

The bulk densities of topsoils are lower than those of the subsoils of both Lupilo and Tukuzi soils. The exceptionally low bulk density of the topsoil of Tukuzi profile can be attributed to the very high organic matter content in the surface ("ngoro") horizon which is a man-made layer resulting from continued addition and burial of organic residues in the top part of the soil. The subsoil of Tukuzi profile is characterized by lower bulk densities than those of Lupilo and in absolute terms these values are low (about 1 g/cc). The particle density values of Tukuzi are relatively lower than those of Lupilo but the observed values are those typical of mineral soils. The low bulk densities and the corresponding high porosity values particularly in Tukuzi are quite typical of the highly weathered soils which tend to develop fluffy and friable consistence because of the dominance of 1:1 lattice silicate clay minerals.

Available water capacity for Tukuzi profile is higher than that of Lupilo profile corresponding very well with higher porosity in the former profile. Nevertheless, the values respectively 144.5 mm/m and 119.6 mm/m are rated as medium.

3.2.2 Chemical properties

Table 4 gives some of the important chemical data of the studied soils. Both Lupilo and Tukuzi soils are acid (pH_{water} <6.5) but the Tukuzi ones are more acid than those of Lupilo. The topsoils of Lupilo are moderately acid (pH 6.0) while those of Tukuzi are strongly acid (pH 5.3). The subsoils of Lupilo are strongly acid (pH of about 5.3) while those of Tukuzi are very strongly acid (pH 4.7). The high acidity particularly in the subsoil of both areas is likely to be a serious limiting factor for crop production.

Available P can be rated as high (P >20 mg/kg) and medium (P >7<20 mg/kg) respectively in the topsoils and in the subsoils of Lupilo soils; while it is low (P <7 mg/kg) throughout Tukuzi profile. Phosphorus level of >7 mg/kg is considered optimum below which P-deficiency symptoms are likely to occur in many crops. From the data it can be inferred that Tukuzi soils have a serious limitation of P.

Organic matter content is medium in the topsoils of Lupilo corresponding to organic carbon level of 1.8%. However, it decreases with depth to low and very low values in the subsoil. In the case of Tukuzi the organic matter content is very high (corresponding to organic carbon content of 4.1%) and is concentrated in the topsoils. Below the topsoils it decreases drastically to low and very low values. This implies that for both areas studied the soil fertility related to organic matter is concentrated mainly in the upper 25 cm of the soil. Total nitrogen content in both Lupilo and Tukuzi is low (<0.2%) and very low (<0.1%) except the topsoil of Tukuzi which has 0.29% (medium).

Table 3 *Some physical characteristics of the studied soils*

Sample and depth (cm)	Munsell soil color		% Particle size distribution			Text-ural class	Silt/ clay ratio	Bulk density g/cc	Particle density g/cc	% Porosity	% AWC* (vol.)	AWC (mm/m)
	dry	moist	sand	silt	clay							
LUPILO												
Ah 0-10	7.5YR4/4 (db)	7.5YR3/2 (db)	63	15	22	SCL	0.7	1.11	2.60	57.3	12.5	119.6
BA 10-25	5YR4/6 (yr)	5YR3/4 (drb)	57	14	29	SCL	0.5	nd	nd	nd	nd	
Bt1 25-60	2.5YR3/6 (dr)	2.5YR3/4 (drb)	51	13	36	SC	0.4	1.39	2.69	48.3	8.4	
Bt2 60-100	2.5YR3/6 (dr)	2.5YR3/4 (drb)	43	12	45	C	0.3	nd	nd	nd	nd	
Bt3 100-155	2.5YR4/8 (r)	2.5YR4/6 (r)	42	9	49	C	0.2	1.41	2.67	47.2	14.7	
TUKUZI												
Ap 0-25	10YR5/4 (yb)	10YR4/4 (dyb)	41	16	43	C	0.4	0.90	2.78	67.6	7.4	144.5
Bt1 25-70	5YR4/6 (yr)	10YR4/4 (rb)	35	13	52	C	0.3	1.15	2.79	58.8	13.0	
Bt2 70-130	nd	2.5YR4/6 (r)	31	12	57	C	0.2	1.08	2.81	61.6	18.7	
Bt3 130-180	nd	2.5YR4/6 (r)	21	14	65	C	0.2	nd	nd	nd	nd	

* estimated as the difference between water held at 10 KPa and that held at 1500 KPa
nd=not determined

db = dark brown
dr = dark red
drb = dark reddish brown
r = red
rb = reddish brown
yb=yellowish brown

C = clay
SCL = sandy clay loam

Table 4 *Some chemical properties of the studied soils*

Horizon	Sample depth (cm)	pH H_2O	pH KCl	P mg/kg	OC %	N %	Ca	Mg	K	Na	CEC soil cmol(+)/kg	CEC clay cmol(+)/kg	BS %
							cmol(+)/kg soil						
LUPILO													
Ap	0 - 10	6.0	5.6	28	1.8	0.12	2.4	1.4	0.42	0.06	7.0	32	61
BA	10 - 25	5.2	4.5	20	0.9	0.07	1.3	0.7	0.33	0.04	7.0	24	34
Bt1	25 - 60	5.4	4.2	24	0.6	0.04	1.6	0.6	0.49	0.07	7.4	21	37
Bt2	60 - 100	5.3	4.5	12	0.4	0.03	1.8	1.2	0.33	0.08	8.8	20	39
Bt3	100 - 155	5.2	4.9	0.4	0.2	0.02	1.5	1.2	0.67	0.06	9.6	20	35
TUKUZI													
Ap	0 - 25	5.3	4.5	1.0	4.1	0.29	3.3	1.9	0.57	0.07	14.6	33	41
Bt1	25 - 70	4.7	4.0	0.1	1.0	0.07	0.7	0.1	0.08	0.08	10.6	20	9
Bt2	70 - 130	4.6	4.2	0.1	0.5	0.04	0.7	0.2	0.31	0.08	10.6	19	12
Bt4	130 - 180	4.7	4.2	0.1	0.2	0.02	0.7	0.4	0.36	0.09	11.6	18	14

Except for topsoil of Tukuzi, the cation exchange capacity (CEC) of both soils are low with values ranging from 7 to about 11 cmol(+)/kg soil. The CEC of the topsoil of Tukuzi is medium (about 14 cmol(+)/kg) and is most likely contributed more by the high organic matter content of this section of the profile. The CEC of clay for both soils range from 18 (in the subsoils) to 33 cmol(+)/kg (in the topsoils). These values (particularly those of the subsoils) suggest that the soils are dominated by kaolinite and sesquioxides (Fe- and Al- oxides). This observation is indeed supported by the clay mineralogical data (see table 5).

The base saturation (BS) values are low (<50%) throughout the two profiles except for the topsoil of Lupilo which has a BS of 69%. The BS in the subsoil of Tukuzi profile is exceedingly low reaching levels of up to 9% in some horizons. Exchangeable Ca is medium throughout Lupilo profile with values ranging from 1.3 to 2.4 cmol(+)/kg soil, while in the case of Tukuzi it is high (3.3 cmol(+)/kg soil) in the topsoil and medium in the subsoil. Exchangeable Mg levels are low to medium throughout Lupilo profile with values ranging from 0.6 to 1.4 cmol(+)/kg soil, whereas in Tukuzi they are medium in the topsoil and very low to low (0.1 to 0.4 cmol(+)/kg) in the subsoil. The exchangeable K is medium (0.42 cmol(+)/kg) in the topsoil of Lupilo profile and low to medium (0.33 to 0.67 cmol(+)/kg). In Tukuzi K levels are medium in the topsoil and low in the subsoil. In terms of nutrient balance Ca/Mg ratios of 2 to 4 are considered favorable. The observed Ca/Mg ratios of most of the horizons of the two profiles are outside this range indicating that there is a sizeable nutrient imbalance in the soils. The K/TEB (total exchangeable bases) ratios are above 2% which is said to be favorable for most tropical crops.

3.2.3 Soil clay mineralogy

The clay mineralogical data accruing from the interpretation of x-ray diffractograms are summarized in table 5. The subsoil clay mineralogy of Lupilo soils is predominantly kaolinitic, containing about 95% kaolinite and about 5% illite. Some traces (<1%) of gibbsite were also identified in these soils. The mineralogical composition of the Tukuzi soils is also predominantly kaolinitic with about 74% kaolinite and accessory amounts of gibbsite (15%), illite (7%) and goethite (4%). The dominance of kaolinite and Fe- and/or Al- oxides in the two profiles clearly points to the advanced stage of weathering in these soils. The content of oxides is higher in Tukuzi soil than in Lupilo soil possibly indicating a relatively more advanced stage of weathering in Tukuzi.

Table 5 Clay mineralogical data of subsoil clay samples of the studied soils

Soil profile	Diagnostic x-ray diffraction peaks	Mineral species and % approximate amounts
Lupilo	7.2Å, 4.4Å, 3.6Å - the peaks disappear after heating at 550°C	kaolinite (95%)
	10Å, 5Å, 3.3Å	illite (5%)
	4.85Å	gibbsite (tr)
Tukuzi	7.2Å, 4.4Å, 3.6Å - the peaks disappear after heating at 550°C	kaolinite (74%)
	10Å, 5Å, 3.3Å	illite (7%)
	4.85Å, 4.37Å	gibbsite (15%)
	4.18Å	goethite (4%)

tr = traces (<1%)

Table 6. Salient morphological and diagnostic features of the studied soils and their classification

Profile	Diagnostic horizons	Other diagnostic features	Depth classes	Mineralogy class	Soil names						
					FAO-Unesco		USDA Soil Taxonomy				
					Level-1	Level-2	Order	Suborder	Great group	Subgroup	Family
Lupilo	*ochric A (ochric epipedon); *argic B (argillic horizon)	Ustic SMR; isohyperthermic STR	Very deep	Kaolinitic	Acrisol	Haplic Acrisol (ACh)	Ultisol	Ustult	Rhodultult	Typic Rhodustult	Isohyperthermic, very deep, kaolinitic, Typic Rhodustult
Tukuzi	*ochric A (ochric epipedon); argic B (argillic horizon)	Ustic SMR, isohyperthermic STR; *ferric properties; *geric properties (small textural gradient in the B horizon)	Very deep	Kaolinitic	Acrisol	Ferric Acrisol (ACf)	Ultisol	Humult	Haplohumult	Ustic Haplohumult	Isohyperthermic, very deep, kaolinitic, Ustic Haplohumult

* terminology used particularly in the FAO-Unesco classification, those without * are used mostly in USDA system.

3.2.4 Soil classification

Table 6 gives a summary of the salient morphological and diagnostic features and the taxonomic names of the studied soils. Both Lupilo and Tukuzi soil profiles have ochric epipedon and argillic subsurface horizon as diagnostic horizons. Other diagnostic features common to both soils include *ustic soil moisture regime* (defining a situation of limited moisture, but moisture is available at the time when conditions are suitable for plant growth), *isohyperthermic soil temperature regime* (describing a mean soil temperature = or >22°C and a difference between mean summer soil temperature and mean winter temperature < 5°C), *very deep* (> 150 cm) depth class and *kaolinitic* clay mineralogical class. Tukuzi profile in addition has *ferric properties* (presence of Fe-Mn nodules) and *geric properties* (small textural differentiation in the B horizon). Using the mentioned diagnostic features Lupilo profile was classified as Haplic Acrisol (FAO-Unesco system) or Isohyperthermic, very deep, kaolinitic, Typic Rhodustult (USDA Soil Taxonomy); and Tukuzi profile as Ferric Acrisol or Isohyperthermic, very deep, kaolinitic, Ustic Haplohumult.

4 CONCLUDING REMARKS AND RECOMMENDATIONS

4.1 Lupilo

The site was located in an area where the present vegetation is secondary forest (*Miombo* woodland). The area around the site has not been used for cultivation for a long time. Under such conditions it would be expected that the soils would have accumulated appreciable amounts of organic matter and other nutrients. However, the data shows low organic matter, low nitrogen and low CEC even in the topsoil. This means that the soils have a low recovery potential (low resilience) in terms of chemical properties.

Although the available water capacity is low, the physical properties of the soil at the site do not pose serious limitations for use and management.

The management aspect of the soil which needs to be emphasized is in the raising and maintenance of chemical soil fertility levels. It should be noted that the practice of *slash and burn* is not a stable management system since it eliminates the natural vegetation in a very short time. Apart from the fact that the original vegetation is not very contributive to soil fertility, once slashed in the early seasons it does not regenerate sufficiently quickly to be available for slashing in the following season(s). That means the practice cannot be continued on the same land. Therefore, experiments should include identification of alternative land management practices which are suitable for the area and that protect the land from further degradation. Such alternatives may ultimately save haphazard destruction of the *Miombo* woodland ecosystem.

4.2 Tukuzi

The site at Tukuzi is intensively cultivated. The *Ngoro* system of land management is well established. Natural vegetation has been cleared a long time ago. The slopes are very steep.

The data indicate that the soils are very old: silt to clay ratios are low. The soils have a low bulk density and poor structure, being fluffy. Available water capacity is also low.

Organic matter levels in the topsoil is high. This is attributable to the *Ngoro* management practice. However, the physical characteristics of the soils are poor. The poor, fluffy structure and low bulk density make these soils vulnerable to both wind and water erosion. It is recommended that erosion studies should go hand in hand with experiments into ways of improving the soil physical properties.

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Appendix 1 Description and analytical data of Lupilo soil profile

Profile number : LP-1 Mapping unit: P12 (Refer technical report 1)
Region : Ruvuma **District** : Mbinga
Map sheet no. : 298/3 **Coordinates** : 35° 8' 48.1" E/10° 52' 39.0" S
Location : 27 km from Mbinga to Kitanda ward (1.5 km east of village office)
Elevation : 930 m asl. **Parent material**: colluvium derived from mixed metamorphic rocks.
Landform : piedmont plain: rolling. **Slope**: 11 %: straight
Surface characteristics: **Outcrops**: 0 % **Erosion**: none or slight. **Deposition**: none.
Drainage class: well drained
Described by: B.M. Msanya, D.N. Kimaro, J.P. Magoggo and A.E. Kiwelu on 25/10/94

Soils: Very deep, well drained, dark reddish brown, sandy clays to clays with thin dark brown sandy clay loam topsoil

Ah 0 - 10 cm: dark brown (7.5YR4/4) dry, dark brown (7.5YR3/2) moist: sandy clay loam: soft dry, friable moist, slightly sticky and slightly plastic wet: moderate fine and medium subangular blocks: many fine and very fine pores: few small irregular hard feldspar nodules: common fine and few medium roots: pieces of charcoal, clay + Fe nodules throughout: gradual smooth boundary to

BA 10 - 25 cm: yellowish red (5YR4/6) dry, dark reddish brown (5YR3/4) moist: sandy clay loam: soft dry, friable moist, slightly sticky and plastic wet: moderate fine and medium subangular blocks: many fine and very fine pores: few medium irregular hard feldspar nodules: few coarse and common fine roots: clear smooth boundary to

Bt1 25 - 60 cm: dark red (2.5YR3/6) dry, dark reddish brown (2.5YR3/4) moist: sandy clay: hard dry, friable moist, sticky and plastic wet: moderate medium subangular blocks and moderate coarse angular blocks: patchy thin clay + iron (hydr)oxide cutans: many fine and very fine pores: frequent small irregular hard feldspar nodules: few coarse and common medium roots: krotovina: diffuse smooth boundary to

Bt2 60 - 100 cm: dark red (2.5YR3/6) dry, dark reddish brown (2.5YR3/4) moist: clay: friable moist, sticky and plastic wet: moderate fine subangular blocks and moderate medium angular blocks: patchy thin clay + iron (hydr)oxide cutans: many fine and very fine pores: few medium angular fresh quartz fragments: frequent small irregular hard feldspar nodules: few coarse and medium roots: clear smooth boundary to

Bt3 100 - 155 cm: red (2.5YR4/8) dry, red (2.5YR4/6) moist: clay: friable moist, sticky and plastic wet: moderate fine angular blocks and moderate medium subangular blocks: patchy thin clay + iron (hydr)oxide cutans: many fine and very fine pores: frequent small irregular hard feldspar nodules: few fine and very fine roots

SOIL CLASSIFICATION: FAO legend : 1989 :Haplic Acrisol (ACh)
USDA Soil Taxonomy:1990 :Isohyperthermic, very deep, kaolinitic, Typic Rhodustult

ANALYTICAL DATA FOR PROFILE LP-1

Horizon		Ah	BA	Bt1	Bt2	Bt3
Depth (cm)		0 - 10	10 - 25	35 - 55	65 - 85	120 - 140
Clay	%	22	29	36	45	49
Silt	%	15	14	13	12	9
Very fine sand	%	8	7	6	1	4
Fine sand	%	20	16	12	12	8
Medium sand	%	22	20	18	16	13
Coarse sand	%	11	12	12	11	12
Very coarse sand	%	2	2	3	3	5
Total sand	%	63	57	51	43	42
Texture class		SCL	SCL	SC	C	C
pH H2O	1:2.5	6.0	5.2	5.4	5.3	5.2
pH KCl	1:2.5	5.6	4.5	4.2	4.5	4.9
EC mS/cm	1:2.5	0.07	0.03	0.23	0.02	0.01
Organic C	%	1.8	0.9	0.6	0.4	0.2
Total N	%	0.12	0.07	0.04	0.03	0.02
C/N		15	13	15	13	10
Available P	mg/kg	28	20	24	12	0.4
CEC NH4OAc	cmol(+)/kg	7.0	7.0	7.6	8.8	9.6
Exch. Ca	cmol(+)/kg	2.4	1.3	1.6	1.8	1.5
Exch. Mg	cmol(+)/kg	1.4	0.7	0.6	1.2	1.2
Exch. K	cmol(+)/kg	0.42	0.33	0.49	0.33	0.67
Exch. Na	cmol(+)/kg	0.06	0.04	0.07	0.08	0.06
Exch. H	cmol(+)/kg	-	0.06	0.09	0.08	0.02
TEB	cmol(+)/kg	4.3	2.4	2.8	3.4	3.4
Base saturation	%	61	34	37	39	35
CECclay	cmol(+)/kg	32	24	21	20	20

Appendix 2 Description and analytical data of Tukuzi soil profile

Profile number : TP-1
Region : Ruvuma
District : Mbinga
Map sheet no. : 298/3
Coordinates : 34° 57' 28.4" E/11° 1' 20.6" S
Location : Tukuzi village. Arusha: 12 km from Mbinga town along road to M/By
Elevation : 1410 m asl. **Parent material**: igneous rocks (possibly granite).
Landform: piedmont plain: rolling. **Slope**: 15 %: straight
Surface characteristics : **Erosion**: none or slight. **Deposition**: none.
Drainage class : well drained
Described by: D.N. Kimaro, B.M. Msanya, J.P. Magoggo and A.E. Kiwelu on 29/10/94

Soil: Very deep, well drained, red clays with very thick dark yellowish brown clay topsoils developed on colluvium. The man-made ("Ngoro") horizon is about 30 cm thick.

Ap 0 - 25 cm: yellowish brown (10YR5/4) dry, dark yellowish brown (10YR4/4) moist; clay; soft dry, very friable moist, slightly sticky and slightly plastic wet; weak medium subangular blocks; many fine and very fine pores; few coarse and many fine roots; abrupt wavy boundary to

Bt1 25 - 70 cm: yellowish red (5YR4/6) dry, reddish brown (5YR4/4) moist; clay; soft dry, friable moist, slightly sticky and slightly plastic wet; moderate medium subangular blocks and moderate coarse angular blocks; many medium and fine pores; few medium angular fresh quartz fragments; frequent small irregular hard Fe & Mn nodules; few coarse and common fine roots; diffuse smooth boundary to

Bt2 70 - 130 cm: red (2.5YR4/6) moist; clay; soft dry, friable moist, slightly sticky and plastic wet; moderate medium subangular blocks and moderate coarse angular blocks; many medium and fine pores; frequent medium irregular hard Fe & Mn nodules; few coarse and common fine roots; diffuse smooth boundary to

Bt3 130 - 180 cm: red (2.5YR4/6) moist; clay; moderate medium subangular blocks and moderate coarse angular blocks; many medium and fine pores; frequent small irregular hard Fe & Mn nodules; common very fine and fine roots

SOIL CLASSIFICATION: FAO legend : 1989 :Ferric Acrisol (ACf)
USDA Soil Taxonomy:1990 :Isohyperthermic, very deep, kaolinitic, Ustic Haplohumult

ANALYTICAL DATA FOR PROFILE TP-1

Horizon		Ap	Bt1	Bt2	Bt3
Depth (cm)		0 - 20	40 - 60	80 - 100	140 - 160
Clay	%	43	52	57	65
Silt	%	16	14	12	14
Very fine sand	%	10	9	9	10
Fine sand	%	17	15	13	7
Medium sand	%	10	8	6	-
Coarse sand	%	3	3	2	3
Very coarse sand	%	1	1	1	1
Total sand	%	41	35	31	21
Texture class		C	C	C	C
pH H2O	1:2.5	5.3	4.7	4.6	4.7
pH KCl	1:2.5	4.5	4.0	4.2	4.2
EC mS/cm	1:2.5	0.07	0.01	0.01	0.01
Organic C	%	4.1	1.0	0.5	0.2
Total N	%	0.29	0.07	0.04	0.02
C/N		14	14	13	10
Available P	mg/kg	1	0.1	0.1	0.1
CEC NH4OAc	cmol(+)/kg	14.3	10.6	10.6	11.6
Exch. Ca	cmol(+)/kg	3.3	0.7	0.7	0.7
Exch. Mg	cmol(+)/kg	1.9	0.1	0.2	0.4
Exch. K	cmol(+)/kg	0.57	0.08	0.31	0.36
Exch. Na	cmol(+)/kg	0.07	0.08	0.08	0.09
Exch. H	cmol(+)/kg	0.05	0.18	0.11	0.03
TEB	cmol(+)/kg	5.8	1.0	1.3	1.6
Base saturation	%	41	9	12	14
CECclay	cmol(+)/kg	33	20	19	18

Appendix 3 Some tree and shrub species found in the Miombo Woodlands, Mbinga

Botanical names	Vernacular names
Urumwa Forest Reserve	
Brachystegia speciformis	Mutundulu
Dichrostachys glomerata	Mutundulu
Pterocarpus angolensis	Mninga
Albizia antunensiana	Mgando Kaguha
Sterculia quiuqueloba	Mguwa
Ostryoderis stuhlumanni	Munyenye
Epythrina abssinica	Mlalwankumba
Pterocarpus odoratum	Mkulungu
Pericopsis angolensis	Mbanga
Phyllanthus discoideus	Lusenga
Uyuikigwa Forest reserve	
Crossopteryx febrifuga	Msanzambake
Sclerocarya birrea	Mun'gong'o
Albizia harvei	Mpogolo
Brachystegia fischeri	Mgela
Commiphora pilosa	Mponda
Popowia obovata	Msalasi
Diplorinchus mossambicensis	Msonga
Phyllanthus engeli	Mgogondi
Pseudolanchnostylis maprouneaefolia	Mtunguru
Strychnos innocua	Mkulwa
Euphorbia bilocularis	Mlangali
Thylachium africanum	Msulula
Combretum ternifolium	Mulujamizi
Paiwaeusa dactylophylla	Mliwamfwengi
Hymenocardia mollis	Mpala
Ximenia americana	Mnembwa
Lannea schimperi	Mgumbu
Monotes adenophyllus	Mguguti
Swartizia madagascariensis	Kananda
Dalbergia melanoxylon	Mgembe
Momusops densiflora	Mkonze
Ichemba Forest Reserve	
Combretum binderanum	Mlandata
Markamia obtusidolia	Mbapa
Zanha africana	Mkalya
Holarrhena febrifuga	Msongaluguka
Burkea africana	Mgando Mkarati
	Mdungwa
Lannea tomentosa	Mtinje
Xylopia antunensii	Mshenene
Randia kuhniana	Mkuondokondo
Ormocarpum aromaticum	Kapyopyo
Chrysophyllum bangweoleuse	Msebeya
Acacia drepanolobium	Ulala

Source: Nobuchi and Senkondo (1994)