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SOIL AND LAND RESOURCES OF MOROGORO URBAN DISTRICT, TANZANIA

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EXECUTIVE SUMMARY

A semi-detailed characterization of soils of Morogoro Urban district was carried out to provide a physical resource base for developing suitable programmes on land use planning, agricultural development and natural resources conservation at district level. The generated information would also be used for develop the agricultural land suitability, with a statement of potential and constraints on sustained use of soil and land resources of Morogoro Urban district. Results of the study could also facilitate transfer of agro-technology from one area to another.

Base map for the study was compiled from aerial-photo interpretation and subsequent overlaying on 1:50,000 scale topographic map of the district. A geological map was later on prepared and overlain on the former map to produce a landform and geology map of the district. A tentative working legend based on landforms and geology was developed for the landform and geology map. Field observations on soil morphology and their spatial distribution were carried out following the established landform and geology units. Soils were studied and described according to standard FAO (1990) guidelines. Both disturbed and undisturbed soil horizon samples were taken for laboratory studies including physico-chemical and mineralogical characterization of the soils.

Field and laboratory data were used to classify the soils in detail using two international soil classification systems commonly used in Tanzania. The systems are the United States Department of Agriculture Soil Taxonomy (up to family level) and the World Reference Base for Soil Resources (FAO, 1998). Four major types of landforms were identified and described. These are the mountains (M), piedmonts (P), peneplains (L) and valleys (V). Eight major types of parent materials were identified and described. A summary description of the soil mapping units follows.

Mountains (M)

Soils developed on hornblende pyroxene granulites with some banded pyroxene granulites

M1

Strongly dissected ridges (1500-2000 m), 50-more than 80 % slopes.

Complex of: rockland **and** shallow to moderately deep, excessively drained, dark yellowish brown, gravely clay loams and sandy clays.

M2

Moderately to strongly dissected ridge crests and slopes (1000-1500 m), 30-80 % slopes.

Association of: (shallow) deep to very deep, well to somewhat excessively drained, yellowish brown to yellowish red, gravely sandy clay loams to clays **and** moderately deep to deep, well to somewhat excessively drained, brown to dark yellowish brown, gravely sandy clay loams. Topsoils are relatively thick **and** deep to very deep, moderately well to well drained, dark brown to brown, gravely sandy clay loams to sandy clays (clays).

M3

Talus slopes (700-1300 m), 10-25 % slopes.

Complex of: scattered rock outcrops **and** cliffs of rock falls **and** deep to very deep, well drained, dark grayish brown to yellowish brown, sandy clay loams to sandy clays.

Soils developed on muscovite-biotite migmatites

M4

Strongly dissected hills, 45-80 % slopes.

Complex of: rockland **and** shallow, excessively drained, very dark gray, extremely gravelly sandy clay loams.

Piedmonts (P)

Soils developed on colluvium derived from hornblende pyroxene granulites and micaceous gneiss
P1
Foothills (600-1000 m), 15-45 % slopes.
Deep to very deep, well drained, red to dark reddish brown, clays with dark brown topsoils. Stonelines comprised mainly of fresh angular quartz gravel and stones are common.

P2
Glacis (540-600 m), 2-15 % slopes.
Deep to very deep, well drained, reddish brown to dark red, clays with weak to moderate structure development.

Soils developed on colluvial/alluvial deposits derived from pyroxene granulites and micaceous gneiss
P3
Alluvial fan (500-550 m), 0-2 % slopes.
Very deep, well drained, highly weathered, red, sandy clays to clays with humiferous topsoils.

Soils developed on colluvial/alluvial derived from biotite muscovite migmatites
P4
Alluvial fan (550-600 m), 2-10 % slopes.
Association of: very deep, well drained, dark reddish brown, sandy clay loams to sandy clays **and** very deep, excessively drained, very pale, sands and sandy clay loams.

Peneplains (L)

Soils developed on muscovite biotite migmatites

L1
Isolated hills (600-800 m), 10-30 % slopes.

Complex of: rock outcrops displaying a rockland formation and gravely/stony pavement on hilly topography. The only inclusions in the unit are pockets of shallow, excessively drained, gravely sandy clay loams and sandy clays. Soils classify as Paralithic Leptosols (FAO, 1998).

Soils developed on colluvium with variable mineralogical composition

L2
Ridge crests (500-540 m), 0-2 % slopes.

Deep to very deep, well drained, dark reddish brown (reddish brown) to red clays with moderate structure and profile development. Thick, ferruginous gravely subsoil layers are common. The soils classify as Rhodi-Acric Ferralsols (pedon SUAP-1), Cutani-Profondic Luvisols (Orthidystric) (pedon TP-1), Rhodi-Vetic Ferralsols (pedon KLWP-1) and Profondi-Abruptic Acrisols (Chromic) (pedon SUAFP-5) (FAO, 1998).

L3
Ridge slopes (420-480 m), 5-8 % slopes.

Deep to very deep, well drained, brownish sandy clay loams to clays with moderate structure and profile development. The soils classify as Cutani-Profondic Luvisols (Orthidystric) (pedon TP-2), Cutani-Profondic Luvisols (Haplic) (pedon MDP-1) and Profondic Acrisols (pedon MAGP-6) (FAO, 1998).

Soils developed on muscovite biotite migmatites

L4

Ridge crests and slopes (420-500 m), 2-5 % slopes.

Association of: moderately deep to deep, well to excessively drained, brownish and very pale sands on mixed bouldery and rocky subsoil. Soils classify as Hyperdystric Cambisols (pedon TP-6) (FAO, 1998). As part of this association are the deep to very deep, well drained, brownish, sandy clay loams to sandy clays with poor to moderate structure and profile development.

Valleys (V)

Soils developed on alluvio-colluvium with variable mineralogical composition

V1

River terrace (<500 m), 0-1 % slopes.

Complex of: very deep, moderately well to imperfectly drained, very dark brown to brown, sandy clays to sandy clay loams with variable salinity and sodicity levels. They classify as Calcari-Mollic Fluvisols (Orthieutric and Haplic) (FAO, 1998) (pedon Msanya/Msaki P-4). A second inclusion consist of very deep, moderately well to imperfectly drained, dark brown, heavy cracking clays with thick, very dark greyish brown, clay topsoils. The soils have irregular white carbonate nodules throughout. Soils classify as Calcari-Salic Vertisols (Pellic, Orthieutric and Haplic) (FAO, 1998) (pedon LUB-1).

V2

Flood plain (<500 m), 0-1 % slopes.

Complex of: very deep, moderately well to imperfectly drained, dark brown to black, heavy cracking clays with thick, very dark greyish brown clay topsoils. The soils have irregular white carbonate nodules throughout. The subsoils are characterized by distinct, partly intersecting slickensides. Presence of a discontinuous, petrocalcic horizon below 100 cm soil depth is characteristic for these soils. Soils classify as Calcari-Salic Vertisols (Pellic, Orthieutric and Haplic) (FAO, 1998) (pedon LUB-1).

The second inclusion consist of very deep, moderately well to imperfectly drained, very dark brown to brown, sandy clays to sandy clay loams. Vertic properties are very weakly expressed as only few pressure faces. These soils have variable salinity and sodicity levels and are underlain by very slightly weathered quartz gravel. They classify as Orthieutri-Hypocalcic Gleysols (FAO, 1998) (pedon TP-4).

Another inclusion consist of relatively young soils developed from recent fluvial sediments on the Ngerengere river plain. They are very deep, poorly drained, dark brown to very dark brown, stratified and mottled sands and sandy clays classifying as Stagni-Mollic Fluvisols (Orthieutric and Haplic) according to FAO (1998) (pedon MAG-1).

Landscape have had a great influence on climate in the district. The mountainous areas are humid and cool. Precipitation is being received in two seasons without a noticeable drought period. The humid climate of the mountains grade to semi-humid, particularly on the piedmonts. The climate in a considerable part of the peneplains trend to semi-arid, as most of it is within the leeward of the Uluguru mountains.

Land degradation in the district is associated with soil erosion, soil fertility deterioration and salt build-up in the soils. In many parts of the district soils are being eroded by water. The main cause is deforestation and improper land and crop husbandry practises. As a consequence, rockfalls and landslides particularly in steep land are not uncommon. Most rills and gullies in the district are still active. Continuous cropping without addition of fertilizer and manurial inputs to the soils has resulted into severe deterioration of soil fertility.

Today, crop yields in most fields are below optimum. Improper drainage especially in paddy fields has accelerated salt build-up in most soils of the river terraces and valley floors.

Most lands in the district have potential to support a wide range of crops depending on the ecological settings. However, prevailing land degradation dictate adoption of conservation tillage practises. These may include afforestation, control of soil erosion, conservation of soil water and organic matter, proper tillage and use of fertilizer and manurial inputs. Development of suitable crop and livestock enterprises should be considered for sustainable production.

How to use this document

The results of the soil and land resources survey of Morogoro Urban district have been published in one volume. Maps at a scale of 1 accompany the report:50,000. Themes presented in the report and maps are landforms, geology, soils and agricultural land suitability. These maps can be used independently without the report. However, if in need of more details on any area in the maps, one is advised to identify the area and the mapping unit code and later on to trace its description in the report.

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ACKNOWLEDGEMENTS

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1. INTRODUCTION

1.1. Background and implementation

Morogoro region is one of the agriculturally most productive areas in Tanzania. This is partly due to relatively favourable climate and potentially fertile soils for a bigger part of the region. There is potential to grow subtropical annual and perennial crops in the mountainous areas and tropical annual and perennial crops in the low lying plains. The most important annual crops being produced in the region are maize, sorghum, millet, rice, potatoes, beans, pulses and oilseeds. The most important perennial crops are sisal and a number of fruit trees. Important vegetables being grown are cabbage, carrots, tomatoes, pepper and amaranths. Although annual production is relatively high, the productive potential of the lands has never been fully utilized.

The most recent soil and land resources coverage for the region was published as Soils, Physiography and Agro-ecological Zones of Tanzania (De Pauw, 1984). The report and map were meant to provide baseline data at exploratory scale for land use planners, conservationists, agriculturists and other users. Although the document has been extensively used as reference material, its scale has been limiting its application in detailed planning for sustainable exploitation and conservation of the soil and land resources, necessitating the need for detailed studies.

As an initiative for launching a soil and land resources survey of Morogoro district, the Department of Soil Science, SUA, prepared a research project proposal which was then submitted to NORAD for approval and funding. Through the NORAD-SUA frame agreement, funds were made available for carrying out a soil and land resources survey of Morogoro district. Administratively the district comprises two units namely Morogoro Urban and Rural district respectively. It was therefore planned to start with the Morogoro urban district. Findings of the study are supposed to serve as a dynamic and multidisciplinary database. The objectives of the study were twofold:

1. To provide a physical resource base for developing suitable programmes on land use planning, agricultural development, conservation and other projects at district level.
2. Description of the agricultural land suitability, with a statement on potential and constraints on sustained use of soil and land resources of Morogoro Urban district.

A semi-detailed inventory and description of landforms and geology, soils, agroclimate and vegetation of the entire Morogoro Urban district was carried out by the Department of Soil Science, SUA, in mid-1999. Field work was carried out in several phases. 2 persons from SUA and 2 persons from NSS as presented below executed the project.

Prof. B.M. Msanya (SUA)	Party Chief, soil and land resources inventory, mapping, description of mapping units, reporting.
Dr. G.G. Kimbi (SUA)	Soil and land resources inventory, description of mapping units, reporting.
Mr. D.N. Kimaro (NSS)	Soil and land resources inventory, description of mapping units, reporting.
Mr. J.D.J. Mbogoni (NSS)	Soil and land resources inventory, description of mapping units, reporting.

Mr. S.V. Assenga at the NSS carried out cartographic work. Soil samples were analysed at the Central Soils Laboratory in Mlingano, Tanga.

1.2 Location of the study area

Figure 1 presents the location of Morogoro district in Tanzania
Morogoro urban district is situated almost at the heart of Morogoro district, between 6°37' and 6°55' Latitude S and 37°33' and 37°51' Longitude E. The district is bordered by Uluguru mountains on the eastern side and Mindu and Nguru ya Ndege hills on the western side.

2. METHODOLOGY

2.1 Prefield activities

Aerial photograph films 1695 (49-56; 64-71; 114-122; 144-151) and 1696 were interpreted to identified major landscapes, relief and landforms in the study area. A photo interpretation map of the district was then prepared. The map was transferred to topographic map sheets 183/1 (Nguru ya Ndege), 183/2 (Mkono wa Mara), 183/3 (Morogoro) and 183/4 (Kingolwira) (SMD, 1970) to serve as a topographic base map. Geological information available in Quarter Degree Sheet 183 (GSD, 1961) was incorporated in the map to form a landform-geology base map to serve as a base map for the field studies. A tentative working legend for the landform-geology map was later on prepared for use in field identification of soil units.

2.2 Field activities

Field activities were basically ground truthing of interpretation maps in terms of major landscapes, geology and soil unit boundaries. Visual observations were used in confirmation of major landforms identified during interpretation of remote sensing information. Apart from the geological and geomorphologic information, which was obtained from literature, hand specimens of major rock types were also studied to identify geological materials in different parts of the study area.

In the field soils were characterized by means of soil observations were made to a maximum depth of 1.5 m. Mapping units identical in landforms, geology and soil morphology were considered to be similar and were given a similar mapping unit code. Mapping units with differing characteristics were considered to be different and therefore different mapping unit codes were assigned to each. In selected representative areas for each soil unit a soil profile pit was made and described according to standard guidelines for soil description (FAO, 1990). From each natural soil horizon a bulk soil sample was collected for laboratory analysis. Undisturbed soil samples were collected from three different depths [topsoil (0 cm), upper subsoil (50 cm) and subsoil (100 cm) for laboratory measurements of moisture retention, bulk density and related aspects.

Figure 1. Location of Morogoro district in Tanzania.

2.3 Post field activities

2.3.1 Laboratory analysis of soil samples

All soil samples were analysed at the Central Soils Laboratory in Mlingano, Tanga according to analytical procedures in use at the National Soil Service (NSS, 1994). A standard survey analytical procedure was used to analyse bulk samples while a pressure membrane apparatus and oven drying were used for analysing undisturbed samples. Details of the procedures are presented in Annex 1.

2.3.2 Map compilation

A topographic base map was fine drawn and printed at the NSS Cartographic Laboratory in Mlingano. All other thematic maps were overlain on this topographic base map.

3. DESCRIPTION OF THE SOIL AND LAND RESOURCES

3.1 Climate

3.1.1 Previous studies

The Morogoro urban district fall within two distinct agro-ecological zones (AEZ) according to De Pauw (1984). These AEZs are E4 (tropical lowlands) and E14 (tropical highlands). Some representative climatic data for AEZ E4 are presented in Table 1. The AEZ E4 has a monomodal rainfall pattern as precipitation does not exceed half evapotranspiration for a bigger part of the year. The month of January is the beginning of the main rain season. Onset dates for precipitation are unreliable. The rain season lasts for 4.5 to 5 months. Whereas lowest precipitation is being received in May, peak precipitation is normally received during the month of April. Precipitation ends during the month of May and the growing periods ends during the month of July.

Daily temperatures in AEZ E4 are higher than 20 °C throughout the year. Highest temperatures are experienced during the months of December through April, coinciding with the rains. Coolest temperatures are experienced during the months of June through August, coinciding with the dry season. Variations in insolation during an average year show a positive relationship to variations in precipitation and temperature. Wind speed is relatively constant except for the months of November and December during which wind speeds are relatively high.

Climate in the AEZ E14 is being strongly influenced by topography. Being relatively higher than the lowland plains, the zone experiences extended growing periods due to high precipitation and relatively low potential evapotranspiration. The AEZ E14 has one dependable growing period of 5.5 to 7 months but often transition from one into next growing period without intermediate dry period. The most likely onset period is the month of January.

3.1.2 Description of climate

Relief and aspect have had a great influence on climate in the district. Areas higher in the landscape such as the Morningside are cooler than those lower in the landscape such as Tungi. The trend of precipitation reveal a similar influence of altitude on precipitation. Whereas high altitude areas receive high precipitation, low altitude areas receive low precipitation. Areas on the leeward receive relatively lower precipitation than those on the windward. Wind movement has been reported to be higher at medium altitudes due to local heating of the air in the valleys during daytime. In late afternoon there is strong movement of the air in most of the dry season (Moberg *et al.*, 1982).

Climatic data for the Tungi area reveal a gradual decrease in precipitation from the east towards the west and northwest in the district. As distance from the Uluguru mountains increase towards these directions aridity intensifies as well. This trend can be attributed to the rainshadow effect of the Uluguru mountains. In the Mkundi and Tungi areas for example rather drought tolerant crops proliferate more than maize. Even the land cover itself tends to shift from predominantly *Brachystegia species* (miombo) to the hardy *Cacia* and *Acacia species*. This is clearly indicated by the extensive bushland and wooded bushland of thorn trees in the Wami plain.

Areas around Tungi and Kingolwira are receiving relatively more precipitation than the Mkundi area due to a decrease in relief relative to the Uluguru mountains. This small relief difference towards the north east end of the Uluguru mountains is responsible for a decrease in the effect of aspect (rainshadow) on precipitation. The distribution of precipitation is best observed in the Kingolwira area. This area experiences a dry season of only 7 months, which is shorter than a dry season of 8 months in other parts of the district.

Table 1. Climatic data of AEZ E4

Month	Mean precipitation			Mean temperature	Mean relative humidity	Mean insolation	Mean wind speed
	*	**	***	***	***	***	***
			mm	°C	%	hours	knots
January	95	124	95	26.3	69	5.7	3
February	102	93	102	26.3	70	5.9	3
March	167	136	167	26.2	73	5.9	3
April	215	159	215	25	80	4.3	2
May	92	64	91	23.5	80	3.9	2
June	26	20	26	21.6	73	4.3	2
July	15	15	15	21.1	71	4.1	3
August	11	11	11	22.1	66	4.2	4
September	18	15	18	23.2	63	4.7	3
October	28	28	29	24.6	61	5.7	4
November	61	51	61	25.7	63	6.2	5
December	78	94	78	26.6	66	5.8	5
Year	908	810	908	24.3	70	5.1	3

Source: EAMD (1975).

*Morogoro Agric Office; 570 m; 6°51' S and 37°40' E (1906-70).
**Tungi Estate; 495 m; 6°46' S and 37°47' E (1933-70).
*** Morogoro Met Station; 579 m; 6°51' S and 37°40' E (1946-60).

Relative air humidity is highest during the months of April and May, conciding with the peak of the growing period. The lowest relative air humidity prevails during the month of October. Variations in insolation during an average year are low. However, highest insolation is being received during the month of November, which is associated with drought and low cloud cover. Lowest insolation is being received during the month of May, which is associated with extended periods of cloud cover and low intensity precipitation.

3.2 Geomorphology, landforms and lithology

3.2.1 Geomorphology

The Gondwana land was fully developed when eastern Tanzania was a stable tectonic land mass before Late Jurassic, more than 165 mill. years ago (King, 1967). The break-up of Gondwana land during the Late Jurassic caused the development of large rift structures along old faults from Permian and older geological periods, which lead to uplifting of the southern Africa margins. During Early Cretaceous (140 mill. Years ago), strong uplift accelerated erosion which is marked by increase in sedimentation on the coast near Dar es Salaam and in the Islands of Zanzibar and Pemba (Kent et al., 1971). These periodicities continued until during the Quaternary (1.8 mill. Years ago) when processes of landscape development could be related to present day slope processes, activities of running water, wind erosion and changes in the protective vegetation cover (Thomas, 1994).

Before 13-12 kyr the area had a sparse vegetation which was related to the aridity of the climate during that time. A change in climate brought increases of precipitation. Therefore the higher rains caused mass loss of soil. Increase of precipitation linked with human induced deforestation increased the magnitude and frequency of erosion and landslides. Sedimentation rates on the coast decreased during the last 20 mill. years (Kent et al., 1970), the period which saw the lowering of the land surface in Morogoro district. The Ngerengere and Kingolwira are reported to have developed during this period (Sampson and Wright, 1964).

3.2.2 Landforms

During this study four major types of landforms were identified in the study area. The first landform type are the very steep mountains comprising of the Uluguru system. The Uluguru system, with a pronounced high-level surface is an outlier of the African land surface of Late Cretaceous - Lower Tertiary age (Mutakyahwa and Valeton, 1995). These mountains rise from an average lowest altitude of 500 m to 2200 m as highest altitude. They differ from each other in altitude range, relief and intensity of dissection. The Uluguru mountains consist of strongly dissected ridges (1500-2000 m asl), moderately to strongly dissected ridge crests and slopes (1000-1500 m asl) and talus slopes (700-1300 m asl). The rocks in the Uluguru mountains trend generally NNE. The northern and north-western faces of the mountains show complex and intense folding and faulting (GSD, 1961).

The mountainous landforms consist also of very steep, moderately to strongly dissected ridge crests and slopes. These stand at an altitude of between 1000-1500 m and they are the products of intense erosion. Talus slopes are extensive in the Uluguru. These are the consequences of erosion, landslides and rockfalls. The peculiar characteristics are severe erosion and presence of scars of rock falls. Strongly dissected hills comprising mainly of Mindu, Lugalla and Msembe hills are part of the mountainous landscape. They are situated at an altitude range of between 700-1100 m.

The second landform consist of Piedmonts. These are foothills (600-1000 m asl), glacis (540-600 m asl) and alluvial fans (500-600 m asl). Most foothills are very steep with predominantly convex slopes. The glacis are gently to steeply sloping and are characterised by moderate to severe erosion. A bigger part of the Sokoine University area is within the glacis. Alluvial fans, as part of the piedmonts, are situated at almost uniform altitude range. Extensive alluvial fans are situated around the strongly dissected Mindu, Lugalla and Msembe hills. The second set of alluvial fans are associated with the Uluguru mountains in areas around Bigwa. Whereas the alluvial fans associated with the Uluguru mountains are almost flat, those around Mindu, Lugalla and Msembe hills have a gently undulating to undulating topography.

The third major landform consist of peneplains situated at an altitude range of 400-800 m. The peneplain units consist of ridge crests and ridge slopes. Most of the peneplain ridge crests are almost flat to gently undulating while ridge slopes are undulating. They extend from the Morogoro Meteorological Station to Bigwa, Tungi and Magadu. Quite few isolated hills are present in the peneplain. These are mainly rock outcrops situated at an average altitude of 600-800 m with undulating to very steep topography. The fourth major landform consist of valleys, which are flat to almost flat river terraces and flood plains at altitudes lower than 500 m. The Ngerengere flood plain is a typical example.

3.2.3 Lithology

The region is part of the Mozambique belt which is a poly-orogenic complex (Muhongo, 1994). The constituting rocks are of Proterozoic, Archean and Early Palaeozoic ages. This rock complex is divided into five sub-units (Sampson and Wright, 1964). Only two of these sub-units are dominant in the Morogoro Urban district area.

3.2.3.1 Hornblende-pyroxene granulites

Dominant minerals in these rocks are calcium-rich plagioclase, some biotite and garnets. Quartz is present in low but varying amounts. The pyroxenes are of the hypersthene $(Mg,Fe)SiO_3$ and the diopside $(Ca,Mg)Si_2O_6$ types. Hypersthene is the commonest mineral in these granulite metamorphic facies although it is the most unstable mineral. Other common and unstable minerals are oligoclase-andesine plagioclase, scapolite and hornblende. Common accessory minerals in the granulites are iron ore and apatite (GSD, 1961; Sampson and Wright, 1964).

3.2.3.2 Biotite-hornblende gneisses and granulites

These rocks are present within the hornblende-pyroxene area surrounding the Uluguru Massif. Quartz is usually common, the associated feldspars are of the oligoclase and microcline types. Hornblende, pyroxene and garnets occur as lenses and bands. Marble is found as small lenses in the northeast to east of the Uluguru mountains. Graphitic rocks are often associated with biotite rich zones. Iron ore and apatite are the common accessory minerals (GSD, 1961; Sampson and Wright, 1964).

3.2.3.3 Muscovite-biotite gneisses and migmatites

These gneisses are of a high metamorphic grade and are the dominant geological material in the Mindu, Lugalla and Msembe hills and a bigger part of peneplain ridge crests north east of Tungi and Kingolwira (GSD, 1961). They contain equal amounts of potassium-feldspars (microcline) and sodium-rich plagioclase (oligoclase) and fairly high amounts of quartz. Pure quartz occurs as bands and lenses. Accessory minerals include apatite, rutile and iron ore. These are occasional dark coloured bands and lenses of hornblende-bearing rocks with garnets, epidote and biotite (Sampson and Wright, 1964). These rocks have been melted to migmatites. Veins of pegmatite's are common in these rocks. The veins contain lenses of pure microcline and quartz, with macrocrystals of muscovite and biotite (Bates and Jackson, 1980).

3.2.3.4 Colluvium

Colluvial materials of diverse mineralogical composition dominate most of the peneplains. The predominant colluvial materials were derived from metasedimentary rocks rich in garnet-biotite gneisses with some microcline and muscovite. In the valleys (river terraces and flood plains) fluvial/alluvial materials of diverse mineralogical composition are dominant. Msanya and Msaki (1982) reported presence of high amounts of easily weatherable minerals biotite, chlorite and epidote. Smectite was also reported to be present in soil, being a probable result of transformation of vermiculite layers as a result of oxidation processes.

3.3 Soils

3.3.1 General description

Climate and its effects on vegetation and geological processes have controlled the landscape and soils in the study area. Landform patterns and geology have had profound influence on types and distribution of soils in the area. Soil profile development reveal markable influence of mass removal of soils by water erosion, land slides and rock falls as well as the influence of alluvio-colluvial processes. Moberg and co-workers (1982) reported similar observations. Climate, parent material and relief were reported to have a close connection with the mineralogical composition and edaphological properties of the soils in the Uluguru and Mindu toposequences.

Mineralogically the Uluguru soil association has a high content of kaolinite and Fe-oxyhydroxides in the clay fraction of the well drained soils. The silt fraction in these soils contain substantial amounts of kaolinite and Fe-oxyhydroxides. This is due to the presence of highly stable micro-peds in that fraction. In the Morningside area, high content of gibbsite in the clay fraction is attributed to rapid weathering and strong leaching caused by high rainfall and excessive drainage in the area (Moberg et al., 1982). In a separate study, Msanya and Msaki (1982) concluded that the parent materials of soils in this toposequence are the same as shown by relatively high C.P.S.D indices within and between profiles, mixed clay mineralogy, similar heavy and light mineral content and dominance of quartz in all soils.

Well drained soils of the Mindu soil association have higher content of feldspars and hydrous mica and lower Fe-oxyhydroxides than the Uluguru soil association. The reason is the low content of Fe-oxyhydroxides and higher content of K-feldspar and muscovite in the parent material. Soils of the Ngerengere river flood plain have high contents of smectite, revealing relative youngness of the soils. Quartz is the most dominant mineral in all soils. Silt contents are higher in soils situated on steep slopes and the Ngerengere river flood plain than those on gentle slopes. Soils of the Mindu association, which developed from coarse textured quartz rich gneiss, are poor in clay and silt contents. Msanya et al (1994) reported dominance of kaolinite in the clay fraction of relatively highly weathered red soils of Morogoro district. Soils around the Mkundi area (alluvial fan) were reported to be sandy loams to sandy clay loams with mixed mineralogy.

Kaaya (1998) described 8 soil units along the Uluguru mountains (Morningside) - Ngerengere river - Mindu mountain toposequence. Soils of the strongly dissected ridge slopes are generally shallow to moderately deep, well drained, red friable sandy clay loams and red clays classifying as Lixisols, Luvisols and Cambisols (FAO, 1988) (Inceptisols, Alfisols (Soil Survey Staff, 1996)). On the piedmonts are deep, well drained, brown friable sandy clay loams and red friable clays classifying as Lixisols and Acrisols (Ultisols, Alfisols and Oxisols). Dominant soils on the glacis and peneplains are very deep, well drained, brown friable sandy clays and red friable clays classifying as Acrisols and Lixisols (Ultisols and Oxisols).

Ridge side slopes on the peneplain have very deep, moderately well to well drained, brown stratified sandy loam, sandy clay and clay sediments classifying as Cambisols (Inceptisols). Flood plains have very deep, imperfectly to poorly drained, brown and greyish brown stratified micaceous sandy clay loams and clay loams classifying as Fluvisols (Entisols). In the lower part of the alluvial fan around Mindu mountains are moderately deep to deep, moderately well drained, brown friable sandy loams and sandy clay loams classifying as Cambisols (Inceptisols). The rest of the alluvial plain has moderately deep to deep, well drained brown friable sandy loams and sandy clay loams classifying as Cambisols (Inceptisols). Soils of the Mindu mountains are shallow to moderately deep, well drained , brown friable sandy loams and sandy clay loams classifying as Cambisols and Leptosols (Inceptisols and Entisols).

3.3.2 Description of mapping units

During the present study soils were described and distinguished on the basis of landforms, relief, parent material, soil morphology and chemical properties. The different soil types were mapped as complexes, associations and topographically uniformly distributed soils. A concise description of the soil mapping units is therefore presented in conformity to the legend construction. Field description and analytical data for representative pedons are presented in Annex 2.

Mountains (M)

Soils developed on hornblende pyroxene granulites with some banded pyroxene granulites

M1

Strongly dissected ridges (1500-2000 m), 50-more than 80 % slopes.

Complex of: rockland **and** shallow to moderately deep, excessively drained, dark yellowish brown, gravely clay loams and sandy clays on saprolite occurring at variable depths. The soils have high contents of kaolinite and Fe-oxyhydroxides. The gibbsite content in the clay fraction is also high.

M2

Moderately to strongly dissected ridge crests and slopes (1000-1500 m), 30-80 % slopes.

Association of: (shallow) deep to very deep, well to somewhat excessively drained, yellowish brown to yellowish red, gravely sandy clay loams to clays **and** moderately deep to deep, well to somewhat excessively drained, brown to dark yellowish brown, gravely sandy clay loams. Topsoils are relatively thick **and** deep to very deep, moderately well to well drained, dark brown to brown, gravely sandy clay loams to sandy clays (clays) with thick black sandy clay loam to clay loam topsoils. Surface stoniness and rock outcrops are common. Representative pedons are LTP-1 and BGP-1.

Clay content increase with depth at variable rates (<40-60 %). The deep and very deep soils have highest clay increases with depth. Fine silt is present in amounts higher than coarse silt while sand content show a small variation with soil depth. Shallow phases of these soils have angular stones within the pedons and overly saprolite.

The organic matter content of the soils is medium, with highest levels in the topsoils. This organic matter is of medium quality. Soil reaction is high (pH>7) throughout. This can be attributed to high levels of exchangeable basic cations particularly Ca and Mg. The CEC of the soils is relatively low. Available P is present in medium amounts throughout the soil depth.

M3

Talus slopes (700-1300 m), 10-25 % slopes.
Complex of: scattered rock outcrops **and** cliffs of rock falls **and** deep to very deep, well drained, dark grayish brown to yellowish brown, sandy clay loams to sandy clays. Topsoils are thick sandy clay loams. Surface stones are common.

Soils developed on muscovite-biotite migmatites

M4

Strongly dissected hills, 45-80 % slopes.

Complex of: rockland **and** shallow, excessively drained, very dark gray, extremely gravelly sandy clay loams.

Piedmonts (P)

Soils developed on colluvium derived from hornblende pyroxene granulites and micaceous gneiss

P1
Foothills (600-1000 m), 15-45 % slopes.
Deep to very deep, well drained, red to dark reddish brown, clays with dark brown topsoils. Stonelines comprised mainly of fresh angular quartz gravel and stones are common.

P2
Glacis (540-600 m), 2-15 % slopes.
Deep to very deep, well drained, reddish brown to dark red, clays with weak to moderate structure development.

Soils developed on colluvial/alluvial deposits derived from pyroxene granulites and micaceous gneiss

P3
Alluvial fan (500-550 m), 0-2 % slopes.
Very deep, well drained, highly weathered, red, sandy clays to clays with humiferous topsoils.

Soils developed on colluvial/alluvial derived from biotite muscovite migmatites

P4
Alluvial fan (550-600 m), 2-10 % slopes.
Association of: very deep, well drained, dark reddish brown, sandy clay loams to sandy clays, with very thick loamy sand topsoils **and** very deep, excessively drained, very pale, sands and sandy clay loams with weak structure and profile development. Representative pedons are BGP-2 and MKP-1.

Peneplains (L)

Soils developed on muscovite biotite migmatites

L1
Isolated hills (600-800 m), 10-30 % slopes.

Complex of: rock outcrops displaying a rockland formation and gravely/stony pavement on hilly topography. The only inclusions in the unit are pockets of shallow, excessively drained, gravely sandy clay loams and sandy clays. Soils classify as Paralithic Leptosols (observation Msembe 2).

Soils developed on colluvium with variable mineralogical composition

L2

Ridge crests (500-540 m), 0-2 % slopes.

Deep to very deep, well drained, dark reddish brown (reddish brown) to red clays with moderate structure and profile development. Topsoils are brownish loams and sandy clay loams. Thick, ferruginous gravely subsoil layers are common. The soils classify as

Rhodi-Acric Ferralsols (pedon SUAP-1), Cutani-Profondic Luvisols (Orthidystric) (pedon TP-1), Rhodi-Vetic Ferralsols (pedon KLWP-1) and Profondi-Abruptic Acrisols (Chromic) (pedon SUAFP-5) (FAO, 1998).

L3

Ridge slopes (420-480 m), 5-8 % slopes.

Deep to very deep, well drained, brownish sandy clay loams to clays with moderate structure and profile development. Uniformly distributed fine quartz gravel is present in variable amounts in some places. The soils classify as Cutani-Profondic Luvisols (Orthidystric) (pedon TP-2), Cutani-Profondic Luvisols (Haplic) (pedon MDP-1) and Profondic Acrisols (pedon MAGP-6) (FAO, 1998).

Soils developed on muscovite biotite migmatites

L4

Ridge crests and slopes (420-500 m), 2-5 % slopes.

Association of: moderately deep to deep, well to excessively drained, brownish and very pale sands on mixed bouldery and rocky subsoil. Soils classify as Hyperdystric Cambisols (pedon TP-6) (FAO, 1998). As part of this association are the deep to very deep, well drained, brownish, sandy clay loams to sandy clays with poor to moderate structure and profile development.

Valleys (V)

Soils developed on alluvio-colluvium with variable mineralogical composition

V1

River terrace (<500 m), 0-1 % slopes.

Complex of: very deep, moderately well to imperfectly drained, very dark brown to brown, sandy clays to sandy clay loams with variable salinity and sodicity levels. The soils have a very slight tendency to swell and shrink and reveal a clear weak structure and profile development. They classify as Calcari-Mollic Fluvisols (Orthieutric and Haplic) (FAO, 1998) (pedon Msanya/Msaki P-4).

A second inclusion consist of very deep, moderately well to imperfectly drained, dark brown, heavy cracking clays with thick, very dark greyish brown, clay topsoils. The soils have irregular white carbonate nodules throughout. The subsoils are characterized by distinct, partly intersecting slickensides. Presence of a discontinuous, petrocalcic horizon below 100 soil depth is characteristic for these soils. Soils classify as Calcari-Salic Vertisols (Pellic, Orthieutric and Haplic) (FAO, 1998) (pedon LUB-1).

V2

Flood plain (<500 m), 0-1 % slopes.

Complex of: very deep, moderately well to imperfectly drained, dark brown to black, heavy cracking clays with thick, very dark greyish brown clay topsoils. The soils have irregular white carbonate nodules throughout. The subsoils are characterized by distinct, partly intersecting slickensides. Presence of a discontinuous, petrocalcic horizon below 100 cm soil depth is characteristic for these soils. Soils classify as Calcari-Salic Vertisols (Pellic, Orthieutric and Haplic) (FAO, 1998) (pedon LUB-1).

The second inclusion consist of very deep, moderately well to imperfectly drained, very dark brown to brown, sandy clays to sandy clay loams. Vertic properties are very weakly expressed as only few pressure faces. These soils have variable salinity and sodicity levels and are underlain by very slightly weathered quartz gravel. They classify as Orthieutri-Hypocalcic Gleysols (FAO, 1998) (pedon TP-4).

Another inclusion consist of relatively young soils developed from recent fluvial sediments on the Ngerengere river plain. They are very deep, poorly drained, dark brown to very dark brown, stratified and mottled sands and sandy clays classifying as Stagni-Mollic Fluvisols (Orthieutric and Haplic) according to FAO (1998) (pedon MAG-1).

3.4 Vegetation

In the lowland plains woodlands occupy about 43 % of the area. These are mainly *Miombo* type of trees (*Brachystegia* spp.) with *Hyparrhenia* as the most dominant grass species. Wooded grasslands occupy about 14 % of the land area. The proportion of hardy species *Acacia, Cacia, Dalbergia, Dichrostachys, Sterculia, Grewia, Tamarindus,* etc increase towards the west and northwest. This trend is attributed to a slight change in climate from semi-humid in the east to relatively semi-arid. Semi-aridity reaches its peak close to the border with Dodoma region. Canopy cover in the plains is being affected by deforestation for fuel wood, building poles, charcoal making and overgrazing.

Woodlands (35 %) and forests (15 %) are the dominant vegetation cover types in the highland areas. Apart from *Brachystegia* and *Milicia* sp. some of the tree species are submontane due to prevalence of cool and humid environment on the highlands. Despite of high canopy cover and high biomass productivity, most of these forests are being indiscriminately exploited, leaving spots of grasslands and bushed grasslands within the forests.

4. LAND USE

4.1 Agriculture

A bigger area of the district is under subsistence cultivation of annual crops maize, sorghum, millet, rice, fruit trees and vegetables either in pure stands or mixed cropping. Maize is the major crop in the district. It is being grown rainfed on the vast peneplains as well as on valleys. The crop flourish well on the mountainous areas but in limited arial extent. Sorghum is the major crop in the west and southwestern part of the district. This part is the driest in the district. Paddy is being grown along river terraces and flood plains during the rain season. On average, holdings are in the range of 2 to 4 hectares. Family labour is the most important source of farm power. Mechanized estate cultivation of sisal is occupying a significant part of the district area. Sisal is being grown for fibre production. Dominant land use types in the district are described.

4.1.1 Maize system

Maize grown in pure stand is common on the glacis and peneplains adjacent to mountainous landscape (Mzinga-SUA-Bigwa stretch). Banana intercropping around homesteads is common. Land is usually prepared manually or mechanically (disc ploughing and harrowing). The crop is usually planted with first rains and harvested in May-July. Limited use is being made of fertilizer inputs.

4.1.2 Maize-sorghum-sunflower system

The enterprise is most common in the western part of the district. The crops are grown either mixed or monoculture in adjacent fields, as a means to avert drought induced crop failure. Commonly no fertilizer inputs are being applied to replenish soil fertility.

4.1.3 Maize-cassava system

This is the most common system of crop production. Cassava is usually planted during the first weeding operation. After the maize crop is harvested cassava is left to grow until the end of the second maize crop when it is harvested for consumption or sale.

4.1.4 Sorghum-millet-cassava

This is the common land use type around the dry Mindu-Msembe area. The crop is usually planted with first rains in December-January and harvested during the May-July period. Cassava, grown as an intercrop, is usually harvested after two years. No fertilizer inputs are being used in this system.

4.1.5 Maize-beans-vegetable system

This is the common system in the Uluguru mountain area. Due to the prevailing cool climate, long-term varieties are being grown. The crop cycle of maize last for about 8 months. Adjacent to the maize fields, particularly on lower parts of the slopes and valley floors, vegetables are being intensively produced. The most common types of vegetables are cabbage, tomato, eggplant, spinach, carrots, pepper and many others. The vegetables and a number of fruits and banana are also being produced for sale.

4.1.6 Rice

The enterprise is limited to river terraces and flood plains. It involves manual land preparation and seed broadcasting. In most cases weeding is done by hand. Supplementary irrigation is being practised particularly during prolonged dry periods. The crop is harvested between May and July. Most of the produce is sold for cash.

4.1.7 Estate sisal production

The enterprise occupies a significant part of the district area. The only estate present in the district is Tungi Ltd. The main product of the industry is fibre, most of which is exported.

4.2 Livestock

Extensive grazing is the most common type of livestock production. Dual-purpose cattle and goats are the main livestock types. Small-scale dairy production is growing steadily in the district. Dairy cattle are usually kept indoors. A substantial proportion of dairy farming is being practised semi-intensively as well. Most of the milk and milk products are being sold locally.

4.3 Forestry

Thick forest reserves exist in the southeastern and eastern borders of the district. These forests are state owned and are meant to conserve the natural ecosystem and provide protection against soil erosion. The forested area is also a potential catchment area. Fuel reserves in the western part of the district are meant to provide fuel wood and charcoal at rather controlled rates.

4.4 Industry

Most industrial activities in the district used to be agricultural processing ventures. They consisted of sisal processing industries, tobacco processing, grain mills and food packaging. The expansion of industrial activities took place during the mid 1970s. During the mid-1970s saw expansion of industrial activities. Apart from oilseed processing, new other ventures were textile, tannery, shoe and canvas industries. Presently, a wide range of industrial establishments is taking place at a rather fast rate. Some of the new industrial activities include soap production.

5. LAND DEGRADATION

5.1 Mountainous and hilly areas

Land is being degraded at a fast rate in the district. Although geological degradation is active, human influence has had the greatest contribution to land degradation. Forest clearing in the Uluguru mountains for timber, building poles, fuel wood and cultivation has exposed soils to erosive forces. Today, the most important forms of land degradation taking place are soil erosion in the form of sheetwash, gully erosion, landslides and rock falls. These processes are responsible for rapid decline of soil depth and fertility in cultivated lands on the Uluguru mountains. Improper tillage is still the most hazardous human influence as it accelerates mass removal of productive soils through water erosion.

5.2 Peneplains

The most active forms of land degradation are soil erosion in the form of sheetwash and gully erosion. Most of these areas have been cleared for cultivation. Improper land and crop husbandry practices have led to accelerated soil erosion. The practice of continuous cultivation without replenishing nutrients to the soils has accelerated a decline in the fertility status of the soils. The productive potential of the lands has therefore deteriorated tremendously.

5.3 Alluvial fans

Most alluvial fans particularly around Nguru ya Ndege, Lugala and Mindu have very deep sands and gravely sands. Building contractors have found these areas to be suitable places for mining sand and gravel. Exploitation of these areas has never been sustainable as most of the quarries are situated close to major roads (danger for initiation of landslides or collapse of roads) or upslope above residential areas (may concentrate runoff potentially capable of destroying homes). Deforestation and bush clearing in these areas has resulted to severe upset of the natural ecosystem. The fertility status of the soils has declined due to low biomass productivity that could have otherwise contributed to build-up of soil organic matter.

5.4 Valleys

Most flood plains are potentially saline, sodic or both. Extensive flood plain areas in the district are already salt affected. This is due to accumulation of salts more than they are being removed from the soil. These lands which would have been suitable areas for production of rice, vegetables or even cereals can not be profitably used at present. One of the reasons for salt build-up could be regular drying up of rivers/streams during the dry seasons. Water flow would have been perennial but since the catchment areas are already degraded, not much can be expected from current land use practices. Only few river terraces can support all year round production. Most of these river terraces tend to dry during the dry seasons as the water flow ceases. The situation has been caused by disturbance in the ecological settings of the catchment areas that used to release steady streams of water throughout the year.

6. AGRICULTURAL DEVELOPMENT POTENTIAL

6.1 Tropical lowland plains

The temperature regime in the plains is suitable for tropical lowland crops. Although the dependable growing period is of medium length, unreliable onset dates may bring about hazards of planting losses or yield reductions. The plains are suitable for a wide range of annual and perennial crops with some degree of drought resistance. Soils are of medium fertility therefore good land and crop husbandry practices are necessary for sustainable production.

Most suited crops for the ridges and ridge slopes in the peneplains are medium term cereals such as maize (Kito, Staha, Katumani), sorghum (Tegemeo, Serena) and millet (Uwele). Early planting and proper weeding are essential for optimum crop yield. Tuber crops such as cassava and sweet potatoes should be considered in the cropping system due to their drought tolerance. Leguminous crops (beans, peas) may be grown intercropped with cereals, to make use of some shading against desicative insolation.

The zone has moderate capacity for production of fodder for livestock. However, more biomass can be produced if selective weeding to remove undesirable grass and shrub species is applied. The land carrying capacity is estimated at 1 livestock unit per square kilometre (De Pauw, 1984).

Valley floors and river terraces have high potential for production of rice, vegetables and off-season maize. Optimum production can be achieved by adoption of proper land and crop husbandry practises. These may include seed selection, timely planting and proper drainage to prevent salt build-up in the soils.

6.2 Tropical highlands

The temperature regime is suitable for tropical highland crops such as beans, maize, vegetables, coffee and fruit trees. Double cropping is usually feasible at higher altitude due to relatively longer growing periods. Soils are generally fertile but proper land use and conservation practices need to be adopted to avoid onset of soil erosion and land slides as most of the slopes are very steep. The zone has high capacity for production of biomass for livestock. The land carrying capacity is estimated at 6 livestock units per square kilometre (De Pauw, 1984).

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ANNEX I
Laboratory procedures for routine soil analysis

Sample preparation:
Air drying, crushing in a mortar and sieved to obtain a fine earth fraction (2 mm). Determinations are performed on the fine earth fraction and results are reported on that basis.

Particle size:
Hydrometer method after destruction of the organic matter and using sodium hexametaphosphate as dispersing agent.

Organic carbon:
Walkley and Black, wet acid-dichromate digestion and $FeSO_4$ titration.

Total nitrogen:
Semi-micro Kjeldahl digestion followed by ammonium distillation and titration with sulphuric acid.

pH:
Potentiometrically using a combined glass-calomel electrode in a 1:2.5 suspension of H_2O and KCl.

Cation exchange capacity:
NH_4 saturation with NH_4OAc at pH 7.

Exchangeable cations:
Displacement with 1 M NH_4OAc at pH 7 and determination of K and Na by flamephotometry and Ca and Mg by EDTA titration.

Available phosphorus:
Kurz-Bray I, extraction with 0.025 M HCl and 0.03 M NH_4F and colorimetric determination of the extractable P.

Profrile number: LTP-1 Mapping unit: M2
Agroecol zone:
Region: Morogoro District: Morogoro Urban
Map sheet no.: 183 Coordinates: 6o51'19.9" S/37o40'12" E Location: LITI, along road to Morningside Elevation: 560 m
Parent material: Horblende pyroxene granulites with some banded pyroxene granulites of the Uluguru mountains
Landform: Strongly dissected ridge crests and slopes
Slope (%): 45; convex
Surface characteristics: Moderate sheet and gully erosion
Deposition: None Natural drainage class: Well drained
Described by B.M. Msanya, D.N. Kimaro and J.D.J. Mbogoni on 06/07/1999.

Ap 0-10 cm: dark reddish brown (5YR3/2 moist);;sandy clay; moderate, fine and medium subangular blocks; friable, sticky, plastic; common fine slightly weathered angular granulites; many fine, many medium pores; many fine roots; clear wavy boundary inclined parallel to the stone line.
BA 10-35 cm: red (2.5YR4/6 dry), dark reddish brown (2.5YR3/3 moist); clay; moderate, medium and coarse subangular blocks; hard, friable, sticky, plastic; common fine slightly weathered angular granulites; common, fine clay cutans; many fine, common medium pores; many fine, common medium and coarse roots; clear wavy boundary.
B 35-60 cm:yellowish red (5YR4/6 dry), reddish brown (5YR4/4 moist); clay; moderate, medium subangular blocks; slightly hard, friable, sticky, plastic; many fine slightly weathered angular granulites; common, fine and medium clay cutans; many fine, common medium pores; many fine, common medium and coarse roots; clear wavy boundary.
BC 60-120+ cm:yellowish red (5YR4/6 moist); clay; weak, fine and medium subangular blocks; friable; oblique stoneline of many fine and medium slightly weathered angular granulites; common, fine clay cutans; many fine pores; common fine roots.

Table 1. Analytical data for profile LTP1

Horizon		Ap	BA	Bt	Bt/C
Depth	cm	'0-10	'10-35	'35-60	'60-120
Clay	%	26	36	24	24
Fine silt	%	12	12	14	12
Coarse silt	%	8	8	10	12
Sand	%	54	44	52	52
Silt/clay	Ratio	1.3	0.6	1	1
pH H2O	1:2.5	7.4	7.5	7.6	7.9
pH KCl	1:2.5	5.5	5.1	5	5.1
EC	dS/m	0.03	0.03	0.02	0.03
OC	%	0.49	1.58	0.82	0.36
Total N	%	0.05	0.14	0.05	0.02
C/N		10	12	16	18
Bray I P	mg/kg				
Olsen P	mg/kg	7.4	4.07	7.46	
CEC	cmol/kg	7.18	8.98	7.15	5.98
Ca	cmol'kg	5.4	6.2	5.6	4.9
Mg	cmol/kg	2.6	4.2	2.9	2.8
K	cmol/kg	0.08	0.08	0.01	0.01
Na	cmol/kg	0.05	0.05	0.05	0.06
BS	%	100	100	100	100

Profrile number: BGP-1 Mapping unit: M2
Agroecol zone:
Region: Morogoro District: Morogoro Urban
Map sheet no.: 183 Coordinates: 6o49'22" S/37o43'18" E Location: Bigwa
Elevation: 450 m
Parent material: Horblende pyroxene granulites with some banded pyroxene granulites of the Uluguru mountains
Landform: Strongly dissected ridge crests and slopes
Slope (%): 10; slightly convex
Surface characteristics: Severe sheet and rill erosion
Deposition: None Natural drainage class: Well drained
Described by B.M. Msanya, D.N. Kimaro and J.D.J. Mbogoni on 05/07/1999.

Ap 0-15 cm: dark brown (7.5YR3/4 moist); sandy clay; moderate medium angular blocks; friable, sticky, plastic; high biological activity; many fine and medium pores; many fien, very few medium roots; clear wavy boundary.
Bt 15-55 cm: strong brown (7.5YR4/4 moist); clay; weak, medium and coarse angular blocks; hard, friable, sticky, plastic; many fine clay cutans; common fine, few medium pores; common fine, very few medium roots; clear wavy boundary.
Bts1 55-120 cm: reddish brown (5YR4/4 moist); clay; weak, medium angular blocks; very friable, sticky, plastic; few fine clay skins; many very fine pores; common fine roots; clear smooth boundary.
Bts2 120-200 cm: reddish brown (5YR4/4 moist); clay; weak medium angular blocks; very friable, sticky, plastic; few fine clay skins; many very fine pores; few fine roots.

Table 2. Analytical data for profile BGP-1

Horizon		Ap	Bt	Bts1	Bts2
Depth	cm	'0-15	'15-55	'55-120	'120-200
Clay	%	44	60	60	60
Fine silt	%	10	8	3	3
Coarse silt	%	6	2	7	9
Sand	%	40	30	30	28
pH H2O	1:2.5	7.4	7.5	7.6	7.9
pH KCl	1:2.5	5.5	5.1	5	5.1
EC	dS/m	0.03	0.03	0.02	0.03
OC	%	0.49	1.58	0.82	0.36
Total N	%	0.05	0.14	0.05	0.02
C/N		10	12	16	18
Bray I P	mg/kg				
Olsen P	mg/kg	7.4	4.07	7.46	
CEC	cmol/kg	7.18	8.98	7.15	5.98
Ca	cmol'kg	5.4	6.2	5.6	4.9
Mg	cmol/kg	2.6	4.2	2.9	2.8
K	cmol/kg	0.08	0.08	0.01	0.01
Na	cmol/kg	0.05	0.05	0.05	0.06
BS	%	100	100	100	100

Profrile number: BGP-2 Mapping unit: P4
Agroecol zone:
Region: Morogoro District: Morogoro Urban
Map sheet no.: 183 Coordinates: 6o49'03" S/37o43'02" E Location:
BigwaElevation: 450 m
Parent material: Colluvium derived from horblende pyroxene granulites of the Uluguru mountains Landform: Alluvial fan Slope (%): 10; slightly convex
Surface characteristics: Severe sheet and rill erosion Deposition: None
Natural drainage class: Well drained
Described by B.M. Msanya, D.N. Kimaro and J.D.J. Mbogoni on 05/07/1999.

Ap 0-20 cm: dark brown (7.5YR3/3 moist); sandy clay to clay; weak, fine and medium subangular blocks; very friable, sticky, plastic; many fine pores; many fine, few medium roots; clear wavy boundary.
BAt 20-42 cm: yellowish red (5YR4/6 moist); moderate medium angular blocks; friable, sticky, plastic; few medium krotovina; many thin clay skins; many fine and medium, very few coarse pores; many fine, few coarse roots; clear wavy boundary.
Bts1 42-55 cm: yellowish red (5YR4/6 moist); moderate medium angular blocks; friable, sticky, plastic; few medium; many thin clay skins; many fine and medium pores; many fine roots; clear wavy boundary.
Bts2 55-75 cm: red (2.5YR4/8 moist); sandy clay; weak, medium and coarse angular blocks; very friable, very slightly sticky, very slightly plastic; common thin clay skins; many fine pores; common fine roots; diffuse smooth boundary.
Bts3 75-212+ cm: red (2.5YR4/8 moist); sandy clay; weak, medium and coarse angular blocks; very friable, very slightly sticky, very slightly plastic; few thin clay skins; many fine pores; common fine, few coarse roots.

Table 3. Analytical data for profile BGP-2

Horizon		Ap	BAt	Bts1	Bts2	Bts3
Depth	cm	'0-20	'20-42	'42-55	'55-75	'75-212
Clay	%	42	58	68	62	58
Fine silt	%	16	8	6	8	10
Coarse silt	%	4	4	2	4	4
Sand	%	38	30	24	26	28
pH H2O	1:2.5	7.4	7.3	6.7	6.3	6.4
pH KCl	1:2.5	5.6	5.5	5.1	4.7	4.7
EC	dS/m	0.05	0.05	0.07	0.06	0.05
OC	%	0.36	1.64	0.68	0.68	0.32
Total N	%	0.02	0.14	0.05	0.04	0.02
C/N		18	12	14	17	16
Bray I P	mg/kg			1.61	1.03	0.68
Olsen P	mg/kg	7.67	6.65			
CEC	cmol/kg	12.16	16.45	20.14	18.17	16.42
Ca	cmol'kg	8.8	12.6	12.8	9.3	8.4
Mg	cmol/kg	4.7	5.3	4.9	4.3	4.6
K	cmol/kg	0.16	0.18	0.2	0.11	0.07
Na	cmol/kg	0.05	0.06	0.05	0.05	0.05
BS	%	100	100	89	76	79

Profrile number: MKP-1 Mapping unit: P4
Agroecol zone:
Region: Morogoro District: Morogoro Urban
Map sheet no.: 183 Coordinates: 6o43'36" S/37o38'51" E Location: Mkundi
Elevation: 465 m
Parent material: Banded muscovite biotite sediments and superficial sands
Landform: Alluvial fan Slope (%): 6; slightly convex
Surface characteristics: Moderate sheet and gully erosion Deposition: None
Natural drainage class: Well drained
Described by B.M. Msanya, D.N. Kimaro and J.D.J. Mbogoni on 03/07/1999.

Ah 0-15 cm: yellowish red (5YR4/6 dry), reddish brown (5YR4/4 moist); loamy sand; weak, moderate subangular blocks; slightly hard, friable, non sticky, non plastic; few pieces of charcoal; many fine and medium pores; common fine and very fine, few coarse roots; gradual smooth boundary.
BA 15-35 cm: yellowish red (5YR4/6 dry), reddish brown (5YR4/4 moist); loamy sand; weak, fine and medium subangular blocks; slightly hard, friable, slightly sticky, slightly plastic; very few, fine , slightly weathered, irregular quartz gravel; few fine krotovina; very few thin clay skins; many fine and medium pores; few medium and coarse, few fine and very fine roots; gradual smooth boundary.
Bw1 35-75 cm: red (2.5YR4/6 dry), dark reddish brown (2.5YR3/4 moist); sandy clay loam; moderate medium subangular blocks; slightly hard, friable, sticky, plastic; common fine and medium slightly weathered angular quartz gravel; very few thin clay skins; common fine pores; few very fine and medium roots; gradual smooth boundary.
Bw2 75-160+ cm: reddish brown (2.5YR4/4 dry), dark reddish brown (2.5YR3/4 moist); sandy clay; moderate medium subangular blocks; slightly hard, friable sticky, plastic; many fine and medium slightly weathered angular quartz gravel; common fine pores; few very fine and medium pores.

Table 4. Analytical data for profile MKP-1

Horizon		Ah	BA	Bw1	Bw2
Depth	cm	'0-15	'15-35	'35-75	'75-
Clay	%	12	18	26	28
Fine silt	%	6	6	2	2
Coarse silt	%	2	2	4	2
Sand	%	80	74	68	62
pH H2O	1:2.5	6.9	7.1	7.2	7.7
pH KCl	1:2.5	5.4	4.7	4.4	4.5
EC	dS/m	0.02	0.02	0.02	0.03
OC	%	0.66	0.38	0.26	0.19
Total N	%	0.07	0.04	0.03	0.02
C/N		9	10	9	10
Bray I P	mg/kg	3.7			
Olsen P	mg/kg		14.74	8.08	2.58
CEC	cmol/kg	5.32	6.52	7.26	8.15
Ca	cmol'kg	3.3	4.2	5	5.8
Mg	cmol/kg	1.8	2.4	2.7	3.1
K	cmol/kg	0.05	0.05	0.04	0.01
Na	cmol/kg	0.03	0.05	0.06	0.09
BS	%	98	100	100	100

Profrile number: MDP-1 Mapping unit: L3
Agroecol zone:
Region: Morogoro District: Morogoro Urban
Map sheet no.: 183 Coordinates: 6o38'47.7" S/37o39'01.5" E Location: Modeco
Elevation: 410 m
Parent material: Colluvium with variable mineralogical composition
Landform: Ridge slope Slope (%): 6; slightly convex, middle part
Surface characteristics: Slight sheet erosion Deposition: None
Natural drainage class: Well drained
Described by B.M. Msanya, D.N. Kimaro and J.D.J. Mbogoni on 04/07/1999.

Ap 0-10 cm: brown (10YR4/3 moist); sandy clay loam; weak fine subangular blocks; friable, sticky, slightly plastic; many fine very few coarse pores; many fine roots; clear smooth boundary.
Bt1 10-60 cm: dark brown (7.5YR3/3 dry), dark brown (7.5YR3/2 moist); sandy clay; weak coarse columnar breaking to coarse angualr blocks; hard, friable, sticky, plastic; few thin patchy cutans; many fine, very few coarse pores; common fine, very few medium roots; gradual smooth boundary.
Bt2 60-115 cm: dark brown (7.5YR3/4 dry), dark brown (7.5YR3/3 moist); sandy clay; weak, very coarse angular blocks; hard, friable, sticky, plastic; common fine slightly weathered angular quartz gravel; few patchy clay cutans; many fine few medium pores; few fine roots; gradual smooth boundary.
BC 115-200 cm: strong brown (7.5YR4/6 dry), dark brown (7.5YR3/4 moist); sandy clay; weak coarse angular blocks; hard, friable, sticky, plastic; many, fine and medium slightly weathered angular quartz gravel; few patchy clay cutans; 2-3 cm thick stoneline on upper part of horizon; very few fine roots; abrupt wavy boundary.
C 200+ cm: Slightly weathered gneiss.

Analytical data for profile MDP-1

Horizon		Ap	'Bt1	'Bt2	BC
Depth	cm	'0-10	'10-60	'60-115	'115
Clay	%	24	26	32	34
Fine silt	%	4	4	8	10
Coarse silt	%	8	12	8	2
Sand	%	64	58	44	54
pH H2O	1:2.5	8.6	8.6	8.5	8.1
pH KCl	1:2.5	6.6	6.4	6.6	7
EC	dS/m	0.11	0.06	0.12	0.39
OC	%	0.98	0.89	0.68	0.27
Total N	%	0.08	0.08	0.04	0.02
C/N		12	11	17	14
Bray I P	mg/kg				
Olsen P	mg/kg	8.23	9.27	13.67	22.4
CEC	cmol/kg	7.34	7.35	9.43	10.4
Ca	cmol'kg	7.8	6.9	9.1	8.7
Mg	cmol/kg	3.2	4.3	5	5.4
K	cmol/kg	0.21	0.03	0.02	0.14
Na	cmol/kg	0.06	0.05	0.06	0.11
BS	%	100	100	100	100