SOIL SURVEY AND LAND EVALUATION OF A PART OF THE UNIVERSITY FARM - MOROGORO FOR RAINFED AGRICULTURE

BY

HASTON LONGWANI JAMES MPEPO

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DECLARATION

I, HASTON LONGWANI JAMES MPEPO, do hereby declare that except where otherwise acknowledged, this thesis is my own original work, and that it has never been submitted for a degree award in any University.

Signature: .....

Date: 27th September 1984.

ABSTRACT

Lack of a systematic and detailed soil survey and land evaluation report for guiding the utilization of the farm necessitated this study. About 1, 097 ha comprising the Northern part of the farm was covered.

It is possible to grow maize, sorghum, soyabeans, fieldbeans, groundnuts and rice. Maize has a land suitability distribution of 228.5 ha (20.7%) as highly suitable (S1), 223.8 ha (20.4%) as moderately suitable (S2), 334.6 ha (30.6%) as marginally suitable (S3) with 310.3 ha (28.3%) as unsuitable thus not suitable (N1) and not relevant (NR) combined. Fertility problems are very widespread. However low soil moisture retention imposed by coarse texture, compounded with periodic droughts is decisive to yields. The land suitability distribution for sorghum is 250.3 ha (22.7%) as S1, 469.5 ha (42.9%) as S2, 79.1 ha (7.2%) as S3, with 298.3 ha (27.2%) as unsuitable. Sorghum has similar limitations to maize but enjoys a higher land suitability area because of its ability to withstand many environmental problems like drought and is more suited to the area than any other crop. Soyabeans have 250.3 ha (22.7%) as S1, 345.3 ha (31.5%) as S2, 230.2 ha (21.1%) as S3, and 271.4 ha (24.7%) as unsuitable N1 and NR. The main limitations to soyabean production are fertility and nutrients with suspected low levels of rhizobium due to coarse texture and poor water retention imposed similarly. A few areas are too wet for soyabeans. There is 250.3 ha (22.7%) rated as S1 for fieldbeans, 266.2 ha (24.3%) as S2, 297.3 (27.2%)

as S3, and 283.4 ha (25.8%) as unsuitable. Limitations are similar to soyabeans but adaptation to, shorter growing season and lower moisture requirements make beans more suitable. The land suitability distribution for groundnuts is 305.0 ha (27.7%) as S1, 211.5 ha (19.3%) as S2, 230.2 ha (21.1%) as S3 and 350.5 ha (31.9%) as unsuitable. Groundnuts have similar tolerances as fieldbeans. Infact coarse textures enhance good pod formation and growth. The land suitability distribution for rice is 90.8 ha (8.3%) as S1, 58.6 ha (5.4%) as S2, 143.1 ha (12.9%) as S3 and 804.7 ha (73.4%) as unsuitable. Excessive drinage due to unfavourable relief and texture give severe limitations to rice production.

Land suitability evaluation indicates that good farm management involving application of biological and artificial fertilizers, fertility trials and soil testing, supplementary irrigation, timing planting to soil moisture balance studies (fig. 9) and not statistical crop calenders, selection and breed of suitable crop varieties, crop and grazing rotations and establishment of administrative houses in Mindu and Lugala blocks of land will raise farm productivity. Fertility and low moisture retention (fig. 15) and (Table 3) coarse textures (figs. 13 and 14), structurelessness (Plate 11) could be amended by manuring, fire prevention, long fallow periods between rotations, silvicultural , multi cropping practices and pasture establishment. The soils with a high water table should be utilized for rice production (fig. 34).

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1. INTRODUCTION

Agriculture is the mainstay of the Tanzanian economy. Its development is the cornerstone of the country's rural development strategy. Over 90% of Tanzanians derive their living directly from agriculture (Ministry of Finance and Planning 1981). Agricultural development needs soil surveys and land evaluations to provide information to investors, planners, advisory staff and farmers. This information helps to assess and predict land use potential and management requirements for sustained production (Dent and Young 1981). Most of such vital information is lacking for most parts of the country as well as the University farm.

Apart from the 20 ha surveyed by Kesseba et al. in 1972 and two soil transects done by Møberg et al. in 1981, the University farm of Morogoro has not yet been surveyed in systematic detail. In an effort to improve crop production levels affected by periodic drought hazards imposed by unevenly distributed bimodal rainfall; low yields due to fertility, weeds, pests and disease problems, a lot of research has been attempted in formulating appropriate cropping, farming and resource - efficient methods (Keswani and Ndunguru 1982, Anandajayasekeram et al. 1981, Semoka 1983).

This project was initiated to provide a detailed comprehensive soil survey and land evaluation report for annual crops of rainfed agriculture for reference, management and planning purposes. At the moment land utilization does not strictly follow land suitability of the areas for specific crops. Little is known as to what constitutes

the 2,300 ha of the farm. The project was restricted to cover 1,100 ha of land covering the Northern portion of the farm above the Morogoro - Iringa highway. The land use recommendations have been based on the investigations carried out.

2. LITERATURE REVIEW

2.1 Soil Survey, a general appraisal

Soil survey is one of the activities collectively known as natural resource surveys. It is the mostly used natural resource survey in development planning. Soil maps are some of the primary documents on which land development projects are based (Young 1976). Interest in soil surveys has been stimulated by failures of agricultural projects that have been implemented without a resource survey. A historical example of this risky practice was the 1947 East African Groundnuts Scheme in Tanganyika (now Tanzania). The task of soil survey is to gather a lot of environmental information relevant to agriculture. The soil map is the final practical tool that is produced for wide application by various land users.

2.1.1 Soil survey techniques

Standard techniques used to gather information in soil surveys are fieldwork and remote sensing. All surveys except the very highly detailed ones use normal airphotographs. Side-looking airborne radar (SLAR), and satellite scanning photography are also used especially on small scale reconnaissance types of surveys (Young 1976; Dent and Young 1981, ILACO 1981). A pre-fieldwork interpretation using print lay-downs or photo-mosaics is made to provide tentative land units e.g. hill, masses, plain and alluvial areas (Young 1976). The elements of landform, drainage, erosion and

vegetation in physiographic analysis form recognizable local patterns (Vink 1968 , 1970). A second interpretation is used to delineate secondary units within primary ones e.g. crests, pediments, valley floors (Young 1976). At this level the mapping units and the legend are defined (FAO 1979a). Photographic differences in tone, texture, contrast, pattern and shape are used to identify units (FAO 1982, 1967b; Young 1976; Dent and Young 1981). Mapping during the fieldwork phase is done according to the characteristics of the provisional legend and specified intensity (Young 1976, Dent and Young 1981). A grid survey where observations are regularly spaced over the survey area is used especially in large scale intensive surveys and complex areas. The observations are patterned by traverses, augerhole and planned profile sites which are also dictated by the scale. Another form of observation is the free survey. This method is used by experienced surveyors who make their own judgements on where to locate augerholes and profile sites using the objectives of the survey and the ground and air photo evidence. A combination of grid and free survey is also used varying with the land characteristics. Data recorded is information on the site (FAO 1977a) identification and location (FAO 1977a, Dent and Young 1981), soil profile description (FAO 1977a)and field tests (FAO, 1979a, Dent and Young 1981 and ILACO 1981). A soil map is drawn after soil profiles and sites have been described, samples tested and analysed for their physical and chemical properties. On the basis of the analytical data the soils are classified using some local systems if in existence or the internationally and widely used ones USDA (1975) and FAO - UNESCO (1974).

Aerial photographs can also be used as base maps for field work and publication depending upon the scale intended for publication (Dent and Young 1981).

2.1.2 Soil classification systems

Soil classification is the process of organizing the properties of soils so that they may be remembered and their relationships may be easily understood (Cline 1949). Soils are grouped on the basis of their distinctive properties into segments, classes or taxa that can be conceived at various levels of abstraction. Since soils belong to diverse populations each population will be fitted into several levels where relationships must be evident from defined criteria for each category (Cline 1949).

The USDA (1975) and the FAO-UNESCO (1974) have gained a growing adoption as classification systems especially in English-speaking African countries. The first American Soil Classification System to gain ground in Africa was the 7th Approximation (USDA 1960). This system after more modification was evolved into the present Taxonomy (USDA 1975). This system of classification is also being tested worldwide for a revised and improved edition of Soil Taxonomy of the near future. It has won wider adoption because its morphometric approach (having quantitative class limits to any property). Properties or

characters are measured in the laboratory or field and classified according to their presence or absence. It is built on well defined concepts and survey procedures of the Soil Survey Staff (1951). However, it has disadvantages of being too laborious, needing well trained staff, well equipped laboratories, and climatic data which are not always available everywhere.

The FAO - UNESCO legend developed by Dudal (1968, 1970) broke the language barriers, isolation and controversy that characterized earlier attempts at collaboration among soil scientists. The ultimate aim was correlation of the various soil maps of the world to make a world wide inventory of soil resources with a common legend. In this system of soil classification, now commonly used in Africa, soil units have two levels; roughly equivalent to the Sub Order and Great Group levels of the Soil Taxonomy. It borrows the morphometric approach but nomenclature is drawn from a number of national systems (FAO, 1974). A soil map of the World has been completed (FAO - UNESCO 1971-78). The FAO-UNESCO legend (1974) has 26 Groups (higher categories) and 106 Units (the lower categories and basic elements). On the World Map 5,000 soil map units, which consist of soil units or associations of soil units appear. Some information on vegetation, climate, geology and geomorphology is given. Some units were artificially created. Most information was supplied from individual countries but lacked from others. At a mapping scale of 1:5,000,000 a quarter of a square centimeter representing 62.5 km^2 was the smallest size mappable. Therefore areas as large as 5,000 ha could not be mapped. (Buringh, 1979).

Though developed merely as a two level legend to act as a common denominator in classifying and documenting World Soil Resources it is now used as a soil classification system and serves to classify soils at least at reconnaissance level of survey. In 1964 The Commission for Technical Co-operation (CCTA) produced a 1:5,000,000 Soil Map of Africa. This publication by D'Hoore (1965) was a combination of the French's Office of Overseas Scientific and Technical Co-operation (OSTORM) and the Belgian's Institut Nationale de l'Etude Agronomique au Congo (INEAC) systems. The Land Resources Division of Britain adopted concepts and units in its mapping work in Africa (Young 1968) from these systems.

Another soil classification system of International standing deserving separate treatment is the OSTORM. It is based on the earlier works of G. Aubert, P. Duchaufor and J. Boulaine. It has 12 classes on which all soils of the world can be accommodated (ILACO 1981). The high level units comprise classes, subclasses, groups and subgroups, while the low level units comprise families, series, types and phases.

2.1.3 Soil Survey in Tanzania

The history of soil survey work in Tanzania dates back to the pioneering works of Milne (1935). The earliest review of major soil survey works carried out in Tanzania was compiled by Baker (1970). Milne (1935-36, 1947) used the Catena concept to map soils on their slope relationships. Similar survey works with an ecological approach and of a reconnaissance

type were done by Calton (1952, 1954). These works were published at a scale of 1:4,000,000. Anon (1956) and Anderson (1967) improved the details of these publications to 1:3,000,000. A much more detailed Provisional Soil Maps of Tanzania was published by Samki (1977) at a scale of 1:2,000,000.

A critique of some of the soil classification maps in Tanzania was made by Uriyo (1970). The reliability of the early maps e.g. Calton's (1952) depended upon accessibility. Parts with good road and railway networks were better surveyed than the remote ones. Therefore the utility of these maps was limited. The mapping also did not refer to systematic and detailed study of the soils for their genetic, morphological, physical and chemical properties. The purpose and scale of these maps had not been precisely defined (Uriyo, 1970). At such scales of mapping smaller than 1:2,000,000 most units are based on extrapolations and associations of vegetation to soils and bear little relevance to soil properties. According to Uriyo (1970) the terminologies used in the early classification were also confusing. The CCTA (1964) published a Soil Map of Africa on which Tanzania was covered, based on existing works to that date. This map also suffered the same deficiencies of unreliability and confusing terminology (Uriyo, 1970). The map by Scott (1969) at a scale of 1:4,000,000 was similarly deficient. Other criticisms of the early survey works are in their bias towards the catena concept. In general the soils are more closely associated with the underlying rocks or parent material than with any topographic sequence (Uriyo 1970). According to Kesseba (1970)

early soil survey work lacked common methodology in soil survey and soil analysis. The physical, mineralogical and microbiological properties were also reported as having been neglected.

Another criticism of the early soil survey and classification work was lack of coordination in information and activities between different organisations often existing in different ministries. Examples of these early organisations are: The Water Development and Irrigation Division, The Soil Engineering Unit, The Land Planning Unit and later The Bureau of Resource Assessment and Land Use Planning (BRALUP). Kesseba et al (1972) describe the form that characterized early soil survey and classification work as cartographical, where soils were described according to slope forms. The trend to detailed and systematic soil survey and classification work was attempted by Anderson (1961, 1963). Although such schemes produced high quality work, they required enormous capital outlay in terms of manpower and finance. However such surveys provided ample information for planning (Uriyo, 1970). This trend of classification was termed as utilitarian (Kesseba et al, 1972). In this scheme, large scale surveys are oriented towards problem solving. A well documented soils Bibliography of Tanzania was given by Cook (1975). This bibliography covers all soil-related research publications to that date. The use of International classification systems such as the 7th Approximation with precisely defined morphological and analytical data was recommended (Kesseba et al, 1972). The point in favour was allowance of greater communication within

the country and internationally. A new approach to soil mapping in Tanzania for national use was described by Hathout (1973a). The 7th Approximation was emphasised and early works criticized. Attempts at classifying soils in the FAO-UNESCO (1974) were made by Møberg (1973) and the Soil Taxonomy by Samki (1975).

In short the catena concept dominated all soil classification and mapping before the 1970s with information got from field notes, reviews of past surveys, ground surveys and rarely aerial photo interpretation combined with fieldwork. The mapping scales increased with decreased sizes of the survey areas, especially high potential ones. A Soil Survey map of the whole of Tanzania was attempted by the American Peace Corps 1967-68, split into four regions (Johnson and Tiarks 1969; Sheehy and Green 1969; Wengel et al., 1969; and Stuartz and Duckworth 1969). This mapping exercise was published at a scale of 1:1,000,000. This national mapping scheme was the first nationwide application of aerial photography techniques to soil mapping. The aerial photographs were used as base maps for ground traversing with the help of topographic and geological maps. Detailed soil profile descriptions have been rare until the 1960s when they followed the FAO Guidelines (1967a) and the Soil Survey Manual (USDA 1951) with the choice left to the individual surveyors. At the moment the FAO Guidelines for Soil Profile Description (1977a) are followed. The systems FAO-UNESCO (1974) and the USDA (1975) are used to classify soils. Use of satellite imagery has been attempted (Rombulow-Pearse and Kamasho 1982). Vertical colour photography and computer printed maps have been tried on an agricultural planning and conservation project (Stocking, 1983).

2.2.1 Land Evaluation - a general appraisal

Land evaluation is a process of collating and interpreting basic inventories of soil, vegetation, climate and other aspects of land in order to identify and compare land use alternatives (ILACO, 1981). A comparison of requirements of different land uses matching land with the use (FAO, 1976) is done against what the land can offer and a best alternative is selected from social, physical, political, economic (Young, 1973) or even ecological point of view.

The need for systematic land evaluation has come from populated areas of the world where there is competition from non agricultural uses of land, therefore requiring that alternatives be best chosen (Beaty et al, 1979; Davidson, 1980; McCormack and Johnson, 1982). Soil Survey developed first because of the urgent need for food to feed increasing populations in the 1930s. Suddenly soil scientists unearthed too detailed information in forms not often easily understood or usable by land users i.e. planners, foresters, extension workers, farmers, making land evaluation highly needed. The earliest and best known system of land evaluation is the Land Capability System of the Soil Conservation Service of the US Department of Agriculture (Klingebiel and Montgomery, 1961). This system rated permanent physical land characteristics that limit or risk erosion or other hazards. Slopes, soil texture, depth, permeability, water holding capacity and clay type were interpreted. Eight capability classes were created on their assumed capability to produce crops or other uses,

Limitations or erosion risks in land use progressively increase from I to VIII. Groups were identified as arable (classes I-IV), and non arable (V-VIII). Management factors and interaction between crops and effect of crop cover on erosion were not emphasised. This system applies well in areas with abundant land (Woods, 1981) and has been successful in Malawi and Zambia (Shaxson et al., 1977; Department of Agriculture - Zambia, 1977).

The FAO developed a methodology that would use similar concepts and procedures (systematic evaluation) for any kind of land utilization (to compare and refer to). Expert consultations occurred in 1972, 1974 and 1975. The framework for Land Evaluations appeared in 1976 with more details in FAO (1977b, 1979b). The framework has 26 land qualities (Dent and Young 1981). It has a hierarchical order. The highest level is a suitability order. Suitable (S) or Not Suitable (N). The second level is the Suitability class (within the order). This gives the degree of suitability i.e. (1) highly (2) moderately and (3) marginally suitable. The third level is the suitability subclass which denotes the kind of limitations e.g. (c) climatic (w) wetness (t) topographic etc. At the suitability subclass level (within subclasses) degrees of limitations and management requirements are rated for a specific land use in question e.g. rainfed agriculture with special ratings for specific crops. The subclasses also form further mapping units.

The framework is still being tested with further improvements on its limitations and problems of applications (Purnell, 1977). Some common diagnostic criteria for rating land have been agreed upon others have not. On climate, precipitation and evapotranspiration are more significant for their influence on biomass production (yields). On moisture availability, rainfall, moisture retention and available water capacity are used but no standards are yet available, (Purnell 1977). Topography still has disagreements as costs of land improvements often differ from country to country and with site conditions. Wetness (oxygen availability) needs clearer grading as crops differ in their tolerance to poor drainage or moisture limitations or requirements. Moreover lands can also be artificially drained. Depth to watertable seems to be the only easily quantifiable at the moment. Flooding hazards, flash damaging or slow moving water (inundation) differ locally with crops, seasons and management, so common criterion is difficult to arrive at. Nutrient status is still difficult to assess because of the different methods used in the analysis and interactions of variables. There is work on developing a Soil Fertility Capability Index (Buol and Couto 1981). Soil salinity and sodicity have already been established in the US and need local verification on crops tolerance and susceptibility. Physical characteristics bulk density, aggregate stability, COLE and Hydraulic conductivity have not been commonly assessed on their effect on agricultural crops. Criteria for assessing erosion is available but recommendations are not fully quantifiable as yet.

The FAO Framework is also demanding too much data as for practical reasons there is a limit to the number of observations of natural phenomena and experiments that can be made at a site (Veldkamp, 1979). Mixed farming, rotations, multiple cropping make land evaluations too complex. Recently therefore numerical assessment methods to improve on speed, accuracy variability and rapid ability of land evaluations have been developed. Quantitative data makes it easier to make economic decisions (Young, 1973; Miller, 1978; Beckett and Bie, 1978). Computer applications have been tried with success in Canada (Luttmerding 1980). Mathematical models for yield predictions based on simulations and analogue models found on fundamental plant growth requirements (Wit 1978; Beddes et al; 1978) are developing. Computer systematics have also been applied to soil survey and will further facilitate the transfer of Agro-Technology between nations (Moore, 1978).

Technological constraints further limit the effective contribution of the developing countries to adopt, adapt or modify new systematic soil survey and evaluation systems.

2.2.2 Land Evaluation in Tanzania

Land evaluation in Tanzania dates back to the colonial days when attempts were made by farm planning staff and not soil surveyors to use the land according to its capability to produce crops without degradation (Cooper, undated). Early soil survey work was dominated

by ecologically and cartographically oriented workers who were mostly geographers with little or no background in agriculture. The farm planning evaluation systems gathered information on rainfall probability and topography. Land selection and suitability used this criterion. Availability and nature of markets, communication, soil fertility, supply and quality of labour, availability and suitability of irrigation water, incidence of pests and diseases in both animals and crops and flexibility and relationships between enterprises were used in the farm planning. The land evaluation maps were often produced at 1:500 from field work and were not part and parcel of soil surveys but undertakings by planning staff. The capability classification was on the basis of slopes in relation to erosion. Most of the research on the land evaluation practices occurred in Kenya with recommendations being extrapolated to Tanzania. Since 1967 the Bureau of Resource Assessment and Land Use Planning has carried out broad land evaluations for social and economic planning. The bulk of these evaluations are on demography, rainfall and communications. Detailed soils information has been attempted but in quantity and rates lower than the development demands. An attempt at evolving a common methodology in land evaluation was made by Hathout (1973b) and Hathout and Sumra (1974). A call for proper training, institutions and planning to put agricultural land to its best use avoiding land mismanagement was earlier made by the Land Use Workshop (Uriyo, 1970). Several international organisations have also been carrying out land evaluations often using their own systems.

The haphazard way in which soil survey and land evaluations have occurred came to be improved with the formation of a National Soil Survey Service with FAO assistance in 1975. This organisation uses FAO Guidelines for profile descriptions (1977a) and the FAO-UNESCO legend (1974). The USDA (1975) Soil Taxonomy is also used for correlation of the Taxonomic classification. Standard laboratory methods and fieldwork procedures are followed. The land evaluations follow the FAO Framework (1976) as recommended for adoption in 1980 (Samki and Dewan 1980). This has improved the co-ordination and correlation of the findings tremendously. Contributions for providing methodologies and standards for assessing land qualities have been started e.g. dependable soil moisture (De Pauw (1980). The most recent work that have adopted internationally widely used soil survey procedures, classification and land evaluation systems are De Pauw (1982) and Rombulow-Pearse and Kamasho (1982) with the latter using satellite imagery in the land systems approach.

Ratings for land qualities have just begun to be studied in Tanzania. Previous work was based on extrapolations from other areas e.g. Sudan as in Van der Kevier (1976).

3. THE ENVIRONMENT

3.1 Location

The University farm is located at 6° 51'S Latitude and 37° 39'E Longitude. The location of the farm in relation to these coordinates and major centres of communication locally and internationally is illustrated on the next page (fig. 1). The survey area lies west of Morogoro municipality which has a population of approximately 100,000 people. The town is linked to the old capital Dar es Salaam and the new Capital Dodoma by road and rail. The Mindu hills lie on the west and the Lugala ones on the North West.

3.2 Geomorphology

The farm has a saucer-like shape sandwiched between the Mindu hills on the West and the Uluguru mountains on the South-East. Both mountains have alluvial fans below them formed by fluvial activity. Interfluves rise to a few metres high except occas ionally in Mindu and Lugala where slopes are steep and areas eroded or dissected into a rugged landscape. The dissection of the landscapes by seasonal runoff and active stream channels on the light soils of Mindu and Lugala blocks of land are correlated with erosion and sedimentation of the surroundings and drainage channels exposing rocks to several metres depth. The lower terraces are generally gentle sloping and uneroded in Mafiga, Mindu and Lugala. The Mafiga block is a peneplain of little erosion due to fine texture, stable soil structures and gentle slopes rarely exceeding 4%. Most of the

survey area lies between 500 and 540 metres above sea level (a.s.l.) (Commissioner for Surveys, 1970).

3.3. Hydrology and drainage

The farm is mainly drained by the Ngerengere river (fig. 2). According to the DHV Report (1979), the river Ngerengere rises from the Uluguru mountains in the NW at 1600 m a.s.l. It flows through the University farm in North Easterly direction at 500m a.s.l. The slope gradient of the main course is 0.25%. The chemical composition of the groundwater is 6 ppm F^-, 432 ppm Cl^-, 388 ppm HCO_3^-, 406 ppm SO_4^{2-} and 1719 ppm. Total Dissolved Solids (TDS). In the alluvial sandy deposits of small tributaries of the Ngerengere the groundwater is saline (60-179m S/m) according to the above Report (DHV, 1979). The quantity of groundwater was termed as sufficient because of the valleys being more than 100m in width and sediments being deeper than 6m. The Ngerengere Catchment Area up to the Kihonda gauge site below the farm is 461 km^2. In 1978 only 1.6 litres per second from the Ngerengere river were being used from a possible potential supply of 37 litres per second concluded DHV (1979).

3.4 Geology and mineralogy

The farm lies below the Uluguru and Mindu mountains ranges of the Usagaran system of the Mozambiquan belt (Saggerson, 1962). This system consists of late pre-Cambrian material of which 3 groups of metasediments are found on the farm (fig. 3).

Migmatite and acid gneiss are found in the Mzumbe - Mlali area extending to Mindu, Nguru ya Ndege and Lolamahonda. Acid gneisses of garnet-biotite are also found in Mindu as strongly foliated and migmatized. Garnet-pyroxene granulates form the south of Morogoro sediments overlain by a similar suite of granulites distinguished by hornblende content. The pyroxene granulates of the Uluguru are rich in plagioclase, are fine textured and intervoven with biotite sheets. These rocks are low in silica resulting in clayey soil. In contrast the Mindu mountain rock material contains more metaigneous materials; muscovite, biotite and hornblende - gneiss (Sampson et al, 1961). These rocks are made of material coarser in texture and rich in silica. A small section of the farm below the Lugala hills is underlain by sedments of banded muscovite biotite migmatites occasionally poor in silica.

3.5 Climate

Morogoro town lies at an altitude of 530 m a.s.l. with a distance from the sea of 210 kilometres. The town is sheltered by the Uluguru mountains on the South-East and the Mindu hills on the West. These shelters impose a rain shadow effect on the town. This effect is more evident on the Uluguru mountains 1370 m a.s.l. where more than 1100 mm are recorded e.g. Morning Side. This rainfall drops down to 900 mm on the University Campus 528m a.s.l. and 5 kms away. This trend continues with 800 mm remaining at Mafiga and Mindu 500m a.s.l. and only 3 km away from the campus. The mountain ranges surrounding Morogoro reduce sunshine hours in the early morning and late afternoons. Detailed

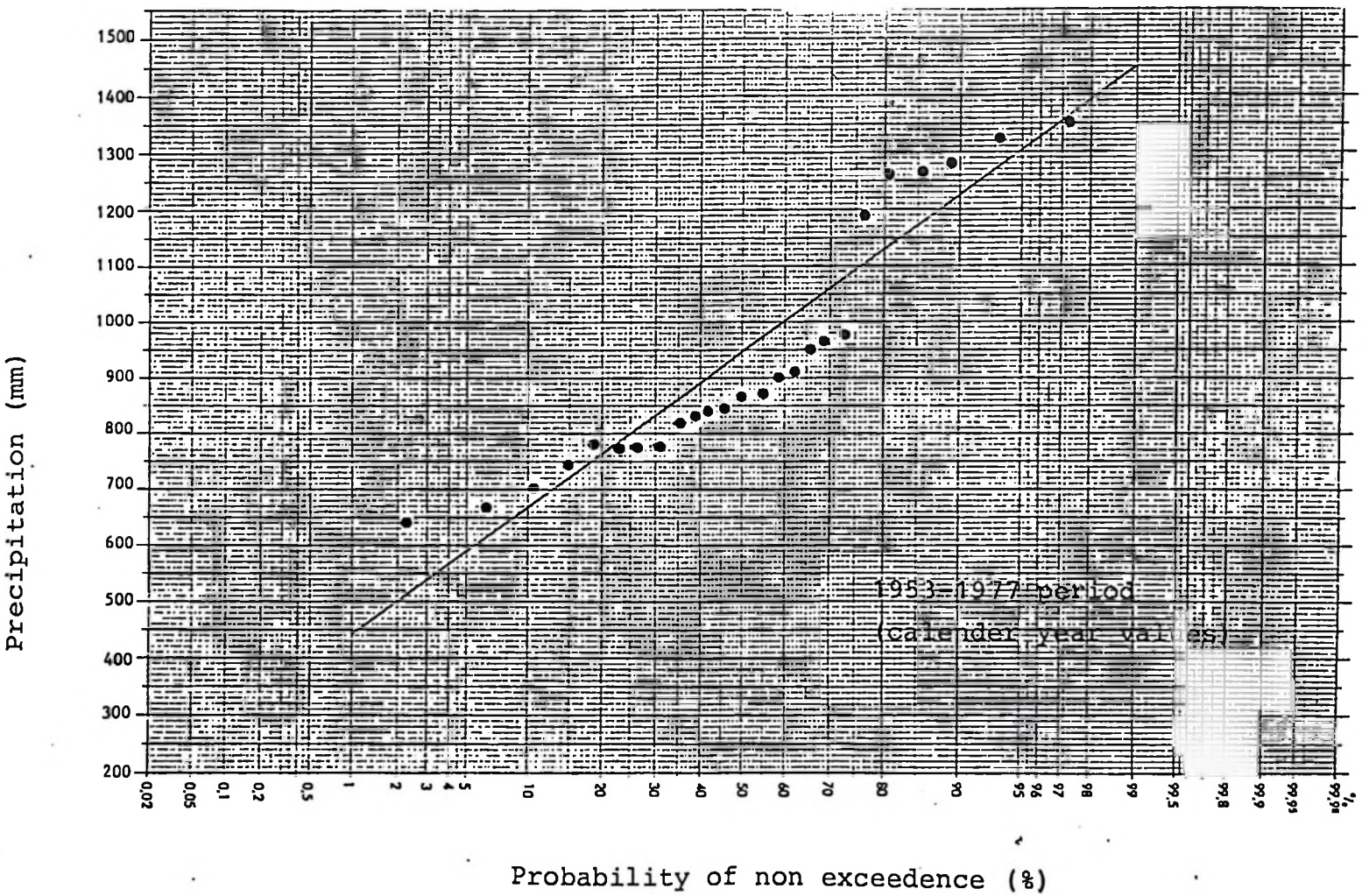


Fig. 8 . Frequency analysis of annual precipitation for Morogoro Agr. Office. (After DHV 1979).

Fig. 9 WATER BALANCE OF SOKOINE UNIVERSITY FARM
(Caculated with Mafiga rainfall 1978 - 81)

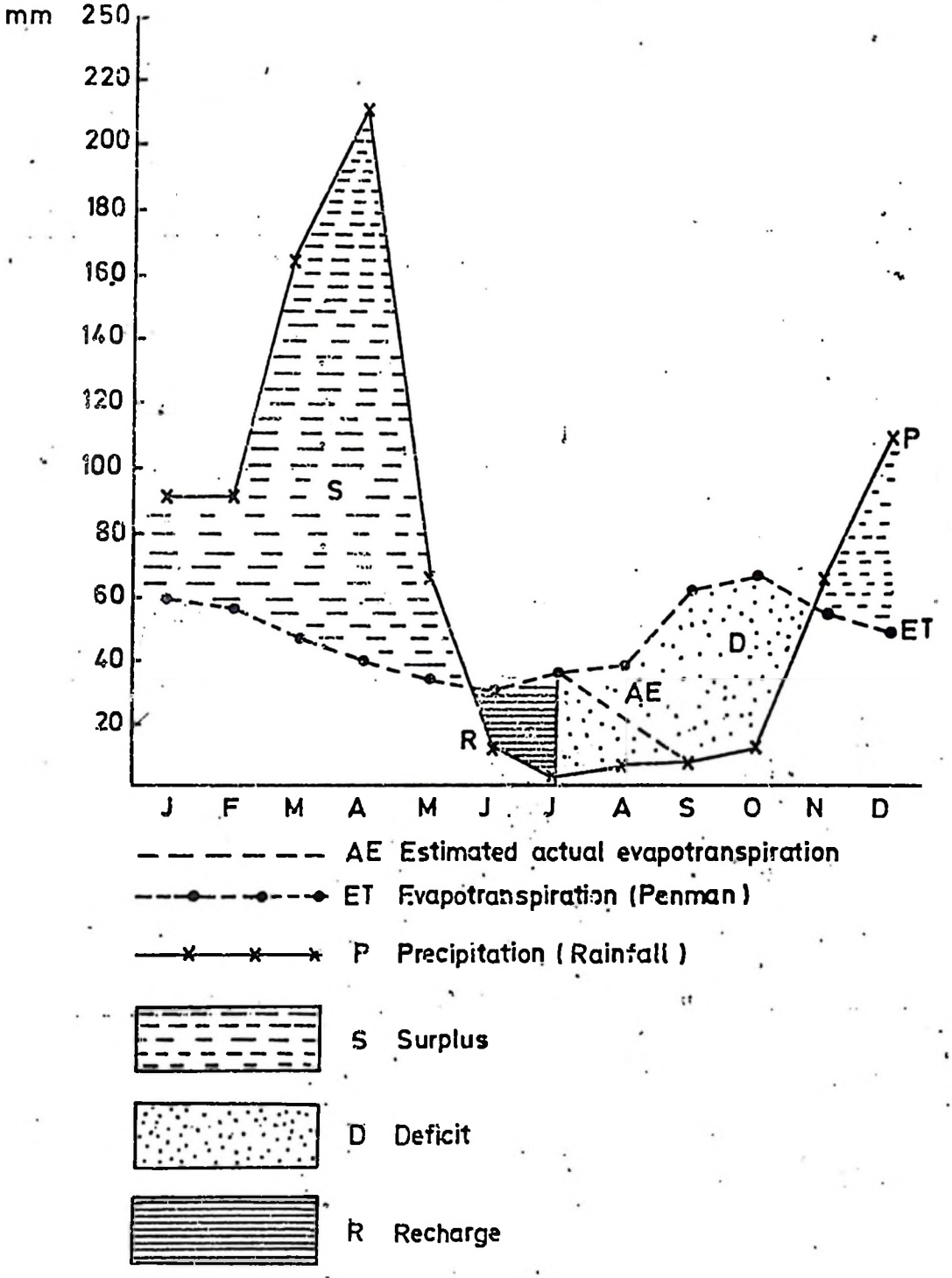


Table.1: Monthly Meteorological Parameters for Morogoro (after HAND, 1975)

Parameter	Observation period	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	MEAN
Mean	1954-70	23.6	23.2	23.4	22.7	21.4	19.9	19.3	20.1	21.6	23.2	24.6	24.3	22.3
Temp.	1970-74	26.2	26.0	26.0	24.9	23.5	22.0	21.7	22.5	23.6	24.8	26.0	26.8	24.5
(°C)	1946-60	26.2	26.2	26.1	25.0	23.5	21.6	21.1	22.1	23.2	24.6	25.6	26.5	24.5
Relative	1954-70	67	71	69	67	62	56	55	52	51	46	48	59	59
Humidity	1947-70	72	72	72	73	72	68	64	63	60	60	62	67	67
(%)	1946-60	69	70	73	80	79	73	70	66	63	61	63	63	69
Daily	1954-70	7.1	7.2	7.1	6.8	7.8	9.0	9.3	6.6	9.6	9.9	9.6	7.6	8.4
Sunshine	1963-74	6.5	7.2	7.0	5.9	6.3	6.4	6.5	6.7	6.4	7.2	7.5	7.0	6.7
(hrs)	1946-61	5.7	5.9	5.9	4.3	3.9	4.3	4.1	4.2	4.7	5.7	6.2	5.8	5.1
Daily	1967-70	522	509	514	455	454	490	501	513	584	632	590	544	525
Radiation	1964-70	520	532	526	456	423	416	403	423	466	514	523	531	478
(langley s/day)														
Daily	1967-70	124	116	127	132	160	178	177	220	262	278	260	155	183
windrun	1963-70	115	100	103	92	111	121	126	137	162	177	160	129	128
(km)	1947-60*	128	120	120	104	112	128	128	128	160	192	176	176	139
Monthly	1967-70	132	119	138	104	133	134	148	166	193	235	218	153	156
Evaporation	1964-70	171	149	166	131	122	126	138	148	167	205	201	183	159
(A Pan) (mm)	1947-60	173	159	167	126	111	106	112	126	146	179	176	179	147
ET (Penman) (mm)	1978-81**	59	56	47	40	35	31	37	47	62	66	55	48	49
Rainfall mean (mm)	1953-77	101	96	141	241	90	22	16	12	20	39	65	95	937
Standard deviation(mm)	1953-77	63	60	70	93	51	20	25	20	24	41	76	75	218
Co-efficient of variation	1953-77	.51	.64	.52	.37	.57	.77	.89	.98	.82	.94	1.01	.70	.23
Co-efficient of skew	1953-77	-	-	-	-	-	-	-	-	-	-	-	-	.77
Probability of exceeding former value	1953-77	-	-	-	-	-	-	-	-	-	-	-	-	93%

* Daily winds from Woodhead (1968)

** ET from Hafiz rainfall and other University Met. Station data

information on the meteorological parameters are given in figures 4 to 9 and table 1 compiled from LAMD (1975), DHV (1979) and records from the University Meteorological station of Morogoro. Monthly rainfall means reflect the high rainfall peak around April while a second peak although less distinct than the former can be distinguished at the end of the year and is best illustrated by records of maximum rainfall in 24 hours (fig. 6). There is a high frequency of getting rainfall between 700 and 1000 mm with a mode between 800 and 1000 mm of this frequency (fig. 7). The high variability of rainfall in Morogoro is shown by Fig. 8 (after DHV, 1979). This shows that the probability of getting a rainfall amount different from the established average is very high. This phenomenon has a serious implication for farming especially planting times and drought hazards. Table 1 gives a high standard deviation, high efficients of variation and a significant coefficient of skew which also shows a high imbalance in rainfall. According to Koppen's classification (ILACO, 1981) the climate of Morogoro is therefore a tropical rainy climate with a distinct dry season. It has a mean monthly precipitation not less than or equal to 60 mm during one month and a hot summer with a mean temperature above 22°C. A water balance model of the University farm (fig. 9) shows a surplus of moisture from precipitation over evapotranspiration around March to May. A soil moisture recharge occurs between the termination of rains in May to July after which a deficit ensues to mid-November when another moisture gain from precipitation initiates a surplus over evapotranspiration. Due to the short period over which consistent data was

available the results of the moisture balance between January and February are not as clear or highly correlated to the long term precipitation patterns recorded for this period.

3.6 Vegetation

Most of the tree vegetation of the farm has been cleared therefore classifications will remain to being extrapolations backwards in time. Remnant trees on interfluves on Uluguru mountain slopes indicate deciduous woodland. The dominant tree vegetation in Mafiga may have been "Miombo" as defined by Lind and Morrison (1974). Otherwise the prevailing vegetation is mainly successive. Tree regrowth is dominated by Ehretia Petiolaris, Lannea, Pteleopsis Mylifolia, Markiamia Obtusifolia and Thylacium Africanum. Detailed descriptions of other vegetation is found under the profile descriptions in the Appendix.

3.7 Land use

Of the 1,100 ha in the survey area, 50 are under forest plantations in Mindu block. There is a 5 ha horticultural unit in Mafiga block. Crops grown on the farm are rice, sorghum, maize, groundnuts, soyabeans, beans, cassava and coconuts. Only sorghum (60 ha), maize (150 ha), cassava (30 ha) and coconuts (342 trees) are currently cropped. The other crops are only grown by squatters. The yields are 720 kg/ha for sorghum, 1440 kg/ha maize, 720 kg/ha beans (1979/80 season only), 1.5 tonnes/ha cassava and 5-6,000 nuts per year of randomly planted coconuts. Farming is 100% market oriented. Fertilization rates are

200 kg/ha triple superphosphate (TSP) as basal dressing for maize and sorghum, then 200 kg/ha calcium ammonium nitrate (CAN) top dressing applied at knee height. Beans were given basal dressing of 100 kg/ha TSP. Cultivation is fully mechanized; Harvesting is done by hand. Crop protection for prevention and cure through sprays and fumigation are practised (Dimoso, 1984).

4. MATERIALS AND METHODS

4.1 Fieldwork

4.1.1 Preliminary investigation

A review of existing literature relevant to the project work was done. Geologic, topographic, climatic maps and aerial photographs were studied. Two reconnaissance journeys for a general land appreciation were made augmented by augering to identify soil variation with landscape. A provisional mapping legend based on the dominant characteristic topography and correlated criteria drainage and depth was designed to form mapping units. The mapping units were built around the subdivision of (Møberg et al. 1981) Uluguru and Mindu associations into phases. The structure of the legend was built in such a way that it would accomodate ranges of land characteristics in the unsurveyed half of the farm.

4.1.2 Mapping

Generally practised soil survey procedures were followed (FAO, 1976a, 1967b, 1977a, 1979a, Dent and Young 1981, Young 1976 and ILACO 1981). Aerial photographs at 1:12,500 scale were used to study vegetation, land use and soil distribution according to topography using tone, texture and contrast. Contrasted areas were delimited for further investigation. Traverses were planned to cover identified soil types from preliminary investigation and photo-interpretation. Starting and finishing points were at prominent features e.g. roads, rivers, fencelines, firebreaks etc.

This made navigation and references simpler. Traverses were also planned to run from highest to lowest point and vice versa to investigate catenary effects. The distance between traverses as well as between augerholes varied with land characteristics. On average 250 metres were applied to separate traverses. The distance between augerholes was fixed at 100 metres.

Preliminary mapping of soil boundaries was simultaneously done in the office and field. Interdependent activities photo-interpretation, augering, profile description and laboratory results facilitated proper mapping. Information was plotted on the aerial photographs following traverse and augerhole patterns. Boundaries were established finally by proper scaling interpretation and interpolation of units to stereoscopic images. Boundary adjustments were made after further field checks to test map reliability. Because of their 4 times larger scale than the 1:50,000 topographic maps the aerial photographs were used to provide a base map. The richness in detail of the aerial photographs was another added advantage. Errors due to image displacement resulting from differences in ground elevation or photo scale occuring radially from the principal point were corrected using the SB 100 Radial Line Plotter. Map accuracy was improved progressively through trial and error. Principal points, roads, river bends, match lines, outlines, road junctions etc were used as control points. Map reliability was higher in Mafiga, and Mindu blocks of land than Bugala because aerial photo coverage for Bugala

was incomplete and so the large part of the block was produced through cartographical enlargements. The final soil map was produced at a scale of 1:15,000.

4.1.3 Profile description and sampling

Observation techniques included augerhole borings, and chance exposures e.g. road cuttings and gullies.. The format used to describe augerhole data is presented in Table 2 on the next page. The profiles were described according to the FAO Guidelines (1977a).

Proper techniques of sampling were followed to avoid errors due to contamination or unrepresentativeness of samples (ILACO, 1981 and FAO 1979a). Except for the top soil where composites were made from 7 sites of the upper 25 cm in each mapping unit, all sampling followed the representative soil profile with two samples taken per horizon. Fresh faces with the most uniform material were sampled. Where a horizon was thicker than 50 cm, this was subdivided for taxonomic classification purposes. On average two profiles were dug per mapping unit of area more than 10% of total surveyed land. The depth of observation during augering was 1.2 metres. Where no limiting materials were encountered profiles were dug up to 2 metres depth.

The classification of the profiles was done after the laboratory analyses according to Soil Taxonomy (1975) and FAO - UNESCO Legend (1974).

Table 2: Augerhole description sheet No. ; Traverse No. ; Bearing ; From to ; Date .

1.	Pit number		
2.	Distance along traverse		
3.	Texture 0-25 cm	S LS SL SCL L CL SC C	S LS SL SCL L CL SC C
	25-50 cm	S LS SL SCL L CL SC C	S LS SL SCL L CL SC C
	50-75 cm	S LS SL SCL L CL SC C	S LS SL SCL L CL SC C
	75-100cm	S LS SL SCL L CL SC C	S LS SL SCL L CL SC C
	100 cm	L LS SL SCL L CL SC C	S LS SL SCL L CL SC C
4.	Depth in (cm)	0-25 25-50 50-75 75-100 >100	0-25 25-50 50-75 75-100 > 100
5.	Depth class (Author's)	5 4 3 2 1	5 4 3 2 1
6.	Limiting material (FAO 1977a)	c k m n s x R	c k m n s x R
7.	Stoniness % class (FAO, 1977 a)	<.01 .01-.1 .1-3 3-15 15-90+	<.01 .01-.1 .1-3 3-15 15-90+
		0 1 2 3 4	0 1 2 3 4
	Rockoutcrops % class (FAO, 1977 a)	0-2 2-10 10-25 25-50 50-90	0-2 2-10 20-25 25-50 50-90
		0 1 2 3 4	0 1 2 3 4
	Termite mounds % class (Dept. of Agric., 1977)	1 1-5 5-10 10	1 1-5 5-10 > 10
		0 1 2 3	0 1 2 3
8.	Slope % (suunto clinometer) and class (FAO, 1977 a)	0-2 2-6 6-13 13-25 25-55+	0-2 2-6 6-13 13-25 25-55+
		A B C D E	A B C D E
9.	Erosion type and class (Dept. of Agric., 1977)	None Sheet Rill Gully	None Sheet Rill Gully
		0 1 2 3	0 1 2 3
10.	Colour at 50 cm depth (Dept of Agric., 1977)		
11.	Mottling depth (Dept. of Agric., 1977)		
12.	Drainage class (FAO 1977 a)	0 1 2 3 4 5 6	0 1 2 3 4 5 6
13.	Mapping unit (Mapping legend)		
14.	Remarks		

4.2 Laboratory work

4.2.1 Physical methods

Particle size distribution was determined by the hydrometer method using Calgon as a dispersing agent (Buoyoucos, 1951).

Weight per unit volume of undisturbed oven dry soil bulk density was determined using 56 mm x 46 mm cylindrical cores.

The specific gravity or weight per unit volume of solid particles was the oven dry weight of the solid phase measured with the aid of a pyconometer.

Ratio of pore space to total bulk volume of solids was calculated as a fraction of differences between specific gravity (S) and the bulk density (D) divided by specific gravity (S) thus

$$\frac{S-D}{S} \times 100$$

Moisture retention characterized by available water capacity was determined as a difference in water content between $\frac{1}{3}$ bar (field capacity) and 15 bar (wilting point) measured by the pressure plate and pressure membrane apparatus respectively (US Soil Conservation Service, 1967).

4.2.2. Chemical methods

Organic carbon was determined using the Walkley Black method (Allison, 1965).

Nitrogen was determined using macro-Kjeldahl digestion (Bremner, 1965).

Exchangeable cations Na^{+}, K^{+}, Ca^{2+}, and Mg^{2+} were determined by Atomic Absorption using leachate extracted by NH_4OAc buffered at pH 7 (Dewis and Freitas, 1970).

Exchangeable acidity was measured by potentio-metric titration using Barium chloride-triethanolamine with pH 8.1 (Mehlich, 1953).

Soil pH was measured in water using a soil solution ratio of 1:1 and in 0.01 M $CaCl_2$ with a 1:2 soil solution ratio using glass and reference electrodes (Dewis and Freitas, 1970).

Available phosphorus was determined using the Bray and Kurtz No. 1 method (Dewis and Freitas, 1970).

Exchangeable aluminium for some profiles was analysed using the method in Black (1965) while other samples were analysed using the method by Øien and Gjerdingen (1972).

Electrical conductivity (EC) was measured on samples from profiles with pH more than 7.5. A soil water paste ratio of 1:5 was used with a conductivity meter. Results were measured in mS/cm (Black 1965).

Cation Exchange Capacity (CEC) was determined as a total of all exchangeable cations.

CEC per 100 g clay was calculated using the formula by ILACO (1981).

$$\text{CEC clay} = \frac{[\text{CEC Soil} - (1.5 \times \text{O.M.\%})] \times 100}{\% \text{ Clay}}$$

Sum of bases per 100g clay was calculated by assuming that the base saturation of the clay and the organic components were equal. So the sum of bases were calculated from CEC clay using the base saturation thus

$$\text{Bases/100g clay} = \frac{\text{CEC 100 g clay} \times \text{BS}}{100} = \text{me/100g clay}$$

4.3 Land evaluation

The principles of the FAO Framework for land evaluation (1976) were followed. The standards and guidelines for rainfed agriculture (FAO 1977b, 1979b) were used but where possible adjusted to local conditions.

5. RESULTS AND DISCUSSION

5.1 Soils

5.1.1 Soil Map Units

Mapping Unit $11C_1$ - FAO 1974: Eutric Fluvisol

- USDA 1975: Fluvic Psammaquent clayey, mixed

Fig. 10 shows area distribution of the soil map unit while its soil and other land characteristics are represented by profile 14 in the appendix. Profile 9 is similar. This mapping unit occupies 90.8 ha of surveyed land or 8.3% (Fig.10). The soils of this mapping unit are alluvial and colluvial deposits from Ngerengere river and overlying mountains and surrounding areas respectively. This unit is associated with very flat topography of less than 2% slopes occupying both the Uluguru and Mindu associations (Fig. 11). The drainage is poor. The range in colour is very dark grayish brown in the top to dark brown moist in the sub surface horizons. The diagnostic surface texture is sandy clay loam increasing in heaviness with depth. The area is subject to annual floods twice a year from the over flow of the Ngerengere river and surrounding catchments. The vegetation has been cleared while the existing one is dominated by weeds. The soils are fertile for all crops.

Fig.10 AREA DISTRIBUTION OF SOIL UNITS

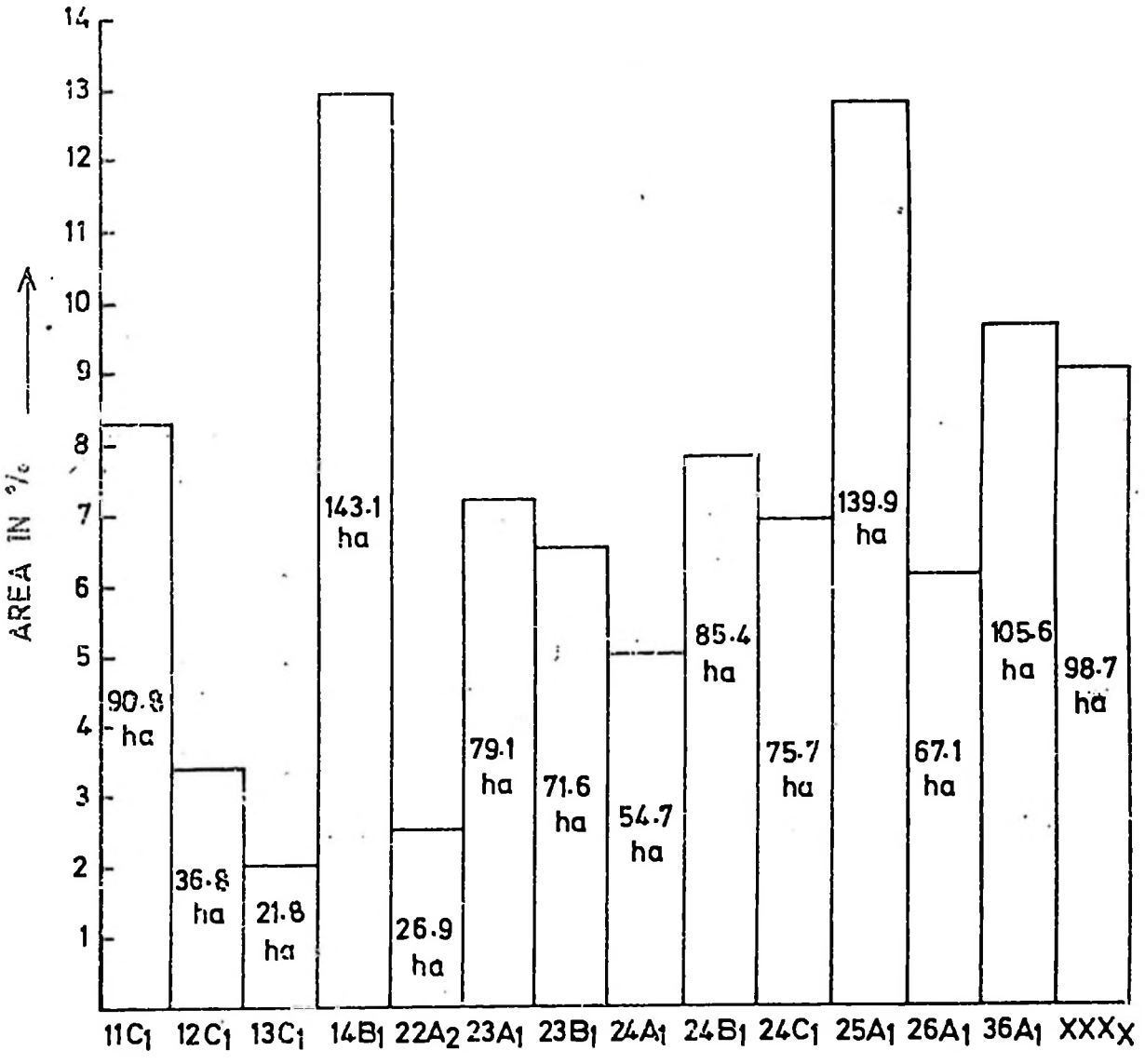


Fig. 4 LANDSCAPE DISTRIBUTION OF SOIL MAP UNITS IN SURVEY AREA. (A)

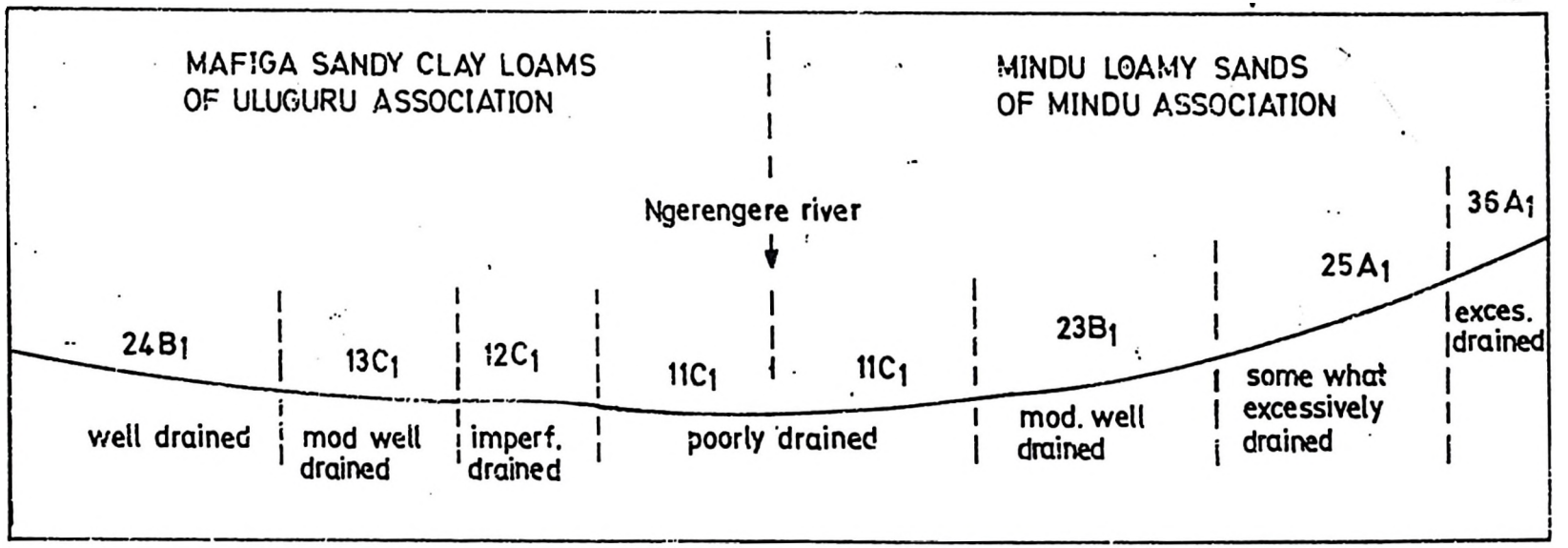
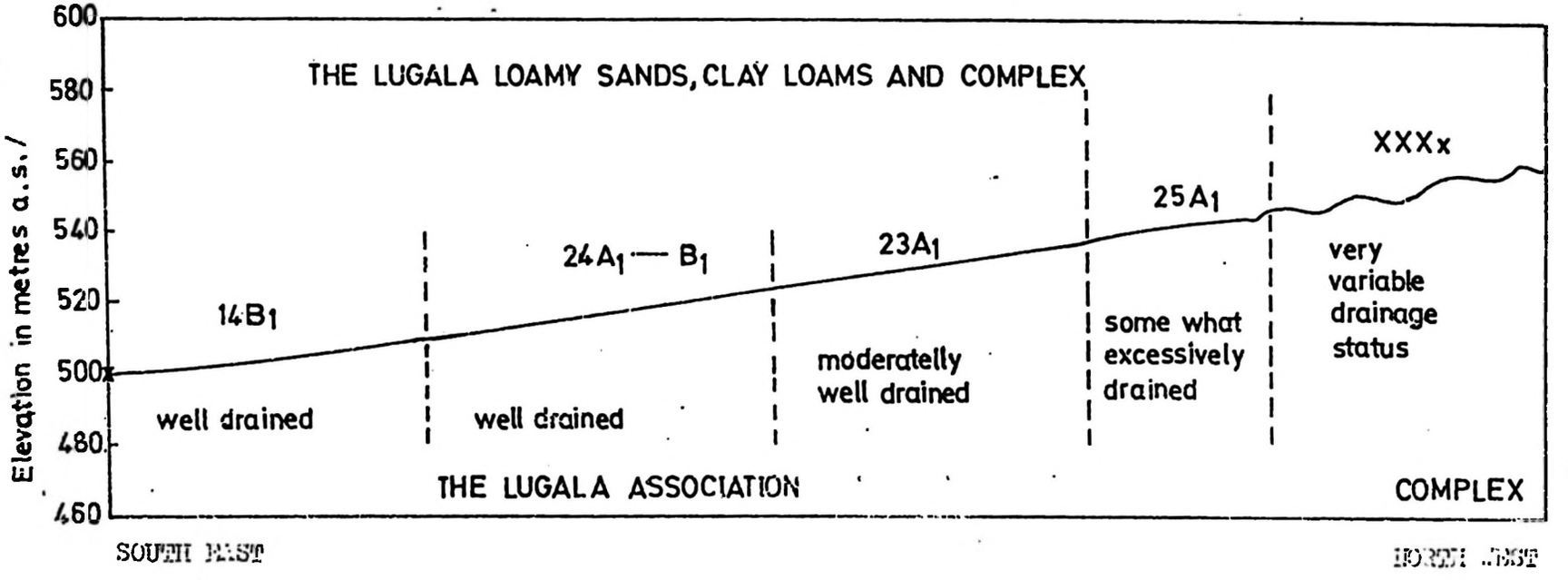


Fig. 12 LANDSCAPE DISTRIBUTION OF SOIL MAP UNITS IN SURVEY AREA (B)



Mapping Unit $12C_1$ - FAO 1974: Gleyic Luvisol

- USDA 1975: Umbric Tropaqualf, clayey, isohyperthermic, deep.

The mapping unit is represented by soil profile number 12. The main characteristics of these soils are a soil texture of sandy clay loam becoming finer with depth to sandy clay. The drainage is moderately well to imperfectly drained due to topography, micro-relief and slow permeability. The colour ranges from very dark gray in the top soil to dark brown in the sub soil. The structure is mainly angular blocky. Iron-manganese concretions are present as the subsoil is fairly reduced. The natural vegetation has been cleared and in some areas replaced by improved pastures. The soils occupy 36.8 ha or 3.4% of the survey area. Their parent material is derived from Uluguru basement (Fig. 5).

Mapping Unit $13C_1$ - FAO 1974: Gleyic Luvisol

- USDA 1975: Umbric Tropaqualf, clayey, isohyperthermic, deep.

These soils occupy 21.8 ha or 2% of the survey area. The distribution of these soils is also given on the soil map (Fig. 28). Relative distribution to other units is also shown (Fig. 10). These soils are mainly found in Mafiga on the Uluguru association. They are related to flat topography 1-3% slopes. The predominant vegetation is grasses, herbs and shrubs as the original vegetation has been cleared for arable farming. Detailed descriptions of vegetation are found under the representative soil profile number 21 in the appendix.

This unit has soils with drak grayish brown colour moist. The loamy texture becomes heavier but lighter in colour with depth. The drainage status is moderately well to imperfectly well drained for upper horizons. Full physical and chemical data is provided in the appendix.

Mapping Unit $14B_1$ - FAO 1974: Eutric Fluvisol

- USDA 1975: Fluventic Ustropepts

This mapping unit is found in Lugala where it is associated with a flat topography 1-3% slopes and is dissected by a stream channel (Fig. 28). The parent material of these soils is dominantly alluvial.

The mode of the unit is represented by profile number 1 and supplemented by profile number 7. These soils are occupying 12.9% of the survey area or 143.1 ha. Profile number 7 deviates from the central concept of the mapping unit because of buried horizons. The ranges in differences in soils within the mapping unit is influenced by microtopography. These soils are friable moist and good moisture retentive. They have good levels of organic matter content in the top soil. The drainage is good. The colour ranges from very dark grayish brown in the top soil due to the organic matter to dark reddish brown in the subsoil. The texture of the top soil is mainly sandy loam. The vegetation of these soils has been cleared except for annual weeds.

Mapping Unit $22A_2$ - FAO 1974: Eutric Gleysol

- USDA 1975: Typic Psammaquent, isohyperthermic, shallow.

This soil is represented by profile No. 16 on the soil map (Fig. 28) where the distribution is also shown. Detailed characteristics are shown in the appendix. This soil unit occupies 26.9 ha or 2.5% of the survey area. The soil is occuring on eroded faces of the Mindu association giving it a shallower depth. The topography is undulating 2-8%. The drainage of these soils ranges is dominantly imperfect with minor to somewhat excessive drainage at higher elevations of small areas of the unit. The bulk of the area lies in a seepage zone with a shallow water table. The natural vegetation is dominantly water loving grasses, herbs, woody climbers, shrubs and sedges and is fully classified in the Appendix.

Mapping Unit $23A_1$ - FAO: 1974 Ferralic Arenosol

- USDA 1975: Aquic Quartzipsamments, isohyperthermic, deep.

This mapping unit occupies 79.1 ha or 7.2% (Fig. 10) of the survey area. The soils are highly weathered and structureless for most of the area. Oxides are evident in all profiles: 8, 6 and 5 of which 8 is the dominant of the mapping unit. Parent material is dominantly gneiss. The drainage of these soils ranges from moderately well drained to somewhat excessively drained varying with microtopography. However, in general moderately well drained soils dominate the unit.

At the time of sampling the vegetation in the Lugala unit had been burnt out. In the Mindu unit the soils occur under a leucaena plantation.

Mapping Unit $23B_1$ - FAO 1974: Pellic Vertisol

- USDA 1975: Typic Haplustolls, isohyperthermic, clayey.

The definition of this mapping unit is centred on profile number 4 found in Lugala (Fig. 28). An associated soil is occuring in Mindu as a boundary between the poorly drained and the excessively drained soils. This latter unit except for drainage status, topography, diagnostic texture of surface horizons and depth differs considerably in chemical characteristics from the central concept because of the differences in parent material and the effects of relief and riverine activity to soil formation. It occupies 6.5% or 71.6 ha of survey area. The soil unit in Lugala is moderately well drained because the profile is in a seepage zone. There is also carbonate accumulation due to insufficient rainfall as reflected in high sodium contents in the analytical results. The soil colour ranges from very dark yellowish grey in the top soil to brown in the subsoil. The texture is fine sandy clay loam throughout. Some cementation occurs in the deeper horizons like Cmg in the appendix.

The dominant structure is prismatic angular blocky and crumb in the surface. The vegetation for these soils are water loving grasses. Detailed descriptions of the vegetation occur in the appendix. The topography on which these soils occur is undulating 2-8%.

These soils are more extensively distributed in the Lugala area. Most of the drainage occurs in situ. Grasses, shrubs and trees found in the area are mainly successive after primary vegetation has been cleared for sisal long time ago. Detailed descriptions of vegetation are found in the appendix. The range in colour of the soils varies with organic matter content and drainage status. Profile 8 is dominantly, very dark grey moist in the surface and very darkish gray with mottles throughout.

Mapping Unit $24A_1$ - FAO 1974: Luvic Arenosol

- USDA 1975: Psammentic Haplustalf, isohyperthemic.

The central concept of this soil is centred on the map unit in Lugala (profile 3 and fig. 28). The $24A_1$ in Mindu is an associated phase differing in colour and parent material. The Mindu unit has a good drainage status and moderate fertility. These characteristics have developed because of the continuous accumulation of organic matter from the established forestry plantation. The soils of this mapping unit occupy about 54.7 ha or 5% of the area. They occur on gently undulating land 2-5% slopes. The predominant soil in Lugala occupies the area between $14A_1$ and $24B_1$ below. This pattern of distribution is occasioned by river activity. The soils of this unit have quartzite schists and gneiss as parent material. The coarse texture of loamy sand gets heavier to sandy clay loam with depth. The reddish brown colours of the subsoil indicate presence of oxides. The soil is well drained because of coarse top soil textures and gentle slopes.

Mapping Unit $24C_1$ - FAO 1974: Eustric Nitosol

USDA 1975: Typic Rhodustalf, clayey, isohyperthermic.

This is typified by characteristics of profile number 10 in Mafiga (Fig. 28). The mapping unit occupies a land area of 6.9% occuring on the Uluguru association of free drainage (Fig. 11). and the depth on these crests rarely exceeds 1.5m. The soils are developed from the Uluguru basement whose geology is also presented (Fig. 3). Profile number 2 is similar in texture, depth, topography and fertility except parent material age, and horizon development and sequence. In the Uluguru basement sandstones were met at 105 cm depth. In Lugala the parent material is colluvial alluvial deposits as reflected by buried horizons. These soils are found on gentle undulating lower slopes of plateaux(3-5%). The vegetation in the mapping unit has been cleared except for annual grasses. The Mafiga unit is further described as having a dark reddish brown surface horizon with a sandy clay loam texture increasing in fineness with depth. The dark red colours indicate oxides. The dominant structure is sub angular blocky. The permeability is moderate. Other physical and chemical characteristics are pvwovided in the appendix.

Mapping Unit $24B_1$ - FAO 1974: Eutric Nitosol

- USDA 1975: Typic Rhodustalf, clayey, isohyperthermic.

This mapping unit is represented by profile No. 11 which lies on the Uluguru association and Mafiga block (Fig. 28). The parent material

is gneiss and schist (Fig. 3). The surface texture is sandy clay loam increasing in fineness to sandy clays with depth. The dark redish brown of the surface becomes bright red with depth due to decreased organic matter. The predominant structure is subangular blocky in the subsoil and porous crumb in the surface soil. Permeablity, nutrient and water retention are good. The vegetation has been cleared but some grasses, herbs, shrubs and trees could still be seen whose detailed classifications are found in the appendix. This unit occupies 84.5 ha or 6.9% of the survey area and is entirely located in Mafiga on undulating topography of convex slopes 3-4%. This unit is similar to $24C_1$ above except for grittiness in texture due to silt deposits from Ngerengere river in the lower half of the mapping unit.

Mapping Unit $25A_1$ - FAO 1974: Albic Arenosol

- USDA 1975: Ustic Quartzipsamment, isohyperthermic, deep.

The soils occupy 12.8% or 139.9 ha of the survey area. The unit is represented by profile number 13 (Fig. 28). Other associated soils in characteristics are found in profile No. 17 and profile No. 22. Extensive areas of these soils are in Mindu and partly Lugala. These soils are loamy sands with practically no increase in clay with depth. They are very deep. Profile 13 is a sequence of deposition because of alluvial activity. These features are less pronounced in profile Nos. 22 and 17 mainly because of the little influence in Ngerengere river has had on these higher elevations. The parent material is fresh colluvial and alluvial sands not yet altered. The topography is undulating 2-8% but 3.5 to 4% on all profile sites.

These soils are somewhat excessively drained and are poor in water and nutrient retention. Their depth is high. They lack structural development and only become massively coherent and hardened in the sub surface horizon because of little silica cementation. The vegetation in the units has been cleared. On site number 17 there was a silvicultural experiment where maize is intercropped with Acacia albida. Other vegetation descriptions from profile 22 are found in the appendix. The colour of the surface soil is dark gray moist becoming lighter to grayish brown with depth due to declining organic matter levels.

Mapping Unit $26A_1$ - FAO 1974: Albic Arenosol

USDA 1975: Ustic Quartzipsamment, isohyperthemic, uncoated.

This soil extensively occurs in Mindu association (Fig.28). It occupies 67.1 ha or 6.1% of the survey area and is represented by profile number 18. The parent material is quartzite and glass. The slope at the site was 8%. These soils are highly eroded and erodible. Their drainage is excessive. They do not have structural development. The dark brown colour in the surface horizon is due to little influence from organic matter. However colour is more influenced by the primary minerals in sand and silt fractions as the clay is too low to detect or exercise any such influence. The texture is therefore sand throughout. Detailed description of analytical and environmental data is found in the appendix. The representative soil pit was sited on the edge of the new Mindu eucalyptus experiment.

Mapping Unit $36A_1$ - FAO 1974: Ferralic Arenosol

- USDA 1975: Ustoxic Quartzipsamment, isohyperthermic, deep.

The mapping unit occupies 9.6% or 105.6 ha of the survey area. It occurs both in Lugala and Mindu blocks (Fig. 25). The unit is typified by profile 15 characteristics. The soil is lying on a rolling topography 8-18% slope (8.5% on most augerhole sites). The parent material is quartzite dominantly. The colour of the soil is brown in the surface becoming yellowish red in the subsoil due to oxide content. These soils are deep sands and are excessively drained. Profile 19 is a close association while profile 20 deviates on the basis of lighter colours and low oxide content. The vegetation of grasses, herbs, climbers, shrubs and trees has been described in the appendix.

Mapping Unit XXX_x - Soil Complex

This mapping unit occupies 9.0% or 98.7 ha of the survey area. This is called a complex because mappable features, texture, slope, depth and drainage occur in a very complex pattern over very small areas like 0.25 ha. At the mapping scale of 1:10,000 it is not possible to map these features separately. The main features of the complex were flat areas occuring between anthills, anthills themselves and rugged country having rocks and gravel and often dissected by drainage channels. The chemical characteristics were 6.8-6.9 pH in 1:1 H_2O, 1.29-1.5% organic carbon and 8.4-9.5 ppm P in the surface horizons.

The flat areas have a vegetation dominated by Dichrostachys Cinerea, Byrsocarpus Orientalis, Securinega Virosa, Combretum I, Pluchea Dioscoridis, Cassia Auriculata, shrubs and Panicum Coloratum grasses. Albizia Antunesiana and Lonchocarpun Capassa, trees are also found. On the anthills the vegetation consists of Pluchea Dioscoridis, . Casia Auriculata, shrubs and Thylacium africanum and M. Angolensis herbs. Albizia Antunesiana, Ferminalia and Ehretia Petiolaris trees are found. Acacia Ataxacantha climbers are common. Dominant grasses are Rhynchelytrum Repens and Penicum Coloratum.

5.1.2 Physical results

A summary of the representative physical results is presented in table 3. below. Detailed description are found in the appendix.

Table 3 : A summary of Soil Physical results

Mapping Unit	Rep. Number	Profile	Depth (cm)	Bulk Density (g/cm^3)	Particle Density (g/cm^3)	Porosity (%)	Texture	AWC (mm/m)
$11C_1$	14		0-25	1.35	2.49	46	SCL	190
			25-125	1.26	2.57	51	SCL	
$12C_1$	12		0-25	1.45	2.48	42	SCL	185
			25-125	1.75	2.49	30	SCL	
$13C_1$	21		0-25	1.49	2.60	43	CL	171
			25-125	1.26	2.63	46	C	
$14B_1$	1		0-25	1.58	2.62	40	SCL	275
			25-125	1.49	2.65	44	SL	
$22A_2$	16		0-25	1.67	2.60	36	LS	115
			25-125	1.71	2.52	33	SCL	
$23A_1$	8		0-25	1.54	2.65	42	S	68
			25-125	1.49	2.64	44	LS	
$23B_1$	4		0-25	1.53	2.42	37	SCL	427
			25-125	1.48	2.48	41	SCL	
$24A_1$	3		0-25	1.35	2.59	48	LS	269
			25-125	1.60	2.64	40	SL	
$24B_1$	11		0-25	1.16	2.60	56	SCL	151
			25-125	1.25	2.50	50	SCL	
$24C_1$	10		0-25	1.39	2.62	47	SCL	206
			25-125	1.50	2.64	44	SC	
$25A_1$	13		0-25	1.16	2.54	54	LS	67
			25-125	1.25	2.66	53	S	
$26A_1$	18		0-25	1.51	2.42	40	S	103
			25-125	1.54	2.55	48	S	
$36A_1$	15		0-25	1.4	2.64	40	S	112
			25-125	1.4	2.65	48	LS	
XXX_x	NR	= NOT RELEVANT		NR	NR	NR	NR	NR

Fig. 13 TEXTURAL DISTRIBUTION OF SURFACE HORIZONS

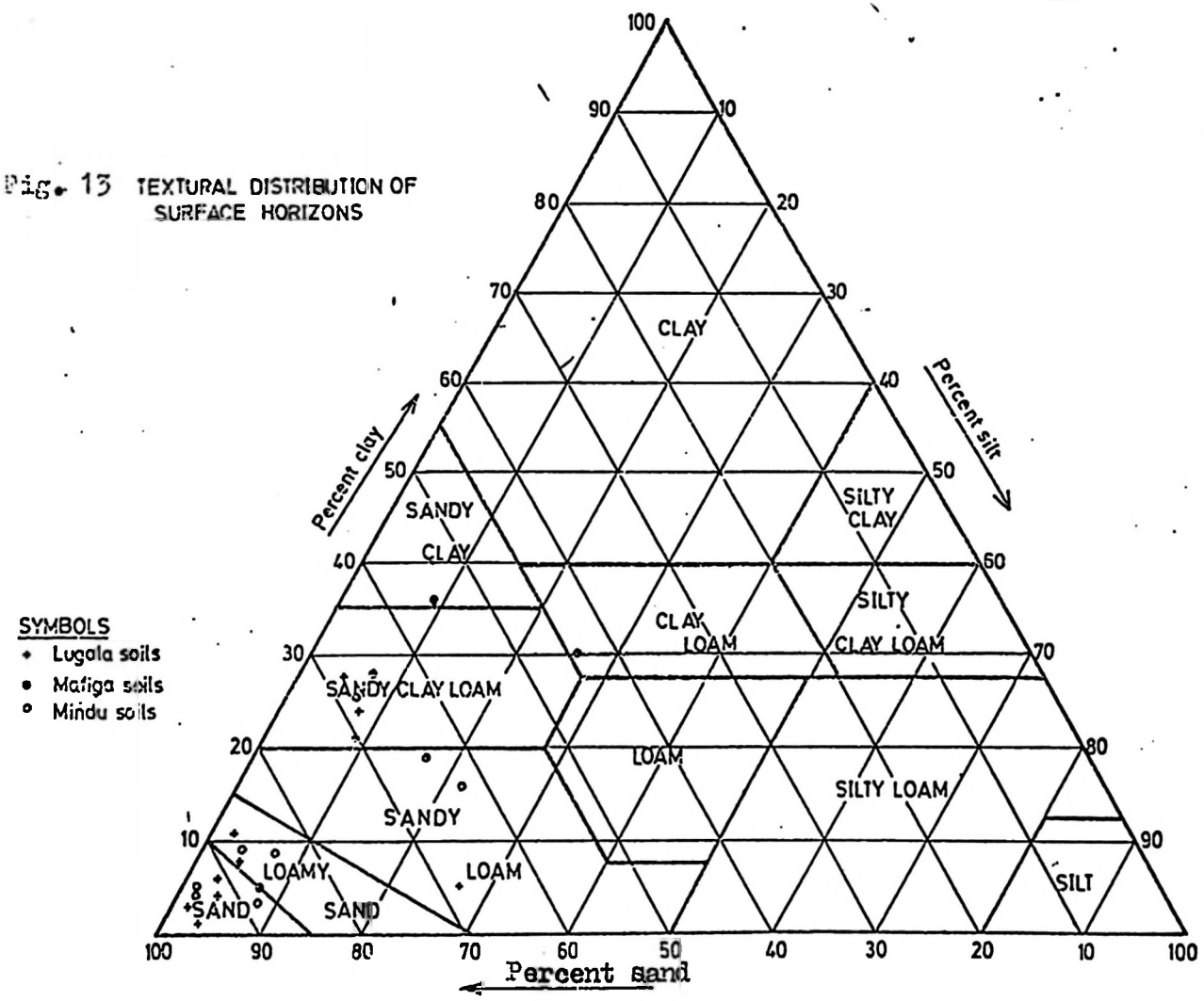


Fig. 14 TEXTURAL DISTRIBUTION OF SUBSURFACE HORIZONS

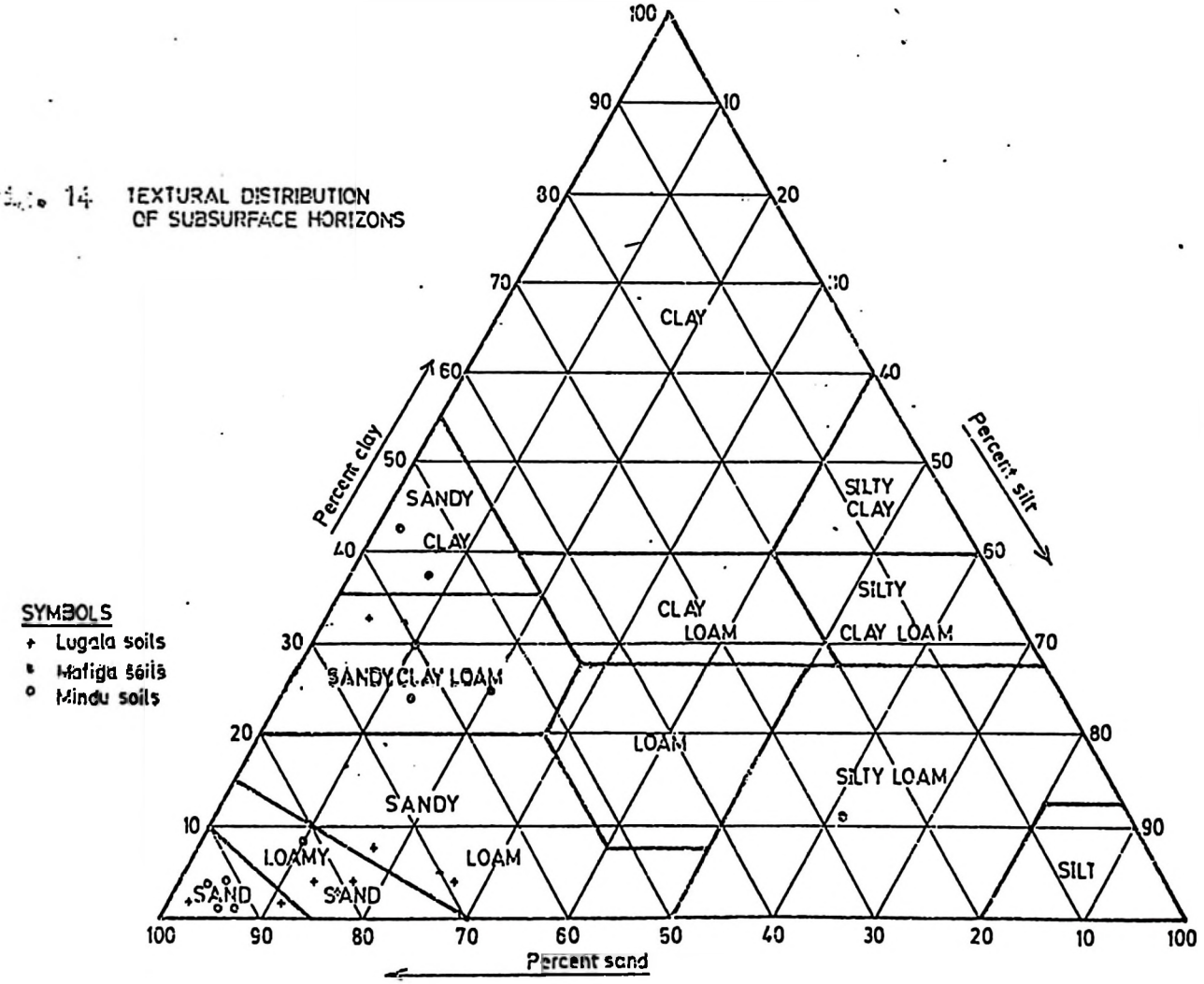
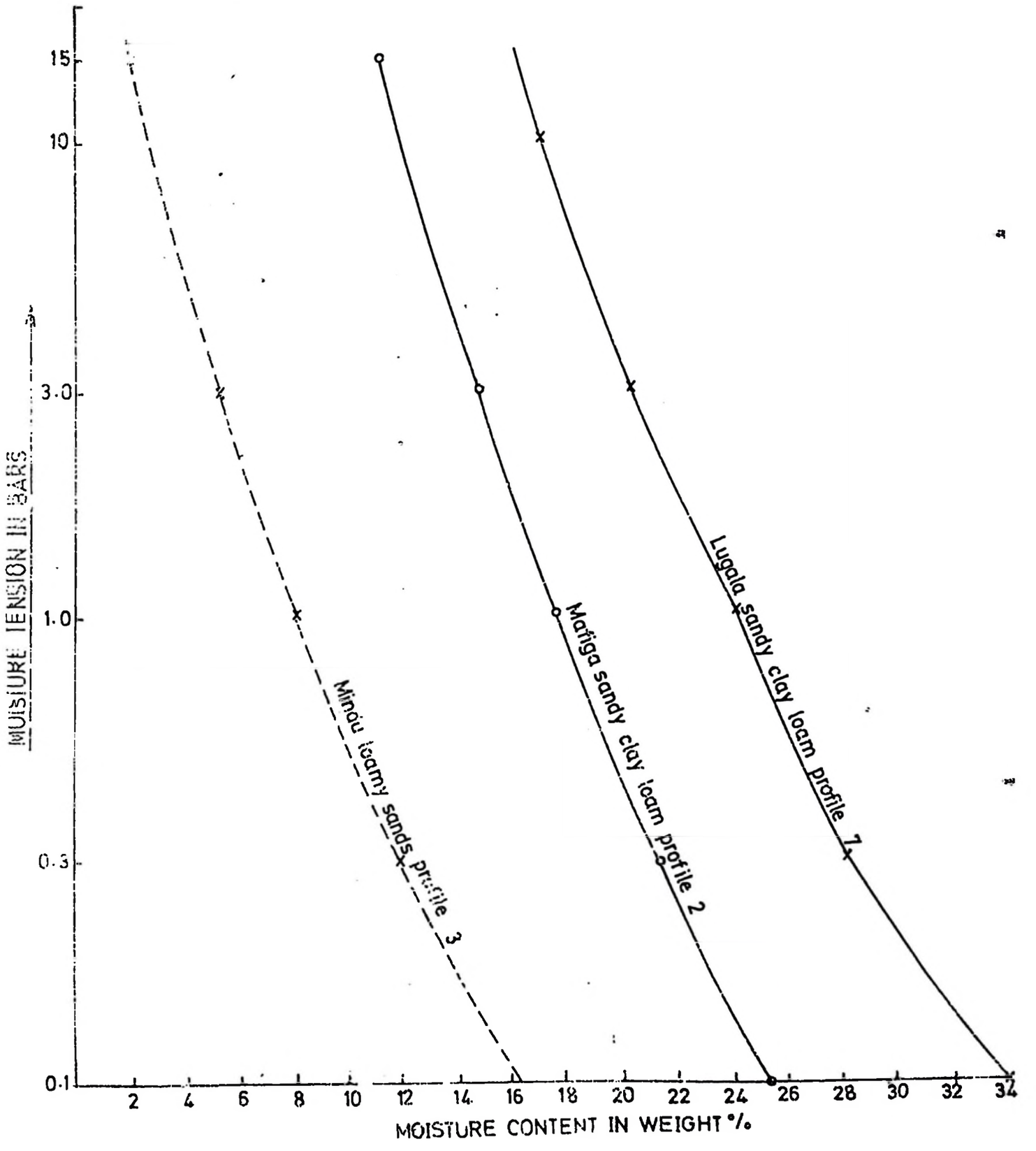


FIG.15 SOIL MOISTURE RETENTION CHARACTERISTICS OF SOME SELECTED SOILS DIAGNOSTIC HORIZONS ONLY



These soil physical results are presented in the appendix for all profiles. Mapping units $22A_2$, $23A_1$, $25A_1$ and $26A_1$ belong to coarse textured groups with less than 18% clay in the diagnostic surface horizon (FAO 1974). Texture together with structure influence evaporation because of their bearing on water movement (Mensah - Bonsu and Lal, 1975). The moisture retention is less than 120 mm/m of available water capacity (AWC) due to coarse textures (Table 3). The coarse textures make these soils highly erodible (Lal, 1981). Texture influences hydraulic conductivity of the soil and it together with rooting depth, rooting density and potential evapotranspiration affects the relationship between transpiration and soil moisture tension (Jackson 1977). Mapping units $14B_1$ and $24B_1$ have medium texture in the top horizons. This texture slightly increases in fineness with depth due to illuviation from top horizons (Buol et al, 1975; Sanchez 1976), and in some instances from fluvial deposits (USDA 1975) from surrounding areas as evident in profile 7. Mapping units $11C_1$, $12C_1$, $13C_1$ and $24C_1$ belong to the fine textured group with texture not coarser than sandy clay loam. These textures become finer with depth due to clay accummulation by illuviation and additions from weathering (Bohn et al 1977, Young 1976). The bulk density of the soils is higher in the clay types ranging from 1.26 to 1.79 g/cm^3. Bulk densities higher than 1.75 g/cm^3 give problems to root penetration (IITACO, 1981). The low bulk densities in the medium textured groups are due to high humus content (Sanchez 1976). Bulk density affects water storage and if too high can affect the plant if occurring in the root zone (Lal 1981). The particle density does not differ so much between the soils. It ranges between 2.42 and

and 2.66 g/cm^3 with most soils above 2.6 g/cm^3 (Table 3). Differences in porosity occur even within textural groups e.g. $22A_2$ and $24A_1$ which differ in porosity of the surface horizon by 12%. This does not correspond to their texture differences. The available water capacity (AWC) measured between 0.3 and 15 bar tension in mm/m depth is low in mapping units $22A_2$, $23A_1$, $25A_1$ $26A_1$ and $36A_1$ while AWC is moderate in $11C_1$, $12C_1$, $13C_1$ and $24B_1$. It is very high in $14B_1$, $23B_1$ and $24C_1$. The organic matter levels influenced the moisture retention for the sandy groups while clay exerted more retention at lower tensions and less at higher tensions in the fine textured groups. The lower moisture tension of 0.3 bars used to estimate field capacity gave too low results of AWC as most soils of the sandy types looked dry. This problem has been also encountered by other workers e.g. Mensah-Bonsu and Lal (1975). No hard pans of significant hardness were encountered in survey area to affect crop growth. Expanding clays could have affected the high AWC values in mapping unit $23B_1$.

5.1.3 Chemical results

A summary of chemical results for representative profiles is presented (Table 4). Detailed ones are found in the appendix.

The sandy soils of $36A_1$, $26A_1$, $23A_1$ and $24A_1$ soil map units show very low organic carbon content ranging from 0.33 to 0.78% in the surface horizons for both Mindu and Lugala (Table 4). Low organic matter and nutrient retention (Young 1976) make the soil susceptible to severe physical deterioration. Organic matter improves exchange capacity of the soil (Bohn et al 1979) and increases resistance to

erosion (Sanchez 1976, Lal and Greenland 1977). In the survey area the organic matter decreased with depth except in the buried horizons. In the subsurface horizons the organic carbon content drops to 0.1%. The mapping units $12C_1$, $13C_1$, $14B_1$ and $24B_1$ are high to moderately high in carbon content.

The sodium content is low in all soils except in mapping units $12C_1$ and $23B_1$ represented by profile 12 and 4 respectively. The range is from 1.7 in the top to 31.5% exchangeable sodium in the subsurface soil.

The electrical conductivity (EC) measured in mS/cm at 25°C was high in profile 4 (Unit $23B_1$) and may be yield depressive for sensitive crops like maize and beans (Bohn et al. 1979)

The potassium content of the soil ranges from 0.21 to 0.3 me/100g soil in the sandy areas. This content improves with fineness in texture ranging from 1.2 me/100g soil to 2.5 me/100g soil in mapping unit $14B_1$ profile 1. The average potassium content of less than 0.5 me/100g soil has also been reported by Møberg et al (1981) in the subsoils of the survey area. The low potassium levels are due to nature of parent material, weathering, and leaching (Kemmler 1980, Juo 1981) and have been reported elsewhere in Tanzania and the tropics (Pagel 1972). The potassium availability as a function of clay mineral group has also been reported. Illitic clays fix more potassium than do kaolinites (Bohn 1979, Mitra et al 1958). So results and ratings have to be interpreted cautiously. Most soils in Mindu and Lugala are very poor in clay content which is also dominated by the kaolinite. Potassium

buffering in these soils is poor. The availability of potassium on sandy soils is reduced by low soil moisture. High pH and reducing conditions have a similar effect. Intensive cultivation leads to potassium deficiencies. This demands that K^+ fertilization be continuous as K^+ release from residuals will often be too slow to meet plant needs. Splitting of potassium applications is also desirable to minimize losses due to leaching and secure best utilization by plants. Liming should be maintained to levels that do not fix K^+ to the extent that it becomes unavailable and affects crop growth.

The calcium content of the soil is medium except for mapping units $23A_1$ represented by profile 8, $26A_1$ by 18 and $36A_1$ by 15 respectively. These soils have acidity problems too. The Ca^{2+} range is from 0.15 to 0.93. A high Ca^{2+} is desirable because it reflects low concentrations of troublesome exchangeable cations primarily Al^{3+} in acid soils (the sandy ones in the mapping area) and in sodic soils (Bohn et al 1979) Economic yields are best where exchange complex is dominated by Ca^{2+}. Moreover high Ca^{2+} indicates a near - neutral pH desirable for most plants and soil micro-organisms (Bohn et al.1979 Williams and Gray 1975)

The magnesium content of the soils in the study area show no deficiencies except for mapping units $26A_1$, $23A_1$ and slightly $25A_1$ ranging between 0.25 and 1.78 me/100g soil. Mg^{2+} content is higher in the alluvial soils around Ngerengere river mapping units $11C_1$ profiles 14 and 9. The magnesium levels above 5 me/100g have been reported by Móberg et al (1981) in the same area.

The range in available phosphorus reported in the study area is from 1.1 ppm in mapping unit $22A_2$ to 66.0 ppm P in $25A_1$. A range from 9.7 - 19.3 has earlier been reported (Dept of Soil Science, 1974-1982). The differences in the ranges occur because the sampling by the latter was restricted to well drained arable lands. This primary nutrient is very important to plant growth. Deficiencies restrict root development (Young 1976). The soils of the survey area are rich in aluminium and iron hydroxides which cause high phosphorus fixation (Sanchez 1976). Lower concentrations of P appear more on the sandy soils than the finer ones according to the findings. The highest level of over 22.9 ppm P was recorded in $14B_1$ and may be caused by high levels of organic matter in the top soil. Therefore organic matter additions improve P availability and mobility. Organic matter must be conserved to conserve P as top soil losses cause P losses. The quantity of fertilization depends upon the plant and the desired yield. However, crop composition at harvest have been used to estimate fertilizer need as 20% is taken up by the plant and 80% remains in the soil (Dabin 1980). Proper placement may improve fertilizer efficiency of soils with high fixing capacity. Liming also improves phosphate uptake by plants.

The total nitrogen of the soil is low i.e. below 0.25% for most profiles. Perhaps the result has to do with the seasonal nitrogen behaviour as most sampling was done during the dry spell after the short rains which may be, lowered the nitrogen levels (Birch 1960, Salter and Goode 1967). Another point to note is that the analytical results of nitrogen must

be evaluated on the scale valid for the method and apparatus used. Nitrogen is a very frequent deficiency in the tropics. It causes single cause of low crop yields (Young 1976). In the survey area nitrogen levels were below 0.1% for sandy soils and ranging between 0.1% to 1.4% on the finer textures of the top horizons in Mafiga on the flat areas of mapping units $12C_1$, $13C_1$ and $11C_1$. Due to the low levels of organic matter in the sandy soils most of the nitrogen especially in the subsoil came from inorganic components. For this reason the calculation of C/N ratio becomes meaningless. The nitrogen levels reported are within the range earlier found by the Department of Soil Science (1974-82) of 0.1-0.9%. Nitrogen affects non legume crop production. The quantity applied must be matched with the ability of a crop to utilize it. Nitrogen should be applied just before the period of maximum uptake by the plant. These observations minimize losses by leaching and denitrification (Bouldin et al, 1980). Volatilization losses could be minimized by soiling up the fertilizer during application or by using ammonium sulphates that are slow reacting. The use of legumes (green manure) and legume fallows could also give sufficient nitrogen for subsequent non-legumes and breeding and planting of high yielding legume varieties improves nitrogen reserves in the soil.

The exchangeable acidity values of 1.6 to 8.5 me/100g soil are much higher compared to those by Moberg et al (1981) of 0.06 to 0.12 me/100g soil. High results have also been reported elsewhere with the method of $BaCl_2$ - ETA buffered at pH 8.2 (Juo 1981).

The pH ($CaCl_2$) of the soil is acid for sandy soils in Mindu and Lugala ranging from 4.0 in mapping unit $23A_1$ to 6.1 in $25A_1$. The importance of this parameter is in the control of the availability of most nutrients (Bohn 1979) with a maxima between 6.0 pH - 7.5 pH in H_2O (Young 1976). The soils of Mafira are slightly acidic with pH ranges between 6 and 7.5 in 1:1 H_2O. All soils with lower topography 0-2% slopes have pH (H_2O) above 6 as these areas are receiving sites for bases. Liming to raise pH to neutrality may be uneconomical than optimal pH 6.5 (Kamprath 1970). Liming should also follow clay mineralogy. The 2:1-dominated clay groups contain more Al^{3+} than the same % of clay and pH (Kamprath 1970). At pH less than 5, Al^{3+} rather than H^+ is dominant (Coleman and Thomas 1967). Good liming rates should depend upon exchangeable aluminium on chemical equivalent bases of lime needed to neutralize Al^{3+} ranging from 1.5 to 3 times. Use of tolerant varieties to Al^{3+} toxicity has been also proposed as a way of managing acidity (Wright 1976). Depending upon parent material of the soil, manganese toxicity is also a common problem associated with acid soils. The depth of liming should be related to rooting habits of the crop. Liming improves roots development and water extraction zones. Organic matter additions though labour intensive may be more economic than fertilizers. The organo-metallic complexes reduce Al^{3+} and Mn^{2+} toxicity by decreasing them in soil solution (Schnitzer and Skinner 1963).

The cation exchange capacity (CEC) for the soils with organic carbon less than 1.50% is very low i.e. below 10 me/100g soil. This correlation has been reported by Bohn et al (1979). The high organic matter contents

give higher CEC due to ionisation of the functional groups that make up the organic matter. The CEC and base saturation is very high for mapping units with 0-2% topography or having clay and humus accumulation from higher areas e.g. units $11C_1$, $12C_1$, $13C_1$, and $14B_1$. The high O.C.% and clay group reflected by textures of the soil is responsible for the high base status and CEC values. Smectite composition 7-26% and kaolinite 30-45% have been reported in mapping unit $11C_1$ by Møberg et al (1981). The smectite is non existent on the upper slopes in units $26A_1$, $25A_1$ and $36A_1$. Kaolinites were the only dominant clay mineral of the crests with 60-64% mineral composition (Møberg et al, 1981). The cation exchange capacity reflects some fertility problems (Young 1976, Sanchez 1976).

Table 4: A summary of soil chemical results for representative soil profiles

Map Unit and Profile No.	Texture	Depth (cm)	O.C. (%)	N (%)	Exchangeable cations me/100g soil 1M NH_4OAc PH=7.0					Sum Bases me/100 g soil	CEC Soil Sum me/100 g soil	Sum bases me/100g clay	CEC me/100g clay	pH		ESP (%)	BSP (%)	P (ppm)	Al (ppm)	EC mS cr
					Na	K	Ca	Mg	H(+)					1:1 H_2O	1:2 $CaCl_2$					
$11C_1$- 14	SCL	0-25	2.57	0.19	1.40	0.55	8.20	7.20	6.6	17.3	23.8	58	80	6.5	5.9	5.9	72	18.7	ND	ND
	SCL	25-125	3.22	0.06	0.71	0.21	6.70	7.60	3.5	15.0	18.4	53	63	6.7	6.2	3.8	82	2.8	ND	ND
$12C_1$- 12	SCL	0-25	0.96	0.14	1.90	1.40	12.20	9.10	8.8	24.3	33.0	79	103	6.1	5.6	5.0	73	9.1	ND	2
	SCL	25-125	0.37	0.05	14.60	0.40	11.10	14.40	4.4	40.2	42.2	88	96	7.5	6.4	31.5	91	1.5	ND	4
$13C_1$- 21	CL	0-25	1.57	1.40	0.33	2.40	17.20	15.20	7.8	35.1	42.9	110	134	6.4	5.8	0.8	82	11.1	ND	ND
	C	25-125	0.78	1.10	0.36	4.00	23.40	23.20	8.1	51.4	59.5	76	87	6.4	6.0	0.6	86	8.1	ND	ND
$14B_1$- 1	SCL	0-25	0.94	0.08	0.15	2.50	8.20	3.80	4.1	14.7	18.7	62	80	6.8	6.8	0.8	78	22.9	ND	ND
	SL	25-125	0.16	0.06	0.17	0.94	12.60	1.70	2.6	6.0	8.6	36	53	6.7	6.5	2.0	70	9.6	ND	ND
$22A_2$- 16	LS	0-25	0.63	0.06	0.39	0.39	1.40	1.20	2.7	3.3	6.0	28	50	6.1	5.2	6.2	55	1.1	ND	ND
	SCL	25-125	0.78	0.06	2.90	0.39	4.5	7.10	4.0	14.9	18.9	44	56	6.7	5.5	15.3	79	1.8	ND	ND
$23A_1$- 8	S	0-25	0.33	0.06	0.42	0.38	0.75	1.20	2.3	2.8	5.1	53	100	5.6	4.6	1.7	35	7.1	5.0	ND
	LS	25-125	0.30	0.04	0.47	0.41	0.57	1.10	2.8	2.6	5.4	24	43	5.0	4.0	21.2	60	1.8	12.1	ND
$23B_1$- 4	SCL	0-25	1.30	0.15	0.74	0.90	10.50	5.80	2.1	17.9	20.0	63	63	7.1	6.8	3.6	90	12.0	ND	4.
	SCL	25-125	0.24	0.12	7.20	0.56	11.40	11.60	1.6	30.8	32.4	97	102	8.3	7.7	22.1	95	4.9	ND	5.
$24A_1$- 3	LS	0-25	0.78	0.14	0.10	1.10	4.00	1.60	1.6	6.8	8.4	60	74	7.0	6.8	1.0	81	10.2	ND	ND
	SL	25-125	0.14	0.11	0.10	0.50	2.40	1.90	3.6	5.0	8.1	36	60	5.7	5.2	2.6	59	3.6	ND	ND
$24B_1$- 10	SCL	0-25	1.50	0.10	0.13	0.61	4.80	4.10	4.7	9.6	14.3	28	42	6.5	6.1	0.9	67	4.0	ND	ND
	CL	25-125	0.70	0.06	0.19	0.17	2.70	4.20	3.9	7.3	11.2	26	39	6.4	6.6	1.7	66	1.8	ND	ND
$24C_1$- 11	CL	0-25	0.48	0.12	0.16	2.50	4.10	4.30	3.1	11.1	14.2	44	50	6.6	6.1	0.6	78	2.2	ND	ND
	C	25-125	0.24	0.04	0.21	0.90	2.00	4.80	5.1	7.2	12.3	23	33	6.0	5.6	1.7	59	2.7	ND	ND
$25A_1$- 13	LS	0-25	1.50	0.08	0.12	0.92	2.90	1.10	2.8	5.1	7.7	38	43	6.7	6.1	1.6	66	66.0	ND	ND
	S	25-125	0.73	0.04	0.11	0.39	1.70	1.10	2.1	3.4	5.5	33	52	6.3	5.8	1.7	25	25.0	ND	ND
$26A_1$- 18	S	0-25	0.40	0.04	0.05	0.46	0.93	0.77	1.9	2.2	3.1	34	48	6.9	5.8	1.5	71	8.9	ND	ND
	S	25-125	0.18	0.03	0.05	0.34	0.28	0.25	1.8	0.9	2.7	16	46	5.9	5.1	1.9	34	4.2	ND	ND
$36A_1$- 15	S	0-25	0.49	0.06	0.05	0.28	0.93	1.20	2.0	2.1	4.1	21	40	6.7	5.7	1.2	53	7.0	0.06*	ND
	LS	25-125	0.14	0.03	0.06	0.26	0.15	1.78	2.5	2.2	4.7	35	73	6.2	5.1	1.4	47	4.9	0.08*	ND

XXX$_1$- NR NR = NOT RELEVANT, ND = NOT DETERMINED (+) = BY TRIETHANOLAMINE EXTRACTION *me/100g soil Øien and Gjerdingen 1972

5.2 Land Evaluation

5.2.1 Evaluation of land qualities

Land suitability evaluation followed selected land qualities critical to selected crops in the study area. Below is a list of land qualities for annual crops maize, sorghum, soyabeans, field-beans and groundnuts.

Slope

This land quality rates the influence of topography and other relief characteristics on agricultural techniques. The influence of slope on erosion and fertility has been researched upon extensively (Hudson 1971, Lal 1976b). This land quality was the first separate in the formation of the soil mapping legend and was prominent.

Wetness or Drainage

This land quality is crucial for most annual crops. Drought induces dessication and crops will give low yields due to reduced photosynthetic activity (Doorenbos and Kassam 1979). Drainage impedance can also depress and lower quality of yields (Young 1976). This land quality was very important in the survey area and formed the second separate of the mapping unit.

Texture

This land quality is the third separate of the soil mapping unit. It was very prominent and is the most influential land quality on all other soils properties. It affects water and nutrient retention as well as soil erodibility (Young 1976, Sanchez 1976, Lal 1981, Lal and Rusell 1981). Texture also influences foot hold for roots (FAO, 1977b).

Depth.

This land quality influences the soil-plant environment in supplying water and nutrients. This land quality is not a severe limitation in the study area except in localized, small unmappable spots. Root impedances affect turgor pressure, cell wall elongation and size of root tips (Russell 1977).

Available water capacity (AWC)

This land quality reflects moisture which is the most limiting land quality in the study area compared to fertility which could be corrected out of the bag. Land characteristics often used to measure this quality are relative evapotranspiration deficit, at critical periods for the crop and probability of rainfall less than a specified amount for a growing season, year or critical period (Dent and Young 1981). A methodology has been provided by the FAO for assessing this land quality through effective rainfall (Dastane 1975). In this localized study area where no significant differences in meteorological parameters occurred land could not be mapped using this moisture

parameter. Such methods are useful in comparing suitabilities between regions. Rainfall data in Morogoro gives average values above 800 mm (Table 1). The rainfall values are above the range of maize requirements of 500-800 mm (Doorenbos and Kassam 1979). Maize is reported to grow in areas with less than 200 mm rainfall in Morocco (FAO/SIDA 1982). The water seasonal requirement of 110-130 day sorghum of 450-650 mm (Doorenbos and Kassam 1979) is more than sufficient. Field beans and soyabeans with seasonal requirements of 300-500 mm and 450-700 mm water respectively (Doorenbos and Kassam, 1979) could be satisfied. Another valid point for the use of the AWC land quality is the fact that within the study area fine textured soils on the valley bottoms grow two crops of maize when the sands on the upper terrace grow one crop and even when the yields of these crops will be still low due to low AWC and drought. The incidence of drought validates the application of the AWC land quality still further. Crops are often most vulnerable to drought during early growth when the AWC of the soils is all that is important (Lal, 1981). A seven day continuous drought has been observed to decrease yields by 54% on average (Wolf, 1975). The drought are common in Morogoro. The probability of receiving 800 mm rainfall in Morogoro is 68% (Jackson, 1969). According to Jackson again the percent probability of receiving 800 mm is 48 percent in 4 out of 5 years where as the probability of two successive years receiving less than 800 mm is 10 percent. Such parameters do not help us in planning our planting dates, which

are very crucial in annual crops especially in areas with marginal rainfall and other areas receiving seasonal rainfall (Birch 1960, Semb and Garberg 1969, Gray 1970). As can be seen from fig. 8 of rainfall exceedence and fig. 6 of rainfall maximums, big amounts of rainfall have been recorded in months when rainfall on average basis is not expected. This limits the practical utility of such studies. Moreover the reality is obscured by hypothetical models themselves. The practical importance of a fluctuation or a trend over a period of consideration and in the future if it continues is difficult to assess (Jackson 1977). It is for this reason that the practical technique to monitor soil moisture requirements and planting dates through water balance studies (FAO,1979c) is recommended. A water balance model for the period 1978 - 81 is given on annual basis fig. (9). The period was limited to 1978 - 81 due to discrepancies and discontinuity of data outside this time period. A longer period than four years is required for a better picture of the water balance situation. In the illustration (fig. 9) a deep sandy loam is assumed with water retention characteristics of 165 mm/m. The water balance figure shows a reserve of water after the rains have terminated around June to July. This reserve could support crop growth around this period. The AWC also shows different retention characteristics for the coarse texture group in Mindu, medium texture groups in Lugala and the fine texture groups in Mafiga (fig. 15). More water retention occurs with increased clay or organic matter content. The organic matter content however is very

important in the surface horizons as it decreases with depth unless the soils have buried horizons. The argument against the importance of AWC is that crops once established will adapt their rooting and metabolic habits to moisture stress. The validity of the use of the AWC lies in its critical importance to seedling establishment because before the roots of a plant are established the plant will depend upon the AWC of the immediate soil environment. In the use of the AWC as a land quality rooting depths and moisture requirements and capacities of various textures were compiled from such works as FAO (1977c) and Doorenbos and Kassam (1979). In the evaluation of meteorological parameters we find that rainfall amounts for Morogoro are more than sufficient for all field crops. The distribution of rainfall is the only decisive factor. This problem could be overcome by one or two supplementary irrigations only whose amounts will depend upon the initial moisture, stage of crop growth and water retention characteristics of the soil. Irrigation practices are highly recommended and should come in to alter the tradition of relying upon nature and blaming it for the unproductiveness of the farm. Such practices should prove feasible, and economically successful since the farm has abundant surface and underground water (DHV 1979). The irrigation practice should be supplemented by other agricultural practices like additions of manures and other crop residues to improve textures and water retention.

Fertility

Fertility was assessed using the land qualities by Sys (1979), Young (1976) and ILACO (1981) after which modifications were also made. The relative importance of fertility and individual parameters has been discussed in the soil chemical results section. In the suitability evaluation fertility characters are reduced to three namely organic carbon, CEC and base saturation percentage (BSP) due to their relative importance in reflecting the levels of other parameters pH, N, P, K, Ca and Mg.

Erosion

Erosion was only indirectly assessed through slope - erosion exponential relationship (Hudson 1971). Erosion has not been rated in quantitative terms. It is one of the least bearing of the parameters on yields. However the erodibility of the soils in the study area especially in Mindu and Lugala is very high due to coarse textures lack of structure, low organic matter and steep slopes.

In the land suitability evaluation of wetland rice, the capability to maintain surface water was rated foremost. The land use requirements of rice were modified after Brinkman (1977), Van der Kevie (1976) and FAO/Staff (1973). Parameters used to rate surface water maintenance were slope in relation to run-off losses and drainage in relation to groundwater losses. The texture of the surface and sub surface horizons affect retention too. The permeability of the soil was qualitatively

estimated from texture determinations and observations in the field. Depth is the non-limiting parameter to rice in the study area. Gravels, stones and rock outcrops were also assessed. Salinity was not rated because not all samples could be analysed for this parameter. It is a very limiting factor to rice (Ponnamperuma 1980). Risks of water shortage and damage by floods were difficult to assess within one year study period but are important land qualities (FAO/Staff 1973). Fertility like for other crops was rated by O.C.%, CEC and BSP. Only the first three prominent land qualities appear in the land suitability mapping as a rule.

5.2.2 Land suitability evaluation results

5.2.2.1 Land suitability evaluation results for maize

Land use requirements and suitability evaluation results are given in Tables 5 and 6 and Fig.29 respectively. The land suitability distribution for maize in the area is given (Fig.16). Of the 1,097 ha in the survey area 20.7% is highly suitable, 20.4% is moderately and 30.6% marginally suitable. Only 19.3% are not suitable. A further 9.0% is also not suitable for the most part and is in the not relevant class. This area is unsuitable due to topographic conditions. The most widespread limiting land quality to maize production is fertility (Fig.17) with 39.3%. The second limiting factor in area ranking is texture and is much more serious than the former with 33.6% because it cannot be readily corrected. Moisture accounts for 28.5% of the affected survey area as expressed by AWC levels. Wetness limitations affect 18.2% of the evaluated areas whereas 9.0% takes the not relevant class. About 16.1% is limited by topography. The evaluation of maize is only qualitative. So results should be interpreted cautiously. The growth of this crop should strictly follow the land suitability evaluation. Supplementary irrigation is recommended because the water use efficiency of this crop is hi (Doorenbos and Kassam 1979). Maize growth should be limited to areas with less than 5% slopes to minimize erosion losses. Early planting is recommended to give better root system development (Gwynne 1964) and maximize utility of nitrogen flushes of the early season (Birch 1960). Therefore when and where the drought strikes supplementary irrigation is the answer.

Fig.16 LAND SUITABILITY DISTRIBUTION FOR MAIZE

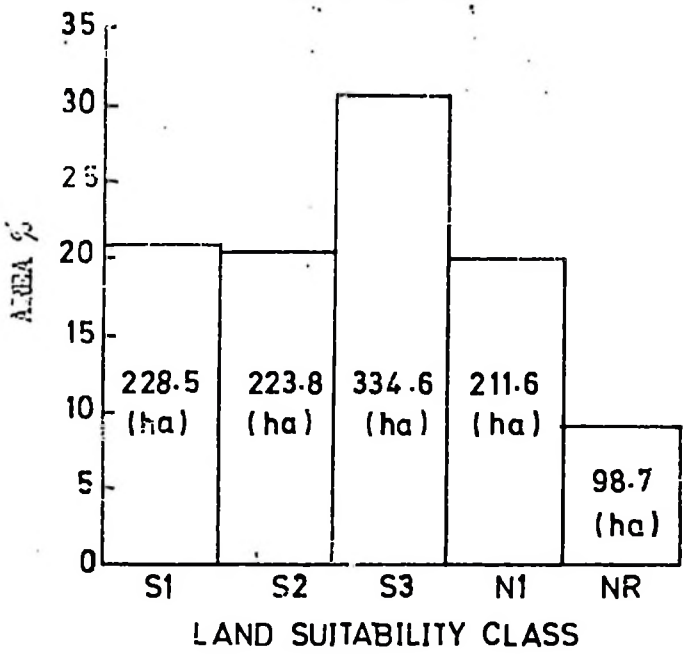


Fig.17 AREA DISTRIBUTION OF LIMITATIONS FOR MAIZE

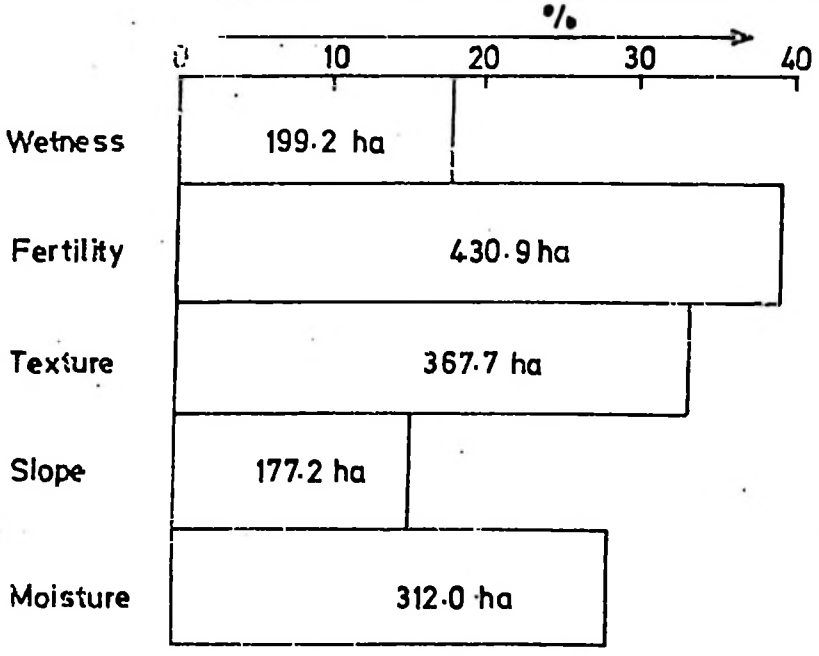


Table 5 : Land use requirements for maize (for ustic moisture regime only)

Land qualities		Range in degree of limitations				
		0	1	2	3	4
		100	98	85	60	45
Slope (s)	Class %	A 0-2	B 2-4	C 4-8	D 8-16	E >16
Wetness (w)	drainage	well drained	moderately well drained	imperfectly drained	poorly drained	very poorly drained
Texture (t)		SC	SCL	LS, SL	LS, S	S
Depth (d)	in cms	>100	75-100	50-75	25-50	<25
Moisture Availability (m)	Available water capacity mm/m	>120	115-120	110-115	100-110	< 100
	pH	5.8-6.5 6.5-7.0	5.5-5.8 6.5-7.0	5.2-5.5 7.0-8.2	< 5.2 > 8.2	< 5.2 > 8.2
Nutrient availability (soil fertility) (f) 0 - 25 cm depth	CEC (me/100g clay)	> 10	8-10	6-8	3-6	3
	O.C. (%)	> 2	1.5-2	0.7-1.5	0.5-0.7	< 0.5
	N (%)	>.2	.15-.2	0.07-0.15	0.05-0.07	< 0.05
	P (ppm)	> 15	10-15	5-10	1-5	< 1
	K (me/100g soil)	> 0.5	0.3-0.5	0.2-0.3	0.1-0.2	< 0.1
	Ca (me/100g soil)	> 6.0	3.8-6.0	2.6-3.8	1.0-2.6	< 1.0
	Mg (me/100g soil)	> 1.4	0.9-1.4	0.6-0.9	0.3-0.6	< 0.3
	ES (%)	> 80	50-80	35-50	35	
Erosion hazard as per crop characteristics and slope %		0-2	2-4	4-8	8-16	>16

Table 6 : Suitability evaluation results of land units for maize (Zea mays)

Soil Mapping Unit	Topography Slope (s)	Susceptibility to erosion (e)	Drainage wetness (w)	Physical Characteristics Texture Upper 25cm (t)	Depth (d)	Fertility characteristics (f) 0 - 25 cm C.E.C	B.S.	O.C.	Moisture (m) AWC mm/m	Land indice	Suitability subclass
$11C_1$	A 0(100)	0(100)	4(35)	1(85)	0(100)	0(100)	1(98)	0(100)	0(100)	29	S3;w
$12C_1$	A 0(100)	0(100)	3(50)	0(100)	0(100)	0(100)	1(98)	2(80)	0(100)	39	S3;w
$13C_1$	A 0(100)	0(100)	1(98)	0(100)	0(100)	0(100)	2(80)	2(84)	0(100)	66	S2;f
$14B_1$	A 0(100)	0(100)	0(100)	0(100)	0(100)	0(100)	1(88)	1(95)	0(100)	84	S1
$22A_2$	B 1(98)	1(98)	1(90)	2(85)	1(93)	3(60)	1(87)	3(53)	1(98)	19	N1;f,t
$23A_1$	B 1(98)	1(98)	1(98)	2(85)	0(100)	3(60)	2(85)	4(45)	1(98)	18	N1;t
$23B_1$	C 2(85)	2(85)	1(98)	0(100)	0(100)	0(100)	0(100)	0(100)	0(100)	71	S2;s,e
$24A_1$	B 1(98)	1(98)	0(100)	2(85)	0(100)	1(95)	0(99)	2(85)	0(100)	67	S2,t,f
$24B_1$	B 1(98)	1(98)	0(100)	0(100)	0(100)	0(100)	1(98)	2(85)	0(100)	80	S1
$24C_1$	B 1(98)	1(98)	0(100)	0(100)	0(100)	0(100)	1(98)	3(60)	0(100)	56	S2;f
$25A_1$	B 1(98)	1(98)	0(100)	2(85)	0(100)	2(85)	1(98)	1(98)	3(60)	40	S3;m,t,f
$26A_1$	B 1(95)	1(85)	0(100)	2(85)	0(100)	2(85)	1(95)	2(85)	3(60)	28	S3;m,t,f
36A	C 2(85)	2(85)	0(100)	2(85)	0(100)	3(60)	1(90)	4(45)	2(80)	18	N1;f,m,s
XXX_x	NR = Not relevant		NR	NR	NR	NR	NR	NR	NR	NR	NR

5.2.2 .2 Land suitability evaluation results for sorghum

The land suitability requirements and evaluation results are presented in Tables 7 and 8 and Fig. 30 . About 22.7% of the survey area is highly suitable for sorghum while 42.9% (Fig.18) is rated as class S2. Another 7.2% is rated as marginally suitable. The not suitable class with severe limitations that can readily be corrected NI occupies 18.2% of the land. About 9.0% of the land belongs to the not relevant class at current level of the survey scale. Sorghum enjoys a higher % of suitability because of its adaptation abilities to a range of environmental conditions (Young 1976, Doorenbos and Kassam 1979, ILACO 1981). Sorghum tolerates low soil moisture. It has an extensive root system that can explore big volumes of the soil environment for water. It effectively controls evapotranspiration and has a stomata with ability to recover rapidly after periods of water stress. It has the ability to withstand dessication. Formation of additional head bearing tillers compensates for yield losses due to water stress experienced in the earlier growth stages as long as the growing season is long enough. The same effect of yield declines by water stress from pollination failure during the flowering period is similarly reduced (Doorenbos and Kassam 1979). The most limiting factor for sorghum is texture affecting 43.2% of the Survey area due to poor foothold effect. The severity of this problem to yield is not as highly serious as the distribution of limitations (Fig. 19) suggests. Wetness (drainage) rates second with 37.3% of the area affected due to low moisture caused by coarse texture. Fertility is another limitation factor with 11.7% after the 20% land area limited by moisture retention and 15.7% by erosion. Another 6.5% is limited by slope.

Fig.18 LAND SUITABILITY DISTRIBUTION FOR SORGHUM

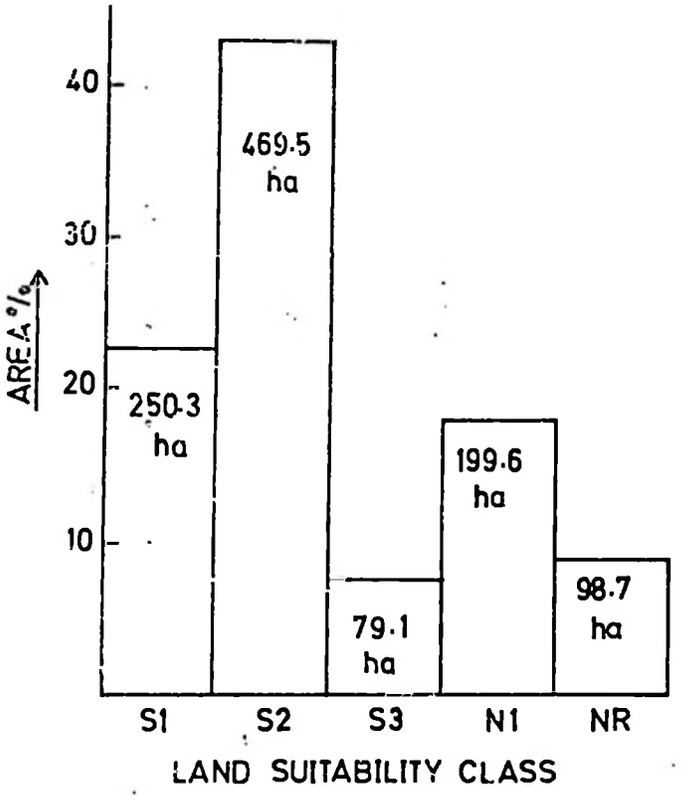


Fig.19 AREA DISTRIBUTION OF LIMITATIONS FOR SORGHUM

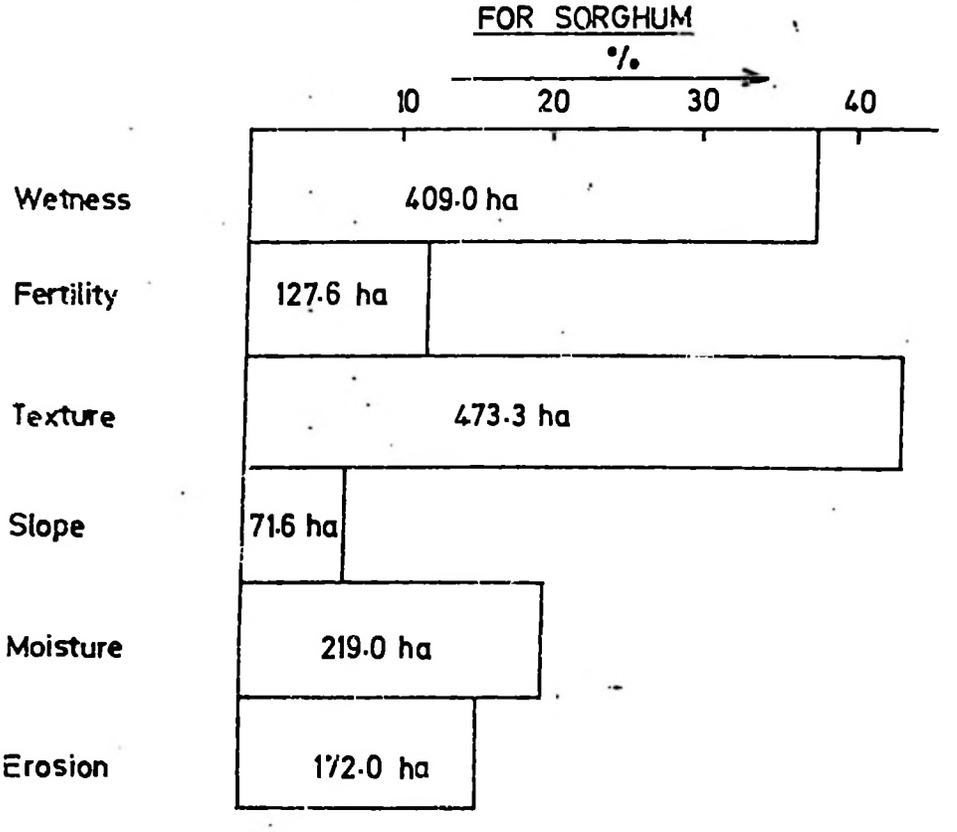


Table 7 : Land use requirements for sorghum (Sorghum vulgare)

Land qualities		Range in degree of limitation				
		0	1	2	3	4
		100	98	85	60	45
Slope (s)	Class	A	B	C	D	E
	%	0-2	2-4	4-8	8-16	16
Drainage wetness (w)		well drained	moderately drained	imperfectly drained	poorly drained	very poorly drained
Texture (t)		SC,SCL,SL	SC, SCL, SL	SL, LS	LS, S	S
Depth (d)		>100	75-100	50-75	25-50	<25
Moisture availability (m)	Available water capacity mm/m	110	110-75	60-75	50-35	< 35
Nutrient availability soil fertility (f) 0 - 25 cm depth	pH	5.8-7.0	5.5-5.8 7.0-8.0	5.2-5.5 8.0-8.2	5.0-5.2 8.2-8.5	< 5.0 > 8.5
	CEC (me/100g clay)	> 10	7-10	5-7	3-5	< 3
	OC (%)	> 2	1.2-2	0.7-1.2	0.4-0.7	< 0.4
	N (%)	>0.2	0.12-0.2	0.07-0.12	0.04-0.07	< 0.04
	P (ppm)	> 15	8-15	5-8	1-5	< 1
	K (me/100g soil)	> 0.5	0.2-0.5	0.15-0.2	0.1-0.15	< 0.1
	Ca (me/100g soil)	> 6.0	3.5-6.0	2.5-3.5	1.0-2.5	< 1.0
	Mg (me/100g soil)	> 1.4	0.7-1.4	0.5-0.7	0.2-0.5	< 0.2
	BS (%)	> 80	40-80	30-40	< 30	<20
Erosion hazard as per crop characteristics and slope %		0-2	2-4	4-8	8-16	> 16

Table 8: Land suitability evaluation results for corn

Soil mapping unit	Topography slope (s)	Susceptibility to erosion (e)	Drainage wetness (w)	Physical characters		Fertility characters (f) 0 - 25 cm depth			Moisture (m) AWC mm/m	Land indice	Suitability subclass
				Texture (t)	Depth (d)	C.E.C.	B.S.	O.C.			
$11C_1$	A 0(100)	0(100)	3(55)	0(100)	0(100)	0(100)	1(98)	1(100)	0(100)	54	S2;w
$12C_1$	A 0(100)	0(100)	3(60)	0(100)	0(100)	0(100)	1(98)	2(85)	0(100)	50	S2;w
$13C_1$	A 0(100)	0(100)	1(98)	0(100)	0(100)	0(100)	0(100)	1(98)	0(100)	96	S1
$14B_1$	A 0(100)	0(100)	1(100)	0(100)	0(100)	0(100)	1(98)	2(85)	0(100)	83	S1
$22A_2$	B 1(98)	1(98)	2(85)	3(60)	1(98)	2(85)	2(98)	3(60)	0(100)	24	N1;f,t
$23A_1$	B 1(98)	1(98)	1(98)	2(85)	0(100)	1(98)	2(85)	3(60)	2(85)	34	S3;f,t,m
$23B_1$	C 2(85)	2(85)	0(100)	0(100)	0(100)	0(100)	0(100)	1(98)	0(100)	71	S2;s,e
$24A_1$	B 1(98)	1(98)	0(100)	2(85)	0(100)	1(98)	0(100)	2(85)	0(100)	68	S2;f,t
$24B_1$	B 1(98)	1(98)	0(100)	0(100)	0(100)	0(100)	1(90)	1(98)	0(100)	86	S1
$24C_1$	B 1(98)	1(98)	0(100)	0(100)	0(100)	0(100)	1(98)	3(60)	0(100)	56	S2;f
$25A_1$	B 1(98)	1(98)	0(100)	2(85)	0(100)	2(85)	1(95)	1(98)	2(85)	55	S2;m,t
$26A_1$	B 1(95)	1(85)	0(100)	2(85)	0(100)	3(60)	1(98)	3(60)	0(100)	24	N1;f,t,e
$36A_1$	C 1(85)	2(85)	0(100)	2(85)	0(100)	3(60)	1(90)	3(60)	0(100)	20	N1;f,t,s
XX_x	NR = Not relevant	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR

5.2.2.3 Land suitability evaluation for soyabeans

About 22.7% of the survey area rates as S1 for soyabeans with another 31.5% as S2 followed by 21.1% to the marginally suitable land S3 (Fig. 20). About 15.7% of the land has very severe limitations and is not suitable (N1). The rest of the 9.0% of the surveyed land rates as not relevant (NR) to the current evaluation. The distribution of area in terms of limitations is highest on fertility with 56.6%. This does not mean that fertility is more important than slope affecting 6.5% area (Fig.19) as the latter is more difficult to correct. The second widespread limitation is texture (47,1%)followed by erosion (15.7%) and poor drainage (11.7%). The yields of soyabeans vary with water availability critically (Doorenbos and Kassam, 1979). It extracts water mainly from 0.6-1.3m depth. The texture limitation has been illustrated (Fig. 21). Moderately sandy soils however rate well (Young 1976, Doorenbos and Kassam, 1979, ILACO 1981). This crop produces less erosion losses (Lal 1976a). The requirements of soyabeans are comparable to maize (ILACO 1981) except for the tolerance of wetness (Young 1976). Ranges in the land suitability requirements (Table 9) were modified after these documents. It is recommended that seeds be inoculated before planting to improve nodulation. Supplementary irrigation is also required for this crop which demands a lot of water.

Fig.20. LAND SUITABILITY DISTRIBUTION FOR SOYABEANS

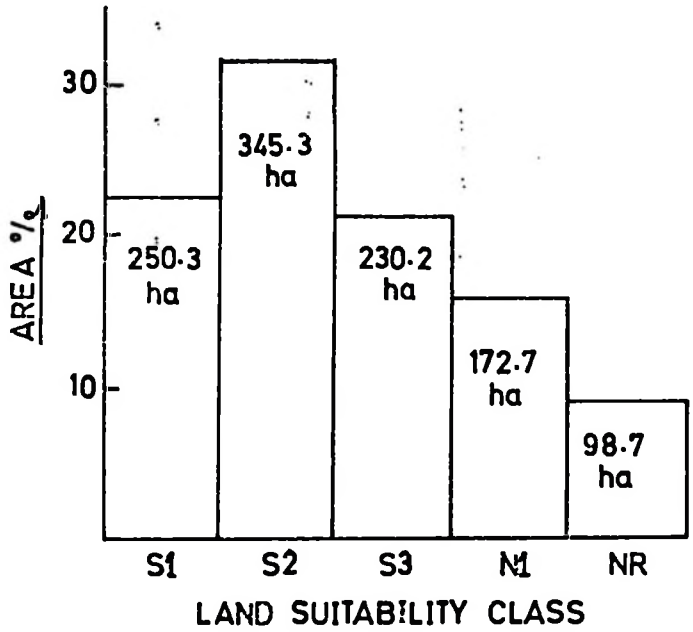


Fig.21 AREA DISTRIBUTION OF LIMITATIONS FOR SOYABEANS

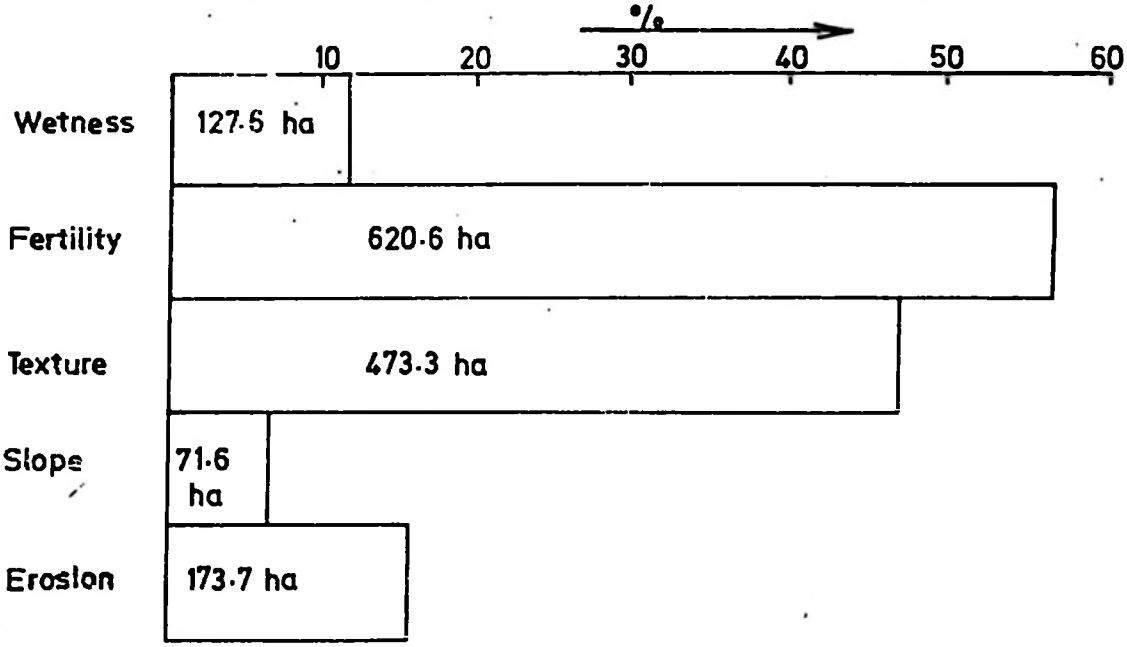


Table 9 : Land use requirements for soyabeans (Glycine max)

Land qualities/ characteristics		Range in degree of limitations				
		0	1	2	3	4
		100	98	85	60	45
Slope (s)	Class %	A 0-2	B 2-4	C 4-8	D 8-16	E >16
Wetness (w) drainage		well drained	moderately well drained	imperfectly drained	poorly drained	very poorly drained
Texture (t)		SC, SCL, CL	SC, SCL, SL	SL, LS	LS, S	S
Depth (d)	in cms	>75	50-75	25-50	10-25	<10
Moisture Availability (m)	Available water capacity mm/m	> 100	50-100	35-50	20-35	<20
Nutrient availability (soil fertility) (f) 0 - 25 cm depth	pH	6.0-7.0	5.8-6.0 7.0-7.5	5.5-5.8 7.5-8.0	5.0-5.5 8.0	<5.0 >8.0
	CEC (me/100g clay)	> 10	8-10	6-8	3-6	<3
	O.C. (%)	> 2	1.5-2	0.7-1.5	0.5-0.7	<0.5
	N (%)	> 2	15-2	0.07-0.15	0.05-0.07	<0.05
	P (ppm)	>15	10-15	5-10	1-5	<1
	K (me/100g soil)	>0.5	0.3-0.5	0.2-0.3	0.1-0.2	<0.1
	Ca (me/100g soil)	>6.0	3.8-6.0	2.6-3.8	1.0-2.6	<1.0
	Mg (me/100g soil)	>1.4	0.9-1.4	0.6-0.9	0.3-0.6	<0.3
	B.S. (%)	>80	50-80	35-50	<35	<35
Erosion hazard as per crop characteristics and slope %		0-3	3-5	5-10	10-16	>16

Table 10: Suitability evaluation results for soyabeans (Glycine max)

Mapping Unit	Topography slope (s)	Erosion susceptibility (e)	Wetness drainage (w)	Physical characteristics		Fertility (f) characters 0 - 25 cm			Moisture (m) AWC m/mm	Land indice	Suitability subclass
				Texture (t)	Depth (d)	C.E.C.	B.S.	O.C.			
$11B_1$	A 0(100)	0(100)	4(35)	1(98)	0(100)	0(100)	1(98)	0(100)	0(100)	33	S3;w
$12C_1$	A 0(100)	0(100)	3(50)	0(100)	0(100)	0(100)	1(98)	2(85)	0(100)	42	S3;w,f
$13C_1$	A 0(100)	0(100)	1(98)	0(100)	0(100)	0(100)	0(100)	1(98)	0(100)	96	S1
$14B_1$	A 0(100)	0(100)	0(100)	0(100)	0(100)	0(100)	1(98)	2(85)	0(100)	83	S1
$22A_2$	B 1(98)	0(99)	1(98)	3(60)	0(100)	2(85)	1(98)	3(60)	0(100)	29	S3;t,f
$23A_1$	B 1(98)	0(99)	0(99)	2(85)	0(100)	1(98)	2(80)	2(85)	1(98)	53	S2;f,t
$23B_1$	C 2(85)	1(98)	0(99)	0(100)	0(100)	0(100)	0(100)	2(85)	0(100)	70	S2;s,f
$24A_1$	B 0(99)	1(98)	0(100)	2(85)	0(100)	1(98)	0(100)	2(85)	0(100)	69	S2;f,t
$24B_1$	B 0(99)	1(98)	0(100)	0(100)	0(100)	0(100)	1(98)	1(98)	0(100)	93	S1
$24C_1$	B 0(99)	1(98)	0(100)	0(100)	0(100)	0(100)	1(98)	4(45)	0(100)	43	S3;f
$25A_1$	B 1(98)	1(98)	0(100)	2(85)	0(100)	2(85)	2(95)	1(98)	1(98)	61	S2; f,t
$26A_1$	B 2(85)	1(95)	0(100)	2(85)	0(100)	3(60)	1(98)	4(45)	0(100)	18	N1;f,t,s
$36A_1$	C 2(85)	2(85)	0(100)	2(85)	0(100)	3(60)	1(98)	4(45)	0(100)	19	N1;f,t,
XXX_x	NR = NOT RELEVANT		NR	NR	NR	NR	NR	NR	NR	NR	NR

5.2.2.4 Land suitability evaluation results for field beans

The land use requirements of field beans are presented (Table 11). The land suitability evaluation results of this crop are also given (Table 12) and (Fig.32). In the area distribution of suitability classes about 22.7% have been evaluated as highly suited for field beans (Class S1), (Fig.22). Another 24.3% of the land area is classified as moderately suited. The land area covered by marginal suitability class S3 is 27.2%. About 16.8% were rated as not suitable. The remainder of the area 9.0% was not found relevant to the current suitability evaluation exercise. The most widespread limitation is fertility (47.6%). Despite the erratic rainfall of Morogoro field beans are recommended because they have a short growing season 60-90 days for green beans and 90-120 days for dry beans (Doorenbos and Kassam 1979). The fertility requirements of field beans are also low (Young 1976). However field beans are less tolerant to wetness than soyabeans (Young 1976). Texture is another prevalent limitation for field beans with 17.6% of the area affected. Some areas are too wet for good field bean growth (11.7%). Field beans will tolerate low moisture limitations therefore this land quality affects only 2.5% of the area. Because field beans provide a good cover to erosion only 16.1% of the area was evaluated as being limited by this land quality. Beans are suited to areas of medium rainfall as excessive rain and hot weather cause flower and pod drop and increase incidence of diseases (Doorenbos and Kassam, 1979).

Fig.22 LAND SUITABILITY DISTRIBUTION FOR FIELD BEANS

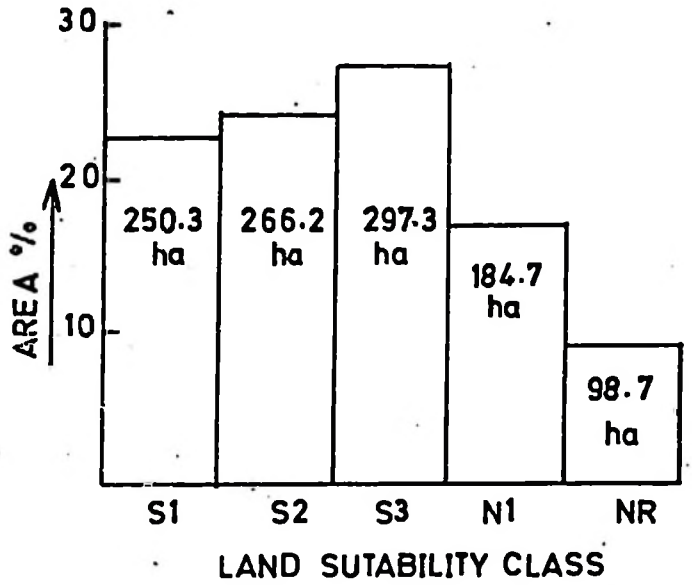


Fig23 DISTRIBUTION OF LIMITATIONS FOR FIELD BEANS

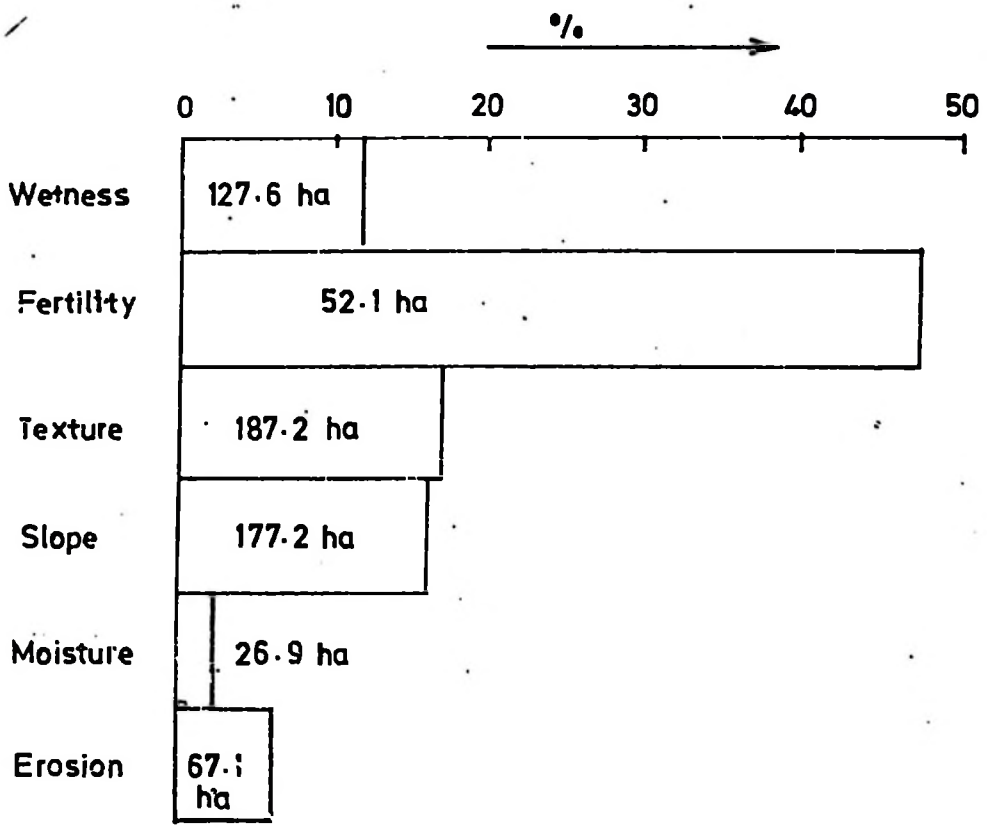


Table 11 : Land use requirements for field beans (Phaseolus vulgaris)

Land qualities/ characteristics		Range in degree of limitations				
		0	1	2	3	4
		100	98	85	60	45
Slope (s)	Class	A	B	C	D	E
	%	0-2	2-4	4-8	8-16	>16
Wetness (w)		well drained	moderately well drained	imperfectly drained	poorly drained	very poorly drained
Texture (t)		SC	CL, SCL, LS	CL, SL, LS, S	LS	S
Depth (d)	in cms	> 75	50-75	25-50	10-25	< 10
Moisture Availability (m)	Available water capacity mm/m	> 90	45-90	30-45	20-30	< 20
	pH	6.0-7.0	5.8-6.0 7.0-7.5	5.5-5.8 7.5-8.0	5.0-5.5 8.0	< 5.0 8.0
Nutrient availability Soil fertility (f) 0 - 25 cm depth	CEC (mẽ/100g clay)	> 10	8-10	6-8	3-6	< 3
	OC (%)	> 2	5-2			
	N (%)	> 0.2	.15-.2	.07-.15	.05-.07	<0.05
	P (ppm)	> 15	10-15	5-10	1-5	< 1
	K (me/100g soil)	> 0.5	0.3-0.5	0.2-0.3	0.1-0.2	< .1
	Ca(me/100g soil)	> 6.0	3.8-6	2.6-3.8	1.0-2.6	< 1.0
	Mg(me/100g soil)	> 1.4	0.9-1.4	0.6-0.9	0.3-0.6	< 0.3
	BS (%)	> 80	50-80	35-50	< 35	< 35
Erosion hazard as per crop characteristics and slope %		0-3	3-5	5-10	10-15	>16

Table12 : Land suitability evaluation results for field beans (Phaseolus vulgaris)

Mapping Unit	Topography slope (s)	Erosion susceptibility (e)	Drainage Wetness (w)	Physical characteristics		Fertility characters (f)			Moisture (m) AWC mm/m	Land indice	Suitability subclass
				Texture (t)	Depth (d)	CEC	BS	O.C.			
$11B_1$	A 0(100)	o(100)	4(35)	1(98)	0(100)	0(100)	1(98)	0(100)	0(100)	34	S3;w
$12C_1$	A 0(100)	0(100)	3(50)	0(100)	0(100)	0(100)	1(98)	2(85)	0(100)	42	S3;w
$13C_1$	A 0(100)	0(100)	1(98)	0(100)	0(100)	0(100)	0(100)	1(98)	0(100)	96	S1
$14B_1$	A 0(100)	0(100)	0(100)	0(100)	0(100)	0(100)	1(98)	2(85)	0(100)	83	S1
$22A_2$	B 1(98)	0(99)	1(90)	3(60)	0(100)	2(85)	1(98)	3(60)	0(100)	26	S3;t,f
$23A_1$	B 1(98)	0(99)	0(99)	2(85)	0(100)	3(60)	2(85)	4(45)	1(98)	18	N1;f,t
$23B_1$	C 2(85)	1(98)	0(99)	0(100)	0(100)	0(100)	0(100)	2(85)	1(95)	67	S2s,f
$24A_1$	B 1(98)	0(98)	0(100)	2(85)	0(100)	1(98)	0(100)	2(85)	0(100)	68	S2;t,f
$24B_1$	B 1(98)	1(98)	0(100)	0(100)	0(100)	0(100)	1(98)	1(98)	0(100)	92	S1
$24C_1$	B 1(98)	1(98)	0(100)	0(100)	0(100)	0(100)	1(98)	4(45)	0(100)	42	S3;f
$25A_1$	B 1(98)	1(98)	0(100)	1(98)	0(100)	2(85)	2(95)	1(98)	1(95)	71	S2;f
$26A_1$	B 1(95)	1(95)	0(100)	1(98)	0(100)	3(60)	1(98)	4(45)	0(100)	25	S3;f;e,s
$26A_1$	C 2(85)	2(85)	0(100)	1(98)	0(100)	3(60)	1(98)	4(45)	0(100)	19	N1; f,e;s
XXX_x NR = NOT RELEVANT NR			NR	NR	NR	NR	NR	NR	NR	NR	NR

5.2.2.5 Land suitability evaluation results for groundnuts

Land use requirements of groundnuts are presented (Table 13). The full evaluation results of the suitability of the mapping units for the production of this crop are also given (Table 14). The illustration of the land suitability areas is provided (Fig. 33). About 27.7% of the land area under investigation was classified as highly suitable Si and 19.3% as moderately suitable (Fig. 24). A 21.1% land area was found marginally suitable for groundnuts. About 22.9% is classified as not suitable while the remaining 9.0% is not found relevant at the present suitability evaluation mapping intensity. Fertility is the most widespread limitation affecting 45. 1% of the survey area. Texture is second with 22.1% land area. However groundnuts still prefer sandy loam textures for easy penetration of the pods. The texture referred to that is limiting to smooth groundnut production is the heavy one such as the sandy clay loam, clay and sandy clays found in Mafiga which cause harvesting problems (Young 1976). This problem is not very critical to yields therefore but it makes groundnut production difficult. Slope accounts for 16.1% of the limitation by land area. Some areas are too wet for groundnut production. These account for 11.7% of the evaluated area. Erosion is not so serious for groundnuts as they provide a good cover (Young 1976). Therefore only this land quality did not affect the ratings very much except slightly in mapping unit $36A_1$. The production of groundnuts is highly recommended due to favourable texture especially in Lugala and Mindu. The low fertilizer requirements and the shorter growing period and lower moisture requirements made groundnuts highly suited to the area for production. Seed inoculation for improved nodulation and yields is advised.

Fig.24 LAND SUITABILITY DISTRIBUTION FOR GROUNDNUTS

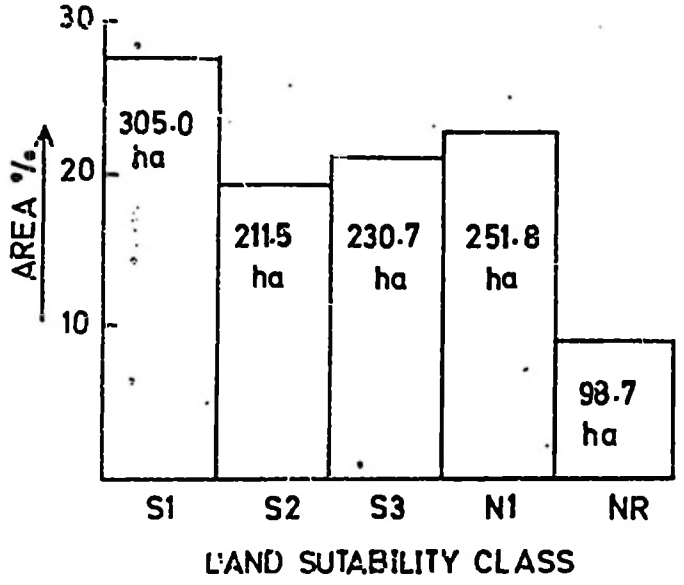


Fig.25 AREA DISTRIBUTION OF LIMITATIONS FOR GROUNDNUTS

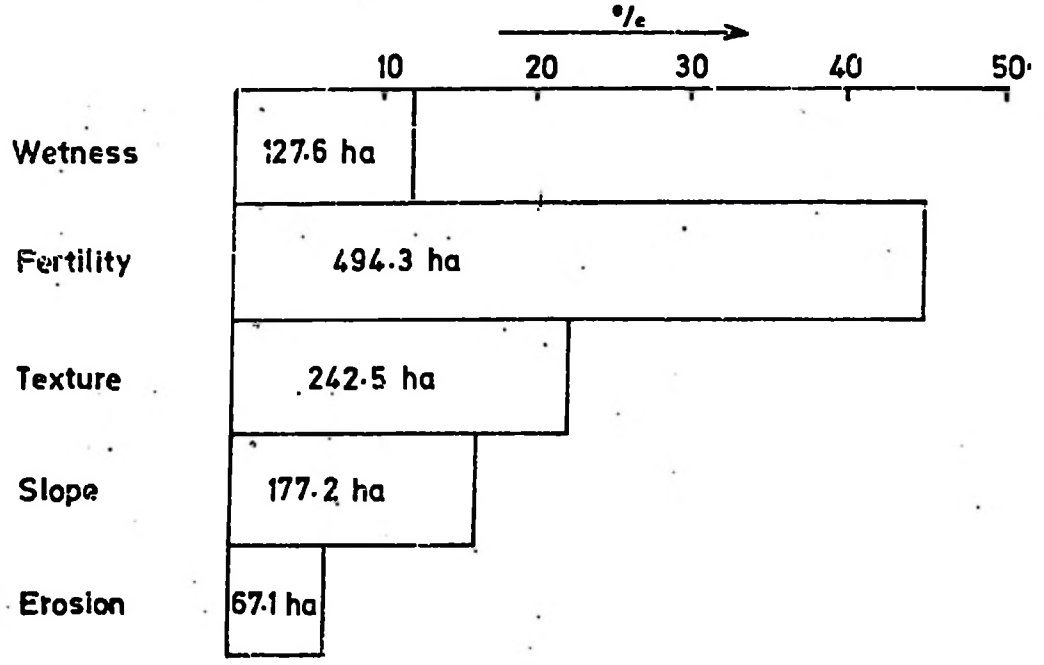


Table 13: Land use requirements for groundnuts (Arachis hypogaea)

Land qualities/ characteristics		Range in degree of limitation				
		0	1	2	3	4
		100	98	85	60	45
Slope (s)	Class	A	B	C	D	E
	%	0-2	2-4	4-8	8-16	>16
Wetness (W)		well drained	moderately drained	imperfectly drained	poorly drained	very poorly drained
Texture (t)		SL	CL, LS, SCL, SC	SCL, LS, SC, S	C, S	C, S
Depth (d)	in cms	>100	75-100	50-75	25-50	<25
Moisture Availability (m)	Available water capacity mm/m	>80	40-80	30-40	20-30	<20
	pH	5.8-6.5	5.5-5.8 6.5-7.0	5.2-5.5 7.0-8.2	5.0-5.2 8.2	<5.0 >8.2
Nutrient availability soil fertility (f) 0 - 25 cm depth	CEC (me/100g clay)	>10	8-10	6-8	3-6	<3
	O.C. (%)	> 2	1.5-2	0.7-1.5	0.5-0.7	<0.5
	N (%)	>0.2	0.1-0.2	0.07-0.15	0.05-0.07	<0.05
	P (ppm)	>15	10-15	5-10	1-5	<1
	K (me/100g soil)	>0.5	0.3-0.5	0.2-0.3	0.1-0.2	<0.1
	Ca (me/100g soil)	>6.0	3.8-6.0	2.6-3.8	1.0-2.6	<1
	Mg (me/100g soil)	>1.4	0.9-1.4	0.6-0.9	0.3-0.6	<0.3
	B.S. (%)	>80	50-80	35-50	<35	
Erosion hazard as per crop characteristics and slope %		0-3	3-5	5-10	10-16	>16

Table 14: Suitability evaluation results for groundnuts.

Mapping Unit	Topography Slope (s)	Susceptibility to erosion (e)	Drainage Wetness (w)	Physical characters		Fertility characters (f) 0 - 25 cm			Moisture (m) AWC mm/m	Land indice	Suitability sub class
				Texture (t)	Depth (d)	CEC	BS	O.C.			
$11B_1$	A 0(100)	0(100)	4(35)	0(100)	0(100)	0(100)	1(98)	0(100)	0(100)	34	S3;w
$12C_1$	A 0(100)	0(100)	3(50)	1(98)	0(100)	0(100)	1(98)	2(85)	0(100)	41	S3;w;f
$13G_1$	A 0(100)	0(100)	1(98)	2(85)	0(100)	0(100)	0(100)	1(98)	0(100)	82	S1
$14B_1$	A 0(100)	0(100)	0(100)	1(98)	0(100)	0(100)	1(98)	2(85)	0(100)	82	S1
$22A_2$	B 1(98)	0(99)	1(90)	2(85)	1(98)	2(85)	2(80)	3(60)	0(100)	33	S3;f,t,
$23A_1$	B 1(98)	1(98)	1(95)	2(85)	0(100)	3(60)	2(85)	4(45)	1(98)	17	N1;f,t
$23B_1$	C 2(85)	1(98)	0(100)	1(98)	0(100)	0(100)	0(100)	2(85)	0(100)	69	S2;s;f
$24A_1$	B 1(98)	1(98)	0(100)	1(98)	0(100)	1(98)	1(98)	2(85)	0(100)	77	S1
$24B_1$	B 1(98)	1(98)	0(100)	2(85)	0(100)	0(100)	1(98)	1(98)	0(100)	78	S1
$24C_1$	B 1(98)	1(98)	0(100)	2(85)	0(100)	0(100)	2(95)	4(45)	0(100)	35	S3;f,t
$25A_1$	B 1(98)	1(98)	0(100)	2(85)	0(100)	2(85)	2(95)	1(98)	2(85)	55	S2;f,t
$26A_1$	B 1(95)	1(95)	0(100)	1(98)	0(100)	3(60)	1(98)	4(45)	0(100)	23	N1; f,e,s
$36A_1$	C 2(85)	2(85)	0(100)	1(98)	0(100)	3(60)	1(98)	4(45)	0(100)	19	N1;f,s,e
XXX_x	NR = NOT RELEVANT NR		NR	NR	NR	NR	NR	NR	NR	NR	NR

5.2.2.6 Land suitability evaluation results for wetland rice

The distribution of land and limitations are given (Figures 26 and 27). Very little of the area (8.3%) is highly suitable (S1) for wetland rice production. Land of moderate suitability occupies about 5.4% while 12.9% is marginally suited. The marginally suited areas do have good texture but the topography (slope), excessive drainage and micro-relief are very limiting (Fig.27). About 6.5% has severe limitations that are manageable (Class N1) while 57.9% of the land area has unmanageable limitations (Class N2). Another 9.0% is considered irrelevant NR to the current suitability evaluation because of the complexity of the land characteristics. The most limiting factor to rice production is lack of enough water under land quality drainage. This affects 75.8% of the area. Topography is another serious and widespread limitation affecting 64.4% of the area surveyed with microrelief limiting some 34.3%. This quality micro-relief was independently assessed of topography otherwise higher %s of affected areas should have been involved. Fertility and permeability affect 10.3% of the land units put together. The distribution in limitations is only illustrative and does not reflect severity of the problem. The methods used are qualitative and restricted to the mapping of the first three pronounced land qualities. The distribution in limitations also overlaps between mapping units. The production of rice in the highly suitable areas is highly recommended as observations of rice production by squatters showed good growth and high potentials. The fertility and water in S1 areas is also not limiting.

Fig 26 LAND SUTABILITY DISTRIBUTION FOR RICE

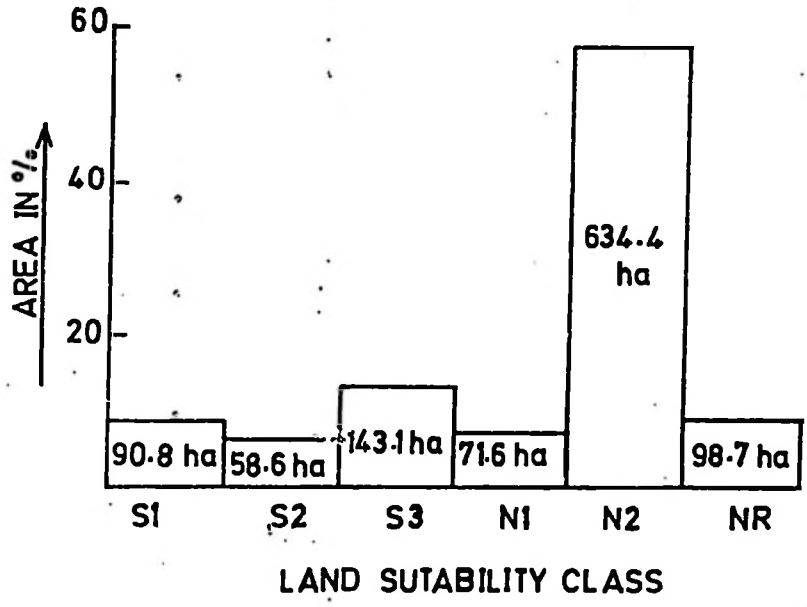


Fig 27 AREA DISTRIBUTION OF LIMITATIONS FOR RICE

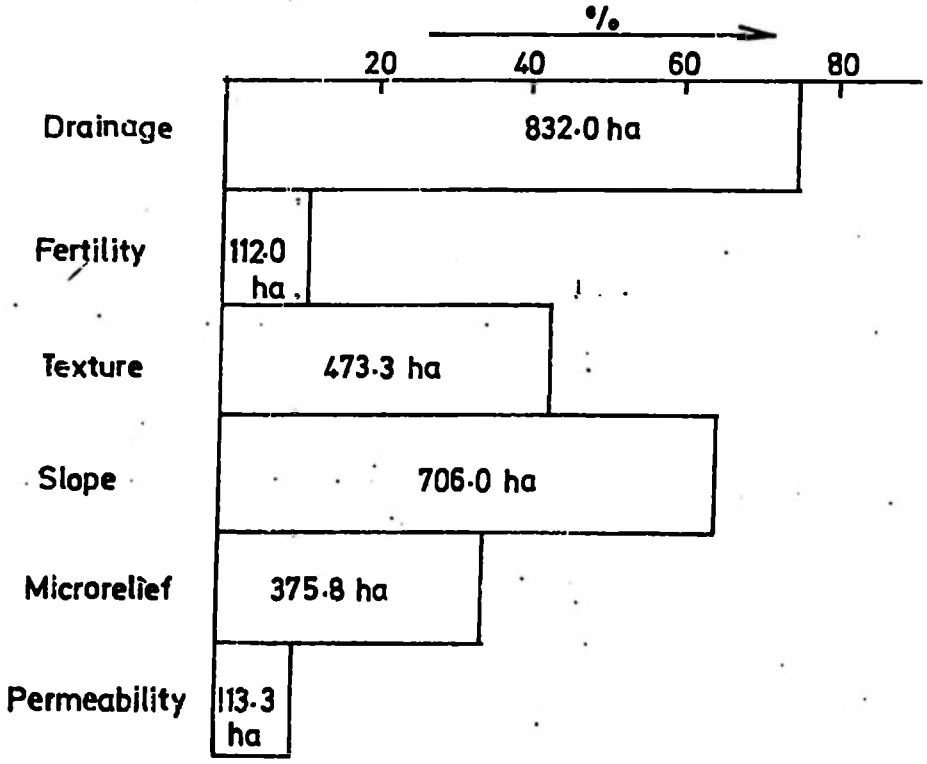


Table15 : Land use requirements for rice(Oryza sativa)

Land qualities/ characteristics		Range in degree of limitation				
		0	1	2	3	4
		100 98	85	60	45	
Capability to maintain surface water	Slope % (s)	A 0.5	B 0.5–1	C 1–2	D 2–3	E >5
	Microrelief (cm) (m)	90% is smooth little or no leveling required	80–90% of land is smooth little leveling required	50–80 of land is smooth	40–45% of land is smooth	
	Drainage class (w)	somewhat poorly to poorly drained	somewhat poorly to poorly drained	somewhat poorly to very poorly drained	well to very poorly drained	excessive to very porrly drai
	Texture of surface and Subsurface horizon (t)	C, SiC, CL, SiCL, SC	C, SiC, SC, SiCL, SCL, CL.	SL to C	LS to C	S to Heavy C
Permeability of subsoil (P)		<0.5 cm/hr	0.5 cm/hr slow	0.5–1.5 cm/hr moderately slow	5–15cm/hr moderately rapid	>15 very rapid
Depth in cm (d)		>75	50–75	25–50	<25	<10
Gravel and stones that hinder cult. (g) (r)		none	none to slightly gravelly	none to slightly gravelly/stony	none to slightly gravelly/stony	none to gravely and slightly st
pH (h)		5.5–7.5	5.0–5.5 7.5–8.0	4.5–5.0 8.0–8.2	4.0–4.5 8.2–8.5	<4.0 >8.5
Salinity EC 5 x 10^6 (a)		<1500	1500–2000	2000–2500	2500–4000	>4000
Fertility (f)	O.C. %	>2	1.5–2	0.7–1.5	0.5–0.7	<0.5
	CEC (me/100g clay)	>10	8–10	6–8	3–6	<3
	BS (%)	>80	50–80	35–50	<35	<35
Risk of damage by water shortage		None	occassional/slight	4 in 10 yrs moderate	mod. to severe 6 in 10 yrs.	very severe 6 in10 yrs
Risk of damage by flash Floods		<1 in 10 yrs	occassional/slight 3 in 10 yrs.	moderate 4 in 10 yrs.	very frequent severe 6 in 10yrs.	>6 in 10 yrs very severe

Table 16: Land evaluation results for land units for rice (Oryza sativa)

Mapping Unit	Topography slope (s)	Microrelief cm heights (m)	Drainage Moisture (w)	Physical characters		Fertility characters (f) 0-25 cm			Permeability (p) cm/hr	Land index	Suitability subclass
				Texture (t) Upper 25cm	Depth (d)	CEC	BS	O.C.			
$11B_1$	1(99)	1(99)	1(98)	1(98)	0(100)	0(100)	2(85)	0(100)	1(98)	78	S1
$12C_1$	1(98)	1(98)	1(85)	0(100)	0(100)	0(100)	2(85)	2(85)	0(99)	58	S2;w,f
$13C_1$	1(98)	1(98)	1(98)	3(60)	0(100)	0(100)	0(100)	0(100)	0(99)	56	S2;t
$14B_1$	1(98)	3(60)	3(60)	1(98)	0(100)	0(100)	1(98)	2(85)	2(85)	25	S3;m,w
$22A_2$	4(45)	4(45)	3(60)	4(45)	0(100)	2(85)	1(98)	3(60)	3(60)	2	N2;s,t,w,n
$23A_1$	4(45)	4(45)	3(45)	4(45)	0(100)	3(60)	3(45)	4(45)	4(45)	0.2	N2;s,t,w
$23B_1$	4(45)	4(45)	2(60)	1(98)	0(100)	0(100)	0(100)	1(98)	1(98)	11	N1;s,m,w
$24A_1$	3(60)	3(60)	3(60)	4(45)	0(100)	1(98)	0(100)	1(45)	4(45)	4	N2;t,p,w,f
$24B_1$	4(45)	4(45)	3(60)	1(98)	0(100)	0(100)	1(98)	1(98)	2(85)	10	N2;s,m,w
$24C_1$	4(45)	4(45)	3(60)	1(98)	0(100)	0(100)	1(98)	4(45)	1(98)	5	N2;s,m,f
$25A_1$	4(45)	4(45)	4(45)	4(45)	0(100)	1(85)	1(98)	1(98)	4(45)	2	N2;s,t,w,
$26A_1$	4(45)	4(45)	4(45)	4(45)	0(100)	3(60)	1(98)	4(45)	4(45)	0	N2;s,t,w
$36A_1$	4(45)	4(45)	4(45)	4(45)	0(100)	3(60)	1(90)	4(45)	4(45)	0	N2;s,t,w
XXX_x	NR = NOT RELEVANT		NR = NOT RELEVANT							NR	NR

6. CONCLUSION

This study shows that soil fertility is the most widespread limiting factor affecting all crops as reflected in the low organic matter content, CEC and base saturation. Texture is limiting in the sandy soils because it makes most of the soils excessively drained. The available water capacity (AWC) determined by texture is a very critical land quality during dry spells. The physical characteristics are more limiting to crop growth i.e. texture and AWC. While fertility problems are widespread these can be corrected out of the bag as long as it is economically viable to do so. The productive potential of the farm is large. Most highly suitable lands for crops are not utilized currently. Greater productivity will be realized through good management including timing of planting not to statistical crop calendars but practical site specific and soil moisture balance studies. The use of fertilizers, organic manures, supplementary irrigations, breed of varieties and selection of those suited to the environment is advisable. Further soil testing and site trials in the mapped areas are needed to assess fertility problems. The data collected was insufficient to provide accurate recommendations. The utilization of the farm could be improved through use and interpretation of the above results. Establishment of paddocks, improved pastures and livestock and housing facilities in Mindu and Lugala will provide better farm utilization by reducing over grazing, and misuse of the farm by outsiders. The coarse texture problem to AWC and fertility could be amended by manuring, fire prevention, long fallows, silvilcultural practices and pasture establishment and rice cultivation for the poorly drained soils, is recommended.

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7. APPENDIX

Information on the site

a. Profile number: 1

b. Classification:

U.S.D.A.: Fluventic Ustropepts

F.A.O.: Eutric Fluvisol

c. Date of examination: 10th August, 1983

d. Location: University Farm. 12,500 m from Morogoro town following the road to Iringa diverting to the former Mafiga Sisal Factory across Ngerengere bridge towards Lugala mountains. Site lies approximately 1,050 m Northwards from Hindu - Lugala - Mazimbu junction UTM Code 37MCC 472485.

e. Elevation: 510 m a.s.l.

f. Landform:

(i) physiographic position: valley bottom

(ii) surrounding land form: flat

(iii) microtopography: nil

g. Slope on which profile is sited: flat (1.5%). Sloping towards Ngerengere river and site seems depressed slightly.

h. Land use: At the time of the soil survey work the land had just been cleared of maize, beans and sorghum harvests. The crop stands were good despite non application of fertilizers.

i. Vegetation: The area had been planted and weeded before only 'black jack' weed was prominent.

General information on the soil:

a. Parent material: colluvial and alluvial sands

b. Drainage: Well to moderately well drained

c. Moisture conditions in profile: The upper 60 cm was just moist. The lower and coarse soil body was dry.

d. Depth of groundwater: More than 3 metres

e. Presence of surface stones and rock outcrops: none

f. Evidence of erosion: none detected at site

g. Presence of salt or alkali: none

h. Human influence: The upper horizons are annually ploughed using a local hand hoe affecting the upper 10 cm. This plow layer has a dark brown colour due to annual burning of plants and organic matter decomposition. The cultivation has made the internal drainage of these soils more pronounced than the surface one.

Profile description:

Ap 0-10 cm Very dark grayish brown (10 YR 3/2) moist, and dark brown (10YR 3/3) dry, sandy loam; strong very fine, angular blocky; sticky, plastic (wet), friable (moist),

hard (dry); many antnests intermixed with pores; many medium roots; abrupt wavy boundary.

Bu 10-25 cm: Very dark gray (10YR 3/1) moist, and dark brown (10YR 3/3) dry, sandy clay loam; strong coarse, angular blocky; sticky, plastic (wet), firm (moist), very hard (dry); many exped, many inped interstistial and tubular simple pores; many fine roots; frequent small soft iron - manganese concretions; clear wavy boundary.

BC 25-60 cm: Dark brown 7.5YR 3/2) moist and dark yellowish brown (10YR 3/4) dry, loamy sand; moderate coarse angular blocky; slightly sticky, slightly plastic (wet), friable (moist), hard (dry); many medium exped, many fine inped pores; few fine roots; weakly cemented; small hard iron-manganese concretions; very few fine gravels of 2-3 mm diameter; abrupt wavy boundary.

CBg 60-80 cm: Dark reddish brown (5YR 3/3) moist and reddish brown (5YR 4/3) dry, sandy loam with many medium distinct reddish brown mottles; weak coarse angular blocky; slightly sticky, slightly plastic (wet), friable (moist), slightly hard (dry); many medium tubular; simple exped pores; very few iron-manganese concretions; very frequent fine gravel 2-3 mm diameter; few fine roots; diffuse smooth boundary.

Cg_1 80–140 cm: Dark brown (7.5YR 4/2) dry, sandy clay loam; with many coarse prominent diffuse dark reddish brown mottles; weak coarse angular blocky; slightly sticky, slightly plastic (wet), very friable (moist) and slightly hard (dry).

Cr_2 140–200 cm: The same as the Cr_1 above except for increased coarse gravelly fragments and structureless properties.

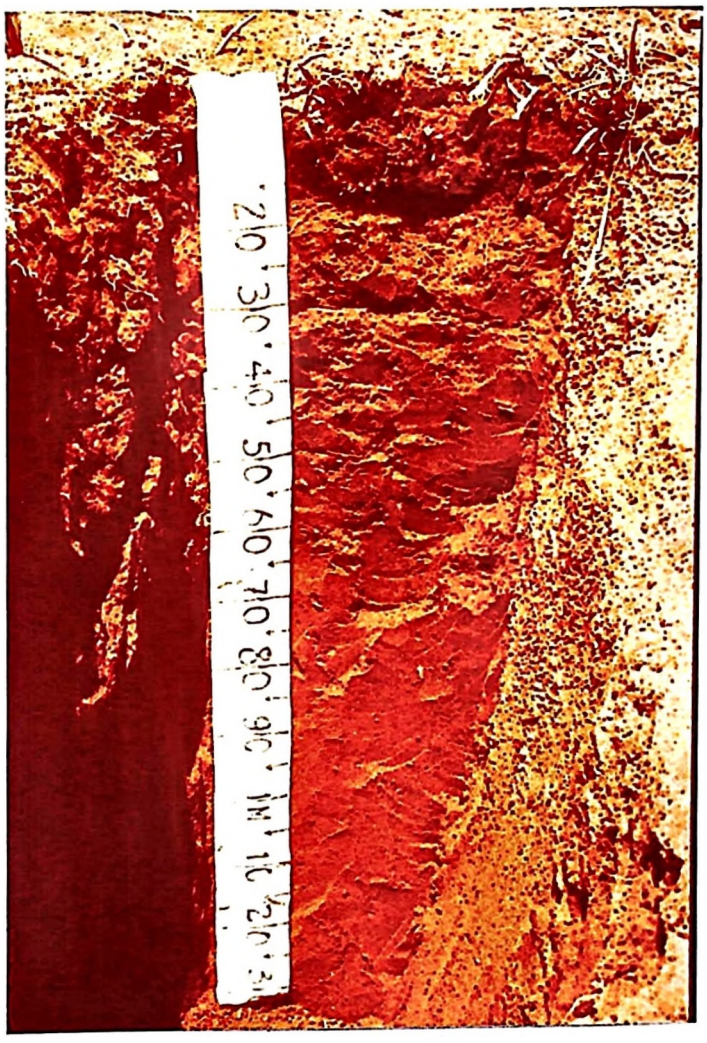

Plate 1: Soil Profile Number 1

SOIL ANALYTICAL DATA

Maping Unit: $14B_1$ — Profile number 1 — Date of sampling 10/8/83

Sample Number	Depth (cm)	Horizon	Particle size distribution			Textural Class	Silt/ Clay
			Sand	Silt	Clay		
11	0-10	Ap	70	12	18	SL	0.65
12	10-25	Bu	68	8	24	SCL	0.32
13	25-60	BC	84	4	12	LS	0.34
14	60-80	CB	80	4	16	SL	0.23
15	80-140	Cg_1	76	4	20	SCL	0.20
16	140-200	Cg_2	76	4	20	SCL	0.20

Bulk density (g/cm^3)	Particle density (g/cm^3)	Porosity (%)	Water content weight % and cm depth at various suctions (bars)					
			1/3 bar = FC		15 bars = PWP		Avail. Water Capacity	
			(%)	(cm)	(%)	(cm)	(%)	(cm)
1.4	2.60	45	23.2	2.3	10.9	1.1	12,3	1.8
1.73	2.63	34	24.9	3.7	8.7	1.3	16.2	4.2
1.59	2.65	40	19.3	6.8	4.6	1.6	14.7	8.2
1.44	2.64	45	16.3	3.3	4.7	0.9	11.6	3.3
1.46	2.65	45	gravelly	ND	ND	ND	= Not determined	
1.47	2.65	45	gravelly	ND	ND	ND	= Not determined	

Sample Number	O.C. %	N %	Exchangeable cations (me/100g soil)					Sum bases	C.E.C. Soil Sum	Sum bases me/100g clay	C.E.C. me/100g clay
			Na	K	Ca	Mg	H (+)				
11	1.15	0.23	0.15	2.81	8.64	3.91	4.2	15.56	19.8	73	93
12	0.73	0.13	0.15	2.12	7.82	3.67	3.9	13.76	17.7	51	66
13	0.13	0.10	0.11	0.83	2.42	2.05	2.8	5.41	8.2	44	66
14	0.12	0.06	0.15	0.97	2.25	2.39	2.7	5.76	8.5	35	51
15	0.19	0.03	0.21	0.98	3.96	1.22	2.5	6.37	8.9	30	42
16	0.19	0.03	0.21	0.98	3.96	1.22	2.5	6.37	8.9	30	42

(+) By triethanolamine extraction.

Sample Number	pH		Exchangeable Sodium %	Base Saturation %	Available P (ppm)
	1:1 H_2O	1:2 $CaCl_2$			
11	6.8	6.6	0.8	78	29.8
12	7.0	6.7	0.9	78	16.1
13	6.9	6.7	1.4	66	23.1
14	6.7	6.5	1.8	68	10.5
15	6.5	6.4	2.4	72	2.5
16	6.4	5.5	2.4	72	2.5

Information on the site

a. Profile number 2

b. Classification:

U.S.D.A.: Fluventic Ustropepts

F.A.O. Eustric fluvisol

c. Date of examination: 2nd March 1983

d. Location: University farm, about 3,400 metres from the Ngerengere Ngerengere - University farm bridge along the road to the South African National Congress (ANC) Refugee Camp. 100 m Eastwards; approximates 7 kms from Morogoro town UTM Code 37. CC 488484.

e. Elevation: 485 m a.s.l.

f. Land-form:

(i) physiographic position - valley bottom

(ii) surrounding landform - undulating

(iii) microtopography - nil

g. Slope on which profile is sited: gently sloping towards Ngerengere river 3.5%

h. Land use: At the time of examination the land was being prepared by tractor tillage for maize planting. Cultivation is done annually by local people staying next to the University Farm. No details on rotations, yields and other management practices could be obtained.

i. Vegetation: The vegetation had been ploughed under at the time of observation.

General information on the soil:

a. Parent material: Dominantly colluvial and alluvial deposits with schists in the lower old soil.

b. Drainage: Moderately well drained Class 3.

c. Moisture conditions in profile: Moist in upper 1.6m, just moist below to 2.0m.

d. Depth of groundwater: more than 3 metres

e. Presence of surface stones and rock outcrops: None

f. Evidence of erosion: None detected

g. Presence of salt or alkali: none detected

h. Human influence: This profile shows evidence of a long history of landuse from the artefacts of burnt clay bricks, pieces, charcoal and clay pot remains in the sub surface horizons. This area could have been built of settlements and has up to now been continuously cultivated and has been subject long time ago to floods. This conclusion follows the existence of artefacts in the burried horizons i.e. 2BCb at a depth of 90 - 160 cm.

Profile desdription

Ap 0 - 15 cm: Very dark brown (10YR 3/2) moist and dark brown (10YR 3/3) dry, sandy loam; weak fine crumb to prismatic structure; sticky, plastic (wet), friable (moist), hard (dry); many coarse exped pores; common medium roots; clear smooth lower boundary.

AB 15-22 cm: Very dark brown (10YR 3/2) moist and dark brown (10YR 3/3) dry; sandy clay loam; **moderate fine prismatic;** very sticky, very plastic (wet), friable (moist), very hard (dry); common fine inped, many coarse exped pores and insect nests commonly intermixed with pores; common medium roots; very small soft iron-manganese concretions; clear smooth boundary.

Bu 22-45 cm: Very dark brown (10YR 3/2) moist, and dark brown (10YR 3/3) dry, sandy clay loam; moderate medium prismatic; very sticky, very plastic (wet), firm (moist), very hard (dry); common fine inped, common fine exped pores; few medium roots; few small soft iron-manganese concretions; clear smooth boundary.

Bu_2 45-68 cm: Dark yellowish brown (10YR 3/4) moist, and dark brown (7.5YR 4/4) dry, sandy clay loam; moderate medium prismatic; sticky, plastic (wet), friable (moist), hard (dry); common thick clay : few medium exped pores; few medium roots; clear smooth boundary.

2Ab 68–90 cm: Dark brown (10YR 4/3) moist and dark brown (10YR 4/3) dry, sandy clay loam; moderate medium prismatic; sticky, plastic (wet), friable (moist), very hard (dry); few medium exped and common fine inped pores; few fine roots; clear smooth boundary.

$2Bub_1$ 90–145 cm: Dark yellowish brown (10YR 3/4) moist and dark brown (7.5YR 4/4) dry sandy clay loam; moderate medium prismatic; sticky, plastic (wet), friable (moist) hard (dry); few fine exped interstistial pores; very few very fine roots; clear smooth boundary.

$2Bub_2$ 145–200 cm: The same as the $2Bub_1$ horizon above except for increased gravel content.

Plate 2: Soil profile number 2

SOIL ANALYTICAL DATA

Mapping Unit: $24B_1$ — Profile number 2 — Date of sampling: 22/3/83

Sample Number	Depth (cm)	Horizon	Particle size distribution			Textural Class	Silt/ Clay
			Sand	Silt	Clay		
21	0–15	Ap	78	5	17	SL	0.12
22	15–22	AB	63	11	26	SCL	0.42
23	22–45	Bu_1	64	8	28	SCL	0.29
24	45–68	Bu_2	75	3	22	SCL	0.14
25	68–90	2Ab	69	6	25	SCL	0.24
26	90–145	$2Bub_1$	68	6	26	SCL	0.23
27	145–200	$2Bub_2$	68	6	26	SCL	0.23

Bulk density (g/cm^3)	Particle density (g/cm^3)	Porosity (%)	Water content weight % and cm depth at various suctions (bars)					
			1/3 bar = FC		15 bars = PWP		Avail. Water Capacity	
			(%)	(cm)	(%)	(cm)	(%)	(cm)
1.28	2.46	48	25.8	3.9	6.5	1.0	19.3	3.7
1.22	2.48	51	25.3	1.8	3.3	0.2	22.1	1.9
1.25	2.49	50	24.9	5.7	4.8	1.1	20.1	5.8
1.32	2.54	48	21.5	5.0	4.2	1.0	17.4	5.3
1.43	2.46	42	26.4	5.8	9.1	2.0	17.3	5.4
1.30	2.54	49	23.3	16.3	8.3	8.7	15.0	11.2
1.30	2.54	49	23.3	16.3	8.3	8.7	15.0	11.2

Sample number	O.C.%	N%	Exchangeable cations (me/100g soil)					Sum bases	C.E.C. Soil Sum	Sum bases me/100 g clay	C.E.C. me/100 g clay
			Na	K	Ca	Mg	H(+)				
21	2.27	0.11	0.07	3.79	8.05	3.41	5.1	15.32	20.4	65	86
22	1.62	0.13	0.11	2.70	9.34	4.00	4.9	16.15	21.1	48	65
23	1.33	0.05	0.11	2.98	8.63	3.78	4.0	15.50	19.5	46	58
24	0.58	0.05	0.19	1.82	5.49	3.00	1.5	10.50	12.0	42	48
25	1.74	0.08	0.16	2.34	2.71	3.65	2.55	8.86	11.4	21	27
26	0.52	0.06	0.17	2.43	5.80	4.06	3.0	12.46	15.5	45	55
27	0.52	0.06	0.17	2.43	5.80	4.06	3.0	12.46	15.5	45	55

Sample number	pH		Exchangeable Sodium %	Base Saturation %	Available P (ppm)
	1:1 H_2O	1:2 $CaCl_2$			
21	6.7	6.6	0.3	75	50.4
22	6.3	6.3	0.5	74	49.0
23	6.6	6.4	0.6	80	29.4
24	6.7	6.3	1.6	88	56.0
25	6.9	6.5	1.4	78	31.5
26	7.3	6.7	1.1	81	66.5
27	7.3	6.7	1.1	81	66.5

Information on the site

a. Profile number: 3

b. Classification:

U.S.D.A.: Ustoxic Quartzipsamment

F.A.O.: Luvic Arenosol

c. Date of examination: 11th August, 1983

d. Location: University farm about 2,700 metres from the Ngerengere-University Farm bridge along the road to the ANC refugee camp 400 metres northwestwards along powerline; approximately 7 kms by road from Morogoro town using Iringa road UTM Code 37 M CC 482482.

e. Elevation: 495m a.s.l.

f. Landform:

(i) physiographic position: middle slope of plain

(ii) surrounding land form: plain

(iii) microtopography: nil

g. Slope on which profile is sited: undulating (3%) sloping towards Ngerengere river Southwards.

h. Landuse: Except for small areas under fallow most of the land is hoe cultivated for sorghum, maize, cassava and sweet potatoes.

i. Vegetation: The vegetation has been cleared. Only 'black jack' weeds were evident.

General information on the soil:

a. Parent material: apparently colluvial deposits and in situ quartz

b. Drainage: Well drained - class 4

c. Moisture conditions in the profile: since the profile was examined after the rains after two days of exposure it was dry throughout.

d. Depth of groundwater: several metres deep

e. Presence of surface stones and rock outcrops: none

f. Evidence of erosion: none detected at site

g. Presence of salt or alkali: none

h. Human influence: The annual burning of vegetation gives dark colours to the upper 30 cm of soil

Profile description

Ap 0-13 cm: Very dark grayish brown (10YR 3/2) moist and very dark grayish brown (10YR 3/2) dry, loamy sand; weak coarse crumbs; slightly sticky, slightly plastic (wet), loose (moist), firm (dry); common medium roots; very few fine gravels; clear smooth boundary.

AB: 13-36 cm: Very dark grayish brown (10YR 3/2) moist and brown (10YR 5/3) dry, loamy sand; weak coarse crumby; slightly sticky, slightly plastic (wet), very friable (moist), slightly firm (dry); common medium inped, few coarse exped pores; common coarse roots; clear smooth boundary.

Bu_1 36-80/112 cm: Dark reddish brown (5YR 3/4) moist, and reddish brown (5YR 4/4) dry, sandy clay loam; weak coarse angular blocky; sticky, plastic (wet), friable (moist), slightly hard (dry); few vesicular closed pores; weak cementation by iron oxides; very frequent small hard iron concretions, very frequent fine gravels; common fine roots; clear wavy boundary.

Bu_2 80/112-137 cm: Dark reddish brown (5YR 3/4) moist and reddish brown (5YR 4/3) dry, sandy loam; weak medium subangular blocky; sticky, plastic (wet), soft (moist), slightly firm dry; common coarse vertical exped pores; strongly cemented by iron oxides; frequent coarse gravels; few fine roots; clear irregular boundary to C horizon.

C_s 137-165 cm+: Reddish brown (5YR 4/4) moist and yellowish red (5YR 5/6) dry sand veins between gravels.

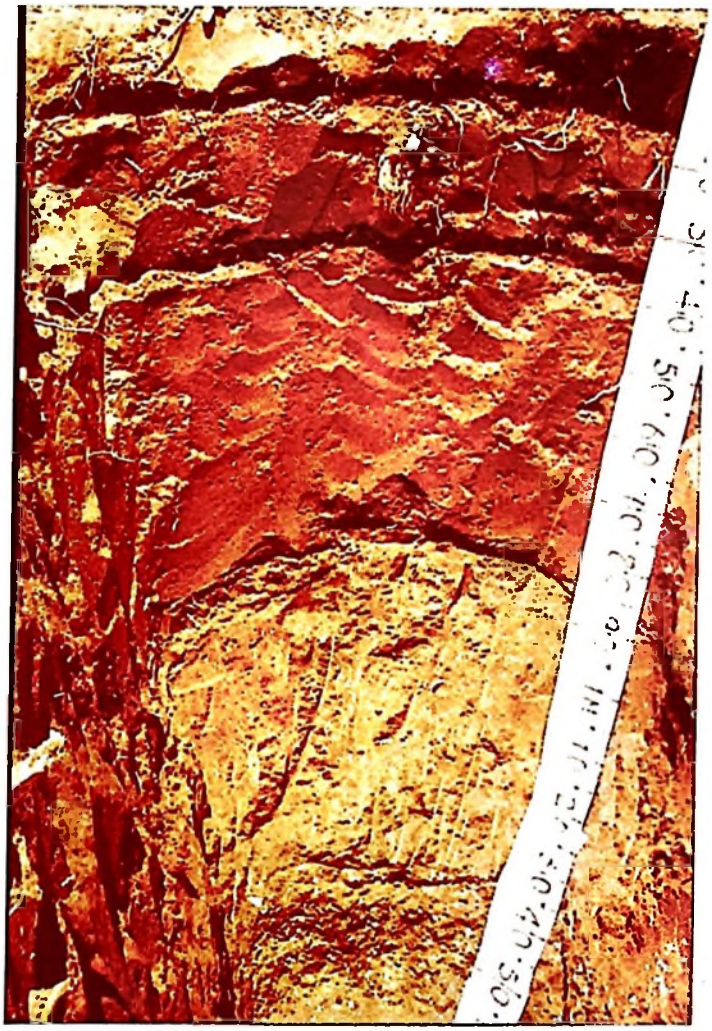

Plate 3: Soil profile number 3

SOIL ANALYTICAL DATA

Mapping Unit: $24A_1$ Profile number 3 Date of sampling: 11/8/83

Sample number	Depth (cm)	Horizon	Particle size distribution			Textural Class	Silt/ Clay
			Sand (%)	Silt (%)	Clay (%)		
31	0-13	Ap	88	4	8	LS	0.50
32	13-36	AB	86	4	10	LS	0.40
33	36-80/112	Bu_1	76	3	21	SCL	0.14
34	80/112-137	Bu_2	78	2	20	SL	0.10
35	137-165+	Cs	90	4	6	S	0.67

Bulk density (g/cm^3)	Particle density (g/cm^3)	Porosity (%)	Water content weight % and cm depth at various suctions (bars)					
			1/3 bar = FC		15 bars = PWP		Avail. water capacity	
			(%)	(cm)	(%)	(cm)	(%)	(cm)
1.24	2.58	52	19.4	2.5	4.4	0.6	15.0	2.4
1.45	2.60	44	21.0	4.8	4.3	1.0	16.7	5.6
1.54	2.62	41	28.5	21.6	9.3	7.1	19.2	22.5
1.64	2.65	38	25.5	6.4	4.8	1.2	20.7	5.1
1.67	2.68	38	18.5	5.2	2.3	0.7	16.2	7.6

Sample number	O.C.%	N%	Exchangeable cations (me/100g soil)					Sum bases	C.E.C. soil sum	Sum bases me/100 g clay	C.E.C. me/100 g clay
			Na	K	Ca	Mg	H(+)				
31	0.62	0.12	0.07	1.29	4.23	1.87	1.7	7.41	9.1	77	95
32	0.94	0.15	0.10	0.91	3.74	1.41	1.5	6.16	7.7	42	53
33	0.17	0.04	0.20	0.69	3.23	2.41	4.9	6.53	11.4	30	53
34	0.16	0.06	0.22	0.40	5.29	1.95	4.2	4.86	9.1	23	44
35	0.10	0.23	0.19	0.38	1.62	1.28	1.8	3.47	5.3	54	82

Sample number	pH		Exchangeable Sodium %	Base Saturation %	Available P (ppm)
	1:1 H_2O	1:2 $CaCl_2$			
31	7.2	7.0	0.8	81	11.6
32	6.8	6.5	1.3	80	8.8
33	5.5	5.0	1.7	57	5.3
34	5.7	5.1	2.4	53	2.1
35	6.0	5.4	3.6	66	3.5

Information on the site

a. Profile number: 4

b. Classification:

U.S.D.A.: Typic Haplustolls

F.A.O.: Luvic Kastanozams

c. Date of examination: 24th March, 1983

d. Location: About 100 metres Eastwards from 400m along Mindu-Lugala - Mazimbu road crossing, approximately 3,400m from the Ngerengere-University Farm bridge. UTM Code 36M CC 471479.

e. Elevation: 520m a.s.l.

f. Landform:

(i) physiographic position: crest

(ii) surrounding landform: undulating

(iii) microtopography: nil

g. Slope on which profile is sited: undulating 7%

h. Land use: at the time of examination the site was under regrown shrubs and lush grass cover. It lacked evidence of earlier cultivation and clearance.

i. Vegetation: shrubs - Compositae 4, Harrisonia Abyssinica, Albizia Anthelminthica, Cassia Auriculata

climbers - Combretum 3, Jasminum Flumincuse

tree - Markamia Obstusifolia,

grass - Androponoid

General information on the soil

a. Parent material: dominantly gneiss

b. Drainage: moderately well drained to imperfectly drained because of seepage and slow permeability of subsoil

c. Moisture conditions in the profile: The upper 50 cm was just moist while the lower horizons were dry due to slow permeability of the subsoil. Light rains followed by one week of drought to the time of sampling.

d. Depth of groundwater: Very deep at this elevation and slope

e. Presence of surface stones and rockoutcrops: none

f. Evidence of erosion: none detected

g. Presence of salt or alkali: Little effeversence

h. Human influence: confined to bush clearing of over 10 years ago and annual burning of grass which give dark top soil colours.

Profile description

Ah (?) 0-8 cm: Very dark gray (10YR 3/1) moist and very dark grayish brown (10YR 3/2) dry, sandy clay loam; weak fine crumb; slightly plastic (wet), friable (moist), slightly firm (dry); very few fine gravels; many fine roots; abrupt smooth boundary.

ABg 8-15 cm: Few fine faint sharp yellowish red mottles; very dark blackish brown (10YR 2/1) moist and very dark brown (10YR 3/1) dry, sandy clay loam; moderate medium to coarse subangular blocky sticky, plastic (wet), friable (moist), hard (dry); common medium roots; abrupt smooth boundary.

Bu 15-28/30 cm: Common fine distinct yellowish red mottles; dark gray (10YR 4/1) moist and very dark yellowish brown (10YR 3/1) dry, sandy clay loam; strong coarse to very coarse angular blocky sticky, plastic (wet), friable (moist), hard dry; common fine exped horizontal interstitial pores; weak cementation; frequent fine gravels; few fine roots; clear wavy boundary.

BCmqg 28/30-50/65 cm: Many medium prominent sharp yellowish red mottles; dark grayish brown (10YR 4/2) moist and brown (10YR 5/3) dry, sandy clay loam, strong coarse angular blocky weak silica cementation, frequent fine gravels; few fine roots; clear irregular boundary.

Cmq 65-105 cm: Brown (10YR 5/3) moist and pale brown (10YR 6/3) dry, sandy clay loam; strong coarse prismatic intermixed with gravels; very sticky, very plastic (wet), firm (moist), extremely hard (dry); very few exped pores; strongly cemented when dry; few fine roots; very frequent coarse gravels clear wavy boundary.

2Cmq 105-150 cm: The same as Cmq except for increased coarse gravels.

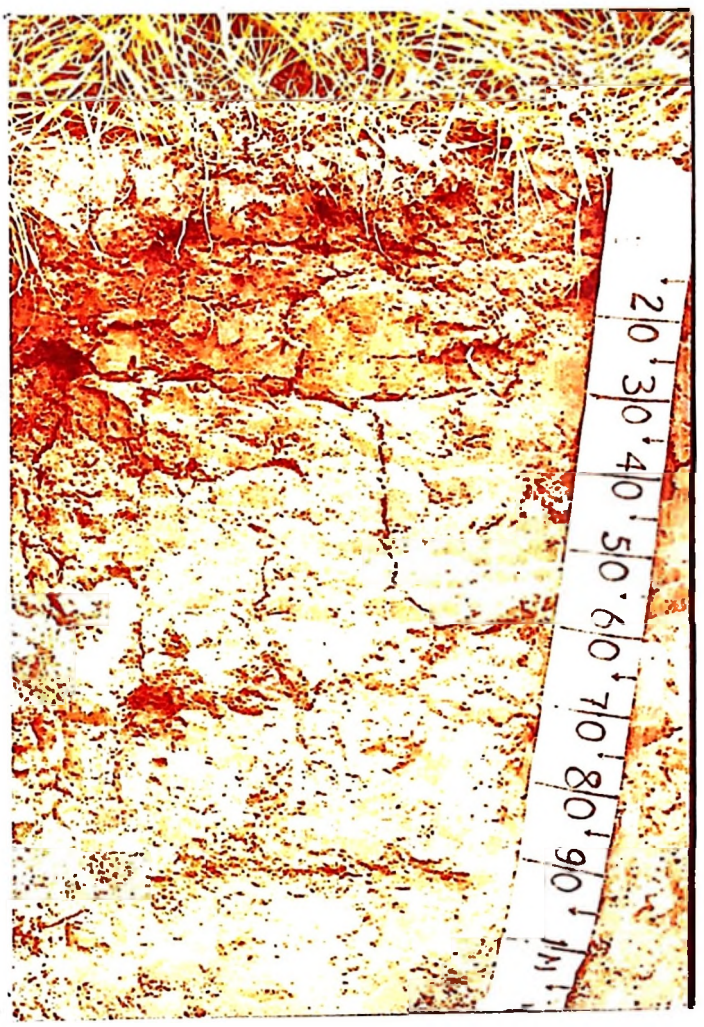

Plate 4: Soil profile number 4

SOIL ANALYTICAL DATA

Mapping Unit: $23B_1$ — Profile number 4 — Date of sampling: 24/3/83

Sample number	Depth (cm)	Horizon	Particle size distribution			Textural Class	Silt/ Clay
			Sand %	Silt %	Clay %		
41	0–8	Ah(?)	73	7	20	SCL	0.35
42	8–15	AB	68	4	28	SCL	0.14
43	15–28/30	Bu	62	4	34	SCL	0.12
44	28/30–50/56	BCmq	63	4	33	SCL	0.12
45	65–105+	Cmq	62	9	29	SCL	0.31

Bulk density (g/cm^3)	Particle density (g/cm^3)	Porosity (%)	Water content weight % and cm depth at various suctions (bars)					
			1/3 bar = FC		15 bars = PWP		Avail. Water capacity	
			(%)	(cm)	(%)	(cm)	(%)	(cm)
1.41	2.30	39	27.1	2.2	20.1	1.6	7.0	0.8
1.65	2,54	35	30.7	2.2	19.3	1.4	11.4	1.3
1.46	2.47	41	34.4	5.2	21.0	3.2	13.4	2.9
1.65	2.52	35	54.5	19.1	24.0	8.3	30.5	17.7
1.32	2.44	46	53.8	21.5	19.0	7.5	34.8	23.0

Sample number	O.C.%	N%	Exchangeable cations (me/100g soil)					Sum bases	C.E.C. Soil Sum	Sum bases me/100g clay	C.E.C. me/100 g clay
			Na	K	Ca	Mg	H(+)				
41	2.09	0.19	0.31	1.49	11.29	5.30	2.9	18.44	21.3	70	80
42	1.16	0.10	0.51	0.68	8.01	4.98	1.5	14.18	15.7	41	45
43	0.58	0.07	1.36	0.54	12.10	7.14	2.0	21.14	23.1	59	64
44	0.41	0.05	4.54	0.57	14.90	10.64	1.0	30.65	31.7	89	92
45	0.06	0.02	9.88	0.54	7.93	12.57	2.2	30.92	33.1	105	113

Sample number	pH		Exchangeable Sodium %	Base Saturation %	Available P (ppm)	Electrical conductivity mS/cm
	1:1 H_2O	1:2 $CaCl_2$				
41	6.9	6.5	1.7	87	22.8	4.4
42	7.0	6.8	3.3	91	7.0	3.5
43	7.3	7.1	5.9	92	6.3	5.3
44	8.0	7.5	14.4	97	6.3	5.5
45	8.5	7.8	29.8	93	3.5	5.5

Information on the site

a. Profile number: 5

b. Classification:

U.S.D.A.: Aquic Psamment

F.A.O.: Luvic Arenosol

c. Date of examination: 25th March, 1983

d. Location: About 5 km from the Ngerengere river University farm access bridge along main road to ex-Mazimbu Estate along Eatern boundary of Lugala farm block about 100 m Westwards. UTM Code 37 M CC 466493

e. Elevation: 520 m a.s.l.

f. Landform:

(i) physiographic position-depression, drainage line

(ii) surrounding landform - undulating

(iii) microtopography - gilgai, natural.

g. Slope on which profile is sited: gently sloping (3%) towards Ngerengere river.

h. Land use: None evident as farm is regrown with grasses and shrubs.

i. Vegetation: Shrubs - Pluchean Dioscoridis, Cassia Auriculata, Byrsocarpus Orientalis, Securinega Virosa, Phyllanthus Madaraspatensis, Combretum I, Dichrostachys Cinerea,

Herb - Thylaccium Africanum

Trees - Albizia Antunesiana Lonchocarpun Capassa

Grass - Panicum coloratum

General information on the soil

a. Parent material: mainly ferro-magnesiun sandy mineral

b. Drainage: well to moderately well drained

c. Moisture conditions in the profile: moist throughout as the profiles were sampled immediately after excavation.

d. Depth of groundwater table: unknown but not more than 3 metres

e. Presence of surface stones and rock outcrops: none

f. Evidence of erosion: none detected

g. Presence of salt or alkali: none

h. Human influence: very slight and confined to dark colours in the plow layer due to annual burning

Profile description

Ap 0-15 cm Very dark gray (10YR 3/1) moist and dark grayish brown (10YR 4/2) dry, sands; structureless and loose crumbs; not sticky, loose (moist), many medium roots; clear smooth boundary.

AB 15-27 cm: Very dark gray (10YR 3/1) moist and dark grayish brown (10YR 4/2) dry, sands; structureless loose (dry); many medium roots clear wavy boundary.

Bg_1 27-117 cm: Very dark grayish brown (10YR 3/2) moist and grayish brown (10YR 5/2) dry, sandy clay loam; with common coarse prominent yellowish brown mottles; weak medium prismatic; sticky, plastic (wet), firm (moist), extremely hard (dry); few coarse inped pores; common medium roots; frequent fine gravels; very frequent soft large iron and manganese concretions.

Bg_2 117-200+ cm: Same as above except for severe variation by reddish brown mottles.

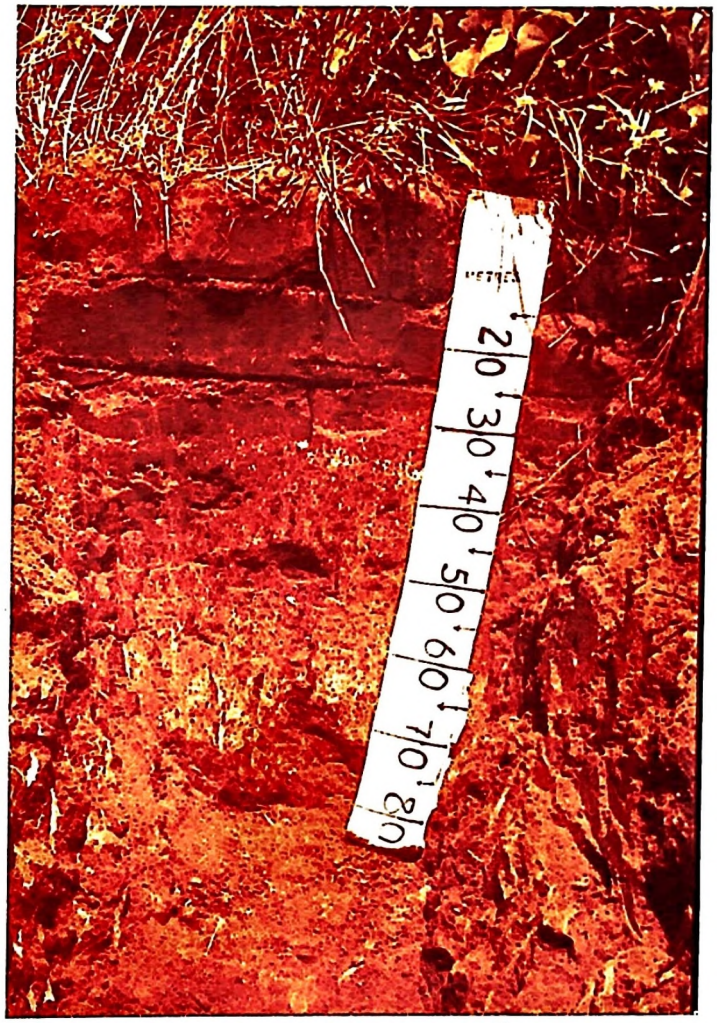

Plate 5: Soil profile number 5

SOIL ANALYTICAL DATA

Mapping Unit: $23A_1$ Profile number 5 Date of sampling: 25/3/83

Sample number	Depth (cm)	Horizon	Particle size distribution			Textural Class	Silt/ Clay
			Sand (%)	Silt (%)	Clay (%)		
51	0–15	Ap	91	3	6	S	0.5
52	15–27	AB	92	3	6	S	0.5
53	27–117	Bt_1	72	4	24	SCL	0.17
54	117–200+	Bt_2	72	4	24	SCL	0.17

Bulk density (g/cm^3)	Particle density (g/cm^3)	Porosity (%)	Water content weight % and cm depth at various suctions (bars)					
			1/3 bar = FC		15 bars = PWP		Avail. Water Capacity	
			(%)	(cm)	(%)	(cm)	(%)	(cm)
1.36	2.55	47	13.1	2.0	6.0	0.9	7.1	1.4
1.37	2.71	49	21.7	2.6	4.4	0.5	17.3	2.8
1.49	2.54	41	26.1	19.4	6.9	6.2	19.2	25.7
1.49	2.54	41	26.1	21.7	6.9	5.7	19.3	23.7

Sample number	O.C.%	N%	Exchangeable cations (me/100g soil)					Sum bases	C.E.C. soil sum	Sum bases me/100 g clay	C.E.C. me/100 g clay
			Na	K	Ca	Mg	H(+)				
51	1.10	0.05	0.11	0.64	3.24	1.33	0.5	5.32	5.8	49	54
52	0.52	0.05	0.13	0.29	3.98	3.85	4.2	8.25	12.4	120	156
53	0.64	0.06	0.13	0.24	1.50	1.14	4.5	3.01	7.6	10	25
54	0.64	0.06	0.13	0.24	1.50	1.14	4.5	3.01	7.6	10	25

Sample number	pH		Exchangeable Sodium %	Base Saturation %	Available P (ppm)
	1:1 H_2O	1:2 $CaCl_2$			
51	6.7	5.6	1.9	91	3.5
52	6.2	5,0	1.0	77	3.5
53	5.9	5.0	1.7	40	3.5
54	5.9	5.2	1.7	40	3.5

Information on the site

a. Profile number: 6

b. Classification:

U.S.D.A.: Ustoxic Quartzipsamment,

F.A.O.: Ferralic Arenosol

c. Date of examination: 25th March 1985

d. Location: Profile is located 4,900 m from Nyamengere river - University Farm access bridge along the main farm road to Lugala farm block Eastern boundary 300m Westwards. UTM Code 37M 00 468489.

e. Elevation: 520m a.s.l.

f. Landform:

(i) physiographic position: plateau of middle slope

(ii) surrounding landform: undulating

(iii) micro-topography: surrounded by low, eroded anthills

g. Slope on which profile is sited: Gently sloping (3%)

h. Land use: There was evidence of hoe cultivation of maize, no fertilizers are used; the crop looked deficient of nitrogen

i. Vegetation: Completely cleared out for cultivation

General information on the soil

a. Parent material: Iron rich quartz and shists

b. Drainage: moderately well drained - Class 3

c. Moisture conditions in the profile: moist throughout

d. Depth of groundwater table: more than 3m

e. Presence of surface stones and rock outcrops: none

f. Evidence of erosion: none

g. Presence of salt alkali: none

h. Human influence: This is limited to old sisal cultivation and present hoe cultivation. Annual burning of crop residues and weeds darkness the A horizon and increases infiltration reducing surface run-off drainage.

Profile description

Ap 0-10 cm: Dark yellowish brown (10YR 3/4) moist and brown (10YR 5/3) dry, loose very fine single grain sand; not sticky, not plastic (wet), loose (moist), loose (dry); many medium roots; abrupt smooth boundary.

AB 10–22 cm: Very dark grayish brown (10YR 3/3) moist and brown (10YR 5/3) dry, loamy sand; with few fine faint diffuse grayish brown mottles; weak very fine prismatic; slightly sticky, slightly plastic (wet), very friable (moist), slightly hard (dry); many medium roots; few small soft iron concretions; abrupt smooth boundary.

BAg 22–47 cm: Dark yellowish brown (10YR 3/4) moist and brown (7.5YR 5/4) dry, sandy loam; with common medium distinct clear yellowish red mottles; weak medium prismatic, slightly sticky, slightly plastic (wet), friable (moist), very hard dry; few tubular random pores; common fine roots; frequent large hard iron concretions; few fine gravels; clear smooth boundary.

$2Bsg_1$ 47–110 cm: Dark yellowish brown (10YR 4/3) moist and yellowish red (5YR 4/6) dry, sandy clay; with common coarse distinct clear yellowish brown mottles; moderate coarse prismatic; sticky, plastic (wet), firm (moist), hard (dry); very frequent large soft iron concretions; very frequent fine gravels.

$2Bsg_2$ 110–200+ cm: The same as Bsg_1 above except for coarse structure and severe mottling.

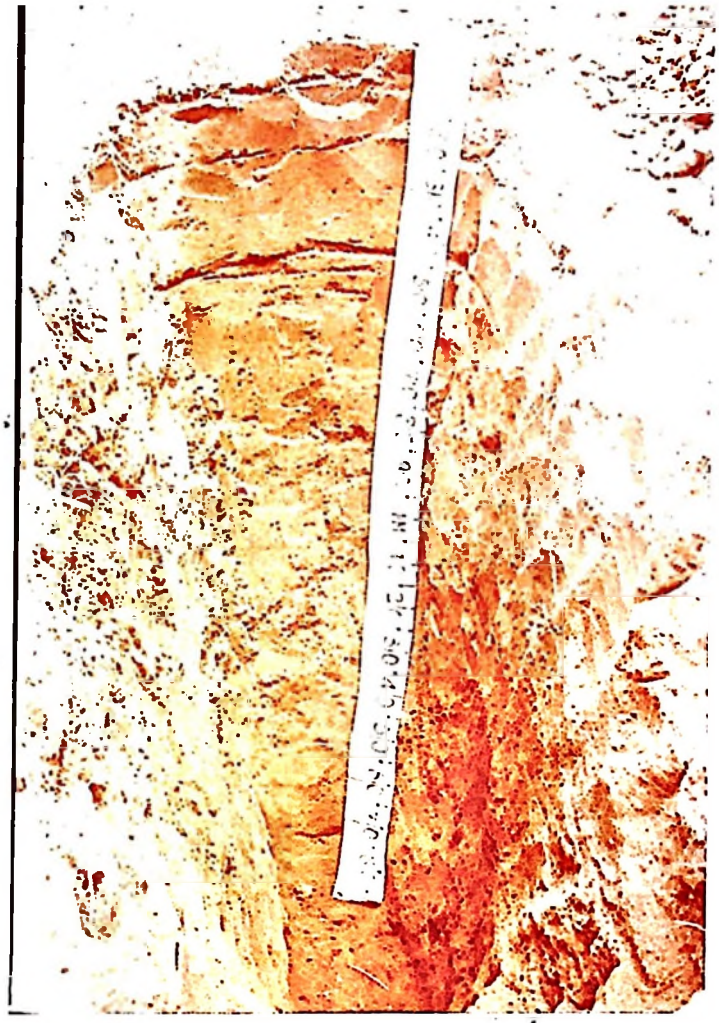

Plate 6: Soil profile number 6

SOIL ANALYTICAL DATA

Mapping Unit: $23A_1$ Profile number 6 Date of sampling: 25/3/83

Sample number	Depth (cm)	Horizon	Particle size distribution			Textural Class	Silt/Clay
			Sand (%)	Silt (%)	Clay (%)		
61	0-10	Ap	91	2	7	S	0.29
62	10-22	AB	87	2	11	LS	0.18
63	22-47	BA	82	3	15	SL	0.20
64	47-110	Bs_1	55	3	42	SC	0.07
65	110-200	Bs_2	55	3	42	SC	0.07

Bulk density (g/cm^3)	Particle density (g/cm^3)	Porosity (%)	Water content weight % and cm depth at various suctions (bars)					
			1/3 bar = FC		15 bars = PWP		Avail. Water capacity	
			(%)	(cm)	(%)	(cm)	(%)	(cm)
1.34	2.59	48	11.2	1.1	1.6	0.2	9.6	1.3
1.44	2.67	46	12.4	1.5	5.3	0.6	7.1	1.2
1.53	2.62	42	16.9	4.2	8.7	2.2	8.2	3.1
1.49	2.33	36	28.3	17.9	22.5	14.2	5.8	4.1
1.49	2.33	36	28.3	25.5	22.5	20.3	5.8	7.8

Sample number	O.C.%	N%	Exchangeable cations (me/100g soil)					Sum bases	C.E.C. soil sum	Sum bases me/100 g clay	C.E.C. me/100 g clay
			Na	K	Ca	Mg	H(+)				
61	1.92	0.08	0.07	0.86	0.87	1.51	3.7	3.31	7.0	14	30
62	1.40	0.04	0.10	0.84	0.77	1.23	9.1	2.94	12.0	19	76
63	1.00	0.05	0.26	0.48	0.64	1.39	5.4	2.77	8.2	13	37
64	0.40	0.06	0.40	0.59	0.82	4.86	6.4	6.67	3.1	13	25
65	0.40	0.06	0.40	0.59	0.82	4.86	6.4	6.67	3.1	13	25

Sample number	pH		Exchangeable Sodium %	Base Saturation %	Available P (ppm)
	1:1 H_2O	1:2 $CaCl_2$			
61	6.0	5.2	1.0	47	15.8
62	5.4	4.5	0.8	25	3.5
63	5.3	4.1	3.2	34	2.1
64	5.0	4.0	3.0	51	1.8
65	5.0	4.0	3.0	51	11.8

Information on site

a. Profile number: 7

b. Classification:

U.S.D.A.: Fluventic Ustropepts

F.A.O.: Eutric Fluvisol

c. Date of examination: 10th August, 1983

d. Location: About 4, 400 metres from the Ngerengere river-University farm access bridge along the main road to Lugala farm block Western boundary about 300 metres North-Eastwards approximately 7.5 kms from Morogoro town. UTM Code 37M CC 468487.

e. Elevation: 525m a.s.l.

f. Landform:

(i) physiographic position: valley bottom

(ii) surrounding land form: flat

(iii) microtopography: levees

g. Slope on which profile is sited: flat (1.5%)

h. Land use: At the time of the survey the land had just been harvested of maize and still had cassava and beans in nearby fields.

i. Vegetation: No vegetation was seen at the site apart from crop residues.

General information on the soil

a. Parent material: successive colluvial sands and silts

b. Drainage: Well to moderately well drained

c. Moisture conditions in the profile: Moist up to 100 cm depth becoming more moist with increased depth.

d. Depth of groundwater: About 3-4 metres as evidenced in the well 40 m away

e. Presence of surface stones and rock outcrops: none

f. Evidence of erosion: none dectected

g. Presence of salt or alkali: none but suspected in subsoil

h. Human influence: Continuous cultivation of the soils as moisture is not limiting i.e. short duration and low moisture demanding crops like beans and sweet potatoes were planted after the main rains in July. The plow layer looks fertile because of the organic matter content due to decomposition, burning and colluvial deposits of clay and silt.

Profile description

Ap 0-15 cm: Very dark gray (10YR 3/1) moist and dark brown (10YR 4/3) dry sandy clay loam; moderate medium crumb to weak medium granular; plastic (wet), friable (moist), slightly hard (dry);

coarse vesicular exped and medium inped pores due to insect activity and clay dispersion by floods; small soft manganese concretions; many medium roots; abrupt smooth boundary.

Au_1 15-30 cm: Dark brown (10YR 3/3) moist and brown to dark brown (10YR 4/3) dry, sandy clay loam; strong medium angular blocky; sticky, plastic (wet), firm (moist), very hard (dry); many coarse exped, few medium inped tubular pores; patchy, common medium roots, very few fine gravels, clear smooth boundary.

Au_2 30-40 cm: Brown to dark brown (7.5YR 4/4) moist and dark reddish brown (5YR 3/4) dry, sandy; loose (dry); few fine gravelly sands; many fine roots; clear smooth boundary.

Bc 40-62 cm: Dark brown (7.5YR 3/2) moist and dark reddish brown (5YR 3/2) dry, sandy loam; weak coarse sub-angular, firm (dry); common very fine vertical exped, many vertical inped pores; weakly cemented; very few fine gravel; few fine roots.

C 62-92/100 cm: Dark reddish brown (5YR 3/3) moist and yellowish red (5YR 4/8) dry, sand; massive structureless, not plastic (wet), loose (moist), very few very fine roots; clear wavy boundary to underlying horizon.

2BC 92/100-110 cm: Very dark gray (5YR 3/1) moist and dary reddish brown (5YR 3/2) dry, sandy loam; weak medium subangular blocky; no roots; lower boundary gradual and wavy.

2Cb 110-200+ cm: Dark reddish brown (5YR 3/4) moist and reddish brown (5YR 4/4) dry, single grain sand; structureless loose, no roots sand extends deeper than 200 cm.

SOIL ANALYTICAL DATA

Mapping Unit: $14B_1$ Profile number 7 Date of sampling: 10/8/83

Sample number	Depth (cm)	Horizon	Particle size distribution Sand %	Silt %	Clay %	Textural Class	Silt/Clay
71	0-15	Ap	70	10	20	SCL	0.50
72	15-30	Au_1	72	6	22	SCL	0.27
73	30-40	Au_2	90	4	6	S	0.56
74	40-62	BC	78	4	18	SL	0.50
75	62-92	C	90	2	8	S	0.26
76	92-110	2Bc	80	6	14	SL	0.38
77	110-200+	2Cb	90	2	8	S	0.25

Bulk density (g/cm^3)	Particle density (g/cm^3)	Porosity (%)	Water content weight % and cm depth at various suctions (bars) 1/3 bar = FC (%)	(cm)	15 bars = PWP (%)	(cm)	Avail. Water capacity (%)	(cm)
1.10	2.61	58	28.3	8.7	11.1	1.7	17.2	2.8
1.51	2.63	43	29.8	4.5	8.5	1.3	21.3	4.8
1.44	2.65	46	35.5	1.0	2.4	0.2	33.1	4.8
1.61	2.63	39	22.8	5.0	2.4	0.5	20.4	7.2
1.50	2.65	43	21.5	6.5	1.2	0.4	20.3	9.1
1.48	2.65	44	23.0	4.2	7.8	1.4	16.5	21.1
1.42	2.65	46	18.6	16.8	2.1	1.9	16.5	21.1

Sample number	O.C.%	N%	Exchangeable cations (me/100g soil)					Sum bases	C.E.C. soil sum	Sum bases me/100 g clay	C.E.C. me/100 g clay
			Na	K	Ca	Mg	H(+)				
71	0.77	0.18	0.10	3.88	9.90	3.39	4.2	17.27	21.5	78	98
72	0.54	0.06	0.08	2.76	7.68	2.60	3.6	13.12	6.7	55	70
73	0.08	0.04	0.07	0.85	1.89	1.05	0.5	3.86	4.4	62	70
74	0.05	0.05	0.08	0.98	4.22	2.32	2.7	7.60	10.3	42	57
75	0.07	0.03	0.07	0.55	1.62	1.15	0.5	3.39	3.9	40	46
76	0.02	0.04	0.18	0.78	4.84	2.63	2.7	8.43	11.1	59	79
77	0.01	0.05	0.45	0.73	2.46	1.71	3.0	5.35	8.4	67	104

Sample number	pH		Exchangeable Sodium %	Base Saturation %	Available P (ppm)
	1:1 H_2O	1:2 $CaCl_2$			
71	6.6	6.1	0.5	80	41.3
72	6.7	6.1	0.5	79	8.1
73	6.9	6.1	1.6	89	17.5
74	6.6	6.0	0.8	74	trace
75	6.9	6.1	1.8	84	10.2
76	6.8	6.1	1.6	75	7.0
77	7.1	6.1	5.4	64	14.0

Information on the site

a. Profile number: 8

b. Classifcation :

U.S.D.A.: Aquic Quartzipsamments

F.A.O.: Ferralic Arenosol

c. Date of examination: 10th August 1983

d. Location: about 7 kms from Morogoro town through ex-Mafiga sisal factory along main access farm road. UTM Code 37M CC 463491.

e. Elevation: 530 m a.s.l.

f. Landform:

(i) physiographic position - plateau

(ii) surrounding landform - undulating

(iii) microtopography - naturally depressed

g. Slope on which profile is sited: gently sloping (3%)

h. Land use: Not presently cultivated. The soil is subjected to annual fires darkening the A horizon.

i. Vegetation: Grasses - Panicum Loratum, Andropogonoid,

Shrubs - Phyllanthus Maderaspatensis, Combretum I

Trees - Pteleopsis Myrtifolia, Dalbergia Melanosylon, Lonchocarpun Capassa.

General information on the soil

a. Parent material: gneiss

b. Drainage: well drained in top soil except subsoil

c. Moisture conditions in the profile: moist throughout

d. Depth of groundwater: Unknown but not more than 4m

e. Presence of surface stones and rock outcrops: none

f. Evidence of erosion: none detected

g. Presence of salt or alkali: none

h. Human influence: Previously sisal cultivated, now annually burnt of grasses and sometimes hoe cultivated for maize and beans.

Profile description:

Ap 0-10 cm: Very dark grayish brown (10YR 3/2) moist and very dark grayish brown (10YR 3/2) dry, sand; structureless; non sticky, non plastic (wet), loose (moist), loose (dry); many medium roots; abrupt smooth boundary.

Au 10-25 cm: Dark brown (10YR 3/3) moist and brown (10YR 4/3) dry, sand; structureless; non sticky, non plastic (wet), loose (moist), loose (dry); many medium roots; gradual smooth boundary.

AB 25-45 Dark yellowish brown (10YR 3/4) moist and brown (10YR 4/3) dry, sand; with few fine faint yellowish red mottles; structureless; non sticky, non plastic (wet), loose (moist), large soft iron-manganese concretions; few coarse roots; gradual wavy boundary.

Bsg_1 45-120 cm: Brown (10YR 4/3) moist and brown 7.5YR 4/4) dry, sandy loam; with common medium distinct clear yellowish brown mottles; weak coarse subangular blocky; slightly sticky, slightly plastic (wet), friable (moist), slightly hard (dry); large soft iron oxide concretions; common tubular and many medium tubular exped pores; few fine roots; abrupt smooth boundary (for sampling purposes).

Bsg_2 120-200+ cm: The same as Bsg_2 above except for more mottling with depth due to occasional flooding by seasonal stream.

SOIL ANALYTICAL DATA

Mapping unit: $23A_1$ — Profile number 8 — Date of sampling: 10/8/83

Sample number	Depth (cm)	Horizon	Particle size distribution			Textural Class	Silt/Clay
			Sand (%)	Silt (%)	Clay (%)		
81	0-10	Ap	94	2	4	S	0.50
82	10-25	Au	92	4	4	S	1.00
83	25-45	ABg	90	4	6	S	0.67
84	45-120	Bsg_1	82	2	16	SL	0.13
85	120-150	Bsg_2	82	2	16	SL	0.13

Bulk density (g/cm^3)	Particle density (g/cm^3)	Porosity (%)	Water content weight % and cm depth at various suctions (bars)					
			1/3 bar = FC		15 bars = PWP		Avail. Water capacity	
			(%)	(cm)	(%)	(cm)	(%)	(cm)
1.51	2.63	42	8.4	0.8	2.7	0.3	5.7	0.9
1.56	2.66	41	8.4	1.3	2.4	0.4	6.0	1.4
1.48	2.64	44	8.1	1.6	3.7	0.7	4.7	1.3
1.50	2.64	43	9.4	7.0	5.6	4.2	3.8	4.3
1.50	2.64	43	9.4	2.8	5.6	1.7	3.8	1.7

Sample number	O.C.%	N%	Exchangeable cations (me/100g soil)					Sum bases	C.E.C. soil sum	Sum bases me/100 g clay	C.E.C. me/100g clay
			Na	K	Ca	Mg	H(+)				
81	0.40	0.05	0.50	0.43	1.02	1.50	1.3	3.45	4.8	68	93
82	0.26	0.06	0.33	0.32	0.48	0.87	1.3	1.97	3.3	37	106
83	0.39	0.04	0.35	0.29	0.72	0.69	2.3	2.05	4.4	38	55
84	0.27	0.04	0.58	0.52	0.41	1.46	3.3	2.97	6.3	16	34
85	0.27	0.04	0.58	0.52	0.41	1.46	4.2	2.97	7.2	17	41

Sample number	pH		Exchangeable Sodium %	Base Saturation %	Available P (ppm)	Exchangeable Aluminium * (ppm)
	1:1 H_2O	1:2 $CaCl_2$				
81	5.8	5.6	10.4	73	3.5	0.2
82	5.6	4.8	10.0	38	trace	0.2
83	5.4	4.5	8.0	69	2.1	0.2
84	4.9	4.0	9.2	48	trace	6.0
85	4.9	4.0	8.1	42	trace	6.0

* By Black (1965) - method.

Information on the site

a. Profile number: 9

b. Classification:

U.S.D.A.: Aquic Tropofluvent

F.A.O.: Eutric Fluvisol

c. Date of examination: 23rd March 1983

d. Location: Profile is sited 100m before the Ngerengere - University farm access bridge, 18 metres Southwestwards UTM Code 37M CC 484458.

e. Elevation: 490 m a.s.l.

f. Landform:

(i) physiographic position: flood plain

(ii) Surrounding landform: flat

(iii) microtopography: leeves partially artificial because of surrounding road creates bank.

g. Slope on which profile is sited: Flat (0-1%) towards the Ngerengere river

h. Land use: The surrounding land is under annual rice how cultivation. The straws and weeds are dried and burnt by local cultivators therefore no records of yields and rotations were available.

i. Vegetation: This had been cleared and cleaned through weeding.

General information on the soil

a. Parent material: Colluvial alluvial deposits

b. Drainage: imperfectly drained as capillarly fringe was barely 78 cm deep .

c. Moisture conditions in the profile: Moist in upper 32 cm very moist from 32 to 78 cm and wet below this depth.

d. Depth of groundwater: Fluctuates between 110 cm in dry season and 0 cm in the wet season when field is flooded.

e. Presence of surface stones and rock outcrops: none

f. Evidence of erosion: none

g. Presence of salt or alkali: none detected but possible

h. Human influence: The annual tillage of the land with a hand hoe and burning of crop residues gives a crumby structure and a dark colour in the surface horizons, although reduction due to waterlogging is also partly responsible for the dark colour.

Profile description

Ap 0-15 cm: Very dark grayish brown (10YR 3/2) and dark brown (10YR 3/3) dry, sandy loam; weak medium crumb; slightly sticky, loose (wet), slightly firm (dry); many fine and medium roots; very few small soft manganese concretions; clear smooth boundary.

AB 15-32 cm: Dark yellowish brown (10YR 3/4) moist and dark brown (10YR 3/3) dry, sandy clay loam; moderate coarse angular blocky, slightly (wet), slightly friable (moist), slightly hard (dry), many medium roots; few soft small manganese concretions; clear smooth boundary.

Btg 32-45 cm: Very dark gray (10YR 3/1) moist and dark brown (10YR 3/3) dry, clay; with few fine distinct yellowish brown mottles, moderate coarse angular blocky sticky, slightly plastic (wet), slightly friable (moist), slightly hard (dry); many medium roots; few soft small manganese concretions; abrupt smooth boundary.

BCg 45-78 cm: Dark brown (10YR 3/3) moist and dark brown (10YR 3/3) with reddish brown mottles dry, fine sandy clay loam; with common medium distinct diffuse yellowish brown mottles; weak coarse angular blocky, sticky, plastic (wet), slightly friable, (moist), common fine roots; clear smooth boundary.

CBg below 78 cm: Dark brown (10YR 3/3) dry, sandy clay loam; with weak many medium prominent yellowish brown mottles; weak, angular blocky sandy loam; sticky, plastic (wet), very friable (moist), hard (dry), few very fine roots; gradual smooth boundary follows water table topography.

Plate 7: Soil profile number 9

SOIL ANALYTICAL DATA

Mapping unit: $11C_1$ — Profile number 9 — Date of sampling: 23/3/83

Sample number	Depth (cm)	Horizon	Particle size distribution			Textural Class	Silt/ Clay
			Sand (%)	Silt (%)	Clay (%)		
91	0-15	Ap	68	16	16	SL	1.00
92	15-32	AB	57	18	25	SCL	0.72
93	32-45	Bu	39	16	45	C	0.36
94	45-78	BCr	59	10	31	SCL	0.36
95	78-110+	CBr	73	7	20	SCL	0.35

Bulk density (g/cm^3)	Particle density (g/cm^3)	Porosity (%)	Water content weight % and cm depth at various suctions (bars)					
			1/3 bar = FC		15 bars = PWP		Avail. Water capacity	
			(%)	(cm)	(%)	(cm)	(%)	(cm)
1.03	2.49	59	31.7	4.8	16.4	2.5	15.4	2.4
1.15	2.42	52	32.2	5.5	18.7	3.2	13.5	2.6
1.13	2.26	50	40.3	5.2	28.3	3.7	12.0	1.8
1,52	2.44	38	35.3	11.6	24.2	8.0	11.1	5.6
1.43	2.51	43	28.7	9.2	15.7	5.0	13.0	5.9

Sample number	O.C.%	N%	Exchangeable cations (me/100g soil)					Sum bases	C.E.C. soil sum	Sum bases me/100 g clay	C.E.C. me/100 g clay
			Na	K	Ca	Mg	H(+)				
91	2.45	0.08	0.78	1.40	12.15	8.91	5.8	23.28	29.1	114	143
92	2.05	0.13	0.98	0.51	7.40	10.58	9.1	19.47	28.6	63	93
93	1.34	0.10	1.22	0.31	9.11	13.00	7.2	23.64	30.8	47	61
94	0.81	0.06	0.89	0.32	8.74	11.44	5.8	21.39	27.2	64	81
95	0.73	0.06	0.64	0.28	6.45	8.26	4.1	15.63	19.7	71	90

Sample number	pH		Exchangeable Sodium %	Base Saturation %	Available P(ppm)
	1:1 H_2O	1:2 $CaCl_2$			
91	6.4	6.0	2.7	80	60.9
92	6.5	5.9	3.4	68	28.4
93	6.7	6.0	4.0	77	3.2
94	6.6	5.9	3.3	79	6.7
95	6.9	6.3	3.2	79	21.0

Information on the site

a. Profile number: 10

b. Classification:

U.S.D.A.: Typic Rhodustalf

F.A.O.: Eutric Nitosol

c. Date of examination: 26th March 1983

d. Location: Profile is located 300 m from Morogoro - Iringa road towards the University farms Mafiga compound 100 Westwards. UTM Code 37M: CC 498456 about 1 km from Morogoro township boundary.

e. Elevation: 505m a.s.l.

f. Landform:

(i) physiographic position: plateau of lower slopes

(ii) surrounding land form: undulating

(iii) microtopography: nil

g. Slope on which profile is sited: gently sloping (4%)

h. Land use: Presently under fallow and used as grazing land

i. Vegetation: Tree - Markamia Obstusfolia Lonchocarpun Capassa

Grass - Andropogonois, Pennisetum Polystachyan

Herb - Lactuca Capansis, Trichodesma Zeylanicum

Shrub - Cordia Ovalia, Abatilon Mauritanum Lantana camara, Maerua Kirkii, Ocimum Basilicum

General information on the soil

a. Parent material: Sandstone

b. Drainage: Very well drained - Class 4

c. Moisture conditions in the profile: Dry throughout

d. Depth of groundwater: Unknown but very deep

e. Presence of surface stones and rock outcrops: None

f. Evidence of erosion; Moderate sheet erosion evident by exposed grass roots

g. Presence of salt or alkali: Nil

h. Human influence: Limited to old sisal planting and presently grazing and burning of annual grasses.

Profile description

Ap 0-15 cm: Dark reddish brown (5YR 3/4) moist and brown to dark brown (7.5YR 4/4) dry, sandy clay loam; moderate medium crumb; sticky, plastic (wet), friable (moist), hard (dry), many medium roots; very few fine gravels; diffuse smooth boundary.

ABs 15–40 cm: Dark reddish brown (2.5YR 3/4) moist and dark red (2.5YR 3/6) dry, sandy clay; weak medium subangular blocky; sticky, plastic (wet), friable (moist), hard (dry); common tubular vertical pores; many medium roots; very few fine gravels; diffuse wavy boundary.

Bws 40–100 cm: Dark red (2.5YR 3/6) moist and red (2.5YR 4/6) dry, sandy clay loam; moderate medium subangular blocky; sticky, plastic (wet), friable (moist), hard (dry); common tubular random pores; common fine roots; few fine gravel; clear smooth boundary to lithic contact.

Cms 100–105 cm: Sandstone, loose

R below 105 cm: Sandstone hard.

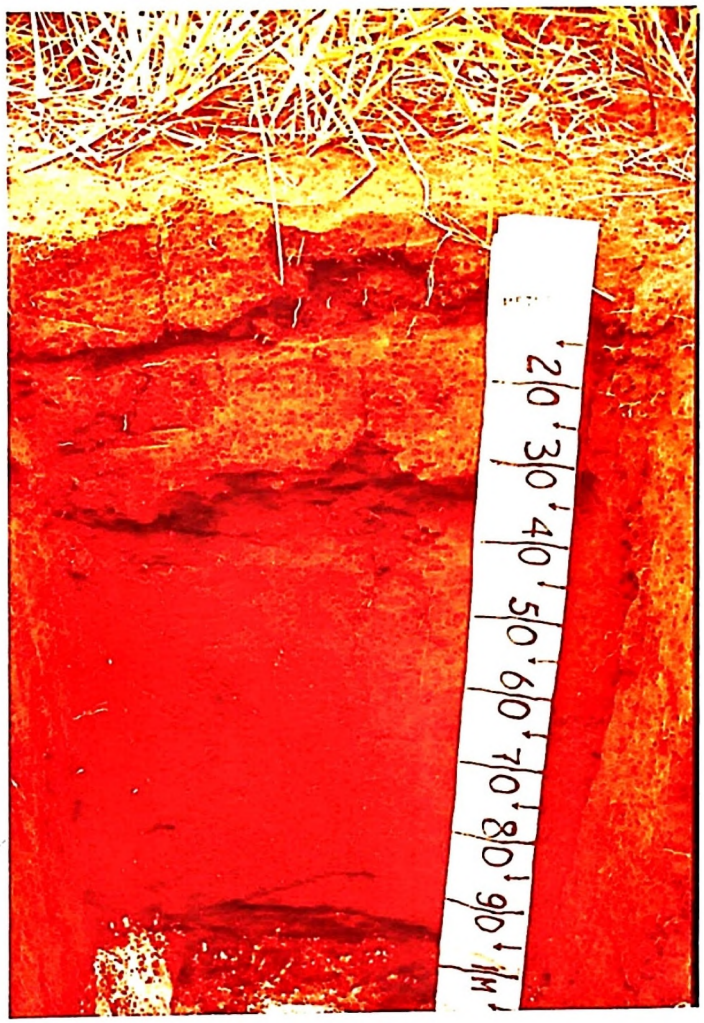

Plate 8: Soil profile number 10

SOIL ANALYTICAL DATA

Mapping unit: 240_1 — Profile number 10 — Date of sampling: 26/3/83

Sample number	Depth (cm)	Horizon	Particle size distribution			Textural Class	Silt/ Clay
			Sand (%)	Silt (%)	Clay (%)		
101	0–15	Ap	63	5	32	SCL	0.23
102	15–40	ABs	60	2	38	SC	0.36
103	40–100	Bws	69	7	24	SCL	0.50
104	100–105	Cms	69	7	24	SCL	0.50

Bulk density (g/cm^3)	Particle density (g/cm^3)	Porosity (%)	Water content weight % and cm depth at various suctions (bars)					
			1/3 bar = FC		15 bars = PWP		Avail. Water capacity	
			(%)	(cm)	(%)	(cm)	(%)	(cm)
1.13	2.70	58	21.5	3.2	10.5	1.6	11.0	1.9
1.18	2.57	54	22.8	5.7	14.4	3.6	8.4	2.5
1.25	2.50	50	28.3	17.0	15.3	9.2	13.1	9.8
1.25	2.50	50	28.3	17.0	15.3	9.2	13.1	1.1

Sample number	O.C.%	N%	Exchangeable cations (me/100g soil)					Sum bases	C.E.C. soil sum	Sum bases me/100 g clay	C.E.C. me/100g clay
			Na	K	Ca	Mg	H(+)				
101	1.97	0.10	0.12	1.07	4.97	4.04	4.4	10.20	14.6	30	43
102	0.99	0.08	0.14	0.14	4.56	4.15	5.1	8.99	14.1	26	41
103.	0.70	0.06	0.19	0.17	2.72	4.40	2.8	7.48	10.3	26	35
104	0.70	0.06	0.19	0.17	2.72	3.95	5.0	7.03	12.0	25	43

Sample number	pH		Exchangeable Sodium %	Base Saturation %	Available P(ppm)
	1:1 H_2O	1:2 $CaCl_2$			
101	6.5	6.1	0.8	70	6.3
102	6.4	6.0	1.0	64	1.8
103	6.77	6.4	1.9	73	1.8
104	6.55	6.2	1.6	58	1.8

Information on the site

a. Profile number: 11

b. Classification:

U.S.D.A.: Typic Rhodulstalf

F.A.O.: Eutric Nitosol

c. Date of examination: 18th August 1983

d. Location: About 2 kms from Morogoro township boundary along Iringa road 500m Westwards. UTM Code 37M CC 492447.

e. Elevation: 495m a.s.l.

f. Landform:

(i) physiographic position. convex slope

(ii) surrounding landform: undulating

(iii) microtopography: nil

g. Slope on which profile is sited: gently sloping (4%)

h. Land use: The land is tractor cultivated for maize annually. No details on yields and management practices were available as cultivation is done by squatters.

i. Vegetation: The original one has been cleared but the following regrowth was evident.

Grasses - Andropogonoid, Cynodon

Herbs - Clorotaria sp., Lactua Capansis

Shrubs - Abutilon Mauritianum, Codia Ovalis, Ocimum Bacilicum

Tree - Lonchocarpun Capassa

General information on the soil:

a. Parent materials: Gneiss; schist

b. Drainage: Well drained - class 4

c. Moisture conditions in the profile: moist throughout

d. Depth of groundwater table: Very deep

e. Presence of surface stones and rock outcrops: Minor gravel patches, moist stones are hardened concretes from old construction work.

f. Evidence of erosion: sheet at the crest

g. Presence of salt or alkali: none

h. Human influence: Tractor ploughing has created a porous friable well aerated crumby top soil

Profile description:

Ap 0-17 cm: Dark reddish brown (5YR 3/3) moist and reddish brown (5YR 4/4) dry, sandy clay loam; moderate medium subangular blocky and crumb; sticky, plastic (wet), friable (moist), slightly hard (dry); many medium roots; clear smooth boundary.

ABs 17-37/55 cm: Dark red (2.5YR 3/6) moist and dark red (2.5YR 3/6) dry sandy clay loam; strong very coarse angular blocky; sticky, plastic (wet), friable (moist), hard (dry); common medium vesicular inped pores; gradual wavy boundary.

Bts_1 37/55-87 cm: Dark red (2.5YR 3/6) moist and red (2.5YR 4/6) dry, sandy clay; moderate subangular blocky; slightly sticky, plastic (wet), firm (moist), very hard (dry); common medium vertical tubular pores; few very fine roots; clear smooth boundary.

Bts_2 87-137 cm: Red (2.5YR 4/6) moist and red (2.5YR 4/8) dry, sandy clay; coarse subangular blocky; plastic (wet), firm friable (moist), very hard (dry); common medium vertical tubular pores; few very fine roots; artificial boundary for sampling purposes.

Bts_3 137-200+ cm: Red (2.5YR 4/6) moist and red (2.5YR 4/8) dry, sandy clay; coarse subangular blocky due to high moisture content; sticky, plastic (wet), friable (moist), very hard (dry); common medium vertical tubular pores; very few very fine roots; artificial boundary for sampling purposes as horizon continues.

SOIL ANALYTICAL DATA

Mapping Unit: $24B_1$ Profile number 11 Date of sampling: 11/8/83

Sample number	Depth (cm)	Horizon	Particle size distribution			Textural class	Silt/ Clay
			Sand (%)	Silt (%)	Clay (%)		
111	0-17	Ap	72	7	21	SCL	0.33
112	17-37/55	ABs	60	6	34	SCL	0.18
113	37/55-87	Bts_1	56	6	38	SC	0.16
114	87-137	Bts_2	56	8	36	SC	0.22
115	137-200+	Bts_3	56	8	36	SC	0.22

Bulk density (g/cm^3)	Particle density (g/cm^3)	Porosity (%)	Water content weight % and cm depth at various suctions (bars)					
			1/3 bar = FC		15 bars = PWP		Avail. Water capacity	
			(%)	(cm)	(%)	(cm)	(%)	(cm)
1.34	2.63	49	22.0	3.7	8.7	1.5	13.3	3.0
1.44	2.60	45	23.5	4.7	13.0	2.6	10.5	3.0
1.53	2.65	42	28.0	14.0	13.6	6.8	14.4	11.0
1.49	2.64	44	30.0	15.0	11.6	5.8	18.4	13.7
1.49	2.64	44	30.0	18.9	11.6	7.3	18.4	17.3

Sample number	O.C.%	N%	Exchangeable cations (me/100g soil)					Sum bases	C.E.C. soil sum	Sum bases me/100 g clay	C.E.C. me/100g clay
			Na	K	Ca	Mg	H(+)				
111	0.52	0.14	0.15	2.89	5.66	3.95	1.7	12.65	14.4	55	62
112	0.43	0.09	0.17	2.13	2.62	4.56	4.5	9.48	14.0	53	38
113	0.09	0.06	0.20	0.29	2.11	4.60	5.9	7.19	13.1	19	34
114	0.31	0.03	0.21	0.21	1.97	4.82	4.7	7.21	11.9	26	32
115	0.31	0.03	0.21	0.21	1.97	4.82	4.7	7.21	11.9	26	32

Sample number	pH		Exchangeable Sodium %	Base Saturation %	Available P (ppm)
	1:1 H_2O	1:2 $CaCl_2$			
111	6.4	6.0	1.1	88	3.3
112	6.7	6.1	0.2	68	1.1
113	6.0	5.5	1.5	55	1.1
114	6.0	5.6	1.8	61	3.5
115	6.0	5.6	1.8	61	3.5

Information on the site

a. Profile number: 12

b. Classification:

U.S.D.A.: Umbric Tropaqualf

F.A.O.: Humic Luvisol

c. Date of examination: 19th August 1983

d. Location: About 400 metres Northeastwards from the ex-sisal factory buildings. UTM Code 37M CC 489457.

e. Elevation: 495m a.s.l.

f. Landform:

(i) physiographic position: slope break to valley bottom

(ii) surrounding landform: flat to undulating (2%)

(iii) microtopography: depressed by road embarkment 0.5m higher.

g. Slope on which profile is sited: 2%

h. Land use: The area is under pastures but was previously planted of sisal. Some wet land rice is cultivated in an adjacent area downslope.

i. Vegetation: Improved pastures.

General information on the soil:

a. Parent material:

b. Drainage: moderately well to imperfectly drained

c. Moisture conditions in the profile: moist between 0. and 50 cm, wet below.

d. Depth of groundwater table: within 3 m.

e. Presence of surface stones and rock outcrops: nil

f. Evidence of erosion: none detected

g. Present of salt or alkali: suspected in subsoil because of yellowish colouration.

h. Human influence: confined to pasturing for grazing.

Profile description:

Ap 0-20 cm: Very dark gray (10YR 3/1) moist and brown to dark brown (10YR 4/3) dry; sandy clay loam; strong very coarse granular; sticky, plastic (wet), friable (moist), hard (dry); common random inped pores; many medium roots; clear smooth boundary.

Bt 20-50 cm: Very dark grayish brown (10YR 3/2) moist and dark grayish brown (10YR 3/1) dry, sandy clay; strong very coarse sub-angular blocky; very sticky, very plastic (wet), firm (moist), hard (dry); few coarse closed inped pores; very few fine gravels; many fine roots; clear smooth boundary.

$2Bt_1$ 50-100 cm: Dark brown (10YR 3/3) moist and pale brown (10YR 4/3) dry, sandy clay; weak angular blocky; very sticky, very plastic (wet), firm (moist), very hard (dry); patchy thick clay cutans; few coarse closed vesicular pores; small soft Fe-Mn concretions; frequent fine gravels, common fine roots; diffuse smooth boundary.

$2Bt_2$ 100-150 cm: Brown to dark brown (10YR 4/3) moist and pale brown (10YR 4/3) dry, sandy clay; weak, medium prismatic; sticky, plastic (wet), friable (moist), hard (dry); patchy thick clay cutans; common medium exped tubular pores; large soft iron-manganese concretions; very frequent coarse gravels; few fine roots, horizon continues below.

SOIL ANALYTICAL DATA

Profile number 12

Mapping Unit: $12C_1$ Date of sampling: 19/8/83

Sample number	Depth (cm)	Horizon	Particle size distribution			Textural class	Silt/ Clay
			Sand (%)	Silt (%)	Clay (%)		
121	0-20	Ap	64	12	24	SCL	0.50
122	20-50	Bt	48	4	48	SC	0.08
123	50-100	$2Bt_1$	50	2	40	SC	0.04
124	100-150	$2Bt_2$	62	3	35	SC	0.09

Bulk density (g/cm^3)	Particle density (g/cm^3)	Porosity (%)	Water content weight % and cm depth at various suctions (bars)					
			1/3 bar = FC		15 bars = PWP		Avail. Water capacity	
			(%)	(cm)	(%)	(cm)	(%)	(cm)
1.45	2.50	42	36.1	7.2	13.1	2.6	23.0	4.6
1.45	2.45	41	38.1	11.1	22.8	6.8	15.3	4.6
1.70	2.48	31	35.5	17.8	17.0	8.5	18.5	9.3
1.80	2.49	28	28.4	19.2	19.2	8.5	11.4	5.7

Sample number	O.C.%	N%	Exchangeable cations (me/100g soil)					Sum bases	C.E.C. soil sum	Sum bases me/100 g clay	C.E.C. me/100 g clay
			Na	K	Ca	Mg	H(+)				
121	0.96	0.14	1.86	1.38	12.16	9.12	8.8	24.32	31.1	97	128
122	0.49	0.08	7.49	0.40	10.57	13.26	7.1	31.72	38.8	64	78
123	0.35	0.05	15.98	0.34	11.40	15.13	4.0	42.85	46.9	88	96
124	0.26	0.03	19.29	0.44	11.40	14.94	0.9	46.07	47.0	129	132

Sample number	pH		Exchangeable Sodium %	Base Saturation %	Available P (ppm)	Electrical conductivity
	1:1 H_2O	1:2 $CaCl_2$				
121	6.1	5.6	5.0	73	9.1	2.5
122	6.7	5.9	19.3	82	trace	3.8
123	7.7	6.3	34.1	92	1.1	3.6
124	8.2	6.9	41.0	98	3.5	4.6

Information on the site

a. Profile number: 13

b. Classification:

U.S.D.A.: Ustic Quartzipsamments

F.A.O.: Albic Arenosol

c. Date of examination: 12th March 1983

d. Location: Profile is located 50m West of Mazimbu estate road about 800m from the Ngerengere river-Mindu farm block bridge. UTM Code 37M CC 483464.

e. Elevation: 485m a.s.l.

f. Landform:

(i) physiographic position: valley bottom, concave slope

(ii) surrounding landform: undulating

(iii) microtopography: nil

g. Slope on which profile is sited: Gently sloping (3%) towards Ngerengere river

h. Land use: At the time of examination the area had just been sown of maize for experimental purposes. Details on yields and fertilization were not readily available.

i. Vegetation: This has been cleared clean.

General information on the soil

a. Parent material: Colluvial, alluvial materials of uplands

b. Drainage: Somewhat excessively drained

c. Moisture conditions in the profile: Just moist up to 50 cm depth and dry from 50 to 102 cm just moist from 102 to 127 cm and dry from 127-200+ cm.

d. Depth of groundwater: More than 3m

e. Presence of surface stones and rock outcrops: None

f. Evidence of erosion: None detected

g. Presence of salt or alkali: None detected

h. Human influence: The area is annually tractor cultivated. The vegetal matter decomposed imparts dark top soil colours, but the aggregate stability is low and erodibility high due to over preparation of these too light textured soils.

Profile description

Ap 0-20 cm: Very dark gray (10YR 3/1) moist and dark grayish brown (10YR 4/2) dry, loamy sand; structureless slightly sticky, slightly plastic (wet), loose (dry); many fine roots; abrupt smooth boundary.

Au 20-50 cm: Very dark gray (10YR 3/1) moist and dark grayish brown (10YR 4/2) dry, loamy sand; structureless loose (dry); many fine roots; weakly cemented by silica; few fine gravels; abrupt smooth boundary.

C 50-102 cm: Brown to dark brown (10YR 4/3) moist and dary gray (10YR 4/1) dry, sands; structureless loose (dry); frequent fine gravels; clear smooth boundary.

2Ab 102-127 cm: Very dark grayish brown (10YR 3/2) moist and dark gray (10YR 4/1) dry, loamy sand; structureless loose (dry); few fine medium exped pores; common fine roots; abrupt smooth boundary.

2Cb 127-164 cm: Dark grayish brown (10YR 4/2) moist and brown (10YR 5/3) dry, sand; structureless; not sticky, few medium vertical exped between ped surfaces; few fine roots; frequent fine gravels; abrupt smooth boundary.

3Ab 164-220+ cm: Very dark grayish brown (10YR 3/2) moist and dark grayish brown (10YR 3/2) dry, loamy sand; structureless loose dry; few very fine roots.

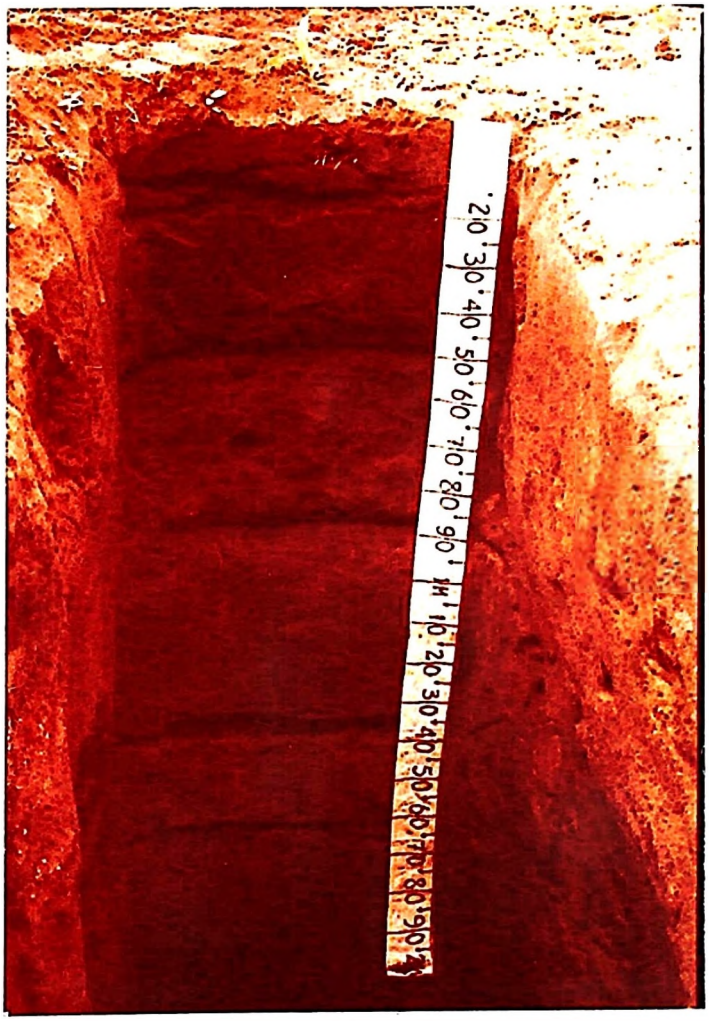

Plate 9: Soil profile number 12

SOIL ANALYTICAL DATA

Mapping Unit: $25A_1$ Profile number 13 Date of sampling: 12/3/83

Sample number	Depth (cm)	Horizon	Particle size distribution Sand (%)	Silt (%)	Clay (%)	Textural class	Silt/Clay
131	0-20	Ap	86	5	9	LS	0.56
132	20-50	Au	86	5	9	LS	0.56
133	50-107	C	97	1	2	S	0.50
134	102-127	2Ab	89	2	9	LS	0.22
135	127-164	2Cb	91	2	7	S	0.29
136	164-200+	3Ab	86	2	11	LS	0.18

Bulk density (g/cm^3)	Particle density (g/cm^3)	Porosity (%)	Water content weight % and cm depth at various suctions (bars) 1/3 bar = FC (%)	(cm)	15 bars = PWP (%)	(cm)	Avail. Water capacity (%)	(cm)
1.15	2.59	54	12.3	2.5	3.5	0.7	8.8	2.0
1.16	2.48	53	11.0	3.3	4.1	1.2	6.9	2.4
1.28	2.65	52	7.2	3.7	1.8	1.0	5.4	3.6
1.21	2.65	54	8.5	2.0	3.7	0.9	4.8	1.2
1.26	2.64	52	7.6	2.8	2.5	0.9	5.0	1.8
1.27	2.68	53	11.9	4.3	5.6	2.0	6.3	2.3

Sample number	O.C.%	N%	Exchangeable cations (me/100g soil)					Sum bases	C.E.C. soil sum	Sum bases me/100 g clay	C.E.C. me/100 g clay
			Na	K	Ca	Mg	H(+)				
131	1.86	0.09	0.12	1.15	2.89	1.23	2.0	5.39	7.4	21	29
132	1.13	0.07	0.12	0.69	2.88	1.02	3.2	4.71	7.9	34	57
133	0.97	0.03	0.06	0.23	0.95	0.77	1.5	2.01	3.5	29	50
134	0.68	0.04	0.13	0.55	2.24	1.51	2.2	4.43	6.6	36	54
135	0.66	0.03	0.12	0.55	1.40	1.33	2.0	3.40	5.4	33	53
136	0.61	0.04	0.11	0.82	2.27	0.69	2.5	3.89	6.4	27	44

Sample number	pH		Exchangeable Sodium %	Base saturation %	Available P (ppm)
	1:1 H_2O	1:2 $CaCl_2$			
131	7.0	6.3	1.6	73	75.6
132	6.3	5.9	1.5	59	56.0
133	6.8	5.8	1.7	57	32.6
134	6.4	6.0	2.0	66	30.8
135	6.2	5.9	2.2	63	14.0
136	5.9	5.6	1.7	61	20.7

Information on the site

a. Profile number: 14

b. Classification:

U.S.D.A.: **Fluvic Psammaquent**

F.A.O.: Eutric Fluvisol

c. Date of examination: 14th March 1983

d. Location: About 100 metres from the University farm - Ngerengere bridge about 70 metres Northwestwards approximately 3.3 kms from Morogoro Township along Iringa road.

e. Elevation: 485m a.s.l.

f. Landform:

(i) physiographic position: flood plain

(ii) surrounding land form: flat 0-2% slope

(iii) microtopography: levees, artificially caused by road work and bridge southwestwards.

g. Slope on which profile is sited: About 1%, almost flat, however the levees caused by earlier flood levels give a sloping direction away from the river.

h. Land use: The land was under rice cultivation at the time of survey. The area is tractor ploughed by local people, immediately after the first rains.

i. Vegetation: This has been cleared clean for cultivation purposes.

General information on the soil

a. Parent material: alluvial deposits of sands and silts mainly

b. Drainage: Poorly drained - Class 1

c. Moisture conditions in the profile: The profile was dry in the upper 25cm, just moist between 25 and 40cm, moist between 40 and 64cm, wet between 64 and 82cm and very wet to the watertable at 130cm.

d. Depth of groundwatertable: It fluctuates from 0cm during the rainy seasons to 130cm during the dry season and 64cm during the short dry spell between the rainy seasons i.e. January to March for 1983.

e. Presence of surface stones and rock outcrops: none

f. Evidence of erosion: none detected

g. Presence of salt or alkali: little effervescence detected with 0.1N HC

h. Human influence: The soil is annually cropped with rice, is very rich in organic matter in the top soil because annual additions of straw.

Profile description

Ap 0-15 cm: Very dark grayish brown (10YR 3/2) moist and very dark grayish brown (10YR 3/2) dry, sandy clay loam; moderate medium angular blocky; sticky, plastic (wet); very friable (moist) slightly hard (dry); few fine exped tubular pores; many medium roots; clear smooth boundary.

AB 15-25 cm: Very dark grayish brown (10YR 3/2) moist and very dark grayish brown (10YR 3/2) dry, sandy clay loam; strong coarse angular blocky; sticky, plastic (wet), friable (moist), firm (dry); common fine tubular pores; common medium roots; clear smooth boundary.

Bg_1 25-40 cm: Very dark grayish brown (10YR 3/2) moist and very dark gray (10YR 3/1) dry, sandy clay loam; with common medium distinct reddish brown mottles; moderate medium columnar; sticky, plastic (wet); firm (moist), extremely hard (dry); common medium exped pores few fine inped pores; common fine roots; clear smooth boundary.

Bg_2 40-64 cm: Very dark grayish brown (10YR 3/2) moist and very dark gray (10Yr 3/1) dry, sandy clay loam; with common medium distinct yellowish brown mottles; moderate medium primatic; very sticky, very plastic (wet), firm (moist), very hard (dry); few fine roots; clear smooth boundary.

CBg 64–82 cm: Dark yellowish brown (10YR 3/4) moist and dark yellowish brown (10YR 3/4) dry sandy clay loam; with many medium distinct diffuse yellowish brown mottles; moderate medium angular to subangular blocky; slightly sticky, plastic (wet), friable (moist), very dry; medium vesicular pores; few very fine roots; gradual smooth boundary.

Cg 82–130 cm: Dark brown (10YR 4/3) moist and dark brown (10YR 4/1) dry, sandy clay loam; with many medium distinct diffuse yellowish brown mottles; structureless; loose (dry); few very fine roots; horizon continues under water.

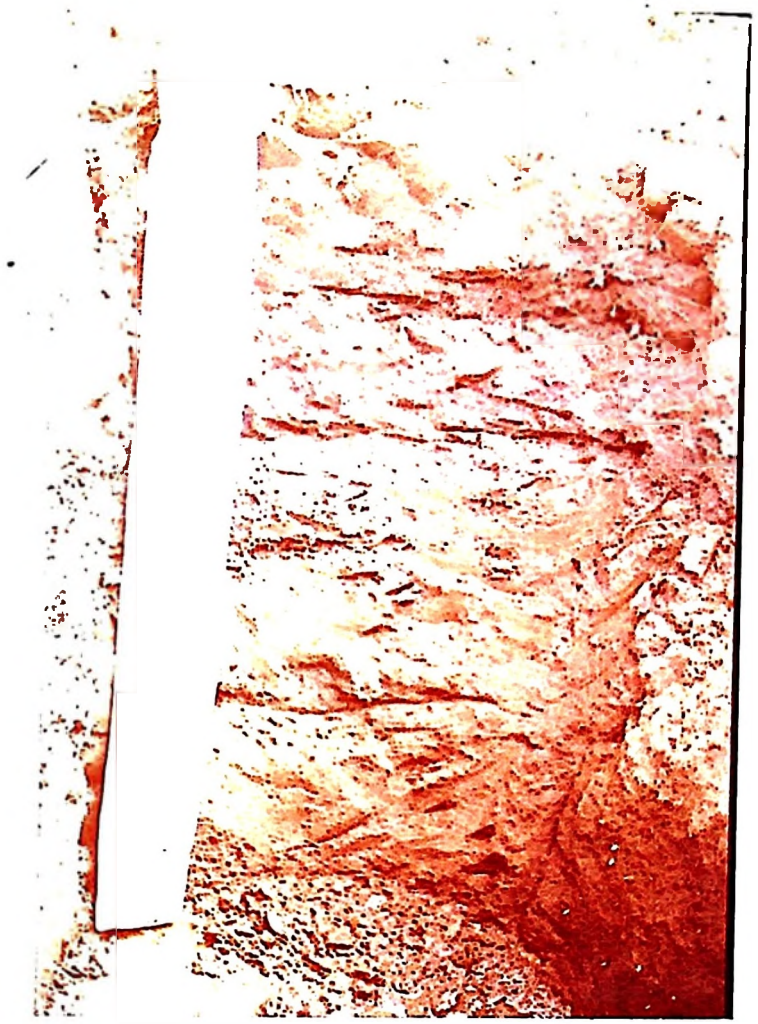

Plate 10: Soil profile number 14

SOIL ANALYTICAL DATA

Mapping Unit: $11C_1$ Profile number 14 Date of sampling: 14/3/83

Sample number	Depth (cm)	Horizon	Particle size distribution			Textural class	Silt/clay
			Sand (%)	Silt (%)	Clay (%)		
141	0-15	Ap	61	16	23	SCL	1.44
142	15-25	AB	64	16	20	SCL	1.25
143	25-40	Bg_1	61	12	27	SCL	0.44
144	40-64	Bg_2	57	12	31	SCL	0.39
145	64-87	CBr	58	7	25	SCL	0.28
146	82-130	Cr	ND	ND	ND	ND	ND

Bulk density (g/cm^3)	Particle density (g/cm^3)	Porosity (%)	Water content weight % and cm depth at various suctions (bars)					
			1/3 bar = FC		15 bars = PWP		Avail. Water capacity	
			(%)	(cm)	(%)	(cm)	(%)	(cm)
1.26	2.48	49	32.9	4.9	13.6	2.0	19.3	3.6
1.43	2.50	43	36.3	3.6	20.0	2.0	16.3	2.3
1.30	2.57	49	33.5	5.0	16.1	2.4	17.4	3.4
1.25	2.51	51	30.0	7.2	18.7	4.5	11.3	3.4
1.22	2.57	53	40.6	7.3	12.1	2.2	28.5	16.7

Sample number	O.C.%	N%	Exchangeable cations (me/100g soil)					Sum bases	C.E.C. soil sum	Sum bases me/100 g clay	C.E.C. me/100 g clay
			Na	K	Ca	Mg	H(+)				
141	2.65	0.19	1.39	0.68	8.41	9.67	6.6	20.20	26.8	65	87
142	2.49	0.18	1.39	0.42	7.83	4.66	6.6	14.30	20.9	50	73
143	1.75	0.10	0.86	0.22	6.84	9.37	5.3	17.29	22.6	52	67
144	1.25	0.06	0.87	0.29	6.88	7.63	3.1	15.67	19.3	42	52
145	0.67	0.05	0.62	0.21	6.56	8.12	4.0	15.51	19.5	56	71
146	ND	0.04	0.48	0.13	6.48	4.31	1.2	11.40	12.6	-	-

Sample number	pH		Exchangeable Sodium %	Base Saturation %	Available P(ppm)
	1:1 H_2O	$CaCl_2$			
141	6.4	5.8	5.2	75	20.0
142	6.6	6.0	6.7	69	17.5
143	6.6	6.1	3.8	77	trace
144	6.8	6.1	4.5	81	4.9
145	6.7	6.3	3.2	78	1.1
146	6.8	6.3	3.8	90	5.3

Information on the site

a. Profile number: 15

b. Classification:

U.S.D.A.: Ustoxic Quartzipsamment

F2A.O.: Ferralic Arenosol

c. Date of examination: 9th August 1983

d. Location: About 4.3 km from Morogoro Township boundary along the Iringa highway through the ex-sisal factory. UTM Code 37M CC 461467.

e. Elevation: 538m a.s.l.

f. Landform:

(i) physiographic position: convex slope

(ii) surrounding landform: rolling

(iii) microtopography: nil

g. Slope on which profile is sited: Rolling 8.5%

h. Land use: The area is burnt annually of vegetation. It is also annually hoe cultivated for intercropped maize sorghum and sweet potatoes between perrenial crop, cassava.

i. Vegetation: The original one has been cleared. The following regrowth was sampled:

Grasses - Eragrostissuperba, Heteropogon Concortus, Rhynchelytrum repens,

Herb - Crolotaria Sp., Lactuca Capansis, Trichodesma Zeylanicum

Climber - Synaptolepsis alternifolia

Trees - Holarrhena Febrifuga, Hymenocardia Acida, Lannea, Ficus Mucuso, Pteleopsis Myrtifolia

General information on the soil

a. Parent material: Predominantly quartzite

b. Drainage: Excessively drained - Class 6

c. Moisture conditions in the profile: Dry throughout

d. Depth of groundwater: Unknown but very deep

e. Presence of surface stones and rock outcrops: None at the site

f. Evidence of erosion: Sheet observed at grass root-soil interface

g. Presence of salt or alkali: None

h. Human influence: Hoe cultivation and annual burning of grasses loosens and darkens plow layer.

Profile description

Ap 0-11 cm: Brown (10YR 4/3) moist and brown (10YR 5/3) dry, fine loamy sand; structureless; non sticky, non plastic (wet), loose (moist), loose (dry); many coarse roots; gradual smooth boundary.

Au 11-28 cm: Dark brown (7.5YR 4/4) moist and brown (7.5YR 5/4) dry, loamy sand; structureless; non sticky, non plastic (wet), loose moist, loose (dry); many medium roots; clear smooth boundary.

AC 28-44 cm: Strong brown (7.5YR 5/6) moist and light brown (7.5YR 6/4) dry, sand; structureless; non sticky, non plastic (wet), (moist), loose (dry); common medium roots; gradual smooth boundary.

Cc_1 44-116 cm: Reddish yellow (5YR 6/8) moist and reddish yellow (5YR 6/6) dry, gravelly sand; structureless; non sticky, non plastic (wet), loose (moist), loose (dry); small hard iron nodules; common medium roots; gradual smooth boundary.

Cc_2 116-175 cm: Reddish yellow (5YR 6/8) moist and reddish yellow (5YR 6/6) dry, coarse loamy sand; structureless; non sticky, non plastic (wet), loose (moist), loose (dry); hard large iron concretions; frequent small stones predominantly gravels; few fine roots; gradual smooth boundary.

$2Cc_3$ 175-200 cm+: Reddish yellow (5YR 6/8) moist and reddish yellow (5YR 6/6) dry, coarse gravelly sand; structureless; non sticky, non plastic (wet), loose (moist), loose (dry); hard large iron concretions; very frequent small stones mixed with coarse gravels; few fine roots; horizon continues.

Plate 11: Soil profile number 15

Mapping Unit: $36A_1$

SOIL ANALYTICAL DATA

Profile number 15

Date of sampling: 9/8/83

Sample number	Depth (cm)	Horizon	Particle size distribution			Textural class	Silt/clay
			Sand (%)	Silt (%)	Clay (%)		
151	0-11	Ap	84	9	7	LS	1.3
152	11-28	Au	84	9	7	LS	1.3
153	28-44	AC	90	6	4	S	1.5
154	44-116	$2Cc_1$	88	8	4	S	2.0
155	116-175	$2Cc_2$	87	7	6	LS	1.2
156	175-200+	$2Cc_3$	ND = Not determined			ND	ND

Bulk density (g/cm^3)	Particle density (g/cm^3)	Porosity (%)	Water content weight % and cm depth at various suctions (bars)					
			1/3 bar = FC		15 bars = PWP		Avail. Water capacity	
			(%)	(cm)	(%)	(cm)	(%)	(cm)
1.38	2.63	48	11.3	1.2	1.9	0.2	9.4	1.4
1.51	2.64	44	11.2	1.9	1.9	0.3	9.3	2.4
1.44	2.64	46	8.0	1.3	2.2	0.4	5.8	1.3
1.52	2.65	43	10.0	7.2	2.9	2.1	7.1	7.8
1.32	2.65	51	12.5	7.4	3.2	1.9	9.4	10.5
Coarse gravels ND = Not determined			ND	ND	ND	ND	ND	ND

Sample number	O.C.%	N%	Exchangeable cations (me/100g soil)					Sum bases	C.E.C. soil sum	Sum bases me/100 g clay	C.E.C. me/100g clay
			Na	K	Ca	Mg	H(+)				
151	0.61	0.06	0.05	0.31	0.84	1.08	1.8	2.28	4.1	19	34
152	0.37	0.06	0.05	0.25	0.40	1.30	2.2	2.00	4.2	22	46
153	0.22	0.03	0.06	0.29	0.19	1.55	1.5	2.09	3.6	28	76
154	0.15	0.03	0.07	0.32	0.15	2.88	1.1	3.38	4.5	58	103
155	0.05	0.03	0.05	0.17	0.10	0.90	1.3	1.22	2.5	19	40

Sample number	pH		Exchangeable Sodium %	Base Saturation %	Available P (ppm)	Exchangeable Aluminium* me/100g soil
	1:1 H_2O	1:2 $CaCl_2$				
151	6.7	5.8	1.2	57	5.6	0.06
152	6.7	5.6	1.2	48	8.4	0.06
153	6.5	5.5	1.1	37	3.3	0.06
154	6.4	4.9	1.2	56	9.3	0.11
155	5.7	4.9	2.0	48	2.1	0.06

* Øien and Gjerdingen (1972) - method.

Information on the site

a. Profile number: 16

b. Classification:

U.S.D.A.: Typic Psammaquent

F.A.O.: Eutric Gleysol

c. Date of examination: 9th August 1983

d. Location: Profile is located about 4,800m from Morogoro Township boundary along Iringa road through the ex-sisal factory. UTM Code 37M CC 478467.

e. Elevation: 500m a.s.l.

f. Landform:

(i) physiographic position: Sloping, drainage line

(ii) surrounding landform: undulating

(iii) microtopography: none

g. Slope on which profile is sited: gentle sloping (3%)

h. Land use: Not cultivated but an adjacent area 50m away is maize cultivated

i. Vegetation: Remnant and successive only.

Grasses - Vetiveria Zizaniodes, Panicum Coloratum, Hyperrhenia Nifa, Eragotis Ciliaris

Herbs - Woltheria Indica, Amaranthaceae, Cleomehirta, Corchorus Aestuans, Leucas Martinicensis Sesamum Angustofolium

Woody climber - Combretum 3

Climber - Jasmimum flumincuse

Sedge - Cyperus

Trees - Have been cleared

General information on the soil

a. Parent material: Predominantly Quartzites

b. Drainage: Imperfectly drained

c. Moisture conditions in the profile: Just moist throughout

d. Depth of groundwater: Within 3m depth

e. Presence of surface stones and rock outcrops: None

f. Evidence of erosion: None detected

g. Presence of salt or alkali: None detected

h. Human influence: Confined to annual burning of grass giving darkish gray top soil colours.

Profile description

Ap (h?) 0-10 cm: Dark gray (10YR 4/1) moist and dark gray (10YR 4/1) dry, sand; structureless with few weak very fine unstable crumbs; non sticky, non plastic (wet), loose dry; many medium roots; clear smooth boundary.

ABg 10-26 cm: Very dark gray (10YR 3/1) moist and very dark gray (10YR 3/1) dry, loamy sand; with few fine faint sharp yellowish red mottles; structureless loose (dry); small soft iron concretions; many fine roots; gradual wavy boundary.

Bug_1 26-52 cm: Black (10YR 4/1) moist and dark gray (10YR 4/1) dry, sandy clay loam with few fine faint sharp ye yellowish red mottles; very coarse angular blocky sticky, plastic (wet), firm (moist), hard (dry); small soft iron concretions; common fine prominent yellowish red mottles; rusty root channels; common fine roots; clear smooth boundary.

Bug_2 52-85 cm: Black (10YR 4/1) moist and dark gray (10YR 4/1) dry, gravelly sandy clay loam with common medium distinct yellowish brown mottles; strong very coarse prismatic; sticky, plastic (wet), hard (dry); big hard iron concretions; rusty roots; gradual wavy boundary.

Csr Below 85 cm: The same as Bug_2 above except for increase in gradual and small stones and severe reduction due to under ground water influence.

Mapping Unit: $22A_2$

SOIL ANALYTICAL DATA

Profile number 16

Date of sampling: 9/8/83

Sample number	Depth (cm)	Horizon	Particle size distribution			Textural Class	Silt/ Clay
			Sand (%)	Silt (%)	Clay (%)		
161	0-10	Ah(?)	92	2	6	S	0.33
162	10-26	ABg	82	6	12	LS	0.50
163	26-52	Bug_1	68	2	30	SCL	0.07
164	52-85	Bug_2	68	2	30	SCL	0.07
165	85+	Csr	ND	ND	ND	ND	ND

Bulk density (g/cm^3)	Particle density (g/cm^3)	Porosity (%)	Water content weight % and cm depth at various suctions (bars)					
			1/3 bar = FC		15 bars = PWP		Avail. Water capacity	
			(%)	(cm)	(%)	(cm)	(%)	(cm)
1.51	2.62	42	16.9	1.7	1.0	0.1	15.9	2.4
1.82	2.58	29	18.9	3.0	4.8	0.8	14.1	4.1
1.71	2.54	33	19.3	5.0	9.0	2.4	10.3	5.0
1.71	2.50	32	17.5	5.8	7.5	2.5	10.0	3.3
ND	ND	ND	ND	ND	ND	ND	ND	ND

Sample number	O.C.%	N%	Exchangeable cations (me/100g soil)					Sum bases	C.E.C. soil sum	Sum bases me/100 g clay	C.E.C. me/100 g clay
			Na	K	Ca	Mg	H(+)				
161	0.65	0.07	0.21	0.55	1.3	0.76	2.2	2.82	5.0	32	55
162	0.61	0.06	0.57	0.22	1.4	1.56	3.3	3.75	7.1	24	45
163	0.78	0.06	2.87	0.39	4.49	7.05	4.0	14.80	18.8	44	56
164	0.78	0.06	2.87	0.39	4.49	7.05	4.0	14.80	18.8	44	56
165	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Sample number	pH		Exchangeable Sodium %	Base Saturations %	Available P (ppm)
	1:1 H_2O	1:2 $CaCl_2$			
161	5.9	5.3	4.2	58	trace
162	6.2	6.1	8.1	53	2.1
163	6.7	5.5	15.3	79	1.8
164	6.7	5.5	15.3	79	1.8
165	ND	ND	ND	ND	ND

Information on the site

a. Profile number: 17

b. Classification:

U.S.D.A.: Ustic Quartzipsamment

F.A.O.: Albic Arenosol

c. Date of examination: 9th August 1983

d. Location: Profile is located at UTM Code 37M CC 480456.

e. Elevation: 498m a.s.l.

f. Landform:

(i) physiographic position: plain

(ii) surrounding land: undulating (3.5%)

(iii) microtopography: nil

g. Slope on which profile is sited: gentle (3.5%)

h. Land use: The land has been cleared for future forestry plantation experiments. There is an Acacia Lubida/maize siviculture experiment adjacently.

General information on the soil

a. Parent material: Colluvial and alluvial deposits

b. Drainage: Excessive to somewhat excessively drained

c. Moisture conditions in the profile: It was just moist in the upper 50 cm because of better moisture retention due to organic matter and dry in the coarse subsoil.

d. Depth to groundwater: Above 2.5 metres

e. Presence of surface stones and rock outcrops: None

f. Evidence of erosion: None detected

g. Presence of salt or alkali: Apparently free

h. Human influence: Annual weeding of grasses through deep plou ploughing to coarse fire breaks as site falls on fire line.

Profile description

Ap 0-14 cm: Very dark grayish brown (10YR 3/2) moist and grayish brown (10YR 5/2) dry, loamy sand; structureless loose (dry); very few coarse gravels; common very fine roots; clear smooth boundary.

Au 14-47 cm: Very dark grayish brown (10YR 3/2) moist and dark grayish brown (10YR 4/2) dry, loamy sand; structureless; loose (dry); very frequent fine gravels; few very fine roots; clear smooth boundary.

AC 47-91 cm: Very dark grayish brown (10YR 3/2) moist and brown to dark brown (10YR 4/3) dry, sand; structureless; loose (dry); very frequent fine gravels; few very fine roots; clear smooth boundary.

C 91-112 cm: Brown to dark brown (10YR 4/3) moist and dark yellowish brown (10YR 4/4) dry, sand; structureless; non sticky, non plastic (wet), loose (moist); loose (dry), many gravels; clear smooth boundary.

2AC 112-154 cm: Dark brown (10YR 3/3) moist and dark brown (10YR 4/3) dry, sand; structureless; non sticky, non plastic (wet), loose (moist, loose very frequent fine gravels; few very fine roots; clear smooth boundary.

2C 154-200+ cm: Brown to dark brown (10YR 4/3) moist and dark yellowish brown (10YR 4/4) dry sand; structureless; non sticky, non plastic (wet), loose many coarse gravels; few very fine roots, horizon continues below this depth.

Mapping Unit: $25A_1$

SOIL ANALYTICAL DATA

Profile number 17

Date of sampling: 9/8/83

Sample number	Depth (cm)	Horizon	Particle size distribution			Textural Class	Silt/ Clay
			Sand (%)	Silt (%)	Clay (%)		
171	0-14	Ap	84	9	7	LS	1.27
172	14-47	Au	88	4	8	LS	0.57
173	47-91	AC	92	2	6	S	0.33
174	91-112	C	94	2	4	S	0.50
175	112-154	2AC	94	2	4	S	0.50
176	154-200+	2C	94	2	4	S	0.50

Bulk density (g/cm^3)	Particle density (g/cm^3)	Porosity (%)	Water content weight % and cm depth at various suctions (bars)					
			1/3 bar = FC		15 bars = PWP		Avail. Water capacity	
			(%)	(cm)	(%)	(cm)	(%)	(cm)
1.40	2.69	48	21.9	3.1	3.3	0.5	18.6	3.6
1.45	2.60	44	21.5	7.0	1.7	0.6	19.8	9.5
1.50	2.65	43	17.2	7.6	1.3	0.6	15.9	10.5
1.52	2.70	43	12.7	3.7	1.5	0.3	11.2	3.6
1.50	2.64	44	17.2	7.4	2.1	0.9	15.1	9.5
1.54	2.72	43	15.6	7.1	2.8	1.3	12.8	9.1

Sample number	O.C.%	N%	Exchangeable cations (me/100g soil)					Sum bases	C.E.C. soil sum	Sum bases me/100 g clay	C.E.C. me/100 g clay
			Na	K	Ca	Mg	H(+)				
171	1.13	0.04	0.11	0.69	2.18	1.70	2.9	4.68	7.6	42	67
172	0.55	0.05	0.09	0.26	1.81	1.79	1.8	3.95	5.8	37	54
173	0.32	0.04	0.17	0.22	1,28	1.48	1.1	3.15	4.3	42	57
174	0.13	0.04	0.27	0.24	0.65	1.16	1.1	2.32	3.4	53	78
175	0.10	0.02	0.18	0.24	0.78	1.14	0.8	2.34	3.1	53	70
176	0.12	0.02	0.17	0.28	0.74	1.08	0.9	2.27	3.2	53	73

Sample number	pH		Exchangeable Sodium %	Base Saturation %	Available P (ppm)
	1:1 H_2O	1:2 $CaCl_2$			
171	5.9	5.2	1.5	62	28.9
172	5.8	5.2	1.6	69	23.1
173	5.9	5.4	4.0	74	16.4
174	6.8	5.5	7.9	68	17.5
175	6.9	5.5	5.8	76	15.4
176	6.9	5.8	5.4	72	12.6

Information on the site

a. Profile number: 18

b. Classification:

U.S.D.A.: Typic Ustipsamment

F.A.O.: Albic Arenosol

c. Date of examination: 9th August 1983

d. Location: Profile is located at UTM Code 37 M CC 475454

e. Elevation: 510m a.s.l.

f. Landform:

(i) physiographic position: concave slope

(ii) surrounding landform: rolling

(iii) microtopography: none

g. Slope on which profile is sited: (8%) rolling

h. Land use: Presently not cultivated except for eucalyptus plantation 10 metres below the site.

i. Vegetation: Burnt out at the time of sampling and is mainly successive

General information on the soil

a. Parent material: Quartz and colluvial sands

b. Drainage: Excessively drained

c. Moisture conditions in the profile: Dry throughout

d. Depth of groundwater: Unknown but very deep.

e. Presence of surface stones and rock outcrops: None

f. Evidence of erosion: Small gullies 0.5 x 0.5m width and depth respectively.

g. Presence of salt or alkali: None

h. Human influence: Limited to annual burning of grasses giving a gray colour of to the A and AC horizons.

Profile description

Ap 0-13 cm: Dark brown (10YR 3/3) moist and grayish brown (10YR 5/2) dry, sand; structureless; non sticky, non plastic (wet), loose many medium roots; clear smooth boundary.

AC_1 13-33 cm: Brown (7.5YR 5/4) moist and brown (10YR 5/3) dry, sand; structureless; non sticky, non plastic (wet), loose common fine roots; clear smooth boundary.

AC_2 33-64 cm: Brown (7.5YR 5/4) moist and brown (10YR 5/3) dry, sand; massive coherent; non sticky, non plastic (wet), loose (moist) loose (dry); very few fine roots; clear smooth boundary.

C_1 64–100 cm: Pinkish gray (7.5YR 7/2) moist and pinkish gray (7.5YR 7/2) dry, structureless small hard iron oxide concretions; very frequent fine gravels; few fine roots; clear smooth boundary.

C_2 100–140 cm: Pinkish gray (7.5YR 7/2) moist and pinkish gray (7.5YR 7/2) dry, sand; structureless loose big hard iron concretions; very frequent coarse gravels; very few fine roots; horizon continues below.

Mapping unit: $26A_1$

SOIL ANALYTICAL DATA

Profile number 18

Date of sampling: 9/8/83

Sample number	Depth (cm)	Horizon	Particle size distribution			Textural Class	Silt/ Clay
			Sand (%)	Silt (%)	Clay (%)		
181	0-13	Ap	94	2	4	S	0.50
182	13-33	AC_1	94	2	4	S	0.50
183	33-64	AC_2	92	2	6	S	0.33
184	64-100	C_1	94	2	4	S	0.50
185	100-140+	C_2	94	2	4	S	0.50

Bulk density (g/cm^3)	Particle density (g/cm^3)	Porosity (%)	Water content weight % and cm depth at various suctions (bars)					
			1/3 bar = FC		15 bars = PWP		Avail. water capacity	
			(%)	(cm)	(%)	(cm)	(%)	(cm)
1.40	2.38	41	8.1	1.1	2.2	0.3	5.9	1.1
1.61	2.45	34	9.2	1.9	1.4	0.3	7.8	2.5
1.57	2.50	37	14.2	4.4	3.3	1.0	10.9	5.3
1.51	2.60	42	6.2	2.3	3.6	1.3	2.6	1.4
Gravels	ND = Not determined		ND	ND	ND	ND	ND	ND

Sample number	O.C.%	N%	Exchangeable cations (me/100g soil)					Sum bases	C.E.C. soil sum	Sum bases me/100 g clay	C.E.C. me/100 g clay
			Na	K	Ca	Mg	H(+)				
181	0.57	0.04	0.04	0.50	1.23	0.87	0.9	2.64	3.5	38	50
182	0.31	0.03	0.05	0.42	0.63	0.67	0.9	1.77	3.7	30	45
183	0.12	0.03	0.05	0.42	0.29	0.21	2.0	0.97	3.0	14	43
184	0.24	0.02	0.05	0.26	0.26	0.28	1.6	0.85	2.5	17	48
185	Gravelly	ND = Not determined						ND	ND	ND	ND

Sample number	pH		Exchangeable Sodium %	Base Saturation %	Available P (ppm)
	1:1 H_2O	1:2 $CaCl_2$			
181	7.0	5.8	1.1	75	9.1
182	6.8	5.7	1.9	67	8.8
183	6.0	5.1	1.7	33	4.2
184	5.7	5.1	2.0	35	4.2
185	ND = Not Determined		ND	ND	ND

Information on the soil

a. Profile number: 19

b. Classification:

U.S.D.A.: Ustoxic Quartzipsamment

F.A.O.: Ferralic Arenosol

c. Date of Examination: 19th October 1983

d. Location: Profile is located at UTM Code 37U CC 473476

e. Elevation: 530m a.s.l.

f. Landform:

(i) physiographic position: plateau (crest)

(ii) surrounding landform: rolling over 8%

(iii) microtopography: nil

g. Slope on which profile is sited: gentle (2.5%)

h. Land use: Formerly planted with sisal, now regrown bush with annually burnt grasses

i. Vegetation: Mainly successive and is characterized by the following plants:

Grasses - Andropogonoid, mainly

Herbs - Clotaloria sp. Maerua Grantii

Woody climber - Hippocratea

Shrub - Phyllanthus Haderaspatensis

Combretum I

Tree - Markamia Obtusifolia, Dalbergia Melanoxylon

General information on the soil

a. Parent material: Quartzite, glass

b. Drainage: Excessive - class 6

c. Moisture conditions in the profile: dry throughout

d. Depth of groundwater table: Very deep and unknown

e. Presence of surface stones and rock outcrops: none

f. Evidence of erosion: none detected

g. Presence of salt or alkali: none

h. Human influence: Annual burning of grasses gives darker A and AC horizons. Very little else human activity was traceable.

Profile description

Ap 0-25 cm: Dark brown (10YR 3/3) moist and grayish brown (10YR 5/2) dry, sand; structureless; non sticky, non plastic (wet), loose (moist), loose (dry); many coarse roots; clear smooth boundary.

Au 25-57 cm: Dark yellowish brown (10YR 3/4) moist and grayish brown (10YR 5/2) dry, sand;; structureless; non sticky, non plastic (wet), loose (moist), loose (dry); many coarse exped tubular pores; many medium roots; clear smooth boundary.

AC_1 57-125 cm: Strong brown (7.5YR 5/8) moist and pink (7.5YR 7/4) dry, sand; structureless; non sticky, non plastic (wet), loose (moist), loose (dry); many coarse exped tubular pores; many medium roots; clear smooth boundary.

AC_2 125-200 cm: Strong brown (7.5YR 5/8) moist and pink (7.5YR 7/4) dry, gravelly sand; structureless; non sticky, non plastic (wet), loose (moist), loose (dry); many coarse tubular exped pores; few fine roots; horizon continue below.

Sample number	O.C.%	N%	Exchangeable cations (me/100g soil)					Sum bases	C.E.C. soil sum	Sum bases me/100 g clay	C.E.C. me/100 g clay
			Na	K	Ca	Mg	H(+)				
191	0.73	0.08	0.12	0.26	2.13	3.10	2.4	5.61	8.0	100	270
192	0.41	0.02	0.20	0.29	0.71	1.20	2.4	2.40	4.8	11	55
193	0.12	0.03	0.14	0.17	0.35	1.50	2.5	2.16	4.7	40	211
194	0.07	0.04	0.19	0.16	0.28	0.90	2.5	1.53	4.0	9	71

Sample number	pH		Exchangeable Sodium %	Base Saturation %	Available P (ppm)
	1:1 H_2O	1:2 $CaCl_2$			
191	6.0	5.6	1.5	70	7.7
192	6.3	4.7	4.2	50	3.5
193	5.7	4.5	3.0	46	6.3
194	6.1	4.7	4.8	38	9.5

Mapping Unit: $36A_1$

SOIL ANALYTICAL DATA

Profile number 19

Date of sampling: 17/10/83

Sample number	Depth (cm)	Horizon	Particle size distribution			Textural class	Silt/ Clay
			Sand (%)	Silt (%)	Clay (%)		
191	0-25	Ap	96	2	2	S	1.0
192	25-57	Au	94	2	4	S	0.5
193	57-125	AC_1	95	4	1	S	4.0
194	125-200+	AC_2	96	2	2	S	1.0

Bulk density (g/cm^3)	Particle density (g/cm^3)	Porosity (%)	Water content weight % and cm depth at various suctions (bars)					
			1/3 bar = FC		15 bars = PWP		Avail. Water capacity	
			(%)	(cm)	(%)	(cm)	(%)	(cm)
1.45	2.63	45	10.2	2.6	1.3	0.3	9.9	3.6
1.83	2.64	31	9.2	2.9	1.3	0.3	7.9	3.2
1.48	2.65	44	9.6	6.5	1.0	0.7	8.6	8.7
1.73	2.65	35	9.5	7.2	1.1	0.8	8.4	10.9

Information on the site

a. Profile number: 20

b. Classification:

U.S.D.A.: Ustic Quartzipsamment

F.A.O.: Albic Arenosol

c. Date of examination: 21st October 1983

d. Location: Profile is sited at UTM Code 37M CC 474475

e. Elevation: 515m a.s.l.

f. Landform:

(i) physiographic position: convex slope

(ii) surrounding landform: rolling

(iii) microtopography: excavated quarry

g. Slope on which profile is sited: 8% rolling

h. Land use: Subsoil excavated as building sand for Morogoro town

i. Vegetation: Grasses - mainly Pennisetum Polystachyan

Herbs - Sesamum Angustifolium, Gotalaria sp.

Shrubs - Phyllanthus Maderaspatensis, Maerua Angolensis

Tree - Markamia Obtusifolia

General information on the soil

a. Parent material: Quartz predominantly

b. Drainage: Excessively drained

c. Moisture conditions in the profile: Dry throughout

d. Depth of groundwater table: Unknown but very deep

e. Presence of surface stones and rock outcrops: Nil

f. Evidence of erosion: None readily detected, sheet possible

g. Presence of salt or alkali: None

h. Human influence: The site has been opened up for digging out building sand for Morogoro town but was previously planted with sisal

Profile description

Ap 0-20 cm: Dark brown (10YR 3/3) moist and grayish brown (10YR 5/2) dry sand; structureless; non sticky, non plastic (wet), loose (moist), loose (dry); many coarse roots; gradual smooth boundary.

Au 20-45 cm: Dark brown (10YR 3/3) moist and grayish brown (10YR 5/2) dry, sand; structureless; non sticky, non plastic (wet), loose (moist), loose (dry); common medium roots; gradual wavy boundary.

AC 45-95/115cm: Brown (7.5YR 5/4) moist and pinkish gray (7.5YR 7/2) dry, sand; structureless; non sticky, non plastic (wet), loose (moist), loose (dry); few coarse roots; diffuse irregular boundary.

C_1 95/115-200+cm: Reddish yellow (7.5YR 6/6) moist and pink (7.5YR 8/4) dry, sand; structureless; non sticky, non plastic (wet), loose (moist), loose (dry); few fine gravels, few coarse roots; horizon continues.

Mapping Unit: $36A_1$

soil SOIL ANALYTICAL DATA

Profile number 20

Date of sampling: 21/10/83

Sample number	Depth (cm)	Horizon	Particle size distribution			Textural class	Silt/ Clay
			Sand (%)	Silt (%)	Clay (%)		
201	0-20	Ap	94	2	4	S	0.50
202	20-45	Au	96	2	2	S	1.00
203	45-95	AC	96	2	2	S	1.00
204	95-200+	2AC	96	2	2	S	1.00

Bulk density (g/cm^3)	Particle density (g/cm^3)	Porosity (%)	Water content weight % and cm depth at various suctions (bars)					
			1/3 bar = FC		15 bars = PWP		Avail. Water capacity	
			(%)	(cm)	(%)	(cm)	(%)	(cm)
1.53	2.61	44	7.6	1.5	1.2	1.5	6.6	2.0
1.53	2.64	44	7.7	1.9	0.9	1.9	6.8	2.6
1.63	2.65	41	8.1	4.1	0.8	4.1	7.3	5.9
1.58	2.64	43	8.2	8.6	0.6	8.6	7.6	12.6

Sample number	O.C.%	N%	Exchangeable cations (me/100g soil)					Sum bases	C.E.C. soil sum	Sum bases me/100g clay	C.E.C. me/100 g clay
			Na	K	Ca	Mg	H(+)				
201	0.65	0.08	0.11	0.24	2.12	3.00	2.3	5.47	7.8	105	151
202	0.33	0.05	0.20	0.25	0.65	0.10	2.4	1.20	3.6	51	155
203	0.15	0.05	0.13	0.15	0.33	1.30	3.4	1.91	5.3	91	253
204	0.18	0.03	0.15	0.14	0.25	0.80	2.5	1.34	3.8	62	176

Sample number	pH		Exchangeable Sodium %	Base Saturation %	Available P (ppm)	Exchangeable Aluminium* me/100g soil
	1:1 H_2O	1:2 $CaCl_2$				
201	6.1	5.3	0.8	70	10.8	0.06
202	5.2	4.3	1.7	33	6.3	0.11
203	5.5	4.2	2.6	36	3.5	0.11
204	5.5	4.3	1.4	35	6.2	0.06

* Øien and Gjerdingen (1972) - method

Information on the site

a. Profile number: 21

b. Classification

U.S.D.A.: Umbric Tropaqualf

F.A.O.: Gleyic Luvisol

c. Date of examination: 13th October 1983

d. Location: Profile is sited at UTM Code 371 CC 489448

e. Elevation: 490m a.s.l.

f. Landform:

(i) physiographic position: valley bottom

(ii) surrounding landform: flat

(iii) microtopography: none

g. Slope on which profile is sited: 1.0% flat

h. Land use: The land had just been burnt of maize crop residues at the time of examination. The area also grows rice with the first rains and maize is planted towards the middle of the main rains. No details on management were available as cultivation is done by squatters.

2. Vegetation: The original has been cleared. The following weeds were sampled:

Grasses - Panicum, Brachiaria, Eminii, Sida Alba.

Herbs - Cissampelus Pariera, Compositae I, Crolotaria, sp

Shrub - Compositae 4.

General information on the soil

a. Parent material: Colluvial clay and silt

b. Drainage: Moderately well to imperfectly drained

c. Moist conditions in the profile: Moist throughout

d. Depth of groundwater: Within 3 metres depth

e. Presence of surface stones and rock outcrops: None

f. Evidence of erosion: None

g. Presence of salt or alkali: None

h. Human influence: Confined to plow layer through tillage and burning of crop residues giving porous peds and dark colours.

Profile description

Ap 0-15 cm: Very dark grayish brown (10YR 3/2) moist and grayish brown (10YR 3/3) dry, loam; strong medium angular blocky; very sticky, very plastic (wet), firm (moist), very hard (dry); few fine tubular inped, many very fine tubular exped pores; frequent small soft iron-manganese concretions; many medium roots; abrupt smooth boundary.

Au 15-35 cm: Dark yellowish brown (10YR 4/4) moist and brown (7.5YR 5/4) dry, sandy clay; moderate fine angular blocky sticky, plastic (wet), firm (moist), slightly hard (dry); few medium tubular exped, common coarse tubular inped pores along pressure faces; very frequent small soft iron-manganese concretions; common very fine roots; clear smooth boundary.

Bt 35-73 cm: Dark yellowish brown (10YR 3/4) moist and (10YR 4/4) dry, clay; moderate medium angular blocky sticky, very plastic (wet), slightly firm (moist), hard (dry); patchy thick cutans ped faces; common coarse tubular in ped, many very fine exped tubular pores; frequent small soft manganese concretions; few very fine roots; gradual wavy boundary.

Bwg_1 73-133 cm: Very dark gray (10YR 3/1) moist and very dark grayish brown (10YR 3/2) dry clay; with common medium prominent yellowish brown mottles; weak medium angular blocky sticky, plastic (wet), firm (moist), hard (dry); common thin cutans on ped faces; common medium tubular in ped pores; very frequent small soft manganese concretions; few very fine roots; abrupt smooth boundary artificially put for sampling purposes.

Bwg_2 133-200+ cm: The same as Bwg, above except for darker grayish brown (10YR 3/2) and more moisture.

Mapping Unit: 130_1

SOIL ANALYTICAL DATA

Profile number 21

Date of sampling: 13/4/83

Sample number	Depth (cm)	Horizon	Particle size distribution			Textural class	Silt/ Clay
			Sand (%)	Silt (%)	Clay (%)		
211	0-15	Ap	40	36	24	L	1.50
212	15-35	Ag	48	16	36	SC	0.40
213	35-73	Bt	20	10	70	C	0.14
214	73-133	Bwg_1	24	12	64	C	0.19
215	133-200+	Bwg_2	37	11	52	C	0.21

Bulk density (g/cm^3)	Particle density (g/cm^3)	Porosity (%)	Water concent weight % and cm depth at various suctions (bars)					
			1/3 bar = FC		15 bars = PWP		Avail. Water capacity	
			(%)	(cm)	(%)	(cm)	(%)	(cm)
1.49	2.60	43	27.1	4.1	12.0	1.8	15.1	3.4
1.48	2.60	43	25.6	5.1	13.0	3.3	12.6	4.7
1.48	2.61	43	27.2	10.3	18.0	6.8	9.2	5.2
1.39	2.63	47	25.0	15.0	15.0	7.5	10.0	7.0
1.39	2.64	47	25.0	16.8	15.0	10.1	10.0	9.3

Sample number	O.C. %	N%	Exchangeable cations (me/100g soil)					Sum bases	C.E.C. soil sum	Sum bases me/100 g clay	C.E.C. me/100g clay
			Na	K	Ca	Mg	H(+)				
211	1.59	0.11	0.33	2.80	18.75	12.50	7.7	34.4	42.1	130	158
212	1.54	0.17	0.32	1.97	15.63	17.80	7.9	35.7	43.6	90	110
213	1.46	0.13	0.32	1.32	23.13	22.20	8.3	47.0	55.3	62	73
214	0.47	0.10	0.33	9.87	23.75	24.00	7.8	58.0	65.8	89	101
215	0.42	0.10	0.42	0.82	24.38	23.50	8.3	49.1	57.4	93	108

Sample number	pH		Exchangeable Sodium %	Base Saturation %	Available P(ppm)
	1:1 H_2O	1:2 $CaCl_2$			
211	6.3	5.8	0.8	82	10.5
212	6.4	5.8	0.7	82	11.6
213	6.3	5.8	0.6	85	8.8
214	6.3	6.1	0.5	88	7.7
215	6.7	6.2	0.7	86	7.7

Information on the site

a. Profile number: 22

b. Classification:

U.S.D.A.: Ustic Quartzipsamment

F.A.O.: Albic Arenosol

c. Date of examination: 17th October 1983

d. Location: Profile located at UTM Code 37M CC 477472

e. Elevation: 510m a.s.l.

f. Landform:

(i) physiographic position: plain

(ii) surrounding landform: undulating

(iii) microtopography: none

g. Slope on which profile is sited: 4.5%

h. Land use: Annual cultivation of maize and sorghum by squatters, no details on yields and management practices were available

i. Vegetation: Original vegetation has been cleared for cultivation. Weedy regrowth was sampled:

Grasses - These were burnt out

Herbs - Clotalaria sp, Leucas Martinensis, Aspilia sp.

Shrubs - Veronica Sp I, Combretum 2, Combretum I

Trees - There have been cleared.

General information on the soil

a. Parent material: Apparently colluvial sand from Hindu mountains

b. Drainage: Somewhat excessively drained - class 5

c. Moisture conditions in the profile: Dry throughout.

d. Depth of groundwater: Below 4 metres at this elevation, topography and texture.

e. Presence of surface stones and rock outcrops: None

f. Evidence of erosion: None detected

g. Presence of salt or alkali: None

h. Human influence: Annual tillage sometimes by hired tractors at times by hoes loosens plough layer. Burning adds to dark colours of top soil. Strong structural development lacks in the upper 50 cm

Profile description

Ap 0-15 cm: Very dark grayish brown (10YR 3/2) moist and dark grayish brown (10YR 4/2) dry, sand; structureless; non sticky, non plastic (wet), loose (moist), loose

(dry); common fine roots; clear smooth boundary.

Au 15–40 cm — Very dark grayish brown (10YR 3/2) moist and dark grayish brown (10YR 4/2) dry, loamy sand; structureless; non sticky, non plastic (wet), loose (moist), loose (dry); common fine roots; clear smooth boundary.

AC 40–85 cm: — Brown (10YR 4/3) moist and pale brown (10YR 6/3) dry, sand; massive grain; structureless; non sticky, non plastic (wet), loose (moist), slightly firm (dry); many coarse inped and exped tubular pores; few fine roots; gradual wavy boundary.

C_1 85–145 cmt: — Light brownish gray (10YR 6/2) moist and pinkish gray (7.5YR 6/2) dry, gravelly sand; structureless; non sticky, non plastic (wet), loose many coarse in ped and tubular pores; few very fine roots; horizon continues below.

Mapping Unit: $25A_1$

SOIL ANALYTICAL DATA

Profile number 22

Date of sampling: 17/10/83

Sample number	Depth (cm)	Horizon	Particle size distribution			Textural class	Silt/Clay
			Sand (%)	Silt (%)	Clay (%)		
221	0–15	Ap	90	4	6	S	0.67
222	15–40	Au	86	4	10	LS	0.40
223	40–85	AC	94	2	4	S	0.50
224	85–145+	C_1	94	2	4	S	0.50

Bulk density (g/cm^3)	Particle density (g/cm^3)	Porosity (%)	Water content weight % and cm depth at various suctions (bars)					
			1/3 bar = FC		15 bars = PWP		Avail. Water capacity	
			(%)	(cm)	(%)	(cm)	(%)	(cm)
1.40	2.61	47	6.9	1.0	3.0	0.5	3.9	0.8
1.50	2.63	43	8.9	2.2	3.2	0.8	5.2	2.0
1.59	2.66	40	10.9	4.9	1.2	0.5	9.7	6.9
1.72	2.65	35	8.2	4.9	1.1	0.6	7.1	7.3

Sample number	O.C.%	N%	Exchangeable cations (me/100g soil)					Sum bases	C.E.C. soil sum	Sum bases me/100 g clay	C.E.C. me/100g clay
			Na	K	Ca	Mg	H(+)				
221	0.77	0.10	0.18	1.18	2.38	2.80	2.5	6.54	9.0	77	107
222	0.60	0.07	0.14	0.43	1.48	1.51	2.3	4.35	6.7	30	41
223	0.25	0.01	0.19	0.38	0.69	1.22	2.5	2.48	5.0	30	60
224	0.11	0.03	0.32	0.24	0.38	0.96	2.5	1.65	4.2	16	40

Sample number	pH		Exchangeable Sodium %	Base Saturation %	Available P (ppm)	Exchangeable Aluminium* me/100 g soil
	1:1 H_2O	1:2 $CaCl_2$				
221	6.3	5.4	2.0	72	27.4	0.06
222	5.1	4.6	2.1	74	11.6	0.28
223	6.6	4.9	3.8	50	9.2	0.06
224	6.5	5.3	7.6	39	9.8	0.06

* Øien and Gjerdingen (1972) - method