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LAND RESOURCES INVENTORY AND SUITABILITY ASSESSMENT FOR THE MAJOR LAND USE TYPES IN MOROGORO URBAN DISTRICT, TANZANIA

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PREFACE AND ACKNOWLEDGEMENTS

This work is a semi-detailed explanatory report for the soil map of Morogoro Urban District, Tanzania at a scale of 1:50,000. It contains information that can be used for general land use planning activities in the area, particularly for the production of the major crops (maize, rice, sorghum, beans, banana and vegetables). The report will be a useful tool for use by the Researchers, District Agricultural & Livestock Development Officer (DALDO) and District Extension Officers in delivering their advisory services to farmers. Description of soil properties is given in both report and map (in form of mapping units), which identify the constraints and potentials of the study area. Since the study area includes the SUA farm, the work will be a very useful guideline for planning and management of research activities by SUA staff.

The authors wish to thank all those who in one way or another contributed to the successful completion of this work. Many thanks are due to the Norwegian Agency for Development Co-operation (NORAD) for providing funds to carry out this study through the SUA-NORAD TAN 091 project on Soils and Land Resources of Morogoro Rural and Urban Districts. Sincere thanks are also due to Dr. B.P. Mbilinyi of the Department of Agricultural Engineering and Land Planning, Sokoine University of Agriculture (SUA), for his technical assistance in Remote Sensing and Geographical Information Systems.

Prof. B.M. Msanya

Project leader May, 2001

EXECUTIVE SUMMARY

Land resources inventory and suitability assessment of Morogoro Urban District was carried out to asses the potentials and constraints of the various land units for the production of smallholder low input rainfed maize, rice, sorghum, beans, banana and vegetables. The study covered a total area of approximately 52,125 ha. Morogoro Urban District is situated almost at the heart of Morogoro District, between latitudes $6^{o}37'$ and $6^{o}55'$S and longitudes $37^{o}33'$ and $37^{o}51'$E. The district is bordered by Uluguru Mountains on the south eastern side and Mindu and Nguru ya Ndege hills on the western side. A bigger part of the district comprises plains of various forms and areal extent.

Relief and slope aspect have a great influence on the climate of 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 rainfall reveals a similar influence of altitude on rainfall. Rainfall is higher at high altitudes and tends to be lower at low altitudes. Areas on the leeward side of the Uluguru Mountains receive relatively lower rainfall than those on the windward side. The onset dates for rainfall are unreliable, although the rainy season continues for 4 to 5 months. During the growing period, rainfall is lowest in the month of May whereas peak rainfall is normally received in April. Climatic data of the district reveal a gradual decrease in rainfall from the east towards the west and northwest. In the Tungi-Mkonowamara areas a rather dry condition prevails. The SUA-Kingolwira areas receive relatively more rainfall than Tungi-Mkonowamara area. This trend can be attributed to the rainshadow effect of the Uluguru Mountains.

The geology of Morogoro Urban District comprises four major rock/lithology types. These include hornblende-pyroxene granulites, muscovite-biotite gneiss and migmatites, colluvium and alluvium. The hornblende-pyroxene granulites are the dominant rock types and occupy the major part of the Uluguru Mountains and foothills. The dominant minerals in these rocks are calcium-rich plagioclase, hypersthene ($(Mg,Fe)SiO_3$) and diopside ($Ca,MgSi_2O_6$). The muscovite-biotite gneisses and migmatites are dominant in the Mindu-Lugala hills and a bigger part of the Tungi-Mkonowamara peneplains. They are of a high metamorphic grade containing equal amounts of potassium-feldspars (microcline) and sodium-rich plagioclase (oligoclase). Quartz is present in fairly high amounts. Colluvial materials of diverse mineralogical composition dominate most of the piedmont slopes and peneplains. Alluvial materials are dominant in the river terraces and flood plains.

Climate and its effects on geological processes influence evolution of landforms in the study area. Marked influence on landforms by water erosion as well as colluvio-alluvial processes were observed in the field and through soil profile development. In the current study, six major landform types were identified in the district. The landforms of the Uluguru Mountains display a marked variation in altitude, relief and intensity of dissection. The strongly dissected ridges (1500-2000 m asl) are a manifestation of

intense erosion in form of mass movements. The Uluguru mountain foothills (600-900 m asl) are predominantly steep convex slopes. The Mindu-Lugala hills situated at an altitude range of 700-1100 m asl are strongly dissected with hilly topography. The Mzinga-Bigwa piedmonts consist of glacis and alluvial fans. They are gently sloping and are characterised by moderate to severe erosion. Extensive areas of alluvial fans and hill wash sands are found around the strongly dissected Mindu-Lugala hills. Whereas the piedmont slopes associated with the Uluguru Mountains are gently undulating, those of the Mindu-Lugala hills have an undulating topography. Other major important landforms in the district are the peneplains which are situated at an altitude of 300-600 m asl. The peneplains consist of ridge summits and slopes alternating with narrow valley bottoms. The valleys, being flat to almost flat with river terraces and flood plains occurring at an altitudes lower than 400 m asl.

Climate, landform patterns and parent materials have had profound influence on types and distribution of soils in the district. Soil profile development reveals marked influence of mass removal of soils by water erosion particularly mass movements in the mountains and colluvio-alluvial processes in the piedmont slopes and peneplains. There is a considerable variation in soil depth, texture, drainage condition and soil chemical properties among the landform units. The mountain ridge slopes have relatively shallow soils and gravely soil textures. This can be attributed to severe erosion caused by mass removal of soil materials mainly by high rainfall. The piedmont slopes and peneplains with colluvial material derived from granulites and mixed gneisses have very deep soils with high amounts of clay content. This is due to constant addition of new soil materials and *in situ* weathering coupled with low rate of erosion. Landforms associated with migmatites like Mindu-Lugala piedmont slopes and Tungi Mkonowamara peneplains have the highest amount of sand content. This can be explained by the nature of the parent materials which are richer in felsic minerals. Valley soils have medium textures and are stratified as a result of cyclic deposition of materials of diverse origin.

The mineralogy of the soils of the Uluguru Mountains, the piedmont slopes and the peneplains are mainly kaolinitic. The soils of the mountain ridges have high content of gibbsite in the clay fraction, which can be attributed to rapid weathering and strong leaching caused by high rainfall and excessive drainage. Soils of the river terraces and flood plains have relatively high contents of smectite and illite in the clay fraction, revealing the relative young age of the soils.

Soils of the mountains are slightly acidic to acidic (pH<5.5). Piedmonts have nearly neutral reaction (pH 6.0-7.5) except for the glacis which are strongly acidic (pH<5.5). Most soils of the peneplains are moderately acid except for those associated with migmatites, which are strongly acid (pH<5.5). Valleys have nearly neutral to alkaline soils with ESP ranging between 5 and 37%. Organic carbon and nitrogen levels for all soils are very low with values less than 1.0% and 0.1% respectively. Available P is also

low (<5 mg/kg). Nutrient retention capacity of soils is low (CEC <12 cmol(+)/kg) except in the valleys where nutrient retention is high (CEC 20-30 cmol(+)/kg).

According to FAO-World Reference Base nine major soil types were identified and classified. The soils of the strongly dissected mountain ridge slopes are Leptosols, Lixisols, Luvisols and Cambisols. Dominant soils on the piedmonts and peneplains are Lixisols and Acrisols while the ridge side slopes on the peneplains have soils classified as Cambisols. The soils of the river terraces and flood plains are Fluvisols, Vertisols and Gleysols while those of the Mindu hills and surrounding areas are classified as Leptosols, Cambisols and Arenosols.

Six major land utilisation types namely; smallholder low input rainfed maize, rice, sorghum, beans, bananas and vegetables were identified and evaluated in Morogoro Urban District. Land suitability classification indicates that, none of the land mapping units is highly suitable for all the studied land utilisation types. This is because its natural fertility has been depleted over time through leaching, erosion and nutrient mining through continuous cropping. Among the six LUTs, vegetable production was more suited to the area for it could be grown in about 80% of the area. Beans rank the second followed by maize. Sorghum was found to be the fourth LUT in the area while rice was the least. Moisture supply soil fertility and erosion hazards are among the most limiting factors for production of most crops in the area.

Deliberate efforts should be taken to establish critical zones for afforestation, reduce burning through introduction of by laws and appropriate training programmes, use of grass barriers and cultivation of perennial crops. Further research on soil erosion particularly mass movements, gullying and sheet wash is prerequisite in order to come up with acceptable soil conservation packages for the district.

It is strongly suggested that emphasis should be put on the use of organic and non acidifying fertilisers and afforestation of hilltops. Use of indigenous fertilisers such as rock phosphate and manures could immensely contribute to the improvement of soil fertility in Morogoro Urban District.

Water harvesting techniques, growing of drought tolerant crops and use of organic fertilisers will improve the sustainability of agricultural production in the area. The focus should be on the use of integrated nutrient management techniques.

Provision of drainage systems in the poorly drained areas will control and keep the ground water levels low. This will also enhance regular flushing of the soils thus avoiding the building up of harmful levels of salts. Saline soils could also be managed through proper crop selection and planting of saline tolerant crops. Sorghum withstands poor drainage condition and can cope very well with drought and saline conditions.

Frequent floods especially by the Ngerengere river could be reduced by flood protection works like construction of ditches and dikes with outlets to the present natural drainage system. Agricultural mechanisation and use of organic fertilisers will in the long run improve soil structure of the lands in the district and ultimately enhance soil workability.

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LIST OF ABBREVIATIONS

FAO	= Food and Agriculture Organization of United Nations
UNESCO	= United Nations Educational Scientific and Cultural Organization
USDA	= United States Department of Agriculture
NORAD	= Norwegian Agency for Development Co-operation
NSS	= National Soil Service
SUA	= Sokoine University of Agriculture
ILACO	= International Land Development Consultants
CEC	= Cation exchange capacity
ALES	= Automated Land Evaluation System
ESP	= Exchangeable sodium percent
MU-P	= Morogoro Urban profile (no. 1 - 25)
C:N	= Carbon to Nitrogen ratio
ETo	= Potential evapotranspiration
BS	= Base saturation
GIS	= Geographical Information Systems
LMU	= Land mapping unit
URT	= United Republic of Tanzania
LQ	= Land quality
LUR	= Land use rquirement
PRA	= Participatory Rural Appraisal
LUT	= Land utilisation type
SISTAN	= Soil Informatio System for Tanzania
WRB	= World Reference Base

1.0 INTRODUCTION

Morogoro region is one of the most productive agricultural area in Tanzania. This is partly attributed to relatively favourable climate and potentially fertile soils in the major 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 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 grown are cabbage, carrots, tomatoes, pepper and amaranthus. Despite the fact that Morogoro region has high potential for agricultural production, land productivity has remained low (Kileo, 2000; Mwango, 2000). The need to increase production is a prerequisite to supply food to the growing population both in rural and urban areas. Increasing production can be achieved to a great extent by formulation and implementation of proper land use planning policies. However, formulation of land use policies require knowledge on potential and constraints of the various agro-ecological zones which require proper soils and land resources data. For Morogoro region these data are limited and only available for few scattered areas.

The most recent soils and land resources information 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 an exploratory scale for land use planners, conservationists, agriculturists and other users. Although the document has been extensively used as reference material, its small scale has limited application in detailed planning for sustainable exploitation and conservation of the soil and land resources, necessitating the need for more 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 SUA-NORAD frame agreement, funds were made available for carrying out a soil and land resources survey of Morogoro district. Administratively, the district comprises of two units namely Morogoro Urban District and Morogoro Rural District respectively. Findings of the study will serve as a dynamic and multidisciplinary database for planning purposes in the two districts. The current study was aimed at mapping the soils and land resources of Morogoro Urban District and to evaluate their potentials and constraints for various uses. Specifically the study addressed the following objectives:

(i) To characterise the soils and land resources of the area
(ii) To map the soils and land resources at the scale appropriate for the above objective
(iii) To generate and provide database for land resources in sufficient detail for use by SUA researchers, land use planners and farmers in the district
(iv) To asses the suitability of the district with respect to production of major crops.

2.0 MATERIALS AND METHODS

2.1 Pre-field work

Aerial photograph films 1695 (49-56; 64-71; 114-122; 144-151) and 1696 were interpreted to identify major landscapes featurs, relief and landforms in the study area. A photo interpretation map of the district was then transferred to topographic map sheets 183/1 (Nguru ya Ndege), 183/2 (Mkonowamara), 183/3 (Morogoro) and 183/4 (Kingolwira) (Survey and Mapping Division, 1970). Geological information available in Quarter Degree Sheet 183 (Geological Survey Department, 1961) was incorporated in the map to form a landform-geology base map at 1:50,000 scale to serve as a base map for field identification of soils.

2.2 Field work

Visual observations were made to confirm major landforms identified during interpretation of remote sensing information. Apart from the geological 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. A combination of both free survey (Dent and Young, 1981) and transect observations were used to collect data on landforms and soil related properties.

In each mapping unit soil observations by hand augering were made to a maximum depth of 1.5 m to characterise soils. Soils identical in landforms, parent material, relief, topography and morphology were considered to be similar and were accorded a similar mapping unit. 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). Site characteristics and soil profile morphology were the main features which were inventoried. From each natural soil horizon a bulk soil samples were collected for laboratory analysis.

2.3 Post fieldwork

2.3.1 Laboratory analysis

Texture was determined by Bouyoucos hydrometer method (Day, 1965) after dispersing soil with calgon. PH was measured in water at the ratio of 1:2.5 soil-water. Organic carbon was determined by the Walkley and Black method (Nelson and Sommers, 1982). Kjeldahl method (Bremner and Mulvaney, 1982 was used 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 CEC and exchangeable bases were extracted by saturating soils with neutral 1M NH_4OAc (Thomas, 1982) and the absorbed NH_4^+ displaced by K^+ using 1M KCl and then determined by Kjeldahl distillation method for the estimation of CEC of the soil. The bases Ca^{2+}, Mg^{2+} K^+ and Na^+ displaced by NH_4^+ were measured by atomic absorption spectrophotometer. X-ray diffraction analysis was done for subsoil clay samples (Dixon and Weed, 1989; Msanya *et al.*, 1998).

2.3.2 Soil classification

Using both field and laboratory data, the soils were classified to level-3 of the FAO World Reference Base (FAO, 1998), and to subgroup level of the USDA Soil Taxonomy (Soil Survey Staff, 1999).

2.3.3 Compilation of soil map and legend

The following map polygons were delineated on the basis of the following hierarchy elements:
Major landscape, parent material, landforms and altitude, dissection and relative position on the landscape, slope classes and soil properties. The legend is given on the soil map (back cover). Each mapping unit has a symbol referring to the landform. Further sub division is based on slope class and soil characteristics and is indicated by a number followed by the capital letter. The "soil description " column in the legend gives the main characteristics of the soil types i.e. soil depth, drainage, colour, texture and other diagnostic characteristics that separate each soil unit from the others identified.

2.4 Land evaluation

The land evaluation method applied in this study basically follows the procedures laid down in the FAO Framework for Land Evaluation (FAO, 1976). Firstly the land utilization types (LUTs) were described. Data on land resources and socio-economics were coded using land characteristics specification dictionary into a digital data base file. This step was followed by the comparison of the optimal environmental requirements of the LUTs with the actual conditions of the land a process refered to as matching. The matching process in this study was done using the Automated Land Evaluation System (ALES) programme (Rossiter and Van Wambeke, 1989; 1994). The tracts of the land being used for suitability assessment in this study are land mapping units of the physiography and soil map (Back cover).

2.4.1 Description of the land utilisation types (LUTs)

Land utilisation types in the study area were selected and described on the basis of field observations, farming systems, produce (varieties grown), labour input, farm size, land tenure, yields and prices of the produce as obtained by farmers. Information on land utilisation types was also used to generate data for screening by ALES.

2.4.2 Rating of land use requirements (LURs)

Land suitability in this study was assessed on the basis of those land use requirements (LURs) that were considered diagnostic for the identified LUTs. In the study area the diagnostic LURs taken into consideration are: moisture availability, nutrient availability, nutrient retention capacity, erosion hazard, temperature regime, oxygen availability to root zone, wetness and rooting conditions. LURs are composed of certain land

characteristics (LCs). For example the LUR "Nutrient retention capacity" is composed of the LCs "apparent CEC, sum of basic cations and percentage base saturation".

Using land characteristics specifications and land use requirements, the expert models in the form of decision trees for each specific land utilisation type were constructed in ALES programme. These are structured representations of the reasoning processes (expert knowledge system) needed to reach decisions. Class limit sets in the decision trees for the selected LUTs were mainly based on literature sources and information obtained from PRA and field observations. Rating of the LURs was done using severity levels as follows: (1) no limitation, (2) moderate limitation, (3) severe limitation and (4) very severe limitation.

2.5 Land suitability classification

Land suitability classification takes into account sustainable use of the lands basing on the environmental resources (physical suitability) and socio-economic factors (economic suitability) (FAO, 1976, Kimaro and Kips, 1991, Rossiter, 1995, 1996). In this study only physical suitability was considered.

5.2.1 Physical suitability classification

Physical suitability ratings of the mapping units were determined using decision trees severity levels constructed in ALES computer programme. The rating followed the Liebig's law of minimum (Rossiter and Van Wambeke, 1989), by which the most limiting LUR determines the suitability class. Four physical suitability classes were defined as (1) good potential, (2) moderate potential, (3) poor potential and (4) very poor potential. In the evaluation, ALES was used to predict yields on the basis of limiting yield factors. Predictions were made by multiplying the chosen yield factors with the optimum attainable yield. The yield factors used were derived from the proposed FAO suitability classes i.e. 80 - 100 % S1, 40 - 80 % S2, 20 - 40 % S3, and 0 - 20 % N of the optimum yield (FAO, 1984). The ALES yield factors were class 1 = 1, class 2 = 0.8, class 3 = 0.4 and class 4 = 0.2. These factors were used to predict the final physical suitability classification.

3.0 RESULTS AND DISCUSSIONS

3.1 Physical environment

3.1.1 Location

Morogoro Urban District is situated almost at the heart of Morogoro district, between $6^{o}37'$ and $6^{o}55'$S and $37^{o}33'$ and $37^{o}51'$E. The district is bordered by Uluguru Mountains on the south eastern side and Mindu and Nguru ya Ndege hills on the western side. A bigger part of the district comprises plains of various forms and extent.

3.1.2 Climate

The climatic characteristics were analysed to determine trends and seasons during an

average year from long term records. Potential evapotranspiration (ET_o) was determined according to the Penman and Monteith formular available in CropWat (FAO, 1992). Length of dry, intermediate and humid periods were determined according to following definitions:

-dry period rainfall being lower than $0.5ET_o$
-intermediate period rainfall being higher than $0.5ET_o$ but lower than ET_o
-humid period rainfall being higher than ETo
-beginning of rainfall rainfall being equal to or higher than $0.5ET_o$ following a dry season
-end of rainfall rainfall being equal to or lower than $0.5ET_o$ following an intermediate or a humid period
-end of growing period evapotranspiration of 100 mm of soil water following end of rainfall

Relief and slope aspect have had a great influence on climate of the district. Areas higher in altitude such as Uluguru Mountains are cooler than the plains. The trend of rainfall reveals a similar influence of altitude on rainfall. Rainfall is higher in areas of high altitude and tends to be low at low altitude areas. Areas on the leeward receive relatively lower rainfall than those on the positive side. 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).

The Morogoro Urban District falls 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 Morogoro Urban District are presented in Figure 1.

Onset dates for rainfall is unreliable. However, The main rain season starts from March to May with peak rainfall in the month of April. Generally daily temperatures are higher than 20°C throughout the year. Highest temperatures are experienced during the months of December to March coinciding with the dry season. Wind speed is relatively constant except for the months of November and December, which have relatively high wind speeds during the year.

As distance from the Uluguru Mountains increases towards the plains aridity intensifies. This trend can be attributed to the rain shadow 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 Kingolwira are receiving relatively more rainfall 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 (rain shadow) on rainfall. Relative air humidity is highest during the months of April and May, coinciding 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 rainfall.

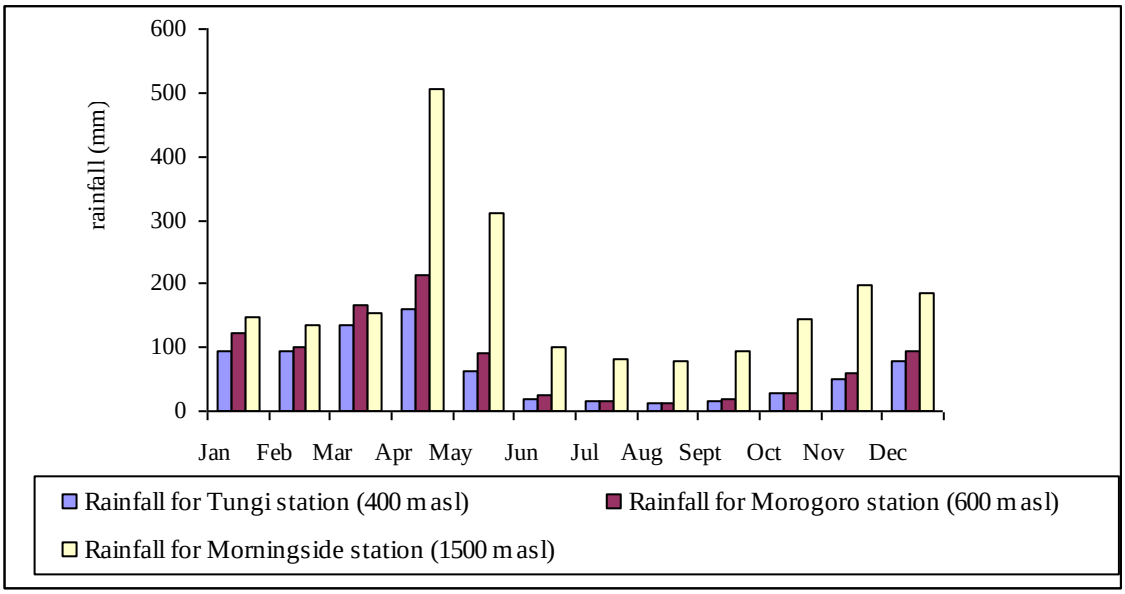

Figure 1. Mean monthly rainfall data for Morogoro Urban District

3.1.3 Geology and landforms

Geology

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.

Hornblende-pyroxene granulites with some banded 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 ($Ca,MgSi_2O_6$) types. Hypersthene is the commonest mineral in these granulite metamorphic facies although it is the unstable mineral. Other common and unstable minerals are oligoclase-andesine plagioclase, scapolite and hornblende. (Sampson and Wright, 1964).

Muscovite-biotite gneisses and migmatites

These gneisses are of a high metamorphic grade and are the dominant geological material in the Mindu, Lugala and Msembe hills and a bigger part of peneplain ridge crests north east of Tungi and Kingolwira (Sampson and Wright, 1964). They contain equal amounts of potassium-fedspars (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 pegmatites in these rocks contain lenses of pure microcline and quartz, with macrocrystals of muscovite and biotite (Bates and Jackson, 1980).

Colluvium and alluvium

Colluvial materials of diverse mineralogical composition dominate most of the piedmonts and peneplains. The predominant colluvial materials are derived from metasedimentary rocks rich in 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 Msaky (1983) reported presence of high amounts of easily weatherable minerals biotite, chlorite and epidote in these landscapes. Smectite was also reported to be present in soils, being a probable result of transformation of vermiculite layers by oxidation processes.

Landforms

During this study four major types of landforms were identified in the study area. The first landforms 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 display marked variation 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 (Sampson and Wright, 1964).

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 are the products of intense erosion. Talus slopes are extensive in the Ulugurus. These are the consequences of erosion, landslides and rockfalls (Kimaaro *et al*., 1999). The peculiar characteristics are severe erosion and presence of scars of landslides and rock falls. Strongly dissected hills comprising mainly of Mindu, Lugala and Msembe hills are part of the mountainous landscape. They are situated at an altitude range of between 700-1100 m.

The second landform type comprises 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. Alluvial fans, as part of the piedmonts, are situated at almost uniform altitude range. Extensive alluvial fans are situated around the strongly dissected Mindu, Lugala and Msembe hills. The second set of alluvial fans is associated with the Uluguru Mountains in areas around Bigwa. Whereas the alluvial fans associated with the Uluguru Mountains are almost flat to a gently undulating, those around Mindu, Lugala and Msembe hills have an undulating topography.

The third major landform consists 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 form the most extensive land unit in the district. 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 landforms consist of valleys, being flat to almost flat river terraces and flood plains at altitudes lower than 500 m. The Ngerengere flood plain is a typical example.

3.1.4 Natural vegetation

Woodlands occupy the major part of the foothills and some areas in the plains. These are mainly *Miombo* type of trees (*Brachystegia* spp.), with *Hyparrhenia* as the most dominant grass species. 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

South and South east to relatively semi-arid. Canopy cover in the plains is being affected by deforestation for fuel wood, building poles, charcoal making and overgrazing.

Woodlands and forests are the dominant vegetation cover types in the Uluguru Mountains. Apart from *Brachystegia* and *Milicia* sp. some of the tree species are submontane rain forests 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.

Grasslands are dominant in the cultivated lands. Most of the forest and woodland vegetation were cleared for cultivation. The land cover of grasses and herbs is therefore seen mainly in lands under fallow.

3.1.5 Present land use

Agriculture and livestock production

A bigger area of the district is under subsistence cultivation of annual crops maize, sorghum, millet and vegetables either in pure stand or mixed cropping. Paddy is being grown in river terraces and flood plains. On average, farm size is in the range of 0.5 to 2 acres. Family labour is therefore the most important source of farm power, facilitating hand tilling of the fields. Mechanised estate cultivation of sisal is occupying a significant part of the plains in the district. Sisal is being grown for fibre production. 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. Most of the milk and milk products are being consumed within the district.

Forestry

Thick forest reserves exist in the south-eastern 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.

Industry

Most industrial activities in the district used to be sisal processing, particularly decortication, brushing and baling. However, the mid 1970s saw expansion of industrial activities. Grain milling, tobacco processing, textile, tanneries, shoe factories and oilseed processing were launched during this period. Presently, a wide range of industrial establishments is taking place at a rather fast rate. Some of the new industrial activities include soap production and tobacco processing.

3.1.6 Soils

General description

Climate and its effects on vegetation and geological processes have controlled the landscape and soil evolution in the study area. Landform patterns and geology have had profound influence on types and distribution of soils in the area (Msanya *et al*., 2000). Soil profile development reveals markable influence of mass removal of soils by water erosion, landslides and rockfalls as well as the influence of alluvio-colluvial processes. Similar observations were reported by Moberg *et al*., 1982 and Kimaro *et a.,* 1999. Climate, parent material and relief show close connection with the mineralogical composition and edaphological properties of the soils in the Uluguru and Mindu toposequences (Msanya, 1980; Msanya and Msaky, 1983). Mineralogically the Uluguru soil asociation has a high content of kaolinite and Fe-oxyhydroxides in the clay fraction of the well drained soils. The silt fraction in these soils contains substantial amounts of kaolinite and Fe-oxyhydroxides. This is due to the presence of highly stable micro-peds in that fraction. In the Uluguru Mountains, high content of gibbsite in the clay fraction is attributed to rapid weathering and strong leaching caused by high rainfall and excessive drainage (Moberg *et al.,* 1982). Msanya and Msaky (1983) concluded that the parent materials of soils in the study area are the same as shown by relatively high comparative particle size distribution indices (C.P.S.D) within and between profiles, mixed clay mineralogy, similar heavy and light mineral content and dominance of quartz in all soils (Msanya 1980).

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 lower 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 high 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) are sandy loams to sandy clay loams with mixed mineralogy.

In this study soils were studied in the Uluguru Mountains, Ngerengere river and Mindu Mountain toposequence. Soils of the strongly dissected ridge slopes are generally shallow to moderately deep, well drained, red clays and brown sand clay loams classifying as Lixisols, Luvisols and Cambisols. On the piedmonts, the soils are deep, well drained, brown friable sandy clay loams and red friable clays classifying as Lixisols and Acrisols. Dominant soils on the glacis and peneplains are very deep, well drained, brown friable sandy clays and red friable clays classifiyng as Acrisols and Lixisols.

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. Flood plains have very deep, imperfectly to poorly drained, brown and grayish brown stratified micaceous sandy clay loams and clay loams classifying as Fluvisols. In the lower part of the alluvial fan around Mindu hills are moderately deep to deep, moderately well drained, brown friable sandy loams and sandy clay loams classifying as Cambisols. The rest of the alluvial plain has moderately deep to deep, well drained brown friable sandy loams and sandy clay loams classifying as Cambisols. Soils of the Mindu hills are shallow to moderately deep, well drained, brown friable sandy loams and sandy clay loams classifying as Cambisols and Leptosols.

Soil physico-chemical and mineralogical properties

There is considerable variation in soil depth, texture, drainage condition and chemical properties of the soils in the District (Table 1).The mountain ridge slopes have relatively shallow soils and gravely soil textures. The pidmont slopes and paneplains have very deep soils with high amounts of clay content. The soils of the landforms associated with Mindu Lugala slopes and Tungi Mkono wa Mara paneplains have the highest amount of sand content. Valley soils have medium textures.

Soils of the mountains are slightly acidic to acidic (pH<5.5). Piedmonts have nearly neutral reaction except for the glacis which are strongly acidic. Most soils of the peneplains are moderately acid except for those associated with migmatites, which are strongly acid (pH<5.5). Valleys have nearly neutral to alkaline soils with ESP ranging between 5 and 37%. Organic carbon and nitrogen levels for all soils are very low with values less than 1.0% and 0.1% respectively. Available P is also low (<5 mg/kg). Nutrient retention capacity of soils is low (CEC <12 cmol(+)/kg) except in the valleys where nutrient retention is high (CEC 20-30 cmol(+)/kg).

Table 1. Physico-chemical properties and clay mineralogy of the soils of Morogoro Urban District

Landform	Soil depth	Soil drainage	Soil texture	pH	OC %	N %	P mg/kg	ESP	CEC cmol(+)/kg	BS %	Clay mineralogy
Uluguru mountain strongly dissected ridge slopes (Units M1, M2, M3)	S-MD	E-W	grSCL, SC-C	5.5-6.0	0.1-1.2	0.01-0.05	1.0-5.0	Tr	4.0-12.0	20-85	kaolinite (84%), gibbsite (7%), illite (5%), mica-vermiculite (4%)
Uluguru mountain foothills (Unit P1)	D-VD	W	SC-C	5.0-6.5	0.5-1.0	0.01-0.10	1.0-2.0	Tr	10.0-13.0	30-65	kaolinite (80%), mica-vermiculite (8%), illite (6%), gibbsite (6%)
Mindu-Lugala hills (Units M4, L1)	S	E	grSL-SCL	5.5-6.5	0.3-0.8	0.03-0.06	2.0-3.0	Tr	7.0-10.0	70-95	kaolinite (55%), illite (35%), smectite (10%),
Mzinga-Bigwa piedmont slopes (Units P2, P3),	VD	W	C	6.0-7.5	0.2-0.60	0.03-0.05	0.4-1.0	Tr	6.0-10.0	80-100	kaolinite (85%), illite (8%), gibbsite (6%), smectite (1%)
Mindu-Lugala piedmont slopes (Unit P4)	VD	E-W	LS-SL	6.0-7.0	0.3-0.4	0.04-0.08	0.7-1.4	Tr	8.0-14.0	80-100	kaolinite (50%), smectite (16%), illite (34%)
SUA-Kingolwira peneplains with undulating slopes (Units L2, L3)	D-VD	W	SC-C	4.5-6.5	0.3-0.7	0.04-0.05	1.2-1.8	Tr	10.0-12.0	25-45	kaolinite (78%), illite (10%), smectite (7%), mica-vermiculite (5%),
Tungi-Mkonowamara peneplains (Units L4, L5, L6)	MD-D	E-W	LS, SL-SCL	4.5-5.5	0.3-0.5	0.04-0.08	1.0-1.5	Tr	9.0-11.0	30-40	kaolinite (48%), smectite (20%), illite (32%)
Valleys with river terraces and floodplains (Units V1, V2)	VD	MW-P	L, CL-C	6.5-8.0	0.6-1.6	0.06-0.10	8.0-9.0	5-37	20.0-30.0	75-80	kaolinite (40%), smectite (26%), illite (30%), gibbsite (4%)

S=Shallow, MD=Moderately deep, D=Deep, VD=Very deep.E=Excessively drained, W=Well drained, MW=Moderately well drained, P=Poorly drainedtr=trace

3.2 Description of mapping units

The soils were described and distinguished on the basis of landforms, relief, parent material, soil morphology and chemical properties. Soil profiles representing the major land units are presented in Appendix 1. An accompanying soil map with a descriptive legend is presented the back cover. The different soil types were mapped as complexes, and associations. A concise description of the mapping units is therefore presented in conformity to the legend construction.

Mountains (M)

Soils developed on hornblende pyroxene granulites with some banded pyroxene granulites

Mapping unit M1
Strongly dissected ridges (1500-2000 m), 50-more than 80 % slopes. The soils are a **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 classify as *Hapli-Lithic Leptosols, Hapli-Orthieutric Regosols* and *Cutani-Profondic Luvisols.* Profiles **MU-P1, MU-P2** and **MU-P3** are representative

Mapping unit M2
Moderately to strongly dissected ridge crests and slopes (1000-1500 m), 30-80 % slopes. The soils are an **Association of:** shallow and 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. The soils classify as *Haplic Phaeozems, Hapli-Epidystric Cambisols* and *Profondi-Stagnic Lixisols*. Profiles **MU-P4, MU-P5** and **MU-P6** are representative

Mapping unit M3
Talus slopes (700-1300 m), 10-25 % slopes. The soils are a **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. The soils classify as *Haplic Phaeozems* and *Ferri-Profondic Lixisols*. Profiles **MU-P7** and **MU-P8** are representative

Table 2. Salient site features, landform, and soils of the study area

Map symbol	Landform (elevation m asl)	Dominant slope (%)	Soil description	Area (ha)
Mountains (M) **Soils developed on hornblende pyroxene granulites with some banded pyroxene granulites**				
M1	Strongly dissected ridges (1500-2000)	50->80	**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 classify as *Hapli-Lithic Leptosols*, *Hapli-Orthieutric Regosols* and *Cutani-Profondic Luvisols.* Profiles **MU-P1, MU-P2** and **MU-P3** are representative	1550
M2	Moderately to strongly dissected ridge crests and slopes (1000-1500)	30-80	**Association of:** shallow and 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. The soils classify as *Haplic Phaeozems*, *Hapli-Epidystric Cambisols* and *Profondi-Stagnic Lixisols*. Profiles **MU-P4, MU-P5** and **MU-P6** are representative	3817
M3	Tallus slopes (700-1300)	10-25	**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. The soils classify as *Haplic Phaeozems* and *Ferri-Profondic Lixisols*. Profiles **MU-P7** and **MU-P8** are representative	1043
Soils developed on muscovite-biotite migmatites				
M4	Strongly dissected hills	45-80	**Complex of:** rockland **and** very shallow, excessively drained dark reddish brown sandy clay loams over extremely gravely materials. The soils classify as *Hapli-Lithic Leptosols.* Soil profile **MU-P3** is representative	3547
Piedmonts (P) **Soils developed on colluvium derived from hornblende pyroxene granulites and micaceous gneiss**				
P1	Foothills (600-1000)	15-45	**Complex of:** very deep, well drained dark red to red clays with thin dark reddish brown clay topsoils **and** deep, well drained dark red to red clays with thin dark brown sandy clay topsoils. Stonelines comprising mainly of fresh angular quartz gravel and stones are common. The soils classify as *Hapli-Profondic Acrisols* and *Hapli-Chromic Lixisols*. Profiles **MU-P9** and **MU-P10** are representative	2805
P2	Glacis (540-600)	2-15	**Complex of:** very deep, well drained red sandy clays with very thin dark brown sandy clay topsoils **and** very deep, well drained strong brown to reddish brown clays with thick dark brown clay topsoils. The soils classify as *Chromi-Profondic Luvisols* and *Chromi-Profondic Lixisols*. Profiles **MU-P11** and **MU-P12** are representative	1973

Table 2 continue

Map symbol	Landform (elevation m asl)	Dominant slope (%)	Soil description	Area (ha)
Soils developed on colluvial/alluvial deposits derived from hornblende pyroxene granulites and micaceous gneiss				
P3	Alluvial fan (500-550)	0-2	Very deep, well drained yellowish red to red clays with thick dark brown clay topsoils. The soils classify as *Chromi-Profondic Lixisols.* Soil profile **MU-P13** is representative	1119
Soils developed on colluvial/alluvial deposits derived from muscovite-biotite migmatites				
P4	Alluvial fan (550-600)	2-10	Very deep, well drained reddish brown, dark reddish brown to very pale sandy clay loams, sandy clays to sands with weak structural profile development and very thick loamy sand topsoils. The soils classify as *Chromi-Rhodic Cambisols.* Soil profile **MU-P14** is representative	6402
Peneplains (L) **Soils developed on muscovite-biotite migmatites**				
L1	Isolated hills (600-800)	10-30	**Complex of:** rock outcrops **and** very shallow, excessively drained gravely dark reddish brown sandy clay loams and sandy clays over slightly weathered gravely materials. The soils classify as *Hapli-Lithic Leptosols.* Soil profile **MU-P3** is representative	137
Soils developed on colluvium mainly derived from hornblende pyroxene granulites and micaceous gneiss				
L2	Ridge crests (500-540)	0-2	**Complex of:** very deep, well drained dark red clays with thick dark reddish brown clay topsoils **and** very deep, well drained dark brown to strong brown sandy clay loams with thin brown sandy loam topsoils **and** very deep, well drained yellowish red to strong brown clays with thick dark brown sandy clay topsoils. The soils classify as *Rhodi-Ferric Ferralsols*, *Chromi-Profondic Luvisols* and *Ferri-Profondic Acrisols*. Profiles **MU-P15, MU-P16** and **MU-P17** are representative	2815
L3	Ridge slopes (420-480)	5-8	**Complex of:** very deep, well drained yellowish red to strong brown clays with thick dark brown sandy clay topsoils **and** very deep, well drained dark brown to strong brown sandy clay loams with thin brown sandy loam topsoils. The soils classify as *Chromi-Profondic Luvisols* and *Ferri-Profondic Acrisols*. Profiles **MU-P16** and **MU-P17** are representative	4186
Soils developed on muscovite-biotite migmatites				
L4	Ridge crests and slopes (420-500)	2-5	**Complex of:** moderately deep, well to somewhat excessively drained reddish brown to dark red sandy clay loams with thick dark reddish brown sandy clay loam topsoils **and** very deep, excessively drained pale brown to yellowish sands with thin brown sand topsoils. The soils classify as *Eutri-Chromic Cambisols* and *Dystri-Lamellic Arenosols*. Profiles **MU-P18** and **MU-P19** are representative	6400

Table 2 continue

Map symbol	Landform (elevation m asl	Dominant slope (%)	Soil description	Area (ha)
Soils developed on colluvium with variable mineralogical composition				
L5	Ridge crests and slopes (420-500)	2-3	**Association of:** moderately deep, well drained dark reddish brown to dark red sandy clays to clays with thin dark reddish brown sandy clay topsoils **and** very deep, well drained yellowish red to strong brown clays with thick dark brown sandy clay topsoils. The soils classify as *Rhodi-Profondic Lixisols* and *Ferri-Profondic Acrisols*. Profiles **MU-P17** and **MU-P20** are representative	3625
L6	Ridge slopes and valley bottoms (<500)	1-2	**Complex of:** very deep, well drained dark reddish brown sandy clays with thick very dark reddish brown sandy clay loam topsoils **and** very deep, imperfectly drained very dark brown to dark brown sandy clay to sandy clay loams with very thick black sandy clay loam topsoils. The soils classify as *Rhodi-Profondic Lixisols* and *Hapli-Eutric Gleysols*. Profiles **MU-P21** and **MU-P22** are representative	7700
Valleys (V) **Soils developed on alluvio-colluvium with variable mineralogical composition**				
V1	River terrace (<500)	0-1	**Complex of:** very deep, moderately well drained black sandy clay loams over very dark grey to dark yellowish brown saprolite **and** deep, very poorly drained very dark grey sandy clays with very deep cracks (>100 cm); 3-10 cm wide and gilgai micro-relief and very thick black sandy clay topsoils **and** very deep, stratified, imperfectly drained dark brown to dark reddish brown sandy clays to clays with thick very dark brown clay topsoils. The soils have variable salinity and sodicity levels. The soils classify as *Hypereutri-Mollic Fluvisols, Endosodi-Pellic Vertisols* and *Hapli-Orthieutric Fluvisols*. Profiles **MU-P23, MU-P24** and **MU-P25** are representative	211
V2	Flood plain (<500)	0-1	**Complex of:** very deep, moderately well drained black sandy clay loams over very dark grey to dark yellowish brown saprolite **and** deep, poorly to very poorly drained very dark grey cracking sandy clays and clays with very thick black sandy clay topsoils. The soils have variable salinity and sodicity levels **and** very deep, imperfectly drained very dark brown to dark brown sandy clays to sandy clay loams with very thick black sandy clay loam topsoils. The soils classify as *Hypereutri-Mollic Fluvisols, Endosodi-Pellic Vertisols* and *Hapli-Eutric Gleysols*. Profiles **MU-P23, MU-P24** and **MU-P22** are representative	4795

Soils developed on muscovite-biotite migmatites

Mapping unit M4
Strongly dissected hills, 45-80 % slopes. The soils are a **complex of:** rockland **and** very shallow, excessively drained dark reddish brown sandy clay loams over extremely gravely materials. The soils classify as *Hapli-Lithic Leptosols.* Soil profile **MU-P3** is representative

Piedmonts (P)

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

Mapping unit P1
Foothills (600-1000 m), 15-45 % slopes. The soils are a **complex of:** very deep, well drained dark red to red clays with thin dark reddish brown clay topsoils **and** deep, well drained dark red to red clays with thin dark brown sandy clay topsoils. Stonelines comprising mainly of fresh angular quartz gravel and stones are common. The soils classify as *Hapli-Profondic Acrisols* and *Hapli-Chromic Lixisols*. Profiles **MU-P9** and **MU-P10** are representative

Mapping unit P2
Glacis (540-600 m), 2-15 % slopes. The soils are a **complex of:** very deep, well drained red sandy clays with very thin dark brown sandy clay topsoils **and** very deep, well drained strong brown to reddish brown clays with thick dark brown clay topsoils. The soils classify as *Chromi-Profondic Luvisols* and *Chromi-Profondic Lixisols*. Profiles **MU-P11** and **MU-P12** are representative

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

Mapping unit P3
Alluvial fan (500-550 m), 0-2 % slopes. The soils are Very deep, well drained yellowish red to red clays with thick dark brown clay topsoils. The soils classify as *Chromi-Profondic Lixisols.* Soil profile **MU-P13** is representative

Soils developed on colluvial/alluvial deposits derived from muscovite-biotite migmatites

Mapping unit P4
Alluvial fan (550-600 m), 2-10 % slopes. The soils are very deep, well drained reddish brown, dark reddish brown to very pale sandy clay loams, sandy clays to sands with weak structural profile development and very thick loamy sand topsoils. The soils classify as *Chromi-Rhodic Cambisols.* Soil profile **MU-P14** is representative

Peneplains (L)

Soils developed on muscovite biotite migmatites

Mapping unit L1
Isolated hills (600-800 m), 10-30 % slopes. The soils are a **complex of:** rock outcrops **and** very shallow, excessively drained gravely dark reddish brown sandy clay loams and sandy clays over slightly weathered gravely materials. The soils classify as *Hapli-Lithic Leptosols.* Soil profile **MU-P3** is representative

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

Mapping unit L2
Ridge crests (500-540 m), 0-2 % slopes. The soils are a **complex of:** very deep, well drained dark red clays with thick dark reddish brown clay topsoils **and** very deep, well drained dark brown to strong brown sandy clay loams with thin brown sandy loam topsoils **and** very deep, well drained yellowish red to strong brown clays with thick dark brown sandy clay topsoils. The soils classify as *Rhodi-Ferric Ferralsols, Chromi-Profondic Luvisols* and *Ferri-Profondic Acrisols*. Profiles **MU-P15, MU-P16** and **MU-P17** are representative

Mapping unit L3
Ridge slopes (420-480 m), 5-8 % slopes. The soils are a **complex of:** very deep, well drained yellowish red to strong brown clays with thick dark brown sandy clay topsoils **and** very deep, well drained dark brown to strong brown sandy clay loams with thin brown sandy loam topsoils. The soils classify as *Chromi-Profondic Luvisols* and *Ferri-Profondic Acrisols*. Profiles **MU-P16** and **MU-P17** are representative

Soils developed on muscovite biotite migmatites

Mapping unit L4
Ridge crests and slopes (420-500 m), 2-5 % slopes. The soils are a **complex of:** moderately deep, well to somewhat excessively drained reddish brown to dark red sandy clay loams with thick dark reddish brown sandy clay loam topsoils **and** very deep, excessively drained pale brown to yellowish sands with thin brown sand topsoils. The soils classify as *Eutri-Chromic Cambisols* and *Dystri-Lamellic Arenosols*. Profiles **MU-P18** and **MU-P19** are representative

Soils developed on colluvium with variable mineralogical composition

Mapping unit L5
Ridge crests and slopes with 2-3% slope gradient. The soils are an **association of:** moderately deep, well drained dark reddish brown to dark red sandy clays to clays

with thin dark reddish brown sandy clay topsoils **and** very deep, well drained yellowish red to strong brown clays with thick dark brown sandy clay topsoils. The soils classify as *Rhodi-Profondic Lixisols* and *Ferri-Profondic Acrisols*. Profiles **MU-P17** and **MU-P20** are representative

Mapping unit L6
Ridge slopes and valley bottoms with 1-2% slopes. The soils are a **complex of:** very deep, well drained dark reddish brown sandy clays with thick very dark reddish brown sandy clay loam topsoils **and** very deep, imperfectly drained very dark brown to dark brown sandy clay to sandy clay loams with very thick black sandy clay loam topsoils. The soils classify as *Rhodi-Profondic Lixisols* and *Hapli-Eutric Gleysols*. Profiles **MU-P21** and **MU-P22** are representative

Valleys (V)

Soils developed on alluvio-colluvium with variable mineralogical composition

Mapping unit V1
River terrace (<500 m), 0-1 % slopes. The soils are a **complex of:** very deep, moderately well drained black sandy clay loams over very dark grey to dark yellowish brown saprolite **and** deep, very poorly drained very dark grey sandy clays with very deep cracks (>100 cm); 3-10 cm wide and gilgai micro-relief and very thick black sandy clay topsoils **and** very deep, stratified, imperfectly drained dark brown to dark reddish brown sandy clays to clays with thick very dark brown clay topsoils. The soils have variable salinity and sodicity levels. The soils classify as *Hypereutri-Mollic Fluvisols*, *Endosodi-Pellic Vertisols* and *Hapli-Orthieutric Fluvisols*. Profiles **MU-P23, MU-P24** and **MU-P25** are representative

Mapping unit V2
Flood plain (<500 m), 0-1 % slopes. The soils are a **complex of:** very deep, moderately well drained black sandy clay loams over very dark grey to dark yellowish brown saprolite **and** deep, poorly to very poorly drained very dark grey cracking sandy clays and clays with very thick black sandy clay topsoils. The soils have variable salinity and sodicity levels **and** very deep, imperfectly drained very dark brown to dark brown sandy clays to sandy clay loams with very thick black sandy clay loam topsoils. The soils classify as *Hypereutri-Mollic Fluvisols*, *Endosodi-Pellic Vertisols* and *Hapli-Eutric Gleysols*. Profiles **MU-P23, MU-P24** and **MU-P22** are representative

3.3 Land evaluation
3.3.1 Description of land utilisation types (LUTs)
Six major land utilisation types were identified from the results of land use and socio-economic survey carried out in the Morogoro Urban District (Table 3). These land utilisation types are: smallholder low input rainfed maize, rice, sorghum, beans, bananas and vegetables. All the studied LUTs are characterised by high labour intensity, low capital investment and production is basically subsistence. Local

cultivars are commonly used with inadequate advisory services.

Table 3. Description of the land utilisation types (LUTs) in the study area

LUTs	Produce	Management	Labour	Level of technology	Farm size (ha)	Land tenure	Yield range (kg/ha)
Smallholder low input rainfed maize	Maize: Kito, Staha and other local varieties	Single and sequential cropping systems	High, family, (65-70 md/ha)	low	0.5-3.0	Customary	500-1200
Smallholder low input rainfed rice	Lowland rice: Selected local varieties	Monocropping system	High, family (70-240 md/ha)	low	0.25-2.0	Customary	900-1200
Smallholder low input rainfed beans	Local and improved varieties	Single and mixed cropping system	Low, family, (100-212 md/ha)	low	0.5-3.0	Customary	500-1000
Smallholder low input rainfed sorghum	Selected local and improved varieties	Single cropping system	High, family (60-100 md/ha)	low	0.5-3.0	Customary	750-1200
Smallholder low input rainfed banana	Selected local varieties	Single and mixed cropping system	High, family (22-40 md/ha)	low	0.5-3.0	Customary	2000-4000
Low input rainfed vegetables	Selected varieties	Single cropping system (gardens)	High, family (80-115 md/ha)	low	0.01-0.1	Customary	3000-6000

3.3.2 Land suitability classification

In this study only physical land suitability classification was carried out for the lands of Morogoro Urban District. The land suitability for the six studied LUTs are summarised in Table 4. The results show that about 70% of the area (LMUs M2, P1, P4, L2, L3, L5, L6 and some parts of LMUs M1, M3, L4, V1 and V2) has poor potential, 20% (LMUs M4, P3, L1 and some parts of LMUs M1, L4, V1 and V2) have very poor potential and only about 10% (some parts of LMUs P2) have moderate potential for maize production. The major limiting factors are soil fertility, drainage conditions, erosion hazards and moisture availability.

80% of the area (LMUs M1, M2, M3, M4, P1, P2, P3, P4, L1, L2, L3, L4, L5 and some parts of LMU L6) have very poor potential for rice production while only 20% (LMU V1, V2 and some parts of LMU L6 have poor potential for rice production. The main limiting factors are topography, wetness and soil fertility.

Land mapping units P2, P3, P4 and some parts of LMUs L2, L3 and L4) occupying about 21% of the study area has moderate potential for sorghum production. LMUs M4, L1 and parts of LMUs M1, V1 and V2 which is about 9% of the area have very poor potential while about 70% (LMUs M2, M3, P1, L5, L6 and some parts of LMUs M1, L2, L3, L4, V1 and V2) have poor potential for sorghum production. The most limiting factors are soil fertility, rooting condition and moisture availability.

As for beans about 72% (LMUs M2, M3, P1, P4, L2, L3, L5, L6 and some parts of LMUs M1, L4, V1 and V2) has poor potential while only about 20% of the area (LMUs M4, L1 and some parts of LMUs M1, L4, V1 and V2) have very poor potential for beans farming. Only about 8% of the area (LMUs P2 and P3) has moderate potential for this LUT. The major limitations include erosion hazard,

rooting conditions, moisture availability, soil fertility and poor drainage conditions. Land mapping units M4, P4, L1, L4, L5, L6 and some parts of LMUs M1, V1 and V2) occupying about 30% of the study area has very poor potential for banana production while the rest about 70% (LMUs M2, M3, P1, P2, L2, L3 and some parts of LMUs M1, V1 and V2 have poor potential for banana farming. The most limiting factors are soil fertility, rooting condition and moisture availability.

As far as vegetable production is concerned, about 44% (LMUs P1, P4, L4, L5, L6 and some parts of LMUs M1, M3, L2, L3, V1 and V2) has poor potential while about 36% of the area (LMUs M2, P2, P3 and some parts of LMUs M3, L2, L3, V1 and V2) has moderate potential for vegetables production. Only about 20% of the area (LMUs M4, L1 and some parts of LMUs M1, V1 and V2) was found to have very poor potential for this LUT. The major limitations include erosion hazard, rooting conditions, moisture availability and poor drainage conditions.

There was no any mapping unit classified as having good potential (highly suitable) for any of the six studied LUTs. This is because its natural fertility has been depleted over time through leaching, erosion and nutrient mining through continuous cropping. Among the six LUTs, vegetable production was more suited to the area for it can be grown in about 80% of the area. This is because most of the area has enough rainfall to supply moisture, which is among the factors for production of most crops. Also the crop (vegetables) can thrive well even in soils with relatively poor fertility (Kips *et.al.,* 1989). Beans rank the second followed by maize. Sorghum was found to be the fourth LUT in the area while rice was the least LUT.

Table 4. Physical suitability classification for the major land use types in Morogoro Urban District

LMU	Soil unit	Land use types						Area (ha)
		Maize	**Rice**	**Sorghum**	**Beans**	**Bananas**	**Vegetables**	
M1	**Mountain ridges**	3e/na &3e/na/nr &4e/o/r	4tg/wt & 4r/tg/wt	3e/m/na & 3e/m/nr & 4r	3e/m &3e/m/na & 4o/r	3e/r & 3e/na/r & 4o/r	3e/na & 4r	1550
	Hapli-Orthieutric Regosols (20 %)	4e/o/r	4r/tg/wt	4r	4o/r	4o/r	4r	
	Cutani-Profondic Luvisols (50 %)	3e/na	4tg/wt	3e/m/na	3e/m	3e/r	3e/na	
	Hapli-Lithic Leptosols (30 %)	3e/na/nr	4tg/wt	3e/m/nr	3e/m/na	3e/na/r	3e/na	
M2	**Mountain ridges**	3e/na & 3e/na/nr & 3na/o	4tg/wt	3e/m &3e/m/na & 3m/o	3e/m/na & 3m/na/o	3e/na & 3e/na/o	2e/m/na &2e/m/na/nr &2e/m	3817
	Profondi-Stagnic Lixisols (40 %)	3e/na/nr	4tg/wt	3e/m	3e/m/na	3e/na	2e/m/na/nr	
	Haplic Phaeozems (40 %)	3e/na	4tg/wt	3e/m/na	3e/m/na	3e/na	2e/m/na	
	Hapli-Epidystric Cambisols (20%)	3na/o	4tg/wt	3m/o	3m/na/o	3e/na/o	2e/m/na/o	
M3	**Tallus slopes**	4na & 3na	4na/tg/wt & 4tg/wt	3m/nr & 3m	3m/na/nr &3m/na	3na/nr & 3e/na	2e/m/na/nr & 3na	1043
	Haplic Phaeozems (45 %)	3na	4tg/wt	3m	3m/na	3e/na	3na	
	Ferri-Profondic Lixisols (55 %)	4na	4na/tg/wt	3m/nr	3m/na/nr	3na/nr	2e/m/na/nr	
M4	**Dissected hills**	4e/m/o/r	4r/tg/wt	4r	4o/r	4o/r	4r	3547
	Hapli-Lithic Leptosols (100 %)	4e/m/o/r	4r/tg/wt	4r	4o/r	4o/r	4r	
P1	**Foothills**	3na & 3na/nr	4tg/wt	3e/na	3e/na	3e & 3e/na	3e &3e/na	2805
	Hapli-Profondic Acrisols (30 %)	3na/nr	4tg/wt	3e/na	3e/na	3e/na	3e/na	
	Hapli-Chromic Lixisols (70 %)	3na	4tg/wt	3e/na	3e/na	3e	3e	
P2	**Glacis**	2e/m/na & 3na/nr	4tg/wt	2nr & 2na/nr	2e/r & 2e/na/nr/r	3m	2e & 2e/na/nr	1973
	Chromi-Profondic Luvisols (40 %)	2e/m/na	4tg/wt	2nr	2e/r	3m	2e	
	Chromi-Profondic Lixisols (60 %)	3na/nr	4tg/wt	2na/nr	2e/na/nr/r	3m	2e/na/nr	
P3	**Alluvial fan**	4na	4na/tg/wt	2na/nr	2e/na	3m/na	2e/na	1119
	Chromi-Profondic Lixisols (100%)	4na	4na/tg/wt	2na/nr	2e/na	3m/na	2e/na	
P4	**Alluvial fan**	3m/na/nr	4tg/wt	2m/na/nr	3m/na	4m	3na	6402
	Chromi-Rhodic Cambisols (100%)	3m/na/nr	4tg/wt	2m/na/nr	3m/na	4m	3na	
L1	**Isolated hills**	4m/o/r	4r/tg/wt	4r	4nr	4o/r	4r	137
	Hapli-Lithic Leptosols (100 %)	4m/o/r	4r/tg/wt	4r	4nr	4o/r	4r	
L2	**Ridge crests**	3na/nr & 3na	4wt & 4tg/wt	2na/nr & 3na & 3nr	3na	3m/na & 3m/na/nr	3na & 2na/nr	2815
	Rhodi-Ferric Ferralsols (30 %)	3na/nr	4wt	3nr	3na	3m/na/nr	3na	
	Chromi-Profondic Luvisols (40 %)	3na	4tg/wt	2na/nr	3na	3m/na	3na	
	Ferri-Profondic Acrisols (30 %)	3na/nr	4wt	3na	3na	3m/na	2na/nr	

Table 4. continued

LMU	Soil unit	Land use types						Area (ha)
		Maize	**Rice**	**Sorghum**	**Beans**	**Bananas**	**Vegetables**	
L3	**Ridge slopes**	3na & 3na/nr	4tg/wt & 4wt	2na/nr & 3na	3na	3na & 3m/na	3na & 2na/nr	4186
	Chromi-Profondic Luvisols (55 %)	3na	4tg/wt	2na/nr	3na	3na	3na	
	Ferri-Profondic Acrisols (45 %)	3na/nr	4wt	3na	3na	3m/na	2na/nr	
L4	**Ridge crests and slopes**	3m/na/r & 4na/nr/o	4wt & 4nr/wt	2m/na/nr & 3m/nr/o	3m/na & 4o	4m & 4m/o	3m/na & 3m/nr/o	6400
	Eutri-Chromic Cambisols (60 %)	3m/na/r	4wt	2m/na/nr	3m/na	4m	3m/na	
	Dystri-Lamellic Arenosols (40 %)	4m/nr/o	4nr/wt	3m/nr/o	4o	4m/o	3m/nr/o	
L5	**Ridge crests and slopes**	3m/na/nr	4wt	3na	3m/na	4m	3m	3625
	Rhodi-Profondic Lixisols (60 %)	3m/na/nr	4wt	3na	3m/na	4m	3m	
	Ferri-Profondic Acrisols (40 %)	3m/na/nr	4wt	3na	3m/na	4m	3m	
L6	**Slopes and valley bottoms**	3m/na/nr & 3m/o	3wt & 4wt	3na & 3o	3m/na & 3m/na/o	4m	3m & 3m/na	7700
	Rhodi-Profondic Lixisols (50 %)	3m/na/nr	4wt	3na	3m/na	4m	3m/na	
	Hapli-Eutric Gleysols (50 %)	3m/o	3wt	3o	3m/na/o	4m	3m	
V1	**River terrace**	3na/o & 3na/nr & 4o	3na & 3na/wt	3o & 3na & 4o	3o & 3na & 4o	3m/o & 3na & 4o	2na/o & 3na & 4o	211
	Hypereutri-Mollic Fluvisols (30 %)	3na/nr	3na/wt	3na	3na	3na	3na	
	Endosodi-Pellic Vertisols (30 %)	4o	3na	4o	4o	4o	4o	
	Hapli-Orthieutric Fluvisols (40 %)	3na/o	3na	3o	3o	3m/o	2na/o	
V2	**Flood plain**	3na/nr & 3o & 4o	3na/wt &2na & 3na	3na & 3o & 4o	3na &3na/o & 4o	3na & 3m/na/o & 4o	3na &2o & 4o	4795
	Hypereutri-Mollic Fluvisols (40 %)	3na/nr	3na/wt	3na	3na	3na	3na	
	Endosodi-Pellic Vertisols (30 %)	4o	3na	4o	4o	4o	4o	
	Hapli-Eutric Gleysols (30 %)	3o	2na	3o	3na/o	3m/na/o	2o	

na = nutrient availability, wt = wetness, o = drainage conditions, nr = nutrient retention, tg = topography, r = rooting conditions, m = moisture availability, e = erosion hazards, LMU = Land mapping unit.

4.0 CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

Climate, landform patterns and parent materials have had profound influence on types and distribution of soils in the district. Human activities particularly deforestation, cultivation without proper conservation measures and annual bush and forest fires have also influenced the soils. Soil profile development reveals marked influence of mass removal of soils by water erosion particularly mass movements in the mountains and colluvio-alluvial processes in the piedmont slopes and peneplains. There is considerable variation in soil depth, texture, drainage condition and soil chemical properties among the landform units. The mountain ridge slopes have relatively shallow soils and gravely soil textures. This can be attributed to severe erosion caused by mass removal of soil materials mainly by high rainfall. The piedmont slopes and peneplains with colluvial material derived from granulites and mixed gneisses have very deep soils with high amounts of clay content. This is due to constant addition of new soil materials and *in situ* weathering coupled with low rate of erosion. Landforms associated with migmatites like Mindu-Lugala piedmont slopes and Tungi Mkonowamara peneplains have the highest amount of sand content. This can be explained by the nature of the parent materials which are richer in felsic minerals. Valley soils have medium textures and are stratified as a result of cyclic deposition of materials of diverse origin.

The mineralogy of the soils of the Uluguru Mountains, the piedmont slopes and the peneplains are mainly kaolinitic. The soils of the mountain ridges have high content of gibbsite in the clay fraction, which can be attributed to rapid weathering and strong leaching caused by high rainfall and excessive drainage. Soils of the river terraces and flood plains have relatively high contents of smectite and illite in the clay fraction, revealing the relative young age of the soils.

Soils of the mountains are slightly acidic to acidic (pH<5.5). Piedmonts have nearly neutral reaction (pH 6.0-7.5) except for the glacis which are strongly acidic (pH<5.5). Most soils of the peneplains are moderately acid except for those associated with migmatites, which are strongly acid (pH<5.5). Valleys have nearly neutral to alkaline soils with ESP ranging between 5 and 37%. Organic carbon and nitrogen levels for all soils are very low with values less than 1.0% and 0.1% respectively. Available P is also low (<5 mg/kg). Nutrient retention capacity of soils is low (CEC <12 cmol(+)/kg) except in the valleys where nutrient retention is high (CEC 20-30 cmol(+)/kg).

According to FAO-World Reference Base nine major soil types were identified and classified. The soils of the strongly dissected mountain ridge slopes are Leptosols, Lixisols, Luvisols and Cambisols. Dominant soils on the piedmonts and peneplains are Lixisols and Acrisols while the ridge side slopes on the peneplains have soils classified as Cambisols. The soils of the river terraces and flood plains are Fluvisols, Vertisols and

Gleysols while those of the Mindu hills and surrounding areas are classified as Leptosols, Cambisols and Arenosols.

Six major land utilisation types namely smallholder low input rainfed maize, rice, sorghum, beans, bananas and vegetables were identified and evaluated in Morogoro Urban District. Land suitability classification indicates that, none of the land mapping units is highly suitable for all the studied land utilisation types. This is because its natural fertility has been depleted over time through leaching, erosion and nutrient mining through continuous cropping. Among the six LUTs, vegetable production was more suited to the area for it could be grown to about 80% of the area. Beans rank the second followed by maize. Sorghum was found to be the fourth LUT in the area while rice was the least. Moisture supply soil fertility and erosion hazards are among the most limiting factors for production of most crops in the area. A summary of some limiting land qualities for agricultural production and proposed land management in the district is presented in Table 5.

4.2 Recommendations

In the Uluguru Mountains and Mindu-Lugala hills, shallow soil depth, excessive soil drainage and steep slopes are the key limiting land qualities. Severe soil erosion and low soil fertility pose serious constraints to agricultural production in these areas. Deliberate efforts should be taken to establish critical zones for afforestation, reduce burning through introduction of bylaws and appropriate training programmes, use of grass barriers and cultivation of perennial crops. Further research on soil erosion particularly mass movements is important in order to come up with appropriate soil conservation packages for these units.

Soil fertility is a major limiting land quality that poses limitations to agricultural productivity in the Uluguru foothills, Mzinga-Bigwa piedmonts and SUA-Kingolwira peneplains. It is strongly suggested that emphasis should be put on the use of organic and non acidifying fertilisers and afforestation of hilltops. Use of indigenous fertilisers such as rock phosphate and manurescould immensely contribute to the improvement of soil fertility in the area.

Excessive soil drainage, low soil moisture due to inadequate rainfall and low water holding capacity of the soil due to low organic matter and poor supply of major nutrients form the biggest limitation to agricultural production in the Mindu-Lugala piedmonts and Tungi-Mkonowamara peneplains. Water harvesting techniques, growing of drought tolerant crops and use of organic fertilisers will improve the sustainability of agricultural production in these units. The focus should be on the use of itegrated nutrient management techniques.

Valleys have poor soil drainage, unfavourable levels of salinity and poor workability of the soils. Provision of drainage systems in these areas will control and keep the ground water levels low. This will also enhance regular flushing of the soils thus avoiding the building up of harmful levels of salts. Saline soils could also be managed through proper crop selection and planting of saline tolerant crops. Sorghum withstands poor drainage condition and can cope very well with drought and saline conditions. Frequent floods especially by the Ngerengere river could be reduced by construction of ditches and dikes with outlets to the present natural drainage system. Agricultural mechanisation and use of organic fertilisers will in the long run improve and enhance soil workability of these units.

Table 5. Landforms, soil types, derived limitations and proposed land management

Landform	Soil type (FAO-WRB)	Key limiting land qualities	Proposed land management strategies
Uluguru mountain strongly dissected ridge slopes (UnitsM1, M2, M3)	Lithic and Paralithic Leptosols, Hapli-Profondic Lixisols, Orthidystri and Hypereutri-Episkeletic Cambisols, Episkeletic and Endoskeletic Phaeozems	Soil depth, soil drainage, slope, soil erosion, soil fertility	Establishment of critical zones for afforestation Reduce burning Introduction of zero grazing Use of grass barriers Cultivation of perennial crops Research on soil erosion particularly mass movements
Uluguru mountain foothills (Unit P1)	Chromi-Profondic Acrisols, Chromic Lixisols	Soil fertility, soil erosion	Use of organic and non acidifying inorganic fertilizers Use of other indigenous fertiliser materials Introduction of contouring and grass strips Afforestation of hill tops
Mindu-Lugala hills (Units M4, L1)	Paralithic Leptosols	Soil depth, soil drainage, soil erosion	Afforestation Control of bush fires
Mzinga-Bigwa piedmont slopes with glacis and alluvialfans (Units P2, P3)	Rhodi and Chromi-Profondic Luvisols, Chromi-Profondic Lixisols	Soil fertility	Use of organic and non acidifying inorganic fertilizers Introduction of zero grazing
Mindu-Lugala piedmont slopes with alluvial fans and hill wash sands (Unit P4)	Orthieutri-Chromic Cambisols, Orthidystric Arenosols	Soil drainage, soil moisture, soil fertility	Introduction of water harvesting techniques Grow drought tolerant crops Use of organic fertiliser
SUA-Kingolwira peneplains with undulating slopes (Units L2, L3)	Rhodi-Acric Ferralsols, Cutani-Profondic Luvisols	Soil fertility	Use of organic and non acidifying inorganic fertilizers
Tungi-Mkonowamara peneplains with undulating to rolling slopes (Units L4, L5, L6)	Hyperdystric Cambisols, Cutani-Orthidystric Luvisols	Soil drainage, soil moisture, soil fertility	Introduction of water harvesting techniques Grow drought tolerant crops Use of organic fertiliser
Valleys with river terraces and floodplains (Units V1, V2)	Stagni-Mollic Fluvisols, Calcari-Salic Vertisols	Soil drainage, salinity/sodicity, soil workability	Crop selection Provision of drainage systems Introduction of mechanisation and use of organic fertilisers

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6.0 APPENDICES

Appendix 1. Some representative soil profiles for the major land mapping units

Profile number: MU-P1 Mapping unit: M1 Agro-ecol. zone:
Region: MOROGORO
District: MOROGORO URBAN
Map sheet no. : 183/3
Co-ordinates: 37°40'02"E/ 6°52'39"S
Location : Ruvuma Village about 100 m SE from S&W Project House. Elevation: 960 m asl. Parent material: hornblende pyroxene granulites and gneiss. Landform: mountains; mountainous. Slope: 49 %; convex; 300 m long; middle slope.
Surface characteristics: Stones: 10 % Erosion: Inter-rill/sheet/gully/landslide; Severe. Deposition: none. Natural vegetation: Cleared. Land use: Cultivation of vegetables, Bananas, Cassava and Sugarcane.
Natural drainage class: Well to somewhat excessively drained.
Described by D.N. Kimaro, B.M. Msanya, and G.G. Kimbi on 03/05/2000.

Soils are shallow, well to somewhat excessively drained, dark brown sandy clays overlaying a deep weathered saprolite.

Ap 0 - 30 cm: dark brown (7.5YR3/8) moist; gravely sandy clay; friable moist, slightly sticky and slightly plastic wet; moderate fine and medium subangular blocks; many fine pores; very few and common very fine roots; clear smooth boundary to

C 30 - 35/50 cm: very dark greyish brown (10YR3/2) moist; sandy loam; friable moist, non-sticky and non-plastic wet; structureless massive; many fine pores; frequent small irregular slightly weathered biotite gneiss fragments; few very fine roots; clear wavy boundary to

CR 35/50 - 130 cm: dark yellowish brown (10YR4/4) moist; loamy sand; friable moist, non-sticky and non-plastic wet; structureless massive; many very fine pores; very few small irregular slightly weathered biotite gneiss fragments; very few very fine roots.

SOIL CLASSIFICATION: WRB (FAO, 1998):Hapli- Orthieutric Regosols
USDA Soil Taxonomy (Soil Survey Staff, 1999): Typic Ustorthents

ANALYTICAL DATA FOR PROFILE MU-P1

Horizon	Ap	C	CR
Depth (cm)	0-30	30-35/50	35/50-130
Clay (%)	18	14	6
Silt (%)	21	23	15
Sand (%)	61	63	79
Texture class	SC	SL	LS
AWC (mm/m)	nd	nd	nd
Bulk density (g/cc)	nd	nd	nd
pH H_2O 1:2.5	5.5	6.0	6.4
pH KCl 1:2.5	5.0	5.1	5.3
EC 1:2.5 (mS/cm)	nd	nd	nd
ESP	3.17	3.64	2.62
Organic C (%)	0.7	0.8	0.1
Total N (%)	0.01	0.06	0.06
C/N	10.0	13.3	1.67
Avail. P BrayI (mg/kg)	4.0	6.0	5.0
Avail. P Olsen (mg/kg)	nd	nd	nd
CEC NH_4OAc (cmol(+)/kg)	6.0	5.5	6.5
Exch. Ca (cmol(+)/kg)	2.6	2.6	2.7
Exch. Mg (cmol(+)/kg)	1.2	1.0	1.6
Exch. K (cmol(+)/kg)	0.16	0.21	0.11
Exch. Na (cmol(+)/kg)	0.19	0.20	0.17
Base saturation (%)	69	72	70
CEC_{Clay} (cmol(+)/kg)	19.9	19.6	102

nd = not determined

Profile number: MU-P2 Mapping unit: M1 Agro-ecol. zone:
Region: MOROGORO
District: MOROGORO URBAN
Map sheet no. : 183/3
Co-ordinates: 37°40'7.0" E/ 6°52' 27.8" S
Location: About 100 m SW of village cemetery (Mgambazi Juu village)
Elevation: 975 m asl. Parent material: Gneiss. Landform: mountain; mountainous. Slope: 60 %; complex, 120 m, lower slope.
Surface characteristics: Erosion: rill, inter-rill; moderate. Deposition: none. Natural vegetation: Cleared land. Land use: Fallow land.
Natural drainage class: moderately well drained
Described by D.N. Kimaro, B.M. Msanya, E.P. Kileo and G.G. Kimbi on 24/08/2000.

Soil: Soils are moderately deep, moderately well drained dark yellowish brown sandy clays with thin very dark brown sandy clay topsoils.

Ap 0 - 5 cm: very dark brown (10YR2/2) moist; sandy clay; friable moist, slightly sticky and slightly plastic wet; moderate fine and medium subangular blocky; many very fine and few medium pores; frequent small and medium irregular fresh and slightly weathered quartz and feldspars fragments; many very fine and fine roots; clear smooth boundary to
BCt 5 - 30/35 cm: dark yellowish brown (10YR3/6) dry, dark yellowish brown (10YR3/4) moist; sandy clay; hard dry, friable moist, sticky and plastic wet; moderate medium and coarse subangular blocky; broken thin clay cutans; many very fine and medium pores; very frequent large and medium irregular fresh and slightly weathered quartz, gneiss and feldspars fragments; few very fine and fine roots; gradual wavy boundary to
CB 30/35 - 50 cm: dark yellowish brown (10YR6/4) dry, dark yellowish brown (10YR4/4) moist; sandy clay; friable moist, slightly sticky and slightly plastic wet; weak medium and coarse subangular blocky; many very fine and fine pores; very frequent large and medium angular fresh and slightly weathered quartz, feldspars and gneiss fragments; very few very fine roots; gradual smooth boundary to
C 50 - 140 cm: weathering rocks (saprolite) and narrow tongues of soil materials.

SOIL CLASSIFICATION: WRB (FAO, 1998): Cutani- Profondic Luvisols
USDA Soil Taxonomy (Soil Survey Staff, 1999): Inceptic Haplustalfs

ANALYTICAL DATA FOR PROFILE MU-P2

Horizon	Ap	BCt	CB
Depth (cm)	0-5	5-30/35	30/35-50
Clay (%)	35	47	39
Silt (%)	6	4	8
Sand (%)	59	49	53
Texture class	SC	SC	SC
AWC (mm/m)	nd	nd	nd
Bulk density (g/cc)	nd	nd	nd
pH H_2O 1:2.5	6.4	6.4	6.5
pH KCl 1:2.5	6.0	6.1	6.0
EC 1:2.5 (mS/cm)	nd	nd	nd
ESP	1.19	1.19	1.25
Organic C (%)	2.1	1.3	0.2
Total N (%)	0.1	0.1	0.01
C/N	21	13	20
Avail. P BrayI (mg/kg)	14.0	1.0	1.0
Avail. P Olsen (mg/kg)	nd	nd	nd
CEC NH_4OAc (cmol(+)/kg)	18.5	19.3	16.0
Exch. Ca (cmol(+)/kg)	8.4	8.0	7.2
Exch. Mg (cmol(+)/kg)	2.5	3.3	2.3
Exch. K (cmol(+)/kg)	1.1	1.17	0.57
Exch. Na (cmol(+)/kg)	0.22	0.23	0.20
Base saturation (%)	66	66	64
CEC_{Clay} (cmol(+)/kg)	22.3	31.5	30.4

nd = not determined

Profile number: **MU-P3** Mapping unit: P4 Agro-ecol. zone:
Region: MOROGORO
District: MOROGORO URBAN
Map sheet no. : 183/1
Coordinates: 37°38'25" E/ 6°43'45" S
Location: Msembe mountain area
Elevation: 750 m asl. Parent material: Banded muscovite biotite sediments and superficial sands. Landform: Isolated hills; hilly. Slope: >80 %; complex slope; Surface characteristics: Erosion: severe sheet and rill erosion. Rock outcrops: rockland Stones: 70-80 %; Cracks: none Deposition: none. Natural drainage class: excessively drained. Natural vegetation: bushed grassland composed of *Combretum spp.,* Grass species include *Hyperrhenia rufa.* Land use: Used for grazing.

Described by D.N. Kimaro, B.M. Msanya, E.P. Kileo and S.B. Mwango on 23/12/1999

Soils are very shallow, excessively drained dark reddish brown sandy clay loams over a slightly weathered rock materials.

Ah 0 - 10 cm: red (2.5YR4/6) dry, dark reddish brown (2.5YR3/4) moist; gravely sandy clay loam; slightly hard dry, friable moist, sticky and plastic wet; moderate medium subangular blocky; common fine pores; frequent small angular slightly weathered quartz fragments; few very fine and medium roots; gradual smooth boundary to

CR 10+ slightly weathered rock.

SOIL CLASSIFICATION: WRB (FAO 1998): Hapli-Lithic Leptosols
USDA-Soil Taxonomy (Soil Survey Staff, 1999): Lithic Ustorthents

ANALYTICAL DATA FOR PROFILE MU-P3

Horizon	Ah	CR
Depth (cm)	0-10	10+
Clay %	26	nd
Silt %	6	nd
Sand %	68	nd
Texture class	SCL	nd
Bulk density g/cc	1.4	nd
AWC mm/m	nd	nd
pH H_2O 1:2.5	7.2	nd
pH KCl 1:2.5	4.4	nd
EC 1:2.5 mS/cm	0.02	nd
ESP	0.83	nd
Organic C %	0.26	nd
Total N %	0.03	nd
C/N	9	nd
Avail. P Bray-1 mg/kg	nd	nd
Avail. P Olsen mg/kg	8.1	nd
CEC NH_4OAc cmol(+)/kg	7.26	nd
Exch. Ca cmol(+)/kg	4.1	nd
Exch. Mg cmol(+)/g	2.7	nd
Exch. K cmol(+)/kg	0.04	nd
Exch. Na cmol(+)/kg	0.06	nd
Base saturation %	95	nd
CEC clay cmol(+)/kg	24.5	nd

nd= not determined

Profile number: MU-P4 Mapping unit: M2 Agro-ecol. zone:
Region: MOROGORO
District: MOROGORO URBAN
Map sheet no. : 183/3
Co-ordinates: 37°40'5.2" E/ 6°52'27.1" S
Location: About 100 m East of Ruvuma Village Headquarter
Elevation: 1090 m asl. Parent material: colluvium. Landform: mountain; mountainous. Slope: 24 %, lower slope
Surface characteristics : Erosion: Rill, Inter-rill, gully; moderate. Deposition: none. Natural vegetation: Grassland. Land use: Cultivation of annual crops.
Natural drainage class: moderate to imperfectly drained
Described by D.N. Kimaro, G.G. Kimbi, B.M. Msanya and E.P. Kileo on 11/05/2000.

Soil: Soils are very deep, moderately to imperfectly drained dark yellowish brown to dark brown and brown sandy clay loams with thick black sandy loam topsoils.

Ap 0 - 10/25 cm: black (7.5YR2.5/1) moist; sandy loam; friable moist, slightly sticky and slightly plastic wet; moderate fine and medium subangular blocks; many very fine and fine pores; frequent medium and coarse angular fresh and weathered feldspars fragments; many very fine and fine roots; clear wavy boundary to

BAt 10/25 - 32 cm: dark yellowish brown (7.5YR3/4) moist; sandy clay loam; friable moist, slightly sticky and slightly plastic wet; moderate medium and coarse subangular blocks; patchy thin clay cutans; many very fine and few coarse pores; frequent small and medium angular fresh and weathered feldspars fragments; few very fine roots; gradual smooth boundary to

Bt 32 - 76 cm: dark brown (7.5YR3/3) moist; sandy clay loam; few fine distinct clear mottles; firm moist, sticky and plastic wet; moderate medium and coarse subangular blocks; continuous moderately thick clay cutans; many very fine and few coarse pores; very frequent small and medium angular fresh and weathered feldspars fragments; few very fine roots; gradual smooth boundary to

BCt 76 - 160 cm: brown (7.5YR4/4) moist; sandy clay loam; firm moist, sticky and plastic wet; weak coarse subangular blocks; continuous moderately thick clay cutans; many fine and very fine pores; very frequent small and medium angular fresh and weathered feldspars and quartz fragments; very few fine roots; few scattered angular stones at Bt and BCt.

SOIL CLASSIFICATION: WRB (FAO, 1998): Profondi- Stagnic Lixisols
USDA Soil Taxonomy (Soil Survey Staff, 1999): Typic Haplustalfs

ANALYTICAL DATA FOR PROFILE MU-P4

Horizon	Ap	BAt	Bt	BCt
Depth (cm)	0-10/25	10/25-32	32-76	76-160+
Clay (%)	19	28	29	27
Silt (%)	9	7	5	7
Sand (%)	72	65	66	66
Texture class	SL	SCL	SCL	SCL
AWC (mm/m)	nd	nd	nd	nd
Bulk density (g/cc)	nd	nd	nd	nd
pH H_2O 1:2.5	5.1	5.4	5.6	6.1
pH KCl 1:2.5	4.2	4.5	4.5	5.0
EC 1:2.5 (mS/cm)	nd	nd	nd	nd
ESP	0.94	1.86	1.63	1.62
Organic C (%)	0.6	0.3	0.2	0.2
Total N (%)	0.09	0.05	0.04	0.04
C/N	6.7	6.0	5.0	5.0
Avail. P BrayI (mg/kg)	14.0	1.0	2.0	1.0
Avail. P Olsen (mg/kg)	nd	nd	nd	nd
CEC NH_4OAc (cmol(+)/kg)	9.6	7.0	8.0	7.4
Exch. Ca (cmol(+)/kg)	4.3	3.8	4.2	3.6
Exch. Mg (cmol(+)/kg)	2.8	1.9	2.5	1.9
Exch. K (cmol(+)/kg)	0.17	0.11	0.09	0.07
Exch. Na (cmol(+)/kg)	0.09	0.13	0.13	0.12
Base saturation (%)	77	85	87	80
CEC_{Clay} (cmol(+)/kg)	39.6	21.3	26.0	25.0

nd = not determined

Profile number : MU-P5 Mapping unit: M2 Agro-ecol. zone:
Region : MOROGORO
District : MOROGORO URBAN
Map sheet no. : 183/3
Co-ordinates : 37°40'07" E/ 6°52'28.9" S
Location : About 160 m East of Ruvuma Village Headquarter
Elevation : 1100 m asl. Parent material: Biotite gneiss- pyroxine granulites. Landform:
mountain; mountainous. Slope: 55 %; convex
Surface characteristics : Erosion: Landslide, gully, inter-rill, rill; severe. Deposition: none. Natural vegetation: Grassland. Land use: Cultivation of maize and cassava.
Natural drainage class : well drained
Described by D.N. Kimaro, B.M. Msanya, G.G. Kimbi, and E.P. Kileo on 17/05/2000.

Soil: Soils are deep, well drained dark yellowish brown sandy clay loams with very thick black sandy clay loam topsoils.

Ap 0 - 40 cm: black (10YR2/1) moist; sandy clay loam; friable moist, slightly sticky and slightly plastic wet; moderate medium and coarse subangular blocks; many very fine and fine pores; very frequent large and medium angular fresh and slightly weathered feldspars fragments; many very fine and fine roots; clear smooth boundary to

BC 40 – 75/100 cm: dark yellowish brown (10YR4/4) moist; sandy clay loam; friable moist, sticky and plastic wet; moderate coarse and medium subangular blocks; patchy thin clay cutans; many very fine and fine pores; very frequent large and medium angular fresh and slightly weathered feldspars fragments; common very fine roots; clear smooth boundary to

C 75/100 - 170 cm: yellowish brown (10YR5/6) moist; sandy loam; friable moist, non-sticky and non-plastic wet; structureless massive; many very fine pores; very few very fine roots.

SOIL CLASSIFICATION: WRB (FAO, 1998): Haplic Phaeozems
USDA Soil Taxonomy (Soil Survey Staff, 1999): Entic Haplustolls

ANALYTICAL DATA FOR PROFILE MU-P5

Horizon	Ap	BC	C
Depth (cm)	0-40	40-75/100	75/100-170
Clay (%)	27	27	15
Silt (%)	7	7	22
Sand (%)	66	66	63
Texture class	SCL	SCL	SL
AWC (mm/m)	nd	nd	nd
Bulk density (g/cc)	nd	nd	nd
pH H_2O 1:2.5	6.3	6.4	6.0
pH KCl 1:2.5	5.1	5.2	5.2
EC 1:2.5 (mS/cm)	nd	nd	nd
ESP	1.02	3.38	3.64
Organic C (%)	0.9	0.2	0.2
Total N (%)	0.11	0.05	0.04
C/N	8.2	4.0	5.0
Avail. P BrayI (mg/kg)	3.0	3.0	2.0
Avail. P Olsen (mg/kg)	nd	nd	nd
CEC NH_4OAc (cmol(+)/kg)	9.8	7.4	5.5
Exch. Ca (cmol(+)/kg)	4.7	3.6	2.6
Exch. Mg (cmol(+)/kg)	2.9	1.6	1.0
Exch. K (cmol(+)/kg)	0.21	0.21	0.21
Exch. Na (cmol(+)/kg)	0.10	0.25	0.20
Base saturation (%)	81	76	73
CEC_{Clay} (cmol(+)/kg)	24.8	24.8	32.1

nd = not determined

Profile number: MU-P6 Mapping unit: M2 Agro-ecol. zone:
Region: MOROGORO
District: MOROGORO URBAN
Map sheet no. : 183/3
Co-ordinates : 37°40'04"E/ 6°52'41"S
Location : Tulo Kyani
Elevation : 1200 m asl. Parent material: colluvium. Landform: mountain; mountainous. Slope: 65 %; complex, 200 m, upper slope.
Surface characteristics : Outcrops: 15 % Stones: 15 % Erosion: landslide, inter-rill; severe. Deposition: none. Natural vegetation: Cleared land. Land use: Cultivation of beans, bananas and cassava.
Natural drainage class : moderately well drained

Described by D.N. Kimaro, B.M. Msanya and G.G. Kimbi on 18/09/2000.

Soil: Soils are deep, moderately well drained dark yellowish brown sandy clay loams with thick dark brown sandy clay loam topsoils.

Ap1 0 - 12/26 cm: dark brown (10YR3/3) moist; sandy clay loam; friable moist, slightly sticky and slightly plastic wet; weak fine and medium subangular blocks; many very fine pores; frequent small, medium and large angular and spherical fresh and weathered quartz and granulite fragments; many fine and common very fine roots; gradual wavy boundary to

Ap2 12/26 - 40/50 cm: dark yellowish brown (10YR4/4) moist; sandy clay loam; friable moist, sticky and plastic wet; moderately weak fine and medium subangular blocks; many fine pores; very frequent small, medium and large angular and spherical fresh and weathered quartz and granulite fragments; many fine and few very fine roots; abrupt wavy boundary to

Bw 40/50 – 100/105 cm: dark yellowish brown (10YR4/6) moist; sandy clay loam; friable moist, slightly sticky and plastic wet; weak medium and coarse subangular blocks; many fine and very fine pores; frequent small and medium angular fresh and weathered pyroxene granulite fragments; many fine roots; gradual wavy boundary to

CR 100/105 - 170 cm: very dark greyish brown (10YR3/2) moist; sandy clay loam; friable moist, slightly sticky and plastic wet; weak fine and medium subangular blocks; many very fine pores; frequent small, medium and large angular and spherical fresh and weathered quartz granulite fragments; many very fine roots.

SOIL CLASSIFICATION: WRB (FAO, 1998): Hapli- Epidystric Cambisols
USDA Soil Taxonomy (Soil Survey Staff, 1999): Typic Dystrustepts

ANALYTICAL DATA FOR PROFILE MU-P6

Horizon	Ap1	Ap2	Bw	CR
Depth (cm)	0-12/26	12/26-40/50	40/50-100/105	100/105-170+
Clay (%)	28	28	24	24
Silt (%)	17	17	15	15
Sand (%)	55	55	61	61
Texture class	SCL	SCL	SCL	SCL
AWC (mm/m)	nd	nd	nd	nd
Bulk density (g/cc)	nd	nd	nd	nd
pH H_2O 1:2.5	6.0	5.9	6.1	6.5
pH KCl 1:2.5	4.4	4.3	4.3	4.0
EC 1:2.5 (mS/cm)	nd	nd	nd	nd
ESP	0.66	0.69	0.66	1.47
Organic C (%)	1.2	1.4	0.3	0.2
Total N (%)	0.11	0.10	0.05	0.04
C/N	10.9	14.0	6.0	5.0
Avail. P BrayI (mg/kg)	1.0	1.0	1.0	1.0
Avail. P Olsen (mg/kg)	nd	nd	nd	nd
CEC NH_4OAc (cmol(+)/kg)	15.2	16.0	10.0	10.2
Exch. Ca (cmol(+)/kg)	3.3	3.1	2.4	2.7
Exch. Mg (cmol(+)/kg)	2.6	3.0	2.9	3.0
Exch. K (cmol(+)/kg)	0.33	0.34	0.09	0.11
Exch. Na (cmol(+)/kg)	0.10	0.11	0.07	0.15
Base saturation (%)	42	41	52	58
CEC_{Clay} (cmol(+)/kg)	39.5	39.9	39.9	39.6

nd = not determined

Profile number: MU-P7 Mapping unit: M3 Agro-ecol. zone:
Region: Morogoro
District: MOROGORO URBAN
Map sheet no. : 183/3
Co-ordinates: 37°37'54.1" E/ 6°52'50.9" S
Location: Mvomelo area
Elevation: 1340 m asl. Parent material: Colluvium. Landform: mountain; mountainous. Slope: 21 %; straight
Surface characteristics : Erosion: rill, inter-rill, sheet; moderate. Deposition: none. Natural vegetation: Grassland. Land use: Cultivation of annual crops.
Natural drainage class: well drained
Described by D.N. Kimaro, B.M. Msanya, E.P. Kileo and G.G. Kimbi on 17/05/2000.

Soil: Soils are deep, well drained dark greyish brown sandy clay loams with very thick very dark grey sandy clay loam topsoils.

Ap 0 - 50 cm: very dark grey (10YR3/1) moist; sandy clay loam; friable moist, slightly sticky and plastic wet; moderate coarse subangular blocky; many very fine and fine pores; frequent small and large angular fresh and slightly weathered quartz fragments; few medium irregular soft clay, Fe & Mn nodules; many very fine and few coarse roots; abrupt smooth boundary to

Bt 50 - 100 cm: dark greyish brown (10YR4/2) moist; sandy clay loam; friable moist, sticky and plastic wet; weak coarse subangular blocky; continuous moderately thick clay cutans; many very fine and fine pores; frequent small and large angular fresh and slightly weathered quartz, feldspars and mica fragments; common very fine roots; clear smooth boundary to

C 100 - 150 cm: friable moist, non-sticky and non-plastic wet; structureless and massive; many very fine pores; very few very fine roots; slightly weathered saprolite.
SOIL CLASSIFICATION: WRB (FAO, 1998): Haplic Phaeozems
USDA Soil Taxonomy (Soil Survey Staff, 1999): Pachic Argiustolls

ANALYTICAL DATA FOR PROFILE MU-P7

Horizon	Ap	Bt	C
Depth (cm)	0-50	50-100	100-150+
Clay (%)	31	45	7
Silt (%)	11	9	14
Sand (%)	58	46	79
Texture class	SCL	SC	LS
AWC (mm/m)	nd	nd	nd
Bulk density (g/cc)	nd	nd	nd
pH H_2O 1:2.5	5.2	5.3	5.9
pH KCl 1:2.5	4.5	4.6	5.1
EC 1:2.5 (mS/cm)	nd	nd	nd
ESP	0.91	1.76	2.62
Organic C (%)	0.80	0.30	0.10
Total N (%)	0.09	0.04	0.02
C/N	4.4	7.5	5.0
Avail. P BrayI (mg/kg)	16	1.0	1.0
Avail. P Olsen (mg/kg)	nd	nd	nd
CEC NH_4OAc (cmol(+)/kg)	8.8	6.8	6.5
Exch. Ca (cmol(+)/kg)	3.9	3.9	2.7
Exch. Mg (cmol(+)/kg)	1.3	2.2	1.6
Exch. K (cmol(+)/kg)	0.13	0.13	0.11
Exch. Na (cmol(+)/kg)	0.08	0.12	0.17
Base saturation (%)	61	93	70
CEC_{Clay} (cmol(+)/kg)	19.5	12.8	88.0

nd = not determined

Profile number: MU-P8 Mapping unit: M3 Agro-ecol. zone:
Region : MOROGORO
District : MOROGORO URBAN
Map sheet no. : 183/3
Co-ordinates : 37°39'46.1"E/ 6°52'50.9"S
Location : Mgambazi area
Elevation : 1288 m asl. Parent material: colluvium. Landform: mountain; mountainous. Slope: 9 %
Surface characteristics : Erosion: sheet; moderate. Deposition: none. Natural vegetation: Grassland. Land use: Cultivation of field crops.
Natural drainage class : moderately well drained
Described by D.N. Kimaro, B.M. Msanya, G.G. Kimbi, and E.P. Kileo on 01/06/2000.

Soil: Soils are very deep, moderate to well drained yellowish brown to yellow sandy clay loams with very thick very dark brown sandy clay loam topsoils.

Ap 0 - 50/60 cm: very dark brown (10YR2/2) moist; sandy clay loam; friable moist, slightly sticky and slightly plastic wet; weak medium subangular blocks; many fine and very fine pores; very frequent small and large angular fresh and slightly weathered feldspars fragments; very few small irregular soft Fe & Mn nodules; many very fine and few coarse roots; clear wavy boundary to

BCt1 50/60 – 90/100 cm: yellowish brown (10YR5/6) moist; sandy clay loam; firm moist, slightly sticky and slightly plastic wet; weak medium and coarse subangular blocks; broken moderately thick clay cutans; many very fine and few coarse pores; very frequent small and large angular fresh and slightly weathered feldspars fragments; very few small irregular soft Fe & Mn nodules; common very fine roots; gradual .wavy boundary to

BCt2 90/100 - 160 cm: yellow (10YR5/3) moist; sandy clay loam; friable moist, slightly sticky and slightly plastic wet; weak medium and coarse subangular blocks; broken moderately thick clay cutans; many fine and few coarse pores; few small and large angular fresh and slightly weathered feldspars, quartz and mica fragments; frequent small irregular soft manganese nodules; few very fine roots.
SOIL CLASSIFICATION: WRB (FAO, 1998): Ferri-Profondic Lixisols
USDA Soil Taxonomy (Soil Survey Staff, 1999): Kanhaplic Haplustalfs

ANALYTICAL DATA FOR PROFILE MU-P8

Horizon	Ap	BCt1	BCt2
Depth (cm)	0-50/60	50/60-90/100	90/100-160+
Clay (%)	25	31	31
Silt (%)	5	5	7
Sand (%)	70	64	62
Texture class	SCL	SCL	SCL
AWC (mm/m)	nd	nd	nd
Bulk density (g/cc)	nd	nd	nd
pH H_2O 1:2.5	6.0	6.1	6.4
pH KCl 1:2.5	5.1	5.0	5.2
EC 1:2.5 (mS/cm)	nd	nd	nd
ESP	2.07	2.75	1.82
Organic C (%)	0.3	0.1	0.1
Total N (%)	0.05	0.03	0.02
C/N	6.0	3.3	5.0
Avail. P BrayI (mg/kg)	1.0	2.0	2.0
Avail. P Olsen (mg/kg)	nd	nd	nd
CEC NH_4OAc (cmol(+)/kg)	5.8	4.0	4.4
Exch. Ca (cmol(+)/kg)	1.6	1.6	1.7
Exch. Mg (cmol(+)/kg)	1.1	1.5	1.8
Exch. K (cmol(+)/kg)	0.11	0.11	0.10
Exch. Na (cmol(+)/kg)	0.12	0.11	0.08
Base saturation (%)	51	83	84
CEC_{Clay} (cmol(+)/kg)	19.0	11.7	13.1

nd = not determined

Profile number: MU-P9 Mapping unit: P1 Agro-ecol. zone:
Region : MOROGORO
District : MOROGORO URBAN
Map sheet no. : 183/3
Co-ordinates : 37°40'06"E/ 6°51'11"S
Location : Nyandira msichoke-Mr. Juma's farm
Elevation : 670 m asl. Parent material: mud clay colluvium over pyroxene granulites. Landform: foothills; rolling. Slope: 32 %; complex, middle slope.
Surface characteristics: Erosion: inter-rill, gully; severe. Deposition: none. Natural vegetation: Cleared land. Land use: Cultivation of maize and cassava.
Natural drainage class : well drained
Described by D.N. Kimaro, G.G. Kimbi, and B.M Msanya on 06/09/2000.

Soil: Soils are very deep, well drained dark red to red clays with thin dark reddish brown clay topsoils.

Ap 0 - 10 cm: dark reddish brown (2.5YR3/4) dry, dark reddish brown (2.5YR3/3) moist; clay; slightly hard dry, friable moist, sticky and plastic wet; moderate fine and medium subangular blocks; many very fine and few medium pores; very few medium angular fresh quartz fragments; many very fine and few medium roots; clear smooth boundary to
Bt1 10 - 30 cm: red (2.5YR4/6) dry, dark red (2.5YR3/6) moist; clay; slightly hard dry, friable moist, sticky and plastic wet; moderate fine and medium subangular blocks; broken thin clay cutans; many very fine pores; very few small angular fresh quartz fragments; very frequent small, medium and large spherical and irregular soft clay nodules; many very fine and few medium roots; diffuse smooth boundary to
Bt2 30 - 80 cm: red (10R4/8) moist; clay; very friable moist, sticky and plastic wet; moderately weak fine and medium subangular blocks; patchy thin clay cutans; many very fine pores; frequent small and medium spherical and irregular soft clay nodules; few very fine roots; diffuse smooth boundary to
Bt3 80 - 150 cm: red (10R4/8) moist; clay; very friable moist, sticky and plastic wet; moderately weak fine and medium subangular blocks; patchy thin clay cutans; many very fine pores; frequent small and medium spherical and irregular soft clay nodules; very few very fine roots

SOIL CLASSIFICATION: WRB (FAO, 1998): Hapli- Profondic Acrisols
USDA Soil Taxonomy (Soil Survey Staff, 1999): Kandic Paleustalfs

ANALYTICAL DATA FOR PROFILE MU-P9

Horizon	Ap	Bt1	Bt2	Bt3
Depth (cm)	0-10	10-30	30-80	80-150
Clay (%)	56	66	70	68
Silt (%)	7	3	3	3
Sand (%)	37	31	27	29
Texture class	C	C	C	C
AWC (mm/m)	nd	nd	nd	nd
Bulk density (g/cc)	nd	nd	nd	nd
pH H_2O 1:2.5	6.4	5.5	5.7	6.1
pH KCl 1:2.5	4.9	4.1	4.3	4.6
EC 1:2.5 (mS/cm)	nd	nd	nd	nd
ESP	1.49	0.82	0.65	1.35
Organic C (%)	1.9	0.5	0.3	0.2
Total N (%)	0.23	0.06	0.05	0.06
C/N	8.3	8.3	6.0	3.3
Avail. P BrayI (mg/kg)	2.0	1.0	1.0	1.0
Avail. P Olsen (mg/kg)	nd	nd	nd	nd
CEC NH_4OAc (cmol(+)/kg)	14.8	11.0	10.8	10.4
Exch. Ca (cmol(+)/kg)	3.0	0.6	0.7	0.5
Exch. Mg (cmol(+)/kg)	4.4	2.9	3.7	3.5
Exch. K (cmol(+)/kg)	1.02	0.37	0.11	0.11
Exch. Na (cmol(+)/kg)	0.22	0.09	0.07	0.14
Base saturation (%)	58	36	42	41
CEC_{Clay} (cmol(+)/kg)	14.7	14.1	13.0	14.3

nd = not determined

Profile number: MU-P10 Mapping unit: P1 Agro-ecol. zone:
Region: MOROGORO
District: MOROGORO URBAN
Map sheet no. : 183/3
Co-ordinates: 37°40'05"E/ 6°51'18"S
Location: Nyandira-Mlima bundi
Elevation: 720 m asl. Parent material: mud clays colluvium over pyroxene granulites. Landform: foothills; hilly. Slope: 48 %; complex, 110 m, middle slope. Surface characteristics: Stones: 15 % Erosion: inter-rill, rill, gully; moderate to severe. Deposition: none. Natural vegetation: Cleared land. Land use: Cultivation of maize, cassava, bananas and pigeon peas.
Natural drainage class: well drained
Described by D.N. Kimaro, B.M. Msanya, G.G. Kimbi, and E.P. Kileo on 06/09/2000.

Soil: Soils are deep, well drained dark red to red clays with thin dark brown sandy clay topsoils.

Ap 0 - 6 cm: brown (7.5YR4/3) dry, dark brown (7.5YR3/2) moist; sandy clay; slightly hard dry, friable moist, sticky and plastic wet; moderate fine and medium subangular blocky; many very fine pores; few small, medium and large angular and spherical fresh and weathered quartz and gneiss fragments; common very fine roots; clear smooth boundary to

Bt1 6 - 30 cm: dark red (2.5YR3/6) moist; clay; friable moist, sticky and plastic wet; strong fine subangular blocky and medium angular blocky; broken thin clay cutans; many fine pores; frequent small, medium and large angular and spherical fresh and weathered quartz and gneiss fragments; frequent small and medium spherical and irregular soft clay nodules; few very fine roots; gradual smooth boundary to

Bt2 30 - 85 cm: red (2.5YR4/6) moist; clay; very friable moist, sticky and plastic wet; moderate fine and medium subangular blocky; patchy thin clay cutans; many very fine pores; frequent small, medium and large spherical and angular fresh and weathered quartz and gneiss fragments; frequent small and medium spherical and irregular soft clay nodules; few very fine roots; abrupt smooth boundary to

C 85 - 150 cm: strong brown (7.5YR4/6) moist; sandy loam; very friable moist, non-sticky and non-plastic wet; structureless and massive; very few very fine roots

SOIL CLASSIFICATION: WRB (FAO, 1998): Hapli-Chromic Lixisols
USDA Soil Taxonomy (Soil Survey Staff, 1999): Kanhaplic Haplustalfs

ANALYTICAL DATA FOR PROFILE MU-P10

Horizon	Ap	Bt1	Bt2	C
Depth (cm)	0-6	6-30	30-85	85-150+
Clay (%)	38	70	54	14
Silt (%)	13	9	13	15
Sand (%)	49	21	33	71
Texture class	SC	C	C	SL
AWC (mm/m)	nd	nd	nd	nd
Bulk density (g/cc)	nd	nd	nd	nd
pH H_2O 1:2.5	6.2	5.9	5.6	6.2
pH KCl 1:2.5	5.9	4.5	4.8	4.8
EC 1:2.5 (mS/cm)	nd	nd	nd	nd
ESP	1.69	0.66	0.82	1.37
Organic C (%)	0.8	0.7	0.3	0.1
Total N (%)	0.18	0.08	0.06	0.02
C/N	4.4	8.8	5.0	5.0
Avail. P BrayI (mg/kg)	3.0	1.0	1.0	1.0
Avail. P Olsen (mg/kg)	nd	nd	nd	nd
CEC NH_4OAc (cmol(+)/kg)	17.2	15.2	13.4	10.2
Exch. Ca (cmol(+)/kg)	8.1	3.6	2.8	3.1
Exch. Mg (cmol(+)/kg)	5.6	5.6	4.9	4.7
Exch. K (cmol(+)/kg)	0.75	0.21	0.10	0.06
Exch. Na (cmol(+)/kg)	0.29	0.10	0.11	0.14
Base saturation (%)	86	62	59	78
CEC_{Clay} (cmol(+)/kg)	38.0	18.3	22.9	70.4

nd = not determined

Profile number: MU-P11 Mapping unit: P2 Agro-ecol. zone:
Region: MOROGORO
District: MOROGORO URBAN
Map sheet no. : 183/3
Co-ordinates: 37°39'08" E/ 6°51'57" S
Location: Vilengwe village (about 0.5 km SE of Magadu primary school).
Elevation: 780 m asl. Parent material: colluvium mainly mud clays derived from hornblende pyroxene granulites and micaceous gneisses. The rock fragments observed in the C horizon were mainly micaceous gneisses with quartz and feldspars. Landform: foothills; hilly. Slope: 15 %; middle-upper slope.
Surface characteristics: Outcrops: 15 % Stones: 15 % Erosion: rill; moderate. Deposition: none. Natural vegetation: Few scattered *Pterocarpus angolensis, Julbernardia globiflora, Combretum spp., Brachystegia spp*. and herbaceous species including *Hyparrhenia rufa* and *Sporobolus pyramidalis*. Land use: Cultivation of maize, bananas, groundnuts, mango, cassava and sweet potatoes.
Natural drainage class: well drained
Described by D.N. Kimaro, B.M. Msanya, G.G. Kimbi and E.P. Kileo on 05/10/2000.

Soil: Soils are very deep, well drained red sandy clays with very thin dark brown sandy clay topsoils.

Ap 0 - 5 cm: dark brown (7.5YR3/3) moist, brown (7.5YR4/3) dry; sandy clay; slightly hard dry, friable moist, slightly sticky and slightly plastic wet; moderate fine and medium granular structure; many very fine pores; many fine roots; abrupt smooth boundary to

Bt1 5-31 cm: dark red (2.5YR3/6) moist, red (2.5YR4/6) dry; clay; hard dry, friable moist, sticky and plastic wet; strong medium angular blocky; common fine to medium pores; few faint clay cutans; common fine roots; abrupt smooth boundary to
Stone-line 31 – 39 cm: Stone-line composed mainly of fresh angular quartz gravel and stones (1- 10 cm); abrupt smooth boundary to
Bt2 39 – 92/116 cm: red (2.5YR4/8) moist, red (2.5YR4/8) dry; sandy clay; slightly hard dry, friable moist, slightly sticky and plastic wet; strong medium angular blocky; common fine and few medium pores; few small (0.2-0.5 cm) angular slightly weathered quartz and feldspars fragments; few faint clay cutans; few fine roots; clear wavy boundary to

BC 92/116-145 cm: red (2.5YR4/6) moist, red (2.5YR5/8) dry; sandy loam; slightly hard dry, friable moist, slightly sticky and slightly plastic wet; strong fine angular blocky; common fine pores; very frequent small to medium (0.2-1.2 cm) angular slightly weathered quartz and feldspars fragments; few very fine roots; clear smooth boundary to

C 145-200+ cm: weathered micaceous gneiss with quartz and feldspars.

SOIL CLASSIFICATION: WRB (FAO, 1998): Chromi-Profondic Luvisols
USDA Soil Taxonomy (Soil Survey Staff, 1999): Ultic Haplustalfs

ANALYTICAL DATA FOR PROFILE MU-P11

Horizon	Ap	Bt1	Stone-line	Bt2	BC
Depth (cm)	0-5	5-31	31-39	39-92/116	92/116-145
Clay (%)	37	52	nd	47	24
Silt (%)	13	5	nd	7	15
Sand (%)	50	43	nd	46	61
Texture class	SC	C	gravels	SC	SL
AWC (mm/m)	nd	nd	nd	nd	nd
Bulk density (g/cc)	1.37	1.46	nd	1.42	nd
pH H_2O 1:2.5	5.8	6.0	nd	6.8	6.9
pH KCl 1:2.5	5.1	5.6	nd	6.1	6.0
EC 1:2.5 (mS/cm)	nd	nd	nd	nd	nd
ESP	3.36	1.71	nd	1.23	1.56
Organic C (%)	1.38	0.47	nd	0.23	0.07
Total N (%)	0.13	0.08	nd	0.05	0.03
C/N	nd	nd	nd	nd	nd
Avail. P BrayI (mg/kg)	6.0	5.0	nd	1.0	1.0
Avail. P Olsen (mg/kg)	nd	nd	nd	nd	nd
CEC NH_4OAc (cmol(+)/kg)	14.6	15.2	nd	13.8	10.3
Exch. Ca (cmol(+)/kg)	4.4	5.0	nd	3.2	2.2
Exch. Mg (cmol(+)/kg)	2.7	1.6	nd	1.8	1.6
Exch. K (cmol(+)/kg)	0.97	0.24	nd	0.20	0.12
Exch. Na (cmol(+)/kg)	0.49	0.26	nd	0.17	0.16
Base saturation (%)	59	47	nd	39	40
CEC_{Clay} (cmol(+)/kg)	26.4.	25.9	nd	27.9	41.4

nd = not determined

Profile number: MU-P12 Mapping unit: P2 Agroecol zone:
Region: Morogoro
District: Morogoro Urban
Map sheet no.: 183/3
Coordinates: 6°49′22″ S/37°43′18″ E
Location: Bigwa (Rwegimbura's farm)
Elevation: 450 m asl
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, E.P. Kileo and G.G. Kimbi on 05/07/1999.

Soils: Soils are very deep, well drained, strong brown to reddish brown clays with thick dark brown clay topsoils.

Ap 0-15 cm: dark brown (7.5YR3/4 moist); clay; moderate medium angular blocky; friable, sticky, plastic; high biological activity; many fine and medium pores; many fin, very few medium roots; clear wavy boundary to

Bt 15-55 cm: strong brown (7.5YR4/4 moist); clay; weak, medium and coarse angular blocky; hard, friable, sticky, plastic; many fine clay cutans; common fine, few medium pores; common fine, very few medium roots; clear wavy boundary to

Bts1 55-120 cm: reddish brown (5YR4/4 moist); clay; weak, medium angular blocky; very friable, sticky, plastic; few fine clay skins; many very fine pores; common fine roots; clear smooth boundary to

Bts2 120-200 cm: reddish brown (5YR4/4 moist); clay; weak medium angular blocky; very friable, sticky, plastic; few fine clay skins; many very fine pores; few fine roots.
SOIL CLASSIFICATION: WRB (FAO, 1998): Chromi-Profondic Lixisols USDA Soil Taxonomy (Soil Survey Staff, 1999): Kanhaplic Haplustalfs

ANALYTICAL DATA FOR PROFILE MU-P12

Horizon	Ap	Bt	Bts1	Bts2
Depth cm	0-15	15-55	55-120	120-200
Clay %	44	60	60	60
Silt %	16	10	10	12
Sand %	40	30	30	28
Textural class	C	C	C	C
Silt/clay ratio	0.36	0.17	0.17	0.2
pH H_2O 1:2.5	6.3	5.8	5.3	5.4
pH KCl 1:2.5	5.3	4.7	4.5	5.4
EC dS/m	0.03	0.03	0.02	0.03
ESP	4.1	5.8	3.0	1.4
OC %	2.51	0.89	0.51	0.48
Total N %	0.24	0.08	0.05	0.05
C/N ratio	10.5	11.0	10.2	9.6
Bray I P mg/kg	204	3.01	0.39	0.44
Olsen P mg/kg	nd	nd	nd	nd
CEC cmol(+)/kg	19.0	12.4	10.2	10.6
Ca cmol(+)/kg	5.47	2.00	2.52	1.28
Mg cmol(+)/kg	5.64	2.10	2.82	4.47
K cmol(+)/kg	4.22	3.54	1.03	0.37
Na cmol(+)/kg	0.78	0.72	0.31	0.15
BS %	100	100	100	100
CEC claycmol(+)/kg	23.5	15.6	14.1	14.9

nd=not determined

Profrile number: MU-P13 Mapping unit: P3; Agroecol zone:
Region: Morogoro
District: Morogoro Urban
Map sheet no.: 183/3
Coordinates: 6°49′03″S/37°43′02″E
Location: Bigwa (Mr. Emilian Jaka's farm)
Elevation: 450 m asl
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 G.G. Kimbi, B.M. Msanya, D.N. Kimaro and E.P. Kileo on 05/07/1999.

Soils: Soils are very deep, well drained, yellowish red to red clays with thick dark brown clay topsoils.

Ap 0-20 cm: dark brown (7.5YR3/3 moist); clay; weak, fine and medium subangular blocks; very friable, sticky, plastic; many fine pores; many fine, few medium roots; clear wavy boundary to

BAt 20-42 cm: yellowish red (5YR4/6 moist); clay; 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 to

Bts1 42-55 cm: yellowish red (5YR4/6 moist); clay; moderate medium angular blocks; friable, sticky, plastic; few medium; many thin clay skins; many fine and medium pores; many fine roots; clear wavy boundary to

Bts2 55-75 cm: red (2.5YR4/8 moist); 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 to
Bts3 75-212+ cm: red (2.5YR4/8 moist); 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.

SOIL CLASSIFICATION: WRB (FAO, 1998): Chromi-Profondic Lixisols
USDA Soil Taxonomy (Soil Survey Staff, 1999): Kandic Paleustalfs

ANALYTICAL DATA FOR PROFILE MU-P13

Horizon	Ap	BAt	Bts1	Bts2	Bts3
Depth cm	0-20	20-42	42-55	55-75	75-212
Clay %	42	58	68	62	58
Silt %	20	12	8	12	14
Sand %	38	30	24	26	28
Textural class	C	C	C	C	C
Silt/clay ratio	0.48	0.21	0.12	0.19	0.24
pH H_2O 1:2.5	6.7	6.9	5.9	5.4	5.5
pH KCl 1:2.5	5.5	5.4	4.7	4.4	4.3
EC dS/cm	0.05	0.05	0.07	0.06	0.05
ESP	2.32	1.93	1.18	0.98	0.61
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 ratio	18	12	14	17	16
Bray I P mg/kg	4.76	2.18	1.77	1.94	0.61
Olsen P mg/kg	nd	nd	nd	nd	nd
CEC cmol(+)/kg	14.2	11.4	10.2	9.2	8.2
Ca cmol(+)/kg	7.09	4.81	3.23	2.68	1.01
Mg cmol(+)/kg	3.09	2.73	2.41	1.30	2.86
K cmol(+)/kg	1.36	0.92	0.55	0.29	0.06
Na cmol(+)/kg	0.33	0.22	0.12	0.09	0.05
BS %	84	76	62	47	49
CEC clay cmol(+)/kg	30.9	9.9	11.6	11.1	12.2

nd=not determined

Profile number: MU-P14 Mapping unit: P4 Agro-ecol. zone:
Region: MOROGORO
District: MOROGORO URBAN
Map sheet no. : 183/1
Coordinates: 37°38'51. 0" E/ 6°43'36.1" S
Location: MKUNDI
Elevation: 465 m asl. Parent material: Banded muscovite biotite sediments and superficial sands derived from Nguru ya Ndege mountains. Landform: Alluvial fan; undulating. Slope: 6 %; convex
Surface characteristics: Erosion: none or slight. Deposition: none.
Natural drainage class: well drained
Described by B.M. Msanya, D.N. Kimaro, E.P. Kileo and S.B. Mwango on 23/12/1999

Soils are very deep, well drained reddish brown to dark reddish brown loamy sand to sandy clay loams, with thick reddish brown loamy sand topsoils.

Ah 0 - 15 cm: yellowish red (5YR4/6) dry, reddish brown (5YR4/4) moist; loamy sand; slightly hard dry, friable moist, non-sticky and non-plastic wet; weak medium subangular blocky; many fine and medium pores; common fine and very fine roots; gradual smooth boundary to

BA 15 - 35 cm: yellowish red (5YR4/6) dry, reddish brown (5YR4/4) moist; loamy sand; slightly hard dry, friable moist, slightly sticky and slightly plastic wet; weak fine and medium subangular blocky; patchy thin clay cutans; many fine and medium pores; very few small angular slightly weathered quartz fragments; few medium and coarse roots; gradual smooth boundary to

Bw1 35 - 75 cm: red (2.5YR4/6) dry, dark reddish brown (2.5YR3/4) moist; sandy clay loam; slightly hard dry, friable moist, sticky and plastic wet; moderate medium subangular blocky; patchy thin clay cutans; common fine pores; frequent small angular slightly weathered quartz fragments; few very fine and medium roots; gradual smooth boundary to

Bw2 75 - 160+ cm: reddish brown (2.5YR4/4) dry, dark reddish brown (2.5YR3/4) moist; sandy clay; slightly hard dry, friable moist, sticky and plastic wet; moderate medium subangular blocky; common fine pores; very frequent medium angular slightly weathered quartz fragments; few very fine and medium roots

SOIL CLASSIFICATION: WRB (FAO 1998): Chromi-Rhodic Cambisols (Hypereutric)
USDA-Soil Taxonomy (Soil Survey Staff, 1999): Typic Haplustepts

ANALYTICAL DATA FOR PROFILE MU-P14

Horizon	Ah	BA	Bw1	Bw2
Depth (cm)	0-15	15-35	35-75	75-160+
Clay %	12	18	26	28
Silt %	8	8	6	4
Sand %	80	74	68	62
Texture class	LS	LS	SCL	SC
Bulk density g/cc	1.4	nd	1.4	1.5
AWC mm/m	nd	nd	nd	130
pH H_2O 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 1:2.5 mS/cm	0.02	0.02	0.02	0.03
ESP	0.56	0.77	0.83	1.10
Organic C %	0.66	0.38	0.26	0.19
Total N %	0.07	0.04	0.03	0.02
C/N	9	10	9	10
Avail. P Bray-1 mg/kg	3.7	nd	nd	nd
Avail. P Olsen mg/kg	nd	14.7	8.1	2.6
CEC NH_4OAc cmol(+)/kg	5.32	6.52	7.26	8.15
Exch. Ca cmol(+)/kg	3.3	3.8	4.1	4.4
Exch. Mg cmol(+)/g	1.8	2.4	2.7	2.9
Exch. K cmol(+)/kg	0.05	0.05	0.04	0.01
Exch. Na cmol(+)/kg	0.03	0.05	0.06	0.09
Base saturation %	97.0	97	95	91
CEC clay cmol(+)/kg	23.4	28.9	24.5	26.8

nd= not determined

Profile number: MU-P15 Mapping unit: L2 Agro-ecol. zone:
Region: MOROGORO
District: MOROGORO URBAN
Map sheet no. : 183/3
Co-ordinates: 37°38'50.3″E/ 6°50'34.4″S
Location: SUA Botanical garden, 450 m west of Morogoro-Mzinga road.
Elevation: 630 m asl. Parent material: colluvium derived from mafic metamorphic rocks. Landform: plain; flat or almost flat, slopes: 0.5 %; straight, middle slope.
Surface characteristics: Outcrops: none Stones: none; Cracks: none. Erosion: slight sheet erosion. Deposition: none.
Natural drainage class: well drained

Described by B.M. Msanya, D.N. Kimaro, G.G. Kimbi and E.P. Kileo on 8/12/2000.

Soil: Soils are very deep, well drained dark red clays with thick dark reddish brown clay topsoils.

Ah 0 - 16 cm: dark reddish brown (2.5YR3/4) dry, dark reddish brown (2.5YR3/3) moist; clay; slightly hard dry, friable moist, slightly sticky and slightly plastic wet; moderate fine subangular blocky; common coarse and few medium pores; many fine and few coarse roots; clear smooth boundary to

Bs1 16-40 cm: red (2.5YR4/8) dry, dark red (2.5YR3/6) moist; clay; slightly hard dry, very friable moist, slightly sticky and slightly plastic wet; weak fine subangular blocky; common fine and many very fine pores; many fine and few coarse roots; few crotovinas; gradual smooth boundary to

Bs2 40 – 75 cm: red (2.5YR4/8) dry, dark red (2.5YR3/6) moist; clay; soft dry, very friable moist, slightly sticky and slightly plastic wet; weak fine and medium subangular blocky; common medium and many very fine pores; few medium spherical soft clay nodules; common fine and few coarse roots; few crotovinas; diffuse smooth boundary to

Bs3 75-130 cm: dark red (2.5YR3/6) moist; clay; very friable moist, slightly sticky and slightly plastic wet; weak fine subangular blocky; many very fine and few fine pores; frequent medium irregular soft clay nodules; few fine and coarse roots; diffuse smooth boundary to

Bs4 130-205 cm: dark red (2.5YR3/6) moist; clay; very friable moist, slightly sticky and slightly plastic wet; weak fine subangular blocky; many very fine and few fine pores; frequent medium irregular soft clay nodules; few fine roots.

SOIL CLASSIFICATION: WRB (FAO, 1998): Rhodi-Ferric Ferralsols
USDA Soil Taxonomy (Soil Survey Staff, 1999): Rhodic Haplustox

ANALYTICAL DATA FOR PROFILE MU-P15

Horizon	Ah	Bs1	Bs2	Bs3	Bs4
Depth (cm)	0-16	16-40	40-75	75-130	130-205
Clay (%)	58	62	64	65	62
Silt (%)	10	9	9	10	10
Sand (%)	32	29	27	25	28
Texture class	C	C	C	C	C
AWC (mm/m)	nd	nd	nd	nd	nd
Bulk density (g/cc)	nd	nd	nd	nd	nd
pH H_2O 1:2.5	5.8	5.1	5.5	5.5	6.0
pH KCl 1:2.5	4.5	4.0	4.0	4.1	4.0
EC 1:2.5 (mS/cm)	nd	nd	nd	nd	nd
ESP	3.0	2.7	3.3	3.1	3.2
Organic C (%)	1.3	0.6	0.4	0.3	0.2
Total N (%)	0.10	0.05	0.04	0.06	0.03
C/N	13	13	11	5	7
Avail. P BrayI (mg/kg)	2.1	1.5	0.5	0.5	0.5
Avail. P Olsen (mg/kg)	nd	nd	nd	nd	nd
CEC NH_4OAc (cmol(+)/kg)	9.2	9.8	6.4	6.2	6.0
Exch. Ca (cmol(+)/kg)	2.2	0.6	0.6	0.3	0.5
Exch. Mg (cmol(+)/kg)	2.5	1.5	2.1	1.9	1.5
Exch. K (cmol(+)/kg)	0.46	0.29	0.16	0.14	0.14
Exch. Na (cmol(+)/kg)	0.28	0.26	0.21	0.19	0.19
Base saturation (%)	44	27	47	41	40
CEC_{Clay} (cmol(+)/kg)	8.1	12.5	7.8	7.9	8.6

nd = not determined

Profile number: MU-P16 Mapping unit: L2 Agroecol zone:
Region: Morogoro
District: Morogoro Urban
Map sheet no.: 183/3
Coordinates: 6°38′47.7″ S/37°39′01.5″ E
Location: Modeco
Elevation: 410 m asl
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, E.P. Kileo and G.G. Kimbi on 04/07/1999.

Soils: Soils are very deep, well drained, dark brown to strong brown sandy clay loams with thin brown sandy loam topsoils.

Ap 0-10 cm: brown (10YR4/3 moist); sandy loam; weak fine subangular blocky; friable, sticky, slightly plastic; many fine very few coarse pores; many fine roots; clear smooth boundary to

Bt1 10-60 cm: dark brown (7.5YR3/3 dry), dark brown (7.5YR3/2 moist); sandy clay loam; weak coarse columnar breaking to coarse angualr blocky; hard, friable, sticky, plastic; few thin patchy cutans; many fine, very few coarse pores; common fine, very few medium roots; gradual smooth boundary to

Bt2 60-115 cm: dark brown (7.5YR3/4 dry), dark brown (7.5YR3/3 moist); sandy clay loam; weak, very coarse angular blocky; 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 to

BC 115-200 cm: strong brown (7.5YR4/6 dry), dark brown (7.5YR3/4 moist); sandy clay loam; weak coarse angular blocky; 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 to
C 200+ cm: Slightly weathered gneiss.

SOIL CLASSIFICATION: WRB (FAO, 1998): Chromi-Profondic Luvisols

USDA Soil Taxonomy (Soil Survey Staff, 1999): Typic Haplustalfs

ANALYTICAL DATA FOR PROFILE MU-P16

Horizon	Ap	Bt1	Bt2	BC
Depth cm	0-10	10-60	60-115	115-200
Clay %	19	23	28	26
Silt %	4	5	6	6
Sand %	77	72	66	68
Textural class	SL	SCL	SCL	SCL
pH H_2O 1:2.5	8.1	8.0	7.9	8.0
pH KCl 1:2.5	7.3	6.7	6.9	7.4
EC dS/m	0.11	0.06	0.12	0.39
ESP	1.64	0.74	0.89	3.36
OC %	0.98	0.89	0.68	0.27
Total N %	0.08	0.08	0.04	0.02
C/N ratio	12	11	17	14
Bray I P mg/kg	4.59	0.89	0.77	0.87
Olsen P mg/kg	nd	nd	nd	nd
CEC cmol(+)/kg	12.2	16.2	17.8	14.6
Ca cmol(+)/kg	9.9	9.6	14.9	10.6
Mg cmol(+)/kg	1.2	3.4	1.8	2.1
K cmol(+)/kg	0.15	0.16	0.16	0.18
Na cmol(+)/kg	0.20	0.12	0.16	0.49
BS %	94	82	96	92
CEC clay cmol(+)/kg	46.4	57.1	55.2	52.6

nd=not determined

Profile number: MU-P17 Mapping unit: L2 Agro-ecol. zone:
Region: MOROGORO
District: MOROGORO URBAN
Map sheet no. : 183/3
Co-ordinates: 37°38'24" E/ 6°51'15" S
Location: Magadu (about 2 km southwest of Sokoine University of Agriculture main campus on Morogoro-Mzinga road and 100 m to the west of the road in in SUA farm).
Elevation: 530 m asl. Parent material: coluvial deposits derived from Uluguru Mountains. Landform: Gently undulating plain. Slope: 3 %; middle slope.
Surface characteristics: Outcrops: none Stones: none; Cracks: none. Erosion: Moderate sheet erosion. Deposition: colluvial deposits. Natural vegetation: most of the natural woody vegetation has been cleared resulting in a complex of secondary savanna patches composed of *Acacia spp.Adansonia digitata* and *Cassia spp.* Grass species include *Hyperrhenia rufa.*
Land use: Cultivation of maize, Groundnuts and beans.
Natural drainage class: Well drained

Described by B.M. Msanya, D.N. Kimaro, G.G. Kimbi and E.P. Kileo on 06/11/2000.

Soil: Soils are very deep, well drained yellowish red to strong brown clays with thick dark brown sandy clay topsoils.

Ap 0 - 13 cm: dark brown (7.5YR3/4) moist, brown (7.5YR4/6) dry; sandy clay; hard dry, friable moist, sticky and plastic wet; moderate fine and medium crumb structure; common very fine and fine pores; many very and fine roots; abrupt smooth boundary to

BA 13-28 cm: reddish brown (5YR4/4) moist, yellowish red (5YR5/6) dry; sandy clay; hard dry, friable moist, sticky and plastic wet; moderately strong fine to medium subangular blocky; common very fine to fine and few medium pores; common very fine to fine roots; clear smooth boundary to

Bt1 28 – 74 cm: yellowish red (5YR4/6) moist, yellowish red (5YR5/6) dry; clay; hard dry, friable moist, very sticky and very plastic wet; moderate fine subangular blocky; common very fine to fine tubular pores; few faint clay and sesquioxides cutans; very few fine (1-2 mm) hard spherical black Mn nodules; few termite channels; common very fine to fine roots; diffuse smooth boundary to

Bt2 74-152 cm: yellowish red (5YR4/6) moist, yellowish red (5YR4/6) dry; clay; hard dry, friable moist, very sticky and very plastic wet; moderate fine and medium subangular blocky; common very fine to fine pores; common faint clay and sesquioxides cutans; few fine (2-4 mm) hard spherical black and brownish Fe-Mn nodules and few fine to medium (5-12 mm) irregular soft aggregations of clay; few termite channels; few very fine to fine roots; gradual smooth boundary to

Bt3 152-200+ cm: strong brown (7.5YR4/6) moist, strong brown (7.5YR5/6) dry; clay; hard dry, friable moist, very sticky and very plastic wet; moderate fine and medium subangular blocky; common very fine and fine pores; common faint clay and sesquioxides cutans; few fine (2-4 mm) hard spherical black and brownish Fe-Mn nodules and few fine to medium (5-12 mm) irregular soft aggregations of clay; few termite channels; few very fine to fine roots.

SOIL CLASSIFICATION: WRB (FAO, 1998): Ferri-Profondic Acrisols
USDA Soil Taxonomy (Soil Survey Staff, 1999): Ultic Paleustults

ANALYTICAL DATA FOR PROFILE MU-P17

Horizon	Ap	BA	Bt1	Bt2	Bt3
Depth (cm)	0-13	13-28	28-74	74-152	152-200+
Clay (%)	46.8	49.8	59.2	63	65
Silt (%)	4.8	4.8	4.6	6.8	6.8
Sand (%)	48.4	45.4	36.2	30.2	28.2
Texture class	SC	SC	C	C	C
AWC (mm/m)	nd	nd	nd	nd	nd
Bulk density (g/cc)	1.35	nd	1.26	1.28	nd
pH H_2O 1:2.5	4.8	4.6	4.8	5.2	5.0
pH KCl 1:2.5	3.8	3.7	3.9	4.1	3.9
EC 1:2.5 (mS/cm)	nd	nd	nd	nd	nd
ESP	8.0	8.4	9.3	9.2	9.0
Organic C (%)	1.1	1.0	0.7	0.5	0.3
Total N (%)	0.12	0.07	0.05	0.05	0.05
C/N	9.2	14	14	10	6
Avail. P BrayI (mg/kg)	3.6	1.3	1.2	1.4	1.8
Avail. P Olsen (mg/kg)	nd	nd	nd	nd	nd
CEC NH_4OAc (cmol(+)/kg)	13.8	12.2	12.0	12.4	13.4
Exch. Ca (cmol(+)/kg)	0.4	1.4	1.0	1.2	0.9
Exch. Mg (cmol(+)/kg)	4.2	1.0	1.1	1.1	1.2
Exch. K (cmol(+)/kg)	0.82	0.44	0.51	0.12	0.16
Exch. Na (cmol(+)/kg)	1.10	1.02	1.12	1.14	1.21
Base saturation (%)	48	32	31	29	26
CEC_{Clay} (cmol(+)/kg)	21.2	17.7	16.4	16.8	19.0

nd = not determined

Profile number: MU-P18 Mapping unit: L4 Agro-ecol. zone:
Region: MOROGORO
District: MOROGORO URBAN
Map sheet no. : 183/3
Co-ordinates: 37°42'E/ 6°46'S
Location: Tungi Sisal Estate, block M, Kiyegeya part
Elevation: 560 m asl. Parent material: Gneiss. Landform: Almost flat crest on a peneplain with.slopes: 0-1 %; middle slope.
Surface characteristics: Outcrops: none Stones: none; Cracks: none. Erosion: slight sheet erosion. Deposition: colluvial deposits. Natural vegetation: Natural vegetation has been cleared. Land use: sisal cultivation.
Natural drainage class: Well to somewhat excessively drained

Described by B.M. Msanya, D.N. Kimaro, E.P. Kileo and G.G. Kimbi on 10/12/2000.

Soil: Soils are moderately shallow, well to somewhat excessively drained reddish brown to dark red sandy clay loams with thick dark reddish brown sandy clay loam topsoils.

Ah 0 - 15 cm: dark reddish brown (5YR3/2) moist; sandy clay loam; slightly hard dry, friable moist, slightly sticky and non plastic wet; moderate fine granular and medium subangular blocky; many fine, common medium and few coarse pores; many fine and medium and few coarse roots; clear smooth boundary to

BA 15-30 cm: dark reddish brown (2.5YR3/4) moist; sandy clay loam; very hard dry, friable moist, sticky and plastic wet; weak medium angular blocky; common medium many fine and few coarse pores; many fine and very few coarse roots; few fine and coarse quartz particles; clear smooth boundary to

Bw1 30 – 45 cm: reddish brown (2.5YR4/4) moist; sandy clay loam; very hard dry, friable moist, sticky and plastic wet; weak medium angular blocky; many medium and fine and few coarse pores; many fine and few medium roots; few medium quartz particles; gradual smooth boundary to

Bw2 45-55 cm: dark red (2.5YR3/6) moist; sandy clay loam; hard dry, friable moist, sticky and plastic wet; weak fine and medium angular blocky; common medium and many fine pores; few medium and many fine roots; few medium quartz particles; clear smooth boundary to

BC 55+ cm: layer dominated quartzitic gravels

SOIL CLASSIFICATION: WRB (FAO, 1998): Eutri-Chromic Cambisols
USDA Soil Taxonomy (Soil Survey Staff, 1999): Typic Haplustepts

ANALYTICAL DATA FOR PROFILE : MU-P18

Horizon	Ah	BA	Bw1	Bw2
Depth (cm)	0-15	15-30	30-45	45-55
Clay (%)	21	22	25	24
Silt (%)	7	6	6	7
Sand (%)	72	72	69	69
Texture class	SCL	SCL	SCL	SCL
AWC (mm/m)	nd	nd	nd	Nd
Bulk density (g/cc)	nd	nd	nd	Nd
pH H_2O 1:2.5	7.9	6.4	5.9	5.9
pH KCl 1:2.5	7.1	5.2	4.5	4.8
EC 1:2.5 (mS/cm)	nd	nd	nd	Nd
ESP	0.58	0.88	0.83	0.83
Organic C (%)	1.8	0.9	0.6	0.5
Total N (%)	0.20	0.10	0.05	0.04
C/N	9	9	12	12.5
Avail. P BrayI (mg/kg)	nd	0.1	0.1	0.1
Avail. P Olsen (mg/kg)	4.6	nd	nd	nd
CEC NH_4OAc (cmol(+)/kg)	17.3	11.3	12.0	12.0
Exch. Ca (cmol(+)/kg)	11.4	6.9	6.9	6.9
Exch. Mg (cmol(+)/kg)	3.9	1.8	2.3	1.8
Exch. K (cmol(+)/kg)	0.40	0.10	0.10	0.10
Exch. Na (cmol(+)/kg)	0.10	0.10	0.10	0.10
Base saturation (%)	91	79	78	74
CEC_{Clay} (cmol(+)/kg)	52.8	37.3	39.7	42.8

nd = not determined

Profile number: MU-P19 Mapping unit: L4 Agro-ecol. zone:
Region: MOROGORO
District: MOROGORO URBAN
Map sheet no. : 183/3
Co-ordinates: 37°43'E/ 6°44'S
Location: Tungi Sisal Estate, field L, Kiyegeya part
Elevation: 565 m asl. Parent material: Gneiss. Landform: nearly flat crest on a peneplain; gently undulating with.slopes: 2-3 %; middle slope.
Surface characteristics: Outcrops: none Stones: none; Cracks: none. Erosion: moderate sheet erosion. Deposition: colluvial deposits. Natural vegetation: wooded grassland. Land use: sisal cultivation.
Natural drainage class: excessively drained

Described by B.M. Msanya, E.P. Kileo, D.N. Kimaro and G.G. Kimbi on 11/12/2000.

Soil: Soils are very deep, excessively drained pale brown to yellowish sands with thin brown sand topsoils.

Ah 0 - 10 cm: brown (10YR5/3) moist; sand; loose moist, non sticky and non plastic wet; structureless single grain; very porous; common medium and fine roots; clear smooth boundary to

AC 10-40 cm: pale brown (10YR6/3) moist; sand; structureless single grain; loose moist, non sticky and non plastic wet; very porous; few medium and common fine roots; few medium quartz fragments; thin dark reddish brown clay bands 10 cm apart; diffuse smooth boundary to

C1 40 – 120 cm: yellowish brown (10YR5/8) moist; sand; structureless single grain loose moist, non sticky and non plastic wet; very porous; few medium and common fine roots; few medium quartz fragments; thin dark reddish brown clay bands 10-15 cm apart; diffuse smooth boundary to

C2 120-150 cm: reddish yellow (7.5YR7/6) moist; sand; structureless single grain; loose moist, non sticky and non plastic wet; very porous; few medium quartz fragments; few fine roots.

SOIL CLASSIFICATION: WRB (FAO, 1998): Dystri-Lamellic Arenosols

USDA Soil Taxonomy (Soil Survey Staff, 1999): Lamellic Ustic Quartzipsamments

ANALYTICAL DATA FOR PROFILE MU-P19

Horizon	Ah	AC	C1	C2
Depth (cm)	0-10	10-40	40-120	120-150
Clay (%)	7	6	5	5
Silt (%)	5	4	3	2
Sand (%)	88	90	92	93
Texture class	S	S	S	S
AWC (mm/m)	nd	nd	nd	nd
Bulk density (g/cc)	nd	nd	nd	nd
pH H_2O 1:2.5	4.9	5.1	5.3	6.0
pH KCl 1:2.5	3.9	3.9	4.0	4.5
EC 1:2.5 (mS/cm)	nd	nd	nd	nd
ESP	4.35	8.33	25	3.45
Organic C (%)	2.2	2.0	0.2	0.1
Total N (%)	0.21	0.19	0.02	0.01
C/N	10.5	10.5	10	10
Avail. P BrayI (mg/kg)	2.1	1.9	2.0	0.5
Avail. P Olsen (mg/kg)	nd	nd	nd	nd
CEC NH_4OAc (cmol(+)/kg)	2.3	1.2	0.8	2.9
Exch. Ca (cmol(+)/kg)	0.4	0.1	0.1	0.1
Exch. Mg (cmol(+)/kg)	0.1	0.1	0.1	0.1
Exch. K (cmol(+)/kg)	0.1	0.1	0.1	0.1
Exch. Na (cmol(+)/kg)	0.1	0.1	0.2	0.1
Base saturation (%)	26	17	38	7

nd = not determined

Profile number: MU-P20 Mapping unit: L5 Agro-ecol. zone:
Region: MOROGORO
District: MOROGORO RURAL
Map sheet no. : 183/1
Coordinates: 37°36' 0.0" E/ 6°37'0.1" S
Location: NAFCO seed farm, about 2 km south of turn to NAFCO junction; 5 m east of Morogoro-Dodoma road.
Elevation: 460 m asl. Parent material: Colluvium material derived from banded muscovite biotite migmatites of Nguru ya Ndege mountains
Landform: Peneplain-summit; nearly flat to undulating. Slope: 2 %; straight: Surface characteristics: Erosion: none or slight. Deposition: none: Natural drainage class: well drained
Described by D.N. Kimaro, B.M. Msanya, S.B. Mwango and E.P. Kileo on 22/12/2000

Soils are moderately deep, well drained dark reddish brown to dark red sandy clay to clays, with thin dark reddish brown sandy clay topsoils.

Ah 0 - 10 cm: dark reddish brown (5YR3/4) dry, dark reddish brown (5YR3/3) moist; sandy clay; slightly hard dry, friable moist, slightly sticky and slightly plastic wet; moderate fine and medium subangular blocks; many fine pores; many fine roots; clear smooth boundary to

BA 10 - 26 cm: dark red (2.5YR3/6) dry, dark reddish brown (2.5YR3/4) moist; sandy clay; soft dry, friable moist, sticky and plastic wet; moderate fine and medium subangular blocks; patchy thin clay cutans; many fine and few medium pores; many fine roots; gradual smooth boundary to

Bts1 26 - 53 cm: reddish brown (2.5YR4/4) dry, dark red (2.5YR3/6) moist; clay; soft dry, friable moist, sticky and plastic wet; moderate fine and medium subangular blocks; patchy thin clay cutans; many fine and few medium pores; very few small irregular fresh quartz fragments; common fine roots; gradual smooth boundary to

Bts2 53 - 80 cm: red (2.5YR4/6) dry, dark red (2.5YR3/6) moist; clay; soft dry, friable moist, sticky and plastic wet; weak fine and medium subangular blocks; many very fine and medium pores; very few small irregular weathered quartz fragments; many very fine and medium roots.

SOIL CLASSIFICATION: WRB (FAO 1998): Rhodi-Profondic Lixisols
USDA-Soil Taxonomy (Soil Survey Staff, 1999): Kanhaplic Rhodustalfs

ANALYTICAL DATA FOR PROFILE MU-P20

Horizon	Ah	BA	Bts1	Bts2
Depth (cm)	0-10	10-26	26-53	53-80
Clay %	30	34	42	46
Silt %	14	5	5	6
Sand %	56	61	53	48
Texture class	SCL	SC	SC	SC
Bulk density g/cc	1.5	nd	1.4	nd
AWC mm/80 cm	nd	nd	nd	82.5
pH H_2O 1:2.5	6.2	6.5	6.70	6.6
pH KCl 1:2.5	5.1	5.3	5.6	5.5
EC 1:2.5 mS/cm	0.06	0.03	0.15	0.12
ESP	1.21	0.61	1.97	1.21
Organic C %	1.29	0.54	0.30	0.23
Total N %	0.13	0.05	0.03	0.02
C/N	9.9	10.8	10	11.5
Avail. P Bray-1 mg/kg	1.46	0.26	0.46	0.39
Avail. P Olsen mg/kg	nd	nd	nd	nd
CEC NH_4OAc cmol(+)/kg	17.4	9.9	13.2	15.7
Exch. Ca cmol(+)/kg	4.2	3.3	7.0	9.0
Exch. Mg cmol(+)/g	3.3	3.4	3.7	3.1
Exch. K cmol(+)/kg	1.60	0.28	2.4	0.98
Exch. Na cmol(+)/kg	0.21	0.06	0.26	0.19
$CaCO_3$ %	3.6	3.3	2.2	2.0
Base saturation %	53	71	100	85
CEC clay cmol(+)/kg	43	21	29	32

nd= not determined

Profile number: MU-P21 Mapping unit: L6 Agro-ecol. zone:
Region : MOROGORO
District : MOROGORO RURAL
Map sheet no. : 183/1
Coordinates : 37°35'16" E/ 6°37'30" S
Location : About 30 km from Morogoro town (Mkundi Maili Kumi na Nane).
Elevation : 480 m.a.s.l. Parent material: Colluvium mainly red clays derived from banded muscovite biotite migmatites of Nguru ya Ndege mountains. Landform: peneplain-backslopes; gently undulating. Slope: 2 %; convex. Natural vegetation: Thickets, bushes, remnants of miombo woodland with grass undergrowth's. Land use: Grazing. Human influences: Animal trampling, bush clearing and charcoal burning.
Surface characteristics : Erosion: severe sheet erosion. Deposition: none.
Described by E.P. Kileo, B.M. Msanya, D.N. Kimaro and S.B. Mwango on 19/12/1999
Soils are very deep, well drained dark reddish brown sandy clays, with thick very dark reddish brown sandy clay loam topsoils.

Ah 0 - 17/20 cm: very dark brown (7.5YR2.5/2) dry, dark reddish brown (5YR3/2) moist; sandy clay loam; friable moist, slightly sticky and slightly plastic wet; moderately weak medium subangular blocks; many very fine and few medium pores; many fine and few medium roots; clear wavy boundary to

Bt 17/20 - 114 cm: dark red (2.5YR3/6) dry, dark reddish brown (2.5YR3/3) moist; sandy clay; hard dry, friable moist, sticky and plastic wet; moderate medium and coarse subangular blocks; few medium and many very fine pores; few fine and common medium roots; abrupt smooth boundary to

C 114 - 170 cm: dark reddish brown (2.5YR3/4) dry, dark reddish brown (2.5YR3/3) moist; sandy clay; slightly hard dry, friable moist, slightly sticky and slightly plastic wet; structureless massive; very few fine root; many medium and coarse angular and spherical fresh quartz and banded muscovite biotite migmatitic fragments; fine roots

SOIL CLASSIFICATION: WRB (FAO 1998): Rhodi-Profondic Lixisols (Haplic)
USDA-Soil Taxonomy (Soil Survey Staff, 1999): Kanhaplic Rhodustalfs

ANALYTICAL DATA FOR PROFILE MU-P21

Horizon	Ah	Bt	C
Depth (cm)	0-17/20	17/20-114	114-170+
Clay %	30	42	44
Silt %	14	5	5
Sand %	56	53	51
Texture class	SCL	SC	SC
Bulk density g/cc	1.5	1.4	nd
AWC mm/m	nd	84.8	nd
pH H_2O 1:2.5	6.8	7.0	8.0
pH KCl 1:2.5	5.2	5.4	7.4
EC 1:2.5 mS/cm	0.08	0.04	0.17
ESP	1.76	0.76	4.20
Organic C %	1.39	0.44	0.32
Total N %	0.11	0.06	0.05
C/N	12.6	7.3	6.4
Avail. P Bray-1 mg/kg	1.53	0.26	nd
Avail. P Olsen mg/kg	nd	0.23	0.45
CEC NH_4OAc cmol(+)/kg	18.4	7.2	43.2
Exch. Ca cmol(+)/kg	5.2	3.3	9.0
Exch. Mg cmol(+)/g	3.3	3.4	3.7
Exch. K cmol(+)/kg	1.70	0.29	2.5
Exch. Na cmol(+)/kg	0.21	0.06	0.26
Base saturation %	57	98	35
CEC clay cmol(+)/kg	45.9	13.4	94.8

nd= not determined

Profile number: MU-P22 Mapping unit: L2 Agro-ecol. zone:
Region: MOROGORO
District: MOROGORO URBAN
Map sheet no. : 183/3
Co-ordinates: 37°43'E/ 6°46'S
Location: Tungi Sisal Estate, block K
Elevation: 433 m asl. Parent material: Mixed alluvial/coluvial deposits. Landform: Floodplain; Flat with. Slopes: 0-1 %; middle slope.
Surface characteristics: Outcrops: none Stones: none; Cracks: none. Erosion: slight sheet erosion. Deposition: alluvio-colluvial deposits. Natural vegetation: Natural vegetation has been cleared. Land use: cultivation of sisal.
Natural drainage class: imperfectly drained

Described by B.M. Msanya, D.N. Kimaro, G.G. Kimbi and E.P. Kileo on 06/12/2000.

Soil: Soils are very deep, imperfectly drained very dark brown to dark brown sandy clay to sandy clay loams with very thick black sandy clay loam topsoils.

Ahg 0 - 15 cm: black (10YR2/1) moist; sandy clay loam; very hard dry, friable moist, sticky and plastic wet; weak coarse and fine subangular blocky; common dark brown mottles; many medium and few coarse pores; many medium and fine roots; gradual smooth boundary to

ABg 15-48 cm: black (10YR2/1) moist; sandy clay; very hard dry, firm moist, sticky and plastic wet; weak medium and coarse angular blocky; many dark brown mottles; many medium and few coarse pores; many medium and common fine roots; pressure skins; diffuse smooth boundary to

Bwg1 48 – 79 cm: very dark brown (10YR2/2) moist; sandy clay; very hard dry, friable moist, sticky and plastic wet; weak medium and coarse angular blocky; many dark brown mottles; common medium and few fine pores; common medium and few roots; pressure skins; slightly calcareous; clear smooth boundary to

Bwg2 79-150 cm: dark brown (10YR3/3) moist; sandy clay loam; very hard dry, friable moist, sticky and plastic wet; weak medium and coarse angular blocky; many dark brown mottles; few very fine pores; pressure skins; slightly calcareous; clear smooth boundary to

C 150+ cm: weathered gravel, dominated by quartz

SOIL CLASSIFICATION: WRB (FAO, 1998): Hapli-Eutric Gleysols
USDA Soil Taxonomy (Soil Survey Staff, 1999): Aquic Haplustepts

ANALYTICAL DATA FOR PROFILE MU-P22

Horizon	Ahg	ABg	Bwg1	Bwg2
Depth (cm)	0-15	15-48	48-79	79-150
Clay (%)	34	38	38	28
Silt (%)	10	8	11	12
Sand (%)	56	54	51	60
Texture class	SCL	SC	SC	SCL
AWC (mm/m)	nd	nd	nd	nd
Bulk density (g/cc)	nd	nd	nd	Nd
pH H_2O 1:2.5	6.3	6.4	6.4	7.2
pH KCl 1:2.5	5.3	5.6	5.6	6.2
EC 1:2.5 (mS/cm)	nd	nd	nd	nd
ESP	1.39	2.64	4.81	6.12
Organic C (%)	2.8	1.6	0.8	0.5
Total N (%)	0.30	0.20	0.08	0.05
C/N	9.3	8.0	10	10
Avail. P BrayI (mg/kg)	16.5	1.5	0.2	3.2
Avail. P Olsen (mg/kg)	nd	nd	nd	nd
CEC NH_4OAc (cmol(+)/kg)	35.9	30.3	31.2	24.5
Exch. Ca (cmol(+)/kg)	16.1	14.1	18.1	15.4
Exch. Mg (cmol(+)/kg)	9.2	6.6	7.9	14.5
Exch. K (cmol(+)/kg)	0.30	0.10	0.10	0.10
Exch. Na (cmol(+)/kg)	0.50	0.80	1.50	1.50
Base saturation (%)	73	71	88	100
CEC_{Clay} (cmol(+)/kg)	77.2	65.2	75.0	81.3

nd = not determined

Profile number: MU-P23 Mapping unit: V2 Agro-ecol. zone:
Region : MOROGORO
District : MOROGORO URBAN
Map sheet no. : 183/1
Coordinates : 37°34'27" E/ 6°38'50" S
Location : About 3 km west of Morogoro-Dodoma road (Dr. Fungo's junction)
Elevation : 420 m asl. Parent material: Fluvial materials mainly sandy derived from banded muscovite biotite migmatites of Nguru ya Ndege Mountains. Landform: peneplain-valley bottom; gently undulating. Slope: 2 %; concave. Natural vegetation: Acacia woodland and few scattered miombo trees. Land use: Grazing. Human influences: Trees clearing for charcoal burning, animal trampling. Surface characteristics : Erosion: Severe sheet erosion. Deposition: Alluvial materials.
Natural drainage class : moderately well drained
Described by B.M. Msanya, E.P. Kileo, S.B. Mwango and D.N. Kimaro on 19/12/1999
Soils are shallow, moderately well drained, black sandy clay loams, over very dark grey to dark yellowish brown saprolite.

Ah 0 - 25 cm: black (10YR2/1) moist; sandy clay loam; very friable moist, non-sticky and non-plastic wet; weak medium and coarse subangular blocks; few medium and many very fine pores; common very fine roots; gradual smooth boundary to

C1 25 - 80 cm: very dark grey (10YR3/1) moist; sandy clay loam; very friable moist, sticky and plastic wet; structureless massive; common fine pores; few medium and common fine roots; gradual smooth boundary to

C2 80 - 100 cm: brown (10YR4/3) moist; sandy clay loam; very friable moist, slightly sticky and slightly plastic wet; structureless massive; few medium and common fine pores; few medium and fine roots; clear smooth boundary to

C3 100 - 140 cm: dark yellowish brown (10YR4/6) moist; sandy clay loam; very friable moist, slightly sticky and slightly plastic wet; structureless massive; few medium and common fine pores; few medium roots

SOIL CLASSIFICATION: WRB (FAO 1998): Hypereutri-Mollic Fluvisols (Haplic)
USDA-Soil Taxonomy (Soil Survey Staff, 1999): Fluventic Haplustolls

ANALYTICAL DATA FOR PROFILE MU-P23

Horizon	Ah	C1	C2	C3
Depth (cm)	0-25	25-80	80-100	100-140
Clay %	21	27	32	20
Silt %	6	5	5	5
Sand %	73	68	63	75
Texture class	SCL	SCL	SCL	SCL
Bulk density g/cc	1.4	1.6	1.6	nd
AWC mm/m	nd	nd	89.4	nd
pH H_2O 1:2.5	6.7	6.8	6.9	6.8
pH KCl 1:2.5	5.2	5.1	5.2	5.0
EC 1:2.5 mS/cm	0.03	0.03	0.04	0.02
ESP	0.96	2.80	2.50	1.39
Organic C %	0.79	0.12	0.48	0.24
Total N %	0.07	0.06	0.08	0.03
C/N	11.3	2.0	6.0	8.0
Avail. P Bray-1 mg/kg	1.95	0.99	0.57	0.36
Avail. P Olsen mg/kg	nd	nd	nd	nd
CEC NH_4OAc cmol(+)/kg	5.2	6.0	9.6	3.6
Exch. Ca cmol(+)/kg	3.9	4.1	6.1	2.2
Exch. Mg cmol(+)/g	0.6	0.8	0.1	0.1
Exch. K cmol(+)/kg	0.38	0.43	0.48	0.33
Exch. Na cmol(+)/kg	0.05	0.17	0.24	0.05
Base saturation %	95	92	72	74
CEC clay cmol(+)/kg	11.6	20.4	24.5	13.6

nd= not determined

Profile number: MU-P24 Mapping unit: V2 Agro-ecol. zone:
Region : MOROGORO
District : MOROGORO URBAN
Map sheet no. : 183/1
Coordinates : 37°30'15" E/ 6°32'36" S
Location : About 6 km west of Morogoro-Dodoma road (at Sokoine junction)
Elevation : 420 m asl. Parent material: Recent alluvium materials mainly clay derived from banded muscovite-biotite migmatites of Nguru ya Ndege mountains. Landform: Mbuga; flat or almost flat. Slope: 1 %; concave. Natural vegetation. Acacia woodland and grass undergrowth. Land use: Grazing and rice cultivation.
Surface characteristics : Surface sealing: 1-2 mm. Cracks: very deep cracks (>100 cm); 3-10 cm wide with gilgai micro-relief. Erosion: none or slight. Deposition: Alluvial materials.
Natural drainage class : poorly to very poorly drained
Described by E.P. Kileo, B.M. Msanya, D.N. Kimaro and S.B. Mwango on 21/12/1999

Soils are deep, poorly to very poorly drained very dark grey sandy clays, with very thick black sandy clay topsoils.

Ah 0 - 25/45 cm: black (N2.5/0) sandy clay; firm moist, sticky and plastic wet; weak coarse and medium subangular blocks; medium and many fine pores; many fine roots; clear wavy boundary to

ACk 25/45 - 100 cm: very dark grey (N3/0) moist; sandy clay; very firm moist, very sticky and very plastic wet; moderate coarse angular wedge-shaped blocks and angular prismatic blocks; continuous thick slickensides/press cutans; very fine pores; abundant medium spherical hard carbonates nodules; common fine roots; moderately calcareous; abrupt smooth boundary to

Ck 100 - 160+ cm: greyish brown (2.5Y5/2) moist; clay; very firm moist, very sticky and very plastic wet; weak very coarse prisms; very few moderately thick slickensides/press cutans; common very fine pores; diffuse fine and medium spherical hard carbonates nodules; strongly calcareous

SOIL CLASSIFICATION: WRB (FAO 1998): Endosodi-Pellic Vertisols (Hypereutric)
USDA-Soil Taxonomy (Soil Survey Staff, 1999): Sodic Haplusterts

ANALYTICAL DATA FOR PROFILE MU-P24

Horizon	Ah	ACk	Ck
Depth (cm)	0-25/45	25/45-100	100-160
Clay %	40	41	63
Silt %	10	10	10
Sand %	50	49	27
Texture class	SC	SC	C
Bulk density g/cc	1.6	1.7	1.8
AWC mm/m	nd	113.41	nd
pH H_2O 1:2.5	7.7	8.4	8.6
pH KCl 1:2.5	6.1	7.0	7.2
EC 1:2.5 mS/cm	0.09	0.38	0.94
ESP	4.25	19.1	42.3
Organic C %	0.79	0.52	0.08
Total N %	0.08	0.04	0.03
C/N	9.9	13	2.7
Avail. P Bray-1 mg/kg	nd	nd	nd
Avail. P Olsen mg/kg	0.96	1.68	0.31
CEC NH_4OAc cmol(+)/kg	21.2	20.0	32.6
Exch. Ca cmol(+)/kg	15.1	8.0	7.2
Exch. Mg cmol(+)/g	5.0	6.5	5.5
Exch. K cmol(+)/kg	0.71	0.76	1.4
Exch. Na cmol(+)/kg	0.90	3.82	13.8
Base saturation %	100	95	85
CEC clay cmol(+)/kg	45.7	43.9	50.9

nd= not determined

Profile number: MU-P25 Mapping unit: V1 Agro-ecol. zone:
Region: MOROGORO
District: MOROGORO URBAN
Map sheet no. : 183/3
Co-ordinates: 37°37'35" E/ 6°50'55" S
Location: Magadu (southwest part of Sokoine University of Agriculture farm, about 0.4 km east of Ngerengere River).
Elevation: 500 m asl. Parent material: Alluvio-coluvium. Landform: almost flat river terrace of Ngerengere River; almost flat terrain. Slope: 0.5 %; middle slope.
Surface characteristics: Outcrops: none Stones: none; Fine cracks (< 1 cm) moderately widely spaced (0.5-1 m). Erosion: none. Deposition: alluvio-colluvial deposits. Natural vegetation: most of the natural woody vegetation has been cleared and replaced by valley grasslands composed of *Cyclosorus interruptus* and sedges (*Cyperus exaltatus)*. Land use: Cultivation of maize, Tomatoes, lowland rice and sugarcane.
Natural drainage class: imperfectly drained

Described by B.M. Msanya, D.N. Kimaro, G.G. Kimbi and E.P. Kileo on 05/11/2000.

Soil: Soils are very deep, stratified, imperfectly drained dark brown to dark reddish brown sandy clay to clays with thick very dark brown clay topsoils.

Ap 0 - 12 cm: very dark brown (7.5YR2.5/2) moist, brown (7.5YR4/3) dry; clay; slightly hard dry, firm moist, sticky and plastic wet; moderate fine crumb structure; many very fine and fine pores; common very and fine roots; abrupt smooth boundary to

C 12-30 cm: dark brown (7.5YR3/2) moist, brown (7.5YR4/3) dry; sandy clay; hard dry, firm moist, sticky and plastic wet; structureless and massive; many fine and few medium pores; common fine and few fine roots; clear smooth boundary to

2C 30 – 48 cm: dark reddish brown (5YR3/3) moist, reddish (5YR4/3) dry; sandy clay loam; slightly hard dry, friable moist, non sticky and non plastic wet; structureless and massive; common fine and few medium tubular pores; few fine roots; clear smooth boundary to

3C 48-95 cm: dark reddish brown (2.5YR3/4) moist, red (2.5YR4/6) dry; clay; hard dry, firm moist, very sticky and very plastic wet; structureless and massive; common fine and few medium pores; few fine (2-6 mm) hard spherical black and brownish Fe-Mn (sesquioxides) nodules; few fine roots; clear smooth boundary to

4C 95-110 cm: dark brown (7.5YR3/2) moist, brown (7.5YR4/2) dry; clay; hard dry, firm moist, sticky and plastic wet; structureless and massive; common fine and few medium pores; very few fine roots; clear smooth boundary to

5C 110-140+ cm: dark reddish brown (5YR3/3) moist, reddish brown (5YR4/3) dry; clay; very hard dry, very firm moist, very sticky and very plastic wet; structureless and massive; few fine and few medium pores; few fine (2-6 mm) hard spherical black and brownish Fe-Mn (sesquioxides) nodules; very few very fine roots.

SOIL CLASSIFICATION: WRB (FAO, 1998): Hapli-Orthieutric Fluvisols
USDA Soil Taxonomy (Soil Survey Staff, 1999): Mollic Ustifluvents

ANALYTICAL DATA FOR PROFILE MU-P25

Horizon	Ap	C	2C	3C	4C	5C
Depth (cm)	0-12	12-30	30-48	48-95	95-110	110-140+
Clay (%)	47.4	39.2	20.6	52.8	57.6	70.7
Silt (%)	15.5	11.3	5.1	13.2	17.2	10.2
Sand (%)	37.1	49.5	74.3	34	25.2	19.1
Texture class	C	SC	SCL	C	C	C
AWC (mm/m)	nd	nd	nd	nd	nd	nd
Bulk density (g/cc)	1.26	nd	1.61	1.60	nd	nd
pH H_2O 1:2.5	6.9	6.9	6.4	6.7	6.7	6.6
pH KCl 1:2.5	6.4	6.3	6.1	6.1	5.9	5.9
EC 1:2.5 (mS/cm)	nd	nd	nd	nd	nd	nd
ESP	0.90	1.39	1.57	2.98	1.50	1.70
Organic C (%)	2.10	1.12	0.44	0.88	1.55	0.92
Total N (%)	0.19	0.11	0.05	0.09	0.11	0.10
C/N	11	10	8.8	9.8	14	9.2
Avail. P BrayI (mg/kg)	30.8	5.6	6.3	11.2	11.4	1.0
Avail. P Olsen (mg/kg)	nd	nd	nd	nd	nd	nd
CEC NH_4OAc (cmol(+)/kg)	25.5	15.8	10.8	17.7	24.0	22.8
Exch. Ca (cmol(+)/kg)	13.0	10.0	5.0	7.0	13.0	11.6
Exch. Mg (cmol(+)/kg)	3.5	3.1	1.8	3.6	5.4	4.8
Exch. K (cmol(+)/kg)	2.21	0.59	1.87	1.18	0.45	0.31
Exch. Na (cmol(+)/kg)	0.23	0.22	0.17	0.51	0.36	0.38
Base saturation (%)	74	88	83	69	83	75
CEC_{Clay} (cmol(+)/kg)	38.5	30.4	44.9	27.8	32.4	27.8

nd = not determined

Appendix 2. Land attribute database for Morogoro Urban District

LC	Soil unit	LDS Months	MAT (°C)	TGP (°C)	MTCM (°C)	MAR (mm)	RGP (mm)	STG (%)	Prf. Text	Surf. Text	Sl (%)	ESD (cm)	DRC (class)	Surf. pH	CEC (cmol(+)/kg)	% O.C	%N	P (mg/kg)	K (cmol(+)/kg)	% BS	ESP	Df.
LMU																						
M1	MU-P1	0	19.1	20.1	10.7	2302	1070.8	20	SL	SC	49	130	M.D	5.5	6.0	0.7	0.01	4.0	0.16	69	3.17	none
	MU-P2	0	19.1	20.1	10.7	2302	1070.8	25	SC	SC	60	120	Exc.D	6.4	18.5	2.1	0.10	10.0	1.10	66	1.19	none
	MU-P3	0	19.1	20.1	10.7	2302	1070.8	80	SCL	SCL	>80	10	S.Exc.D	7.2	7.3	0.3	0.03	9.0	0.04	95	0.83	none
M2	MU-P4	0	19.1	20.1	10.7	2302	1070.8	6	SCL	SL	24	160+	IMPD	5.1	9.6	0.6	0.09	14.0	0.17	77	0.94	none
	MU-P5	0	19.1	20.1	10.7	2302	1070.8	10	SCL	SCL	55	170	WD	6.3	9.8	0.9	0.11	3.0	0.21	81	1.02	none
	MU-P6	0	19.1	20.1	10.7	2302	1070.8	15	SCL	SCL	65	170+	M.D	6.0	15.2	1.2	0.11	1.0	0.33	42	0.66	none
M3	MU-P7	0	19.1	20.1	10.7	2302	1070.8	8	SC	SCL	21	150+	WD	5.2	8.8	0.8	0.09	16.0	0.13	61	0.91	none
	MU-P8	0	19.1	20.1	10.7	2302	1070.8	5	SCL	SCL	9	160+	M.D	6.0	5.8	0.3	0.05	1.0	0.11	51	2.07	none
M4	MU-P3	8	24.8	25.6	16.4	810	295	80	SCL	SCL	>80	10	Exc.D	7.2	7.3	0.3	0.03	9.0	0.04	95	0.83	none
P1	MU-P9	6	24.3	25.8	15.9	908	484	15	C	C	32	150	WD	6.4	14.8	1.9	0.23	2.0	1.02	58	1.49	none
	MU-P10	6	24.3	25.8	15.9	908	484	15	C	SC	48	150+	WD	6.2	17.2	0.8	0.18	3.0	0.75	86	1.69	none
P2	MU-P11	7	24.3	25.8	15.9	908	484	10	C	SC	15	145	WD	5.8	14.6	1.4	0.13	6.0	0.97	59	3.36	none
	MU-P12	7	24.3	25.8	15.9	908	484	5	C	C	10	200	WD	6.3	19.0	2.5	0.24	20.4	4.22	100	4.10	none
P3	MU-P13	7	24.3	25.8	15.9	908	484	1	C	C	10	212	WD	6.7	14.2	0.4	0.02	4.8	1.36	84	2.32	none
P4	MU-P14	8	24.8	25.6	16.4	810	295	1	SCL	LS	6	160	WD	6.9	5.3	0.7	0.07	3.7	0.05	97	0.56	none
L1	MU-P3	7	24.8	25.6	16.4	810	295	80	SCL	SCL	>80	10	S.Exc.D	7.2	7.3	0.3	0.03	9.0	0.04	95	0.83	none
L2	MU-P15	6	24.3	25.8	15.9	908	484	1	C	C	0.5	205	WD	5.8	9.2	1.3	0.10	2.1	0.46	59	3.04	none
	MU-P16	6	24.3	25.8	15.9	908	484	1	SCL	SL	6	200	WD	8.1	12.2	1.0	0.08	4.6	0.15	95	1.64	none
	MU-P17	6	24.3	25.8	15.9	908	484	1	C	SC	3	200	WD	4.8	13.8	1.1	0.12	3.6	0.83	48	7.97	none
L3	MU-P16	6	24.3	25.8	15.9	908	484	1	SCL	SL	6	200	WD	8.1	12.2	1.0	0.08	4.6	0.15	95	1.64	none
	MU-P17	6	24.3	25.8	15.9	908	484	1	C	SC	3	200	WD	4.8	13.8	1.1	0.12	3.6	0.83	48	7.97	none
L4	MU-P18	8	24.8	25.6	16.4	810	295	1	SCL	SCL	1	55	S.Exc.D	7.9	17.3	1.7	0.17	4.6	0.40	91	0.58	none
	MU-P19	8	24.8	25.6	16.4	810	295	1	S	S	3	150	Exc.D	4.9	2.3	2.2	0.22	2.1	0.10	26	4.30	none
L5	MU-P20	8	24.3	25.8	15.9	810	295	1	SC	SCL	2	80	WD	6.2	17.4	1.29	0.13	1.5	1.60	53	1.21	none
	MU-P17	8	24.3	25.8	15.9	810	295	1	C	SC	3	200	WD	4.8	13.8	1.10	0.12	3.6	0.83	48	7.97	none
L6	MU-P21	8	24.3	25.8	15.9	810	295	1	SC	SCL	2	170	WD	6.8	18.4	1.40	0.11	1.5	1.70	57	1.8	none
	MU-P22	8	24.3	25.8	15.9	810	295	1	SC	SCL	1	150	IMPD	6.3	35.9	2.8	0.28	16.5	0.30	73	1.39	none
V1	MU-P23	6	24.3	25.8	15.9	908	484	1	SCL	SCL	2	140	M.D	6.7	5.2	0.8	0.07	1.9	0.38	95	0.96	annual
	MU-P24	6	24.3	25.8	15.9	908	484	1	SC	SC	1	160	VPD	7.7	21.2	0.8	0.08	1.0	0.71	100	4.25	annual
	MU-P25	6	24.3	25.8	15.9	908	484	1	C	C	0.5	140+	IMPD	6.9	25.5	2.1	0.19	30.8	2.21	74	0.90	annual
V2	MU-P23	6	24.3	25.8	15.9	908	484	1	SCL	SCL	2	140	M.D	6.7	5.2	0.8	0.07	1.9	0.38	95	0.96	annual
	MU-P24	6	24.3	25.8	15.9	908	484	1	SC	SC	1	160	VPD	7.7	21.2	0.8	0.08	1.0	0.71	100	4.25	annual
	MU-P22	6	24.3	25.8	15.9	908	484	1	SC	SCL	1	150	IMPD	6.3	35.9	2.8	0.28	16.5	0.30	73	1.39	annual

Alt = Altitude, MAT = Mean annual temperature, MAR = mean annual rainfall, RGP = Rainfall during growing period, ESD = Effective soil depth, Exc.D = Excessively drained, WD = well drained, IMP.D = Imperfectly drained, S.Exc.D = somewhat excessively drained, IMPD = imperfectly drained, M.D = Moderately well drained, VPD = very poorly drained, Exc.D = Excessively drained, DRC= Drainage class, Surf pH= Surface pH, P= available P., Sl = Slope (%), LDS = Length of dry season, MTCM = Mean minimum temperature of the coldest month, TGP = Mean temperature in growing period, STG = Stones and gravels, Prf. Text = Profile texture, Surf. Text = Profile texture, Df. = Duration of flooding.

Appendix 3a. Rating of land use requirements for rainfed vegetables production

Land quality	Diagnostic factor	Unit	Good (1)	Moderate (2)	Poor (3)	Very poor (4)
Moisture availability	Mean annual precipitation	mm	800-1200	500-800 1200-2000	350-500 2000-3000	< 350 > 3000
	Number of dry months (<75 mm)	months	1-7	7-8	8-9	9-12
Temperature regime	Mean annual temperature	^{o}C	> 18-22	22-26 15-18	26-30 10-15	> 30 < 10
Oxygen availability	Soil drainage class	class	Well, moderately well	Somewhat excessive, imperfect	Poor, excessive	Very poor
Rooting condition	Effective soil depth	cm	>50-80+	30-50	15-30	< 15
	Stones and gravels	%	< 5	5-15	15-35	> 35
	Surface soil texture	class	Si, SiL, L, SCL, CL	LS, SL, C, SC, SiCL	S, SiC	SiCm, Cm
Erosion hazards	Dominant slope class	%	< 5	5-8	8-16	> 16
	Surface soil texture	class	S, SL, LS, L	SCL, SiCL, SiL, CL	SC, SiC, Si	C
Nutrients availability	Soil reaction	pH	5.5-6.5	6.5-7.0 5.0-5.5	7.0-7.5 4.0-5.0	> 7.5 < 4.0
	Topsoil OC	%	> 2.5	2.5-0.5	0.1-0.5	< 0.1
	Topsoil N	%	> 0.2	0.1-0.2	< 0.1	
	Topsoil available P	mg/kg	> 20	7-20	1-7	0-1
	Topsoil K	cmol(+)/kg	> 4.8	2.4-4.8	< 2.4	
Nutrients retention capacity	Topsoil CEC	cmol(+)/kg	10-60	3-10	1-3	0-1
	Topsoil BS	%	> 80	40-80	20-40	< 20

C= Clay; CL= Clay loam; L= Loam; LS= Loamy sand; S= Sand; SC= Sandy clay; SCL= Sandy clay loam; SL= Sandy loam; SiC= Silty clay; SiCL= Silty clay loam; SiL= Silt loam, SiCm = Silty massive clay, Cm = Massive clay.

Appendix 3b. Rating of land use requirements for rainfed sorghum production

Land quality	Diagnostic factor	Unit	Good (1)	Moderate (2)	Poor (3)	Very poor (4)
Moisture availability	Mean annual precipitation	mm	600-1000	400-600 1000-1500	250-400 1500-2500	< 250
	Total rainfall in growing period	months	300-650	250-300 650-1000	200-250 1000-1500	< 200 > 1500
Air humidity	Mean R.H. of least humid month in growing season	%	60	55-60	50-55	< 50
Temperature regime	Mean annual temperature	^{o}C	24-30	30-32 20-24	32-35 15-20	< 35 > 35
Oxygen availability	Soil drainage class	class	Well, moderately well	Somewhat excessive	Poor, imperfectly poor	Very poor, excessive
Rooting condition	Effective soil depth	cm	>60	40-60	20-40	< 20
	Stones and gravels	%	< 5	5-15	15-35	> 35
	Surface soil texture	class	SiC, SiL, Si, SC, C, SCL, L, SiCL, CL	SL	LS, S	SiCm, Cm
Erosion hazards	Dominant slope class	%	< 4	4-8	8-16	> 16
	Surface soil texture	class	S, SL, LS, L	SCL, SiCL, SiL, CL	SC, SiC, Si	C
Nutrients availability	Soil reaction	pH	6.0-7.0	7.0-8.0 5.0-6.0	8.0-8.7 4.3-5.0	> 8.7 < 4.3
	Topsoil OC	%	> 2.0	1.0-2.0	0.5-0.1	< 0.5
	Topsoil N	%	> 0.2	0.1-0.2	0.02-0.1	< 0.02
	Topsoil available P	mg/kg	> 20	7-20	1-7	0-1
Nutrients retention capacity	Topsoil CEC	cmol(+)/kg	> 25	13-25	6-13	0-6
	Topsoil BS	%	> 80	40-80	30-40	< 30
Soil sodicity	ESP	%	<20	20-28	28-35	>35

C= Clay; CL= Clay loam; L= Loam; LS= Loamy sand; S= Sand; SC= Sandy clay; SCL= Sandy clay loam; SL= Sandy loam; SiC= Silty clay; SiCL= Silty clay loam; SiL= Silt loam, SiCm = Silty massive clay, Cm = Massive clay.

Appendix 3c. Rating of land use requirements for rainfed bananas production

Land quality	Diagnostic factor	Unit	Good (1)	Moderate (2)	Poor (3)	Very poor (4)
Moisture availability	Mean annual precipitation	mm	1250-2000	1000-1250 2000-3000	850-1000 3000-4000	< 850 > 4000
	Length of dry season (P<1/2 PET)	months	< 3	3-4	4-6	> 6
Air humidity	Mean R.H. of least humid month in growing season	%	> 60	55-60	50-55	< 50
Temperature regime	Mean annual temperature	^{o}C	18-24	16-18	14-16	< 14
	Average min. temperature of the coldest month	^{o}C	>15	8-15	2-8	<2
Oxygen availability	Soil drainage class	class	Well, moderately well	Somewhat excessive	Poor, imperfectly poor	Very poor, excessive
Rooting condition	Effective soil depth	cm	>80	40-80	20-40	< 20
	Stones and gravels	%	< 5	5-15	15-35	> 35
	Surface soil texture	class	SiCL, Si, SiL, SC, L, SCL, CL, SL, LS	SC	C, SiC	SiCm, Cm
Erosion hazards	Dominant slope class	%	< 4	4-8	8-16	> 16
	Surface soil texture	class	S, SL, LS, L	SCL, SiCL, SiL, CL	SC, SiC, Si	C
Nutrients availability	Soil reaction	pH	6.0-7.0	7.0-7.5 5.5-6.0	7.5-8.5 4.5-5.5	> 8.5 < 4.5
	Topsoil OC	%	> 1.5	0.8-1.5	0.4-0.8	< 0.4
	Topsoil N	%	> 0.12	0.05-0.12	0.02-0.05	< 0.02
	Topsoil available P	mg/kg	> 20	8-20	4-8	0-4
	Topsoil K	cmol(+)/kg	> 3.8	1.5-3.8	0.8-1.5	< 0.8
Nutrients retention capacity	Topsoil CEC	cmol(+)/kg	> 25	13-25	6-13	< 6.0
	Topsoil BS	%	> 80	40-80	30-40	< 30
Soil sodicity	ESP	%	<4	4-8	8-12	>12

C= Clay; CL= Clay loam; L= Loam; LS= Loamy sand; S= Sand; SC= Sandy clay; SCL= Sandy clay loam; SL= Sandy loam; SiC= Silty clay; SiCL= Silty clay loam; SiL= Silt loam, SiCm = Silty massive clay, Cm = Massive clay.

Appendix 3d. Rating of land use requirements for rainfed maize production

Diagnostic factor	Land quality	Unit	Good (1)	Moderate (2)	Poor (3)	Very poor (4)
Moisture availability	Total rainfall in growing period	(mm)	600-1000	400-600	200-400	<200
Temperature regime	Mean temperature in growing period	^{o}C	24-30	20-24; 30-32	15-20; 32-35	<15; >35
Oxygen availability to roots	Soil drainage	class	well	Moderately well	Imperfect	Poor, very poor
Rooting conditions	Effective soil depth	(cm)	>80	40-80	20-40	<20
	Soil texture	class	L, SCL, CL, SiCL.	SC, C, SL.	LS, SiC.	S, SiCm, Cm
Nutrient availability	Soil reaction	pH	6.0-6.5	5.5-6.0; 6.5-7.0	5.0-5.5; 7.0-8.2	<5.0; >8.2
	Topsoil OC	%	>2.0	1.0-2.0	0.5-1.0	<0.5
	Topsoil N. content	%	>0.2	0.1-0.2	0.02-0.1	<0.02
	Topsoil avail. P.	mg/kg	20-40	7-20	1-7	0-1
Nutrient retention capacity	Base saturation Topsoil CEC_{soil}	% cmol(+)/kg	>80 >25	40-80 13-25	20-40 6-12	<20 <6
Soil sodicity	ESP	%	0-15	15-20	20-25	>25
Wetness	Frequency of flooding		none	Biannual	annual	daily, weekly, monthly
	Duration of flooding	days	0-1	1-5	5-15	>15
Erosion hazard	Slope angle	%	<4	4-8	8-16	>16

C= Clay; CL= Clay loam; L= Loam; LS= Loamy sand; S= Sand; SC= Sandy clay; SCL= Sandy clay loam; SL= Sandy loam; SiC= Silty clay; SiCL= Silty clay loam; SiL= Silt loam, SiCm = Silty massive clay, Cm = Massive clay.

Appendix 3e. Rating of land use requirements for rainfed rice production

Land quality	Diagnostic factor	Unit	Good (1)	Moderate (2)	Poor (3)	Very poor (4)
Moisture availability	Total rainfall in growing period	(mm)	550-1000	400-550	200-400	<200
Temperature regime	Mean temperature in growing period	^{o}C	24-28	22-24; 28-30	18-22; 30-35	<18; >35
Moisture retention	Topsoil texture	class	C, SiC, CL.	SC, SiCL, SiL.	SL, L, SCL.	S, LS, SiCm, Cm.
Rooting conditions	Effective soil depth	(cm)	>75	50-75	25-50	<25
Nutrient availability	Soil reaction	pH	5.5-6.0	5.0-5.5; 6.0-7.0	4.0-5.0; 7.0-8.0	<4.0; >8.0
	Topsoil organic carbon	%	2.0-4.0	1.0-2.0	0.5-1.0	<0.5 >5.0
	Topsoil Nitrogen content	%	>0.2	0.1-0.2	0.05-0.1	<0.05
	Topsoil available P.	Mg/kg	20-60	10-20	3-10	0-3
Nutrient retention capacity	Base saturation Topsoil CEC_{soil}	% cmol(+)/kg	>75 >25	50-75 13-25	30-50 6-13	<30 <6
Soil sodicity	ESP	%	0-10	10-15	15-20	>20
Topography	Slope angle	%	<1	1-2	2-4	>4
Wetness	Duration of flooding	days	>15	5-15	1-5	0-1

C= Clay; CL= Clay loam; L= Loam; LS= Loamy sand; S= Sand; SC= Sandy clay; SCL= Sandy clay loam; SL= Sandy loam; SiC= Silty clay; SiCL= Silty clay loam; SiL= Silt loam, SiCm = Silty massive clay, Cm = Massive clay.

Appendix 3f. Rating of land use requirements for rainfed beans production

Land quality	Diagnostic factor	Unit	Good (1)	Moderate (2)	Poor (3)	Very poor (4)
Moisture availability	Mean annual precipitation	mm	600-1000	500-600 1000-2000	400-500 2000-3000	< 400
	Total rainfall in growing period	months	350-600	300-350 600-1000	300-250 1000-2000	< 250 > 2000
Air humidity	Mean R.H. of least humid month in growing season	%	> 60	55-60	50-55	< 50
Temperature regime	Mean temperature in growing period	^{o}C	12-24	27-27 10-12	27-30 8-10	> 30 < 8
Oxygen availability	Soil drainage class	class	Well, moderately well	Somewhat excessive	Poor, imperfectly poor	Very poor, excessive
Rooting condition	Effective soil depth	cm	>80	40-80	20-40	< 20
	Stones and gravels	%	< 5	5-15	15-35	> 35
	Surface soil texture	class	Si, SiL, L, S, SCL, CL, SL, LS	SC, SiCL	C, SiC	SiCm, Cm
Erosion hazards	Dominant slope class	%	< 4	4-8	8-16	> 16
	Surface soil texture	class	S, SL, LS, L	SCL, SiCL, SiL, CL	SC, SiC, Si	C
Nutrients availability	Soil reaction	pH	5.6-7.6	7.6-8.0 5.4-5.6	8.0-8.2 5.2-5.4	> 8.5 < 5.2
	Topsoil OC	%	> 1.2	0.8-1.2	0.4-0.8	< 0.4
	Topsoil N	%	> 0.06	0.04-0.06	0.012-0.024	< 0.024
	Topsoil available P	mg/kg	> 20	7-20	2-7	0-2
	Topsoil K	cmol(+)/kg	> 3.8	1.5-3.8	0.8-1.5	< 0.8
Nutrients retention capacity	Topsoil CEC	cmol(+)/kg	> 25	13-25	6-13	< 6.0
	Topsoil BS	%	> 80	40-80	30-40	< 30
Soil sodicity	(ESP)	%	< 5	5-8	8-12	> 12

C= Clay; CL= Clay loam; L= Loam; LS= Loamy sand; S= Sand; SC= Sandy clay; SCL= Sandy clay loam; SL= Sandy loam; SiC= Silty clay; SiCL= Silty clay loam; SiL= Silt loam, SiCm = Silty massive clay, Cm = Massive clay.

Appendix 4. Guide to general rating of some chemical and physical soil properties Msanya *et al*. (1996) and Kileo, (2000).

1. Organic matter and total nitrogen

	Very low	Low	Medium	High	Very high
Organic matter %	< 1.0	1.0-2.0	2.1-4.2	4.3-6.0	> 6.0
Organic carbon %	< 0.6	0.60-1.25	1.26-2.50	2.51-3.50	>3.5
Total nitrogen %	< 0.10	0.10-0.20	0.21-0.50	> 0.50	

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

2. Soil reaction

Extremely acid	pH <4.5	Neutral	pH 6.6 to 7.3
Very strongly acid	pH 4.5 to 5.0	mildly alkaline	pH 7.4 to 7.8
Strongly acid	pH 5.1 to 5.5	moderate alkaline	pH 7.9 to 8.4
Medium acid	pH 5.6 to 6.0	strongly alkaline	pH 8.5 to 9.0
Slightly acid	pH 6.1 to 6.5	very strongly alkaline	pH > 9.0

3. Available phosphorus

mg/kg	Low	Medium	High
Avail. P (Bray-Kurtz 1	< 7	7-20	> 20
Avail. P (Olsen)	< 5	5-10	> 10

NB. Available phosphorus is determined by the Bray-Kurtz 1 method if the pH H_2O of the soil is less than 7.0. In soils with a pH H_2O of more than 7.0 the Olsen method is used.

4. Cation exchange capacity (CEC)

cmol(+)/kg	Very low	Low	Medium	High	Very high
CEC	< 6.0	6.0-12.0	12.1- 25.0	25.0- 40.0	> 40.0

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

5. Electrical conductivity (ECe)

ECe	< 1.7 dS/m	no yield reduction
ECe	1.7 - 2.5 dS/m	up to 10% yield reduction
ECe	2.5 - 3.8 dS/m	up to 25% yield reduction
ECe	3.8 - 5.9 dS/m	up to 50% yield reduction
ECe	5.9 - 10 dS/m	up to 100% yield reduction

6. Exchangeable calcium

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

7. Exchangeable magnesium (Mg)

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

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

8. Exchangeable potassium (K)

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

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

9. Exchangeable sodium (Na)

cmol(+)/kg	Very low	Low	Medium	High	Very high
Na	< 0.10	0.10-0.30	0.31-0.70	0.71-2.00	> 2.00

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

10. Soil sodicity

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

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

11. Basic infiltration rate (IR)

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

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

12.0 Available water capacity (AWC)

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

Available water capacity is the capacity of the soil to store water that is readily available for uptake by plant roots; usually expressed in millimetres of water per metro depth of soils; technically the difference between the percentage of soil water at field capacity (normally taken as the water content at pF 2.0) and the percentage at wilting point (taken as the water content at pF 4.2). This is applicable for most tropical soils.

13. Aluminium saturation

	Very low	low	Medium	High	Very high
Al saturation %	< 10	10-30	31-50	51-80	> 80

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