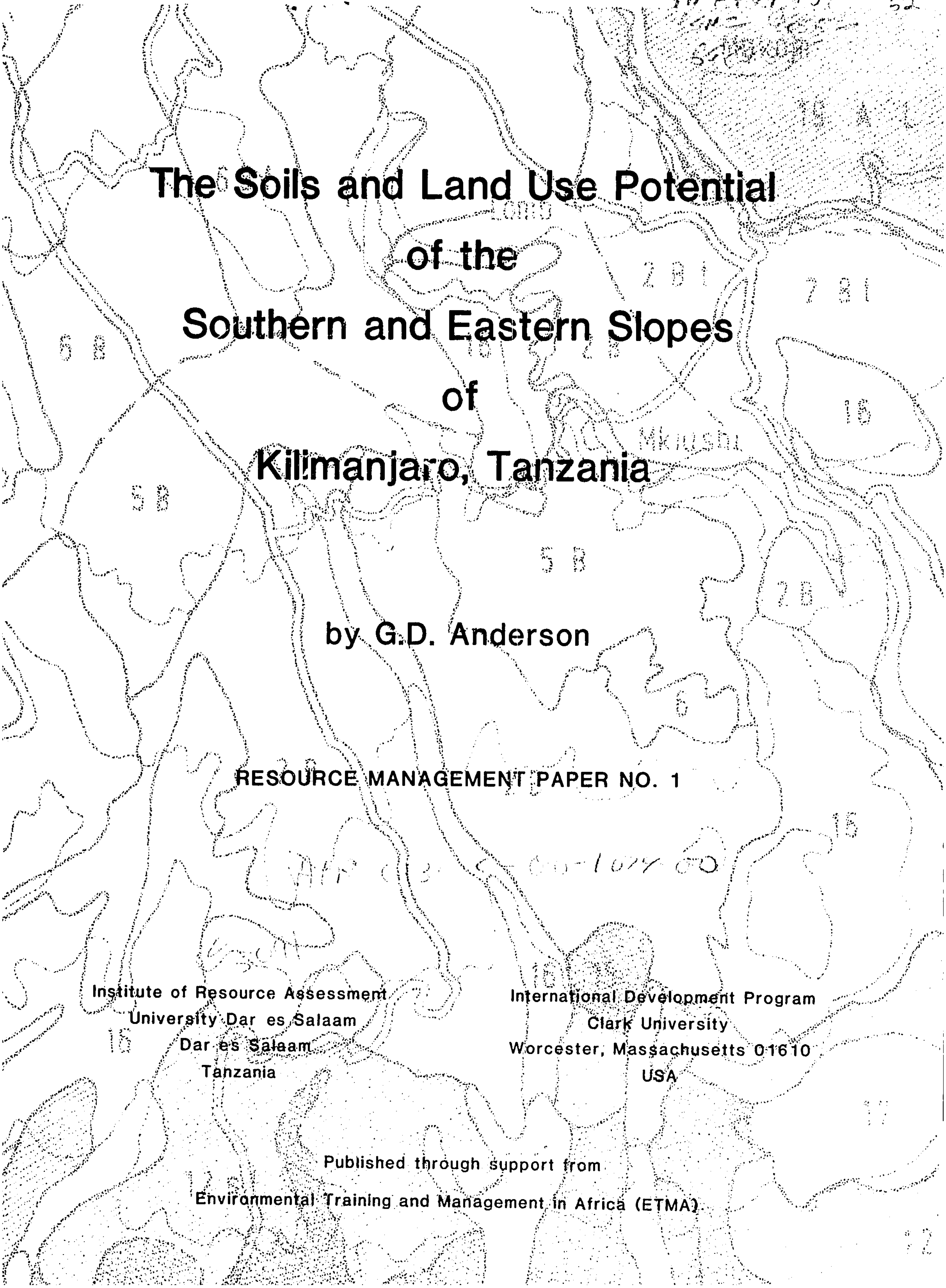

The Soils and Land Use Potential of the Southern and Eastern Slopes of Kilimanjaro, Tanzania

by G.D. Anderson

RESOURCE MANAGEMENT PAPER NO. 1

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FOREWORD

This document is the first in a series on resource issues in Tanzania published jointly by the Institute of Resource Assessment at the University of Dar es Salaam in Tanzania and Clark University in Worcester, Massachusetts, United States. Its completion represents successful long-term cooperation between the two institutions and also reflects a parallel concern for the importance of careful resource use.

This work on the soils and land potential of the southern and eastern slopes of Kilimanjaro started nearly two decades ago. The social and political scene has changed considerably since the project's inception, and the question may be raised whether work compiled over ten years ago is relevant to the Tanzania of today. Among many reasons for a positive answer is that as long as the debate on resource and population continues, so too must the work on the resources themselves. Interest in soils and land use has increased, and the capacity of scientists to deliver cannot keep pace with the demand for work on soils and land use potential. The population of Moshi District, for example, has increased from 125,000 to 1926 to over 750,000 in 1982. With the aid of Japanese development assistance, efforts are being made to intensify land utilisation. Therefore, the report provides a good basis for planning and implementation of agricultural changes.

G.D. Anderson started the work when he was an Agricultural Officer in Tanzania. He completed the study when he was senior lecturer in the Department of Soil Science at the University of Makere in Uganda. The first draft was brought to the director of the Bureau of Resource Assessment and Land Use Planning (now the Institute of Resource Assessment) in 1972. At that time, there was much concern over the rate at which scientific research reports were becoming a collection of fugitive literature, available only in the closets of researchers and their colleagues.

Anderson's effort to disseminate his work met with varied success. He sought to have the work produced in Tanzania. Fortunately, the Rockefeller Foundation made a modest grant available in 1973. The Mapping and Survey

Division of the Ministry of Lands, Housing, and Urban Development agreed to print the maps. They were drafted by Mr. F.A. Msuya from the Geography Department of the University of Dar es Salaam. By 1975, the maps were reproduced in color. The draft manuscript was edited by the Bureau of Resource Assessment and Land Use Planning staff members, including Mrs. Darsch. The manuscript was given to a variety of printers, but eventually had to be withdrawn because no progress was made.

Clark University came to have an important role. Here, I have several individuals to thank: Professor Len Berry, Director of the International Development Program agreed that the research should not be wasted. Final manuscript preparation and production work was undertaken by Clark University staff, including Jim Blair, Ute Dymon, Mary Riggs, Karen Sabasteanski and Sian Steward. John Callahan designed the cover. The manuscript was typed by Marion Dorscheimer of Word Processing of Worcester.

I wish to thank all those who made this volume possible.

Professor Adolfo Mascarenhas
Director
Institute of Resource Assessment
University of Dar es Salaam
Dar es Salaam, Tanzania

PREFACE

The revised edition of this memoir, first produced in August 1968, comes at a time of greatly increased land pressure on Kilimanjaro. Publication of this appraisal of the soils is timely, for soil studies and soil maps are increasingly recognised as the only sound basis for planning and implementing land use policies. Throughout this soil and land use survey, features of soils which influence their crop suitability have been stressed.

In appreciating the land use potential of the different soils and the soil groupings, the complementary approaches of soil survey and soil fertility assessment have been most fruitful and stimulating. Frequently these two lines of study are carried out by different individuals. I regard it as a great privilege to have had the opportunity to undertake this comprehensive study. Without the loyal backing of numerous people this would not have been possible.

To those staff of the Ministry of Agriculture and Co-operatives who helped to carry out this work in the field, office and laboratory, I wish to convey my gratitude. The work load was eased by their ready cooperation, encouragement and forbearance. I am indebted to successive Regional Forestry Officers, Water Development and Land Planning Staff in Arusha and my colleagues at Tengeru. In particular I want to thank Messrs. B.N. Patel, Z. Mmari and S. Faliganga who have worked most closely with me on this project. Finally, I wish to thank my wife whose help in reading and correcting the memoir has been invaluable.

G.D. Anderson

CHAPTER 1: INTRODUCTION AND METHODOLOGY

INTRODUCTION

It was decided at the 1962 Northern Zone Research Conference that a survey of the soils and land use potential of the southern and eastern slopes of Kilimanjaro would be a worthwhile project for the Chemistry Section at Tengeru's Agricultural Research Station. The area's high agricultural potential, the rapidly expanding Chagga population, as well as the accompanying need to intensify land use heightened the need for the work. The survey was to include the production of a soils map on a scale suitable for fairly detailed land use and fertiliser recommendations. A series of fertiliser trials was to be used to assess the fertility of the main soil types.

Following a preliminary reconnaissance of the soils in 1963, a series of 91 fertiliser trials using beans (*Phaseolus vulgaris*) as a test crop were conducted on the southern and eastern slopes of the mountain. The details of these trials and the results for the Rombo, Vunjo and Hai Divisions have been given in Tengeru Reports Nos. 11, 12 and 22 respectively (Anderson, 1963a, 1963b, 1964a) and summarised in No. 50 (Anderson, 1964b). It is not the purpose of this memoir to discuss these trials in detail but the results will be mentioned in the land use potential sections of this report.

Following these trials, the mapping of the soils began. At first, the lack of good aerial photography hindered this, but late in 1963 photographs taken in 1962 and covering most of the mapping area were obtained. Other projects undertaken by the Chemistry Section, Tengeru, prevented rapid progress with the survey but from the outset it was understood that this work should not interfere with more urgent assignments.

The southern and eastern slopes of this snow-capped mountain depict a complexity of geology, topography, climate and vegetation which is probably unmatched elsewhere in Tanzania. The topography varies from slopes of 0° to over

60° within the area surveyed which lies between altitudes 780 m and 2100 m, embracing most of the cultivation zone and a little of the forest. Within the survey area, lavas from both peaks of Kilimanjaro--Mawenzi and Kibo--occur. In addition there are three major centres of parasitic ash cones of differing ages which have influenced the soils over a large part of the area, and also some fluvioglacial deposits and alluvium. As a result of altitudinal differences there is great climatic variation with respect to annual rainfall (less than 500 mm to over 2500 mm) and temperature. Climate changes occur concentrically around the mountain. Associated with the climatic variation, the natural vegetation can be defined after Pratt, Greenway and Gynne (1966) as grassland, bushed grassland, wooded grassland, woodland or forest. Much of the natural vegetation has been modified by man and his animals and this has had important effects on the soils. Many areas are cultivated annually while in the better rainfall localities, coffee and bananas have largely replaced the former woodland or forest.

As a result of the interactions between topography, geology, climate and vegetation, the soil pattern is probably more complex than in any district of similar size (some 1550 sq. km) in Tanzania. Attention has been paid to values and limitations of each soil type and the need to indicate cropping potential during the mapping process.

METHODS OF SURVEY AND LAND USE ASSESSMENT

The survey involved first a preliminary reconnaissance of the soils and the establishment of a working soil classification based on individual soils. As a result, a large number of classification units were delimited initially. Many of these were recognised as superfluous when similar soils were identified in different areas of the mountain. Soils were classified according to their physical and chemical properties. These reflect the diversity of environmental conditions found throughout the study area, conditions themselves reflecting such varied factors as altitude, climate, topography, parent materials, natural vegetation and crop cover. In the final classification, soils which had similar field characteristics were grouped into categories of similar analytical values, including typical profile and the composite topsoil properties. Mapping Units are named according to villages or localities, where the typical profiles were first described and sampled. Boundaries were delimited in the field and extrapolated using a stereoscope on aerial photographs. Most photographs had scales of 1:39,000 or 1:45,000, small areas had a 1:70,000 scale. The soil boundaries were transferred from the aerial photographs onto the 1:50,000 topographic sheets using a Zeiss Stereotop. Acreages were determined using a planimeter. Terminology of soil description was based on the Soil Survey of Great Britain Field Handbook (Crompton, 1960). Methods of soil analysis are recorded in Appendix C.

The material in this report is organised as follows. Chapter 2 contains an examination of the natural resource base of the Kilimanjaro region. The human resources, the people who live there, and their farming systems are described in Chapter 3. Chapter 4 emphasises the time factor of soil formation in the region and the historical changes affecting the current soils. Chapter 5 discusses the evaluation of the soil classification and then applies these principles to the region's soils. In Chapter 6, utilising the classification of actual and potential land use is emphasised. In addition, practical recommendations for planners are offered. Finally, Chapter 7 summarises the report's most salient points. The bibliography is an alphabetical list of text references. There are three appendices which explain in detail the criteria used throughout the study.

CHAPTER 2: NATURAL RESOURCE BASE

PHYSIOGRAPHY, RELIEF AND DRAINAGE

The area surveyed is situated at the southern and eastern slopes of Kilimanjaro between Kibongoto in the west and Tarakia in the northeast. These lie between longitude 37° and 37°41' east and latitude 3° and 3°24' south. Usually the forest edge forms the upper boundary of the area but in certain areas, notably Old Moshi, Marangu and Useri the forest soils have also been examined. The southern boundary of the area follows the main Mombasa-Arusha road, and the western boundary follows the road linking this to Sanya Juu. The Lower Rombo road forms the eastern boundary with the Tarakia river forming the northern limit.

The general physiography of this area resembles that of many dormant volcanoes in other parts of the world. Kilimanjaro has had three main peaks. The Shira Plateau is the denuded remnant of the oldest eruptive centre and has been largely covered by lavas from Kibo. Mawenzi Peak, 5150 m, is the next oldest and most precipitous, while snow-capped Kibo, 5895 m, is the highest point on the continent of Africa.

At the lower altitudes the slopes are gentle (0°-5°) with a relatively shallow depth of volcanic rocks overlying the Achean Basement Complex. Above 1200 m on the south and above about 1400 m on the east, however, the slopes steepen greatly and often exceed 15° even in cultivated areas. Slopes in excess of 25° are mostly restricted to river valleys or to the steeply sloping ash cones. In the high rainfall area of Old Moshi-Kilema, rivers have cut more deeply into the ash than into the similar soils in the drier areas of Kibongoto and Keni. Slopes increase most regularly in the Lyamungu-Uru area on the south where the lava flows have been fairly uniform and little faulted. On the east, fault lines are more common and have caused the formation of steep escarpments especially in Mkuu. The detailed topographic features of the area can be seen on the 1:50,000 topograhic map (Tanzania Map), sheet numbers 56/1, 56/2, 56/3, 56/4, 57/1 and 57/3 which have been used as a base for the soil map, while the general physical features of the whole mountain are clearly shown on the Kilimanjaro special sheet (Kilimanjaro.Map.)

As the south is the wettest side of the mountain (see Figure 1 and Table 2) the main permanent rivers are found there. It is noticeable, however, that nearly all the large rivers arise in areas where lavas predominate and permanent big rivers are rare in the localities with deep ash cover. The main rivers draining the southern slopes are the Kikafu, Weru-Weru, Karanga and Rau to the west of Old Moshi, while the Himo and Sagana drain the Kilema-Marangu-Mwika area. From Mwika to Keni most streams are semi-permanent. However, the lavas of the east side again throw up other almost permanent rivers, namely the Marue and Lume, while the Mashima and Tarakia carry much water during the rains but are dry most of the year. The majority of these rivers drain southwards into the Kikuletwa and thence into the Pangani River System. The Lume and Marue, however, join and form the Lumi which flows east of the North Pare Mountains into Lake Jipe.

GEOLOGY

Since the undertaking of the soil survey a Geological Map of Kilimanjaro has been produced (1965). This map shows the major differences in rock types and forms a useful generalised starting point in considering the parent materials of the soils.

The oldest rocks with extensive exposures in the survey area are the lavas from Mawenzi. These lavas occur from Tarakia to Mengwe and again in the Marangu-Mwika area. They also outcrop occasionally on steep slopes in the Kirua and Keni areas of parasitic cones. Two principal groups of lavas, the Neumann Tower Group and the Mawenzi Group, make up the flows from Mawenzi. They comprise the following range of rock types: ankaramite, olivine basalt, olivine trachybasalts, trachybasalts, olivine trachyandesite, trachyandesite, basalt and andesite. Feldspathic lavas are more characteristic and carry numerous phenocrysts of andesine/bytownite. The general distribution of these rocks in the cultivation zone on the eastern side of the mountain as deduced from petrographic notes on specimens sent to the Geological Survey in Dodoma, is as follows:

Upper Useri	Trachyandesite, trachybasalt or trachyte
Lower Useri	Andesites, basalts and olivine basalts
Upper Mashati	Soda-rich glassy lavas with anorthoclase feldspar
Lower Mashati	Olivine basalt
Mkuu-mokala	Andesite and olivine andesite
Mkuu-Ubaa	Olivine analcitite
Lower Mkuu	Olivine basalt
Mwika	Olivine basalt
Marangu-Mwika	Olivine basalt
Marangu-Kilema	Olivine analcitite
Kilema	Trachyte
Kirua	Olivine basalt

Most of these rocks are basic in character and rich in calcium and magnesium-containing minerals such as andesine, labradorite, anorthite, olivine and augite. Amounts of potassium-containing minerals such as biotite, sanidine and anorthoclase are small with the exception of the trachytic rocks which are generally rich in silica also. Most of the foregoing lavas were laid down prior to early Pleistocene times when the Neumann Tower and Mawenzi centres of eruption became dormant.

The lavas of Kibo were deflected from covering the eastern slopes of the mountain by the peak of Mawenzi, but flowed west over the oldest eruptive centre, Shira, as well as to the north and south. Kibo lavas outcrop on the cultivation slopes between Masama and Uru. For the most part they consist of the rhomb porphyry group and are characterised by large phenocrysts of rhombic anorthoclase feldspar in a glassy matrix. In Upper Machame-Uru, however, trachytes, trachyandesites and phonolites also outcrop. Unlike the Mawenzi lavas, those from Kibo are relatively rich in potassium and proportionately low in magnesium.

Subsequent to most of the lava depositions on the plains numerous parasitic cones were thrown up and 263 of these have been mapped (Geological Map of Kilimanjaro, 1964). Within the mapping area there are three main centres of parasitic cones. The Kibogoto-Masama centre is the oldest of these and consists of a number of very old and eroded scoria and ash cones. In the Old Moshi-Kilema sector the lavas are largely overlaid by thick pyroclastic deposits. Most recent of the centres of parasitic activity is the Mwika-Keni or Rombo zone. Here the scoria and ash cones are more distinct than in the other two areas. To the north of the main Rombo zone there is another isolated cone named Kileo in Mkuu. Most of these pyroclastic deposits are low in potassium. Those in the Kibongoto-Masama zone however are, like the Kibo lavas, better supplied with this element. The boundaries between pyroclastic rocks and lavas are not always clearly discernible and transition zones with mixed lavas, scoria and ash often form the parent materials of soils as in Machame, Kilema and Mwika.

As a result of glaciation, glacial and fluvioglacial flows have added to the complexity of the parent materials of the soils. Fluvioglacial sands and boulder deposits overlie lavas throughout much of Marangu. North of Useri in Nanjara area, fluvioglacial deposits south of the Tarakia river have given rise to a dark brown soil, in marked contrast to the nearby red earths.

To the east of Kimo a considerable area is covered by calcareous lapilla tuffs. These have originated from Lake Chala when this caldera lake formed in geologically recent times. Also, east of Himo is the sole occurrence of Achean Basemen Complex rocks within the mapping area. This is the iselberg hill in the neighbourhood of Riata. The western edge of the area has been influenced greatly by younger rocks derived from Mount Meru in the form of Lahar outwash fans and agglomerates. These form the parent materials of the stony immature soils occurring between Sanya Juu and the junction with the Moshi-Arusha road. Most recent soil parent materials in the area are the colluvial/alluvial fans which cover considerable areas in the lower river courses all around the mountain. The Rau alluvium is one of the most extensive of these. It is even more prevalent below the Moshi-Mombasa road, where it coalesces with that of other rivers to form the extensive Kahe-Arusha Clini alluvium, now extensively irrigated.

From the foregoing it will be clear that the soils have developed from a wide range of parent materials.

CLIMATE

Kilimanjaro, rising as it does to a height of over 5800 m from a plain of general level about 600 m, has a variety of climates. Temperature, rainfall, radiation and wind velocity all influence the growth of plants. A consideration of the effect of climate on the growth of pasture plants at three widely separated places on Kilimanjaro has been described elsewhere (Anderson and Naveh, 1968). Radiation is known to increase with altitude when there are equivalent amounts of cloud cover, while wind velocity is very much influenced by aspect, topography and shelter. Temperature and rainfall usually exert the greatest influence on crop growth and rock weathering, and it is these that will be considered in most detail here.

Temperature

Temperatures are greatly influenced by altitude. As a rough estimate the mean annual temperature near the Equator may be calculated from Hardy's (1963) formula: $T=30-0.6A$ where T is in °C and A is the altitude in metres. Accordingly the mean annual temperature should vary between about 19° and 25°C within the survey area and this formula fits well with data for Moshi Town. As Kilimanjaro is a long way from the sea there is a wide variation between the day and night temperatures, especially at the higher altitudes. Frosts may occasionally be experienced above the 2000 m level during July and August. With the lower temperatures at higher altitudes, production of organic matter tends to be greater than its decomposition and so the soils tend to be high in organic matter.

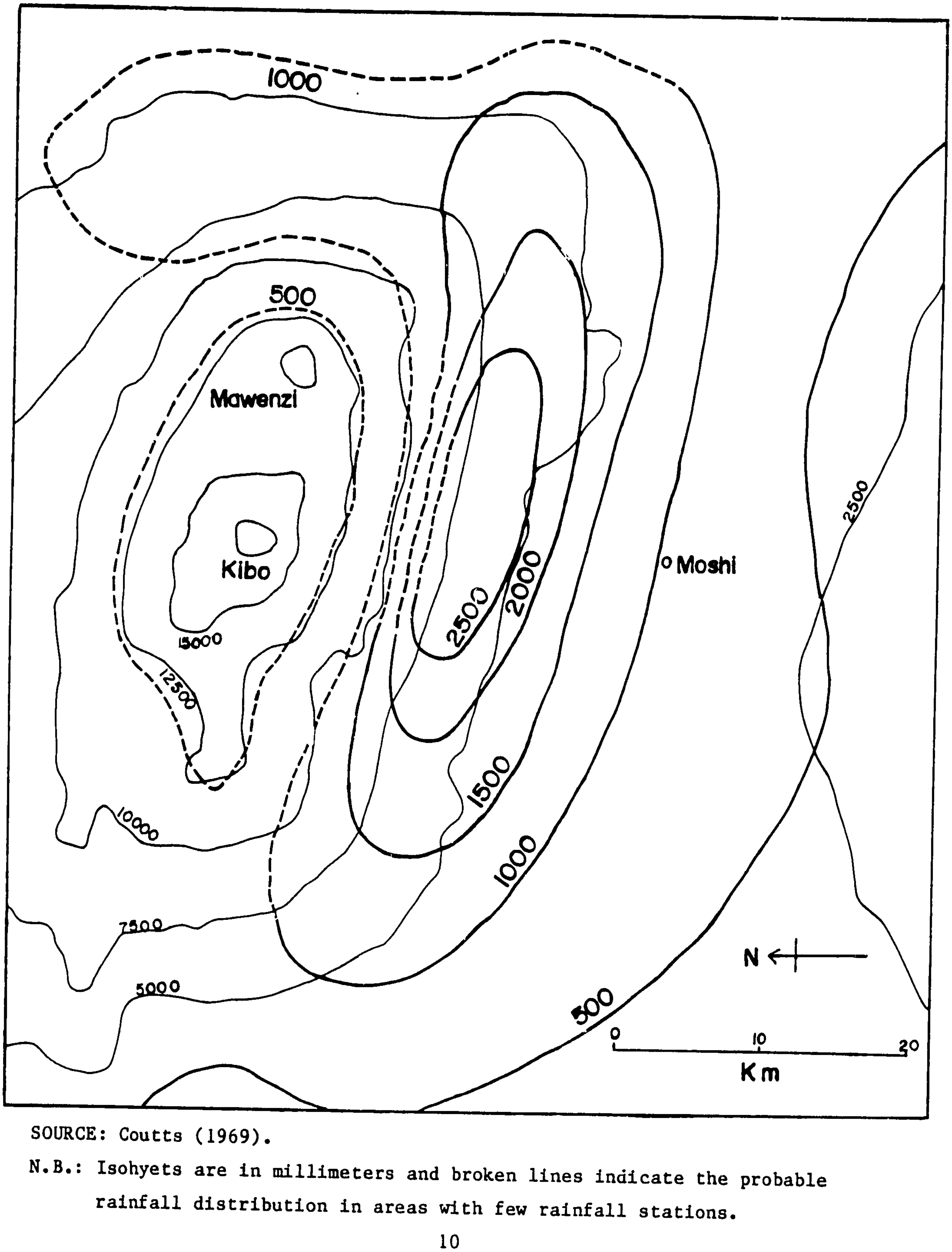
Rainfall

Figure 1 shows the general pattern of the mean annual rainfall in Kilimanjaro District. The south-facing slopes receive much more rain than the north, west or east, and between 1200 and 2500 m in the south considerable areas receive over 1500 mm annually. In contrast, most of east Kilimanjaro receives less than 1500 mm on average. The broad relationship of rainfall to altitude on the south and east slopes of the mountain has been given as: Rainfall (mm) = 0.5H (ft) - 660 (Robinson, 1967). While this equation works well on the southern slopes, it does not hold in the northeastern and southwestern sectors of the survey area, as altitude is not the only factor determining rainfall.

The mean monthly and annual rainfalls together with the altitudes and soil unit for 20 stations in the mapping area are recorded in Table 1. These stations have been used in addition to others to produce the isohyets in Figure 1, (after Coutts, 1968). They are also the basis of the approximate rainfall ranges given in the description of the soils. Mean annual rainfalls for three altitudinal zones for each of three sectors have been given previously (Anderson, 1964c) and are reproduced below with some modification in the light of later records (Table 2). It is clear that the south-facing slopes receive much more rain than the eastern sector. Distribution of rainfall is bimodal with peaks in April and November. The southern and southeastern slopes receive much of their rain in the March-May period, but the eastern sector (North Rombo) usually gets the bulk of its rain in the October-December period.

FIGURE 1

MEAN ANNUAL RAINFALL FOR KILIMANJARO DISTRICT



SOURCE: Coutts (1969).

N.B.: Isohyets are in millimeters and broken lines indicate the probable rainfall distribution in areas with few rainfall stations.

TABLE 1

RAINFALL FOR 20 STATIONS IN THE SURVEY AREA (mm)

STATION	Altitude* (m)	No. Years Recorded		Mean Monthly (mm) Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual Rainfall (mm) Ave.	Approx. Range
Kikafu Estate	960	29	Samborai Series	48	53	103	327	239	36	17	14	16	32	51	57	992	850 - 1150
Moshi Met. Stn	800	44	(Town)	40	44	117	290	158	30	12	12	13	34	55	48	852	700 - 1000
Kibosho Mission	1455	34	Umbwe Complex	76	72	159	594	643	204	117	55	39	41	95	91	2184	1900 - 2500
Rombo Mission	1410	35	Marangu Series (19a)	81	93	224	277	115	30	23	43	38	86	271	202	1484	1300 - 1700
Old Moshi Sch.	900	26	Samborai Series	60	47	151	421	292	75	32	23	24	33	71	82	1311	1150 - 1450
Lyamungu	1230	30	Msinga Series	44	65	109	537	456	112	60	35	31	37	97	80	1663	1450 - 1850
Himo Sisal Est.	945	28	Himo Series	52	55	120	185	114	21	12	12	10	35	109	74	798	650 - 950
Marangu Sch.	1410	17	Maranug Series (19a)	70	86	195	391	263	67	65	65	49	88	174	114	1625	1450 - 1850
Old Moshi Forest	1020	19	Manu Complex (6B)	83	97	177	567	411	132	100	53	38	84	171	123	2033	1750 - 2250
Macheme	1500	10	Old Moshi Series (2A)	83	66	96	564	560	161	130	53	29	30	85	71	1929	1700 - 2100
Moshi Prison	900	9	Samborai Series	59	46	91	320	116	30	8	6	16	36	101	78	906	750 - 1050
Kibongoto	1230	27	Old Moshi Series (2A)	58	57	102	349	250	37	21	12	13	27	100	88	1112	950 - 1250
Lyakirimy Mwika	1500	8	Kokiris Complex	130	133	285	364	238	57	75	69	46	117	277	158	1941	1700 - 2200
Kirua Vunjo	1650	6	Masama Series	89	121	328	617	342	92	119	73	42	164	300	168	2460	2200 - 2700
Mwika Mid. Sch.	1050	4	Kondeni Series	79	64	192	292	110	30	53	52	27	123	213	150	1410	1200 - 1600
Nanjara Mid. Sch.	1650	55	Nanjara Series	200	58	162	200	33	4	8	22	15	128	246	209	1284	950 - 1550
Msinga Farm Inst.	1140	3	Msinga Series	39	49	128	562	329	76	32	25	10	29	132	105	1514	1300 - 1700
Mweka College	1440	1	Umbwe Complex	51	45	395	655	259	211	36	32	5	26	47	90	1850	1650 - 2050
Kibohehe Est.	1110	4	Kibohehe Series	28	58	144	399	236	37	27	12	35	39	69	52	1036	850 - 1250
Marangu Storage	2160	9	(Forest)	131	166	164	202	167	132	101	76	54	52	101	70	1414	1200 - 1600

SOURCE: East African Meteorological Department, 1964.

*Altitudes changed to metric system.

mountain. Within the area of the soil survey, fourteen fairly distinct types of natural vegetation have been separated and are here described adopting the classification and terminology proposed by Pratt, Greenway, and Gynne (1966). The vegetation boundaries are not sharp but merge gradually. The general succession of vegetation types from the plains to the forest on the southern and eastern slopes of the mountain is as follows:

Southern Slopes	Eastern Slopes
Wooded Grassland (Bushed Grassland on steep or eroded areas)	Bushed Grassland (Bushland on eroded areas)
Woodland	Wooded Grassland
Medium-altitude Forest	Various types of Woodland
High-altitude Forest	High-altitude dry Forest (Upland Grasslands on gently sloping sites

At the lower altitudes both South and East Kilimanjaro have areas of seasonally waterlogged Wooded Grasslands, but Riverine Forest occurs only on the south side. The description of the vegetation types which follows is a general account. A more specific account is given in the description of each soil unit and the specifics recorded are listed in Appendix B. As the vegetation has mostly been modified by human activities, the title of each vegetation type first bears the name of the principal indigenous species followed by the cropping pattern superimposed, in parentheses.

VEGEGATION TYPES

A. Wooded Grasslands

1. Medium-height Hyparrhenia-Panicum/Combretum-Acacia Wooded Grassland (largely cropped with maize, beans or finger millet)

This occupies extensive areas of the lower slopes of the mountain bordering the Mombasa-Moshi road. Rainfall is usually less than 1000 mm and altitudes mountain. Within the area of the soil survey, fourteen fairly distinct types of natural vegetation have been separated and are here described adopting the classification and terminology proposed by Pratt, Greenway, and Gynne (1966). The vegetation boundaries are not sharp but merge gradually. The general succession of vegetation types from the plains to the forest on the southern and eastern slopes of the mountain is as follows:

Southern Slopes

- Wooded Grassland (Bushed Grassland on steep or eroded areas)
- Woodland
- Medium-altitude Forest
- High-altitude Forest

Eastern Slopes

- Bushed Grassland (Bushland on eroded areas)
- Wooded Grassland
- Various types of Woodland
- High-altitude dry Forest (Upland Grasslands on gently sloping sites

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VEGEGATION TYPES

A. Wooded Grasslands

1. Medium-height Hyparrhenia-Panicum/Combretum-Acacia Wooded Grassland (largely cropped with maize, beans or finger millet)

This occupies extensive areas of the lower slopes of the mountain bordering the Mombasa-Moshi road. Rainfall is usually less than 1000 mm and altitudes below 1200 m). The soils are not very deep and may be stony. The combination of low rainfall, high temperatures and freely drained soils means that fairly drought-resistant species survive best. Hyparrhenia dissoluta and Panicum maximum are the most obvious grasses, but others occurring include Aristida sp., Sorghum verticilliflorum, Panicum coleratum, Eragrostis sp., Cenchrus ciliaris, Digitaria spp., Chloris gayana and Cynodon dactylon. As altitude increases the species Combretum spp. occurs, among which Combretum gueinzii is common. Acacia tortilis occurs in some areas while A. mellifera is more common on shallower soils. Croton macrostachys (Mfurufuru) also occurs. Maize, beans, finger millet, castor and sisal have largely replaced the indigenous vegetation. Grass is also extensively cut for fodder.

2. Tall Hyparrhenia-Panicum/Croton-Combretum-Rauvolfia Wooded Grassland (mostly replaced by maize, beans, millet and some bananas)

This type occurs on the upper part of the plains in Kilema, Marangu, Mwika and Mkuu. Hyparrhenia dissoluta and Panicum maximum are again the most common grasses, but while Combretum spp. are still common, small trees of Croton macrostachys and Rauvolfia caffra and even some Albizzia schimperiana also occur. Other trees include Acacia tortilis and A. polyacantha. The grasses Hyparrhenia filipendula, Digitaria sp., Aristida sp., Heteropogon contortus and Rhyncheletrum repens are also common. The rainfall is greater than for Type 1, but probably does not exceed 1125 mm on average. Besides maize, beans and millet, bananas, cassava and even small areas of coffee have replaced the indigenous vegetation. Both grazing and the cutting of grass for fodder are practised.

3. Medium Height Hyparrhenia-Cynodon/Acacia Tortilis Seasonally Waterlogged Wooded Grassland (usually grazed)

This type covers most of the seasonal water courses on both the south and east sides of the mountain. Besides Acacia tortilis, A. polyacantha, A. seyal, A. mellifera and A. stulmannii may also occur. Hyparrhenia rufa commonly occurs but where the soils are more moist and grazed, Cynodon dactylon and C. plectostachyus are more common. These seasonal gently sloping watercourses are used for grazing, but some areas are planted with arable crops including maize, beans and vegetables.

4. Medium Height Hyparrhenia-Themeda/Acacia Polyacantha Wooded Grassland (largely cultivated with maize, beans and pyrethrum)

Within the survey area this type is restricted to the altitudes of 1500-1800 m in Useri where the soil is of fluvioglacial origin and dark brown in colour. Rainfall rarely exceeds 900 mm annually. The Acacias are more common along the drainage lines. Other species which may occur include Rauvolfia caffra and Croton macrostachys while Cupressus lusitanica and Grevillea robusta have been planted extensively. Besides Hyparrhenia filipendula, H. hirta and Themada triandra, Setaria sphacelata, Digitaria sp., Erogrostis sp. and Chloris gayana also occur. Much of this type is being cultivated with maize, beans, finger millet and castor, while at the higher elevations pyrethrum and Irish potatoes are grown. Pastures are both grazed and cut so that there is little grass left to burn.

B. Bushed Grassland

5. Medium-height Aristida-Heteropogon/Acacia-Combretum Bushed Grassland (chiefly grazed, some maize, beans, finger millet and sorghum)

This extends over much of the lower areas on the east side of the mountain from Himo to Useri. Rainfall rarely exceeds 750 mm and may be below 500 mm where Acacia species are more common. Besides Aristida adscensionis and Heteropogon contortus, Eragrostis superba, Chloris roxburghiana, Themeda triantra, Rhycheletrum repens, Panicum coloratum, Pennisetum mezianum, Digitaria scalarum, Cynodon dactylon and Cenchrus ciliaris occur. The Combretum species are usually small and tend to be replaced by Acacia mellifera, A. stuhlmannii, A. drepanalobium and A. nilotica in the drier areas. Occasional taller trees of *A. tortilis* also occur where this type merges into Wooded Grassland. The basal cover of the grasslands here is rarely more than 40 percent and in areas of overgrazing, frequently much less. Soil erosion, therefore, commonly occurs.

6. *Medium-height Hyparrhenia-Heteropogon/Combretum-Acacia Bushed Grassland (grazed, rarely cultivated, frequently burnt)*

This type is restricted to the volcanic ash and scoria cones in the drier areas which occur in the lower Kirua-Keni area. *Hyparrhenia filipendula* is common while *H. dissoluta* is less so. Besides *Heteropogon contortus*, *Aristida adscensionis*, *Sporobolus fimbriatus* and *Cenchrus ciliaris* occur. *Combretum guineense* is common while dwarf *Acacia stuhlmannii*, *A. nilotica* and *A. mellifera* are also found. Because of the excessively drained soils and steep slopes this area is rarely cultivated and often subjected to fires.

C. *Woodlands*

7. *Acacia/Commiphora Bushland (rarely cultivated, often overgrazed)*

These areas are restricted to steeply sloping or eroded lands with rainfalls of under 900 mm. With the cutting of grass for fodder and the grazing of many areas of Wooded Grassland and Bushed Grassland, however, fire is much less common than formerly. Consequently the area of Bushland has tended to increase in recent years and there are considerable tracts of country which now contain dwarf bushes notably of *Acacia mellifera*, *A. stuhlmannii*, *A. drepanalobium* and *Commiphora sp.*, with occasional taller trees of *Acacia tortilis*. Some of the areas supporting bushland are very stony while others are on relatively deep soils. All, however, tend to have a poor ground cover of grasses brought about either by overgrazing or erosion, the latter depending very much on the former. Among the grasses found in this type are *Aristida adscensionis*, *Chloris roxburghiana*, *Digitaria scalarum*, *Cynodon dactylon*, *Erogrostis sp.*, *Harpachne schimperi* and *Rhyncheletrum repens*.

D. Woodlands

8. Albizzia/Croton/Rauvolfia Woodland (largely replaced by coffee, bananas and maize)

This type forms a narrow belt on the more undulating topography just above the plains on the southern slopes. On the east of the mountain it is more extensive and occurs at higher altitudes. The common trees are Albizzia schimperiana, A. petersiana, Croton macrostachys and Rauvolfia caffra. Trees of these species in this woodland type rarely exceed 12 m in height, and 8-10 m would be more normal. Other species present include Trema orientalis, Cordia holstii, Ficus sp., Mimusops sp. and Lantana salviifolia. The grasses which are common in cultivated areas include Hyparrhenia spp., especially H. hirta, Eragrostis superba, Aristida Digitaria scalarum, D. diagonalis, Heteropogon contortus, Panicum maximum, Sporobolus pyramidalis and Rhyncheletrum repens. Coffee has replaced this type to a considerable extent and usually requires some irrigation for high yields. Areas of maize, beans, bananas, Grevillea robusta and Eucalyptus sp. have also displaced much of the original woodland.

9. Acacia abyssinica Woodland (mainly cropped with maize, pyrethrum and potatoes)

This distinctive type occurs only in the north east of the survey area above 1500 m in Useri. It is characterised by well-grown (up to 18 m) tall trees of Acacia abyssinica. A. polyacantha is found at the lower altitudes. Other trees found are Albizzia schimperiana, A. petersiana, Rauvolfia caffra and Croton macrostachys. Among the grasses are Digitaria sp., Themeda triandra, Eragrostis tenuifolia, E. curvula and Hyparrhenia hirta. Though some coffee is grown in this area, maize, beans, pyrethrum and Irish potatoes are more common.

E. Forests

10. Albizzia/Rauvolfia Medium Altitude Forest (now mostly coffee and bananas)

On the southern slopes of the mountain, the most extensive area of former forested land belongs to this type. Here it is most widespread within the altitudinal ranges of 100-700 m. To the east it is much less extensive and is replaced largely by Albizzia/Rauvolfia Woodland. The difference between these two types depends largely on the presence or absence of lianes, the size of the trees and the associated tree species. Besides the common Albizia spp., Rauvolfia caffra and Croton macrostachys, Newtonia buchananii, Macaranga kilimandscharica, Fauria saligna, Olea welwitchii, Ficus capensis and Teclea viridis occur. Many of the trees on this type have been replaced by coffee and bananas which together make up the dominant vegetation in the area shown on the map. In addition there are small areas of pasture in which the grasses Pennisetum clandestinum, Eragrostis curvula Sporobolus pyramidalis, Digitaria spp. and Cyperus spp. are found sometimes with the clovers Trifolium semipilosum and T. usambarensis. Other prevalent species are the hedge plant Dracen a stevoneri var. kilimandscharica, Pteridium aquilinum (bracken), Veronica sp. and Lantana salviifolia. Maize, beans, yams, sweet potatoes and sugar cane are also grown but the area covered by these crops is much less than that by coffee and bananas.

11. Lowland Riverine Forest

At the lower elevations this is the only type of forest to be found. It fringes most of the permanent watercourses, being widest where there are alluvial fans, as exemplified in the Rau Forest to the south east of Moshi. The small area of this type has not been studied closely, but the vegetation is composed of very mixed species including Cordyla africana with lianes.

While most of the big trees remain, much of the undergrowth of such species as Veronica and Lantana has been cleared and coffee, sugar cane or vegetables are frequently seen.

12. High Altitude Ocotea/Podocarpus Rain Forest

Here, Ocotea and Podocarpus species are the trees of greatest economic importance though seldom the most common. The type occupies most of the land above 1700 m on the southern slopes but is rare north of Mkuu on the east side (Wood, 1965). While there is a considerable overlap of species, there is a greater tendency for Ocotea usambarensis, the East African Camphor wood, to occur on the ash derived soils (Steele, 1963) while Podocarpus milanjianus seems to be more common on the less freely drained lava-derived soils. On this basis the high altitude rain forest is tentatively divided into two subtypes: the Ocotea Rain Forest and the Podocarpus Rain Forest.

12A. High Altitude Ocotea Rain Forest

The following species commonly occur in this forest on volcanic ash and in the cultivated areas formerly under forest on ash. Conopharyngia usambarensis, Syzygium guineense, Olea hochstetteri, Macaranga kilimandscharica, Agauria salicifolia, Myrica salicifolia, M. meyerjohannis, Hagenia abyssinica, Landolphis kilimandjarica, Cassia didymototrya, Dodonea viscosa, Newtonia buchanani, Podocarpus mileangianus, Fagaropsis angolensis, Dombeya mastersii, Parinari holstii, Kigelia aethiopica and Rauvolfia caffra have also been noted together with rather poor specimens of Albizzia spp. Among the grasses are Digitaria sp., Eragrostis spp., Sporobolus pyramidalis, Hyparrhenia hirta, Cyperus spp. and particularly in areas cleared from forest, Fimbristylis diphylla and Rhyncheletrum repens. In cultivated areas both coffee and bananas are poor. Yams, sweet potatoes and Irish potatoes are also grown.

12B. Podocarpus High Altitude Forest

At the lower altitudes Podocarpus milanjianus is the most common species of Podocarpus but above 3400 m this is replaced by P. gracilior (Wood, 1965). Other species in this sub-type on the Masia complex which have not already been noted on the ash-derived soils of Old Moshi include Trichelia roka, Mimusops sp., Ilex mitis, Rapanea rhododendroides, Eckebergia rueppellania, Xymolos monospora, and Olea africana while the common grasses include Pennisetum clandestinum, Eragrostis spp., Sporobolus pyramidalis, S. pellucidus and Exotheca abyssinica.

13. High Altitude Dry Forest

On the eastern side of the mountain the forest contains many of the same species as in the South Kilimanjaro Rain Forests. Trees are shorter, however, and in the drier northeast section rarely exceed 12 m. Species occurring in the Useri Forest include Macaranga kilimanjarica, Conopharyngia usambarensis, Olea africana, O. chryophylla and Xymalos monosphora, Agauria salicifolia, Hagenia abyssinica, Podocarpus milanjianus, Cassipourea malosana, Eckebergia ruepelliana, Galiniera coffeoides, Ocotea usambarensis and Euclea divinorum. An even drier type of forest exists on the northern slopes of the mountain in which Juniperus procea and Olea spp. are common. Among the grasses occurring in the cleared part of this eastern forest type are Pennisetum clandestinum, Hyparrhenia hirta, Eragrostis sp., Sporobolus pyramidalis, and Digitaria sp. The areas cleared from this Dry Forest for a number of years do not support very good crops. Coffee, bananas and annual crops are poor and even bracken does not grow very vigorously.

14. Upland Eragrostis/Fimbrystilis Grassland

This area is mostly the Useri Glades, but considerable areas of secondary grassland also occur in patches on the upper cultivation slopes of the area shown as Upland Dry Forest. The most common plants are Erangrostis spp. especially E. tenuifolia, Hyparrhenia hirta, Exotheca abyssinica, Cyperus spp. and Fimbristylis diphylla. Among the non-graminae which are scattered throughout this type are Artemesia afra, Myrica meyerijohannis, Agauria salicifolia and Pteridium aquilinum. Pennisetum clandestinum is common on cattle tracks where there is higher fertility. It is perhaps significant that the glades on Kilimanjaro are mostly in relatively low rainfall areas having prolonged dry periods. Frequent fires and grazing are also factors perpetuating the absence of forest in the glades. However, shallow acid soils sometimes with imperfect drainage are considered a more fundamental reason than fire or grazing for the existence of the Useri Glades although undoubtedly these help to tip the balance in favour of grassland. The reason for the shallow soil of the Useri glades may date back to the Ice Age and periglacial phenomena, but the present soils are much different from the neighbouring soils on steeper slopes which support forest (see Uhini Series). Furthermore, the pattern of the glades is too regular for their formation to be ascribed simply to grazing, burning or cultivation. It reflects very much the topography and geomorphology of the area as both the soil and vegetation maps show.

CHAPTER 3: THE PEOPLE AND THEIR FARMING SYSTEMS

HISTORICAL BACKGROUND

One of the most characteristic features of the Chagga is that they are people with an identity. They live on a mountain which is visible on a clear day for abouc 250 km in most directions. As long ago as 1840 Rebmann, who walked from Mombasa, was captivated by the beauty of Kilimanjaro, the invigorating climate and the well-being of its people.

How long the mountain has been peopled is difficult to assess. However, being a focal point of trade routes between the coastal ports and the great lakes it was well suited to attract settlement. At all seasons it offered water, bananas for food and grass for cattle. It was therefore well suited to the hunter, the pastoralist and the cultivator. Kilimanjaro may have been used as a stopping place on many routes, but often it turned out to be the end of the journey (Stahl, 1965).

The mountain area has absorbed many immigrants. Part of the strength and diversity of the Chagga is undoubtedly due to their cross-bred inheritance. The variety of skills and crafts including honey-hunting, elephant-trapping, cattle-keeping, cultivating, house-making, pottery manufacture, wood carving and black-smithing all bear witness to this. By the second half of the nineteenth century, Kilema had become the first natural halt after Taveta for traders coming both via the Pangani valley and the Taita Hills. One of the most remembered chiefs of Kilema, Rongoma, is reputed to have come from the Pangani and so impressed the Wakilema that he became their Mangi.[1] It was not until later that the Kilema chiefs moved higher up the mountain because of clan wars and Masai raids.

[1]Mangi is a Chagga word meaning a local chief.

The diversity in origin of the Kilimanjaro people is clear from their present affinities with other tribes. The Kamba and Masai have moved to the eastern side, the former to cultivate and the latter to graze. Masai have also moved into the western areas and Pare onto the southern slopes, while even Kikuyu had moved into the northern zone until they were evicted in 1954 because of the Mau-Mau troubles. In the past people would move in from the north, from the Taita and Kamba Hills, from the coast and Usambaras, from the south and possibly Unyamwezi. Chagga clan histories and dialects would be fruitful fields of study in elucidating the origins of the people on different parts of the mountain.

At the beginning of the nineteenth century there were over 100 individual political units. By 1899 this number had been reduced to 37 and by 1961 to 15. The chiefdoms under their hereditary chiefs remained the units of government on the mountain until 1962. The Chagga Council formed in 1921 provided a foothold for a new democratically elected element which from 1952 onwards slowly began to gain authority at the expense of the hereditary chiefs. The great change came in 1962 when the newly elected Kilimanjaro District Council absorbed the old Chagga Council, abolished the hereditary chieftainship and became the single local authority. An idea of the size and population of the chiefdoms in 1961 is given by the following numbers of taxpayers (after Stahl, 1964). The position of these chiefdoms except Arusha Chini and Kahe, which do not occur in the survey area, is shown in Table 3.

It can be seen that present day developments and future possibilities for the Chagga people and their chiefs have their origins in this history. For a fuller account of the background and the people of the mountain the reader is referred to Meyer (1900), Dundas (1924) and Stahl (1964), as well as the general Bibliography on Kilimanjaro (1965) in Tanganyika Notes and Records.

TABLE 3

NUMBER OF TAXPAYERS BY CHIEFDOM - 1946-61

DIVISIONAL GROUPING (1946-61)	CHIEFDOM	NO. OF TAXPAYERS
	Siha (Kibongoto)	3082
	Masama	5271
HAI	Machame	7923
	Kibosho	7492
	Uru	6049
	Moshi	4299
		34116
	Kirua	3501
	Kilema	2813
	Marangu	4685
VUNJO	Mamba	4433
	Mwika	2722
	Arusha Chini	666
	Kahe	1060
		19880
	Keni Mriti Mengwe	2967
ROMBO	Mkuu	3272
	Mashati	4041
	Useri	6354
		16634

SOURCE: after Stahl, 1964.

In 1926 the total population of the district was estimated to be 125,000. In 1967, as the above table shows, it is over 500,000. This is a 400 percent increase in 32 years. Children under 15 years of age account for 53 percent of the population in the highlands and 47 percent in the lowlands.

Maro's (forthcoming) analysis of the Population Census (1967) of Kilimanjaro District is given below.

TABLE 4

POPULATION AND DENSITY* BY DIVISION (1967)

DIVISION	HOUSEHOLDS	TOTAL POP.	MALE	FEMALE	AREA (SQ KM)	POPULATION DENSITY/SQ.KM
Hai Central	19,237	94,542	45,033	49,509	533	178
Hai East	15,519	78,816	39,550	39,266	991	80
Hai West	14,260	67,563	34,983	32,580	2056	33
Rombo North	12,859	65,696	31,339	34,357	428	96
Rombo South	8,932	48,357	21,994	26,363	282	172
Vunjo East	13,080	71,201	32,463	38,738	310	230
Vunjo West	9,086	47,657	22,870	24,787	387	123
Moshi Town	7,730	26,969	15,169	11,800	-	-
TOTAL	92,973	500,801	243,401	257,400	5248	95

SOURCE: Maro (Forthcoming thesis), 1967.

*Figures have been changed to the metric system.

The impact of population growth manifests itself in various ways. There is much less land available for cultivation and settlement in the lower areas than at the time this survey commenced in 1963. The aerial photographs taken in 1962 show areas almost devoid of settlement where now much of the land is cultivated. If the number of taxpayers in 1961 is any guide, there were nearly five times as many people in the Vunjo Division as in Moshi Town. Now there are less than four times as many, indicating that Moshi has grown rapidly. As the population increases, the chances of the more efficient types of farming demanding lower manhours of input per unit of income become less, and more land is needed for maize growing and subsistence agriculture.

AGRICULTURE AND FARMING SYSTEMS

The primary crop in this area is coffee. Since the planting of the first coffee tree at Kilema Mission over 65 years ago, coffee has become increasingly the basis of Chagga prosperity, which has surpassed that of all other tribes in Tanzania. Even before the introduction of coffee, however, the relatively fertile soils and good rainfall made Kilimanjaro suitable for permanent, as distinct from shifting, cultivation.

There are two main types of land tenure in Kilimanjaro. Kihamba is a type of tenure usually found only where permanent crops are grown and permanent houses built. Land can be inherited or bought and sold,[1] and prices of over Tsh. 7500/=per ha are sometimes paid.[2] The kihamba land is the real home of the people, where the coffee and bananas are planted and the stall-fed cattle are kept. On the southern slopes most of this type of land is situated between elevations of 1100 and 1800 m, while on the east it lies in a somewhat narrower belt usually between 1400 and 1800 m. Some of the poorer soils just below the forest reserve do not have the kihamba system, but more and more of these areas are being taken over for permanent settlement as the population increases. The kihamba land is thus very densely populated in some areas with over 400 people per square km. According to an economic survey carried out in the Machame Central Area in 1961 (Beck 1963) the size of farms owned varied from less than 0.5 ha to 3.5 ha, with an average of 1.3 ha, the greater part of which were in permanent crops (i.e., coffee and bananas usually interplanted). This is probably fairly typical of much of the intensive coffee/banana zone on the southern slopes. Areas like Machame benefitted from great Mangis, in this case Abdiel Shangali, who managed to secure a 'Lion's share' of the funds available for developments in Kilimanjaro District between 1946 and 1951 (Stahl, 1965). Thus the district developed and prospered much more

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[1]Since Independence in 1961, the sale of land has been made illegal although it is still practised in many areas.

[2]The price quoted is the 1968 price.

than areas that lacked great leaders. Where government was less stable, for example in parts of the Rombo Division which were frequently subject to raids, the population is less dense and the development lagged behind that of other areas. The present size of holdings per family is, however, proportionately greater. The lower areas of the mountain are less settled, possibly because the Masai have suffered a high incidence of disease, particularly malaria, and because of shortage of water. This is rapidly changing and mechanised maize and other arable cropping methods are rapidly superseding traditional, less productive ones.

The average gross income of the 100 farms studied by Beck (1963) in Central Machame in 1961 was Tsh. 2345/=, of which Tsh. 782/= came from coffee, Tsh. 928 from bananas, and Tsh. 465 was non-farm income. The family net income was Tsh. 863/=. This income came from a mean yield of 174 kg[1] of parchment coffee and 304 bunches of bananas per hectare of mixed coffee/banana land. However, impressive as these income figures are compared with many other districts in Tanzania, the yields of coffee even on the best 10 percent of farms were only about 50 percent of that attained at the Coffee Research Station, Lyamungu. The gap between agricultural practice and the best husbandry techniques known with regard to coffee has narrowed considerably since 1961. This is because of improved pruning, weeding, spraying against fungal and insect attack, and thinning of bananas and shade trees.

With the increasing difficulty in selling coffee and the almost inevitable fall in prices, there is need for the poorest to become as efficient as the best at present, and the latter to improve their husbandry still further, even beyond the bounds of present knowledge. This is all the more necessary in view of the continual subdivision of kihamba between the children of a family. While the average farmer in Machame during 1961 received more income from bananas than coffee, this is unlikely to be generally true today with the improved coffee husbandry. It may be, however, that with the falling coffee prices and restricted quota, bananas may give a relatively higher income per acre in the future.

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[1]Bech's data has been converted into the metric system - ed.

For high coffee yields there is a need to ensure that the coffee does not suffer competition for water and nutrients, and to obtain best yields pure stands of coffee are evidently becoming necessary. This does not mean that the shelter and mulching material from nearby pure stands of bananas are not very useful in reducing water loss from leaf and the soil. The only sure test of which is the most monetarily valuable crop, coffee or bananas, is how much profit can be made from a unit area of each grown in pure stands and with the best management. Much of the coffee in the main belt is capable of parchment yields of over 2300 kg per hectare according to the trials reported by Robinson (1967).

In addition to coffee, bananas, maize and beans, the kihamba land is frequently used to grow patches of sweet potatoes and yams with the occasional citrus or avocado pear tree. Also in some areas where irrigation is feasible or the rainfall particularly good, vegetables such as cabbages, onions, cauliflowers, tomatoes, lettuce and Irish potatoes are grown and provide a useful supplement to the income from coffee and bananas.

In addition to these crops some farmers keep one or two cows either in their own house (a practice dying out) or in a specially built stall. These animals are fed mainly on banana leaves, the leaves of a variety of trees, crop residues, and on small pastures which may be grazed or more often cut. During the dry season these dairy animals are often very dependent on supplies of fodder from the Haparrhenia/Combretum wooded grasslands of the lower slopes. For much of the year, grass is cut in these lower areas and carried on the heads of the women or, increasingly, transported by lorry distances of several miles to the homesteads. This fodder is often of poor protein content, certainly for high yielding Jersey or Jersey cross milk cows. The effort expended in transporting such poor quality fodder means that milk is very costly, if not in cash, certainly in effort. Milk is esteemed to such an extent, however, that this effort is not spared. It would be a great saving of labour and cows would yield much better, if some of the legumes and grass/legume mixtures, which have shown themselves capable of producing so much more protein per acre than have pure grass swards (Naveh and Anderson, 1967; Anderson and Naveh, 1968; and Anderson, 1968), were planted not only in the coffee/banana belt, but in some of the drier areas also.

Another source of income from the kihamba land is the production of timber. Under good rainfall conditions, useful planks can be obtained from certain trees within 10-15 years after planting. Grevillea robusta is most popular for this purpose but Cupressus lusitanica is also used, while the rapidity of growth of Eucalyptus saligna means that it can be cut for firewood after 5 years. The latter also rejuvenates very rapidly. The planting of trees on the steeper slopes in many areas could save a great deal of labour in bringing firewood from plantations on the forest edge and trees of the lower areas. There is a demand for Grevillea and Cypress for furniture making. The value of a few timber trees as long-term investment should not be overlooked, for the income over 15 years from such a source may be as great as or greater than that from coffee or bananas grown on equivalent area.

In addition to the kihamba land, most farmers have an area of shamba[1] on the lowest slopes of the mountain on land not yet permanently settled. On these fields maize, beans, cotton and finger millet (Eleusine corocana) are commonly planted, together with some areas of cassava, castor and pigeon pea. Though there has been a notable increase in the area of cultivation on these lower slopes in recent years, there are still some parts, particularly in the Rombo Division, which could be used. There is also a great potential for increased yields per acre. One of the greatest needs in achieving this with maize is row planting on tie-ridges. This can mean a much greater efficiency of moisture utilisation as shown by Macartney (1965) in a dry part of Arusha Region.

The growing of sorghum rather than maize in the driest areas is another means of averting crop failure in years of poor rains. Increased acreages of

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[1]Shamba is used only in the Chagga sense, meaning the plot around the homestead.

cotton and castor at the expense of maize in such areas would also help to raise income. Much of this land will eventually become permanently settled, but at present difficulty of access, lack of permanent water supplies and the relatively poor income compared with the coffee/banana lands discourages permanent settlement. The use of oxen or tractors to cultivate larger acreages, planting of bananas in selected patches with better moisture supply and the integration of livestock keeping for both milk and meat will probably enable more viable settlements to take place in the future. The pattern of settlement, however, is more likely to be one of villages around central water points than the scattered homesteads of the existing kihamba lands. Piping water to Rombo from the southern slopes of the mountain and making this available to the lower areas is likely to encourage greater settlement in these localities.

Though there has been spectacular agriculture development on Kilimanjaro in the last 20 years, there is still a great untapped production potential, well in excess of many other parts of Tanzania. The realisation of this potential depends on the farmers understanding what is possible, and accepting new ideas and findings. Some possibilities for increasing prosperity are mentioned later in the chapter on land use potential as well as in the discussion of the soils.

CHAPTER 4: SOIL DEVELOPMENT

In order to understand the nature of the soils and their potential use, it is necessary to consider the factors responsible for their formation and the pedogenetic processes still going on today. All five of the soil forming factors, parent material, climate, topography, time, and organisms have had a profound effect on the nature of the soils in this area.

INFLUENCE OF PARENT MATERIALS ON THE NATURE OF SOILS

As stressed in the chapter on geology, the variation in types of rocks and the length of time which has elapsed since their deposition is very great. The highly porous ash and scoria have tended to weather both rapidly and deeply at least where there is sufficient rainfall to permit frequent wetting. The more siliceous rocks resist weathering due to their low content of minerals which may be readily attacked. Rocks such as trachytes and phonolytes and to a lesser extent trachybasalts tend to give rise to rather stony soils, which, in some places at high altitudes and where erosion has been active, are no more than a few inches deep. Under such conditions, however, there is frequently partial removal of the more soluble constituents leaving behind a rather softer rock than the original. Rocks which contain very mixed or more basic minerals, particularly the basalts and nephelinites, weather more rapidly and thus tend to give rise to deeper soils, given equivalent slope, time and climatic conditions.

The texture of the parent rock and its content of quartz obviously influence the texture of the resulting soil, particularly its sand content. Harradine and Jenny (1958) have also shown that soils derived from basic igneous rocks have higher moisture equivalents and nitrogen contents than acidic igneous rocks under similar climates. They showed that there was a linear relationship between moisture equivalent and nitrogen content in virgin soils. It is therefore not surprising that the Kilimanjaro rocks, being generally basic in character, tend to give rise to soils which contain considerably more nitrogen than most others in Tanzania.

The mineral apatite which is the main source of phosphate in igneous rocks is also usually higher in basic rocks, which is the main reason the Kilimanjaro soils often contain about ten times as much total phosphorus as the vast areas of soils developed on the Pre-Cambrian Basement Complex. However, basic rocks are generally higher in iron and aluminium and when the soils become acid through leaching these are the chief means of 'fixing' phosphate in forms unavailable to plants.

EFFECTS OF TOPOGRAPHY

Milne (1935) was one of the first to recognise the importance of topography in determining the nature of the soil and coined the word 'catena' to describe a chain of soils on a single parent material in topographic succession. The influence of topography on the nature of soils is essentially two-fold; it governs the drainage regime and greatly influences the amount of water or wind-erosion. As both oxygen and water are essential for the growth of plants, good drainage is as necessary as good rainfall. A large excess of either water or air in the soil, which usually means a paucity of the other, causes restrictions in the rooting and growth of plants. Poor drainage and/or low rainfall often means the accumulation of the soluble products of weathering in the soil. We see this in some of the drier parts of the Alluvial/Colluvial Complex (mapping unit description 38), but the great majority of the soils in the mapping area are freely drained. In fact many derived from ash and scoria on steep slopes are so freely drained that it is difficult for them to retain bases, particularly under high rainfalls. Under such conditions they rapidly become acid.

In addition to excessive drainage, land which is steeply sloping tends to be susceptible to erosion. Despite the good porosity and rainfall acceptance of most of the soils under the higher rainfall conditions, such erosion continues both under perennial crops like coffee and on lands cropped with annuals. The reason is that rain storms may have an intensity above 15 cm per hour for short periods, and few unprotected soils can accept this amount without run-off and concurrent erosion. In the upper areas the small fields and frequent grassy paths generally prevent the serious gully erosion which is very common in the drier, less steeply sloping localities. The explanation of this is that the rainfall acceptance of the soils in the latter areas is much lower due to weak surface structure and a tendency to cap, and also the cultivated areas are larger, giving more opportunity for water to gather momentum. Perhaps surprisingly, where there is intense weathering and leaching, it is the steeper slopes which tend to remain more fertile because of a small regular amount of 'invisible erosion'. On Kilimanjaro, however, the presence of considerable slopes throughout the higher rainfall belt means that there is a great need to prevent this small amount of natural erosion from becoming catastropic. When the most fertile topsoil is lost, the nitrogen supplying power of the soil is greatly reduced, whatever the reserves of other essential elements in the subsoils.

INFLUENCE OF CLIMATE ON NATURE OF SOILS

Climate is perhaps the most important of the soil forming factors influencing the soils in this area, for the major differences in the type of soils found are related to the altitudinal zones. Though the rock types cut across these zones, the succession of soils on each parent material is dependent primarily on the climate, but slope, vegetation and man's use of the land have modifying influences. The soils of the area thus form a succession of climosequences (Jenny 1946) radiating from the mountain. The general climosequence of genetic soil groups according to D'Hoore's (1964) classification is given here in Table 5. The sequence on the younger lavas of the western sector is also shown.

Perhaps the most important influence of climate in soil formation is its governing of the ratio of weathering to leaching. As Crompton (1960) has pointed out with reference to the hills of Britain, soils can be differentiated through an understanding of the relationship of weathering to leaching. Here the highest base saturations are found in the Eutrophic Brown and Ferruginous Tropical Soils, for in these the parent materials are still undergoing rich weathering because of considerable mineral reserve and are not strongly

TABLE 5

CLIMOSEQUENCES

General	Altitudinal range (m)	Younger lavas of Western Sector
Podsolic Soils	Above 1830	Podsolic Soils
Humic Ferrallitic Soils or Humic Ferrisols	1670-1830	Humic Ferrisols
Ferrisols or Ferruginous Tropical Soils	1370-1670	Ferruginous Tropical Soils
Ferruginous Tropical Soils	900-1370	Eutrophic Brown Soils
Reddish-brown Soils of Semi-Arid Regions	Usually below 900 on S, 1400 on E	Reddish Brown Soils Semi-Arid Regions

SOURCE: D'Hoore, 1964.

leached because of the moderate rainfall, which is approximately in the range of 900 mm to 1400 mm. With the Ferrisols and Ferralitic soils on the other hand, the rainfall is such that there is much leaching of the soils and the tendency is for acidity to develop. Scott (1962b) has shown, from analysis of mature well drained soils from all over East Africa, that the base saturation is highest at about 1150 mm annual rainfall. This is the level at which apparently the vegetational cover is most efficient in preventing leaching. Below 1150 mm the vegetation is too sparse to prevent significant leaching of bases during the rains and above it the vegetation is unable to hold the bases against the strong leaching. This figure 1150 mm may be a generalisation, but it is interesting that the mean rainfall for the range of Eutrophic Brown and Ferruginous Tropical Soils on Kilimanjaro is around 1150 mm.

Climate also greatly influences organic matter and nitrogen contents of soils, production of these generally increasing in proportion to decomposition, with rising elevation. This is because growth is optimum in the temperature range 20-28°C while decomposition is greatest between 30 and 40°C (Mohr and Van Baren 1954). The role of leguminous trees, especially Albizzia spp.

which are common here, may also be important in increasing the nitrogen and organic matter of the soils as Jenny (1950) has noted elsewhere. Similar organic carbon levels in the middle and lower altitudinal zones have been attributed to higher silt and clay contents (Anderson, 1964a) which Birch and Friend (1956) have shown can have a considerable influence in conserving organic matter. With the exception of very sandy soils, however, the above authors found that rainfall was far more important in influencing organic matter than temperature or clay content.

Hardy (1963) has suggested that Mohr's Critical Temperature (annual mean of 25°C) is the dividing point between an emphasis on the processes of podsolisation and lateralisation. On this basis and from evidence in the Americas and Java, Hardy has suggested that Arabica Coffee soils above 1000 m elevation are Tropical Podsols. It may be that some of the soils referred to as Humic Ferrisols and Humic Ferrallitic Soils are tending to be podsolised, but none yet exhibit distinct bleached A_2 or humic B_1 horizons. Only above about 1800 m may the beginnings of these characteristics be distinguished beneath the forest. The probable reasons for the absence of podsols at much lower elevations are the comparative juvenility of the parent materials, the variable rainfall distribution producing drying of soils to a considerable depth and the type of plant cover, which in many cases is man-induced. Periodic cultivation must also reduce the possibility of 'mor' humus development.

INFLUENCE OF VEGETATION AND MAN ON THE SOILS

If climate has the greatest influence on the fundamental nature of the soils in this area, then the vegetation and man's use of it can have the biggest modifying influence on the destructive elements of climate, namely temperature and rainfall. To quote Milne, writing in 1940:

> Higher plants do not grow merely in or on the soil any more than micro-organisms do. As participants of a working system they are of the soil and if their living functions are checked for too long, as in excessive

grazing or too long continuance of arable cultivation, the soil reverts towards an inorganic condition in which, being 'dead', it is at the mercy of disintegrating forces.

In the role of vegetation in soil development both the reconstructive action of root systems and the return of nutrients to the surface in leaf fall must be considered. By our use of the land we change the natural vegetation and the soil condition it reflects and sometimes this change can be fundamental, particularly on mature soils where the vegetation often holds a delicate balance in maintaining nutrients against strong leaching conditions. Nye (1960) gives the following figures for nutrients circulated annually by moist Tropical Forest:

TABLE 6

NUTRIENTS CIRCULATED PER HECTARE (KG/ANNUM)*

	Wt. oven-dry material	N	P	K	Ca	Mg
Litter Fall	About 10,448	198	7.2	68	205	45
Timber Fall	About 11,115	36	2.9	6	81	8
Rain Wash		12	3.7	218	29	18
Total addition to soil		246	13.8	292	315	71

SOURCE: Nye, 1960.

*All figures have been converted to metric system - ed.

It can thus be seen that a mature forest can add the equivalent per acre in terms of fertilisers of over 500 kg ammonium sulphate, over 50 kg of single superphosphate (21% P_2O_5) and over 240 kg of muriate of potash (50% K_2O) besides considerable amounts of calcium and magnesium. It is therefore not surprising that the removal of such forests causes the onset of a chain of soil degradation as shown by Jacks (1934), Cunningham (1963) and Nye and Greenland (1964). Something of this process can be observed even on the relatively youthful soils of Kilimanjaro. In several chiefdoms, notably Useri, Old Moshi and Machame, many of the soils just below the forest do not support good crops. The reason is that the natural forest vegetation which was responsible for maintaining the nutrients near the surface was cleared and burned, and the areas planted with crops were unable to hold the released nutrients against the strong leaching of rainwater. Often today these areas are poor pasture and scrubland, largely deserted by the people.

Under high rainfall conditions, as Stephens (1967) has shown, the introduction into the rotation of a period under grass can make important improvements in the supply of nitrogen and potassium and to the rainfall acceptance under subsequent cropping. The value of grass in restoring nutrients to the soil surface, even on a very sandy soil, has also been demonstrated (Anderson, 1968b). The prevention of erosion by means of grass strips and trash bunds also helps to stop the destructive forces of climate from taking their full toll of the soils' capital under cropping. The use of grass or banana mulch from nearby areas is another means of restoring some of the nutrients leached from cropped areas and of protecting the soil against high temperatures and rainbeat. As Jacks, Brind, and Smith (1955) and Robinson and Hosegood (1965) have shown, mulching can have many restorative effects. These principles are relevant to soils at all altitudes and Ovid's saying that "a field becomes exhausted with constant tillage" is everywhere true to some degree. There is therefore a need to consider the crops grown not simply in terms of short term economic gain, but in relation to their value in maintaining soil fertility and the soil's potential to produce future crops. In this respect the writings of Russell (1950), Van der Merwe (1948), Haylett (1959), Nye and Greenland (1960) and the contributors to the All Africa Soil Fertility Symposium (1965) are particularly relevant.

WEATHERING/LEACHING BALANCE

On the south side of the mountain near the forest edge, the rainfall frequently exceeds 2000 mm annually and may be more than 2500 mm. As a result, soils are strongly leached of soluble constituents and soon become strongly acid. There is, however, a difference in the rate of this process between soils developed on ash and those on lavas. Those on ash are usually freely permeable so that water can readily penetrate deep into the subsoil and this results in the rapid leaching of bases. The lavas, on the other hand, resist leaching because water tends to flow down fissures rather than uniformly through the whole mass. This is particularly so in the case of acidic fine-grained rocks like trachytes and phonolytes. Also, pockets in the lava beds tend to be impervious and hold up the water, and with it the nutrients which would be leached on more permeable soils. The ash soils, therefore, are very deeply weathered even at the higher, cooler altitudes where weathering is less intense due to lower temperatures. The lavas have resisted weathering to varying degrees and so give rise to much shallower soils which tend to have more surface wash once they are saturated with water. Hence, the shallow soils over the lavas are perpetuated, due to erosion of the topsoil. They have, however, considerably more fertile subsoils than the ash soils under comparable rainfalls. The free permeability of the ash soils may be a reason why these are often lower in potassium than neighbouring lava-derived soils. However, the main cause is most probably differences in potassium level of parent material, as even the ash soils in the drier areas are markedly lower in potassium than neighbouring lava-derived soils.

It is obvious from the data of soils developed on similar parent materials under different rainfalls that there is progressive leaching of the more soluble constituents of the soil with increasing rainfall. Comparative data showing this have been presented earlier (Anderson, 1964c). The encouragement of a good vegetational cover to offset this tendency is the greatest prerequisite to maintaining fertility, rainfall acceptance, and retentivity and the depth of these soils. Removal of soil constituents in the drainage water would seem to follow Polynovs' (1937) leaching sequence, which gives the following relative mobilities of elements and compounds based on chlorine equal to 100 percent.

In the lower-lying soils, rich weathering and slight leaching lead to the accumulation of more soluble constituents. Particularly where there is some drainage impedance, chlorides and sulphates may accumulate in depressions. With the more intense weathering under moderately wet conditions and moderate temperatures on the mid-slopes, free salts and calcium carbonate become

TABLE 7

POLYNOVS' LEACHING SEQUENCES

	Element or Compound	Relative Mobility (%)
Phase I	Cl	100
	SO_4	57
Phase II	Ca	3.00
	Na	2.40
	Mg	1.30
	K	1.25
Phase III	SiO_2	0.20
Phase IV	Fe_2O_3	0.04
	Al_2O_3	0.02

SOURCE: Polynovs, 1937.

leached together with silica (laterisation), but sufficient calcium, magnesium and potassium remain to prevent the mobilisation and leaching of much iron and aluminium under the influence of organic litter leachates (podsolisation). Sweet (1964) found that the dominant clay mineral in five profiles from the middle zone of east Kilimanjaro was metahalloysite, indicating fairly advanced weathering. At the higher elevations, iron and aluminum oxides are lost under the influence of organic complexing, and the stability of the mid-slope soils, depending largely on free iron oxides, is lost. Hence, this is another reason why the high altitude 'podsolised' soils are less able to resist erosion, particularly if the humic topsoil is oxidised under cultivation. The maintenance of organic matter through sensible crop rotations and mulching is thus important at all altitudes, for the soils cannot maintain adequate rainfall acceptance, nutrient retentivity or moisture reserve without it.

CHAPTER 5: SOIL CLASSIFICATION AND DESCRIPTION OF MAPPING UNITS

SOIL CLASSIFICATION

Various systems of classification of soils are in use in different parts of the world. Some are purely arbitrary, based on a selection of a few seemingly important soil properties relevant to the immediate purpose of a map. This system quite often necessitates re-mapping when economic circumstances change the type of crops which must be grown. In 1949, Baeyens wrote that any classification of tropical soils must be 'genetic and totalitarian', i.e., it must take account of all the pedological factors which have contributed to the formation of the soils and not just single chosen factors or properties which are thought to be of particular importance in the circumstances. Following the production of the first soil map of East Africa in 1936, Milne formulated what he thought was the value of soil survey (1940b). He wrote as long ago as 1940:

> The results of soil survey form the factual basis in the development of sound programs of land use. Soil maps and survey reports are to find their justification as guides to the efficient use of the land. They are necessary documents in the framing of policy whether local or national in regard to rural production.

It is a pity that so many development projects since Milne's day have been attempted without any apparent awareness of the need of such documents. Milne also stated (1940c) that general knowledge is not enough in this respect and that studies for the betterment of the use of the land run the gravest risks of error, if the foundation has not been laid in soil survey.

While Milne laid the basis for soil survey in Tanzania, B. Anderson in his survey of the soils of Kongwa and Nachingwea Districts (1957) and again in his bulletin on the Soils of Tanganyika (1962) continued to use Milne's classifications. There is now a need to consider any scheme of soil classification in the light of international developments. In 1960, the United States Soil

Survey produced a comprehensive system of Soil Classification. However, as the definitions for the soil map of Africa were evolved through the cooperation of many soil scientists in Africa, this latter scheme seemed the more obvious choice in classifying the soils in Tanzania, and in particular of Kilimanjaro. The soil definitions and maps of the continent have been published in both English and French and circulated throughout Africa (D'Hoore, 1964). In the table of soils which follows, D'Hoore's classification is followed, but an attempt is also made to attribute the major soil groups to the United States 7th Approximation of Soil Classification (USDA Survey Staff, 1960) as well. Forty mapping units have been distinguished and these include 25 soil series, some of which are subdivided into variants and 15 complexes.

TABLE 8

SOIL CLASSIFICATIONS

Major Soil After D'Hoore, 1964 (After U.S. System in brackets)	Present Materials	Mapping Units and Symbols on Maps
Lithosols (Entisols)	Meru derived rocks	Kware Complex (1)
	various lavas	Mlombea Creep Complex (39)
Juvenile Soils	volcanic ash	Holili Creep Complex (17)
(Entisols) or (Inceptisols)	alluvial/colluvial materials	Alluvial/Colluvial Complex (38)
Reddish Brown Soils of Semi Arid Regions		
(Aridisols)	tuffaceous grit	Kibouni Series (14)
	basaltic colluvium	Kimanga Series (26)
Eutrophic Brown Soils		
(Andepts)	rhomb/porphyry	Kindi Series (9)
	rhomb/porphyry	Sambarai Series (10)

	basaltic & fluvio glacial materials	Himo Series (21)
	fluvioglacial materials	Nanjara Series (37)
<u>Ferruginous Tropical Soils</u> (Ultustalfs)	volcanic ash	Old Moshi Series - Kibongoto Variant (2A)
	Volcanic ash	Old Moshi Series - Old Moshi Variant (2B)
	mixed lava/ash	Old Moshi Series - Kilema Variant (2Bt)
	Volcanic ash	Old Moshi Series - Mamsera Variant (2C)
	mixed lava/ash	Old Moshi Series - Keni Variant (2Ct)
	volcanic ash	Kibohehe Series (3)
	ash over lavas	Sadala Series (4)
	rhomb/porphyry	Msinga Series (8)
	volcanic ash	Uparu Series (12)
	ash and colluvium	Sango Series (13)
	ash or ash/lava mixture	Pumwani Complex (eroded) (15)
	basalt/analcitite with grits	Marangu series - Marangu Variant (19A)
	basalt/andesite	Marangu Series - Mkuu Variant (19B)
	basalt/andesite	Marangu Series - Mrere Variant (19B)
	mixed basaltic/fluvio-glacial material	Samanga Complex (20)

	ash/lava colluvium	Mwika Series (23)
	ash/lava colluvium	Kondeni Series (24)
	volcanic ash	Mahida Series - Mahida Variant (25A)
	ash over basalt	Mahida Series - Mtembweni Variant (25B)
	basaltic colluvium	Huruma Series (27)
	basaltic/andesitic colluvium	Kitalato Series (30)
	basaltic/andesitic colluvium	Usanyi Series (31)
	basalt and basaltic colluvium	Sambala Complex (eroded) (40)
<u>Humic Ferrisols</u> (Oxisols or Ultisols)	ash/lava colluvium	Masama Series - Masama Variant (5A)
	ash/lava colluvium	Masama Series - Lombeta Variant (5B)
	ash colluvium	Masama Series - Maringa Variant (5C)
	ash/andesitic colluvium	Masama Series - Ushiri Variant (5D)
	rhomb/porphyry	Mrawi Series (11)
	volcanic ash	Nanga Creep Complex (16)
	ash/basalt mixture	Kokirie Complex (22)
	ash/cones	Mengwe Creep Complex - Mengwe Variant (28A)

	ash/scoria cones	Mengwe Creep Complex - Kileo Variant (28B)
	andesitic/basaltic colluvium	Useri Series (32)
	trachybasalts	Mashima Creep Complex (35)
	basaltic lavas	Kimanyatu Series (36)
<u>Humic Ferrallitic Soils</u> (Ultisols)	volcanic ash/scoria	Manu Complex - Nrwaa Variant (6A)
	ash or scoria	Manu Complex - Manu Variant (6B)
	ash or scoria	Manu Complex - Forested Variant (6Bf)
	ash or scoria	Manu Complex - Kasese Variant (60)
	trachyandesite or trachybasalt	Kooti Series (33)
<u>Podsolic Soils</u> (Spodosols)	basalt or analcitite	Masia Complex - Masia Variant (18A)
	basalt or andesite	Masia Complex - Maruveni Variant (18B)
	analcite or andesite	Ubaa Complex (29)
	basaltic lavas	Uhini Series (34)

These forty mapping units have been separated on a basis of their profile characteristics reflecting differences in parent materials, climate, slope, previous and present vegetation and nutrient status. As far as possible the soils have been named according to the locality of the most typical profile. The characteristics of the soils are tabulated in Tables 9 through 20 (pp. 88-98). In the description of each unit which follows, the terminology is after the Field Handbook of the Soil Survey of Great Britain (Crompton, 1960), which in many respects is similar to that of the USDA Soil Survey Manual (USDA Soil Survey Staff, 1951).

As seen above the words 'series' and 'complex' following the names of the units with tables. In most cases the word series means precisely what is defined in the USDA Manual. However, in a few cases soils such as the Old Moshi have been referred to as 'series' but subdivided into variants according to the locality of occurrence. There is no doubt that these variants have fairly similar properties, as evidenced by appendices A3-A8, though there are differences in phosphorus contents which reflect some variation in parent materials and also in rainfall. Time has not permitted detailed enough study to decide whether or not these differences necessitate series subdivision. There are two types of soil complex in the area. One type occurs where the soils vary greatly from point to point because of stoniness or erosion or alluvial/colluvial deposition. The other type which is less common has a variety of distinct soils present, but time has prevented the detailed separation of these, which in many cases are not very obvious on the aerial photography.

Associated with the soil description are Appendices A and B. Appendix A contains the profile descriptions and soil analytical data except for mechanical analyses which are given in Table 21. In Appendix B, the species of vegetation noted on each soil are listed. It should be pointed out, however, that time has not permitted the collection of tree and shrub specimens for identification by the East African Herbarium and that some less common species may therefore be wrongly recorded. The method of identification has usually been to obtain the Chagga name from the local people and then to use the check list (Hora and Greenway, 1940) to find the scientific names. Forest trees have also been elucidated from the lists produced by Steele (1963) and later published (Steele, 1967). Greenway's description of the vegetation on Kilimanjaro (1965) has also been useful. With the grasses, Napper's key (1965) has been used for identification and, with the authorities of the species listed, reference should be made to this work.

DESCRIPTION OF THE MAPPING UNITS

1. Kware Complex

This complex is developed on lava, agglomerate and outwash sands from the blow out of the eastern walls of the Meru Caldera. It is the only mapping unit which has Meru rocks for its parent material and olivine nephelinite is the most common rock type. There are approximately 2166 ha lying to the east of the road between the Moshi-Arusha road turn-off and Sanya Juu. The area mapped lies approximately between altitudes 1000 m and 1250 m and is characterised by undulating mounds of rock debris known as Lahar. The general slope is usually 2-3° and rarely more than 5°, but on mounds it may be 10-15°. These undulations tend to be less pronounced to the south of the area.

The soils are stony and in places very shallow and may be imperfectly drained in the numerous small depressions. Colours are predominantly very dark brown or black (10YR 2,2 to 10YR 2,1) gravelly loams with gritty silty loam subsoils, where there is some depth to rock. Subsoil colour is very dark grey brown (2.5Y 3,2 to 10YR 3,2). Consistency is friable to loose and the soils are usually highly porous at the surface, but hard rock frequently holds up water in depressions. The structure is weak fine crumb to subangular blocky, and roots may be found penetrating into the weathering rock except where the drainage is imperfect. Profile Kibongoto 1 is probably fairly typical of the freely drained areas while Masama 6 represents soil in a slight depression where, due to the base rich material, some salinity may build up in the subsoils (Appendices A1 and A2).

The natural vegetation in this complex is *Hyparrhenia-Panicum/Combretum-Acacia* Wooded Grassland. Other species present include *Cordia holstii*, (Mringa ringa), <u>Kigelia aethiopica</u> (Imumu), <u>Ficus sp.</u> (Mkuyu), <u>Acacia tortilis</u>, and <u>Croton macrostachys</u> (Mfurufuru). Planted trees include <u>Grevillia robusta</u>, <u>Eucalyptus spp.</u> and <u>Cassia siamea</u>. <u>Themeda triandra</u> is a common grass before cultivation but <u>Panicum coloratum</u>, <u>P. maximum</u>, <u>Hyparrhenia sp.</u> and <u>Digitaria spp.</u> also occur. Legumes are fairly common in the grazing land and include <u>Phychosia sennarensis</u> and <u>Glycine javanica</u>. Maize and beans (<u>Phaseolus vulgaris</u>) are the chief crops grown, while bananas are planted along drainage line and around depressions. Finger millet, castor and cassava are also grown. Several swamps occur on the colluvial/alluvial soils interspersed among this complex. Kware is perhaps the largest village, but Liwate is also an important market.

<u>Land Use Potential</u>: The soils are extremely rich in plant foods as Appendix A1 shows. Despite the light texture the total base content and percentage base saturation is the highest of all the soils in the survey area. Total and available phosphorus are also higher than in any other soil. Despite the relatively low rainfall (500-750 mm) these soils are nevertheless high in organic carbon, because of the good base and phosphate status. Potassium supply is, however, high in proportion to magnesium, and potassium induced magnesium deficiency symptoms are often evident on maize. The application of lime to beans has been shown to increase yields slightly (Anderson, 1964c) and this is no doubt due to its effect in reducing the mobility and uptake of potassium ions. Most of the soils would be classified by D'Hoore (1964) as Lithosols. In the more humid areas near Sanya Juu they are deeper and tending to Eutrophic Brown Soils.

There is a good potential for maize and bean cropping and also for cattle keeping where water is accessible. Oxen would seem to be essential for cultivation in many areas; the boulder strewn soils do not lend themselves to tractor cultivation without great effort in stone clearing or costly repairs to tractors and implements. The more gentle movement of the ox plough is much less costly. Planting trees as wind breaks and living fences could make this complex more conducive to permanent settlement, but poor water supplies also hinder this.

2. Old Moshi Series

This series, which is one of the most widely distributed on the mountain, typifies the soils developed on volcanic ash in the Coffee/Banana belt. It occurs in three localities: Kibongoto Masama (2A), Old Moshi-Kirua (2B), and Mwika-Keni (2C). In the areas to the east of each of these localities there lie complexes where ash cover generally overlies lavas on the more gentle slopes, but has been eroded from steeper slopes. These complexes are mapped in Kilema (2Bt) and Keni (2Ct), but not in Machame where the boundary between the old Moshi and Msinga Series represents a transition zone. In all localities other than these complexes, the parent material of the Old Moshi Series is deeply weathered volcanic ash or scoria with basaltic lava fragments occasionally occurring on the steeper slopes and in valleys but rarely contributing significantly to the soils. There is, however, an age difference in the ash of the three localities, Kibongoto being the oldest, Old Moshi-Kilema next and Mwika Keni the most recent.

The rainfall pattern also has exerted a differential effect on the soils of the three ash centres, as has the different nature of the magma from which the ash was formed. These three areas are therefore named the Kibongoto (2A), the Old Moshi (2B) and the Mamsera (2C) Variants. The slopes generally vary between 5-20°, being somewhat steeper in Old Moshi-Kilema than in Kibongoto-Masama and Mwika Keni, almost all localities being too steep for tractor cultivation. The series usually occurs within the 1150-1500 m altitudinal range in both Kibingoto-Masama and Mwika Keni (2A and 2C), but 1000-1400 m is the more normal range under the higher rainfall of Old Moshi-Kirua. The surface texture is usually a silty clay loam at higher altitudes. Subsoils are generally silty clays. The most common surface colour is dark reddish brown (5YR 3,3 or 5YR 3,2). Subsoil are usually dark red (5YR 3,4 or 3,5). Consistence is friable and the surface structure is a moderate crumb becoming subangular blocky to weak prismatic in the subsoil. Root distribution is good and though most roots occur near the surface, they are usually still common at 100 cm depth.

The vegetation was formerly forest, and common trees which still occur are Albizzia schimperiana (Mfuranji), Rauvolfia caffra (Msesewe), Croton macrostachys (Mfurufuru), with Cordia holstii (Mringa ringa), Acacia seyal (Msera), Erythrina abyssinica (Mriri), Ficus capensis (Mkuyu or Mkuu), in the drier lower areas. Other trees occurring are Turraea robusta (Mladeye), Albizzia petersiana (Mwilu), Teclea viridis (Mwarue), Terminalia sericea (Mfuko), Alangium chinense (Mringori), Rapanea rhododendroides (Mwasa), Bridelia micrantha (Mwasa). Among the ground cover Digitaria spp., Rhyncheletrum repens, Panicum trichocladum, Sporobolus pellucidus, Setaria orthosticha, Set. romonyma, Aristida sp., Solanum incanum, and Tridex repens may be found. Most of the localities have an annual rainfall of between 900 and 1400 mm. The most common crops are coffee and bananas and the series is very intensively settled with holdings of rarely more than 1.6 ha. Other crops usually grown are maize, yams, sweet potatoes and sugar cane. Areas of pasture are very small but most families keep 2-3 cattle which are mainly stall fed on banana leaves and grass from the lower areas.

With more detailed mapping it may be possible to separate the soils of the three localities into three distinct series, but here they are presented as three variants of the same series (Old Moshi) and two shallow ash phases 2Bt and 2Ct. All of these have much in common in soil properties, vegetation and productive potential. Some of the differences however are described below.

2A--Kibongoto Variant: This covers approximately 5442 ha and probably receives slightly less rain than the Old Moshi Variant (2B). As with many soils on the mountain slopes the surface soil contains a lower percentage of clay at the higher altitudes. Slopes vary from about 3-15° with an average around 8°. Profile Kibongoto 1 is fairly typical and would be classified as a Ferruginous Tropical Soil. There is scope for limited tractor cultivation, but fields are small and the soil is very sticky when moist. While the mean calcium content of topsoils is similar to 2B and 2C (about 10 milli. equivs 100g, Appendix A3) the potassium is considerably greater and the magnesium less. This is probably due both to a high K content of the magma and slightly lower rainfall. Variant 2A is a little lower than 2B in total and available phosphorus but none of these soils are very responsive to P fertilisers as shown from the bean experiments (Anderson, 1964a).

2B--Old Moshi Variant: These soils occur on slopes of between 5-20°, averaging about 12°. As a result, tractor cultivation is a rarity. Profile Old Moshi 6 is fairly typical of the soils though shows some evidence of lava colluvium. There are about 4606 ha of this variant including 2Bt where much of the ash has been eroded and stones are common. Profile Old Moshi 6 (Appendix A4) is fairly typical of the Shimbwe, Kishumundu, Fakeni, Shia and Sango localities while Kirua 2 is an example of the Kirua area (Appendix A5). Profile Kilema 3 (Appendix A6) represents the stony phase in the Mkiashi area of Kilema. These would all be classified as Ferruginous Tropical Soils. Mean analytical data for topsoils of 2B show that this variant is slightly higher in total and 0.3N HCL soluble phosphorus but considerably lower in exchangeable potassium. Some responses to phosphorus and potassium have in fact been experienced on beans (Anderson, 1964b).

2C--Mamsera Variant: This, together with the slightly stony phase 2Ct, covers approximately 1685 ha in northern Mwika and Keni. The slopes may vary from 1 to 15° where the series gives way to the Mengwe variant of the Nanga Creep Complex (16B). Areas are, however, more gently sloping on this variant than with 2A and 2C. Though potassium contents of topsoils are very variable, the mean data for this sector and the profile Keni 3 (Appendix A7) show lower 0.3N HCL soluble phosphorus and slightly higher K contents than the Old Moshi variant. Profile Keni 2 (Appendix A8) represents an area where the ash cover is often eroded and basaltic lavas outcrop. The soils are, however, all low in potassium and in places are responsive to phosphorus applied to annual crops.

Land Use Potential: These deep, freely drained soils occurring under good rainfalls have a high potential for a wide range of crops. Because of topography, however, mechanical cultivation is difficult and therefore tree crops providing a good canopy to the soil are preferable. Coffee and bananas are the most obvious choice of crops, but citrus, avocado (Clutia abysinica) and possibly spices may also be grown. Pasture legumes will generally grow reasonably well and intensively managed fodder plots either for cutting or grazing could do much to supply the necessary protein for grade dairy cattle. Maize and beans are not the best crops for growing under the rainfall of this series, as erosion, fungal attack and sometimes excess rain all contribute to loss of yield. Vegetables such as tomatoes, onions and cabbages may give a more profitable return than maize but, like maize and beans, are best avoided during the heavy rains. Where they are grown, however, yields may be increased considerably by light dressings of P and K fertilisers. This is probably true for pasture legumes too, but maybe not for tree crops, with the exception of bananas, which frequently show K-deficiency symptoms. Coffee may give economic returns to nitrogen application as recommended by the Coffee Research Station (Robinson, 1967). Where arable cropping is practised, contour banks, grass/legume strips, trash bunds and mulching are very necessary to conserve these rather erodible soils.

Water availability for domestic use and livestock is limited because of the elevated position of these soils which are often situated, at least in 2B, above the steep-sided valleys of the Nanga Creep Complex (16). Some areas, however, are supplied from furrows running from the forest. Communications are difficult during the rains, as the silty clay subsoils when wet provide poor traction for motor vehicles. Constructing more durable roads is a necessary prerequisite for the proper development of the area to enable both the spread of education and new ideas and the ready marketing of cash crops such as bananas, coffee, fruit and vegetables. The Old Moshi Series is placed in Land Use Group 1.

3. Kibohehe Series

This series is developed on volcanic ash like the Old Moshi and has much in common with it. It covers approximately 4603 ha between about 1000m and

1200 m in Masama and Kibongoto. The slopes vary between about 2 and 15° but are more gentle than the Old Moshi Series. The rainfall is probably within the range 850-2250 mm and it is because of this that the Kibohehe Series is heavier textured, somewhat less weathered and of higher base status than the Old Moshi. Slopes usually vary between 5 and 25° with an average of about 12°.

The surface texture is a silty clay loam while the subsoil is a friable silty clay, sometimes with small fragments of weathering rock or ash. Surface colours are usually about 5YR 3,2. Profile Masama 7 is fairly typical of this series (Appendix A9).

The vegetation was formerly forest, but this has been cleared and largely replaced by coffee and bananas. Trees present include *Albizzia schimperiana* (Mruka), *Albizzia petersiana*, *Kigelia aethiopica* (Mumu), *Croton macrostachys* (Mfurufuru), *Rauvolfia caffra* (Msesewe), *Cordia holstii* (Mringaringa), *Acacia seyal* (Mrera) and *Techlea viridis* (Mwarue), while *Clutia abyssinica* (Avocado or Mbarajiji) and *Grevillia robusta* are often planted. Among the grasses, *Panicum maximum*, *Cynodon dactylon* and *Chloris gayana* are fairly common.

The nutrient status of this series is good, both phosphorus and potassium being in fair supply. Base saturation is around 90 percent at the surface and the soil has a high exchange capacity and organic matter content. It would appear from the numerous cracks which occur in the soil surface upon drying and the high exchange capacity that there is a considerable proportion of 2:1 clay minerals in this soil. It would be classified as a Ferruginous Tropical Soil.

Land Use Potential: The depth and good physical and chemical status of this soil make it well suited to perennial crops such as coffee, sugar cane, bananas or citrus. However, as the clay holds the moisture rather tenaciously, highest yields are usually only possible under irrigation. Where arable cropping is practised good yields of maize or beans can be obtained.

Generally, however, slopes are not easy to cultivate mechanically. It is placed in Land Use Group 3.

4. Sadala Series

This series of gritty or sandy clay loams covers about 1342 ha between 900 m and 1100 m in lower Masama. It is developed mainly on ash colluvium overlying rhomb porphyry. The surface colour is usually dark brown (.5 YR 3,1 - 5 YR 3,2), while the subsoil is dark reddish brown (5 YR 3.5,4) with dark brown or black coatings on weathering rock faces. Consistence is friable and the soil is porous apart from a tendency to cap at the surface which makes it erodible.

The natural vegetation is open woodland with _Combretum spp_. common. _Panicum maximum_, _P. infestrum_, _Digitaria sp_., _Indigofera colutea_ make up the ground cover. The rainfall probably averages between 700 and 900 mm annually.

While the mean pH of topsoils (Appendix A 10) is similar to the Kibohehe Series, the exchange capacity and base contents are lower with the exception of potassium which is slightly higher. Both total and acid soluble phosphorus are slightly higher than in Kibohehe, but the organic matter content is considerably lower reflecting the drier climate. There is a slight rise in total base content in the deepest horizon of Profile Masama 5 and the series is classified as a Ferruginous Tropical Soil. The main fertiliser need is probably nitrogen for non-leguminous crops.

Land Use Potential: The gentle slopes of this series make it generally well suited to mechanical cultivation. Maize and beans normally grow well, but can be affected by drought in a dry year. As the soil tends to cap, a legume-rich pasture/arable rotation with the provision of some _Eucalyptus_ or _Grevillea_ shade trees and shelter belts would be useful. There should not be much difficulty in keeping grade dairy cattle. Water supplies may be difficult to maintain locally during the dry season. Sadala Series is placed in

Land Use Group 7.

5. Masama Complex

This complex covers approximately 3278 ha in upper Masama, Kibongoto and Machame (Masama Variant 5A), 918 ha in Kirua and Kilema (Lombeta Variant 5B), and 334 ha in upper Mwika-Keni (Moshi Variant 5C). The parent material is mainly ash with incursions of basaltic or trachytic scoriacious lavas locally. Soils are very deep and freely drained despite the high rainfall in the 1250-2000 mm range. They lie next in the catena above the Old Moshi Series (2) and are associated with the deeply dissected valleys of the Nanga Creep Complex (16). The altitudinal range is approximately 1300-1700 m being higher in 2A and 2C than 2B.

The surface texture is usually a humic sandy loam but may be clay loam where eroded. Topsoil colour is usually 7.5 YR 3,1 with 5 YR 3,4-6 being normal in the subsoil or on eroded areas, except near lava fragments where it may be 10 YR 3,2.5 with red brown mottling. Roots ramify throughout the surface metre or more of these porous soils, but tend to be concentrated near the surface. The structure is moderate crumb to fine subangular blocky in the upper horizons, with subsoils usually being weak prismatic. This complex fits into D'Hoore's (1964) group of Humic Ferrisols.

The remaining trees are considerably shorter in stature than those of the Old Moshi Series but many of the same species occur. Albizzia schimperiana (Mruka or Mfuranje) and Rauvolfia caffra (Msesewe) are the most common. Others occurring include Landolphia kilimandjarica (Kiwaru), Macaranga kilimandscharice (Muhaa), Agauria salicifolia (Mwana) and Croton macrostachys (Mfurufuru). The common grasses are Eragrostis tenuifolia, Digitaria sp., Sporobous pyramidalis, Rhyncheletrum roseum and Pennisetum clandestinum, while Cyporus rotundus is also notable. The three variants of this complex are briefly discussed in turn.

Masama Variant (5A)

This soil is strongly acid and has a low nutrient status below the surface 12 in. (30 mm) or so of soil (Appendix A11). While the total phosphorus is in moderate supply the 0.3N NCI soluble P is very low. Potassium supply, in common with most of the Kilimanjaro ash soils under high rainfall is low. Profile Masama 4 is fairly typical of this variant.

Lombeta Variant (5B)

Under the somewhat higher rainfall conditions in Kirua and Kilema this complex occupies a relatively narrow belt compared to the Masama Variant covering about 918 ha in all. Profile Kilema 2 is fairly representative and as the data in Appendix A12 show the soils are very similar to the Masama Variant.

Maringa Variant (5C)

This variant occupies a similar position in the catena on the ash in the Keni-Mwika area to 5A and 5B in the other areas of ash soils. It lies between 1600 m and 1900 m in the Moshi-Mringa area of Mwika. No profile has been excavated in this small area, but the soils are similar to the Lombeta and Masama Variants (Appendix A12).

Land Use Potential: The bean experiments conducted on all three variants showed striking responses to phosphorus and potassium and some response to lime in all three localities. Only on the Masama Variant where the trials were planted later in the season after the rains had finished were the yields satisfactory, yields elsewhere being of the order of 220-450 kg/ha. Growing beans at these elevations on Kilimanjaro, at least during the rains, is not to be recommended. Coffee and bananas on this complex are very poor. The latter frequently exhibits acute K-deficiency symptoms and both crops show the effects of nitrogen shortage and low temperatures. Tea would probably grow better and give a better return than coffee on these soils. As far as is known the effect of P, K and lime fertilisers on coffee growth has not been investigated though nitrogen in combination with copper fungicidal spray has been shown to give some striking responses in areas similar to these soils (Robinson 1967). Steepness of slopes suggests that arable crops should be kept to a minimum. Fruits such as plums can be grown on the less acid soils as at Kilema, while the possibility of apples and pears is worth investigation. Legumes for fodder could be established with the help of fertilisers, and provide the protein necessary to feed grade dairy cattle and enhance milk supplies. On steep slopes or exposed areas afforestation has much to commend it and pines (Pinus patula, Cupressus sp.), wattle (Acacia mollissima) and Eucalyptus spp. all grow reasonably well. Whether tea could be developed on this complex or not, there is a need to find ways of improving the coffee if it is to be allowed to retain its present proportions on these potentially quite productive soils.

6. Manu Complex

These soils occupy the next highest altitudes to the Masama Complex in the ash catena, usually lying above 1600 m and bordering on the forest. Slopes are even steeper than the Masama complex and may be 5-30°, averaging about 18°. The soils are deeply weathered, ash being visible only on steep slopes. There are again three localities of occurrences in the three main areas of parasitic volcanoes. These have been named the Nrwaa Variant (6A) occurring in upper Kibongoto-Machame, the Manu Variant (6B) in Old Moshi-Kilema and the Kasese Variant (6C) in Mwika-Keni. A forested phase (6Bf) of the Manu Variant has also been studied.

The surface texture is a humic fine sandy loam, sometimes a loamy sand on stable sites, but subsoils are of clay loam texture. Colours may be black or dark reddish brown at the surface (10 YR 2,2, 7.5 YR 3,2 or 5 YR 3.5,3), according to the amount of erosion or cultivation. Subsoils may be reddish brown (5 YR 3-3.5,4) to red (5 YR 3,6 or 4,6), occasionally dark red (2.5 YR

3,6) on very steep slopes. The structure is moderate crumb to subangular blocky becoming weak prismatic in the subsoil. Permeability is moderate throughout with abundant fine fissures, but there is a tendency for the surface to cap when cultivated. The deep friable subsoils are prone to gully erosion, and as a result this complex is dissected by the very steep valleys of the Nanga Creep Complex (16). Roots tend to be concentrated near the surface because of acidity and poor nutrient status in the subsoils.

The remnants of the forest vegetation consist of rather small tree species compared with those on the more fertile soils at lower altitudes. Albizzia schimperania (Mruka) and Rauvolfia caffra (Msesewe) may still be seen but Paurindiantha holstii (Mawana), Conpharyngia holstii (Mracha), Olea hochstetteri (Masingo), Agauria salicifolia (Mwana), Randolphia kilimandjarica (Kirwiro), Croton macrostachys (Mfurufuru), Macaranga kilimandscharica (Muhaa), Syzygium guincense (Masai), are also fairly common. In the ground cover bracken (Pteridium aquilinum) Exotheca abyssinica, Eragrostic tennuifolia, Sporobolus indicus, Rhyncheletrun repens, Digitaria spp., Pennisetum clandestinum, Fimbristylis diphylla are fairly common on uncultivated ground, of which there is a considerable amount. Coffee and bananas are usually extremely poor as are the other crops maize, beans, sweet potatoes and yams. Rainfall ranges between 1500 and 2500 mm annually and results in strongly leached acidic soils which are classified as Humic Perrallitic, though podsolisation is also evident. The three variants are briefly described.

Manu Complex - Nrwaa Variant (6A)

Profile Machame 3 (Appendix A 13) is an example of this variant which covers approximately 2098 ha. This profile and the mean data for topsoils show that the soils are extremely acid and of very low base status. The mean base saturation of topsoils is only 12 percent and potassium is probably most in demand for acid tolerant crops, though lime is necessary to grow most fodder legumes satisfactorily. HCI soluble phosphorus is low also, but with perennial crops is probably less limiting than other elements.

Manu Complex - Manu Variant (6B)

Profile Kirua 1 represents this variant which is some 1919 ha in extent. As Appendix A14 shows, the pH and base contents are similar to the Nrwaa Variant, but phosphorus soluble in HCI is considerably lower.

Manu Complex - Forested Phase (6Bf)

A profile representing this area is Old Moshi 4. Phase 6Bf is situated above 6B in Old Moshi-Kirua (Appendix A15). Patches of the area mapped as forest have been cultivated in the past, but have fallen back to scrub because of poor yields. Pyrethrum has been tried, yet failed because the soils are too acid. Trees of the forest on this area include Albizzia shimperanica (Mruka), Dodonea viscosa (Iturua), Cassia didymobotrya (Evenu), Macaranga kilimadscharica (Muhaha), Myrica salicifolia (Mpache), Agauria salicifolia (Mwana), Ocotea usambaransis Camphor, Syzygium guineense (Masai), Celtis africana (Mrido), Croton sylvatious (Mrindawa) and Comopharyngia holstii (Mracha), Podocarpus milanjanus (Podo) and Croton macrostachys (Mfurufuru). Bracken is common in the ground flora.

The analytical data on Profile Old Moshi 4, like those of Machame 3, show that the soil is extremely acid, low in bases and available phosphorus.

Manu Complex - Kasese Variant (6C)

There are only about 334 ha of the Manu Complex mapped in the Mwika-Keni area and most of this occurs on Kasese Hill. No profile pit has been excavated in this small area but the soils are similar to those in the Nrwaa and Manu Variants, as the data for topsoils in Appendix A14 show.

Land Use Potential: The Manu Complex is one of the most nutrient deficient soils within the mapping area and it has Group 5 land use potential. Besides needing lime and potassium for most crops, these strongly acid soils need phosphorus at least for annuals, as the bean experiments showed. The soils are the result of a very high rainfall on an extremely porous ash which have combined to produce strong leaching of the bases. As several areas have been abandoned which were cultivated previously, it is obvious that perennial crops hold the best promise on this complex as they both protect the soil and return nutrients to the surface, thus maintaining the fertility. Perennial crops which can stand acute acidity are most useful as the cost of liming these soils would be very great. Pines (especially Pinus patula) and wattle (Acacia mollisima) will grow well and it is probable that tea would do likewise with the help of some fertiliser. In fact, tea is likely to yield a much better profit per acre on these acid soils than Arabica coffee which demands a higher pH and nutrient status. While bananas grow in places, the yields are very low and leaves frequently show potassium deficiency. Irish potatoes would probably also thrive better with an NPK compound fertiliser especially one high in potassium. Improved pastures have possibilities with fertilisers, but there would be a need for some lime to establish most legumes satisfactorily.

With any form of arable cropping strict measures of soil conservation must be adopted on these steeply sloping soils, to preserve the more fertile topsoil. Failure to do this will quickly result in rapid decline in yields and greater fertiliser costs to maintain or restore yields.

7. Umbwe Complex

This complex of soils covers approximately 2296 ha in upper Lyamungu, Kibosho and Uru, roughly between about 1350 m and 1550 m elevation. The soils are developed chiefly on a fine-grained trachyte, but in the lower parts and to the east on porphyry. Slopes vary between 2-3° and 25° with an average of about 12°.

The soils are stony and of gritty loam texture at the surface with sandy clay loam subsoils. Surface colours are dark brown in the range 10YR 2.5/3 to 7.5YR 3/2. The structure is weak and surface wash is common. The vegetation was formerly forest and Cordia holstii (Mringaringa), Croton macrostachys (Mfurufuru), Albizzia schimperiana (Mruka) and Rauvolfia caffra (Msesewe) are common together with planted Grevillea robusta and Cupressus lusitanica. Coffee and bananas are the main cultivated crops but maize, yams, beans and sweet potatoes are also planted. Common plants in the small areas of rocky pasture are Pennisutem clandestinum, Eragrostis sp., Digitaria sp. and Cyperus spp. Others present are listed in Appendix B7. The rainfall probably averages about 2200 mm annually with a range of about 2000-2500 mm.

Profile Kibosho 2 is fairly representative and is classified as a Ferruginous Tropical Soil. Despite such a high rainfall the soils are not strongly acid because of the relatively recent deposition of these Kibo lavas and the steepness of the terrain resulting in much erosion. Both phosphorus and potassium are probably adequate for most crops, but magnesium is rather low. Under the high rainfall conditions nitrates are readily leached and nitrogen fertilisers are likely to give good responses to many crops.

Land Use Potential: Because of slopes and stoniness, this complex is unsuited to mechanical cultivation. Good crops of bananas and coffee are obtained and there is a high potential for pasture plants. It is possible that vegetables and temperate fruits would grow on the deeper soils, with timber or fodder legumes, particularly Desmodium uncinatum, on the steep and rocky slopes. The need for grass/legume strips to prevent these erodible soils from washing, is everywhere evident.

8. Msinga Series

This covers some 6269 ha of land between Lyamungu and Uru within the altitudinal range of approximately 1100 to 1400 m. Slopes range from 1-2° to over 15° but average about 8°. On the steeper slopes rocks outcrop, but generally the soils are 1.5-1.8 m deep overlying the parent rhomb porphyry. At the higher altitudes the parent material may be colluvium or boulders from the later trachyte lava flows and in the west there may have been some slight ash influence, most of which has been eroded. Hence the dotted boundary between this series and the Old Moshi-Kibongoto variant.

The soils are fine sandy or silty clay lomas, usually dark brown (7.5YR 3/2) at the surface with subsoils 5-6YR 3/3-4. They are of friable consistence, but are generally more prone to cracking when dry and stickiness when wet, than the neighbouring Old Moshi soils developed on ash. There is some tendency to form a surface cap during rainfall. Roots are well distributed throughout the profile.

The vegetation was formerly medium altitude forest but has been replaced largely by coffee and bananas which grow very well. Trees remaining include Rauvolfia caffra, Albizzia schimperiana, Croton macrostachys, Cordia holstii, with planted Grevillea robusta and mangoes. The common plants in the ground cover are Digitaria spp., Cyperus retundus, Panicum maximum, Urochloa bolbodes, Crotalaria sp., Eragrostis tenuifolia and Solanum incanum. Others present are listed in Appendix B8. Rainfall ranges from about 1400-1800 mm over the series.

As there is a gradation of properties with altitude over this series, Profile Kibosho 1 (Appendix A17) typifies the lower areas while Lyamungu 1 (Appendix A18) represents the higher altitude soils which inclined to be more acid in the subsoil. Msinga Series has tendency for induced magnesium deficiency due to the high potassium contents. Research is needed to discover corrective measures for different crops.

Land Use Potential: Besides producing good coffee and bananas this series could grow more citrus, avocado pears, vegetables and legume-rich fodders for cattle. Lucerne has thrived at Msinga Farmers' Training Centre for a number of years and Glycine javanica, Desmodium spp., and Doliches formosus also grow well. Together with Setaria splendida and Chleris gayana these legumes could provide more nutritious fodder for much greater milk production.

9. Kindi Series

The Kindi Series covers transition zone of former woodland between the Msinga and Sambarai Series. It is a narrow belt running from Machame to Uru between the altitudes of approximately 1000-1150 m and covers about 2804 ha. Profile drainage is free. Slopes are usually in the range of 3-12° averaging about 6°.

Like the lower lying Sambarai Series, the Kindi is developed on rhomb porphyry, possibly with some fluvioglacial wash in places. The surface soils are dark brown to dark reddish brown (7.5YR 3,2 to 5YR 2,2) silty clay loams with moderate crumb structure. There is some tendency for the surface to cap during storms.

The remnants of the former woodland vegetation are often the same species as found on the Msinga Series, but with some *Combretum sp.* also present. Woodland has largely been replaced by coffee and bananas, maize, beans, and cassava. *Sorghum verticilliflorum*, *Cynodon dactylon*, *Digitaria scalarum* and *Panicum maximum* are common grasses with *Tridex repens* and *Cyperus rotundus* frequent weeds. Rainfall probably ranges from about 900 to 1300 mm.

Profile Lyamungu 4 (Appendix A19) represents this series. The soils are well supplied with bases, but like the Msinga Series potassium is relatively high in proportion to magnesium. Total phosphorus is lower than in many soils but availability is probably adequate for most crops, though some annual crops may respond slightly to application of superphosphate. Manganese is low and investigations are needed into possible responses on a number of crops. Because of its juvenility and good base status, these soils are classified as Eutrophic Brown Soils.

Land Use Potential: For optimum yields, coffee usually needs some irrigation in this series. There is a considerable potential for citrus and avocado expansion and, where irrigation is possible, vegetable growing also. The gentle slopes make this series suitable for mechanised cultivation of a range of crops. Maize, beans, cassava, finger millet and castor can all be grown. In addition there is considerable scope for improved pastures and milk production.

10. Sambarai Series

There are about 4043 ha of this series covering the lower areas of Machame to Uru to the north of the main Moshi to Arusha road. The series has been split into upper and lower phases by a dotted line on the map, the lower tending to be slightly more sloping (averaging about 5°) than the upper which averages only 2-3°. The lower phase is also slightly more stony with somewhat shallower soils. Rainfall is probably on the order of 850-1150 mm averaging about 1000 mm.

The surface soils are commonly dark reddish brown (6 YR 3,2) sandy clay loams with subsoils reddish brown in the range 5YR 3,4-6. Outcrops of boulders of rhomb porphyry occur occasionally. Because of the higher temperatures and poorer vegetation cover, the structure is less stable than the previous series and there is a noticeable tendency for the surface to cap under arable cropping.

The vegetation was formerly open wooded grassland in which *Hyparrhenia dissoluta*, *Panicum maximum* and *Combretum gueinzii* (Kimaroro) were common. Today, the series is largely cropped with maize, beans and finger millet and there is also some sisal. Common grasses and other trees are listed in Appendix B10. Profile Kibosho 4 is fairly representative of this series and a description is given in Appendix A20.

Land Use Potential: The relatively few bananas and coffee trees growing on this series are poor unless irrigated, because of inadequate rainfall. Like the Kindi Series the soils are of good base status, though low in exchangeable manganese. Phosphorus availability is high and the total phosphorus content is also considerably higher than in the Kindi Series.

With the gentle slopes over most of this series there is much scope for mechanised agriculture. Maize, beans, finger millet may all be grown, while castor, cassava and citrus are possibilities for perennial crops. Without sisal growth, the land offers opportunities for more intensively managed pastures and, with a few shade trees, grade cattle. The need for fuel supplies, shelter and cattle fences are good reasons for planting rows of *Eucalyptus* for multi-purpose use. Poor water supplies are some hindrance to widely scattered settlement on this series. There is a need to investigate the effect of manganese sulphate on various crops, and to work out rotations to prevent serious capping of the surface soils.

11. Mrawi Series

Situated below the forest in Kibosho and Uru chiefdoms this series covers about 1340 ha. Slopes are steep averaging about 12° and rock outcrops are common. The parent material is trachyte possibly with some rhomb porphyry at the lower elevations. Surface soils are dark brown (7.5YR 3,2) humic sandy loams while subsoils are dark brown gritty or sandy clay loams with weak prismatic structure. Roots are well distributed into the fissured rock.

The vegetation was formerly high altitude *Ocotea/Podocarpus* rain forest, but has been replaced by coffee, bananas, maize, beans, pasture, yams and sweet potatoes. Common trees remaining include *Rauvolfia caffra*, *Croton macrostachys*, *Albizzia schimperiana* and *Olea africana*, while *Grevillea robusta* and *Cypress* have been widely planted. The ground cover consists mainly of *Pennisetum clandestinum*, *Cyperus spp.*, *Digitaria scalarum*, *Eragrostis tenuifolia* and *Rumex sp*. Other species are listed in Appendix B11. Rainfall is very high and probably ranges between 1700 and 2500 mm annually.

Appendix A21 gives a description of a profile on this series. Despite strong leaching conditions, the soils are not strongly acid, but are unsuitable for good growth of acid-sensitive crops like lucerne or pyrethrum. Total phosphorus is fairly high but availability may not be adequate for some annual crops. The profile surface is well supplied with potassium, but the mean of seven topsoils indicates that some of these on more gently sloping sites may be inadequate for crops such as bananas, especially under the high rainfall conditions. Despite the presence of some mineral reserve in the subsoils this series would probably be best classified as a Humic Ferrisol, as the base saturation is low.

Land Use Potential: Because of the very high rainfall and acid soils neither Arabica coffee nor bananas are at their best on this series. There is some possibility of replacing some of the poor coffee with tea. Pines and wattle are more at home than Grevillea or Cypress and there is considerable scope for tree planting on the steeper slopes. Protein-rich fodder legumes such as Desmodium sp. could be planted to improve milk supplies. Lucerne, however, will probably not thrive without liming. It is probable that some non-legume crops would respond to nitrogen application under these high rainfall conditions. Legume or grass strips are needed to conserve the soil.

12. Upare Series

This series covers approximately 1832 ha in between about 850 m and 1200 m in lower Old Moshi-Kirua. Slopes generally range between 5 and 15° and average about 8°. The soils are deep freely drained dark reddish brown (5YR 3,3) sandy clay loams with dark red (2.5YR 3,4-5) silty clay subsoils. They are developed on ash colluvium. The surface has a weak crumb structure and is very prone to capping and erosion. Roots are well distributed throughout the profile.

The natural vegetation is Hyparrhemia/Panicum/Combretum-Acacia Wooded Grassland in which Hyparrhenia dissoluta, Panicum maximum, Sorghum verticilliflorum and Aristida ascensionis are common grasses and Combretum guenzii, Croton macrostachys and Acacia mellifera common trees. Other species are recorded in Appendix B12 while Appendix A22 gives a description and data for a typical profile. Rainfall probably ranges between 750 and 1000 mm. In common with other ash derived soils this series is rather low in exchangeable potassium, but phosphate availability is probably adequate for most crops.

Land Use Potential: Most of this series is suitable for mechanical cultivation and has a good potential for maize, beans, sorghum and finger millet. Castor and cassava thrive and citrus would probably grow also. Shelter belts of *Grevillea* and *Eucalyptus* species could enable the land to be divided up into manageable units besides giving some protection to crops and livestock. With the tendency of these soils to cap and erode, pastures must be established in rotation with arable crops. Grass/legumes strips would also prevent soil and water loss. Tie-ridge cropping is recommended for most arable crops.

13. Sango Series

The Sango Series occupies the more gentle slopes (3-8° averaging about 5°) in Old Moshi-Kirua and is situated below the Uparu Series just above the main Moshi-Mombasa road. It is derived from volcanic ash and ash colluvium from parasitic cones. The soils are dark reddish brown silty loams to silty clay loams of relatively uniform colour throughout the profile. They are friable, but tend to cap at the surface.

Like the Uparu Series, the natural vegetation is Wooded Grassland, but the size and variety of trees is less. *Combretum* species are very common while *Acacia species* are more common than on the former. The chief grasses are *Hyparrhenia dissoluta*, *Panicum maximum*, *Aristida adscensionis* and *Heteropogon contortus*. Other species are listed in Appendix B13. Basal cover rarely exceeds 60 percent and may fall to 20 percent or less where overgrazed. Rainfall is probably in the range of 650-900 mm. A profile description with data is given in Appendix A23. This series is considerably better supplied with potassium and has much higher contents of available phosphorus than the Uparu Series. Despite a somewhat lower rainfall there is a slightly higher carbon content which probably reflects some increase in clay content and better phosphate status. It is classified as a Ferruginous Tropical Soil.

Land Use Potential: The reliability of good maize yields on this series is considerably less than the Uparu. Tie-ridge cropping to conserve moisture and soil is therefore even more necessary. Sorghum, finger millet, castor and cassava are safer crops than maize. Shelter belts of Eucalyptus could become the means of fencing livestock and provide local firewood. Water shortages make focal-type village settlement more practical than the development of scattered homesteads. This series, then, is suited to mechanised arable cultivation rather than intensive small fields. There is also scope for improved pastures.

14. Kibouni Series

The Kibouni Series is developed mainly on a calcareous lapilli tuff which probably originated from the Lake Chala caldera. It also includes some soils derived from colluvium washed from the Msangasanga Hills. The series covers approximately 1805 ha lying within the altitudinal range of 850-1150 m in the Mwika to Keni-Mengwe area.

The surface soil is usually a dark brown (7,5YR 3/2) sandy loam to loam with weak crumb structure, while the subsoil is a dark reddish brown (5YR 3.5/4) silty clay loam with moderate subangular blocky structure. There is a tendency for surface-capping. Roots ramify freely throughout the profile but usually are less common immediately below the surface.

The vegetation is medium height *Arista-Heteropogon/Acacia-Combretum* Bushed Grassland. Besides *Aristida adscensionis* and *Heteropogon contortus*, *Eragrostis superba* *Cynodon dactylon*, *Panicum maximum*, *Chloris roxburghiana*, *Cenchrus cilaris* and *Indigofera sp*. commonly occur. Among the bushes *Warburgia stuhlmannii*, *Acacia mellifera*, *A. tortilis*, *A. stuhlmannii* and *Combretum* species are common. Others are listed in Appendix B14. A profile description with analytical data is given in Appendix A24. The soils are well supplied with bases in general and with phosphate. Exchangeable manganese is low, however, and may be inhibiting the yields of some crops.

Land Use Potential: Maize is often poor in years of low or badly distributed rainfall. This series probably receives only 700-750 mm on average. Finger millet, castor, cassava, beans, cotton and possibly groundnuts are arable crops capable of utilising the dry conditions. The tendency for the surface soil to cap, however, means that continued arable cropping is likely to lead to soil erosion. A rotation including sown legume-rich pastures would help to maintain some stability in the soil, besides supplying much needed protein for livestock and some nitrogen for subsequent arable crops. With most arable crops a tie-ridge system of cultivation is best in order to make use of the limited rainfall. Grass strips are needed throughout all arable areas. There is scope for planting *Eucalyptus sp.* to enable both land enclosure for livestock and provision of firewood.

15. Pumwani Complex

These are badly eroded,often stony soils developed mainly on ash with exposed lavas in some areas. The complex covers approximately 2833 ha of land, generally with slopes of 5-15° mainly lying between Old Moshi and Mwika, and associated with the Upare Sango and Kibouni Series. Colours vary with the parent material degree of erosion and the rainfall, but are often dark reddish brown 5YR 3/3-4. Texture likewise varies from gritty loams to more commonly silty clay loams.

The vegetation is *Acacia/Commiphora* Bushland or Bushed Grassland. Common species include *Acacia mellifera*, *A. stuhlmannii*, *A. nilotica*, *A. tortilis*, *A. nigrescens*, *Commiphora schimperi* and *Combratum sp.* The grasses include *Hyparrhenia dissoluta*, *H. filipendula*, *Digitaria scalarum*, *Aristida adscensions* and *Chloris pycnothrix* with *Indigofera sp.*

Because of the dry climate and erosion these soils are often immature. They are very variable so that no profile could be expected to represent more than a limited area. No description of a profile is given therefore, but mean analytical data for composite topsoils are recorded in Appendix A48.

Land Use Potential: The slopes and gullied nature of this complex mean that mechanised cultivation is difficult or impossible. The rainfall which probably averages between 600 to 1000 mm also limits arable cropping. Grazing, or planting *Eucalyptus* trees as a supply of firewood and building materials, for more useful soils in the neighborhood is probably the best use for much of this complex. Limited areas of crops, particularly the more drought resistant, may also be grown. However, because of the very erodible nature of most soils, strict soil conservation measures are needed. Here again limited water supplies mean that the focal type of settlement is more suitable than the uniformly distributed dwellings which occur in the coffee/banana areas.

16. Nanga Creep Complex

Approximately 3219 ha of these soils lie in the steeply sloping valleys which cut into the ash deposits particularly in Old Moshi-Kirua. Due to the porous ash, few of the rivers are neat and the Nanga, flowing as it does from a particularly large incision into the mountain, is more permanent than most. Slopes on this compiex vary from 15° to over 60° and are usually so steep and excessively drained that at least at the lower elevation few large trees develop. Over the lower part of the complex the natural vegetation is Wooded Grassland in which *Hyparrhenia spp.*, *Heteropogon contortus* and *Eragroatis cilianensis* are common. Trees include *Combretum spp.*, *Ficus capensis*, *Rauvolfia caffra* and *Erythrina abyssinica*. At higher elevations, *Albizzia sp.* and *Rapanea rhodendroides* have been noted in areas cropped chiefly with maize, bananas, casava and yams. Any coffee is generally poor. The complex is too variable for any single profile to represent a very large area, but some idea of these soils may be obtained from the description and data of a soil on the Mengwe Creep Complex (Appendix A39) which is formed on comparable slopes on ash cones under similar rainfalls.

Land Use Potential: Due to the steep slopes and excessive drainage these soils are not cultivated much at the lower altitudes. Under the greater rainfalls at higher elevations they are cropped but because of rapid loss of topsoil crops soon suffer nitrogen deficiency and after a few years the natural vegetation is allowed to take over again. If these soils are to remain productive it is essential to plant close grass strips along the contour, to ridge-crop, and to mulch as much as possible to prevent erosion. Bananas and fodder legumes for cattle could be planted much more on these slopes, the steeper of which could provide income from timber or firewood if planted with Grevillen, pines, Cypress or Eucalyptus. Cropping with tea is a possibility at the higher altitudes, if the soils were well conserved.

17. Holili Creep Complex

There are approximately 3219 ha of this complex which occurs on the steeply sloping ash and scoria cones in the lower areas of Kirua to Keni-Mriti Mengwe. Like the Nanga Complex, slopes are often very steep usually in the range of 15° to 60°. Textures are sandy loams to clay loams and the soils are deep, friable and excessively drained. Colours are variable but often dark reddish brown (5YR 3/4) or dark brown (7.5YR 3/2) at the surface, largely depending on the rainfall and the age of the ash cone.

The vegetation is usually bushed grassland and there is little cultivation. Common grasses include Aristida sp., Hyparrhenia sp., Heteropogon contortus, Digitarin scalarum with Indigofera sp., Combretum species, Acacia stuhlmannii and A. nilotica.

Data for topsoil on this complex are given in Appendix A23. Despite the relatively dry climate, the excessive drainage seems to have caused the soils to be acid and particularly low in potassium and phosphorus.

Land Use Potential: Steepness of slopes, shallowness, excessive drainage and aridity of climate usually inhibit the growth of worthwhile maize crops and arable cropping of any kind is rare. At present this complex is either grazed or out for fodder and often burnt. There seems little else for which most of it could be used. However, planting Eucalyptus spp. in the more favourable sites could provide a source of firewood, fencing and building materials for the people living in the neighbouring areas of higher soil potential.

18. Masia Complex

This complex is found on slopes of 10-25° just below the forest in Marangu-Mamba (18A) and Mkuu-Mashati (18B). The two variants Masia 1430 ha and Maruveni 816 ha are developed on olivine analcitite and andesite respectively with basalts common to both. All the soils are very stony with frequent rock outcrops. Surface soils are organic loams, very dark brown (7.5 YR 2/2) to 10 YR 2/2) with brown subsoils, commonly (7.5 YR 3/4) loams to clay loams. Drainage may be slightly imperfect. Erosion of topsoil frequently occurs under the high rainfall conditions and this is one reason for the shallow soils, another being slow weathering with the low temperatures at these altitudes usually above 1600 m.

Appendices A25 and A26 give descriptions of soils on Masia Variant and its forested phase. Time has not permitted the excavation of a profile on the smaller Maruveni Variant but the topsoils are very similar to those recorded for the Masia Variant, exchangeable potassium and, in this case, acid soluble phosphorus being low.

Land Use Potential: Acid tolerant crops are best, but the high rainfall, particularly of the Masia variant, usually means that annuals are grown during the October-December rains. Tea, pines, and on Maruveni variant, possibly plums and other temperate fruits could be grown. While there is much scope for improved pastures, lucerne does not grow well because of acidity. Potassium and some phosphate may be necessary for most legumes, as demonstrated by the bean experiments.

19. Marangu Series

This occupies some 1768 ha (Marangu Variant), 1468 ha (Mkuu Variant) and 1174 ha (Mrere Variant). With closer study these 3 variants could possibly be separated into three or more distinct series. They all, however, occur between elevations of about 1300 m and 1700 m and each has been divided into an upper (more acid) and lower phase on the map. While the Marangu variant may be on basalt or analcitite with some fluvioglacial sandy deposits, the Mkuu and Mrere variants are on basalt or andesite. All are stony, especially the upper phase. Surface soils are usually dark brown sandy loams (6-7.5 YR 3/2), while the subsoils are variable coloured gritty or sandy clay loams. Surface soils tend to cap and hence erode under cultivation.

The vegetation was formerly Albizzia/Rauvolfia forest which has largely been replaced by coffee and bananas with maize, beans and small pastures. Species are listed in Appendix B19. Rainfall probably ranges from about 1400 to 1900 mm over the Marangu variant, but is more probably within the 1000 to 1700 mm range on the Mkuu and Mrere variants.

Appendices A27 to A30 inclusive give descriptions and data for the three variants including the upper and lower phases of the Marangu variant. While this variant is reasonably well supplied with bases and phosphate, the Mkuu and Mrere Variants are poor in these and therefore much more responsive to fertiliser applications as the bean experiments showed.

Land Use Potential: There is considerable scope for greater production of vegetables, legume-rich pastures, and thus more milk. The steeper slopes are suited to afforestation. Temperate fruits may be a possibility on the drier Mkuu and Mrere variants. Often P and K fertilisers are needed on these latter and here the temperate fodder legumes will probably not thrive without light dressings of lime.

20. Samanga Complex

This covers approximately 1566 ha in lower Marangu. The soils are underlain by basaltic lavas which outcrop particularly on the steeper slopes, while there are additives of both fluvioglacial sands and volcanic ash in places. Slopes range from about 3 to 15° averaging 8-10°. The surface soils are usually dark reddish brown (5YR 3/3) sandy clay loams, but may be silty clay loams where there has been ash influence. Subsoils are often stony with weak prismatic structure. Surface capping is frequently pronounced.

The vegetation was formerly Hyparrhenia-Panicum/Combretum wooded grassland in the main with some Albizzia/Croton/Rauvolfia woodland on the upper phase. Species are listed in Appendix B20. This has mostly been replaced by maize, beans and sisal. Rainfall probably averages between 750 to 1000 mm annually.

Appendice A31 contains a soil description and chemical data of a profile mainly derived from leached fluvioglacial material and particularly low in potassium. This is not so true of the complex as a whole as the topsoil mean shows. A straight response to superphosphate occurred with the bean trials in this complex and the data show this may be expected.

Land Use Potential: This complex requires the more drought-resistant crops. Much of the area may be tractor cultivated, though occasional boulders sometimes make this hazardous. Improved pastures, Eucalyptus belts, tie-ridged sorghum, maize beans and other arable crops could replace some of the land under sisal.

21. Himo Series

Lying in the lower areas of Kilema and Marangu, this Eutrophic Brown Soil covers about 1416 ha. Slopes rarely exceed 10° and 4° would be above average. The series is developed on basalt with some fluvioglacial overlay. Soils are often little over a metre deep. Altitudes range from 800 to 1000 m and the rainfall from about 700 to 900 mm annually. The surface soils are dark brown to dark reddish brown (7.5 YR - 5 YR 3/2) silty clay loams. Subsoils are dark reddish brown (5 YR 3/3) gritty loams to clay loams. Roots are well distributed throughout these soils, often entering the fissured rock.

The vegetation is Hyparrhenia-Panicum/Combretum-Acacia Wooded Grassland but much of this has been replaced by maize, beans and finger millet. A profile description and analytical data are given in Appendix A32 while the species of vegetation noted are listed in Appendix B21.

This series has good base saturation and is adequately supplied with both phosphorus and potassium. Though the carbon content is lower than soils under a wetter climate, it is well distributed throughout the profile.

Land Use Potential: This gently sloping series is well suited to mechanical cultivation. Maize, beans, finger millet, castor and cotton could all be grown more intensively while there is scope for improved pastures and Eucalyptus belts. Lack of water supplies inhibits scattered settlement which is another reason for mechanised cultivation.

22. Kokirie Complex

These Humic Ferrisols occupy about 1225 ha in upper Mwika-Mamba. They are developed on a mixture of basaltic lavas and ash, with the latter tending to be eroded on the steeper slopes which may be up to 25° and average about 15°. Surface soils are often dark brown (7.5 YR 3/2) humic sandy loams but may be redder sandy clay loams where ash influence is pronounced. Subsoils are usually silty clay loams or gritty clay loams with weak prismatic structure.

The vegetation was formerly forest with Rauvolfia and Albizzia species common and the species listed in Appendix B22 also occurring. Coffee and bananas are the chief crops, but maize, beans, yams and sweet potatoes are also grown. Livestock are mainly stall fed but there are small patches of grazing land. Appendix A33 gives a description and analytical data. While phosphorus is probably adequate for many crops, under the high rainfall conditions (about 1700-2200 mm) annually, both potassium and manganese are very low. Deficiency symptoms of potassium are frequently seen on bananas. Some deficiencies of phosphorus on beans have also been noted.

Land Use Potential: The high rainfall and acidic soils of this complex do not support the best coffee. Tea might suit these conditions better, while there is scope for more legume-rich fodder areas. Trees, particularly cypress, pines and wattle, grow well, and also *Grevillea* at the lower elevations. Soil conservation is much needed. N, K and Mn are probably deficient for most crops, while legumes require more phosphorus.

23. Mwika Series

Covering approximately 1426 ha, the Mwika Series occurs between altitudes of 1200 m and 1500 m in Mwika-Mamba. The slopes are variable, usually ranging from 5-20° with an average of about 12°. Though not distinguished on the map, there is an upper and lower phase showing quite a range of properties. Appendix A34 gives a description of a soil on the upper, more acid phase, while lower phase data (Profile Mwika 3) are also given. The surface of the Mwika Series is usually a dark reddish brown sandy loam to sandy clay loam, while the subsoil is often dark reddish brown (5 YR 3/4) or dark brown where weathering lavas are near. Like the Kokirie, the Mwika Series is developed on a mixture of basaltic and ash colluvium.

The vegetation was formerly forest, which has now been largely replaced by coffee, bananas, maize, beans, yams and occasional sugar cane and grass patches. Indigenous species are listed in Appendix B23. The data in Appendix A34 show the upper phase and the mean of 7 topsoils to be very low in potassium in common with many of the soils of basaltic origin. Both the potassium and the phosphorus status improve at lower elevations, as the acidity and rainfall diminish.

Land Use Potential: There are a variety of crops which can be grown on this series, but perhaps improved legume-rich fodder pastures, citrus fruits and vegetables would give as good return as most other crops. Tree planting on the steeper slopes is suggested. Potassium and phosphorus are required for most crops while lime would be essential for lucerne on the more acid soils. Coffee tends to be rather poor on the upper phase.

24. Kondeni Series

The Kondeni Series covers approximately 1348 ha of Lower Mwika and Mamba. Slopes are usually in the range of 3-8°, the deep friable soils being developed on ash colluvium. They are usually dark reddish brown (5 YR 3/4) silty clay loams with weak crumb structure at the surface. Subsoils are reddish brown silty clay loams (5 YR 3-3.5/4) with weak prismatic structure. The vegetation was formerly *Hyparrhenia-Panicum/Combretum-Croton/Rauvolfia* Wooded Grassland, but this has largely been replaced by maize and beans, with some bananas and irrigated coffee. Species are listed in Appendix B24. Grass is often cut here to feed the cattle kept higher up the mountain.

Appendix A35 contains a description of soil in this series. The potassium status and availability of phosphorus in the topsoils is much better than in the Kwika Series, which lies higher up the slope. Carbon content, however, is much lower.

Land Use Potential: As the rainfall is around 750-1000 mm only, the crops grown must be fairly drought tolerant. Maize, beans, sorghum, castor and cassava usually yield fairly well. There is scope for improved pastures, *Eucalyptus* shelter belts and possibly citrus, but strict soil conservation measures including grass strips, ridge-cropping and pastures are needed if this is not to erode under tractor cultivation.

25. Mahida Series

This soil occurs in Mwika and Keni below the Mamsera variant of the Old Moshi Series (20). It covers about 2943 ha of moderately sloping, (5-12°) rolling country. The parent material is ash from the cones of the Msangasanga Hills which form the Holili Creep Complex (17). Vegetation is Hyparrhenia/Combretum Wooded Grassland and the species are listed in Appendix B25.

The surface soils are dark reddish brown (5 YR 3/3) sandy clay loams with moderate crumb structure, while subsoils are slightly redder (5 YR 3/4) silty clays with weak prismatic structure. Appendix A36 gives an example. Besides the Mahida Variant (25A), the Mtembweni Variant (25B) is included in this series. This has occasional outcrops of lava boulders, but otherwise seems very little different from the Mahida Variant. Like the Kondeni Series, this series is better supplied with potassium than the soil next to it higher up the mountain. Phosphate availability is also fair, but manganese is low.

Land Use Potential: Much of it receives too little rain (approximately 600-900 mm to support good yields of any but drought-resistant crops. However, there is a possibility of much improved pastures, some citrus, bananas, cotton and castor. Soil conservation and crop rotations are important as these ash soils can easily erode. Nitrogen is probably the main fertiliser requirement but in some of the higher areas, potassium is also needed for optimum yields. Belts of Eucalyptus trees could provide wind breaks, fencing and building materials.

26. Kimanga Series

This occurs in lower Mseri-Mashati and is one of the driest areas covered by the survey--rainfall is probably in the range of 500-750 mm. Slopes are gentle, usually 3-8°. Because of the dry climate soils are not always deep and basalt boulders may outcrop. The soils are fine sandy clay loams (usually 5 YR 3/3) at the surface and readily cap on exposure to rainbeat. Subsoils are dark reddish brown (5 YR 3/4) silty or gritty clay loams with weak prismatic structure. Both phosphate and potassium have fair availability, but the carbon and nitrogen contents are low. Appendix A37 gives a profile description and data.

The vegetation was Aristida-Heteropogon/Acacia-Combretum Bushed Grassland, but has been largely replaced by maize, beans, sorghum and finger millet. Species noted are listed in Appendix B26.

Land Use Potential: Only the most drought-resistant crops such as sorghum, cotton, castor and finger millet give satisfactory yields and there is therefore a great need to prevent any runoff by tie-ridge cropping. The 3367 ha of this series are probably best left predominantly to grazing, but even this can cause much erosion unless stock numbers are strictly controlled. Water supplies inhibit widely scattered permanent settlement.

27. Huruma Series

This covers approximately 1542 ha of moderately sloping land between the elevations of 1200-1500 m in Mkuu and Mashati. Slopes are usually in the range 4 to 12° and there has been a considerable amount of gullying. The soils are dark reddish brown silty clay loams of weak subangular blocky structure, with occasional boulders of basalt outcropping. Parent material is mainly colluvium derived from basalt or andesite. Subsoil has silty or sandy clay loam textures and weak prismatic structure.

The vegetation was largely Hyparrhenia-Panicum/Combretum/Croton/Rauvolfia Wooded Grassland. Other species still present are listed in Appendix B27. Rainfall is probably in the 750-1000 mm range.

A profile description and data are given in Appendix A38. In common with the other soils derived from basalt, the data indicate that potassium is in short supply. Both total and acid soluble phosphorus are also low. Unlike many soils on the mountain, pH rises with depth.

Land Use Potential: The more drought-resistant crops again grow best, but if deficiencies of P and K were corrected, maize and legumes might grow better. One of the highest responses to P and K fertilisers with the bean trials occurred on this soil. There is scope for improved pastures, planting of *Eucalyptus* and *Grevillea* trees and much improvement in maize and other crop husbandry. Water supplies necessitate the focal type of village settlement. It is possible that some wheat might be grown if soils were well conserved.

28. Mengwe Creep Complex

Found on slopes greater than 15° on the steep ash cones of the Mengwe zone within the altitudinal range of approximately 1400 and 1800 m these soils cover about 537 ha (Mengwe Variant 28A). They also cover about 50 ha on the isolated scoriaceous cone of Kileo Variant (28B) in Mkuu. The soils are deep friable sandy to silty clay loams, usually dark reddish brown with dark red ash with dark red subsoils (2.5 YR 3/4-2.5 YR 3/6). As such, they are as red as any soil in the mapping area and this is due to their excessive drainage. The vegetation was formerly *Albizzia/Rauvolfia* Medium Altitude Forest, but has been replaced largely by coffee, bananas, maize, yams and sweet potatoes. Species of indigenous vegetation are listed in Appendix B28. The cover of trees and the basal ground cover is much poorer on the Kileo variant. Rainfall probably ranges between about 1400 and 1800 mm.

Appendix A39 contains a description of a profile on the Mengwe Variant together with topsoil data. Both total and acid soluble phosphorus are low and potassium is extremely low, particularly in the subsoils. Despite their juvenility these soils have developed considerable acidity. The carbon content is low for this altitude and reflects both erosion and a shorter period of moisture availability.

Land Use Potential: Perennial crops are best able to utilise these excessively drained soils. Bananas, grass strips and afforestation should therefore provide the main crops for the steeper slopes. Because of erosion and moisture availability, bananas and grass/legume strips are very important in conserving soil and water and providing fodder and building materials.

29. Ubaa Complex

This is another steeply sloping soil, but is developed on olivine analcitite or andesite in the Ubaa district of Upper Mkuu. It covers about 191 ha of steep slopes (10-25°) and is badly eroded and stony. The surface soil is a dark brown (7.5 YR 3/2) humic sandy loam with weak crumb structure and is very friable. Subsoils are reddish brown to dark reddish brown (5 YR 3.5/4) gritty clays or clay loams.

The vegetation cover is very poor on this podsolic soil. Though formerly dry forest, the Cassipourea sp. common, it is now largely poor grassland, more akin to vegetation type 14. Species noted are listed in Appendix B29. Rainfall probably ranges between 1000 to 1500 mm.

The data in Appendix A40 show that these soils are extremely acid, low in phosphorus and extremely deficient in all bases, particularly potassium.

Land Use Potential: This complex is one of the poorest of the mapping units and supports poor crops of coffee, bananas, maize, yams and sweet potatoes. Pasture covers a large part of the area, but is poor in both its species and basal cover. Afforestation, Irish potatoes and possibly tea seem the most sensible crops, but bananas and grass/legume strips with the help of fertilisers could play an important part in soil conservation and at the same time raise milk yields.

30. Kitalato Series

This covers about 3367 ha in lower Useri and Mashati. It is developed on basaltic/andesitic colluvial material on even slopes of 2-10° within the range of approximately 1100 m to 4700 m. The surface soils are dark reddish brown silty clay loams with moderate to weak crumb structure and tend to cap. Subsoils are also dark reddish brown (4 YR 3/4) silty clay loams.

Vegetation was formerly Aristida-Heteropogon/Acacia-Combretum Bushed Grassland with the species listed in Appendix B30. Rainfall probably ranges between 600 and 800 mm.

A profile description and data are given in Appendix A41. Though potassium is low in the subsoils, the surface is well supplied. Acid soluble phosphorus is very low while the poor carbon contents reflect the dry climate.

Land Use Potential: Sorghum, finger millet, castor, cassava and beans are more reliable crops than maize. Because of surface capping, tie-ridge cropping, grass strips and pasture leys should be essential parts of the farming system. Eucalyptus belts could supply shelter, a means of fencing and firewood.

31. Usanyi Series

This occurs on slopes usually of 5-15° within the altitudes of 1400 m and 1600 m in Useri. The soils are developed on basalt and colluvium, are fairly deep and support the best coffee and the greatest density of people in Useri district. They cover about 1785 ha. Surface soils are usually dark reddish brown (5 YR 3/3) sandy clay loams with moderate crumb to subangular blocky structure, while the subsoils, like the Kitalato series are dark reddish brown (4 YR 3/4) clay loams, the vegetation was formerly Albizzin/Rauvolfia/Croton Woodland with the species noted in Appendices A42 and B31. Rainfall probably ranges between 900 and 1100 mm.

The analytical data show a much higher potassium status for this series compared to the Kitalato. Phosphorus soluble in HCI is probably inadequate for most annual crops.

Land Use Potential: This soil is the best of the reddish soils in Useri. Above it, the Useri Series is much more acid while below the Kitalato has a much lower rainfall. Coffee and bananas grow reasonably well but may respond to applications of N and P fertilisers. There is also scope for improved legume-rich pasture strips on the contour, and afforestation with Eucalyptus or Grevillea on the steeper slopes.

32. Useri Series

Though situated just above the Usanyi Series, this series is considerably more acid, due both to greater rainfall and its trachytic parent material. It covers approximately 1166 ha of moderately sloping land (3-15°). The surface soils are dark reddish brown fine sandy loams (5 YR 3/3) with moderate fine crumb structure. Subsoils are also dark reddish brown (4-5 YR 3/4) silty clay loams, with weak prismatic structure.

The vegetation was formerly Albizzia/Rauvolfia/Croton Woodland with the species listed in Appendix B32. Rainfall probably ranges from about 900 to 1200 mm and falls mainly in the October-January period.

Appendix A43 gives a profile description and data. This series is very acid and is classified as a Humic Ferrisol tending to a Humic Ferrallitic. Both phosphorus and potassium are low, but as the mean of 5 composite samples is somewhat better than the profile, this is probably atypical of the series as it occurs near the crest of a steep-sided valley.

Land Use Potential: Coffee is relatively poor on this series and bananas frequently show potassium deficiency symptoms. Improved pastures, potatoes, vegetables and possibly temperate fruits are suggested emphases, but none of these is likely to grow well without P and K fertilisers. Afforestation with pines or wattle would be best on the steeper slopes of this erodible soil.

33. Kooti Series

This is developed on andesite and colluvium in Upper Useri. It covers about 1068 ha of steeply sloping (5-10°) country, within the altitudinal range of 1600 m to 1800 m. The soils are dark brown (7.5 YR 3/2) humic sandy loams with dark reddish brown (5 YR 3/3-4) silty clay loam subsoils with clay skins and weak prismatic structure.

Vegetation was formerly dry forest with *Albizzia sp*. and *Ficus sp*. remaining. Appendix B33 gives the other species noted while a soil description and data are given in Appendix A44. Both the phosphorus soluble in HCI and the potassium status are low.

Land Use Potential: Acid-tolerant crops grow best. Afforestation with pines or tea planting can probably make the best use of these soils. With P and K fertilisers, and possibly light dressings of lime, there may be scope for temperate fruits and legume-rich pastures.

34. Uhini Series

This area of high altitude podsolic soils covers approximately 724 ha of relatively gently sloping glades within the forest. Slopes rarely exceed 15° and are usually about 10° which is much less than the surrounding forested lands. The origin of the glades is obscure though Wood (1965) has offered some explanations. There is a black (2.5 YR 2/0) acid mat on the soil surface (mor humus). Subsoils are gritty clay loams, being very dark brown (10 yr 2/2).

The vegetation consists of *Eragrostis spp*. and *Fimbrystilis diphylla*, while Kikuyu grass (*Pennisetum clandestinum*) occurs on cattle tracks. *Artemesia afra* is a common shrub. Appendix B34 gives further species noted while the soil description and data are in Appendix A45.

Land Use Potential: At present these soils are used solely for grazing but they could support the more acid-tolerant vegetables if P and K fertilisers were applied. Afforestation with pines or wattle and improved pastures are other possibilities.

35. Mashima Complex

In contrast to the strongly acid soils of the Uhini Series, this more steeply sloping complex is considerably higher in bases, particularly calcium and potassium. It is therefore probable that much better yields can be obtained. Appendix A46 gives a description of a soil cleared from the forest for a few years, as well as composite soil data from within the forest, while Appendix B35 gives some of the common species of this dry type of forest.

Land Use Potential: Clearing such lands and planting more productive tree species would be a more profitable use than at present. It might be possible to integrate vegetables and fruit growing in contour strips within the forest, but monkey damage may be a problem. Complete clearing of such steep slopes can only result in erosion and rapid loss of fertility.

36. Kimanyatu Series

This small area of approximately 909 ha in the north of Useri District is more fertile than the surrounding soils at similar altitudes. It owes this to fluvioglacial action. The soils are dark reddish brown (7.5 YR 3.2-5 YR 3.2) sandy medium loams with reddish brown subsoils of sandy clay loam texture. These soils are derived mainly from fluvioglacial deposits. The rainfall is probably in the 900-1150 mm range and the deep friable soils support or have supported a good stand of *migunga* (*Acacia abyssinica*) which averages about 12 m in height. *Albizzia schimperiana* and *Acacia brevispica* are also common. *Pennisetum clandestinum* is a common grass. Unfortunately, it was not possible to have a pit dug on this series. The vegetation noted is listed in Appendix B36.

Land Use Potential: The main high value crop on this series at present is pyrethrum which grows quite well. There are small areas of coffee and considerable room remains for expansion of both these crops on such relatively fertile soils. Responses to potassium are unlikely but superphosphate would probably give some yield increase on most annual crops at least in the higher, more acid parts of the series. Sweet potatoes and wheat would perhaps give better returns than maize, at this altitude.

37. Nanjara Series

The Nanjara Series covers about 1937 ha in the north of Useri District within the altitudinal range of 1500-1800 m. It is developed on variably textured material of fluvioglacial origin. Slopes are rarely more than 5°. These soils are young and usually weathering boulders or gravel are encountered below 100 cm. Unlike most other soils on the mountain, the topsoil colour is very dark brown, frequently 10 YR 2.2 occasionally 7.5 YR 3.2 at higher altitudes with only a slight change in the subsoil to 10 YR 2.3. Surface soils are generally fine sandy clay loams with an unusually stable coarse crumb to subangular blocky structure. Subsoils are silty clay loams with moderate prismatic structure. Because of their stable structure and good rainfall infiltration, these soils are not easily eroded. The rainfall over this series is probably within the 650-900 mm range on average and falls mainly in the October-December period.

The vegetation is dominantly grassland with *Themeda triandra*, *Cynodon dactylon* and *Hyparrhenia dissoluta*, *Eragrostis sp*. and *Setaria sphacelata* being common in different areas. *Indigofera sp*. occur frequently. *Acacia tortilis*, *Acacia mellifera* and *Erythrina abbysinica* are among the few tree species. Other species are listed in Appendix B37. In certain areas at lower altitudes, overgrazing and consequent erosion of topsoils occurs. Maize, beans, bananas and pyrethrum are the chief crops. Appendix A47 gives a description and data for this series.

Land Use Potential: These soils are used mainly for maize and bean growing at present. Many of them will, however, support quite good pyrethrum and grazing. The low rainfall prevents coffee from thriving but Cypress and drought-resistant trees such as *Eucalyptus sp.* and *Cassia siamea* will. Trees could therefore provide the means of fencing and thus facilitate rotational grazing of pastures. This means there could be much improvement in the utilisation of both natural and reseeded pastures. The gentle slopes offer the possibility of increased mechanisation in maize and bean growing though boulders in some areas will hinder this. The emphasis in future should therefore be on increased mechanisation of maize, bean and possibly wheat growing, with afforestation of stony areas, fencing and sowing of grass/legume pastures for beef and local milk production. Nitrogen should be the main fertiliser requirement for most crops.

38. Alluvial/Colluvial Complex

This complex is very variable and often owes its local characteristics to the surrounding soils. In some parts steeply sloping colluvial soils make up the majority of the area, in others fertile alluvium or poorly drained soils. As a result, no profile description could be typical and a variety of crops are suited to the different areas, some of which are listed in the section on land use groups.

39. Mlombea Creep Complex

The essential features of these soils are their steeply sloping nature. Parent materials are diverse around the mountain as are climatic conditions. The fertility of these soils likewise varies with these factors. As a result of the interaction of climate and fertility, several crops are grown including maize and coffee, but trees, whether natural or planted, seem to be common to most areas of this creep complex.

40. Sambala Complex

This badly eroded, often stony area covers about 1588 ha on the eastern slopes of the mountain. Its occurrence is sometimes associated with fault lines. Erosion has made the soil depth variable and gullies prevent the safe use of tractors on this complex. It resembles the Pumwani Complex (15) in many respects but differs in being more stony and being developed essentially from lavals. As it occurs in dry areas, the vegetation tends to be overgrazed and consequently *Acacia* bushes are spreading so that the vegetation is mainly bushland. Species are recorded in Appendix B40. The complexity of soils means that any description of a profile would not represent any large area, therefore none is given. Grazing or afforestation with *Eucalyptus* species seem the most sensible uses of this area.

TABLE 9 - GENERAL CHARACTERISTICS OF SOILS: KWARE COMPLEX AND OLD MOSHI SERIES

Name and Symbol	Locality	Parent Material	Natural Vegetation Type	Approx. Annual Rain (mm)	Slope °'s	Approx. Top-soil (cm)	Depth Top-rock (cm)	Texture Sur-face (Field Grade)	Texture Sub-soil (Field Grade)	Colour Sur-face	Colour Sub-soil	Structure Sur-face	Structure Sub-soil	Surface Consis-tence	Land Use Present	Land Use Potential
KWARE COMPLEX (1)	Lower Kobogo to Kware	Meru agglo-merateland/ Laneretum wash.	Hyparrenia/ Panicum/ Combretum/ Wooded Grassland	700-1000	1-5	12	60	Gritty loam	Loamy gravel	Black	Dark brown	Moder-ate crumb	Weak sub-angular blocky	Friable	Maize Beans Grazing	Improved pas-ture, more intensive arable cropping. Needs N and possibly Mn.
OLD MOSHI SERIES (2A)	Kibongoto Masama	Ash	Formerly forest of Albizzia/ Rauvolfia	1200-1500	5-20	16	Deep	Silty clay loam	Fine sandy clay	Dark red brown	Dark red	Moder-ate crumb	Weak pris-matic	Friable open	Mainly coffee, bananas	Citrus, legume-rich pastures, vegetables. Slight response to P
OLD MOSHI SERIES, OLD MOSHI VARIANT (2B)	Old Moshi Kilema	Mainly ash, some lavas	Formerly forest of Albizzia/ Rauvolfia	1200-1800	5-20	15	Deep	Silty clay loam	Silty clay	Dark red brown	Red brown	Moder-ate crumb	Weak pris-matic	Friable open	Mainly coffee, bananas	Citrus, legume-rich pastures, vegetables. Slight response to P
OLD MOSHI SERIES, KILEMA VARIANT (2Bt)		Mixed ash/ lavas	Formerly forest of Albizzia/ Rauvolfia	1200-1800	5-20	18	Usu-ally over 150	Sandy loam	Coarse sandy clay loam	Dark brown	Dark yellow brown	Weak crumb	Very weak pris-matic	Friable tending to cap	Mainly coffee, bananas. Small areas arable and pasture	Citrus, legume-rich pastures, vegetables. Slight response to P
OLD MOSHI SERIES, MAMSERA VARIANT (2C)	Mwika Keni	Ash	Medium altitude forest of Albizzia/ Rauvolfia	1200-1800	5-20	18	Deep	Silty clay loam	Gritty clay loam	Dark red brown	Dark red brown	Crumb	Weak pris-matic	Friable open	Mainly coffee, bananas, some maize, beans	Intensive coffee, bananas, citrus, veg., improved pas-ture. Often some response to P

TABLE 10 - GENERAL CHARACTERISTICS OF SOILS: KIBOHEHE, SADALA AND MASAMA SERIES

Name and Symbol	Locality	Parent Material	Natural Vegetation Type	Approx. Annual Rain (mm)	Slope °'s	Approx. Top-soil (cm)	Depth Top-rock (cm)	Texture (Field Grade) Sur-face	Texture (Field Grade) Sub-soil	Colour Sur-face	Colour Sub-soil	Structure Sur-face	Structure Sub-soil	Surface Consis-tence	Land Use Present	Land Use Potential
KIBOHEHE SERIES (3)	Lower Masama	Ash/ colluvium	Formerly woodland of Albizzia/ Croton/ Rauvolfia	1000-1200	2-15	20	Usually deep	Clay loam	Silty clay	Dark red brown	Dark red brown	Moderate crumb to sub-angular blocky	Weak pris-matic	Friable open	Irrigated coffee, veg., citrus, bananas, maize	Expansion of citrus and legume-rich pastures
SADALA SERIES (4)	Lower Masama	Ash/ colluvium over lava	Hyparrhenia/ Panicum/ Combretum Wooded grassland	800-1000	0-10	15	Usually deep	Silty clay loam	Gritty clay loam	Dark brown	Yellow red-dish	Fine crumb	Weak pris-matic	Tends to cap	Grazing, maize, beans	Improved pasture and citrus expansion, intensive maize/bean farming
MASAMA SERIES, MASAMA VARIANT (5A)	Upper Masama Kibongoto	Ash/ Trachyte colluvium	Albizzia/ Rauvolfia forest	1200-1800	5-20	14	Deep	Sandy loam	Sandy clay loam	Very dark brown	Very dark brown	Weak fine crumb	Moderate pris-matic	Friable	Largely coffee, bananas	Improved pasture, possibly tea, afforestation. Needs NPK
MASAMA SERIES, MASAMA VARIANT (5A)	Masama Kibongoto	Mainly ash with some lava colluvium	Forest Albizzia/ Rauvolfia with some Ocotea	1500-1800	3-20	14	Usually over 150	Loam	Sandy clay	Very dark brown	Dark red-brown to dark grey	Weak fine crumb	Moderate pris-matic	Friable with tendency to cap	Mainly coffee, bananas, yams, maize, sweet potatoes	Vegetables, improved pasture, afforestation, possibly tea, plums
MASAMA SERIES, LOMBETA VARIANT (5B)	Old Moshi Kilema	Mainly ash, some lava colluvium	Albizzia/ Rauvolfia/ Ocotea forest	1500-2000	3-20	14	Usually over 150	Sandy loam	Sandy clay	Dark brown	Dark red-brown	Weak fine crumb	Weak pris-matic	Friable tending to cap	Poor coffee, bananas, maize	Vegetables, improved pasture, afforestation, possibly tea, plums

TABLE ii - GENERAL CHARACTERISTICS OF SOILS: MANU COMPLEX, UMBWE COMPLEX, MSINGA SERIES AND KINDI SERIES

Name and Symbol	Locality	Parent Material	Natural Vegetation Type	Approx. Annual Rain (mm)	Slope °'s	Approx. Top-soil (cm)	Depth Top-rock	Texture Sur-face (Field Grade)	Texture Sub-soil (Field Grade)	Colour Sur-face	Colour Sub-soil	Structure Sur-face	Structure Sub-soil	Surface Consis-tence	Land Use Present	Land Use Potential
MANU COMPLEX, NRWAA VARIANT (6A)	Kibongoto Machame	Ash over-lying Trachyte	*Ocotea* rain forest	1800-2200	5-25	10	Very deep	Humic sandy loam	Sandy clay loam	Dark brown	Red-brown	Weak fine crumb	Weak pris-matic	Very friable tending to cap	Poor coffee, bananas maize, scrub pasture	Pines, improved pastures, tea, potatoes
MANU COMPLEX, VARIANT (6B)	Old Moshi Kilema	Mainly ash	*Ocotea* rain forest	1800-2200	5-25	10	Very deep	Organ-ic loam	Sandy clay loam	Dark red-brown	Dark red	Weak fine crumb	Weak pris-matic	Very friable	Poor coffee, bananas, maize, scrub pasture	Pines, improved pastures, tea, potatoes
UMBWE COMPLEX (7)	Upper Uru-Kibosho	Rhombporphyry or Trachyte		2800-2100	5-25	15	Often less than 100	Gritty humic loam	Moder-ate pris-matic	Very dark brown	Brown	Weak sub-angu-lar blocky	Moder-ate pris-matic	Friable	Coffee, bananas, maize, beans	Afforestation, potatoes, improved pasture
MSINGA SERIES (8)	Lyamungu Kibosho Uru	Rhomb-porphyry	*Albizzia/ Rauvolfia* forest	1400-1700	3-15	20	Usu-ally over 150	Sandy clay loam	Silty clay loam	Dark brown	Dark red-brown	Moder-ate crumb to sub-angular blocky	Moder-ate pris-matic	Friable slight tendency to cap	Good coffee, bananas, veg.	Improved pastures, veg., citrus, *Grevillea*, hard woods
KINDI SERIES (9)	Lower Uru to Lyamungu	Rhomb-porphyry	*Albizzia/ Rauvolfia* woodland	1000-1300	1-10	15	Over 100	Silty clay loam	Gritty clay loam	Dark brown	Dark red-brown	Moder-ate crumb	Moder-ate pris-matic	Friable tends to cap	Irri-gated coffee, mainly beans, finger millet, few bananas	Mechanized arable, improved pastures, citrus, castor, irrigated coffee, veg.

TABLE 12 - GENERAL CHARACTERISTICS OF SOILS: SAMBORAI, MRA, UPARU, SANGO AND KIBOUNI SERIES

Name and Symbol	Locality	Parent Material	Natural Vegetation Type	Approx. Annual Rain (mm)	Slope °'s	Approx. Top-soil (cm)	Depth Top-rock (cm)	Texture Sur-face (Field Grade)	Texture Sub-soil (Field Grade)	Colour Sur-face	Colour Sub-soil	Structure Sur-face	Structure Sub-soil	Surface Consis-tence	Land Use Present	Land Use Potential
SAMBORAI SERIES (10)	Lower Uru to Machame	Rhomb-porphyry	Wooded grasslands Panicum/ Hyparrhenia/ Combretum	750-950	1-8	12	Usually over 100	Sandy clay loam	Gritty clay loam	Dark brown	Red-brown	Weak sub-angular blocky	Weak pris-matic	Friable tending to cap	Maize beans	Mechanized arable, maize, beans, sorghum, finger millet, castor, shelter salts
MRA SERIES (11)	Upper Lyamungu to Uru	Rhomb-porphyry, some Trachyte	Ocotea/ Podocarpus rain forest	2000-2500	5-25	15	Usually over 100	Humic sandy loam	Grey clay loam	Dark brown	Dark brown	Weak crumb	Weak pris-matic	Very friable	Coffee, bananas, maize	Afforestation, improved pasture, veg., possibly tea
UPARU SERIES (12)	Lower Kirua, Old Moshi	Mainly ash, colluvium	Hyparrhenia/ Panicum/ Combretum-Acacia Wooded grassland	750-1000	3-15	14	Usually over 100	Sandy clay	Silty clay	Dark red-brown	Dark red	Weak fine crumb	Moder-ate pris-matic	Friable tends to cap	Maize, beans, castor, finger millet, grazing	Sorghum, citrus improved pasture Eucalyptus belts
SANGO SERIES (13)	Lower Old Moshi Kirua	Ash and ash colluvium	Hyparrhenia/ Panicum/ Combretum Acacia Wooded grassland	650-900	2-8	16	Usually over 100	Silty loam	Silty clay loam	Dark red-brown	Dark red-brown	Mod-erate crumb	Mod-erate pris-matic	Friable with slight tendency to cap	Maize, beans, castor, cassava finger millet, grazing	Mechanized arable, improved pasture, shelter belts
KIBOUNI SERIES (14)	Lower Mwika-Keni	Tuffaceous grit and ash colluvium	Aristida Heteropogan/ Acacia Combretum Bushed grassland	500-750	0-8	15	Usually over 100	Loam	Silty clay	Dark brown	Dark red-brown	Weak crumb	Moder-ate sub angular blocky	Friable tends to cap	Grazing with some maize, beans, sorghum	Improved pasture castor, finger millet, possibly groundnuts, needs grass-strips, tie-ridging

TABLE 13 - GENERAL CHARACTERISTICS OF SOILS: PUMWANI, NANGA, HOLILI AND MASIA COMPLEXES

Name and Symbol	Locality	Parent Material	Natural Vegetation Type	Approx. Annual Rain (mm)	Slope °'s	Approx. Topsoil (cm)	Depth Toprock (cm)	Texture (Field Grade) Surface	Texture (Field Grade) Subsoil	Colour Surface	Colour Subsoil	Structure Surface	Structure Subsoil	Surface Consistence	Land Use Present	Land Use Potential
PUMWANI COMPLEX (15)	Lower Old Moshi Kilema	Ash colluvium	Hyparrhenia Panicum/ Combretum Acacia Wooded grassland	600-1000	5-25	15	Variable Usually over 100	Sandy clay loam	Silty clay loam	Dark red-brown	Dark red	Weak fine crumb	Weak prismatic	Friable tends to cap	Grazing Grass-cutting Maize	Improved pasture Eucalyptus belts, tie-ridged, drought resistant, arable crops
NANGA CREEP COMPLEX (16)	Old Moshi Kilema	Volcanic ash	Forest Woodland or Wooded grassland	1000-2000	15-60	10	Very deep	Fine sandy clay loam	Silty clay loam	Dark red-brown	Dark red	Moderate crumb	Weak prismatic	Very friable	Clumps of bananas, coffee, maize among wooded grassland	Afforestation, improved fodder, legume strips, potatoes, possibly tea in upper areas
HOLILI CREEP COMPLEX (17)	Lower Keni and Kirua	Little weathered ash and scoria zones	Hyparrhenia Heteropogon/ Combretum Acacia Bushed grassland	500-900	15-60	10	Very variable	Gritty loam	Sandy clay loam	Red-brown	Red-brown	Weak crumb	Very weak prismatic	Friable tends to cap	Mainly grazing	Eucalyptus belts, improved pasture, sorghum, cassava, finger millet
MASIA COMPLEX (18A) and (18B)	Upper Marangu, Mkuu	Olivine analcitite or andesite or basalt	Formerly Ocotea/ Podocarpus Rain forest	1500-2500	5-20	10	Frequently less than 100	Humic loam	Silty clay loam	Very dark brown	Brown	Moderate fine crumb	Moderate subangular blocky	Very friable	Rather poor coffee, bananas, pasture	Afforestation, potatoes, improved pasture, possibly tea

TABLE 14 - GENERAL CHARACTERISTICS OF SOILS: MARANGU SERIES

Name and Symbol	Locality	Parent Material	Natural Vegetation Type	Approx. Annual Rain (mm)	Slope °'s	Approx. Top-soil (cm)	Depth Top-rock (cm)	Texture Sur-face (Field Grade)	Texture Sub-soil (Field Grade)	Colour Sur-face	Colour Sub-soil	Structure Sur-face	Structure Sub-soil	Surface Consis-tence	Land Use Present	Land Use Potential
MARANGU SERIES, MARANGU VARIANT (19; upper phase)	Arisi Marangu	Olivine analcitite with fluvio-glacial admixture	Albizzia/Rauvolfia medium altitude forest	1500-2000	5-20	10	Usually over 100 variable	Humic sandy loam	Sandy clay loam	Very dark brown	Dark red-brown	Weak crumb	Very weak pris-matic	Very friable tending to cap	Coffee, bananas yams, sweet potato	Vegetables, Afforestation, possibly temperate fruits, legume-rich pastures. Needs P and K, sometimes lime
MARANGU SERIES, MARANGU VARIANT (19A; lower phase)	Kinyangi Central Marangu	Olivine analcitite	Albizzia/Rauvolfia medium altitude forest	1300-1800	3-15	12	Usually over 120 variable	Sandy loam	Gritty clay loam	Dark brown	Dark red-brown some-times mottled	Mod-erate crumb to sub-angular blocky	Weak pris-matic	Friable surface tends to cap	Coffee, bananas maize, yams, sweet potato beans, small pastures	Vegetables, Afforestation, citrus, legume-rich pastures. Needs P and K fertilisers
MARANGU SERIES, MKUU VARIANT (19B)	Mkuu, Kilamfua Masasani	Andesite	Albizzia/Rauvolfia Woodland forest	1100-1500	5-20	12	Usually over 100 variable	Silty loam	Sandy clay loam	Dark brown	Dark brown	Mod-erate crumb	Weak to mod-erate pris-matic	Friable tends to cap	Coffee, bananas maize, yams, sweet potato Small pastures	Vegetables, Afforestation, legume-rich pastures, possibly temperate fruits
MARANGU SERIES, MRERE VARIANT (19C)	Mashati	Andesite or glassy lava	Albizzia/Rauvolfia Woodland forest	1000-1400	5-20	12	Usually over 80 variable	Sandy loam	Sandy clay loam	Dark red-brown	Dark red-brown	Mod-erate crumb	Weak pris-matic	Friable	Coffee, bananas yams, sweet potato Small pastures	Vegetables, Afforestation, legume-rich pastures, possibly temperate fruits

TABLE 15 - GENERAL CHARACTERISTICS OF SOILS: SAMANGA COMPLEX, HIMO SERIES, KOKERIE COMPLEX AND MWIKA SERIES

Name and Symbol	Locality	Parent Material	Natural Vegetation Type	Approx. Annual Rain (mm)	Slope °'s	Approx. Top-soil (cm)	Depth Top-rock (cm)	Texture Sur-face (Field Grade)	Texture Sub-soil (Field Grade)	Colour Sur-face	Colour Sub-soil	Structure Sur-face	Structure Sub-soil	Surface Consis-tence	Land Use Present	Land Use Potential
SAMANGA COMPLEX (20)	Lower Marangu Kilema	Basalt fluvio-glacial sand mixture	Tall Hyparrhenia Panicum/ Croton Rauvolfia Wooded grassland, Woodland	750-1000	3-15	15	Usu-ally over 100	Sandy clay loam	Sandy clay loam	Dark red-brown	Dark red-brown	Weak crumb to sub angular blocky	Weak pris-matic	Friable tends to cap	Maize, beans, some bananas irri-gated coffee, sisal, fodder, grass-land	Intensified arable, improved pas-ture, citrus castor, eucalyptus, and Crevillea belts, Needs P and often K fertil-izers
HIMO SERIES (21)	Himo Lower Marangu	Basalt with fluvio-glacial admixture	Hyparrhenia/ Panicum Combretum Acacia Wooded grassland	650-950	2-8	15	Usu-ally over 60	Silty clay loam	Sandy clay loam	Dark red-brown	Dark red-brown	Weak crumb	Mod-erate sub-angu-lar blocky to prismatic	Friable with slight cap	Maize, beans, finger millet, sisal, castor, fodder pastures	Mechanized maize, beans, millet, improved pastures, pos-sibly citrus, shelter belts of Eucalyptus
KOKERIE COMPLEX (22)	Upper Mamba-Mwika	Basaltic ash mixture	Albizzia/ Rauvolfia forest	1500-2000	5-20	15	Usu-ally over 50	Organ-ic loam	Silty clay	Dark brown	Dark red-brown	Mod-erate sub-angular blocky	Weak pris-matic	Friable	Mainly coffee, bananas with small areas of pasture, maize, beans	Vegetables, Afforestation, with pines, cypress, legume-rich pasture. Needs P and K, often lime
MWIKA SERIES (23)	Mwika-Mamba below road	Ash/ lava colluvium	Albizzia/ Rauvolfia forest	1200-1600	5-15	15	Usu-ally over 150	Sandy loam	Clay loam	Dark red-brown	Dark brown to dark red-brown	Weak crumb	Weak pris-matic	Very friable, tends to cap	Mainly coffee, bananas maize, beans, yams	Vegetables, citrus, rich pastures. Some response to P

TABLE 16 - GENERAL CHARACTERISTICS OF SOILS: KONDENI, MAHIDA, KIMANGA AND HARUMA SERIES

Name and Symbol	Locality	Parent Material	Natural Vegetation Type	Approx. Annual Rain (mm)	Slope °'s	Approx. Top-soil (cm)	Depth Top-rock (cm)	Texture Sur-face (Field Grade)	Texture Sub-soil (Field Grade)	Colour Sur-face	Colour Sub-soil	Structure Sur-face	Structure Sub-soil	Surface Consis-tence	Land Use Present	Land Use Potential
KONDENI SERIES (24)	Lower Mwika	Mainly ash colluvium	Hyparrhenia Panicum/ Combretum Rauvolfia Wooded grassland	750-1000	3-10	15	Deep	Silty clay loam	Silty clay loam	Dark red-brown	Dark red-brown to red-brown	Weak crumb	Weak pris-matic	Friable tends to cap	Maize, beans, fodder grass-lands, some bananas a little irrigated coffee	Mechanized arable, legume-rich pastures, citrus, castor, Eucalyptus/ Grevillea belts
MAHIDA SERIES	Lower Mwika	Ash and scoria	Hyparrhenia Combretum Wooded grassland	750-1000	3-15	15	Deep	Fine sandy	Silty clay	Dark red-brown	Dark red-brown	Moder-ate crumb	Weak to mod-erate prismatic	Friable	Maize, beans, some bananas grazing land	More intensive arable, improved pastures, citrus, Eucalyptus/ Grevillea belts
KIMANGA SERIES (26)	Lower Useri to Mkuu	Basaltic colluvium	Aristida-Heteropogon/ Acacia Combretum Bushed grassland	500-750	1-10	15	Deep	Fine sandy clay loam	Silty clay loam	Dark red-brown	Dark red-brown	Weak crumb to sub angu-lar blocky	Very weak pris-matic	Slightly hard, tends to cap	Grazing maize, beans, finger millet	Improved pasture intensified maize, beans, millet, castor, cassava, Eucalyptus belts
HARUMA SERIES (27)	Lower Mkuu	Basaltic colluvium	Albizzia/ Croton/ Rauvolfia Wooded grassland	750-900	3-12	15	Over 100	Silty clay loam Occa-sional boulders	Silty clay loam	Dark red-brown	Dark red-brown	Weak crumb to sub-angular blocky	Weak pris-matic	Slightly hard when dry, tends to cap	Maize, beans, finger millet fodder grasses	Improved pasture castor, citrus, Grevillea belts. Needs P and K fertilisers

TABLE 17 - GENERAL CHARACTERISTICS OF SOILS: MENGWE CREEP AND UBAA COMPLEXES, KITA-LATO AND USANYI SERIES

Name and Symbol	Locality	Parent Material	Natural Vegetation Type	Approx. Annual Rain (mm)	Slope °'s	Approx. Top-soil (cm)	Depth Top-rock (cm)	Texture Sur-face (Field Grade)	Texture Sub-soil (Field Grade)	Colour Sur-face	Colour Sub-soil	Structure Sur-face	Structure Sub-soil	Surface Consis-tence	Land Use Present	Land Use Potential
MENGWE CREEP COMPLEX	Upper Keni	Ash and scoria cones	*Albizzia/ Rauvolfia* forest	1250-1750	15-60	10	Very deep	Sandy clay loam	Silty clay loam	Dark red-brown	Dark red-brown	Moder-ate crumb	Moder-ate sub-angular blocky	Very friable	Mainly coffee, bananas	Afforestation, possibly temp-erate fruits/ vegetables
UBAA COMPLEX (29)	Ubaa Mkuu	Silicsous analcitite	High alti-tude forest now poor grassland	1000-1300	5-20	12	Usu-ally less than 100	Humic sandy loam	Gritty clay loam	Dark brown	Dark red-brown	Weak crumb	Moder-ate crumb pris-matic	Very friable tends to cap	Poor coffee/ bananas pasture	Afforestation, possibly temp-erate fruits, legume-rich pastures. Needs N,P and K fertilisers, some lime for crops
KITA-LATO SERIES (30)	Lower Useri Mashati	Ash and basaltic andesitico/ colluvium	*Aristida Heteropogon/ Combretum Acacia* Bushed grassland	650-800	1-10	10	Usu-ally over 100	Silty clay loam	Silty clay loam	Dark red-brown	Dark red-brown	Weak to moder-ate sub-angu-lar blocky	Weak sub-angu-lar blocky tending to pris-matic	Slightly hard, tends to cap	Largely grazed, some maize, beans finger millet, sorghum	Improved pas-ture, castor, more intensive maize, beans millet, Eucalyptus belts
USANYI SERIES (31)	Lower Useri	Basalt and colluvium	*Rauvolfia Albizzia* Woodland	850-1100	5-15	15	Usu-ally over 100	Gritty clay loam	Sandy clay loam	Dark red-brown	Dark red-brown	Moder-ate sub-angular blocky	Weak pris-matic	Friable	Coffee, bananas Some maize, beans, pasture	Vegetables, citrus, legume-rich pastures. Some responses to P

TABLE 18 - GENERAL CHARACTERISTICS OF SOILS: USERI, KOOTI AND UHINI SERIES, MASHIMA COMPLEX

Name and Symbol	Locality	Parent Material	Natural Vegetation Type	Approx. Annual Rain (mm)	Slope °'s	Approx. Top-soil (cm)	Depth Top-rock (cm)	Texture Sur-face (Field Grade)	Texture Sub-soil (Field Grade)	Colour Sur-face	Colour Sub-soil	Structure Sur-face	Structure Sub-soil	Surface Consis-tence	Land Use Present	Land Use Potential
USERI SERIES (32)	Samanga-Useri	Trachytes, trachy-basalt colluvium	Croton/ Rauvolfia Woodland	850-1150	5-20	12	Over 150	Fine sandy loam	Silty clay loam	Dark red-brown	Dark red-brown		Moder-ate	Very friable	Mainly coffee, bananas Poor pasture maize, beans	Potatoes, veg., improved pas-ture, temper-ate fruits, possibly tea, Afforestation
KOOTI SERIES (33)	Upper Useri	Andesitic colluvium	Albizzia/ Rauvolfia Ocotea Dry forest	1000-1300	5-20	20	Over 150	Humic sandy loam	Silty clay loam	Dark brown	Dark red-brown	Weak crumb	Weak pris-matic	Very friable	Poor coffee, bananas Much scrub grass-land	Afforestation, with pines, wattle, potato possibly tea. Needs NPK for most crops, lime for some
UHINI SERIES (34)	Useri glades	Mainly basalt	High alti-tude grass-land, Eragrestis/ Fimbristylis	1200-1500	5-15	20	Usu-ally under 100	Humic loam	Silty clay loam	Black	Dark brown	Fib-rous	Weak sub-angular blocky	Very friable	Rather poor grass-land	Afforestation, vegetables, possibly tea. Need NPK for most and lime for some
MASHIMA COMPLEX (35)	Upper Useri	Basalt and trachy-basalt	Dry Ocotea forest	1200-1500	5-25	10	Usu-ally less than 100 variable	Organ-ic loam	Silty loam	Very dark brown	Dark brown	Weak crumb	Weak pris-matic	Very friable	Forest	Reafforestation, with soft woods, possibly veg. and temperate fruit strips

TABLE 19 - GENERAL CHARACTERISTICS OF SOILS: NANJARA SERIES, KIMA-NYATU, MLOMBAA CREEP, ALLUVIUM COLLUVIUM AND SAMBALA COMPLEXES

Name and Symbol	Locality	Parent Material	Natural Vegetation Type	Approx. Annual Rain (mm)	Slope °'s	Approx. Top-soil (cm)	Depth Top-rock (cm)	Texture Sur-face (Field Grade)	Texture Sub-soil (Field Grade)	Colour Sur-face	Colour Sub-soil	Structure Sur-face	Structure Sub-soil	Surface Consis-tence	Land Use Present	Land Use Potential
NANJARA SERIES (37)	Nanjara Useri	Fluvio-glacial material	Hyparrhenia-Themeda/Acacia Polyacantha Wooded grassland	750-1100	3-10	20	Usu-ally over 100	Gritty clay loam with occasional basalt, andesite, boulders	Gravel clay loam	Very dark brown	Dark brown	Moder-ate crumb	Moder-ate pris-matic	Friable	Maize, beans, finger millet, grazing	Irrigated coffee, vegetables, wheat, pyrethrum
KIMA-NYATU (36)	Upper Useri	Fluvio-glacial material over basalt	Acacia abyssinica Woodland	850-1200	5-20	15	Usu-ally over 100	Humic loam	Silty clay loam	Dark brown	Dark red-brown	Moder-ate crumb	Moder-ate pris-matic	Very friable	Maize, beans, pyre-thrum, some coffee	Coffee, temper-ate fruits, legume-rich pastures, veg. Some response to P
MLOMBAA CREEP	Kirongas round mountain	Variable	Variable, often woodland or forest	Vari-able	Usu-ally over 15	Vari-able	Vari-able	Vari-able often loams	Vari-able	Often dark brown	Brown	Crumb	Often sub-angular blocky	Friable	Variable	Afforestation, some veg.
ALLUVIUM COLLUVIUM COMPLEX (39)	Lower valleys	Variable alluvial/colluvium	Variable	Vari-able	Usu-ally under 10	Vari-able	Vari-able	Very vari-able	Very vari-able	Usu-ally brown	Usu-ally brown	Vari-able	Vari-able	Usually friable	Arable crops grazing	Some irriga-tion, veg., dry season grazing, Eucalyptus, plantings
SAMBALA COMPLEX (40)	East Kiliman-jaro	Usually basaltic colluvium	Bushland or bushed grassland	Less than 1000	5-15	Very vari-able eroded	Vari-able	Vari-able loams	Vari-able	Usu-ally dark red-brown	Dark brown to dark red	Weak	Weak pris-matic	Often compact	Poor grazing	Afforestation, with Eucalyp-tus, improved pasture

TABLE 20 - MECHANICAL ANALYSIS (Percentage of oven dry soil)

Profile and Depth (cm)	Clay	Silt	Fine Sand	Coarse Sand
KIBONGOTO 2: KWARE COMPLEX (1)				
0-12	22.1	25.7	28.2	14.5
13-37	25.6	24.7	26.7	12.8
37-60	12.4	17.9	28.9	37.2
MASAMA 6: KWARE COMPLEX (1)				
0-15	16.2	23.9	25.7	24.1
15-40	12.4	26.2	29.4	27.0
40-65	12.4	25.0	31.6	28.7
65+	5.6	13.6	23.4	54.5
KIBONGOTO 1: OLD MOSHI SERIES - KIBONGOTO VARIANT (2A)				
0-16	19.6	28.5	39.2	2.7
16-36	14.0	36.8	37.9	1.6
36-66	21.8	39.8	38.5	0.8
66-140	30.6	26.0	26.0	0.8
140-180+	34.7	24.9	29.1	0.8
OLD MOSHI 6: OLD MOSHI SERIES - OLD MOSHI VARIANT (2B)				
0-5	36.6	34.6	24.3	2.3
15-40	42.8	30.4	20.7	2.3
40-100	45.3	30.6	18.3	1.5
100-180	48.2	28.6	15.1	1.2
KIRUA 2: OLD MOSHI SERIES - OLD MOSHI VARIANT (2B)				
0-14	15.9	46.1	26.4	5.4
14-40	21.4	40.0	30.6	6.1
40-90	23.3	33.3	33.9	4.3
90-160+	52.6	20.6	18.7	3.8
KENI 2: OLD MOSHI SERIES - KENI VARIANT (2C)				
0-15	16.2	36.1	43.5	3.0
15-35	18.5	33.0	44.2	2.9
35-65	20.0	31.1	45.5	3.0
65-100	22.1	29.2	45.0	0.9
100-140+	28.2	30.1	36.3	4.4
KIRUA 3: UPARU SERIES (12)				
0-14	21.8	29.7	35.0	2.9
14-30	26.2	34.0	33.6	2.7
30-60	33.7	28.9	32.8	1.1
60-90	63.9	17.2	12.9	1.4
90-170+	58.6	20.3	16.5	1.2

Profile and Depth (cm)	Clay	Silt	Fine Sand	Coarse Sand
MARANGU 3: MASIA COMPLEX - MASIA VARIANT (18A)				
0-3	9.5	36.4	23.9	14.2
3-20	13.6	43.4	26.4	13.1
20-50	12.4	46.3	27.8	13.9
50-95	22.5	35.6	32.8	12.6
95-145	28.5	28.4	27.7	12.7
145-180+	24.5	23.2	36.6	15.6
MASAMA 5: SADALA SERIES (4)				
0-15	24.5	33.6	21.2	12.4
15-35	34.0	34.2	17.3	13.0
35-70	40.9	26.1	13.5	17.9
70-110	36.8	20.9	14.8	26.4
110-145	29.5	20.1	16.8	32.3
145-200+	26.0	20.9	18.0	33.3
MASAMA 4: MASAMA SERIES - MASAMA VARIANT (5A)				
0-14	13.4	35.7	30.0	5.6
14-35	31.8	36.9	13.5	8.2
35-110	36.3	33.9	20.6	9.2
110-150	34.2	32.9	16.6	13.7
150-190+	27.8	35.1	13.1	15.3
KIRUA 1: MANU COMPLEX - MANU VARIANT (6B)				
0-10	28.7	20.0	32.8	1.6
30-55	30.1	20.2	36.9	1.6
55-80	28.2	26.0	41.6	5.7
130-170+	29.8	25.4	38.2	1.3
KIBOSHO 1: MSINGA SERIES (8)				
0-20	28.1	27.4	24.1	5.9
20-50	33.3	27.1	22.7	5.3
50-100	41.1	23.3	18.6	4.7
100-120	45.2	22.2	13.8	4.6
120-180+	28.8	29.3	24.8	6.4
LYAMUNGU 1: MSINGA SERIES - UPPER PHASE (8)				
0-12	15.7	34.8	32.4	4.9
12-26	18.7	31.5	41.5	4.3
26-56	41.1	20.3	29.0	3.7
56-120	43.8	19.0	26.6	3.0
120-155+	46.2	22.5	22.2	2.2
URU 1: MRAWI SERIES (11)				
0-15	14.9	34.1	38.6	6.4
15-70	11.4	36.4	44.0	77.6
70-100	14.1	33.0	37.6	7.9
100-135	15.7	31.4	29.1	13.8
135-205+	15.6	30.0	25.7	19.0

Profile and Depth (cm)	Clay	Silt	Fine Sand	Coarse Sand
MWIKA 1: MWIKA SERIES (23)				
0-15	21.1	15.2	38.7	11.9
15-40	28.9	14.1	39.7	12.9
40-100	25.9	13.4	46.5	12.8
100-140	24.9	13.6	48.2	18.0
140-180+	26.8	22.0	43.6	15.9
MWIKA 2: KONDENI SERIES (24)				
0-15	11.1	39.9	34.6	13.6
15-42	13.3	33.7	37.6	12.9
42-105	12.2	32.6	41.9	12.2
105-180+	14.3	33.7	42.1	11.8
MARANGU 5: MARANGU SERIES - LOWER PHASE (19A)				
0-9	13.2	24.4	36.0	13.7
9-29	14.2	31.4	32.7	16.2
98-132	33.6	18.8	22.3	15.6
132-175+	37.7	26.6	25.8	11.9
MARANGU 1: SAMANGA COMPLEX (20)				
0-13	17.5	32.3	40.0	2.6
13-31	24.2	24.5	44.8	2.9
31-70	33.4	21.8	35.7	2.8
70-109	55.7	17.4	26.0	2.7
109-180+	51.1	17.5	21.8	2.8
108+	45.6	18.5	23.9	2.9
KILEMA 4: HIMO SERIES (21)				
0-15	19.2	40.9	25.4	2.0
15-35	19.1	41.4	30.8	2.8
35-60	20.2	38.4	37.2	2.4
60-90+	24.5	30.6	40.6	1.9
USERI 3: USERI SERIES (32)				
0-12	21.0	34.9	37.1	2.7
12-28	12.4	33.9	48.0	2.4
28-80	3.9	37.9	52.2	2.2
80-110	5.0	35.7	56.5	1.4
110-170	6.1	30.2	50.3	1.2
USERI 4: NANJARA SERIES (37)				
	14.5	40.3	25.9	9.2
	30.7	34.3	27.4	5.0
	31.1	28.2	35.6	2.8
	35.6	27.3	29.4	2.1
	36.0	25.4	29.9	
	40.4	25.4	20.4	6.6

*All figures are correct to the nearest %

CHAPTER 6: LAND USE POTENTIAL

PRINCIPLES OF LAND USE

A variety of environmental and soil factors influence the potential for different kinds of land use on Mount Kilimanjaro. Climate is perhaps the most obvious and important. This plays a major role in determining the natural vegetation and the range of crops and profoundly influences both the physical and chemical properties of the soils. As shown on the map of natural vegetation and present land use there is a close relationship between rainfall, vegetation and crops grown. Rainfall and temperature, by governing the growth and decomposition balance of plant materials, markedly affect the organic matter contents of soils. This in turn, influences their physical, chemical and biological properties. Both the nature of soils and the crops which can be grown are thus profoundly affected by climate.

Perhaps the next most important factor determining land use potential on Mount Kilimanjaro is soil depth. Shallow soils are less suitable for deep rooting perennial crops, particularly in areas of less favourable rainfall where moisture storage in the soil profile may be critical. Most shallow soils occur on rocks resistant to weathering such as the more siliceous trachytes and phonolites. Steepness of slope, however, has a decided effect on soil depth. Where steep slopes are cultivated, erosion is active and loss of topsoil has reduced soil depth and even exposed the underlying rocks. Steep slopes rule out mechanical cultivation and the possibility of this also has an influence on the choice of crops in each locality.

Among the soil physical properties texture is probably the most important, influencing both the moisture and plant nutrients which a soil can hold. Water-holding capacity has been shown to be largely a function of the particle size distribution and the organic matter (Salter, Berry and Williams, 1966). Structural development and stability, which influences the rate of water infiltration and percolation, the aeration and ease of root development in a soil, is mainly determined by the particle size distribution and the mineralogical nature of the clay fraction. Soils high in silt and fine sand tend to be the least stable and when cultivated readily form a cap on the surface as a result of rain beat. Rotations including some perennial crops help to prevent the surface structure from becoming so weak that rainfall runs off, causing topsoil erosion and thus reduced nutrient status, particularly nitrogen supplying power. The maintenance of good air/water relations thus depends largely on the soil texture and consistence and the maintenance of structural stability by systems of cropping and soil conservation adapted to the texture, slope and erodibility of the particular soil.

Differences in soil fertility also influence the present land use considerably, but unlike physical and climatic differences these can be altered relatively easily by using lime and fertilisers. In most areas, moderate lime and fertiliser application would be the best ways to increase production of crops, notably Arabica coffee, beans, vegetables and fodder legumes where these already grow moderately well. In other areas where such crops are very poor, introducing more acid-tolerant crops such as tea, Irish potatoes and pine trees, could constitute a better means of soils utilisation than maintaining present crops by heavy expenditure on lime and fertilisers.

Another factor influencing the potential for different crops is the present population density and the size of holdings. While other crops can and should be grown in parts of the coffee/banana belt, it would be difficult to suggest anything very much more efficient for most of it than the coffee/banana system with stall fed cattle. This provides a staple food, a high value cash crop and some animal protein valuable in maintaining a healthy population. Only a hectare of this system is capable of supporting a family with an income very much greater than most other systems operative in Tanzania.

CROP DIVERSIFICATION AND NEW CROP POSSIBILITIES

With a certain limit to the amount of coffee which can be sold on the world market, only the best soils capable of sustained high-level low-cost production are likely to remain under coffee. The questions arise as to what alternatives are possible to replace the poorer stands of coffee and what means are available for improved productivity of the acreage remaining under coffee. The same questions need to be asked of all crops grown in the area, if for no better reason than that a rotation of crops tends to conserve soil fertility and reduces build-up of pests and diseases. Consideration is first given to existing crops in the area followed by discussion of some possible new introductions.

EXISTING CROPS AND SUGGESTED CHANGES IN EMPHASIS

Cereal Crops: Maize is the predominant cereal grown on the mountain. Production from the lower zone has greatly increased in recent years making Kilimanjaro one of Tanzania's principle maize growing areas despite the fact that bananas remain the staple diet of most people. Increased tractor cultivation has facilitated this rising production but there are considerable dangers, not least through reduced grazing land without comparable reduction of livestock. These problems are discussed under land management and soil conservation. Maize is still grown near the forest in many areas though it may take up to eleven months to ripen and rarely yields more than five bags per acre (1000 kg/ha). There are undoubtedly more profitable crops to grow at these high altitudes, but the desire to ensure some maize supply still persists.

A few maize trials with fertilisers carried out in East Kilimanjaro have been reported (Anderson 1969). Sorghum is not grown as extensively as it might be, probably because of the preference for maize, particularly as a saleable crop. Sorghum's yield potential where rainfalls are small and unreliable give it distinct advantages over maize on many of the lower slopes, particularly on East Kilimanjaro. Finger millet also grows very well in the middle and lower zones. Like maize, much of it is exported from the area, though some is used to make mbege, the local beer, brewed from a mixture of bananas and finger millet. Finger millet is more protective of the soil surface than maize or sorghum and is quite drought-resistant. Its inclusion among the arable crops grown in the drier, more erodible areas is very desirable.

Grain Legume: Beans (Paseolus vulgaris) are widely grown on the mountain usually interplanted with maize which seems often to benefit by way of increased nitrogen supply. The highest rainfall areas with lower soil fertility and disease problems are not well suited to beans. The crop is very responsive to phosphorus, lime and potassium and has been used to assess the fertility status of the main soils on the mountain. Detailed results of trials in different areas have been reported in Tengeru (Reports Nos. 11, 12, 22 and 30) while the overall picture has been summarised in a previous paper (Anderson 1972). The map showing the responses to lime (L), Potassium (K), and Phosphorus (P) in the different localities is reproduced here (Figure 2).

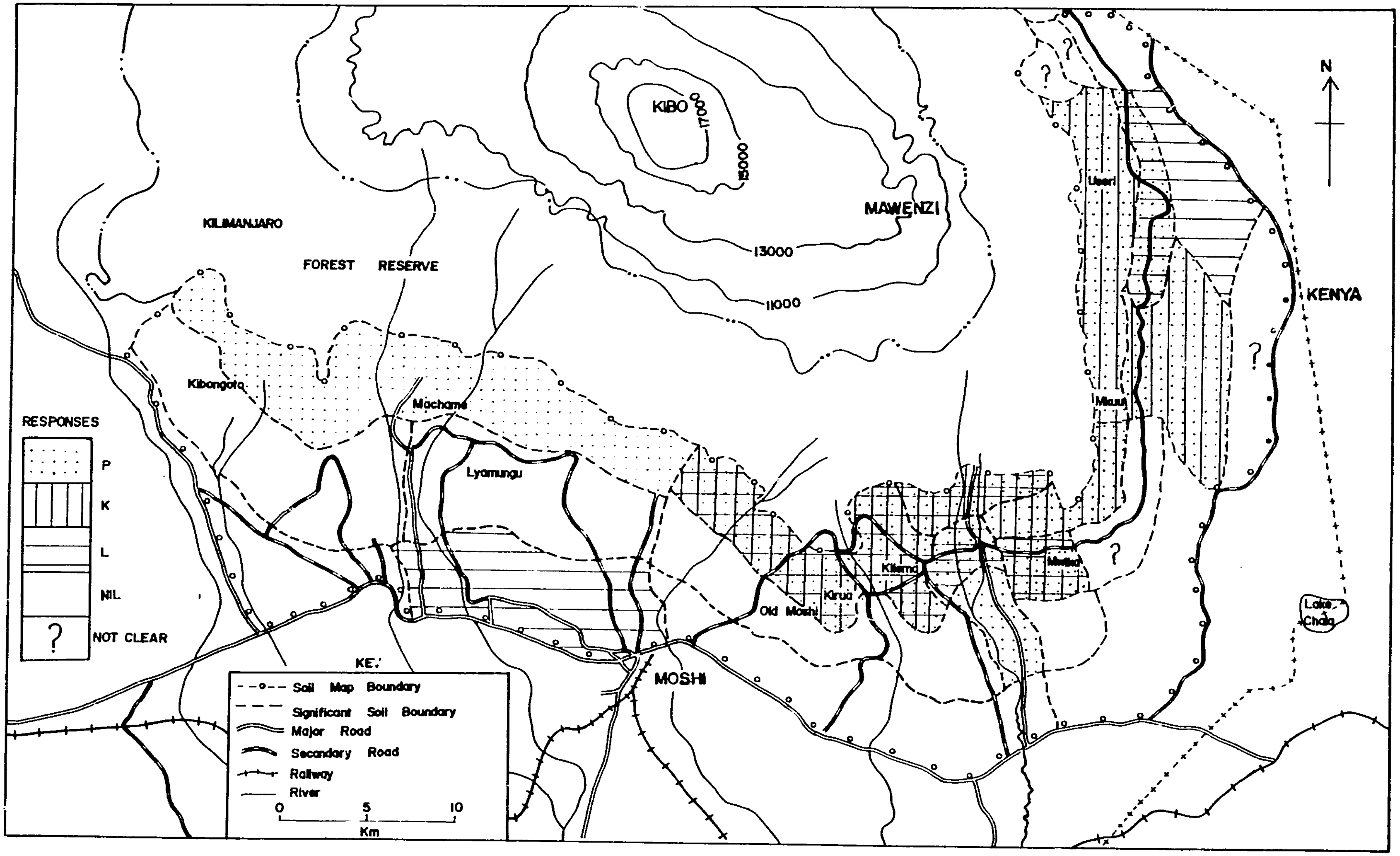
Another good standby in drier areas is pigeon pea and both this and groundnuts could well be grown more extensively thus providing additional sources of cash income and more protein for people and animals.

Bananas are the chief food crop on the mountain and the standard of husbandry has improved considerably in recent years. There is still some need to reduce the number of suckers to 2-3 per stool and to practise more mulching. In addition there is considerable scope for fertiliser studies on the crop, for bananas are very responsive to fertilisers. Production in the upper zone could be greatly improved by application of N and K fertilisers in order to correct obvious deficiencies of these, while applications of phosphorus and lime are also likely to benefit the crop in some areas.

Other Food Groups: Yams and sweet potatoes are grown throughout the coffee/ banana area and these provide an alternate carbohydrate to bananas and maize. While these crops vary the diet, it is probable that some of the acreage devoted to them could more profitably be planted with other crops. Their dense cover aids soil conservation on steep slopes, however. Cassava is widely grown throughout the mountain. It is very drought-resistant, ensuring

FIGURE 2

SKETCH MAP OF SOUTH AND EAST KILIMANJARO SHOWING RESPONSES TO L, P AND K



SOURCE: Anderson (1972).

some crop in a poor year in drought-affected areas. But other crops are more profitable on soils of reasonable fertility from both the nutritional value and the income point of view.

Various vegetables are grown on parts of the mountain, chiefly in the high rainfall areas or where irrigation can be practised. Cabbages, onions, tomatoes, and carrots are popular and increasingly these high-value cash crops receive some fertiliser, particularly nitrogen.

Coffee: Arabica coffee is the main basis of Chagga prosperity. From even a hectare of well-managed coffee a family can earn much more than from larger hectarages of other crops. The rapid increase in production from the 173 kg parchment per hectare in 1961 reported by Beck (1963) to the mean of 728 kg/ha on farmers' trial plots in 1965 (Robinson and Tapley, 1967)[1] has resulted mainly from better husbandry. This has usually been in the form of reduced banana stands in coffee, better weeding, pruning, mulching and the use of some nitrogen fertiliser, but probably most of all to systematic application of fungicidal sprays. Despite all these improvements there is still some very poor coffee on the more acid soils of the upper zone especially on Potential Use Groups 5 and 6 and to a lesser extent on Group 4. Alternate crops such as tea would probably be better than attempting to lime the soils in the areas of poorest coffee. There is still some room for coffee to be planted on the more suitable soils such as those of Use Groups 1 and 2, and parts of 3. So production need not fall should other crops take precedence over Groups 5 and 6. Group 4 soils are probably worth maintaining in coffee if the fertility status can be raised by light dressing of lime together with other nutrients as indicated. Where there is the possibility of irrigation, there is no reason why coffee production should not be pushed into the lower zone following the example of the estates.

Other Tree Crops Now Grown: The potential for citrus is well shown by the grapefruits, oranges and lemons which thrive at the Coffee Research Station and elsewhere on the mountain. Citrus, however, is more drought-resistant

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[1]The figures have been converted to the metric system--ed.

than coffee and so is probably more at home on the soils of potential Use Groups 1 and 3 and it can even grow quite well on Group 8 soils. There is considerable scope for citrus expansion in these areas and avocado pears and mangoes might be allied with it. In the drier areas castor thrives and production of this crop could also be expanded.

NEW CROP POSSIBILITIES

Wheat: Wheat has been grown at West Kilimanjaro for many years mainly on Eutrophic Brown Soils where the influence of nitrogen top dressing and bare fallowing has been studied (Anderson, Houston and Northwood, 1966). So far no attempt has been made to grow wheat on South or East Kilimanjaro probably because most areas suitable for mechanical cultivation are at low altitudes or have too much rainfall. In North, Rombo, however, particularly on the Nanjara Series, there are considerable areas of land over 1400 m which could grow wheat provided this does not result in overgrazing of pastures by the cattle.

Seed or Navy Beans: Northern Tanzania has long been a source of seed beans for Europe while white haricot (navy bean) production has recently been introduced. Phaseolus beans grow well on most soils in the middle and lower zones (Anderson, 1972). Whether grown for seed or canning, at present prices beans should give an equal if not better return per acre than maize. Uniform stands of good quality, however, demand fairly large acreages. This is a good crop to grow in rotation with maize and finger millet on the gentle slopes particularly of Use Potential Groups 3, 7 and parts of 8.

Other Field Crops: Another arable crop which may be grown in the drier areas is cotton. The yield potential of this on these volcanic soils should be considerably greater than on many other cotton growing areas of Tanzania. There is little doubt, however, that the crop would respond to fertilisers, particularly nitrogen. Kenaf is a possibility in the higher rainfall areas of the lower zone or where irrigation is feasible. Pyrethrum has been grown in parts of North Rombo for some years. It needs altitudes of over 1500 m, not too much rainfall and fertile soils of moderate to high base status. These requirements are more often found on the eutrophic brown soils of the drier western mountain slopes, but considerable acreages of the upper Nanjara and Kimanyatu Series in North Rombo are capable of greater pyrethrum production.

Irish potatoes are one of the most acid tolerant crops and using N, P and K fertilisers they are capable of reasonable yields on many parts of the upper zone. They do not thrive under very high rainfalls as infection with blight and other diseases is prevalent. On the southern and southeastern slopes of Use Groups 4, 5 and 6, they should preferably be grown during the short October-December rains. In the upper zone of North Rombo they may be better grown in the March-May period which is normally drier, though the rains they are grown in is perhaps less critical here.

Legume-rich Fodder Crops and Pastures: In recent years much research has been carried out on these at various trial sites in Northern Tanzania. Three of these experimental sites were on Kilimanjaro (Lyamungu, Useri and West Kilimanjaro). Much of the detailed work was conducted at Tengeru. Findings have been published in both Tengeru Reports (Nos. 41 and 120) and in the East African Agricultural and Forestry Journal (Naveh and Anderson, 1966, 1966, 1967; Naveh 1966; Anderson and Naveh 1968; Anderson 1968a). As a result of this work a range of legumes are known to be suitable for growing, either in pure stands in legume-rich mixtures with grasses for both fodder and pastures. Lucerne, Desmodium intortum or D. uncinatum proved to be vigorous in pure stands and for inclusion with the more competitive grasses such as Rhodes grass under a cutting regime. In fodder mixtures the climbing legumes Glycine javanica and Dolichos formosus were best for including with tall grasses such as Panicum maximum and Setaria splendida and patches of such mixtures could be the basis of the protein supply for the stall-fed cattle kept on the mountain. Useful legumes indigenous to Kilimanjaro are Rhynchosia sennarensis and Glycine javanica and these, possibly with inclusion of Stylo (Stylosanthes guyanensis) and Siratro (Phaseolus atropurpureum) could improve the pastures of the lower areas. Emphasis is given to legume-rich rather than simple grass pastures, for it is the vital protein from the legume which maintains the condition of beef animals and milk yields from dairy animals, particularly in the dry season. Two types of mixtures, then, have an important role in animal production on Kilimanjaro. Fodder mixtures and pure stands of legumes are needed in small patches on every holding keeping stall-fed cattle. Leys for grazing and cutting are needed to rotate with arable crops on the lower slopes. Good management, so essential in maintaining legume-rich productive swards, can be achieved only where land is fenced into paddocks. Considerable research remains to be done on the effect of grazing mixtures of various types under different intensities. Living fences can be created by planting trees, particularly of Eucalyptus species. This operation can help to save the labour at present expended in preventing animals from grazing arable crops.

Introducing pasture and fodder legumes has much to commend it from the standpoint of soil conservation, maintenance of soil fertility especially nitrogen status and in promoting livestock improvement. The nature of the soil, especially its acidity, needs careful consideration when contemplating sowing legumes of high nutrient demand such as lucerne for which lime, P and K fertilisers would be necessary in much of the upper zone (Use Potential Groups 4, 5 and 6).

TREE CROP POSSIBILITIES

Tea: As already mentioned considerable area of the upper zone Use Potential Groups 5 and 6 particularly are too acid to support good coffee. If they are to be maintained in coffee they will need lime and considerable fertiliser dressings. Tea grows very well on strongly acid soils and requires acidity and exchangeable aluminium to thrive. In their present state these upper areas are more suited to tea than coffee. The choice of some areas on the mountain where tea should supplant coffee would seem logical. There must be an adequate acreage to supply a tea factory. Areas where Use Potential Groups

4, 5 and 6 cover large acreages are the obvious choices and the possibilities of having tea centers on upper Kirua, the Kasese area of Keni and upper Useri-Mashati need investigation.

Temperate Fruits: At the higher altitudes isolated apples and pears and larger numbers of plum trees have been grown for a number of years. There seems little to prevent expansion of this temperate fruit production for local consumption and possibly for canning.

Cashew is another possible crop for the lower drier mountain slopes. In parts of southern Tanzania it survives 5-6 months of drought, often on very poor soils. Though not so far tried, it is probable that it would thrive very well on the lower eastern slopes which have the most spasmodic rainfall. It is unlikely that the crop would stand the cold at higher altitudes where there are more profitable crops to grow on small acreages.

Cocoa has possibilities in selected areas. Its requirements are, however, rather specific. It needs deep friable soils with good base status under well-distributed rainfalls of at least 1200 mm annually and temperatures which rarely drop below 20°C. These conditions tend to rule out any possibility on the east of the mountain as too little rain falls below 1400 m and above this temperatures are too low and soils become increasingly acid. One area where cocoa may be possible is the Msinga-Uru area just north of Moshi; another might be lower Marangu-Mwika. These have high rainfalls, lie below 1200 m and have reasonable soils. Trials are, however, needed before any investment or extensive plantings are made.

Spice production might also be worth investigation on these and other parts of Use Potential Group 1.

Timber demand for a variety of purposes is likely to increase in the future. With the rapid growth of several commercial timber species in the cultivation zone, there are considerable possibilities of farmers augmenting their regular income by growing trees. Some already do this. Grevilla robusta and Cyperus lusitanica are two species which can reach a good size within 8-15 years in the middle zone. These are valuable for furniture construction and can be grown in single rows surrounding holdings or along roads where they interfere least with the yields of other crops like coffee and bananas. In less densely populated areas of more acid soils higher up the mountain, plantations of wattle, Eucalyptus and pines have long been grown. By replacing some wattle and Eucalyptus, which are mainly valuable for firewood, by Pinus patula higher dividends are possible. Though this can bring about important changes in the soils (Robinson, Hosegood & Dyson, 1966) it can be used as building timber or for pulp. Firewood supplies are increasingly short in the lower areas as Combretum and Acacia trees have largely been removed. Here planting Eucalyptus woodlands on hills and steep escarpments and also in single rows or narrow shelter belts is strongly recommended. Single row or narrow belt plantings can readily be converted into fences by stringing wire between the trees and thus can help in improving pasture utilisation and enabling more efficient arable farming. Such practices may not be popular with foresters but can lead to much better land utilisation. Trees also improve the environment for people to live in. All three zones, therefore, have a potential for tree planting, the particular species and type of planting varying with the suitability of soils and climate, the needs and population density of each area.

LAND USE POTENTIAL GROUPS

As shown on the Land Use Potential Map, the 40 soil mapping units have been grouped into 12 potential use groups. This has inevitably meant generalising and suggesting uses which are not necessarily true for all the soils in each group. However, it is convenient in initial planning of schemes for intensification of land use. For detailed implementation of any such schemes reference should always be made to the individual soil units and what has been said about them. There are many ways of expressing the potential of land, among which the productivity ratings of the Soil Survey Manual (USDA Survey Staff, 1951) and the Storie Index (Storie, 1964) are probably the most widely known. In an area of such diversity, however, to ignore the effect of climate as the Storie Index does would be very misleading, particularly for non-specialists. The soils have not therefore been given either a productivity rating or a Storie index, but placed in groups containing soils having similar climate, depths, slopes, physical and chemical properties and thus crop suitabilities. Twelve groups have been separated and these are briefly discussed in turn:

Group 1: Deep Moderately Fertile to Fertile Clay Loams on Slopes of 5-20° under rainfalls of 1000-1500 mm

The soils included in this group are the Old Moshi, Msinga, Mwika, Usanyi, and Kimanyatu series (Units 2A, 2B, 2C, 8, 23, 31 and 36). These grow good coffee and bananas and there is room for expansion of vegetables, citrus and legume-rich fodders for milk production. There is often some response to P on annual crops such as beans and in some areas K also.

Group 2: Stony Fairly Shallow Loams of Moderate Fertility on Slopes of 5-20° under rainfalls 1200-1800 mm

This group includes Marangu series, and the Kokirie and Umbwe Complexes (soil units 7, 19A, 19B, 19C and 22). These support reasonably good coffee and bananas despite their shallowness, but they tend to be more acid than Group 1. Vegetables, Irish potatoes, yams and beans are grown. Some of these areas at the higher altitudes could perhaps grow temperate fruits. Beans often respond to P and K and sometimes lime (Anderson, 1964). Timber production from farmers' holdings could be expanded. The shallow nature of many soils, despite the high rainfall, emphasises the need for soil conservation and prevention of erosion.

Group 3: Deep Slightly Stony Fertile Clay Loams on Slopes of 2-15° with rainfalls of 850-1150 mm

This group includes the Kibohehe, Kindi and the upper part of Nanjara Series (Soil units 3, 9 and 37). These are well supplied with bases and can support irrigated coffee and vegetables, citrus, maize, beans, finger millet, pastures, cassava, and castor at lower altitudes. More pyrethrum and possibly wheat could be produced at the higher altitudes.

Group 4: Deep Friable Acid Loams on Slopes of 5-25° under rainfalls of 1250-1750 mm

The soils in this group include all the variants of the Masama and Useri Series and Mengwe Complex (5, 32 and 28). Only acid-tolerant crops grow well without ameliorative measures: Irish potatoes, sweet potatoes, afforestation with pines or wattle, vegetables and perhaps tea may be grown. Temperate fruits may be possible in selected areas. Crops need N, P and K fertilisers as a rule, and sometimes lime for the less acid-tolerant. Coffee is often rather poor on these soils and in some cases would be better replaced by tea.

Group 5: Deep Very Friable Acid Sandy Loams on slopes of 5-60° under rainfalls of 1500-2500 mm

These soils include Manu and Nanga Complexes and Kooti Series (Units 6, 16 and 33). Such steeply sloping areas are so acid that coffee is very poor and only the most acid-tolerant crops can be contemplated. Pines, wattle, tea, and potatoes are possibilities. Soils need N, P, K for many crops, with liming necessary for lucerne, improved pastures, beans and other base-demanding crops. Though very stable, these steep soils are best suited to perennial crops.

Group 6: Very Stony, Shallow Acid Gritty Loams of Low to Moderate Fertility on slopes of 5-30° under rainfalls of 1500-2500 mm

This group includes Mrawi and Uhini Series, Masia, Ubaa and Mlombea Creep Complexes (soil units 11, 18, 29, 34 and 39). Pines, wattles, tea, Irish potatoes and improved pasture are the crops most suited to these podsolic soils. Coffee and bananas are poor. N, P and K fertilisers are needed for most crops, and lime for all those requiring a reasonable base status.

Group 7: Fertile Clay Loams on slopes of 1-10° under rainfall of 750-950 mm

The lower slope soils, Sadala, Sambarai, Sango, Himo and lower Nanjara Series (Soil Units 4, 10, 13, 21 and part of 37) comprise this group. Mechanised arable cropping is possible and maize, beans and finger millet may be grown. There is scope for introduction of legume-rich pastures, citrus, castor, cotton and possibly cashew with plantations or rows of Eucalyptus or Grevillea to permit fencing of paddocks and shelter. Grass strips and alternating belts of different crops are important means of soil conservation in these arable areas. Where feasible, tied-ridge cropping could aid water infiltration and prevent runoff.

Group 8: Loams to Clay Loams of Low to High Fertility where slopes (1-15°) or stoniness may be some hindrance to mechanical cultivation, under rainfalls of 700-1000 mm

This group includes some very variable soils--Kware Complex, Uparu, Mahina, Kondeni, Huruma, Kitalato Series and Samanga Complex (Units 1, 12, 20, 24, 25, 27 and 30). Maize, beans, finger millet and sorghum are usually the main crops. There is scope for improved pasture, citrus, castor and possibly cotton. Many of these soils need P and some potassium. All need grass strips for rainfall and soil conservation and tied-ridge cropping where feasible.

Group 9: Steeply Sloping or Gullied Areas of Moderate Fertility under rainfalls of 500-900 mm

This group includes some badly eroded areas: Pumwani, Hollili and Sambala Complexes (soil units 15, 17 and 40). Improved pastures, maize, beans, castor and possibly cashew together with Eucalyptus belts and greater soil conservation are means to intensification. Fencing to control grazing is probably the main need to prevent further erosion.

Group 10: Variable Alluvial/Colluvial Complex of Valleys, usually wet, eroded or steeply sloping under rainfalls of 500-1000 mm

The Alluvial/Colluvial Complex (Soil Unit 38) is the sole representative. Dry season grazing, legume-rich pastures, vegetables especially onions and tomatoes are sometimes possible. Commonly, the main uses are dry season grazing, maize and beans. Afforestation of the steeper slopes could provide much needed fuel and building materials for the lower slopes of the mountain.

Group 11: Slightly Stony Forested Loams of Moderate Fertility on slopes of 10-45° under rainfalls of 1000-1750 mm

The only mapped representative of this group is the Mashima Complex (35) but other forested areas would also fit into it. Possible intensification might include re-afforestation with cypress, pines or camphor. Alternatively patches or strips of temperate fruits, tea, Irish potatoes and vegetables could be grown within the forest.

Group 12: Loans to Clay Loams of Moderate Fertility on Slopes of 1-10° under rainfalls of 500-750 mm

This group includes Kimanga and Kibouni Series (soil units 14 and 26). The rainfall is so low that only drought resistant crops are reliable. There is, however, much scope for improved husbandry, water and soil conservation in the production of sorghum, maize, beans, castor, cassava and finger millet. Cotton and cashew might be introduced. Nitrogen is probably the main fertiliser requirement. Water supplies and fences are the main needs for improved livestock management and more efficient use of time by the human population.

LAND MANAGEMENT AND SOIL CONSERVATION

In any area where people earn their living from the land there is always some conflict between what is desirable for maintaining soil fertility and the productive potential of the land, and what may be expedient or even necessary in the short term to reap the maximum income or benefit. Such conflicts are not always easily recognisable but they are always there. There is often the tendency to feel that it is better to have the maximum profit now and not be concerned about crops in years to come. When aiming at optimum land use, however, the temptation to overrate the pressing immediate needs or short term economic gain at the expense of ruining or badly damaging the long term productivity potential of the land, should always be resisted.

FACTORS AFFECTING SOIL DEGRADATION AND EROSION

As mentioned earlier, when man cultivates soil he usually institutes a process of degradation by breaking the close relationship between the soils and its natural vegetation (Milne, 1940a).

The amount and intensity of rain falling on soil affects surface stability and the degree of nutrient leaching and acidity. The tendency of soils to form a surface cap is inversely proportional to the ability of their aggregates to withstand rainfall impact. A major reason for the relative stability of many tropical soils is the presence of hydrous iron oxides, but in the surface soil the amount and nature of organic matter is often equally important. Tropical soils, however, are subjected to much more destructive forces than those of temperate regions: high temperatures cause rapid microbial decomposition of organic matter, while heavy rainfall intensities easily break down aggregates, washing silt and fine sand particles between the coarse sand to form a surface cap. This is usually much less permeable than freshly cultivated soil so that more rain runs off instead of entering the soil. Surface caps therefore prevent air and water reaching the crop roots and in promoting runoff cause erosion of the nutrient rich part of the soil containing much of the organic matter and nitrogen--namely, the topsoil. While the angle and length of slopes are also important in determining runoff and erosion, a surface cap, however slight, is often more critical. The magnitude of degradation this causes depends on the climate and nature of the soils and very much on man's use of the land. A key factor in erosion prevention and maintenance of productivity is thus prevention or limiting of surface-capping.

The time the land is under arable in proportion to perennial crops has important effects on the physical, chemical and biological properties of the soils. Type of plant cover has a big influence on both erosion under the crop itself and that over other crops later. Closely growing crops like pastures can provide good protection for soils, though overgrazing can make them more prone to erosion than some cultivated fields. Pastures by their adventitious root system also favour the formation of stable soil aggregates. The best arable crops to protect the soil are those which are also grasses and closely cover the soil. Wheat and finger millet are two examples. Maize by its concentration of rain water at the stem base is one of the worst crops to grow in areas prone to erosion. It is best grown in rows and as such is suited to planting on tied-ridges (Dagg and Macartney, 1968).

Complete canopy crops such as tea protect the soil once the canopy is established. Roadways and footpaths in such crops are often badly eroded where unprotected by grasses and cut off ditches. Coffee is much less protective as Mitchell (1965) has shown and mulching with grass or banana leaves or contour planting of bananas in coffee should be practised wherever there are erosion tendencies. Cocoa and cashew, once established, tend to form a certain amount of mulch from their leaf fall, but initially at least these crops need mulching with grass, banana or maize trash. Mulching also tends to supress weeds and the value of mulching has been reviewed by Jacks, Brind, and Smith (1955). Crop residues of all kinds can be used and no crop residues should ever be burned, unless there is a danger of infection of other crops with pests or diseases. Bananas, once established and if well managed, form a very good soil protection and become more or less self-mulching, even providing some good mulching material for neighbouring coffee or other tree crops.

MEANS OF SOIL CONSERVATION

Rotations: In areas where arable cropping is practised, rotations provide an outstanding means of soil conservation. One crop protects the soil more than another ensuring that physical deterioration does not become catastrophic. Each crop has somewhat different nutrient requirements and a varying capacity to "mine" the subsoil, returning plant nutrients to the topsoil. Crop selection, particularly for marginal rainfall areas, needs to consider the rainfall amount, distribution and the moisture available in the soil in relation to crop requirements at critical stages of growth as Dagg (1965) has emphasised. Rotations also help to control pests and diseases.

The more gentle lower slopes enable large block cultivation using tractors. Paradoxically, it is these gently sloping areas which are most prone to capping and erosion. The soils here are not well stabilised by hydrous oxides and under the lighter rainfall have low organic matter contents. The most sensible farming for these lower slopes is a system of alternate arable cropping and pasture leys. Sowing some legume-rich mixtures as suggested by Anderson (1968a) would be good for soil conservation, as well as providing much more nutritious fodder for dairy and beef cattle on the mountain than the fibrous Hyparrhenia sp. now used. The value from legume-rich leys sown down for 3-4 years to subsequent arable crops should also be remembered. Improved pastures could also play a part in rotations for the more acid soils in the upper zone. Successful pasture establishment requires good land preparation, timely sowing, accompanied by adequate fertiliser dressings--phosphate is usually vital but lime and potassium would also be necessary in much of the upper zone. Once established, sward maintenance depends largely on grazing control to prevent both overtall grasses shading out legumes, and overgrazing of the legumes, which are preferred to the grasses in the dry season. Individual land tenure or cooperatively owned livestock and the construction of paddocks to control grazing are very necessary prerequisites to successful pasture improvement and management. Without control of grazings and stock numbers the tendency for increased arable cropping will inevitably lead to greater soil erosion. A cheap means of achieving paddocks has already been suggested under New Crop Possibilities.

Use of Fertilisers: Fertilisers are one of the easiest means of management to implement soil conservation. Their use can greatly increase crop yields and the well fed plants have more vigorous root systems and return more crop residues to soils. Organic matter thus increases and stabilises the soil aggregates so that soils are more resistant to disintegration, surface capping and erosion. A paper giving the pattern of fertiliser response with beans on the main soils has been presented (Anderson, 1972) and the map showing this is included in this memoir (Figure 2). While responsiveness of different crops will not be the same even on the same soils, some crops likely to respond to fertiliser applications may be mentioned.

Maize is likely to respond to N on most parts of Kilimanjaro, but in the upper and middle zones phosphorus too will usually be essential to obtain optimum response to N. In the upper zone where maize growing should generally be discouraged, potassium too is probably needed for best yields. It should be remembered that the amount of nitrogen mineralised in soils and available for crop growth depends on the frequency and intensity of wetting and drying (Birch, 1960). Responses to nitrogen are, therefore, likely to be greatest in the upper zone where leaching of nitrates is most intense and where low temperatures and acidity inhibit rapid nitrification. That this is generally the case is borne out by the generally yellow appearance of many crops notably maize, coffee and bananas. In the lower zone, prolonged dry periods and lower total N in the soils probably mean that nitrogen mineralisation tends to be inadequate for optimum crop growth. The middle zone would thus seem to have the most favourable nitrogen supply but as already mentioned most areas when under intensive cropping will probably show response to N on maize and other non-leguminous crops. Generally the longer soil has been cultivated the more likely it is to respond to fertilisers but newly cultivated grassland is often responsive also (Anderson, Houston and Northwood, 1966).

Bananas will usually respond to fertilisers as they are a high nutrient demanding crop, particularly for N and K. Phosphorus is likely to be important in the upper zone and parts of the middle zone where bananas are often stunted. The nutrient requirements of bananas are affected by shade, mulch and the intensity of rainfall removal of nutrients from the leaves. Shade has a nutrient-sparing role with bananas as with cocoa and other crops (Murray, 1961). Maturity is delayed--that is productivity per hectare per annum is reduced--compared to that in full light. Mulches, particularly those of green grass, supply a considerable amount of K and thus reduce the K fertiliser required.

Many nitrogen studies have been done on coffee in East Africa and Robinson (1960) has investigated seasonal trends in nitrate and ammonium accumulation in relation to soil moisture and rainfall. Robinson (1967) and Robinson and Tapley (1967) have also shown that the overall response to N on Kilimanjaro coffee resulted in a yield increase of 19 percent. Though fungicidal sprays appear to be more important, there is no doubt of the value of some correctly applied N fertiliser on coffee.

While perennial tree crops like coffee are less responsive to phosphorus than quick-growing annuals like maize, it is likely that phosphorus will give some response and a positive interaction with N fertiliser over much of the middle and upper zones. Potassium must be important for coffee in the more deficient soils, besides lime which would seem necessary for its vigorous growth on the more acid soils.

With pastures, the requirements vary with the zone and soil, but phosphorus is likely to be needed for the effective establishment of legume-rich swards in most of the area except Use Potential Groups 3, 7, 12 and parts of 8.

A few general principles regarding fertiliser application are worth emphasising. Nutrient requirements of crops are likely to change with both the time and intensity of cropping since the land was first cultivated (c.f. Anderson, Houston and Northwood, 1966). Variety, time of planting, plant population and weed growth all influence responses. With nitrogen in particular, light dressings applied frequently are better than heavy doses because nitrates are readily leached out of the root zone. Applications of phosphorus and potassium are not needed more than once a year and may have useful residual effects for one or more years. Small dressings are again best, particularly with farmers who have limited capital. As shown with maize trials the economics of fertiliser application are very favourable if small levels are used and an attempt is made to supply a little of our major nutrients which are deficient (Anderson, 1969). Lime dressings of around 1120 kg/ha of calcium carbonate should make considerable yield differences where soils are very acid as shown with beans (Anderson, 1972). While there is no doubt that fertilisers can and should make a valuable and immediate contribution to improved production of many crops on the mountains, there is a need for more research to assess optimum rates and economics. Pinthus (1964) has suggested a recurring programme continually attacking the most limiting factor restricting grain yields and this is needed with all crops. Once fertilisers are applied to soils the nutrient balance becomes changed and after a few years other nutrients not included in the initial recommendations may become important.

INFLUENCE OF CULTIVATIONS AND MACHINERY

Having tractors and machinery enables quick cultivation of large acreages. Heavy implements however, can be damaging to land as they pulverise dry soil and puddle it when wet. Care should be taken to use such implements at the correct time, thus ensuring the least damage to soil. Too frequent arable cropping quickly destroys soil structure thus reducing rainfall infiltration and crop yields. Crop rotation is invaluable in aiding maintenance of structure but there are also other means of preventing runoff and erosion. With maize and other row crops a system of tied-ridges is feasible as Dagg and Macartney (1965) have shown. This is capable of preventing erosion and markedly increasing yields in marginal rainfall areas. Where large blocks of land are to be cultivated, however short the arable break, it is wise to leave 2-3 metre wide grass strips (either natural or planted) at intervals running roughly along the contour. Diversion ditches draining water from such contour strips and from roads are another important means of preventing full erosion.

Sheet erosion resulting in loss of topsoil is far more important, even if less obvious, and crop rotations and contour strip cropping should always be practised. Chisel ploughing before the rains, besides reducing runoff, is also a means of ensuring greater moisture availability for the crop.

WHAT IS NEEDED FOR PLANNING AND IMPLEMENTING DEVELOPMENT

Research

While there are many aspects of improvement known to be feasible or which may be deduced from similar situations elsewhere, there is and will remain a need for a continuing research programme for real progress in development. Research is needed into many aspects of agriculture including better crop varieties and testing new crops under various conditions. Optimum fertiliser dressings for a range of crops on different soils, more effective control of weeds, pests and diseases, the balance of annual to perennial crops for different soils, ways of conserving rainfall and soil moisture, are all in need of further investigation. Economic use of machinery, money, land and farmers' time are fields of study ripe for economists. There is also scope for research in extension techniques. These and many other questions await research, manpower and finance to enable answers to be found.

Agricultural Extension

This holds the key to development in many respects, but it is also one of the most difficult fields in which to make headway. Through the extension service government can do many things to stimulate agricultural production, but ultimately the crucial choices rest with thousands of individual farmers, as Dandekar (1972) has emphasised. Extension workers must be supplied with research findings, to enlighten them with possibilities. Once an extension worker has realised that he has something to proclaim to the farmers in his district, he needs a good psychological approach to get the ideas over to them. One major need in this respect is to improve relations between farmers and extension staff. District agricultural staff must not only be seen enthusiastically teaching about new innovations but prepared to help the farmer accept them by giving practical help and demonstrating with their own hands. Much greater confidence would thus be built up between extension workers and farmers. A District Agricultural Officer must also be an innovator trying and observing pieces of research himself or bringing needs for these to the notice of research workers. Every District Agricultural Officer should have his staff drilled in the six most important aims in the district at a particular time. Emphasis on these will change, but without clearly defined aims little will be achieved. Training is an important facet in ensuring an effective extension service and both pre-service and periodic in-service training for all grades of staff are needed. The District Farm Institutes, Agricultural Colleges and the University could all play a part in this training.

One of the best ways to gain acceptance for new ideas is to carry out trials and demonstrate them on farmers' own holdings. This involves much labour but the effort is well worthwhile, if carried out efficiently and with the farmers' benefit in view.

Market and Credit Facilities

No farmer can be expected to grow crops he cannot sell. For crops in demand there must be a fair price which for many commodities should be known prior to planting. The availability of local shops, markets or co-operatives where produce may be sold and essential agricultural supplies (seeds, fertilisers, pesticides, tools and medicines) can be purchased is important for rapid development in any area.

Inevitably in any development, however, money is essential to pay for necessary inputs. Many farmers have most of their capital in assets such as land, houses or buildings and cannot find what may be needed to make real and rapid progress. With inadequate capital a farmer is caught in the vicious circle of low investment--low production--low profit. For many farmers then, some form of credit is essential. However, farmers should not be given loans greater than they can repay in a definite time. The credit facilities offered by Credit Unions have considerable advantages. Here the loans come largely from fellow farmers' savings, and sponsors for each request are usually required before they are given.

Land Tenure

In many areas present agriculture has evolved or is evolving from a system of shifting cultivation. Under this system the land is of minimal value and is often regarded of much less importance than the crop growing on it. Such a system does not promote the idea that land is on trust from one generation to the next and its fertility and cropping potential must therefore be safeguarded. With the kihamba land on Kilimanjaro, land has much more value, though frequently still less than the value of two or three years' coffee crop from it. The situation is changing, however, and some land is now being recognised as worth 10 or more times what it can produce in a year, which is more akin to valuations in developed countries.

The areas not at present under kihamba are very much at the mercy of exploiters. No farmer regards them as his own, therefore all are free to cultivate or graze more or less where they please. Where many people have the right to use the same land, it is apparent from many parts of the world that no one wants to improve it and all wish to take all they can from it. Such is human nature and it is difficult to see how more intensive production can ensue from such areas without an extension of kihamba land or the formation of large co-operatively owned farms. Any land reform, Warriner (1969) emphasises, must avoid becoming a social welfare policy and ignoring the economic base.

Physical and Economic Planning as the Basis for Land Use

So often planning land use is regarded as the sole sphere of economists.

It is often completely forgotten that economists can only base their predictions on present production statistics and their apparent growth rates. In fact the basis of planning must be recognised in another sphere than economics, namely the potential of the physical environment and the capacity of people to adopt new ideas. The nature of the soils, climate and people are the basic raw materials which ultimately determine what is possible. The big misconception of many economists is that land use potential and possible productivity necessarily bear any relationship to present land use. This is not to say that economics and economists have no place in land use planning. However, to the soil surveyor, present land use and productivity can never be regarded as a true indication of potential land use. The nature of soils, vegetation and even the size and type of farms in an area can so rapidly be changed by inputs of fertilisers, new crops, technical knowledge and facilities, that the whole environment is barely recognisable in a few years.

The basis of planning must therefore be an appraisal or survey of the physical environment, soils, climate, water and mineral resources. It is the interaction of soils with the climate which Pereira (1963) has shown markedly affects the natural vegetation and potential land use. Economists can rightly evaluate the cost of inputs necessary in growing different crops but the ultimate value of a crop or farming system must not be assessed in terms of this year's profit or even an average profit over several years.

The value of a crop or farming system must also be evaluated in terms of its longer-term effects on the soil and the subsequent cost to maintain yields and income under the same system or some feasible alternative. Such an evaluation is largely outside the field of economics as the capital depreciation of land in terms of decline in structure and loss of nutrients through erosion and leaching is very difficult or impossible to assess. With present knowledge, we can only say that certain cultural practices cause heavy losses in terms of the land's declining productive potential and therefore must not be allowed.

Whatever the short term economics or gain to the present farmer may be, the productive potential of land must be conserved for future generations by soundly based land use plans for the area. No plans for betterment of land use are free from the gravest risks of error, if the foundation for them has not been laid in soil survey. Happily, the slopes of Kilimanjaro have at least been surveyed on a detailed reconnaissance scale, providing a basis for chiefdom planning. Nevertheless, there will be increasing demand for large-scale soil maps in the future, for the detailed planning of small localities and farms.

CHAPTER 7: SUMMARY

1. A detailed reconnaissance soil survey on a scale of 1:50,000 covering some 1500 sq. km. of the southern and eastern slopes of Kilimanjaro was carried out at convenient periods between 1963 and 1968.

2. About 100 soil profiles covering 40 soil series and complexes were described and sampled and 47 representative descriptions of these are given in the memoir.

3. The soils have been influenced by all the 5 soil forming factors, but climate, the time since deposition and the nature of parent materials appear to be most important.

4. The nature of soils is readily explained by considering the balance between the richness of weathering (governed by the parent material and climate), and intensity of leaching (influenced by climate and topography).

5. Soils range from lithosols, juvenile soils and reddish brown soils in the drier and more eroded areas, through eutrophic brown and ferruginous tropical soils in areas of moderate rainfall, to ferrisols, ferrallitic and podsolic soils in strongly leached areas.

6. The soil mapping was accompanied by an assessment of the soil fertility using beans as a test crop. Significant responses to lime, phosphorus and potassium commonly occurred in the upper zone soils, while much of the middle altitudinal zone responded to phosphorus and some to potassium. In the lower zone the only significant responses were to lime in the western sector where soils were high in potassium (Figure 2).

7. The soils have been arranged into 12 Land Use Potential Groups on the basis of similarity of soil and climatic conditions and suitability for particular crops.

8. Crop rotations, improved crop husbandry, new crop introductions, use of fertilisers and more suitable cultivation techniques are important in relation to soil conservation and more intensive production.

9. New crop possibilities include tea, wheat, cashew, seed and navy beans, legume-rich pastures, temperate fruits and possibly cocoa in selected areas. More widespread production of cotton, castor, groundnuts, citrus as well as trees for timber, fencing paddocks or shelter, are also recommended.

10. Generally responses to nitrogen fertilisers may be expected on most non-leguminous crops, to phosphorus and potassium particularly in the upper and middle zones and to lime with certain crops in both the upper and parts of the lower zone.

11. Tentatively, light dressings at rates of about 40-50 kg/ha P_2O_5, 50 kg/ha K_2O and 1000 kg/ha $CaCO_3$ in areas of deficiencies (Figure 2) are likely to give a worthwhile return on investment. In areas of acute deficiencies in the upper zone, heavier dressings may be well worthwhile on responsive crops.

12. While fertilisers can and should make a valuable and immediate contribution to improved production on the mountain, there is need for more research on a variety of crops to assess optimum rates and economics.

13. Many soils in the lower area are particularly erosion prone and need conservation measures such as rotations including the planting of legume-rich pastures, strip-cropping, introduction of grass strips and where feasible, tied-ridge cropping.

14. Another aspect of planning for conservation is the control of overgrazing and the formation of paddocks for more efficient use of pastures and farmers' time.

15. Reorientation and training of the extension service should have high priority as it holds a major key in plan implementation and development.

16. Practical help and demonstration of what is possible on farmers' own fields is a valuable extension method, though discussions and visits to improved farms also have a place.

17. About 6 main aims of extension need to be clearly defined in each locality--without definite aims little, if anything, will be achieved.

18. A continuing programme of research into the factors most limiting crop and livestock improvement is needed and the extension service as well as research workers need to be involved in both the innovation and the carrying out of such research projects. Extension workers will thus gain fresh insight into what is possible.

19. Intensification programmes require more capital input, but loans should always involve some personal commitment of money by the farmer and also need a sound economic basis to enable repayment. The organisation of credit unions is recommended to encourage farmers to use financial resources to their best advantage.

20. Continued improvement in husbandry also depends on an effective and stable system of land tenure. In the lower areas intensification of land use would seem to depend on either an extension of the kihamba lands or the development of cooperatively owned farms, crops and livestock.

21. The nature of soils and climate govern land use potential. In land use planning these factors should dictate policy more than any short-term economic considerations.

22. More detailed soil studies are needed in these high-potential areas but the existing soil map and memoir should provide a good basis for future investigations.

23. This type of project, involving both a soil survey and the growing of a test crop to assess fertility of defined and mapped soils, is recommended for much wider use.

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<u>APPENDICES</u>

APPENDIX A1 - PROFILE DESCRIPTIONS AND SOIL ANALYTICAL DATA

Profile ID : Kibongoto

Locality: About 50 yards east of bend in road, about 100 yards north of Kibongoto, turn off Maelowate. Lat. 3° 13'S, Long. 37° 6'E

Mapping Unit: Kware Complex (1)

Classified as: Lithosol on Olivine Nephelinite

Vegetation: Formerly wooded Grassland with *Combretum gueinell*, *Croton macrostachys* and occasional *Acacia tortilis*. *Ac. Brevispica* forms clumps of bush thicket while the grasses were *Panicum maximum*, *Hyparrhenia dissoluta*, *Digitaria sp.* and *Cyperus sp.* *Solanum incanum* was also common. Maize and beans were cultivated.

The profile was sited on a slope of about 2° at an elevation of 3900 feet in an area of Meru agglomerate and lahar topography. Drainage was slightly imperfect below 60 cm due to lava.

Profile Description:

0-12 cm Wet, black (2.5Y2/0) gritty loam with moderate crumb to fine subangular blocky structure. Numerous fine lava fragments. Common fine pores and fissures. Abundant fine roots.

12-37 cm Wet, black (2.5Y2/0) gritty silt loam with abundant fine to medium lava fragments. Moderate subangular blocky structure. Friable with abundant fine fissures and rapid permeability. Abundant fine and occasional medium roots.

37-60 cm Wet, very dark grey brown (2.5Y3/2) loamy gravel with black coatings on faces of soft weathering rock. Rock dominant. Hard to dig below 60 cm. Permeability moderate becoming rather slow. Roots common on rock faces.

Depth cm	pH 1:5 Water	pH 1:2.5 M/100 $CaCl_2$	Cond. 1:5 micro-mohs/cm	PHOSPHORUS (ppm) 0.3M HCL	TOTAL	% Organic in total	EXCHANGEABLE BASES (m.e./100gm) Ca	Mg	Na	K	Mn	TOTAL	Capa-city	PERCENT Satur-ation	C	N	C/N
0-12	6.9	6.3	204	272	4250	12.9	23.3	12.0	0.44	8.80	0.01	44.55	50.8	88	5.68	.45	12.6
12-37	7.0	6.5	217	286	5000	28.0	24.0	8.3	0.45	6.50	0.04	39.28			4.65	.36	12.9
37-60	7.0	6.5	302	257	5250	35.2		9.6	1.44	20.8	0.01	42.25	38.2	100	1.49		
Mean of 6 topsoils - Kware Complex																	
0-15		6.5		486	5590	17.6	23.6	9.3		9.1		47.5	56.2	94	4.54		

APPENDIX A2 - PROFILE DESCRIPTIONS AND SOIL ANALYTICAL DATA

Profile ID.: Masama 6

Locality: About 1/2 mile from junction of W. Kilimanjaro and Kware roads, 300 yards from Boloti Swamp. Lat. 3° 16'S, Long. 37° 7'E

Mapping Unit: Kware Complex (1)

Classified as: Lithosol on Olivine Nephelinite

Vegetation: Formerly wooded grassland with *Combretum gueinzii* common and occasional *Croton macrostachys*, *Kigelia aethiopica*, *Ficus sp.* and *Acacia tortilis*. *Panicum maximum*, *Tridex repens* and *Cyperus rotundis* were common as well as planted maize and beans.

The profile was on a 3° irregular slope about 300 yards from the swamp edge at an elevation of 3500 feet. Parent material was Nephelinite of agglomerate/lahar origin. The profile drainage was imperfect.

Profile Description:

0-15 cm Very wet, black (10YR2/1), gravelly loam with abundant subangular lava fragments. Weak subangular blocky structure. Friable with abundant fine fissures and rather rapid permeability. Almost abundant fine roots. Termites common.

15-40 cm Wet, black (10YR2/1), gravelly loam with weak subangular blocky structure. Abundant fine and small stones. Friable with moderate permeability and common roots.

40-65 cm Wet, black (10YR2/1), gravelly sandy clay loam with abundant small and medium stones. Friable with moderate permeability and common roots.

65+ cm Wet, very dark brown (10YR3/2) soft weathering agglomerate. Moderate permeability becoming slow. Few roots mainly on rock faces.

Depth cm	pH 1:5 Water	pH 1:2.5 M/100 $CaCl_2$	Cond. 1:5 micro-mohs/cm	PHOSPHORUS (ppm)			EXCHANGEABLE BASES (m.e./100gm)						Capacity	PERCENT	C	M	C/N
				0.3M HCL	TOTAL	% Organic in total	Ca	Mg	Na	K	Mn	TOTAL		Saturation			
0-15	8.3	7.5	114.7	69	5750	30.4	39.2	13.9	0.95	11.84	0.02	65.91	61.6	100	6.17	0.57	10.0
15-40	8.3	7.4	107.1	69	6130	17.4	27.1	15.9	1.06	13.76	0.02	57.84			5.82	0.53	10.9
40-65	8.0	7.1	85.0	57	4880	29.5	30.2	9.7	1.68	14.08	0.02	55.68			2.03		
65+	7.8	6.8	38.2				11.5	6.2	2.59	25.00	0.01	45.30					

APPENDIX A3 - PROFILE DESCRIPTIONS AND SOIL ANALYTICAL DATA

Profile ID.: Kibongoto 1

Locality: On Wanri Road, 1/2 mile north of junction of Kibongoto-Sanya Juu and Wanri Road in Rabiel Jacob's *shamba*. Lat. 3° 11 1/2'S, Long. 37° 07'E

Mapping Unit: Old Moshi Series (2)
Kibongoto Variant (2A)

Classified as: Ferruginous tropical soil on ash

Vegetation: Formerly forest with *Albizzia schimperiana*, *Croton macrostachys*, *Rauvolfia caffra* and *Turroes robusta*. Now planted with coffee, bananas, maize and beans. *Digitaria sp.*, *Sporobolus pellucidus* and *Rhynchelelrum roseum* were common grasses.

The profile is developed on a convex slope of about 8° about 209 yards above the base of the slope at an elevation of 4200 feet. Profile drainage is free.

Profile Description:

0-16 cm Wet, dark red brown (5YR3/3) silty clay loam with moderate crumb becoming S.A.B. structure. Friable, with abundant fine pores and fissures and abundant roots.

16-36 cm Wet, dark red brown (5YR3/3) silty clay loam with moderate S.A.B. structure and abundant fine to large roots. Moderate permeability.

36-66 cm Wet, dark red brown (5YR3/4) silty clay loam with weak prismatic structure. Friable with common fine to medium roots.

66-140cm Wet, dark red brown (5YR3/4) silty clay loam with weak prismatic structure. Friable with common fine pores and fissures and common roots.

140-180+cm Wet, dark red (4YR3/4) fine sandy clay with weak prismatic structure. Friable fine roots still common.

Depth cm	pH 1:5 Water	pH 1:2.5 M/100 $CaCl_2$	Cond. 1:5 micro-mohs/cm	PHOSPHORUS (ppm) 0.3M HCL	TOTAL	% Organic in total	EXCHANGEABLE BASES (m.e./100gm) Ca	Mg	Na	K	Mn	TOTAL	Capa-city	PERCENT Satur-ation	C	M	C/N
0-16	6.4	5.7	46.3	15	1250	76.0	9.0	4.4	0.28	0.26	0,05	13.99	19.2	73	2.51	0.26	9.7
16-36	6.5	5.5	55.2	13	1250	76.0	7.9	3.8	0.21	0.14	0.02	12.07			1.93	0.21	9.2
36-66	6.1	5.8	195.8	24	815	60.0	5.2	3.6	0.38	0.30	0.02	9.50			0.93		
66-140	6.2	5.8	169.2				4.8	2.9	0.21	0.22	0.01	8.14					
140-180+	6.1	5.8	170.0				4.8	2.1	0.91	0.22	0.01	7.32	10.2	72			
Mean of 8 topsoils - Old Moshi Series - Kibongoto Variant																	
0-15		5.4		14.9	1908	61.1	10.1	3.3		0.90		14.82	21.9	69	2.89		

APPENDIX A4 - PROFILE DESCRIPTIONS AND SOIL ANALYTICAL DATA

Profile ID.: Old Moshi 6

Locality: 50 yards west-northwest of Old Moshi Baraza. Lat. 3° 19'S, Long. 37° 24'E.

Mapping Unit: Old Moshi Series (2)
Old Moshi Variant (2B)

Classified as: Ferruginous tropical soil on ash

Vegetation: Formerly forest, now coffee/banana shamba with *Albizzia schimperiana*, *Cordia Holstii*, *Grevillea robusta* and mango trees. *Solanum incanum* and the grasses *Digitaria sp.*, *Panicum trichocladum* and *Setaria homonyma* were noted.

This profile was developed from a mixture of ash colluvium with some lava fragments on a slope of about 8° at an altitude of 3900 feet. Profile drainage was free.

Profile Description:

0-15 cm Wet, dark red brown (5YR3/3) silty clay loam with occasional subangular lava fragments. Moderate crumb becoming S.A.B. structure. Abundant pores, fissures and roots.

15-40 cm Very moist, dark red brown (5YR3/4) silty clay with moderate S.A.B. structure tending to prismatic. Common fine to large roots. Friable with moderate permeability.

40-100 cm Wet, dark red brown (5YR3/5) silty clay with occasional lava fragments. Friable with common roots. Moderate prismatic structure with shiny coatings on str -ture faces.

100-180+cm Wet, red brown (5YR4/4) silty clay with weak prismatic structure. Friable with moderate permeability. Roots few.

Depth cm	pH 1:5 Water	pH 1:2.5 M/100 $CaCl_2$	Cond. 1:5 micro-mohs/cm	PHOSPHORUS (ppm) 0.3M HCL	TOTAL	% Organic in total	EXCHANGEABLE BASES (m.e./100gm) Ca	Mg	Na	K	Mn	TOTAL	Capa-city	PERCENT Satur-ation	C	M	C/N
0-15	6.6	5.4	38	42.5	3250	36.5	12.6	4.4	0.24	0.22	0.14	17.60	25.9	68	1.93	0.22	8.8
15-40	6.7	5.7	31	42.5	2665	50.0	11.7	5.2	0.37	0.14	0.00	17.41			1.54	0.19	8.1
40-70	6.9	5.8	21	2.9	2500	67.4	8.3	4.6	0.40	0.10	0.02	13.42			0.90		
70-100	6.7	5.7	24				6.7	4.0	0.41	0.06	0.01	11.18					
100-140	6.5	5.6	23														
140-180+	6.6	5.6	21				6.8	3.9	0.43	0.06	0.04	11.23					
Mean of 10 topsoils - Old Moshi Variant																	
0-15		5.8		23.7	2330	42.6	11.8	4.2		0.41		16.78	19.9	81	2.20		

APPENDIX A5 - PROFILE DESCRIPTIONS AND SOIL ANALYTICAL DATA

Profile ID.: Kirua 2

Locality: 100 yards below Dispensary, 10 yards east of main road. Lat. 3° 19'S, Long. 37° 28'E

Mapping Unit: Old Moshi Series (2)
Old Moshi Variant (2B)

Classified as: Ferruginous tropical soil on ash

Vegetation: Formerly forest, now coffee/banana shamba. Trees include *Albizzia schimperiana*, *Ficus sp.*, *Alangium chinense*, *Croton macrostachys*, *Rauvolfia caffra*, *Olea welwitchii*. Grasses included *Digitaria sp.*, *Setaria orthosticha*, *Panicum trichocladum* and *Cyperus sp.* and *Tridex repens* also occurred.

Profile was developed on a slope of about 10° at an elevation of about 4700 feet. Profile drainage free.

Profile Description:

0-14 cm Moist, dark red brown (5YR3/3) fine sandy silty clay loam, with moderate crumb becoming S.A.B. structure. Friable with common fine to medium roots.

14-40 cm Very moist, dark red brown (5YR3/3) fine sandy silty clay loam, with moderate S.A.B. structure. Friable with common roots.

40 -90 cm Very moist, dark red brown (5YR3/6) with (5YR3/3) on root channels, silty clay. Moderate prismatic structure. Friable with common fine pores and fissures. Roots common.

90-160 cm Very moist, dark red brown (5YR3/5) fine sandy clay with weak prismatic structure. Friable with common acres and fissures. Roots common, becoming few.

Depth cm	pH 1:5 Water	pH 1:2.5 M/100 $CaCl_2$	Cond. 1:5 micro-mohs/cm	PHOSPHORUS (ppm) 0.3M HCL	TOTAL	% Organic in total	EXCHANGEABLE BASES (m.e./100gm) Ca	Mg	Na	K	Mn	TOTAL	Capa-city	PERCENT Satur-ation	C	N	C/N
0-14	6.8	5.9	65	210	3800	34.0	11.0	5.6	0.29	1.66	0.07	18.62	27.3	68	3.38		
14-40	7.0	5.9	65		4500	22.8	11.2	5.7	0.28	1.02	0.02	18.2[illegible]			2.48		
40-60	7.4	6.4	160		3440	20.8	16.8	3.7	0.23	0.93	0.02	21.68			1.65		
60-90	7.2	6.4	160				11.2	2.2	0.17	0.77	0.05	14.39					
90-130	7.2	6.5	162				9.7	1.6	0.14	0.64	0.01	12.09					
130-160	7.1	6.5	161				7.9	2.5	0.16	0.53	0.02	11.11					
160+	7.2	6.6	141				9.8	1.7	0.23	0.88	0.01	12.62					

APPENDIX A6 - PROFILE DESCRIPTIONS AND SOIL ANALYTICAL DATA

Profile ID.: Kilema 3

Locality: 300 yards northwest of Kilema Church on football pitch, 80 yards east from road. Lat. 3° 17 1/2'S, Long. 37° 29 1/2'E

Mapping Unit: Old Moshi Series (2)
Kilema Variant (2Bt)

Classified as: Ferruginous tropical soil on ash/lava mixture

Vegetation: Formerly forest with *Albizzia schimperiana*, *Techlen viridis*, *Cordia holstii* common. Grasses included *Digitaria sp.*, *Eragrestis sp.* with *Cyperus rigidifolia* and *C. rotundus*.

Profile was developed on ash colluvium on an 8° slope at an elevation of 4500 feet. Profile drainage free.

Profile Description:

0-18 cm Moist, dark brown (7.5YR3/2) sandy loam, with weak crumb becoming S.A.B. structure. Tendency to cap at surface. Abundant fine and small roots.

18-90 cm Very moist, dark red brown (5YR3/4) fine sandy clay loam with moderate prismatic structure. Friable, finely fissured with common roots.

90-120 cm Moist, dark brown (7.5YR3/4) fine sandy, medium loam, weak prismatic structure with moderate permeability.

120-160 cm Very moist, dark yellow brown (10YR3.5/4) sandy loam. Very weak prismatic structure. Few roots.

160-190+cm Dark yellowish brown (10YR3.4) coarse sandy loam with fine ash fragments. Single grain structure. Very friable with rapid permeability. Few roots.

Depth cm	pH 1:5 Water	pH 1:2.5 M/100 $CaCl_2$	Cond. 1:5 micro-mohs/cm	PHOSPHORUS (ppm) 0.3M HCL	TOTAL	% Organic in total	EXCHANGEABLE BASES (m.e./100gm) Ca	Mg	Na	K	Mn	TOTAL	Capa-city	PERCENT Satur-ation	C	M	C/N
0-18	5.9	5.3	216	25.0	3250	27.7	6.2	2.7	0.15	1.25	0.16	8.26	24.9	33	2.82		
18-55	5.9	5.4	146	27.0	3250	35.4	3.3	2.5	0.18	0.35	0.04	6.37			1.19		
55-90	6.0	5.4	151	25.0	2690	23.8	2.5	1.2	0.19	0.30	0.04	4.23			0.87		
90-120	5.9	5.7	134				1.4	0.9	0.15	0.22	0.02	2.69					
120-160	6.0	5.8	143				0.7	0.8	0.19	0.26	0.01	1.96					
160-190+	5.9	5.7	148				1.7	0.9	0.27	0.40	0.02	3.29					

APPENDIX A7 - PROFILE DESCRIPTIONS AND SOIL ANALYTICAL DATA

Profile ID.: Keni 3

Locality: 1/2 mile below water point near K.N.C.U. Keni-Mriti. Lat 3° 15 1/2'S. Long. 37° 36 1/2'E

Mapping Unit: Old Moshi Series (2) Mamsera Variant (2C)

Classified as: Ferruginous tropical soil on ash/lava colluvium

Vegetation: Formerly forest. Trees include *Cordia holstii*, *Rauvolfia caffra*, *Ficus sp.*, and *Grevillia robusta*. Common grasses include *Digitaria sp.*, *Eragrestis curvule*, and *Cynodon dactylon*. Also present were *Solanum incarnum* and *Indigofera sp.*

Profile developed on slope of about 5° at an elevation of 4700 feet and was freely drained.

Profile Description:

0-18 cm Moist, dark red brown (5YR3/3) silty clay loam with moderate crumb becoming S.A.B. structure. Friable with common pores and fissures.

18-40 cm Moist, dark red brown (5YR3/3) fine sandy clay loam, moderate S.A.B. structure roots common.

40-70 cm Moist, dark red brown (5YR3/4) sandy clay loam with a few fine and small lava fragments. Moderate S.A.B. structure tending to prismatic. Common fibrous roots.

70-100 cm Moist, dark red brown (4YR3/3) silty clay loam. Weak prismatic structure. Friable with common fine pores and fissures. Roots common.

110-185+cm Moist, dark red brown (3YR3/4) silty clay loam with a few fine to large lava fragments. Very weak prismatic structure. Friable with moderate permeability. Few roots.

Depth cm	pH 1:5 Water	pH 1:2.5 M/100 $CaCl_2$	Cond. 1:5 micro-mohs/cm	PHOSPHORUS (ppm) 0.3M HCL	TOTAL	% Organic in total	EXCHANGEABLE BASES (m.e./100gm) Ca	Mg	Na	K	Mn	TOTAL	Capa-city	PERCENT Satur-ation	C	M	C/N
0-18	6.4	5.8	33	28.7	2375	27.9	13.6	6.0	0.17	2.62	0.14	22.53	29.7	76	1.99		
18-40	6.7	6.0	27	9.1	1625	30.0	10.9	5.7	0.18	2.82	0.10	19.70			0.83		
40-70	6.7	6.2	22	4.4	1065	26.6	7.0	3.5	0.21	1.86	0.02	13.59			0.69		
70-110	6.6	6.0	18				6.3	4.3	0.17	0.67	0.02	11.46					
110-145	6.7	6.0	16				6.9	7.0	0.21	0.26	0.01	14.38					
145-185+	6.3	5.8	19				3.5	3.7	0.15	0.29	0.02	7.66					
Mean of 5 topsoils - Mamsera Variant (2C)																	
0-15		5.4		11.6	2331	42.6	10.0	4.1		0.86		15.24	24.6	62	2.19		

APPENDIX A8 - PROFILE DESCRIPTIONS AND ANALYTICAL DATA

Profile ID.: Keni 2

Locality: 40 yards north of Keni Rest House. Lat. 3° 14'S, Long. 37° 36 1/2'E

Mapping Unit: Old Moshi Series (2)
Keni Variant (2Ct)

Classified as: Ferruginous tropical soil on ash/colluvium over lavas

Vegetation: Formerly forest, now coffee, bananas, pit on pasture. Trees include *Rauvolfia caffra*, *Croton macrostachys*, *Ficus carpensis*, *Cassipourea elliotii*. Grasses included *Hyparrhenia sp.*, *Rhyncheletrum roseum*, *Aristida adsensclonis*, *Heteropogon contortus*, *Sporobolus pyramidalis*.

Profile developed on slope of 7° at an elevation of 4600 feet and was freely drained.

Profile Description:

0-15 cm Slightly moist, dark red brown (5YR3/3) loam with a few small angular lava fragments. Weak fine crumb structure. Common very fine pores but slight surface cap; roots abundant.

15-35 cm Slightly moist, dark red brown (5YR3.5/3) sandy clay loam. Moderate fine S.A.B. structure. Abundant fine pores and fissures. Abundant roots.

35-65 cm Very moist, dark red brown (5YR3/4) clay loam with weak prismatic structure. Friable with common roots.

65-100 cm Very moist, dark red brown (4YR3/4) silty clay loam with very weak prismatic structure. Common fine and small roots.

100-140+cm Very moist, dark red brown (4YR3/4) with weathering rock olive brown (2.5Y4/4) gritty clay loam. Extremely stony. Roots still common.

Depth cm	pH 1:5 Water	pH 1:2.5 M/100 $CaCl_2$	Cond. 1:5 micro-mohs/cm	PHOSPHORUS (ppm) 0.3M HCL	TOTAL	% Organic in total	EXCHANGEABLE BASES (m.e./100gm) Ca	Mg	Na	K	Mn	TOTAL	Capacity	PERCENT Saturation	C	M	C/N
0-15	6.1	5.4	28	6.8	2700	29.6	8.8	4.0	0.24	0.61	0.19	13.84	21.4	65	1.69		
15-35	6.2	5.6	22	4.4	2400	26.7	8.9	4.1	0.18	0.26	0.04	13.48			1.13		
35-65	6.1	5.7	30	5.3	1580	25.0	7.5	3.2	0.22	0.10	11.12				0.76		
65-100	5.7	5.4	21														
100-140+	5.9	5.5	26				7.7	2.1	0.30	0.10	0.06	10.26	19.1	54			
Mean of 2 topsoils - Keni Variant																	
		5.3		7.2	2350	30.9	7.9	4.0		0.44		12.65	19.8	64	1.71		

APPENDIX A9 - PROFILE DESCRIPTIONS AND SOIL ANALYTICAL DATA

Profile ID.: Masama 7

Locality: On west boundary of Kibo Estate, 5 yards south of track. Lat. 3° 16 1/2'S. Long. 37° 11'E

Mapping Unit: Kibohehe Series (3)

Classified as: Ferruginous tropical soil on ash colluvium over rhomb prophyry.

Vegetation: Formerly woodland with the following species still common: Cordia hotstii, Rauvolfia caffra, Croton macrostachys, Albizzia schimperiana. Grasses included Panicum maximum, P. trichocladum, Hyparrhenia filipendula.

Profile was developed on ash colluvium on 7° slightly convex slope at an elevation of 3700 feet and was freely drained.

Profile Description:

0-20 cm Moist, dark red brown (5YR3/3) clay loam with moderate crumb becoming S.A.B. structure. Common pores and fine fissures. Common roots and earthworms.

20-45 cm Moist, dark red brown (5YR3/4) silty clay loam with moderate S.A.B. structure. Common roots.

45-85 cm Moist, dark red brown (4YR3/4) silty clay with moderate prismatic structure. Finely fissured with moderate permeability and common roots.

85-115 cm Moist, dark red brown (4YR3/4) silty clay, labile plastic consistence. Few roots. Permeability moderate. Common roots.

115-145+cm Moist, dark red brown (4YR3/4) silty clay with weak prismatic structure. Finely fissured with moderate permeability. Few roots.

Depth cm	pH 1:5 Water	pH 1:2.5 M/100 $CaCl_2$	Cond. 1:5 micro-mohs/cm	PHOSPHORUS (ppm) 0.3M HCL	TOTAL	% Organic in total	EXCHANGEABLE BASES (m.e./100gm) Ca	Mg	Na	K	Mn	TOTAL	Capa-city	PERCENT Satur-ation	C	M	C/N
0-20	6.7	5.9	48	53.3	2000	63.0	17.2	4.9	0.35	2.00	0.07	24.52	20.0	82	5.06	0.40	12.7
20-45	7.0	6.2	38	1.4	1400	81.1	9.3	2.6	0.35	1.68	0.01	13.92			0.83	0.02	11.9
45-85	7.2	6.5	44	0.7	1330	78.9	7.2	3.0	0.40	1.63	0.01	12.24			0.51		
85-115	7.0	6.3	49														
115-145	6.9	6.4	29				6.4	2.7	0.37	0.72	0.01	10.20	12.1	84			
Mean of 5 topsoils - Kibohehe Series (3)																	
0-15		6.1		30.8	2318	51.2	19.4	6.6		1.81		28.18	30.6	92	3.62		

APPENDIX A10 - PROFILE DESCRIPTIONS AND ANALYTICAL DATA

Profile ID.: Masama 5

Locality: 30 yards east-southeast of junction of cattle track and road to Masama. Lat. 3° 18'S, Long. 37° 12'E

Mapping Unit: Sadala Series (4)

Classified as: Ferruginous tropical soil on mixed ash/lava colluvium

Vegetation: Formerly *hyparrhenia* - *Panicum*/*Combretum* wood grassland with *Combretum sp.*, and *Microglossa oblongifolia*. The ground cover was made up with *Panicum maximum*, *P. infestum*, *Digitaria sp.* and *Indigofera colutea*.

Profile was on a 6° slightly concave slope at an elevation of 3500 feet and freely drained.

Profile Description:

0-15 cm	Wet, dark brown (7.5YR3/2) gritty silty clay loam with a few subangular lava fragments and occasional boulders. Moderate fine crumb to S.A.B. structure, with abundant roots.
15-35 cm	Wet, dark red brown (5YR3/4) gritty clay loam with common lava fragments. Moderate S.A.B. structure. Common fine to medium roots.
35-70 cm	Wet, dark red brown (5YR3.5/4) gravelly clay loam with very common lava fragments. Moderate permeability. Roots very common.
70-110 cm	Wet, yellowish red (5YR4/8) and black (5YR2/1) gritty clay loam with soft fissured rock dominant. Common fine roots on rock faces.
110-145 cm	Wet, yellowish (5YR4/8) with (5YR3.5/4) on rock faces. Gritty clay loam. Original rock structure. Roots common.
145-200+cm	Wet, dark brown (7.5YR3/2) with (10YR4/1) weathering rock. Moderate permeability. A few roots on rock faces.

Depth cm	pH 1:5 Water	pH 1:2.5 M/100 $CaCl_2$	Cond. 1:5 micro-mohs/cm	PHOSPHORUS (ppm) 0.3M HCL	TOTAL	% Organic in total	EXCHANGEABLE BASES (m.e./100gm) Ca	Mg	Na	K	Mn	TOTAL	Capa-city	PERCENT Satur-ation	C	M	C/N
0-15	6.6	6.0	51	87.0	2930	57.3	10.9	5.3	0.63	1.60	0.02	18.45	28.2	65	2.63	0.19	13.8
15-35	6.8	5.9	35	57.0	2130	70.7	7.0	3.3	0.52	1.50	0.01	12.33			1.18	0.11	10.7
35-70	6.5	5.6	25	25.0	1750	53.4	4.0	2.6	0.63	1.55	0.01	8.79			0.58		
70-110	6.2	5.4	18				3.0	4.2	0.59	1.11	0.01	8.91					
110-145	6.4	4.9	17														
145-200	6.3	4.5	17				3.1	3.8	1.08	1.25	0.04	9.27	19.7	47			
Mean of topsoils - Sadala Series (4)																	
		6.1		46.0	2597	28.7	12.2	5.6		2.20		19.98	25.4	72	2.48		

APPENDIX A11 - PROFILE DESCRIPTIONS AND SOIL ANALYTICAL DATA

Profile ID.: Masama 4

Locality: Maruken Village above Masama. Lat. 3° 12 1/2'S, Long. 37° 10 1/2'E

Mapping Unit: Masama Series (5)
Masama Variant (5A)

Classified as: Humic Ferrisol

Vegetation: Formerly heavy forest with *Albizzia schimperiana*, *Croton macrostachys*, *Rauvolfia daffra*, and *Ficus sp.* still present. Also planted *Grevillea* and *Cypress* in coffee/banana shambas. Ground cover includes *Digitaria sp.*, *Eragrostis tennifolia*, *Commilina sp.*, *Galinsoga parviflora*, *Cyperus rotundus* and *Sporobolus pyramidalis*.

Profile developed on mixed ash and trachyte colluvium on a 4° convex slope at 4900 feet. Drainage was free.

Profile Description:

0-14 cm Wet, very dark brown (7.5YR3/2) sandy medium loam with common fine S.A. lava fragments. Weak fine crumb structure. Moderate permeability. Abundant fine to medium roots.

14-35 cm Wet, very dark brown (7.5YR3/2) sandy clay loam with moderate S.A.B. structure. Common pores and fissures. Permeability moderate, roots abundant.

35-110 cm Wet, very dark brown (7.5YR3/2) with common soft weathering rocks, dark red brown (5YR3/2 - 7YR4/3) silty clay loam with moderate S.A.B. Roots common.

110-150 cm Wet, very dark grey (10YR3/2.5) fine sandy clay with moderate prismatic structure. Few fine and small roots, moderate permeability.

150-190+cm Wet, very dark grey (10YR3/2.5) with strong brown mottles (7.5YR5/6) fine sandy clay loam. Common rock fragments, weak prismatic structure and very few roots.

Depth cm	pH 1:5 Water	pH 1:2.5 M/100 $CaCl_2$	Cond. 1:5 micro-mohs/cm	PHOSPHORUS (ppm) 0.3N HCL	TOTAL	% Organic in total	EXCHANGEABLE BASES (m.e./100gm) Ca	Mg	Na	K	Mn	TOTAL	Capacity	PERCENT Saturation	C	N	C/N
0-14	6.0	5.1	37	3.4	2130	70.7	5.9	2.9	0.46	0.45	0.02	9.73	15.0	65	2.68	0.26	10.3
14-35	5.7	4.8	27	2.6	2130	64.8	3.3	2.2	0.27	0.40	0.02	6.29			1.41	0.18	8.0
35-65	5.1	4.2	21	3.2	2500	85.0	1.4	0.9	0.38	0.30	0.01	2.99			0.54		
65-110	5.1	4.2	18				1.2	0.7	0.41	0.30	0.02	2.63					
110-150	5.1	4.2	23														
150-190	5.0	4.2	19				1.2	0.5	0.43	0.16	0.02	2.31	13.4	17.2			
Mean of 4 topsoils - Masama Series - Masama Variant (5A)																	
0-15		5.0		14.9	1527	67.5	4.9	2.1		0.50		7.85	30.0	33	4.81		

APPENDIX A12 - PROFILE DESCRIPTIONS AND SOIL ANALYTICAL DATA

Profile ID.: Kilema 2 — Locality: 200 yards below Kyou Village, 5 yards to south of road. Lat. 3° 17'S, Long. 37° 29'E

Mapping Unit: Masama Series (5) Lombeta Variant (5B) — Classified as: Humic Ferrisol

Vegetation: Formerly forest, now poor coffee, bananas and maize, with *Rauvolfia caffra*, *Albizzia schimperiana*, *Croton macrostachys*, *Macaranga kilimandscherica* and planted *Grevillea*. Species in ground cover include *Exotheca abyssinica*, *Pennisetum clandestinum*, *Rhynchelytrum roseum*, *Sporobolus pyramidalis*, *Eragrostis tennifolia*, *Digitaria sp.* and *Cyperus sp.*

Profile developed on ash/lava colluvium on a slope of 10° at an altitude of 5,250 feet. Profile drainage free.

Profile Description:

0-12 cm Moist, dark brown (7.5YR3/2) humic sandy loam with occasional fine S.A. lava fragments. Moderate fine to medium crumb structure. Very friable tending to cap at surface with abundant roots.

12-35 cm Moist, dark brown (7.5YR3/2) sandy loam with weak S.A.B. structure. Very friable with abundant fine roots.

35-95 cm Very moist, dark brown (7.5YR3/2) loam, slightly stony, with very weak S.A.B. structure, friable with common fine and small roots.

95-150 cm Very moist, dark red brown (5YR3/4) with humic coatings (7.5YR3/2) on structure faces. Fine sandy clay loam with weak prismatic structure. Common fine small roots.

150-180+cm Very moist, dark red brown (5YR3/6), sandy clay becoming very stony, very weak prismatic structure, friable, a few roots.

Depth cm	pH 1:5 Water	pH 1:2.5 M/100 $CaCl_2$	Cond. 1:5 micro-mohs/cm	PHOSPHORUS (ppm) 0.3N HCL	TOTAL	% Organic in total	EXCHANGEABLE BASES (m.e./100gm) Ca	Mg	Na	K	Mn	TOTAL	Capa-city	PERCENT Satur-ation	C	N	C/N
0-12	5.8	5.3	166	6.2	2590	46.0	6.5	2.5	0.24	0.52	0.26	10.02	26.7	36	5.85		
12-35	5.5	4.9	157	4.2	3000	45.0	5.3	2.1	0.15	0.40	0.06	8.01			4.88		
35-60	5.5	5.1	202	4.6	2900	48.3	3.0	1.3	0.18	0.45	0.02	4.95			4.73		
60-95	5.7	5.1	185	13.5	2700	38.9	2.2	1.6	0.23	0.45	0.04	4.52					
95-125	5.6	5.2	144				1.7	1.3	0.19	0.35	0.01	3.55					
125-150	5.8	5.2	116				2.0	1.9	0.23	0.45	0.02	4.60					
150-180	5.6	5.1	109				1.4	0.7	0.14	0.26	0.02	2.52					
Mean of 5 topsoils - Masama Series Lombeta Variant (5B)																	
0-15		5.0		11.6	2258	52.7	6.3	2.2		0.42		9.15	24.4	38	3.74		

APPENDIX A13 - PROFILE DESCRIPTIONS AND SOIL ANALYTICAL DATA

Profile ID.: Machame 3

Locality: 250 yards above the valley bottom, 250 yards to ridge crest. Mronga-Mashari.
Lat. 3° 11'S, Long. 37° 13 1/2'E

Mapping Unit: Manu Complex (6)
Nrwaa Variant (6A)

Classified as: Humic Ferrallitic soil on volcanic ash

Vegetation: Formerly *Ocotea* rain forest with *Agauria salicifolia*, *Rauvolfia caffra*, dwarf *Albizzia schimperiana* and planted wattle remaining. Also present *Erica arborea* and *Pteridium aquilinum*, *Ergrcstis sp.* and *Digitaria sp.*

Profile was developed on volcanic ash overlying trachyte, on a 6° slope at an altitute of 5500 feet and was slightly imperfectly drained.

Profile Description:

0-14 cm Wet, dark brown (7.5YR3/2) humic fine sandy loam with weak fine crumb to S.A.B. structure. Abundant fine roots.

14-32 cm Wet, dark brown (7.5YR3/2) fine sandy loam with very weak S.A.B. structure. Almost abundant roots. Greasy consistence. Permeability rather slow.

32-64 cm Wet, red brown (5YR3/6) loam with very weak prismatic structure. Moderate permeability. Common fine roots.

64-100 cm Wet, red brown (5YR3.5/6) fine sandy clay loam with weak prismatic structure. Few roots.

100-130+cm Wet, becoming waterlogged, red brown (5YR4/6) fine sandy clay with small weathering ash fragments. Moderate prismatic structure breaking to S.A.B. Permeability becoming slow. Very few roots.

Depth cm	pH 1:5 Water	pH 1:2.5 M/100 $CaCl_2$	Cond. 1:5 micro-mohs/cm	PHOSPHORUS (ppm) 0.3N HCL	TOTAL	% Organic in total	EXCHANGEABLE BASES (m.e./100gm) Ca	Mg	Na	K	Mn	TOTAL	Capa-city	PERCENT Satur-ation	C	N	C/N
0-14	5.6	4.7	30	18.0	2500	57.4	1.3	0.3	0.20	0.28	0.11	2.19	26.5	8.3	10.20	0.90	10.4
14-32	5.6	4.6	30	17.5	1160	24.7	0.8	0.5	0.17	0.13	0.07	1.67			7.44	0.83	9.1
32-64	5.3	4.8	43	28.7	1875	32.5	0.5	0.3	0.17	0.10	0.01	1.08			6.22		
64-100	6.0	5.3	14														
100-130	5.3	5.2	61				0.6	0.3	0.24	0.19	0.01	1.34					
Mean of 4 topsoils - Manu Complex - Nrwaa Variant (6A)																	
0-15		4.4		33.5	2477	48.0	2.1	0.5		0.26		3.10	28.7	12.0	12.21		

APPENDIX A14 - PROFILE DESCRIPTIONS AND SOIL ANALYTICAL DATA

Profile ID.: Kirua 1

Locality: Manu Village 100 yards south of school, 10 yards below road. Lat. 3°19'S, Long. 37°27 1/2'E

Mapping Unit: Manu Complex (6)
Manu Variant (6B)

Classified as: Humic Ferrallitic soil on volcanic ash

Vegetation: Formerly *Ocotea* rain forest. Species remaining included *Raufolfia caffra*, *Agauria salicifolia*, *Syzygium guineense*, *Croton macrostachys*, *Myrica salicifolia* and *Olea hochstettari*. The ground cover included *Cyperus sp.*, *Fragrostis sp.*, *Fimbristylis diphylla*, poor bracken and *Rumex usambarensis*. Basal cover was 55 percent.

Profile was developed on volcanic ash on a slope of about 20° at an elevation of 5300 feet and was free-draining.

Profile Description:

0-10 cm Moist, dark red brown (5YR3.5/3) organic loam, fibrous, becoming greasy. Abundant fine and small roots. Permeability rather slow.

10-30 cm Moist, red brown (5YR3.5/4) fine sandy loam, moderate S.A.B. structure, very friable, abundant fine roots.

30-55 cm Very moist, yellowish red (5YR3.5/6) sandy clay loam, weak S.A.B. structure, very friable with common roots.

55-80 cm Very moist, dark red brown (5YR3/2.5) humic sandy loam. Weak S.A.B. structure, friable, with almost abundant fine roots.

80-130 cm Very moist becoming wet, dark red brown (5YR3/3.4) sandy clay loam. Weak S.A.B. tending to prismatic. Roots common, becoming fewer.

130-170+cm Wet, dark red (2.5YR3/5) silty clay loam with weak prismatic structure. Friable with moderate permeability. Few roots.

Depth cm	pH 1:5 Water	pH 1:2.5 M/100 $CaCl_2$	Cond. 1:5 micro-mohs/cm	PHOSPHORUS (ppm) 0.3N HCL	TOTAL	% Organic in total	EXCHANGEABLE BASES (m.e./100gm) Ca	Mg	Na	K	Mn	TOTAL	Capa-city	PERCENT Satur-ation	C	N	C/N
0-10	4.8	4.1	110	3.6	1625	69.2	1.4	0.2	0.12	0.3	0.70	2.80	26.2	11	6.36		
10-30	4.8	4.2	116	2.7	1065	67.1	0.7	0.2	0.26	0.30	0.07	1.53			3.87		
30-55	4.9	4.3	111	2.0	1200	70.8	0.6	0.3	0.20	0.26	0.05	1.41			2.26		
55-80	5.0	4.5	152				0.5	0.4	0.17	0.26	0.02	2.80					
80-105	5.2	4.5	26				0.3	0.1	0.19	0.10	0.01	0.70					
105-130	5.1	4.3	20				0.3	0.4	0.13	0.06	0.02	0.91					
130-170	5.0	4.3	23				0.7	0.1	0.19	0.10	0.00	1.09					
Mean of 5 topsoils - Manu Complex - Manu Variant (6B)																	
0-15	4.3			9.6	1830	61.5	1.8	0.4		0.23		2.79	22.1	14	4.49		

APPENDIX A15 - PROFILE DESCRIPTIONS AND SOIL ANALYTICAL DATA

Profile ID.: Old Moshi 4

Locality: 150 yards above Old Moshi forest nursery, 20 yards above road to Kirua. Lat. 3°17'S, Long. 37°25 1/2'E

Mapping Unit: Manu Complex (6) Forested Variant (6Bf)

Classified as: Humic Ferrallitic soil on volcanic ash

Vegetation: Formerly *Ocotea* rain forest with *Syzygium guineense*, *Macarangua kilimandescherica*, *Agauria salicifolia* and *Myrica Salicifolia* remaining, with planted wattle. Ground cover includes *Eragrostis sp.*, *Fimbristylis diphylla*, *Cyperus sp.* and mosses.

Profile was developed on a 12° convex slope, 5 yards below a ridge crest at an elevation of 5000 feet. Drainage was free.

Profile Description:

0-12 cm	Very moist, dark red brown (5YR3/4) humic sandy loam with moderate crumb structure, very friable, abundant fine roots.
12-28 cm	Moist, dark red (3.5YR3/6) fine sandy loam, weak S.A.B. structure, abundant fine roots.
28-45 cm	Moist, dark red (3.5YR2/6) humic loam, very friable, common fine to medium roots.
45-110 cm	Moist, dark red (3.5YR3/6) fine sandy clay loam with weak S.A.B. becoming prismatic structure. Very friable with roots becoming fewer.
110-145 cm	Moist, dark red brown (5YR3/6) silty clay, moderate S.A.B. structure. Few roots.
145-185+cm	Moist, dark brown (7.5YR4/4) with black staining. Weak prismatic structure, friable, with few roots. Permeability moderate.

Depth cm	pH 1:5 Water	pH 1:2.5 M/100 $CaCl_2$	Cond. 1:5 micro-mohs/cm	PHOSPHORUS (ppm) 0.3N HCL	TOTAL	% Organic in total	EXCHANGEABLE BASES (m.e./100gm) Ca	Mg	Na	K	Mn	TOTAL	Capacity	PERCENT Saturation	C	N	C/N
0-12	4.9	4.1	31	7.3	2130	41.3	1.9	0.2	0.36	0.16	0.09	2.62	23.2	11.0	6.26		
12-28	5.0	4.3	19	8.8	2380	55.2	0.7	0.2	0.20	0.14	0.02	1.26			3.51		
28-45	5.1	4.4	19	12.5	3630	62.1	1.0	0.3	0.25	0.10	0.02	1.67			3.35		
45-75	4.7	4.2	16														
75-110	4.8	4.2	14				1.3	0.3	0.24	0.06	0.00	1.90					
110-145	5.0	4.6	14														
145-185+	4.7	4.4	15				1.1	0.3	0.27	0.26	0.00	1.93					
Mean of 6 topsoils - Manu Complex - Manu Variant (6BF)																	
0-15	4.5			12.0	2011	63.5	7.0	1.7		0.46		9.65	26.8	38	6.21		

APPENDIX A16 - PROFILE DESCRIPTIONS AND SOIL ANALYTICAL DATA

Profile ID.: Kibosho 2 — Locality: Umbwe-Kichare, 50 yards south of common. Lat. 3° 12 1/2'S, Long. 37°17'E

Mapping Unit: Umbwe Complex (7) — Classified as: Ferruginous tropical soil tending to Humicferisol

Vegetation: Formerly forest, now coffee/banana shambas with *Croton macrostachys*, *Cordia holstii*, *Rauvolfia caffra*, *Albizzia schimperiana*, and planted *Crevillea*, the common trees. Species in the ground cover were *Pennisetum clandestinum*, *Eragrostis tennifolia*, *Cyperus sp.*, *Digitaria sp.* and *Solanum incanum*.

Profile was developed on glassy rhomb porphyry on a 6° slope at an altitude of 4800 feet and was freely drained.

Profile Description:

0-15 cm — Wet, very dark brown (10YR2.5/3) gritty humic loam with common lava fragments and boulders. Weak S.A.B. structure, abundant fine roots.

15-70 cm — Wet, very dark brown (10YR2.5/3) sandy loam with lava fragments. Weak S.A.B. structure common fine and small roots.

70-110 cm — Wet, brown (7.5YR3/4) with darker humic coatings. Sandy clay loam, moderate prismatic structure. Labile consistence. Few roots.

110-160+cm — Wet, brown (7.5YR3/4) gritty clay loam with common rock fragments, friable with moderate permeability. Shiny clay skins. Few roots.

Depth cm	pH 1:5 Water	pH 1:2.5 M/100 $CaCl_2$	Cond. 1:5 micro-mohs/cm	PHOSPHORUS (ppm) 0.3N HCL	TOTAL	% Organic in total	EXCHANGEABLE BASES (m.e./100gm) Ca	Mg	Na	K	Mn	TOTAL	Capa-city	PERCENT Satur-ation	C	N	C/N
0-15	6.6	5.3	32	40.0	4000	28.1	10.8	2.6	0.30	1.63	0.17	15.50	37.5	41	5.49	0.66	8.3
15-35	6.7	5.5	29	22.5	4250	23.5	10.4	1.9	0.37	1.50	0.01	14.18			4.67	0.57	8.1
35-70	6.7	5.6	24	16.0	4130	31.8	7.5	2.3	0.38	1.11	0.01	11.30			4.48		
70-110	6.6	5.7	17				3.0	1.2	0.37	0.56	0.00	5.13					
110-160+	6.5	5.5	17				3.0	1.2	0.37	0.56	0.00	5.13					
Mean of 10 topsoils on Umbwe Complex (7)																	
0-15		5.0		24.6	2763	36.2	6.6	1.6	0.72	9.26			34.1	29			

APPENDIX A17 - PROFILE DESCRIPTIONS AND SOIL ANALYTICAL DATA

Profile ID.: Kibosho 1 — Locality: Msinga Farm Institute, Kibosho. Lat. 3°16'S, Long. 37°18 1/2'E

Mapping Unit: Msinga Series (8) — Classified as: Ferruginous tropical soil on rhomb porphyry

Vegetation: Formerly forest with *Cordia holstii*, *Croton macrostachys*, *Albizzia schimperiana*, *Rauvolfia caffra* remaining together with planted mangoes, on coffee/banana *shambas*. The ground cover includes *Cyperus rotunous*, *Penicum maximum* *Digitaria scalarum* and locally planted *Setaria splendida*.

The profile was developed on a 5° even slope at an elevation of 3900 feet. Drainage was free.

Profile Description:

0-20 cm — Moist, dark brown (7.5YR3/2) sandy clay loam with moderate S.A.B. structure. Slight tendency to cap when cultivated. Abundant roots.

20-50 cm — Very moist, dark red brown (5YR3/3) fine sandy clay loam with moderate S.A.B. structure and abundant roots.

50-120 cm — Very moist, dark red brown (5YR3/4) silty clay loam with moderate S.A.B. tending to prismatic structure. Common fine pores and fissures. Common roots.

120-180+cm — Very moist, dark red brown (5YR3/4) friable, silty clay loam with moderate prismatic structure. Fine roots still common.

Depth cm	pH 1:5 Water	pH 1:2.5 M/100 $CaCl_2$	Cond. 1:5 micro-mohs/cm	PHOSPHORUS (ppm) 0.3N HCL	TOTAL	% Organic in total	EXCHANGEABLE BASES (m.e./100gm) Ca	Mg	Na	K	Mn	TOTAL	Capacity	PERCENT Saturation	C	N	C/N
0-20	6.5	5.4	68	6.4	2930	57.3	9.2	1.9	0.41	1.60	0.71	13.82	18.6	76	2.85		
20-50	6.5	5.5	116	4.4	2130	50.0	8.5	2.7	0.13	1.73	0.31	13.37			1.69		
50-80	6.7	5.6	121	3.4	1500	41.7	5.8	2.6	0.12	2.03	0.21	10.76			0.83		
80-120	6.6	5.6	56				5.4	1.8	0.11	1.50	0.05	8.86					
120-150	6.7	5.6	47				3.9	2.9	0.08	1.11	0.02	8.01					
150-180	6.7	5.7	70				3.4	1.0	0.10	1.02	0.02	5.54					
Mean of 12 topsoils on Msinga Series																	
0-15	5.5			17.8	3334	49.2	11.4	3.0		1.64		16.07	24.4	68	2.77		

APPENDIX A18 - PROFILE DESCRIPTIONS AND SOIL ANALYTICAL DATA

Profile ID.: Lyamungu 1

Locality: 20 yards west of junction of road running along pasture, Coffee Research Station, about 1/2 mile west of building. Lat.3°131/2'S. Long. 37°14 1/2'E

Mapping Unit: Msinga Series Upper phase (8)

Classified as: Ferruginous tropical soil tending to Humic Ferrisol

Vegetation: Formerly forest, now planted with coffee and bananas. Trees remaining include *Rauvoifia cafira*, *Croton macrostachys*, *Albizzia schimperiana* and planted *Grevillea*. Common species in the pasture around the pit included *Digitaria sp.*, *Eragrostis curvula*, *Urochloa bolbodes*, *Crotalaria sp.*, *Cyperus rotundus* and *Solanum incarnum*. 95 percent basal cover.

The profile was developed on colluvium of mixed rhomb porphyry and trachyte origin, possibly with some ash admixture. The slope was 5° and the elevation 4300 feet.

Profile Description:

0-12 cm Wet, dark brown (7.5YR3/2) fine sandy clay loam with moderate crumb to S.A.B. structure. Abundant fine roots. Occasional earth worms.

12-26 cm Wet, dark brown (7.5YR3/2) clay loam, moderate S.A.B. structure. Very friable, roots almost abundant.

26-56 cm Wet, dark brown (7.53/2) clay loam with moderate S.A.B. Common fine and small roots.

56-120 cm Wet, dark brown (7.5YR3/2) becoming dark red brown (6YR3/2-3 clay loam with weak prismatic structure. Friable. Common fine and small fibrous roots, glossy structure faces.

120-155+cm Wet, dark red brown (5YR3/3) clay loam, friable with roots still common.

Depth cm	pH 1:5 Water	pH 1:2.5 M/100 $CaCl_2$	Cond. 1:5 micro-mohs/cm	PHOSPHORUS (ppm) 0.3N HCL	TOTAL	% Organic in total	EXCHANGEABLE BASES (m.e./100gm) Ca	Mg	Na	K	Mn	TOTAL	Capacity	PERCENT Saturation	C	N	C/N
0-12	6.5	5.5	48	17.5	2380	65.8	14.4	2.2	0.21	2.00	0.93	19.73	25.5	77	3.17	0.34	9.3
12-26	6.7	5.9	28	22.5	2130	58.9	10.4	2.5	0.35	1.92	0.01	15.16			1.99	0.24	8.3
26-56	6.8	6.1	32	15.0	2930	53.1	8.1	2.6	0.25	2.04	0.01	12.99			0.98		
56-88	6.7	5.9	28				5.4	2.1	0.31	1.92	0.01	9.73					
88-120	6.2	5.4	31														
120-155	6.1	5.4	18				4.0	1.4	0.24	1.06	0.02	6.72					

APPENDIX A19 - PROFILE DESCRIPTIONS AND SOIL ANALYTICAL DATA

Profile ID.: Lyamungu 4

Locality: 300 yards east of main road, 400 yards below Mission, Narumu. Lat. 3°16 1/2'E, Long. 37°14 1/2'E

Mapping Unit: Kindi Series (9)

Classified as: Eutrophic brown soil on colluvium developed mainly from rhomb porphyry

Vegetation: Formerly heavy woodland, now coffee, bananas, maize and beans. Trees remaining include *Croton macrostachys*, *Cordia holstii*, *Albizzia schimperiana*, *Rauvolfia caffra*, *Erythrina abyssinica*. The ground cover included *Digitaria sp.*, *Indigofera sp.*, *Cyperus rotundus* and *Tridex repens*.

Profile Description:

0-15 cm Wet, dark red brown (5YR2/2) silty clay loam. Moderate crumb to S.A.B. structure. Friable with tendency to cap. Common roots.

15-40 cm Wet, dark red brown (5YR3/3) silty clay loam with moderate S.A.B. structure. Common fine to large roots.

40-75 cm Wet, dark red brown (5YR3/4) silty clay loam with occasional lava fragments. Moderate prismatic structure. Friable with common roots.

75-160 cm Wet, red brown (5YR3.5/4) sandy clay loam with occasional weathering lava fragments. Moderate prismatic structure. Friable with a few fine roots.

160-190+cm Wet, brown (6YR4/4) gritty clay loam with (7.5YR6/6 and 5YR4/8) weathering rock. Common fine roots.

Depth cm	pH 1:5 Water	pH 1:2.5 M/100 $CaCl_2$	Cond. 1:5 micro-mohs/cm	PHOSPHORUS (ppm) 0.3N HCL	TOTAL	% Organic in total	EXCHANGEABLE BASES (m.e./100gm) Ca	Mg	Na	K	Mn	TOTAL	Capa-city	PERCENT Satur-ation	C	N	C/N
0-15	7.0	6.3	38	16.0	1630	69.3	11.9	2.5	0.35	1.50	0.13	16.48	23.1	71	1.73	0.18	9.6
15-40	7.2	6.4	33	15.0	1465	55.6	7.9	2.0	0.28	1.76	0.02	11.96			0.94	0.09	10.4
40-75	7.0	5.9	23	15.0	1250	60.0	5.4	1.6	0.31	1.30	0.01	8.62			0.56		
75-115	6.4	5.6	19				4.9	1.6	0.38	0.96	0.01	7.85					
115-160	6.6	5.5	15														
160-190	6.5	5.4	16				4.2	2.0	0.52	1.30	0.00	8.02					
Mean of 8 topsoils on Kindi Series																	
0-15	5.9			16.7	1589	56.6	12.3	3.4		1.49		17.67	23.7	75	2.34		

APPENDIX A20 - PROFILE DESCRIPTIONS AND SOIL ANALYTICAL DATA

Profile ID.: Kibosho 4

Locality: Sambarai crossroads 100 yards south of tarmac, 50 yards east of road going south. Lat. 3°20'S, Long. 37°17 1/2'E

Mapping Unit: Sambarai Series (10)

Classified as: Eutrophic brown soil

Vegetation: Hyparrhenia-Panicum/Combretum wooded grassland. Largely cultivated with maize and beans. Some bananas and a little coffee where irrigated. Trees include *Croton macrostachys*, *Combretum sp.*, *Trema orientalis*, *Cordia holstii*, while ground cover includes *Hyparrhenia dissoluta*, *Panicum maximum*, *Digitaria scalarum*, *Chloris pycnothrix*, *Cyperus rotundus* and *Solanum incarnum*.

Profile was developed on colluvium derived from rhomb porphyry on a 2° slope at an elevation of 3200 feet and was freely drained.

Profile Description:

0-12 cm Moist, dark brown (6YR3/2) sandy clay loam with weak S.A.B. structure. Friable but tending to cap. Abundant fine and small roots.

12-30 cm Moist, dark red brown (6YR3/2) sandy clay loam with weak S.A.B. structure and common roots.

30-50 cm Moist, dark red brown (5YR3/3) silty clay loam with weak prismatic structure. Moderate permeability and common roots.

50-125 cm Moist, becoming very moist, dark red brown (5YR3-4/6) silty clay loam with weak prismatic structure. Friable with common roots.

125-170 cm Very moist, red brown (5YR4/7) sandy clay loam with weak prismatic structure. Very friable with common roots.

170-190+cm Very moist, red brown (5YR4/7) gritty clay loam with common small gravel, coarse granular structure. A few fine roots.

Depth cm	pH 1:5 Water	pH 1:2.5 M/100 $CaCl_2$	Cond. 1:5 micro-mohs/cm	PHOSPHORUS (ppm) 0.3N HCL	TOTAL	% Organic in total	EXCHANGEABLE BASES (m.e./100gm) Ca	Mg	Na	K	Mn	TOTAL	Capacity	PERCENT Saturation	C	N	C/N
0-12	7.1	5.9	33	122.5	3250	34.6	15.3	4.6	0.50	1.98	0.02	20.40	28.0	73	2.93	0.21	14.0
12-30	6.9	5.5	18	40.0	2500	27.4	10.7	3.0	0.41	1.50	0.01	15.62			2.00	0.23	8.9
30-50	6.7	5.4	16	32.5	2130	14.8	6.4	2.5	0.45	0.93	0.01	10.29			1.30		
50-80	6.7	5.5	12				5.5	2.7	0.38	0.56	0.02	9.16					
80-125	6.3	5.7	13				3.7	2.2	0.32	0.42	0.01	6.65					
125-170	6.2	5.8	15				3.3	1.9	0.29	0.38	0.01	5.88					
170-190	6.5	5.8	14				3.4	1.8	0.17	0.47	0.01	5.85	11.5	51			

APPENDIX A21 - PROFILE DESCRIPTIONS AND SOIL ANALYTICAL DATA

Profile ID.: Uru 1 Locality: 8 yards from south end of Mrawi Common. Uru north. Lat. 3°14'S, Long. 37°21 1/1'E

Mapping Unit: Mrawi Series (11) Classified as: Humic Ferrisol on trachyte

Vegetation: Formerly forest of *Ocotea usambarensis* and *Podocarpus milanjianus*. Now *Rauvolfia caffra*, *Albizzia petersiana*, *Croton macrostachys*, *Olea africana* and planted *Grevillea* remaining in coffee/banana *shambas*.

The profile was sited in pasture composed of *Digitaria sp.*, *Eragrostis tenuifolia*, *Cyperus sp.*, *Pennisetum clandestinum* and *Rumex usambarensis* with 90 percent basal cover. The slope was 10°, the elevation 5100 feet and profile drainage free.

Profile Description:

0-15 cm Wet, dark brown (7.5YR3/2) fibrous sandy loam, with a few fine rock fragments and occasional outcrops. Very friable abundant roots.

15-70 cm Wet, dark brown (7.5YR3/2) fine sandy loam with weak S.A.B. structure. Friable with common fine roots.

70-100 cm Wet, very dark grey brown (10YR3/2) gravelly clay loam with soft weathering rock (10YR5/4) fragments. Weak prismatic structure. Friable with common fissures and roots.

100-135 cm Wet, dark brown (10YR3/3) gravelly sandy clay loam with weak prismatic structure. Common roots.

135-205+cm Wet, dark brown (10YR3/3-4) gravelly clay loam, very weak prismatic structure. Loose consistence. Rather rapid permeability. Few roots.

Depth cm	pH 1:5 Water	pH 1:2.5 M/100 $CaCl_2$	Cond. 1:5 micro-mohs/cm	PHOSPHORUS (ppm) 0.3M HCL	TOTAL	% Organic in total	EXCHANGEABLE BASES (m.e./100gm) Ca	Mg	Na	K	Mn	TOTAL	Capa-city	PERCENT Satur-ation	C	N	C/N
0-15	6.2	5.0	41	7.7	2930	57.3	5.3	1.7	0.28	1.62	0.19	9.11	24.3	33	4.07	0.46	8.8
15-40	6.0	4.4	21	9.4	3130	53.2	2.8	1.1	0.40	0.30	0.01	4.60			2.48	0.28	8.8
40-70	5.9	4.4	17	16.0	3130	42.0	1.5	1.1	0.44	0.30	0.00	3.34			1.89		
70-100	5.8	4.5	20				1.0	0.8	0.67	0.52	0.00	3.00					
100-135	6.0	4.7	19														
135-175	5.7	4.7	17				1.0	0.8	0.54	1.06	0.01	3.41					
175-205	5.8	4.5	14				1.5	0.6	0.60	1.30	0.01	4.01					
Mean of 7 topsoils - Mrawi Series																	
0-15		4.6		10.0	2821	38.3	3.5	0.9		0.54		5.32	33.4	17	6.91		

APPENDIX A22 - PROFILE DESCRIPTIONS AND SOIL ANALYTICAL DATA

Profile ID.: Kirua 3

Locality: 1/2 mile above Uparu Primary School, 40 yards west of road. Lat. 3°21'S, Long. 37°27'E

Mapping Unit: Uparu Series (12)

Classified as: Ferruginous, a tropical soil on ash colluvium

Vegetation: *Hyparrhenia-Panicum/Combretum* wooded grassland, with *Croton macrostachys*, *Rauvolfia caffra*, *Albizzia*, *schimperiana*, and *Ficus capensis*. Basal grass over 50 percent including *Digitaria sp.*, *Aristida adscensionis*, *Sorghum verticilliflorum* and *Crotalaria sp.* common.

The profile was sited on a 14° slope at an elevation of 3800 feet and was freely draining.

Profile Description:

0-14 cm	Slightly moist, dark red brown (5YR3/3) sandy clay loam with weak fine crumb to S.A.B. structure. Abundant fine roots.
14-30 cm	Moist, dark red brown (5YR3/3) silty clay loam with moderate prismatic structure. Common roots.
30-60 cm	Very moist, dark red brown (2.5YR3/4) silty clay loam with strong prismatic structure. Friable with common fine to medium roots.
60-90 cm	Very moist, dark red brown (2.5YR3.4) silty clay, friable with common roots, and moderate permeability.
90-170+cm	Very moist, dark red (2.5YR3/5) silty clay, with moderate prismatic structure. Friable with common fine pores and fissures, roots becoming few.

Depth cm	pH 1:5 Water	pH 1:2.5 M/100 $CaCl_2$	Cond. 1:5 micro-mohs/cm	PHOSPHORUS (ppm) 0.3N HCL	TOTAL	% Organic in total	EXCHANGEABLE BASES (m.e./100gm) Ca	Mg	Na	K	Mn	TOTAL	Capa-city	PERCENT Satur-ation	C	N	C/N
0-14	7.1	6.0	48	25.0	2130	50.0	13.7	9.1	0.16	0.42	0.79	24.17	26.2	92	2.44		
14-30	7.0	5.8	33	2.7	2930	57.3	11.4	8.0	0.14	0.19	0.05	19.78			2.35		
30-60	6.5	5.5	42	1.1	1750	39.1	5.8	5.2	0.10	0.08	0.17	11.35			1.14		
60-90	6.0	5.3	128				4.0	3.7	0.14	0.22	0.32	8.38					
90-130	6.2	5.6	129				3.5	4.5	0.13	0.19	0.17	8.49					
130-170	6.6	5.8	28				2.8	3.8	0.11	0.06	0.05	6.82					
Mean of 7 topsoils - Uparu																	
0-15		5.8		24.4	1815	54.5	11.4	5.1		0.74		17.69	18.5	90	2.03		

APPENDIX A23 - PROFILE DESCRIPTIONS AND SOIL ANALYTICAL DATA

Profile ID.: Old Moshi 9 — Locality: 300 yards up Sange road from main Moshi/Mombasa road, Lat. 3°22'S, Long. 37°25 1/2'E

Mapping Unit: Sango Series (13) — Classified as: Ferruginous tropical soil on ash colluvium

Vegetation: Hyparrhenia-Panecum/Combretum wooded grassland, largely cultivated with maize, beans and cassava, some bananas and a little coffee. Common grasses include Hyparrhenia dissoluta, Hafilipandula, Cyperus sp., Digitaria scalarum and Setaria sp.

The soil was developed on a 3° slope at 5000 feet elevation, and was freely drained.

Profile Description:

0-16 cm Dry, dark red brown (5YR3/4), silty loam, friable with abundant fine and small roots. Moderate crumb structure.

16-48 cm Dry, dark red brown (5YR3/4) silty clay loam with moderate prismatic structure and abundant pores and fissures. Common roots.

48-78 cm Dry, dark red brown (5YR3/4) silty clay loam, few fine and small roots. Moderate prismatic structure.

78-138+cm Dry, dark red brown (5YR3/4) silty clay loam, moderate prismatic, common fine pores and fissures, moderate permeability. Fine roots still common.

Depth cm	pH 1:5 Water	pH 1:2.5 M/100 $CaCl_2$	Cond. 1:5 micro-mohs/cm	PHOSPHORUS (ppm) 0.3N HCL	TOTAL	% Organic in total	EXCHANGEABLE BASES (m.e./100gm) Ca	Mg	Na	K	Mn	TOTAL	Capa-city	PERCENT Satur-ation	C	N	C/N
0-16	6.5	5.5	45	112.5	3960	44.0	7.7	5.6	0.10	2.27	0.15	15.82	26.0	51	2.29	0.17	13.5
16-48	6.4	5.3	19	62.5	3500	46.0	5.1	5.8	0.07	0.46	0.10	11.53			1.39	0.12	11.6
48-78	6.0	4.9	16	14.0	2400	64.0	2.6	4.3	0.11	0.35	0.09	7.45			0.86		
78-130	6.1	5.2	19				2.1	4.3	0.12	0.27	0.15	6.94	12.2	57			
Mean of 6 topsoils - Sango series (13)																	
0-15		5.8		102.5	3131		12.9	5.7		1.61		20.55	26.5	77	2.28		
Mean of 2 topsoils - Holili Creep Complex (17)																	
0-15		5.1		5.0	812	60.8	7.3	5.1		0.28		13.17	20.9	61	1.69		

APPENDIX A24 - PROFILE DESCRIPTIONS AND SOIL ANALYTICAL DATA

Profile ID.: Keni 4

Locality: Lower Rombo road, 100 yards southeast of Pentecostal Church, Kibouni. Lat. 3°22'S, Long. 37° 38 1/2'E

Mapping Unit: Kibouni Series (14)

Classified as: Reddish brown soil of semi-arid region

Vegetation: Aristida-Neteropogon/Acacia-Combretum bushed grassland, with mungwe and Warburgia stuhlmannii. Common grasses include Neteropogon contortus, Aristida adscensionis, Eragrostis superbam, Panicum coloratum, Themeda triandra, Chloris roxburghiana, Digitaria sp. and Cynodon dactylon.

The profile was developed on a calcareous lapilli tuff on a 2° slope at an elevation of 3100 feet.

Profile Description:

0-15 cm Moist, dark brown (7.5YR3/2) loam with weak crumb structure and tendency to cap at surface. Abundant fine roots.

15-30 cm Moist, dark red brown (5YR3/4) sandy clay loam with moderate S.A.B. structure, common fine roots.

30-60 cm Moist, dark red brown (5YR3.5/4) silty clay loam with moderate S.A.B. structure, slightly compact. Roots common.

60-100+cm Moist, dark red brown (5YR3.5/4) silty clay loam with moderate S.A.B. structure, friable with common roots.

Depth cm	pH 1:5 Water	pH 1:2.5 M/100 $CaCl_2$	Cond. 1:5 micro-mohs/cm	PHOSPHORUS (ppm) 0.3N HCL	TOTAL	% Organic in total	EXCHANGEABLE BASES (m.e./100gm) Ca	Mg	Na	K	Mn	TOTAL	Capa-city	PERCENT Satur-ation	C	N	C/N
0-15	6.7	5.8	36	107.5	3160	32.6	9.7	6.6	0.28	1.85	0.02	18.45	24.5	75	2.04	0.13	15.7
15-30	6.4	5.6	13	56.6	2860	26.2	8.2	6.5	0.32	0.56	0.02	15.60			1.46	0.10	14.6
30-60	6.4	5.6	14	34.5	2665	25.5	7.0	6.1	0.29	0.37	0.01	13.76			1.28		
60-100	6.5	5.7	11				6.5	6.0	0.35	0.27	0.00	13.12					
Mean of 4 topsoils on Kibouni Series (15)																	
0-15		6.3		251	2833	29.2	13.8	5.3		1.72		21.03	24.5	86	1.97		

APPENDIX A25 - PROFILE DESCRIPTIONS AND SOIL ANALYTICAL DATA

Profile ID.: Marangu 3

Locality: 20 yards below forest boundary and junction of *Pinus radiata* and Wattle Masia, Mamba. Lat. 3° 15'S, Long. 37°, 32'E

Mapping Unit: Masia Complex (18)
Masia Variant (18A)

Classified as: Podsolic soil on lava (Basaltic)

Vegetation: Formerly forest, followed by clearance and cultivation pasture. Trees include *Olea africana*, *Macaranga kilimandschrica*, *Myrica salicifolia*, *Croton macrostachys*, *Syzygium guineense* and planted *Pinus radiata*. Ground cover includes *Pennisetum clandestinum*, *Eragrostis tenuifolia*, *Cyperus rotundus*, *Digitaria sp.*, bracken, and brambles (*Rubus volkensii*).

The profile was developed on olivine basalt on a 10° slope at an altitude of 5900 feet and was freely drained.

Profile Description:

0-3 cm Moist, very dark brown (7.5YR2/2) fibrous organic loam. Abundant fine and small roots.

3-20 cm Very moist, dark brown (7.5YR2.5/2) humic sandy loam, with moderate S.A.B. structure. Very friable, with abundant fine roots.

20-50 cm Very moist, dark brown (7.5YR3/2) fine sandy loam. Moderate S.A.B., friable with common roots.

50-90 cm Very moist, brown (7.5YR3/3) fine sandy clay loam with a few lava fragments. Weak prismatic structure and common fine roots.

90-145 cm Very moist, brown (7.5YR3/4) becoming very dark brown (10YR2/3) silty clay loam with moderate S.A.B. structure. Few roots.

145-180+cm Very moist, brown (7.5YR3/3) silty clay loam with rotting rock. Weak prismatic structure. Friable, with moderate permeability. Few roots.

Depth cm	pH 1:5 Water	pH 1:2.5 M/100 $CaCl_2$	Cond. 1:5 micro-mohs/cm	PHOSPHORUS (ppm) 0.3N HCL	TOTAL	% Organic in total	EXCHANGEABLE BASES (m.e./100gm) Ca	Mg	Na	K	Mn	TOTAL	Capa-city	PERCENT Satur-ation	C	N	C/N
0-3	5.5	4.4	55	40.0	2375	84.7	3.8	1.2	0.32	0.28	0.57	6.17	40.0	15	12.19		
3-20	5.6	4.4	41	23.7	2625	87.6	1.8	0.3	0.14	0.06	0.02	2.32			9.19		
20-50	5.6	4.8	36	21.5	2875	46.9	0.7	0.1	0.12	0.06	0.01	0.99			6.60		
50-95	5.7	4.9	33				0.6	0.1	0.10	0.05	0.01	0.76					
95-120	5.8	5.0	26				0.6	0.3	0.08	0.03	0.01	1.02					
120-145	5.4	5.0	34				0.5	0.3	0.05	0.03	0.01	0.89					
145-180+	5.5	5.0	28				0.5	0.2	0.20	0.06	0.02	1.05					
Mean of 5 topsoils - Masia Complex - Masia Variant																	
0-15		4.5		24.7	2846	47.6	2.9	1.0		0.22		4.59	40.1	22	9.41		

APPENDIX A26 - PROFILE DESCRIPTIONS AND SOIL ANALYTICAL DATA

Profile ID. Marangu 4

Locality: Arisi, 200 yards inside Forest Reserve. 70 yards north of road up mountain. Lat. 3° 14'S, Long. 37° 31'E

Mapping Unit: Masia Complex (18) Forested Phase (18AF)

Classified as: Podsolic soil under forest

Vegetation: High altitude *Ocotea/Podocarpus* rain forest, thinned. Species included *Macaranga kilimandscharic*, *Syzygium guineense*, and *Albizzia petersiana*. 100 percent ground cover composed of *Cyperus rigidifolia*, *Sporobolus pyrasidalis*, *Digitaria sp.*, *Eragrostis tennifolia*, *Rumex sp.*, and *Panicum tricocladum*.

The profile was developed on colluvium and fluvioglacial deposits, at an elevation of 6250 feet on a 15° irregular slope with free drainage.

Profile Description:

0-5 cm Moist, very dark brown (10YR2/2) fibrous organic loam with weak crumb structure. Common large boulders. Very abundant fine to small roots.

5-18 cm Very moist, dark brown (7.5YR3/2) humic sandy loam, with small subangular lava fragments. Weak S.A.B. structure. Abundant fine to large roots.

18-60 cm Very moist to wet brown (7.5YR3/4) fine sandy loam becoming clay loam with common small to large lava fragments. Moderate S.A.B. structure. Very friable. Common roots.

60-80+ cm Wet, dark yellow brown (10YR4/4) gritty clay loam with weathering rock grey (2.5Y5/0). Moderate S.A.B. structure, friable with common roots.

Depth cm	pH 1:5 Water	pH 1:2.5 M/100 $CaCl_2$	Cond. 1:5 micro-mohs/cm	PHOSPHORUS (ppm) 0.3N HCL	TOTAL	% Organic in total	EXCHANGEABLE BASES (m.e./100gm) Ca	Mg	Na	K	Mn	TOTAL	Capa-city	PERCENT Satur-ation	C	N	C/N
0-5	5.5	4.6	137	25.0	3000	55.0	8.2	2.3	0.36	0.58	0.41	11.85	43.3	26	11.81		
5-18	5.7	4.7	40	17.5	2875	54.8	2.7	0.9	0.15	0.16	0.05	3.96			9.35		
18-48	5.9	5.0	30	25.0	3250	47.7	0.8	0.1	0.38	0.08	0.30	1.49			5.40		
48-60	6.0	5.0	19				0.7	0.3	0.10	0.06	0.02	1.18					
60-80+	6.2	5.1	34				0.6	0.1	0.11	0.06	0.01	0.88					
Mean of 3 topsoils - Masia Complex - Forested Phase (Marangu)																	
0-15		4.5		22.3	2635	58.8	8.9	2.7		0.52		12.71	38.6	35	11.27		

APPENDIX A27 - PROFILE DESCRIPTIONS AND SOIL ANALYTICAL DATA

Profile ID.: Marangu 5

Locality: 150 yards north-west of Kinyangi, and 15 yards west of road. Lat. 3° 17'S. Long. 37° 31'E

Mapping Unit: Marangu Series (19)
Lower phase (19A)
(Marangu Variant)

Classified as: Ferruginous tropical soil on olivine analcytite

Vegetation: Formerly heavy forest, now mainly coffee/bananas with maize, yams, beans, *Albizzia schimperiana* very common. Also planted *Grevillea*, *Lollondo* and *Cypress*. Ground cover was mainly *Hyparrhenia sp.*, *Eragrostis sp.*, with *Cyperus rotundus* very common. *Rhyncoletrum roseum* and *Aristida sp.* and *Indigofera microcarpa* also present. Basal cover 95 percent.

The profile was sited on a 2-3° irregular slope at an elevation of 4700 feet, and was slightly imperfectly drained.

Profile Description

0-12 cm Moist, dark brown (6.5YR3/2) sandy loam, slightly stony with occasional boulders. Moderate crumb to S.A.B. structure. Abundant fine roots. Surface tends to cap.

12-70 cm Very moist, dark brown (6.5YR3/2) loam becoming sandy clay loam, moderate S.A.B. becoming weak prismatic. Very friable common fine and small roots.

70-100 cm Very moist, dark red brown (7.5YR3/4) gritty clay loam with humic coatings, stony with weak prismatic structure. Friable with moderate permeability.

100-160+cm Wet, dark yellow brown (10YR3/4-5) gravelly clay loam with strong brown mottles, (7.5YR5/6) very stony becoming dominant. Permeability becoming slow due to rock table below. Few roots.

Depth cm	pH 1:5 Water	pH 1:2.5 M/100 $CaCl_2$	Cond. 1:5 micro-mohs/cm	PHOSPHORUS (ppm) 0.3N HCL	TOTAL	% Organic in total	EXCHANGEABLE BASES (m.e./100gm) Ca	Mg	Na	K	Mn	TOTAL	Capa-city	PERCENT Satur-ation	C	N	C/N
0-12	6.0	5.3	45	57.5	5000	43.5	9.1	3.3	0.26	0.42	0.99	14.07	28.4	50	4.12		
12-35	6.2	5.4	25	52.5	4250	38.2	8.0	2.5	0.27	0.30	0.26	11.33			2.63		
35-70	6.3	5.6	37	50.0	3815	37.1	8.5	3.6	0.19	0.22	0.05	12.56			1.88		
70-100	6.9	5.8	36				7.2	2.1	0.10	0.13	0.01	9.63					
100-130	6.9	6.0	28				4.1	1.6	0.26	0.14	0.01	6.11					
130-160+	6.7	6.0	37				4.1	1.4	0.31	0.08	0.02	5.91					
Mean of 5 topsoils - Marangu Series - Marangu (19A) Lower Phase																	
0-15		5.5		47.8	5710	38.8	9.6	3.1		0.43		13.71	30.5	42	3.83		

APPENDIX A28 - PROFILE DESCRIPTIONS AND SOIL ANALYTICAL DATA

Profile ID. Marangu 2

Locality: 75 yards west of road up mountain about 2 miles below forest, Arisi, Lat. 3° 15 1/2'S, Long. 37° 31'E

Mapping Unit: Marangu Series (19)
Upper Phase (19A)
(Marangu Variant)

Classified as: Humic Ferrisol on analcytite with fluvioglacial admixture.

Vegetation: Formerly heavy forest, with Albizzia schimperiana, Rauvolfia caffra and planted Grevillea and Cypres remaining. Coffee/banana shambas. Fit in small fodder paddock. Yam and bananas showing potash deficiency symtpoms. Pasture contained Hyperrhenia hirta, Eragrostis tennifolia, Spcrobelus pyramidalis, Exotheca abyssinica, Cyperus sp. and Indigofera sp.

The profile was developed on a slope of about 9° at an elevation of 5500 feet and was imperfectly drained.

Profile Description:

0-9 cm Wet, very dark brown (7.5YR3/2) sandy loam with a few lava fragments. Very weak crumb tending to S.A.B. structure. Friable, tending to cap. Common fine and small roots.

9-29 cm Wet, dark brown (7.5YR3/2) sandy loam, slightly stony with weak S.A.B. structure, common fine roots, moderate permeability.

29-65 cm Wet, very dark brown (7.5YR3/2) sandy loam, slightly stony with weak S.A.B. structure. Friable with moderate permeability.

65-98 cm Wet, dark red brown (5YR3/5) sandy clay loam, stony, weak prismatic structure, moderate permeability. Common fine roots.

98-132 cm Wet, dark red brown (5YR3/5) sandy clay loam, very stony, very weak prismatic, tending to massive structure. Common pores. Moderate permeability. Few roots.

132-175 cm Wet, dark brown (10YR4/2.5) and (5YR5/6) stony sandy clay. Common fine pores. Permeability rather slow. Very few roots.

Depth cm	pH 1:5 Water	pH 1:2.5 M/100 $CaCl_2$	Cond. 1:5 micro-mohs/cm	PHOSPHORUS (ppm) 0.3N HCL	TOTAL	% Organic in total	EXCHANGEABLE BASES (m.e./100gm) Ca	Mg	Na	K	Mn	TOTAL	Capacity	PERCENT Saturation	C	N	C/N
0-9	6.0	4.9	33	15.0	5050	46.9	5.8	4.4	0.36	0.35	0.05	10.96	25.1	44	6.57		
9-29	6.2	5.1	18	13.7	4000	46.9	5.7	2.2	0.21	0.13	0.07	8.41			4.52		
29-65	6.5	5.4	15	16.1	4450	42.0	6.1	2.8	0.20	0.13	0.01	9.33			3.90		
65-98	6.6	5.4	15				5.2	1.8	0.18	0.06	0.05	7.29					
98-132	6.7	5.5	20														
132-175+	6.7	5.6	18				4.8	2.5		0.31	0.03	8.53					
Mean of 3 topsoils - Marangu Series - Marangu Variant - Upper Phase (19A)																	
					4883	52.6	7.3	3.1		0.33		11.11	28.3	38	5.25		

APPENDIX A29 - PROFILE DESCRIPTIONS AND ANALYTICAL DATA

Profile ID.: Mkuu 3

Locality: 40 yards south of Dandi Uchiwa's shop, 20 yards west of main road. Kilamfua Masaseni. Lat. 3° 11'S, Long. 37° 37'E

Mapping Unit: Marangu Series (19) Mkuu Variant (19B)

Classified as: Humic Ferrisol on andesite

Vegetation: Formerly forest with *Olea africana*, *Croton macrostachys*, *Albizzia schimperiana* and planted *Grevillea*, *Eucalyptus* and wattle. Ground cover included *Aristida adscensionis*, *Eragrostis racmosa*, *Adnropogon dummeri*, *Hyparrhenia dissoluta* and *N. Hirta* and *Microglassa elliptii*.

The profile was on a 10° irregular slope at an altitude of 4850 feet and imperfectly drained.

Profile Description:

0-15 cm Moist, dark brown (7.5YR3/2) silty clay loam with moderate crumb structure. Abundant fine and small roots.

15-40 cm Slightly moist, dark brown (7.5YR3/2) silty clay loam with occasional lava fragments. Moderate S.A.B. structure. Friable with roots common.

40-80 cm Slightly moist, dark brown (7.5YR3/2) sandy clay loam with moderate prismatic structure. Numerous pores and fissures. Common roots.

80-160 cm Moist, dark brown (7.5YR3/2) sandy clay loam with common soft lava fragments, brown (10YR5/2) and (rYR4/8). Roots common becoming few.

160-185+cm Very moist, dark brown (10YR3/3) gritty loam with common lava fragments. Very weak prismatic structure, friable with few roots.

Depth cm	pH 1:5 Water	pH 1:2.5 M/100 $CaCl_2$	Cond. 1:5 micro-mohs/cm	PHOSPHURUS (ppm) 0.3N HCL	TOTAL	% Organic in total	EXCHANGEABLE BASES (m.e./100gm) Ca	Mg	Na	K	Mn	TOTAL	Capa-city	PERCENT Satur-ation	C	N	C/N
0-15	5.3	4.7	27	2.8	1066	69.4	3.7	3.2	0.24	0.10	1.00	8.24	19.6	42	2.81		
15-40	5.1	4.6	9	4.3	875	71.4	2.7	1.6	0.14	0.03	0.04	4.51			1.13		
40-80	5.3	4.7	7				3.1	0.8	0.29	0.03	0.01	4.23			0.88		
80-130	5.5	5.0	7				3.4	1.2	0.46	0.00	0.01	5.07					
130-160	5.4	4.7	5				2.4	0.7	0.50	0.00	0.02	3.62					
160-185+	5.0	4.2	6				1.4	0.6	0.43	0.00	0.02	2.45					
Mean of topsoils - Marangu Series - Muu Variant																	
0-15		5.3	2.41	22.1	3740	49.2	10.2	2.8		0.55		13.84	28.1	49	4.32		

APPENDIX A30 - PROFILE DESCRIPTIONS AND SOIL ANALYTICAL DATA

Profile ID. Mashati 1

Locality: 1/4 mile above Mashati market, Mrere Village. Lat. 3° 8'S, Long. 37° 36'E.

Mapping Unit: Marangu Series (19)
Mrere Variant (19C)

Classified as: Humic Ferrisol

Vegetation: Cleared forest planted with coffee and bananas, maize and beans. Trees remaining *Albizzia schimperiana*, *Rauvolfia caffra*, *Olea africana*, *Ficus vogelii*, *Trema orientalis*. Ground cover included *Eragrostis curvula*, *Digitaria sp.*, *Hyparrhenia hirta*. 80 percent basal cover.

The profile was developed from glassy lava on a 10° slope at an altitude of 5000 feet and was freely drained.

Profile Description:

0-12 cm	Dry, dark red brown (5YR3.5/4) sandy medium loam with moderate crumb structure. Brittle with abundant fine and small roots.
12-32 cm	Slightly moist red brown (5YR3.5/4) loam with moderate S.A.B. structure. Friable with common fine pores. Abundant roots.
32-60 cm	Slightly moist, dark red brown (5YR3/4) sandy clay loam with moderate S.A.B. structure. Common roots.
60-140 cm	Moist, dark red brown (4YR3/4) silty clay loam with occasional lava fragments. Weak prismatic structure. Common fine pores. Common roots becoming fewer.
140-185+cm	Moist, dark red brown (4YR3/6) silty clay with darker coatings on root channels. Slightly stony. Few fine roots.

Depth cm	pH 1:5 Water	pH 1:2.5 M/100 $CaCl_2$	Cond. 1:5 micro-mohs/cm	PHOSPHORUS (ppm) 0.3N HCL	TOTAL	% Organic in total	EXCHANGEABLE BASES (m.e./100gm) Ca	Mg	Na	K	Mn	TOTAL	Capacity	PERCENT Saturation	C	N	C/N
0-12	5.1	4.0	18	9.7	3600	47.0	2.3	1.1	0.17	0.56	0.53	4.56	17.2	26	1.97	.25	7.9
12-32	4.9	4.0	10	7.2	2000	49.0	2.0	0.9	0.12	0.23	0.52	3.77			1.69		
32-60	5.1	4.0	7	4.4	1800	48.9	2.0	1.0	0.12	0.14	0.05	3.31			1.73		
60-95	5.1	5.9	5				1.6	0.9	0.12	0.09	0.01	2.72					
95-140	5.1	4.0	4				2.2	0.7	0.17	0.09	0.00	3.16					
140-185+	5.0	4.1	7				2.5	0.7	0.17	0.06	0.00	3.43					
Mean of 3 topsoils - Marangu Series - Mrere Variant (19C)																	
0-15		4.4		12.6	3280	52.2	2.7	0.7		0.33		4.31	20.1	22	2.93		

APPENDIX A31 - PROFILE DESCRIPTIONS AND SOIL ANALYTICAL DATA

Profile ID.: Marangu 1

Locality: 75 yards south of Samanga Primary School. Lat. 3° 18'S, Long. 37° 31 1/2'E

Mapping Unit: Samanga Complex (20)
Upper Phase

Classified as: Ferruginous tropical soil

Vegetation: Formerly woodland with *Albizzia schimperiana*, *Rauvolfia caffra*, and planted *Grevillea* still present. Grasses included *aristida adscensionis*, *Sporobolus pyramidalis*, *Digitaria scalarum*, *Eragrostis tenuifolia*, *Chloris gayana*, *C. pyocnothrix*, *Arocloa bolbodes* with *Indigofera sp.*

The profile was developed on basalt/fluvioglacial sand mixture, at an elevation of 4100 feet on a 12° slope. Drainage was free.

Profile Description:

0-13 cm Wet, dark red brown (5YR3/3) sandy clay loam, with occasional fine gravel, weak S.A.B. structure. Common fine and small roots.

13-31 cm Very moist, dark red brown (5YR3/3) sandy clay loam, very slightly stony, weak S.A.B. structure. Common fine and small roots.

31-70 cm Very moist, dark red brown (5YR3/4) silty clay loam, with weak prismatic structure. Common fine fissures and pores. Common roots.

70-109 cm Very moist, dark red brown (5YR3/3) clay loam, slightly stony, very weak prismatic structure, moderate permeability. Few fine roots.

109-180+cm Very moist, dark red brown (5YR3/4) silty clay loam with weathering rock, yellow brown (10YR5/6) below 150 cm. Permeability moderate to rapid. Roots very few.

Depth cm	pH 1:5 Water	pH 1:2.5 M/100 $CaCl_2$	Cond. 1:5 micro-mohs/cm	PHOSPHORUS (ppm) 0.3N HCL	TOTAL	% Organic in total	EXCHANGEABLE BASES (m.e./100gm) Ca	Mg	Na	K	Mn	TOTAL	Capacity	PERCENT Saturation	C	N	C/N
0-15	6.6	5.3	44	5.6	2500	50.0	7.2	3.8	0.19	0.10	0.16	11.55	15.7	73	1.61	0.13	12.4
15-31	6.5	5.3	27	5.0	2130	41.3	5.8	2.2	0.24	0.10	0.00	8.34			1.58		
31-70	6.5	5.1	13	2.9	2500	52.4	4.2	2.3	0.27	0.13	0.00	6.90			1.28		
70-109	6.2	4.8	14				2.5	0.8	0.08	0.06	0.15	3.59					
109-150	6.0	4.8	13				2.3	1.7	0.08	0.06	0.13	4.27					
150-180+	6.1	5.0	11				2.8	2.5	0.32	0.08	0.31	6.37					
Mean of 3 topsoils - Samanga Complex (20)																	
0-15	5.4			9.6	3435	46.5	8.6	2.7		0.45		12.14	16.4	72	1.68		

APPENDIX A32 - PROFILE DESCRIPTIONS AND SOIL ANALYTICAL DATA

Profile ID.: Kilema 4 — Locality: Lower Kilema I mile above Mombasa-Moshi Road. Lat. 3° 23'S, Long. 37° 32'E

Mapping Unit: Himo Series (21) — Classified as: Eutrophic brown soil on fluvioglacial basaltic material

Vegetation: *Hyparrhenia-Panicum/Combretum-Acacia* wooded grassland. Trees present include *Acacia mellifora*, *A. polyacentha*, *Ficus sp.*, *Rauvolfia caffra* and *Cordia holstii*. Ground cover included *Digitaria scalarum*, *Hyparrhenia filipendula*, *H. dissoluta*, *Panicum maxicum*, *Aristida adscensionis*, and *Crotalaria sp.* Basal cover was about 25 percent.

The profile was on a 2° even slope at an altitude of 3000 feet with free drainage.

Profile Description:

0-15 cm Moist, dark red brown (5YR3/2) silty clay loam with moderate crumb structure. Slight cap at surface. Abundant fine and small roots.

15-35 cm Moist, dark red brown (5YR3/2.5) silty clay loam with moderate S.A.B. structure. Friable with abundant fissures and pores. Common fine and small roots.

35-60 cm Moist, dark red brown (5YR3/3) sandy clay loam with weak prismatic structure. Roots common.

60-90+ cm Very moist, dark red brown (5YR3/3) gritty clay loam, stony becoming rock dominant. Friable with abundant pores and fissures, common roots.

Depth cm	pH 1:5 Water	pH 1:2.5 M/100 $CaCl_2$	Cond. 1:5 micro-mohs/cm	PHOSPHORUS (ppm) 0.3N HCL	TOTAL	% Organic in total	EXCHANGEABLE BASES (m.e./100gm) Ca	Mg	Na	K	Mn	TOTAL	Capa-city	PERCENT Satur-ation	C	N	C/N
0-15	7.0	6.0	29	96.2	3250	38.5	10.6	4.7	0.47	1.60	0.05	17.42	22.4	78	1.94	0.15	12.9
15-35	6.9	5.8	18	65.0	3630	59.6	8.2	2.0	0.35	0.74	0.01	11.30			0.92	0.09	10.0
35-60	6.9	5.9	22	17.5	2500	20.0	7.5	3.6	0.33	0.83	0.07	12.33			0.81		
60-90+	7.1	6.2	32				7.5	2.9	0.35	0.85	0.05	11.63					
Mean of 5 topsoils - Himo Series (21)																	
0-15	6.1			90.6	3363	36.6	10.2	4.9		1.46		17.02	21.4	79	1.72		

APPENDIX A33 - PROFILE DESCRIPTIONS AND SOIL ANALYTICAL DATA

Profile ID.: Mamba 1 Locality: 20 yards in front of Mamba North Co-operative Society. Lat. 3° 16'S, Long. 37° 32'E

Mapping Unit: Kokirie Complex (22) Classified as: Humic Ferrisol

Vegetation: Former forest, now coffee/banana *shambas* with some maize and pasture. Trees remaining included *Abizzia petersiana*, *Rauvolfia caffra*, *Croton macrostachys*, *Cussonia sp.*, and planted *Grevillea robusta*. Ground cover includes *Pennisetum clandestinum*, *Cyperus rotundus*, *Sporobolus pyramidalis*, and *Eragrostis tenuifolia*.

The profile was developed from a mixture of ash and lava colluvium on a 8° slope at an elevation of 5050 feet and was freely drained.

Profile Description:

0-15 cm Slightly moist, dark brown (7.5YR3/2) organic loam, with moderate S.A.B. structure and abundant roots.

15-40 cm Moist, dark brown (6.5YR3/2) sandy loam with weak S.A.B. structure, common fine pores and roots.

40-70 cm Very moist, dark brown (7.5YR3/2) sandy loam with very weak prismatic structure. Moderate permeability and common roots.

70-140 cm Very moist, dark red brown (5YR3/3) silty clay loam with weak prismatic structure. Fine pores common. roots common becoming fewer.

140-180 cm Very moist, dark red brown (7.5YR3/4) silty clay loam with occasional lava fragments and weak prismatic structure. Moderate permeability. Very few roots.

Depth cm	pH 1:5 Water	pH 1:2.5 M/100 $CaCl_2$	Cond. 1:5 micro-mohs/cm	PHOSPHORUS (ppm) 0.3N HCL	TOTAL	% Organic in total	EXCHANGEABLE BASES (m.e./100gm) Ca	Mg	Na	K	Mn	TOTAL	Capacity	PERCENT Saturation	C	N	C/N
0-15	5.5	4.7	25	9.0	4750	60.5	4.1	1.5	0.12	0.10	0.01	5.83	21.0	28	4.76	.43	11.0
15-40	5.8	4.7	16	10.0	4000	54.6	3.8	0.9	0.12	0.06	0.01	4.89			4.07		
40-70	5.7	4.6	9	13.8	4250	50.0	2.2	0.2	0.11	0.03	0.03	2.47			3.04		
70-110	5.9	4.7	6														
110-140	5.9	4.8	7														
140-180	5.9	4.8	10				3.0	0.4	0.14	0.03	0.00	3.57					
Mean of 6 topsoils - Kokirie Complex (22)																	
0-15		5.2		13.8	3955	51.0	6.6	2.2		0.36		9.51	20.2	45	3.84		

APPENDIX A34 - PROFILE DESCRIPTIONS AND SOIL ANALYTICAL DATA

Profile ID.: Mwika 1 | Locality: 400 yards north of Mwika Bible School. Lat. 3° 17'S, Long. 37° 33'E

Mapping Unit: Mwika Series (23) | Classified as: Ferruginous tropical soil tending to humic ferrisol

Vegetation: Former forest, now coffee/banana *shambas*, also maize, beans and pasture land. Trees remaining included *Albizzia schimperiana*, *Rauvolfia caffra*, and *Croton macrostachys*. Ground cover included *Sporobolus pyramidalis*, *Eragrostis curvula*, *Digitaria scalarum*, *Rhynchelefrum roseum*, *Cyperus rotundus*.

The profile was developed on colluvium, mainly of ash origin with occasional basalt outcrops. The slope was 7° and the altitude was 4900 feet, the drainage being free.

Profile Description:

0-15 cm Slightly moist, dark red brown (5YR3/4) sandy loam with weak crumb structure. Very friable, tending to cap. Abundant fine and small roots.
15-40 cm Moist, dark red brown (5YR3/4) loam with moderate S.A.B. structure, very friable with abundant roots.
40-100 cm Moist, dark red brown (5YR3/4) sandy clay loam with very weak prismatic structure. Common fine and small roots.
100-140 cm Very moist, dark brown (7.5YR3/2) with (5YR3/4) clay loam. Weak prismatic structure with common fine fissures. Few roots.
140-180 cm Very moist, dark brown (10YR3/3) with some (5YR3/4) clay loam, friable with moderate permeability and few roots.

Depth cm	pH 1:5 Water	pH 1:2.5 M/100 $CaCl_2$	Cond. 1:5 micro-mohs/cm	PHOSPHORUS (ppm) 0.3N HCL	TOTAL	% Organic in total	EXCHANGEABLE BASES (m.e./100gm) Ca	Mg	Na	K	Mn	TOTAL	Capa-city	PERCENT Satur-ation	C	N	C/N
Profile Mwika 2																	
0-15	6.0	4.9	22	5.0	1975	49.4	5.4	2.3	0.15	0.13	0.11	8.09	17.5	46	3.56	0.25	14.2
15-40	5.9	4.7	16	6.6	2600	36.9	4.0	1.8	0.24	0.13	0.06	6.23			2.06		
40-70	5.6	4.3	9	7.1	1600	37.5	2.5	0.7	0.38	0.13	0.02	3.73			1.46		
70-100	5.7	4.7	9														
100-140	5.8	4.8	9														
140-180	5.8	4.9	11				2.4	0.5	0.30	0.06	0.03	3.29	10.1	33			
Profile Mwika 3																	
0-10	6.8	5.8	80	17.5	2500	50.0	12.3	6.6	0.24	0.90	0.05	20.09	27.0	74	4.39		
10-30	6.9	5.7	48	21.5	2400	43.7	8.7	2.6	0.22	1.22	0.01	12.75			1.70		
30-55	6.8	5.8	40	11.1	2200	45.4	6.2	3.6	0.18	0.90	0.01	10.89			0.81		
55-90	7.0	5.8	35				6.5	4.9	0.14	0.40	0.02	11.96					
90-125	6.9	6.0	36				5.7	2.9	0.22	0.14	0.00	8.86					
125-160+	6.7	5.8	35				7.4	3.5	0.15	0.13	0.00	11.18	17.3	65			
Mean of 7 topsoils - Mwika Series (23)																	
0-15	5.4			3.3	1993	52.8	7.0	2.7		0.16		9.82	17.0	61	2.32		

APPENDIX A35 - PROFILE DESCRIPTIONS AND SOIL ANALYTICAL DATA

Profile ID.: Mwika 2

Locality: 5 miles south of Mwika Village, 30 yards west of main road. Lat. 3° 19 1/2'S, Long. 37° 33 1/2'E

Mapping Unit: Kondeni Series (24)

Classified as: Ferruginous tropical soil

Vegetation: Formerly woodland with *Combretum guinenzii*, *Rauvolfia caffra*, *Cardia holstii* remaining. Now maize, beans, bananas, and occasional irrigated coffee *shambas*. Pit on pasture composed of *Nyparrhenia filipendula*, *N. dissoluta*, *Rhynclcletrum roseum*. 50 percent basal cover. Grass cut for fodder.

The profile was developed on ash colluvium on a 4° slope at an altitude of 3500 feet and was freely drained.

Profile Description:

0-15 cm Dry, dark red brown (5YR3/4) silty clay loam with weak crumb to S.A.B. structure, tending to cap at surface. Abundant fine and small roots.

15-42 cm Dry, dark red brown (5YR3/4) silty clay loam. Moderate S.A.B. structure, brittle, with abundant roots.

42-105 cm Dry, becoming slisghtly moist, red brown (5YR3.5/4) silty clay loam with weak prismatic structure. Abundant very fine pores, common fine to large roots.

105-180+cm Slightly moist, becoming moist, dark red brown (5YR3/4) silty clay loam with weak prismatic structure. Brittle becoming crumbly. Moderate permeability, roots common becoming few.

Depth cm	pH 1:5 Water	pH 1:2.5 M/100 $CaCl_2$	Cond. 1:5 micro-mohs/cm	PHOSPHORUS (ppm) 0.3N HCL	TOTAL	% Organic in total	EXCHANGEABLE BASES (m.e./100gm) Ca	Mg	Na	K	Mn	TOTAL	Capa-city	PERCENT Satur-ation	C	N	C/N
0-15	6.5	5.6	46	12.5	2200	26.4	7.0	4.1	0.18	0.74	0.03	12.05	16.8	72	1.8	0.13	13.9
15-42	5.6	4.6	22	8.8	2600	31.5	3.9	3.4	0.29	0.16	0.03	7.78			1.02		
42-72	5.1	4.3	19	6.1	2100	41.0	2.7	2.1	0.24	0.16	0.03	5.23			0.90		
72-105	5.2	4.7	13														
105-140	5.4	5.0	19				2.0	2.1	0.10	0.32	0.02	4.54	9.8	47			
Mean of 3 topsoils - Kondeni Series (24)																	
-15		6.0		23.5	2067	34.2	8.5	4.2		1.08		13.69	16.8	72	1.62		

APPENDIX A36 - PROFILE DESCRIPTIONS AND SOIL ANALYTICAL DATA

Profile ID.: Keni 5

Locality: About 800 yards north of Msangasanga Hills, near shop, 20 yards east of road, Lat. 3° 18'S, Long. 37° 37'E

Mapping Unit: Mahida Series (25)
Mahida Variant (25A)

Classified as: Ferruginous tropical soil on volcanic ash

Vegetation: *Hyparrhenia/Combretum* wooded grassland now largely cultivated with maize, beans and some bananas. Trees include *Combretum sp.*, *Rauvolfia caffra*, *Ficus sp.*, and *Erythrina abyssinica*. Grasses include *Hyparrhenia dissoluta*, *N. filipendula*, *Themeda triandra* and some *Cynodon dactylon*.

The profile was on a 6° slope at an elevation of 3900 feet and was freely drained.

Profile Description:

0-15 cm Moist, dark red brown (5YR3/3) fine sandy clay loam with moderate crumb structure. Friable with abundant fine roots.

15-35 cm Moist, dark red brown (5YR3/4) silty clay loam, moderate S.A.B. with common roots.

35-60 cm Moist, dark red brown (5YR3/4) silty clay, crumbly to labile. finely porous and fissured.

60-90+ cm Moist, dark red brown (5YR3/4) sandy clay loam, with weak prismatic structure. Labile consistence, moderate permeability, roots common.

Depth cm	pH 1:5 Water	pH 1:2.5 M/100 $CaCl_2$	Cond. 1:5 micro-mohs/cm	PHOSPHORUS (ppm) 0.3N HCL	TOTAL	% Organic in total	EXCHANGEABLE BASES (m.e./100gm) Ca	Mg	Na	K	Mn	TOTAL	Capacity	PERCENT Saturation	C	N	C/N
0-15	6.6	5.6	18	31.2	2500	40.0	10.7	7.1	0.36	0.95	0.06	19.17	27.5	70	2.64	0.16	16.5
15-35	6.5	5.6	13	19.5	2350	46.8	9.9	6.2	0.24	0.31	0.01	16.66			1.69	0.12	14.1
35-60	6.7	5.6	12	19.5	2185	70.3	9.6	6.2	0.35	0.17	0.00	16.32			1.56		
60-90+	6.7	5.7	12				11.2	6.8	0.36	0.15	0.00	18.51	26.0	71			
Mean of 5 topsoils - Mahida Series (25)																	
0-15		5.4		18.1	2660	38.9	7.9	4.7		0.28		13.49	20.9	74	1.92		

APPENDIX A37 - PROFILE DESCRIPTIONS AND SOIL ANALYTICAL DATA

Profile ID.: Mashati 2

Locality: 4 miles below Mashati, 100 yards west of water point, Lat. 3° 9'S, Long. 37° 39'E

Mapping Unit: Kimanga Series (26)

Classified as: Reddish brown soil of semi-arid regions

Vegetation: *Aristida-Heteropogon/Acacia-Combretum* bushed grassland with basal cover about 70 percent. Other species include *Cynodon dactylon*, *Cenchrus ciliaris*, *Solanum*, *Acacia mellifora*, *Indigofera sp.* and occasional *Euphorbia candelabra*. Planted crops include maize, beans, castor, Eleusine, and sisal hedges.

The profile was sited on a 2° slope at an elevation of 3700 feet on basaltic colluvium, and was freely drained.

Profile Description:

0-15 cm Dry, dark red brown (5YR3/3) fine sandy clay loam with occasional small lava fragments. Weak crumb to S.A.B. structure tending to cap at surface. Abundant small, few large roots.

15-30 cm Dry, dark red brown (5YR3/4) silty clay loam, very slightly stony with weak prismatic structure. Common fine and small roots.

30-70 cm Dry, dark red brown (5YR3/4) silty clay loam, a few small stones, brittle consistence, moderate permeability, common roots.

70-150 cm Slightly moist, becoming moist, dark red brown (5YR3/4) silty clay loam, slightly stony with very weak prismatic structure, moderate permeability, few roots becoming more common with depth.

150-190+cm Moist, dark red brown (5YR3/3) gritty clay loam with grey-brown (2.5YR5/2) rotting rock. Rock dominant. Permeability rapid. Fine and small roots almost abundant.

Depth cm	pH 1:5 Water	pH 1:2.5 M/100 $CaCl_2$	Cond. 1:5 micro-mohs/cm	PHOSPHORUS (ppm) 0.3N HCL	TOTAL	% Organic in total	EXCHANGEABLE BASES (m.e./100gm) Ca	Mg	Na	K	Mn	TOTAL	Capacity	PERCENT Saturation	C	N	C/N
0-15	5.8	5.1	24	25.0	2400	40.0	7.5	3.0	0.15	1.60	C,05	12.30	20.1	61	1.32	0.16	8.3
15-30	6.1	5.4	15	17.0	2230	46.0	6.8	2.9	0.24	1.08	0.02	11.04			1.03		
30-70	6.4	5.8	25	15.0	1820	47.8	6.4	4.9	0.17	.99	0.00	12.46			0.79		
70-110	6.6	5.8	27				5.8	3.5	0.15	1.22	0.00	10.67					
110-150	6.8	6.0	37				5.4	4.2	0.17	1.41	0.00	11.18					
150-190+	6.9	6.0	30				4.9	3.5	0.32	1.22	0.01	9.95	16.3	61			
Mean of 6 topsoils - Kimanga Series (26)																	
0-15		5.4		27.5	2683	55.3	8.0	3.4		1.75		13.45	19.8	68	1.34		

APPENDIX A38 - PROFILE DESCRIPTIONS AND SOIL ANALYTICAL DATA

Profile ID.: Mkuu 4

Locality: Kilamfua, 5 yards south of boundary of Huruma Convent, 200 yards west of road entering Huruma. Lat. 3° 11'S, Long. 37° 37'E

Mapping Unit: Huruma Series (27)

Classified as: Ferruginous tropical soil on basaltic colluvium

Vegetation: Wooded grassland with *Acacia polyacantha*, *Rauvolfia caffra* and *Ficus vogelii*. Ground cover included *Aristida adscensionis*, *Ryacheletrum roseum*, *Eragrostis curvula*, *Sorghum verticilliflorum*, *Indigofera sp.*, *Hyparrhenia rufa*, *Stylosanthes sp.* Grass cut for fodder.

The profile was developed on a 6° slope at an elevation of 4350 feet and was freely drained.

Profile Description:

0-15 cm	Moist, dry red brown (5YR3/3) silty clay loam with very occasional lava boulders. Moderate crumb to S.A.B. structure with some tendency to surface cap. Abundant fine and small roots.
15-50 cm	Slightly moist, dark red brown (5YR3/3) silty clay loam with very occasional boulders. Moderate prismatic structure, roots abundant.
50-100 cm	Dry, dark red brown (5YR3/3) silty clay loam with moderate prismatic structure. Friable with common fine roots.
100-130 cm	Dry, dark red brown (5YR3/3) silty clay loam with weak prismatic structure, slightly hard, brittle, few fine roots.
130-175+cm	Slightly moist, dark red brown (5YR3/3) sandy clay loam, with very weak prismatic structure. Moderate permeability. Few roots.

Depth cm	pH 1:5 Water	pH 1:2.5 M/100 $CaCl_2$	Cond. 1:5 micro-mohs/cm	PHOSPHORUS (ppm) 0.3N HCL	TOTAL	% Organic in total	EXCHANGEABLE BASES (m.e./100gm) Ca	Mg	Na	K	Mn	TOTAL	Capa-city	PERCENT Satur-ation	C	N	C/N
0-15	5.6	5.1	16	4.2	1375	70.9	8.6	3.7	0.14	0.19	0.97	13.60	20.4	66	2.16		
15-50	5.6	5.1	15	2.7	1065	64.8	6.3	2.4	0.15	0.06	0.02	8.93			1.20		
50-100	6.1	5.4	13	2.5	900	30.0	6.6	1.3	0.12	0.06	0.01	8.09			0.84		
100-130	6.2	5.6	11				6.6	1.6	0.24	0.03	0.01	8.47					
130-175+	6.3	5.8	12				5.4	1.6	0.15	0.03	0.01	7.18					
Mean of 4 topsoils - Huruma Series (27)																	
0-15		4.9		2.4	1296	66.1	5.9	2.5		0.25		9.30	20.1	58	1.77		

APPENDIX A39 - PROFILE DESCRIPTIONS AND SOIL ANALYTICAL DATA

Profile ID.: Keni 6

Locality: Mriti-Mengwe, 150 yards north of crest of hill, 25 yards west of main road, Lat. 3° 15 1/2'S, Long. 37° 37'E

Mapping Unit: Mengwe Creep Complex (28) Mengwe Variant 28A

Classified as: Humic Ferrisol

Vegetation: Former forest, now coffee/banana/maize *shambas*. Trees included *Teclea viridis*, *Croton macrostachys*, *Cassipourea malosana*, and planted *Grevillea* and *Cypress*. Pit was on grass patch with *Aristida adscensiahis*, *Hyparrhenia rufa*, *Andropogon sp.*, *Rhynchalctrum roscum*, and *Indigofera sp.*, with 70 percent basal cover.

The profile was developed on volcanic ash on a convex slope of 18° at an elevation of 4800 feet. Drainage free to excessive.

Profile Description:

0-20 cm	Moist, dark red brown (2.5YR3/4) fine sandy clay loam with moderate coarse crumb to S.A.B. structure. Very friable. Abundant fine to medium roots.
20-50 cm	Moist, dark red brown (2.5YR3/4) silty clay loam with weak S.A.B. structure. Friable with common roots.
50-100 cm	Moist, dark red (2.5YR3/4) silty clay loam with occasional cinder fragments. Moderate prismatic structure. Friable with abundant pores and fissures. Common fine and small roots.
100-140 cm	Moist, dark red (2.5YR3/4) silty clay loam with occasional cinder fragments. Moderate S.A.B. structure with tendency to prismatic. Friable with abundant pores and fissures. Few roots.
140-175+cm	Very moist, dark red (2.5YR3/6) silty clay with occasional cinders, weak prismatic structure, friable, roots few.

Depth cm	pH 1:5 Water	pH 1:2.5 M/100 $CaCl_2$	Cond. 1:5 micro-mohs/cm	PHOSPHORUS (ppm) 0.3N HCL	TOTAL	% Organic in total	EXCHANGEABLE BASES (m.e./100gm) Ca	Mg	Na	K	Mn	TOTAL	Capa-city	PERCENT Satur-ation	C	N	C/N
0-20	5.9	5.1	19	2.0	10.00	55.0	7.0	3.8	0.10	0.29	0.58	11.08	23.9	49	2.18		
20-50	5.9	5.1	14	1.4	7.00	50.1	4.6	2.8	0.14	0.03	0.12	7.60			0.96		
50-100	5.8	5.1	8	2.9	10.00	50.0	4.6	2.0	0.21	0.03	0.01	6.85			0.40		
100-140	5.9	5.3	9				4.8	3.0	0.32	0.03	0.01	8.16					
140-175+	6.0	5.4	11				4.0	1.6	0.32	0.03	0.02	5.97					
Mean of 4 topsoils - Mengwe Complex (28A)																	
0-15	5.0			5.0	1784	60.2	3.2	4.9		0.30		14.05	22.8	59	2.84		

APPENDIX A40 - PROFILE DESCRIPTIONS AND SOIL ANALYTICAL DATA

Profile ID.: Mkuu 2

Locality: 450 yards above Primary School, 70 yards off bend in road, Ubaa, Lat. 3° 11'S, Long. 37° 35 1/2'E

Mapping Unit: Ubaa Complex (29)

Classified as: Podsolic Soil

Vegetation: Probably former forest, now poor grassland with occasional coffee and bananas and scattered planted *Grevillea* and wattle. Grasses include *Andropogon dummeri*, *Sporobolus pyrasidalis*, *Eragrostis curvula*, *Pimbristylla diphylla*, *Rhyncheletrum roseum*, *Aristida andconsionis*, *Exetheca abyssinica*, *Cyperus sp.*, and occasional shrubs of *Doronaea viscosa*, and the tree *Macaramea kilimandacharica*.

The profile was developed on a siliceous analcitite at an elevation of 5350 feet on a 14° convex slope. Drainage was free, and the site eroded.

Profile Description:

0-12 cm Moist, difficult dark brown (7.5YR3/2) humic sandy loam with weak crumb to single grain structure. Very friable, with abundant fine and small roots. Surface tending to cap.

12-44 cm Moist, dark brown (7.5YR3/2) fine sandy loam with a few S.A.B. lava fragments. Weak S.A.B., friable, common fibrous roots.

44-78 cm Very moist, red brown (5YR3.5/4) silty clay loam with no crate prismatic structure. Finely fissured with few pores. Common fine roots.

78-110 cm Moist, red brown (5YR3.5/4) gritty clay with a few lava fragments. Moderate prismatic structure, common roots.

110-150 cm Moist, dark red brown (5YR3.5/4) gritty silty clay loam with dark brown (7.5YR3/2) and (5YR4/6) weathering rock. Weak S.A.B. structure with few roots.

150-195+cm Slightly moist, dark brown (10YR3/3) gravelly loam with grey rock fragments. Weak S.A.B. structure. Few roots.

Depth cm	pH 1:5 Water	pH 1:2.5 M/100 $CaCl_2$	Cond. 1:5 micro-mohs/cm	PHOSPHORUS (ppm) 0.3N HCL	TOTAL	% Organic in total	EXCHANGEABLE BASES (m.e./100gm) Ca	Mg	Na	K	Mn	TOTAL	Capacity	PERCENT Saturation	C	N	C/N
0-12	4.5	3.8	31	10.6	1700	58.8	1.1	0.3	0.14	0.12	0.35	2.01	25.4	8	4.92		
12-44	4.8	4.2	9	8.8	1190	45.4	1.2	0.1	0.09	0.03	0.02	1.44			2.26		
44-78	4.7	4.0	7	5.0	1065	60.1	0.6	0.2	0.12	0.03	0.02	1.07			1.19		
78-110	4.8	4.1	6				1.0	0.2	0.21	0.03	0.01	1.45					
110-150	5.0	4.4	19				1.1	0.1	0.21	0.03	0.01	1.45					
150-195+	4.9	4.1	65				0.9	0.1	0.14	0.07	0.02	1.25	19.7	6			
Mean of 3 topsoils - Ubaa Complex (29)																	
0-15		4.2		6.8	2153	51.7	2.1	0.4		0.14		3.00	26.5	10	6.58		

APPENDIX A41 - PROFILE DESCRIPTIONS AND SOIL ANALYTICAL DATA

Profile ID.: Userl 5

Locality: 200 yards below fault line, 30 yards south of road from Userl to Rombo-Masai, Lat. 3° 41'S, Long. 35° 36'E

Mapping Unit: Kitalato Series (30)

Classified as: Ferruginous tropical soil on basaltic/andesitic colluvium

Vegetation: Bushed grassland with combretum sp., Kigalia aethiopia and colonising Acacia Stuhlmanii, 90 percent basal cover consisting of Hyparrhenia sp., Rhyncheletrum roseum, Eragrostis tenuifolia, Aristida adscensionia and Heteropogon contortus, Eragrostis syperba. Area largely cultivated with maize, beans, finger millet, patches of bananas.

The profile was on a 5° convex slope at an elevation of 4500 feet and was freely drained.

Profile Description:

0-10 cm Dry, dark red brown (5YR3/5) silty clay loam with moderate medium crumb structure and abundant fine foots. Some tendency to cap.

10-33 cm Slightly moist, dark red brown (5YR3/3) silty clay loam, moderate S.A.B. structure, brittle consistence. Abundant roots.

33-60 cm Slightly moist, dark red brown (5YR3/3) fine sandy clay loam, very slightly stony with moderate S.A.B. structure. Common roots.

60-95 cm Slightly moist, dark red brown (4YR3/4) silty clay loam, weak S.A.B. tending to prismatic structure. Common roots.

95-185+cm Moist, dark red brown (4YR3/4) silty clay loam, very weak prismatic structure, friable with abundant fine pores, roots common becoming few.

Depth cm	pH 1:5 Water	pH 1:2.5 M/100 $CaCl_2$	Cond. 1:5 micro-mohs/cm	PHOSPHORUS (ppm) 0.3N HCL	TOTAL	% Organic in total	EXCHANGEABLE BASES (m.e./100gm) Ca	Mg	Na	K	Mn	TOTAL	Capa-city	PERCENT Satur-ation	C	N	C/N
0-10	6.0	5.1	30	3.1	1750	61.1	4.0	3.8	0.14	0.74	0.36	9.24	15.3	60	2.16	0.16	13.5
10-33	6.0	5.0	37	3.0	1450	66.9	3.4	2.2	0.17	0.55	0.38	6.70			1.56		
33-60	5.6	4.7	16	1.0	1500	64.0	6.9	2.4	0.09	0.26	9.67				1.56		
60-95	5.3	4.5	15				4.1	1.4	0.07	0.06	0.08	5.71					
95-140	5.7	5.2	15				3.3	1.8	0.09	0.03	0.01	5.23					
140-185+	5.9	5.3	25				2.4	1.4	0.10	0.03	0.01	3.94	7.4	53			
Mean of 7 topsoils - Kitalato Series (30)																	
0-15		5.1		4.1	1980	62.6	4.4	3.2		0.69		8.79	14.6	66	1.57		

APPENDIX A42 - PROFILE DESCRIPTIONS AND SOIL ANALYTICAL DATA

Profile ID.: Useri 6

Locality: 500 yards below junction to school on Useri/Rhombo-Masai road, 20 yards north of road. Lat. 3° 4 1/2'S, Long. 37° 36'E

Mapping Unit: Usanyi Series (31)

Classified as: Ferruginous tropical soil

Vegetation: Formerly heavy woodland with *Rauvolfia caffra*, *Albizzia schlaperiana*, *Cordia holstii*. Now coffee, banana, maize and beans with some planted *Grevillea robusta*, grasses included *Digitaria sp.*, *Eragrostis superba*, *Rhynchelytrum roseum*, *Harpachne schimperi*, *Sporobolus pellucidus*, with *Solanum incanum*. Basal cover was about 70 percent.

The profile was developed from basalt on an 8° slope at an altitude of 5000 feet and was freely drained.

Profile Description:

0-20 cm Dry, dark red brown (5YR3/3) gritty clay loam, with moderate S.A.B. structure brittle, common fine and small roots.

20-45 cm Very slightly moist, dark red brown (4YR3/4) sandy clay loam, with moderate S.A.B. Abundant fine pores, common fine roots.

45-70 cm Slightly moist, dark red brown (4YR3/3) sandy clay loam with weak prismatic structure. Abundant fine pores and fissures. Common fine and small roots and ant burrows.

70-140 cm Moist, dark red brown (4YR3/4) sandy clay loam with weathering rock light yellow (10YR6/4). Weak prismatic structure. Common pores, few roots.

140-150+cm Moist, dark red brown (4YR3/4) gritty clay loam, with dark stained soft rock, very weak prismatic structure. Common pores and a few fissures. Very few roots.

Depth cm	pH 1:5 Water	pH 1:2.5 M/100 $CaCl_2$	Cond. 1:5 micro-mohs/cm	PHOSPHORUS (ppm) 0.3N HCL	TOTAL	% Organic in total	EXCHANGEABLE BASES (m.e./100gm) Ca	Mg	Na	K	Mn	TOTAL	Capa-city	PERCENT Satur-ation	C	N	CN
0-20	6.4	5.5	47	11.0	2100	42.9	9.4	4.5	0.12	1.22	N.D.		21.2		1.80	0.19	9.5
20-45	6.5	5.8	100	4.9	1800	55.6	9.3	4.0	0.21	0.86	0.86	15.23			1.32		
45-70	6.7	5.9	25	4.3	1800	46.7	7.9	3.9	0.24	1.25	N.D.						
70-105	5.8	5.3	100				4.7	2.1	0.22	2.08	1.34	10.44					
105-140	5.7	5.3	75				3.6	1.2	0.24	1.54	N.D.						
140-180+	5.9	5.4	40				2.4	1.2	0.29	1.08	N.D.						
Mean of 5 topsoils - Usanyi Series (31)																	
0-15		5.5		14.7	2295	42.0	9.7	3.8		1.37		15.42	20.5	75	1.88		

APPENDIX A43 - PROFILE DESCRIPTIONS AND SOIL ANALYTICAL DATA

Profile ID.: Useri 3

Locality: About 300 yards south of agriculture houses, Samanga, Useri, Lat. 3° 5 1/2'S, Long. 37° 35 1/2'E

Mapping Unit: Useri Series (32)

Classified as: Humic ferrisol tending to humic ferrallitic

Vegetation: Formerly woodland with *Ficus sp.*, and *Croton megalocarpus* remaining. Also, planted *Grevillea* and wattle, mainly coffee/banana shambas with considerable areas of poor pasture. Maize and beans also planted. Grasses included *Hyparrhenia rufa*. *Eragrostis curvula*, *Digitaria sp.* and *Sporobolus sp.* Pit was sited on pasture with 90 percent basal cover.

The profile was developed on colluvium, largely of trachyte and trachybasalt origin. The slope was 5°, the elevation 5300 feet and the drainage was free.

Profile Description:

0-12	cm	Moist, dark red brown (5YR3/3) fine sandy loam with moderate crumb structure. Common pores and fissures and extremely abundant fine and small roots.
12-28	cm	Moist, dark red brown (5YR3/4) sandy loam with S.A.B. structure, very friable, abundant roots.
28-80	cm	Moist, dark red brown (5YR3/4) becoming (4YR3/4) loam, with weak S.A.B. becoming prismatic structure. Common fine and small roots.
80-110	cm	Moist, dark red brown (4YR3/4) silty clay loam with moderate prismatic structure. Common very fine pores and fissures.
110-170+	cm	Moist, dark red brown (5YR3/4) with (5YR3/3) on structure faces, clay loam with a few small soft lava fragments. Strong, coarse granular structure tending to prismatic. Abundant fine fissures, few roots.

Depth cm	pH 1:5 Water	pH 1:2.5 M/100 $CaCl_2$	Cond. 1:5 micro-mohs/cm	PHOSPHORUS (ppm) 0.3N HCL	TOTAL	% Organic in total	EXCHANGEABLE BASES (m.e./100gm) Ca	Mg	Na	K	Mn	TOTAL	Capacity	PERCENT Saturation	C	N	C/N
0-12	4.9	4.0	24	2.8	1800	51.1	2.8	1.5	0.14	0.13	0.44	5.01	21.4	23	3.47	0.32	10.5
12-28	4.8	3.9	20				1.4	0.3	0.14	0.13	0.32	2.29			2.27		
28-55	4.8	3.9	16				1.1	0.4	0.10	0.06	0.26	1.92			1.90		
55-80	4.9	3.9	11														
80-110	4.9	4.0	10														
110-140	4.9	4.1	9														
140-170+	5.1	4.0	11				1.6	0.4	0.18	0.10	0.02	2.30	10.0	23			
Mean of 5 topsoils - Useri Series (32)																	
0-15		4.5		4.6	1745	58.0	4.3	1.8		0.42		6.93	17.5	41	2.41		

APPENDIX A44 - PROFILE DESCRIPTIONS AND SOIL ANALYTICAL DATA

Profile ID.: Useri 8

Locality: I mile below forest, 20 yards west of right angle bend in road, Kooti, Olele. Lat. 3° 6 1/2'S, Long. 37° 34 1/2'E

Mapping Unit: Kooti Series (33)

Classified as: Humic ferrallitic on andesitic colluvium

Vegetation: Formerly forest with *Albizzia petersiana*, *Ficus sp.*, *Acacia abyssinica* remaining. Poor coffee and bananas, much scrub grassland. Planted wattle and *Cypress*. The grassland was dominated by *Hyparrhenia hirta* with *Eragrostis sp.* Basal cover was 70-80 percent

The profile was developed on a 10° irregular slope at 5800 feet elevation and drainage was free.

Profile Description:

- 0-20 cm Dry, dark brown (7.5YR3/2) humic sandy loam with weak crumb structure, very friable with abundant pores and fissures. Very abundant fine occasional woody roots.
- 20-45 cm Very slightly moist, dark red brown (5YR3.5/4) loam, with weak S.A.B. structure, very friable, abundant roots.
- 45-70 cm Slightly moist, dark red brown (5YR3.5/4) fine sandy loam, weak prismatic structure with common very fine pores.
- 70-150 cm Moist, dark red (3.5YR3/6) sandy becoming silty clay loam, with weak prismatic structure. Common roots becoming few.
- 150-180+cm Moist, dark red brown (5YR3/3-4) silty clay, with darker colour of clay skins, very weak, prismatic with tendency to massive structure. Ward consistence, permeability rather slow when wet. Few roots.

Depth cm	pH 1:5 Water	pH 1:2.5 M/100 $CaCl_2$	Cond. 1:5 micro-mohs/cm	PHOSPHORUS (ppm) 0.3N HCL	TOTAL	% Organic in total	EXCHANGEABLE BASES (m.e./100gm) Ca	Mg	Na	K	Mn	TOTAL	Capacity	PERCENT Saturation	C	N	C/N
0-20	5.5	4.4	16	5.0	2400	54.0	3.9	1.7	0.07	0.09	0.81	6.51	26.1	25	5.49	.54	10.2
20-45	5.2	4.2	10	2.3	2500	64.8	1.1	0.2	0.14	0.10	0.53	2.07			3.90		
45-70	5.2	4.3	13	6.1	2400	48.3	1.0	0.1	0.12	0.10	0.60	1.92			2.60		
70-115	5.0	4.2	8				1.1	0.3	0.18	0.09	0.35	2.02					
115-150	5.2	4.2	7				0.6	0.1	0.27	0.06							
150-180+	4.9	4.2	12				1.2	0.3	0.15	0.06	0.33	1.26	12.7	10			
Mean of 9 topsoil - Kooti Series (33)																	
0-15		4.2		6.8	1533	46.5	4.1	1.4		0.29		6.43	26.3	23	7.25		

APPENDIX A45 - PROFILE DESCRIPTIONS AND SOIL ANALYTICAL DATA

Profile ID.: Useri 9

Locality: 400 yards above bottom end of Useri glade, 25 yards south of track.
Lat. 3° 6'S, Long. 37° 32 1/2'E

Mapping Unit: Uhini Series (34)

Classified as: Podsolic soil on olivine basalt

Vegetation: Grassland, with scattered *Agauria salicifolia* mainly in receiving sites. Common species were *Eragrostis sp.* *Hyparrhenia sp.*, *Fimbrostylis diphylla*, *Rumex usambarensis*, *brachen*, and *Artemesia afra*. Also, *Ponnisetum clandestinum* particularly on cattle tracks. *Helichrysum meyeri-johannis* also occurred.

The profile was on a slope of about 12° at an altitude of 7200 feet, and was freely drained.

Profile Description:

0-7 cm	Wet, black (2.5YR2/0) fibrous mor humus of labile consistence. Abundant fine and small roots.
7-20 cm	Very moist, black, (10YR2/1) greasy, humic loam, of crumbly consistence with abundant roots.
20-35 cm	Very moist, very dark brown (10YR2/2) humic loam with weak S.A.B. structure, very friable with abundant fine and small roots.
35-65 cm	Wet, dark brown (7.5YR3/2) sandy clay loam with weak S.A.B. structure, common roots.
65-90 cm	Very moist, very dark brown (10YR2/2) silty clay loam, friable with abundant fine pores, common roots but many dead.
90-150 cm	Moist, dark brown (10YR3/3-3.5) gritty clay loam, slightly stony, very weak prismatic structure. Common fine and small roots mainly dead with iron coatings on lava fragments.
150-210+cm	Wet, weathering rock dominant, dark red brown (2.5YR3/4) with soil between (5YR3.5/4) becoming (10YR3/4) clay loam between weathering rock. Friable with few roots.

Depth cm	pH 1:5 Water	pH 1:2.5 M/100 $CaCl_2$	Cond. 1:5 micro-mohs/cm	PHOSPHORUS (ppm) 0.3N HCL	TOTAL	% Organic in total	EXCHANGEABLE BASES (m.e./100gm) Ca	Mg	Na	K	Mn	TOTAL	Capa-city	PERCENT Satur-ation	C	N	C/N
0-7	5.7	4.5	16	11.0	2900	52.4	15.7	3.0	0.30	0.51	0.72	20.23	54.1	37	12.65		
7-20	5.5	4.2	16	6.8	2480	72.6	4.3	0.4	0.21	0.23	0.41	5.45			11.15		
20-35	5.4	4.3	15	2.0	2400	70.0	1.7	0.2	0.18	0.12	0.15	2.35			8.81		
35-65	5.4	4.3	13				1.2	0.2	0.28	0.13	0.12	1.93					
65-90	5.4	4.3	12				1.1	0.1	0.14	0.06	0.01	1.41					
90-125	4.8	4.4	8				0.7	0.1	0.15	0.03	0.00	0.98					
150-175	4.5	3.9	7														
175-210+	4.5	3.9	8				1.2	0.1	0.18	0.06	0.02	1.56					
Mean of 5 topsoils - Uhini Series (34)																	
0-15		4.8		11.7	2336	54.6	9.0	2.2		0.26		12.32	41.4	30	9.93		

APPENDIX A46 - PROFILE DESCRIPTIONS AND SOIL ANALYTICAL DATA

Profile ID. Useri 1 Locality: 50 yards south of road to Useri Glade, 400 yards below forest. Lat. 3° 6'S, Long. 37° 34'E

Mapping Unit: Mashima Complex (35) Classified as: Humic ferrisol on trachybasalt

Vegetation: Formerly high altitude dry *Ocotea/Podocarpus* forest. Now cultivated with poor crops of maize, bananas and pyrethrum. Grass species included *Eragrositis sp.*, *Rhyncheletrum roseum*, *Dicanthium sp.*, *Pennisetum clandestinum* and *Hypparrhenia sp.* Poor bracken is also present.

The profile was listed on a 10° slope at an altitude of 6360 feet and was freely drained.

Profile Description:

0-4 cm Wet, very dark brown (10YR2/2) organic loam with weak granularate crumb structure. Abundant fine to small root.

4-15 cm Wet, very dark brown (10YR2/2) organic sandy loam with moderate S.A.B. structure. Friable with abundant roots.

15-30 cm Wet, dark red brown (5YR3/2.5) sandy loam with a few S.A. lava fragments. Weak S.A.B. structure. Friable with fine common roots.

30-70 cm Moist, dark red brown (5YR3/4) silty loam with a few lava fragments and weak S.A.B. structure. Rather rapid permeability becoming moderate. Common roots.

70-90 cm Moist, dark brown (7.5YR4/4) silty loam with less weathered lava fragments. Very weak prismatic structure. Few roots, mainly dead.

90-150+cm Moist, dark yellowish brown (10YR4/8.5) gritty, silty loam becoming rock dominant. Few fine and small roots, mainly dead.

Depth cm	pH 1:5 Water	pH 1:2.5 M/100 $CaCl_2$	Cond. 1:5 micro-mohs/cm	PHOSPHORUS (ppm) 0.3N HCL	TOTAL	% Organic in total	EXCHANGEABLE BASES (m.e./100gm) Ca	Mg	Na	K	Mn	TOTAL	Capa-city	PERCENT Satur-ation	C	N	C/N
0-4	6.1	4.8		13.3			9.4	2.6	0.18	0.26	0.44	12.88			6.52		
4-15	5.7	4.5		6.5			1.5	2.5	0.14	0.14	0.13	4.41			6.69		
15-30	5.8	4.6		3.5											4.39		
30-50	5.6	4.4															
50-70	5.5	4.3															
70-90	5.2	4.4															
90-120	5.3	4.6															
120-150+	5.1	4.6															
Mean of 4 topsoils - Mashima Complex (35)																	
					563	48.4	19.8	3.8	3.8	0.56		25.05	33.6	49	10.27		

APPENDIX A47 - PROFILE DESCRIPTIONS AND SOIL ANALYTICAL DATA

Profile ID.: Useri 7

Locality: 300 yards above main road to Tarakia on road to Primary School, Nanjara, Lat. 3° 1'S, Long. 37° 34'E

Mapping Unit: Nanjara Series (37)

Classified as: Eutrophic brown soil on fluvioglacial material

Vegetation: Wooded grassland with occasional *Erithryn abyssinica*, *Acacia polpacantha*, *Astuhlmanni*, *Lantana sp.*, and planted *Cypress* and *Grevillea*. Main crops were maize and banana, fodder grassland, mainly composed of *Hyparrhenia sp.* especially *N. fillibpondula*. Also some *Themeda triandra*, *Digitaria sp.* and *Eragrostis sp.* Basal cover 50 percent due to tall *Hyparrhenia sp.*

The profile was developed on an even 5° slope at an elevation of 5500 feet. Occasional outcrops of basalt and adesitic boulders.

Profile Description:

0-20 cm Dry, very dark brown (10YR2/2) gritty clay loam with occasional large boulders. Strong crumb structure, hard, abundant fine and small roots.

20-40 cm Very slightly moist, very dark brown (10YR2/3) gritty clay loam with strong S.A.B. structure, hard, common fibrous roots.

40-60 cm Very slightly moist, very dark brown (10YR2/3) silty clay loam, stony, with strong prismatic structure, common fine to medium fissures. Permeability rather slow when wet. Common fine and small roots.

60-85 cm Slightly moist, dark brown (7.5YR3/2) gritty clay loam, very stony with soft rock, moderate prismatic structure. Common roots.

85-110 cm Slightly moist, dark brown (7.5YR3/2) gravelly clay loam, with greyish brown (2.5YR5/2) weathering rock dominant. Weak S.A.B. single grain structure. Abundant pores and fissures. Rapid permeability. Abundant fine roots.

Depth cm	pH 1:5 Water	pH 1:2.5 M/100 $CaCl_2$	Cond. 1:5 micro-mohs/cm	PHOSPHORUS (ppm) 0.3N HCL	TOTAL	% Organic in total	EXCHANGEABLE BASES (m.e./100gm) Ca	Mg	Na	K	Mn	TOTAL	Capa-city	PERCENT Satur-ation	C	N	C/N
0-20	5.8	5.1	58	56.5	3720	25.3	13.7	5.4	0.21	1.40	1.63	22.34	29.0	77	3.44	0.27	12.8
20-40	5.4	4.7	48	18.7	3450	41.3	10.5	4.0	0.16	0.72	1.00	16.38			2.03		
40-60	5.8	5.0	45	6.0	2900	31.7	10.2	3.3	0.31	0.64	0.26	14.71					
60-85	6.0	5.2	31				10.7	3.7	0.20	0.56	0.21	15.37					
85-110+	6.1	5.0	39				9.8	4.2	0.27	0.56	0.05	14.89	16.2	92			
Mean of 9 topsoils - Nanjara Series (37)																	
0-15		5.4		156.0	3728	28.0	15.3	4.9		1.36		22.25	27.9	79	3.01		

APPENDIX A48 - ANALYTICAL DATA FOR TWO SOIL COMPLEXES

Depth cm	pH 1:5 Water	pH 1:2.5 M/100 $CaCl_2$	Cond. 1:5 micro-mohs/cm	PHOSPHORUS (ppm) 0.3N HCL	TOTAL	% Organic in total	EXCHANGEABLE BASES (m.e./100gm) Ca	Mg	Na	K	Mn	TOTAL	Capa-city	PERCENT Satur-ation	C	N	C/N
Mean of 2 topsoils - Pumwani Complex (15)																	
0-15	6.9	5.9	65	57.2	1224	30.0	9.7	3.7	0.36	1.46	0.04	15.26	17.7	90	1.44	0.12	12.0
Mean of 3 topsoils on Alluvial/Colluvial Complex (38) - Useri Area Only																	
0-15	6.4	5.5	38	87.7	3442	34.0	14.7	4.3	0.19	0.61	0.37	20.17			2.77		

APPENDIX B

BOTANICAL SPECIES NOTED ON EACH SOIL MAPPING UNIT

APPENDIX B1 — KWARE COMPLEX

Common or Local Name	Scientific Name
Mringaringa	*Cordia holstii* (Guerke)
Mlandee	*Croton megalocarpus* (Hatch.)
Mkuyu	*Ficus sp.* (L)
Mumu or Imumu	*Kigelia aethipica* (K. Schum.
Msesewe	*Rauvolfia caffra* (Sond.)
Mruka or Alfuranje	*Albizzia schimperjana* (Oliv.)
Mfurufuru	*Croton macrostachys* (Hochst.)
Kimaroro	*Combretum gueinzii* (Sond.)
Mkunga	*Salacia simtata* (Loes.)
Mladehe	*Turraea robusta* (Guerke)
Sodom apple	*Solanum incanum* (L)

APPENDIX B.2A — OLD MOSHI SERIES - KIBONGOTO VARIANT

Mjuju	*Dombeya sp.* (Car.)
Mrere, Mseri	*Ocotea usambarensis* (Eng.)
Mshishina, Mfifina	*Commiphora zimmermannii* (Eng.)
Mfurufuru	*Croton macrostachys* (Hochst.)
Msesewe	*Rauvolfia caffra* (Sond.)
Mkuyu	*Ficus sp.* (L)
Mbarajiji	*Clutia abyssinica* (J & Spach)
Mwaru	*Bridelia nicrantha* (Baill.)
Mkumburi	*Mimusops aedificatoria* (Mildbr.)
Mriri	*Erythrina abyssinica* (Lam.)
Mringa ringa	*Cordia holstii* (Guerke)
Mwilu	*Albizzia potersiana* (Bolle)
Mladeye	*Turraea robusta* (Guerke)
Mruka, Mfuranje	*Albizzia schimperiana* (Oliv.)
Mruwia	*Entandrophragme sp.* (C.DC.)

Ground Cover

Sporobolus pellucidus
Eragrostis sp.
Digitaria sp.
Cyperus sp.
Hyparrhenia sp.
Rhyncheletrum roseum

Common or Local Name	Scientific Name
APPENDIX B.2B	OLD MOSHI SERIES - OLD MOSHI VARIANT
Mbuko, Mpuko	Terminalia sericea (Burch.)
Mkuu	Ficus capensis (Thumb.)
Mringonu	Alangium chinense (Laur) Rehden.
Mchiyo	Olea welwitshii (Knobl & Schell)
Mbarajiji	Clutia abyssinica (Jamb. & Spach)
Mfuka	Faurea saligna (Harv.)
Mwilu	Albizzia petersiana (Bolle) Oliv.
Mruwia	Entandrophragma sp. (C.D.)
Mkumburi	Mimusops aedificatoria (Mildbr.)
Mera, Msera, Mwera	Acacia seyal (Del.)
Msasame, Msasa, Msamama	Gymnosporia rehmannii (Szysz.)
Mringaringa	Cordia holstii (Guerke)
Mfurufuru	Croton macrostachys (Hochst.)
APPENDIX B.2Bt	OLD MOSHI SERIES - KILEMA VARIANT
Muria, Mwarue, Mwarie	Teclea viridis (Verdoorn)
Mchiyo, Mchiho	Olea welwitschii (Knobl) (Gilg & Schell.)
Mruka	Albizzia schimperiana (Oliv.)
	Acacia hilotica (L) Willd ox (De)
Mringaringa	Cordia holstii (Guerke)
Mwilu	Albizzia petersiana (Bolle) Oliv.
Mborori	Cussonia sp. (Thumb.)
	Ground Cover
	Cynodon dactylon
	Digitaria sp.
	Hyparrhenia rufa
	Rhyncheletrum sp.
	Eragrostis sp.
	Andropogon sp.
APPENDIX B.2C	OLD MOSHI SERIES - MAMSERA VARIANT
Mdidi	Cassipovrea elliotii (Alston.)
Msesewe	Rauvolfia caffra (Sond.)
Mriri	Erythrina abyssinica (Lam.)
Mwasa	Rapanea chododendroides (Gilg)
Mborori	Cussonia sp. (Thumb)
Mwilu	Albizzia petersiana (Bolle) Oliv.)
Mruka	Albizzia schimperania (Oliv.)
Mkuyu	Ficus sp. (L)
Mringaringa	Cordia holstii (Guerke)
Mchio Mchiyo	Oloea welwitschii (Knobl.) Gilg. Schellenb.)

Common or Local Name	Scientific Name
	Ground Cover
	Eragrostis sp.
	Digitaria sp.
	Cynodon dactylon
APPENDIX B.3	KIBOHEHE SERIES
Mruka	Albizzia schimperiana (Oliv.)
Mwilu	Albizzia petersiana (Bolle) Oliv.
Mumu	Kigelia aethiopica (Deene)
Msesewe	Rauvolfia caffra (K.Schum.
Mringaringa	Cordia holstii (Guerke)
Mrera	Sechlea virdis (Verdoorn)
Mbarajiji (avocado)	Olatia abyssinica (Jaub & Spach.)
	Grevillea robusta
	Ground Cover
	Panicum maximum
	Cynodon dactylon
	Chloris gayana
APPENDIX B.4	SADALA SERIES
Mrera	Acacia seyal (Del.)
Mimarora	Combretum sp.
Mwesi	Trema guineensis
Mrinda	Croton silvatious (Hochst)
Mkuu	Ficus sp.
	Ground Cover
	Hyparrhenia dissolute
	Panicum maximum
	Cynodon dactylon
	Digitaria scalarum
	Indigofera sp.
	Aristida adscensionis
	Cyperus rotundus
	Sorghum verticilliflorum
	Chloris gayana
APPENDIX B.5A	MASAMA SERIES - MASAMA VARIANT
Mwana	Agauria salicifolia (Comm. ex. Lam. Hook f. ex. Oliv.)
Mrere (Camphor)	Ocotoa usumbbarensis (Engl.)
Mkuyu	Ficus sp. (L)

Common or Local Name	Scientific Name
Mumu or Imumu	Kigelia aethiopica (K.Schum.)
Mruka	Albizzia sp. (Dorazz.)
Mringaringa	Cordia holstii (Guerke)
Mfurufuru	Croton macrostachys (Hochst)
Msesewe	Rauvolfin caffra (Sond.)
Mruka	Albizzia schimperiana (Oliv.)

Ground Cover

Cyperus
Pennisetum clandestinum
Digitaria

APPENDIX B.5B MASAMA SERIES - LOMBETA VARIANT

Msamama	Gymnosperia rehmannii (Szysz.)
Mfurufuru	Croton macrostachys (Hochst.)
Masingo	Dodonaea sp. (L)
Iturua	Dodonaea viscosa (L)
Mpacho	(Myrica kilimandscharica (Eng.)
	(Myrica meyeri-johannis (Eng.)
Mwana	Agauria salicifolia (Hook.f.)
Masai	Syzyglium guineense (D.C.)
Mracha, Mrasha	Conopharyngia holstii (Stapf.)
Mringaringa	Cordia holstii (Guerke)
Mruka	Albizzia schimperiana (Oliv.)
Muhaa	Macaranga kilimandscharica (Pax.)

Ground Cover

Eragrostis tonuifolia
Cyperus sp.
Fimbristylis diphylla
Digitaria sp.
Indigofera sp.
Bracken-Pteridium aquilinum

APPENDIX B.5C MASAMA SERIES - MARINGA VARIANT

APPENDIX B.5D MASAMA SERIES - USHIRA VARIANT

Ficus sp.

Ground Cover

Hyparrhenia ruf.
Eragrostis sp.
Cyperus sp.

Common or Local Name	Scientific Name
APPENDIX B.6A	MANU COMPLEX - NRWAA VARIANT
Mkiu	Dombeya mastersii (Hook f.)
Mfu	Fagaropsis angolensis (Engl.)
	Herungana madagascariensis (Lam.)
Mbura	Parinari holstii (Engl.)
Mrere, Mseri	Ocotea Usambarensis (Engl.)
Mwana	Agauria salicifolia (Hook.f.)
Rangasama	Croton sylvaticus (Hochst.)
Masai	Syzygium guindense (Willd DC)
Mruka	Albizzia schimperiana (Oliv.)
Giant Hentler	Erica arborea
	Ground Cover
	Eragrostis sp.
APPENDIX B.6B	MANU COMPLEX - MANU VARIANT
Evenu	Cassia didymobotrya (Feson)
Mrido	Maesa Lanceolata (Forak)
Mracha, Mrasha	Conopharyngia holstii (Stapf.)
Mkufi	Newtonia buchananii (Baker) Gilb & Bout.
Uruka	Albizzia sp. (Durazz)
Masai	Syzygium guineense (Willd) DC
Masingo	Olea hochstetteri (Baker)
Iturua	Dodonaea viscosa (L)
Wattle	Acacia moliissima
Masile (hedge plant)	Dracena steudneri var. Kilimandscharica (Engl.)
Kiviru	Landolphia kilimanscharica (Stajrf.)
Muhaha, Muhaa	Macaranga kilimandscharica (Pax.)
Mawana, Mwana	Agauria salicifolia (Hook.f.)
Mtosi	Podocarpus milanjianus (Rendle)
Msesewe	Rauvolfin caffra (Sond.)
Mseri, Mrere	Ocotea usambarensis (Engl.)
Mrindo, Marido	Celtis africana (Burm.f.)
Mpache	(Myrica salicifolia (Hochst ex.A.Rich.)
Mwesi, Mshinga, Mwesi	(Myrica meyeri-johannis (Engl.)
	Trema orientalis (L) Bl.
Mkuyu	Trema guineansis (Ficalho)
Cypress (poor)	Ficus sp. (L)
Mwanga	Cypressus lusitanica
	Hagenia abyssinica (Bruce) (J.E.Gmel)
Mwawana	Paurindiantha holstii (K. Schum)
Mrindawa	Croton sylvatious (Hochst)
Mringoni	Alangium chinense (Leur.)
Mfurufuru	Croton macrostachys (A.Rich.)
	Pinusepatula
Mfwanji	Albizzia schimperiana (Oliv.)
Giant Heather	Erica arborea

Common or Local Name	Scientific Name
	Ground Cover
	Fimbristylis diphylla
	Rhyncheletrum repens
	Hyparrhenia sp.
	Eragrostic tenuifolia
	Sporobolus indicus, s. pyramidalis
	Poor Bracken Pteridium aguilinum
	Digitaria sp.
	Rumax usambarensis
	Cyperus sp.
APPENDIX B.7	UMBWE COMPLEX
Alfuranje, Mruka	Albizzia schimperiana (Oliv.)
Mringaringa	Cordia holstii (Guerks)
Mfurufuru	Croton macrostachys (Hochst.)
	Grevillia robusta
	Acacia brevispica (Harms)
Msesewe	Rauvolfia caffra (Sond.)
Cypress	Cupressus Lusitanica
	Ground Cover
	Ptoridium aquiliunum
	Eragrostis toniufolia
	Andropogon
	Pennisetum clandestinum
	Solanum incanum
APPENDIX B.8	MSINGA SERIES
Msasa	Ficuas exasperata (Vahl)
(Alfuranje) Mruka (Tall)	Albizzia schimperiana (Oliv.)
Mringaringa	Cordia holstii (Guerke)
Mfurufuru	Croton macrostachys (Hochst.)
Mwarie	Teclea viridis (Verdoorn)
Ndrugunu	Entandrophragma sp. (C.DC.)
Msesewe	Rauvolfia caffra (Sond.)
Meresi	Grevillea robusta
	Ground Cover
	Hyparrhenia dissoluta
	Panicum maximum
	Cyperus rotundus
	Digitaria scallarum

Common or Local Name	Scientific Name
APPENDIX B.9	KINDI SERIES
Mkondokonde	Pigeum africana (Kalkm)
	Prunus africana (Hook.f.)
(Alfuranje) Mruka	Albizzia schimperiana (Oliv.)
Mringaringa	Cordia holstii (Guerke)
Mfurufuru	Croton macrostachys (Hochst.)
Msesewe	Rauvolfia caffra (Sond.)
Kapok	
Mviri	Erythrina abysinica (Lam)
Meresi	Grevillea robusta
	Ground Cover
	Panicum maximum
	Digitaria scalarum
	Penuisetum
	Indigofera sp.
	Cyperus sp.
	Hyparrhenia sp.
	Chloris pyonothrix
APPENDIX B.10	SAMBARAI SERIES
Mbarajiji (Avocado)	Clutia abyssinica (Jamb & Spach)
Msesewe	Rauvolfia caffra (Sond.)
Msoo	Oxystigma msoo (Harms)
Kimaroro	Combretum sp. (Loefl.)
Mriri	Erythrina abyssinica (lam)
Mfurufuru	Croton macrostachys (Hochst.)
Mringaringa	Cordia holstii (Guerke)
Meresi	Grevillea robusta
Mruka	Albizzia schimperiana (Oliv)
Mwesi	Trema guineensis (Ficalho)
Idaawa, Mrindawa	Croton sylvaticus (Hochst.)
Mwezi	Trema orientalis (L) Bl.
Mwario	Techlea viridis (Verdoorn)
Mshamama	Cymnosporia rehmannii (Szysz)
	Ground Cover
	Solanum incanum
	Cynodon dactylon
	Sporobolus sp.
	Sorghum verticilliflorum
	Cyperus rotundus
	Digitoria scalarum
	Tridex repens
	Hyparrhenia dissoluta
	Panicum maximum
	Chloris pycnethrix
	Themeds triandra
	Indigofera sp.

Common or Local Name	Scientific Name
APPENDIX B.11	MRAWI SERIES
Mwesi	*Trema orientalis* (L) Bl.
Mruka	*Albizzia schimperiana* (Oliv)
Mfurufuru	*Croton macrostachys* (Hochst.)
Muha, Mhaha, Mhaa	*Macaranga kilimandschnarica* (Engl.)
Mwana	*Agauria salicifolia* (Comm. ex. Lem. Hook.F. ex Oliv)
Meresi	*Grevillia robusta*
Msenefu	*Olea africana* (Mill)
	Eucalyptus
Mwingomu	*Alangium chinense* (Low) Rehder
Masewo	*Rauvolfia caffra* (Sond.)
	Ground Cover
	Rumex usambarenis
	Digitaria sp.
	Bracken 4' tall
	Eragrostis tennuifolia
	Pennisetum clandestinum
APPENDIX B.12	UPARE SERIES
Mschishina (Mfifina)	*Commiphora zimmermannii* (Engl.)
	Euphorbia candelabrum (Trem ex Kotschy)
Mruwia	*Entandrophragma sp.* (C.DC.)
Mkumburi	*Mimusops aedificatoria* (Milldbr)
Mkuu	*Ficua capensis* (Thumb)
Mwilu	*Albizzia petersiana* (Bolle) Oliv
Kimororo	*Combretum sp.* (Loefl.)
Mruka	*Albizzia schimperiana* (Oliv)
Mfurufuru	*Croton macrostachys* (Hochst.)
Mklangoyo	*Allophylus sp.* (L)
Msesewe	*Rauvolfia caffra* (Sond.)
Mtemboe	*Ficus vegelii* (Hig.)
Mriri, Mdidi	*Erythrina abyssinica* (Lam)
Mkinyi	*Euclea divinorum* (Hiern)
Munga	*Acacia sp.* (Willd.)
	Ground Cover
	Hyparrhenia dissoluta
	Tridex repens
	Sorghum verticilliflorum
	Themeda sp.
	Aristida adscenscioris
	Digitaria
	Sorghum verticilliflorum
	Crotalaria sp.
	Rhyncheletrum roseum
	Urochloa sp.

Common or Local Name — Scientific Name

APPENDIX B.13 — SANGO SERIES

Mlama
Kimroro

Combretum binderanum (Kotschy)
Combretum sp. (Loofl)
Acacia stuhlmannii (Lamb)
Acacia drepanolobium (Harms)
Acacia mallifera (Vahl) (Benth)
Euphorbia candelabrum (Trem ex Kotschy)

Ground Cover

Cynodon dactylon
Heteropogon contortus
Digitaria sp.
Hyparrhenia filipendula
Hyparrhenia hirta
Cyperus rigidifolia
Seteria sp.

APPENDIX B.14 — KIBOUNI SERIES

Mimaroro

Mgunga

Mkaa

Combretum sp. (Loefl)
Acacia tortilis (Forsk) (Hayne)
Acacia stuhlmannii (Taub.)
Acacia nilotica (L) (Willd.ex) Del.
Warburgia stuhlmannii (Engl.)

Ground Cover

Pennisetum mezianum
Cynodon dactylon
Chloris roxburghiana (Shult)
Heteropogon contortus
Eragrostis superba
Aristidia adsamsimus
Indigofera sp.
Elousine indica
Cynodon plectostachys
Panicum maximum
P. Coleratum
Cenchrus ciliaris
Themeda triandra

Common or Local Name	Scientific Name
APPENDIX B.15	PUMWANI COMPLEX
	Commiphora schimperi (Engl.)
	Acacia stuhlmannii (Taub.)
	Acacia mollifera (Vahl) (Bonth)
	Acacia nigrescens (Oliv)
	Combretum sp. (Loefl.)
Kimaroro	*Acacia tortilis var. spirocarpa* (Forsk) (Hayne)
	Ground Cover
	Indigofera sp.
	Digitaria sp.
	Hyparrhenia filipendula
	Hyparrhenia dissoluta
	Eragrostis ciliarensis
	Aristida adscensionis
APPENDIX B.16	NANGA CREEP COMPLEX
Mborori	*Cussonia sp.* (Thumb)
Mkuu	*Ficus capensis* (Thumb)
Mboromo	*Albizzia gumifera* C.A.S.M.
Msesewe	*Rauvolfia caffra* (Sond.)
(Alfuranje) Mruka	*Albizzia schimperiana* (Oliv)
Mriri	*Erythrina abyssinica* (Lam)
Mwasa	*Rapanea chododendroides* (Mez)
Meresi	*Grevillea robusta*
Cypress	*Cypressus lusitanica*
	Acacia nilotica sub sp. subalata (Vatke)
	Ground Cover
	Rhyncheletrum
	Sporobolus pyramidalis
	Hyparrhenia rufa
	Eragrostis siliapensis
	Digitaria scalarum
	Aristida sp.
	Sporobolus sp.
	Heteropogon contortus
	Setaria splendida

Common or Local Name	Scientific Name
APPENDIX B.17	HOLILI CREEP COMPLEX
Kimororo	*Combretum sp.* (Loefl)
	Acacia nilotica sub sp. subalata (Vatke)
	Acacia stuhlmannii (Taub)
	Acacia mellifera (Vahl) (Benth)
	Ground Cover
	Sporobolus fimbriatus
	Cochrus ciliaris
	Aristida adscensionis
	Hyparrhenia sp.
	Heteropogon contortus
	Digitarium scalarum
	Indigofera sp.
APPENDIX B.18A	MASIA COMPLEX - MASIA VARIANT
Mwindiri, Mdidi	*Erithryna abyssinica* (Lam)
Menefu	*Olea africana* (Mill)
Mkongoni	*Trichelia roka* (Forsk)
Mkondekonde	*Mimusops sp.* (L)
Mrashna	*Conopharyngia holstii* (Stapf.)
	Ilex mitis (Radlk.)
	Rapanea rhododendroides (Mez)
	Eckebergia rueppelliana (A. Rich)
Podo	*Podocarpus milanjianus* (Rendle)
Mruka	*Albizzia schimperiana* (Oliv)
Mrilu	*Albizzia petersiana* (Oliv)
Mringonu	*Alangium chinense* (Rend)
Mpache	*Myrica salicifolia* (Hochst ex A. Rich.)
Mwana	*Agauria salicifolia* (Hook.f.)
	Xymalos monospora (Baill.)
Mracha	*Conoplharyngia johnstonii* (Stapf)
Mwanana	*Paurindiantha holstii* (K. Schum)
Muhaa	*Macaranga kilimandscherica* (Pax)
Mwanga	*Hagenia abyssinica* (Willd)
(Brambles)	*Rubus sp.*
Mwengele, Mwengeli	*Cissuspadenocaulis* (Steud.)
Msingo	*Olea bochstetteri* (Baker)
	Ground Cover
	Trifolium semipilosum
	Pennisetum clandestinum
	Panicum tricoclaudum

Common or Local Name	Scientific Name
APPENDIX B.18B	MASIA COMPLEX - MARUVENI VARIANT
Wattle	Acacia mollissima
Mriri	Eruthrina abyssinica (Lam)
Mwarue	Bridelia micrantha (Hochst)
Modi, Mbodi	Pigenum africanum
Motali, Muhatali	Techlea viridis (Verdoorn)
Msenefu	Olea africana (Mill)
Mringaringa	Cordia holstii (Guerke)
Mkrori	Cussonia sp. (Thumb)
	Ground Cover
	Exotheca abyssinica
	Pennisetum clandestinum
	Digitaria sp.
	Eragrostis pyramidalis
APPENDIX B.19A	MARANGU SERIES - MARANGU VARIANT
Mruka	Albizzia schimperiana (Oliv)
Msesewe	Rauvolfia caffra (Sond.)
Muliandege	Turraea robusta (Guerke)
Mfurufuru	Croton macrostachys (Hochst)
Mwezi	Trena orientalis (L) Bl
Mringoni	Alanigiua chinense (Rehd)
	Vernonia sp. (Schrab)
Lantana	Lantana salviifolia (Jacq)
Lippia	Lippia ukambensis (Vatke)
	Cordia abyssinica (R.Br.)
Mkufi	Newtonia buchananii (Baker) Gilb & Bout.
Muhai	Mascaranga kilimandscharica (Pax)
Msingo	Olea hochstetteri (Bak)
Mwengere, Mwengeli	Cissus adenocaulis (Stend)
Mrie	Chlorophora excelsa (Benth & Hook.f.)
	Olea kilimandscharica (Knobl)
	Eucalyptus
Mwanana	Paurindiantha holstii (K.Schum)
	Ground Cover
	Ponnisetum clandestinum
	Preridium aquilinium
	Dracena steudneris var. kilimandscharicaa
	Rumex sp.
	Eragrostis sp.
	Fimbristylis diphylla
	Cynodon dactylon

Common or Local Name	Scientific Name

APPENDIX B.19A (continued)

	Trifolium semiphosium
	Cyperus rotundus
	Eragrostis curvula
	Andropogon sp.
	Sporobolus sp.

APPENDIX B.19B MARANGU SERIES - MKUU VARIANT

Mruka	Albizzia schimperiana (Oliv)
Mwarue	Teclea viridis (Verdoorn)
Mbodi, Mbordi	Pigeum africanum
Mborori	Cussonia sp. (Thumb)
Mringaringa	Cordia holstii (Guerke)
Meresi	Grevillea robusta
Mwilu	Albizzia petersiana (Bolle) (Oliv)
Mrenefu	Olea african (Lam)
Mfurufuru	Croton macroschachys (Hochst)

Ground Cover

Erogrostis racemosa
Hyparrhenia hirta
Andropogon dummeri

APPENDIX B.19C MARANGU SERIES - MRERE VARIANT

Mtembo	Ficua vogelii (Hiq)
Msenefu	Olea africana (Lam)
Mbodi	Pigeum. africanum
Mfurufuru	Croton macrostachys (A.Rich)
Maidi	Erythrina abyssinica (Lam)
Msesewe	Rauvolfia caffra (Sond)
Mruku	Albizzia schimperiana (Oliv)
Mwezi	Trema orientalis (L) Bl.

Ground Cover

Hyparrhenia sp.
Harpachne schimperi
Rhynchelerrum sp.
Aristida adscensionis (L)

Common or Local Name	Scientific Name
APPENDIX B.20	SAMANGA COMPLEX
Msesewe	*Rauvolfia caffra* (Sond.)
Mkongonia	*Trichilia emetica* (Vahl)
Mriri	*Erythrina abyssinica* (Lam)
Mringaringa	*Cordia holstii* (Guerke)
Kimaroro	*Combretum guineese* (Splendens, Exell)
Mruka	*Albizzia schimperiana* (Oliv)
	Grevillea robusta
	Ground Cover
	Hyparrhenia sp.
APPENDIX B.21	HIMO SERIES
	Acacia mellifera (Vahl) (Benth)
	Ficus rafensis (Thumb)
	Combretum guineese (Sond.)
Kimaroro	*Cordia holstii* (Guerke)
Mringaringa	*Rauvolfia caffra* (Sond)
Msesewe	*Tapura fischeri* (Engl)
Mbambua	*Acacia tortilis* (Forsk)
	Acacia stuhlmannii (Taub)
	Ground Cover
	Urochloa
	Hyparrhenia dissoluta
	Panicum maximum
	Aristida adscensionis
	Digitaria scalarum
	Hyparrhenia filipendula
	Sorghum verticilliflorum
	Indigofera sp.
APPENDIX B.22	KOKIRIE COMPLEX
Msesewe	*Rauvolfia caffra* (Sond)
Mwuri, Mfaronje	*Albizzia potersiana* (Oliv)
Mengere	*Cussonia sp.* (Thumb)
Parichacha	*Croton macrostachys* (Hochst. ex A. Rich)
Mhaa	*Mararanga kilimandscharica* (Engl)
Mwesi	*Trema orentalis* (L) Bl
Mpache	*Myrica salicifolia* (Hochst ex A. Rich)
Masai	*Syzygium guineense* (DC)
Mringonu	*Alangium chinense* (Rehd)

Common or Local Name	Scientific Name

APPENDIX B.22 (continued)

Ground Cover

	Cyperus rotundus
	Sporbolus pyriamidalis
	Eragrostis tenuifolin
	Pennisetum elandestinum
	Andropogon sp.
	Digitaria sp.
	Paspalum sp.
	Rhyncheletrum roseum

APPENDIX B.23 — MWIKA SERIES

Mfuranje	Albizzia schimperiana (Oliv)
Masai	Syzgium guineense (Willd) (DC)
Mringoni	Alangium chinense (Rehd)
Mesi	Trema orientalis (L) Bl
Loliondo	Olea welwitchii (Gilg & Schnell)
Mkuu	Ficus sp. (L)
Msesewe	Rauvolfia caffra (K. Schum)
Mfurufuru	Croton macrosiachys (Hochst)
Mringaringa	Cordia holstii (Guerke)

Ground Cover

	Sporobolus pyramiadalis
	Digitaria scalarum
	Eragrostis curvula
	Rhynchleletrum roseum
	Cyperus rotundus
	Solanum incanum

APPENDIX B.24 — KONDENI SERIES

Kimaroro	Combretum gueinzii (Sond)
Mringaringa	Cordia holstii (Guerke)
Mango	Megifera indica
Msesewe	Rauvolfia caffra (K.Schum)
	Acacia mellifera (Vahl) (Benth)
	Acacia tortilis (Forsk) Hayne
Mfurufuru	Croton macrostachys (Hochst)

Ground Cover

	Hyporrhenia dissoluta
	Rhyncheletrum roseum
	Sporobolus sp.

Common or Local Name		Scientific Name
APPENDIX B.24 (continued)		Aristida sp.
		Digitaria sp.
		Eragrostis sp.
		Indigofera sp.
		Panicum maximum
APPENDIX B.25A	MAHIDA SERIES - MAHIDA VARIANT	
Kimaroro		Combretum gueinzii (Sond)
Mkuu		Ficus carpensis (Thumb)
Mdidi, Mriri		Erythrina abyssinica (Lam)
Munga		Acacia nilotica (L) Willd ex De
Molangoya		Allophylus sp. (L)
Mpuko		Terminalia Sericea (Burch)
	Ground Cover	
		Hyparrhenia sp.
		Eragrostis superba
		Aristida adscensious
		Cynodon dactylon
APPENDIX B.25B	MAHIDA SERIES - MTEMBWENI VARIANT	
Mkuyu		Ficus sp. (L)
	Ground Cover	
		Aristida sp.
		Hyparrhenia disoluta
		Digitaria sp.
		Cynodon dactylon
		Eragrostis superba
APPENDIX B.26	KIMANGA SERIES	
		Acacia mellifera (Vahl) (Benth)
		Euphorbia candelabrum (Trem ex Korschy)
		Combretum sp.
		Acacia stuhlmannii (Taub)
		Acacia tortilis (Forsk) Hayne
	Ground Cover	
		Cynodon dactylon
		Chloris rozburghiana
		Aristida adscensionis
		Heteropogon contortus
		Solanum incanum

Common or Local Name	Scientific Name
APPENDIX B.27	HURUMA SERIES
Mriri, Ndiri	Erythrina abyssinica (Lam)
	Acacia polyacantha (Willd)
Mlenbo	Ficus vogelii (Miq)
Msesewe	Rauvolfia caffra (Sond)
	Ground Cover
	Heteropogon contortus
	Hyparrhenia dissoluta
	Aristida adscensionis
	Rhyncheletrum roseum
	Hyparrhenia rufa
	Eragrostis curvula
	Sorghum verticilliflorum
	Stylosanthes sp.
	Indigofera sp.
APPENDIX B.28A	MENGWE CREEP COMPLEX - MENGWE VARIANT
Mwindidi	Erythrina abyssinica (Lam)
Mwasa	Rapanea rhodindrodes (Mez)
Mriri, Mdiri	Cassipourea malosana (Bak) Alston
Msesewe	Rauvolfia caffra (Sond)
Mfurufuru	Croton mecrostachys (Hochst)
Mkuyu	Ficus Sp. (L)
Mwarue	Tacloa virid's (Verdorn)
	Ground Cover
	Aristidida adsiensionis
	Hyparrhenia rufa
	Rhyncheletrum riolum
	Setaria splendida
APPENDIX B.28B	MENGWE CREEP COMPLEX - KILEO VARIANT
Mwindidi	Erythrina abyssinica (Lam)
	Ground Cover
	Aristida sp.
	Sporobolus sp.
	Heteropogon contortus

Common or Local Name	Scientific Name
APPENDIX B.29	UBAA COMPLEX
Mdidi, Ndidi	*Cassipourea eliiottii* (Alston)
Mkinyi	*Euclea divinorum* (Hiern)
Malangole	*Allophylus sp.* (L)
Msindi	*Diosphyros mespiliformis* (A.DC)
Mwaha	*Maranga kilimandscharica* (Pax)
Mkwaju	*Tamarindus indica* (L)
Meresi	*Grevillia robusta*
	Dodo aea viscosa (L)
	Ground Cover
	Cyperus sp.
	Sporobolus pyramidalis
	Eragrostis curvula
	Hyparrhenia rufa
	Heteropogon contortus
	Rumex sp.
	Rhyncheletrum roseum
	Erotheca abyssinica
	Andropogon dummeri
APPENDIX B.30	KITALATO SERIES
Mringandi	*Acacia sp.*
Mnyakatu	*Acacia polyacantha* (Willd)
Mlangoli	*Aloophylus sp.* (L)
	Euphorbia candelabrum (Trem ex Kotschy)
	Acacia stuhlmannii (Taub)
Imumu	*Kigelia aethipica* (K.Schum)
Mkuyu	*Ficus sp.*
	Ground Cover
	Chloris roxburghiana
	Heteropogon contortus
	Aristida adscensious
	Cenchrus ciliaris
	Cynodon dactylon
	Eragrostis superba
	Eragrostis holstii
	Sporobolus pyramidalis
	Hyparrhenia rufa
	Harpachne schimperi
	Digitaria scalarum

Common or Local Name	Scientific Name
APPENDIX B.31	USANYI SERIES
Mlandae	Turraea robusta (Guerke)
Mringaringa	Cordia holstii (Guerke)
Msesewe	Rauvolfia caffra (K.Schum)
Mruka	Albizzia schimperiana (Oliv)
	Ground Cover
	Hyparrheinia rufa
	Eragrostis superba
	Rhyncheletrum roseum
	Sporobolus pellucirus
	Digitaria scalarum
APPENDIX B.32	USERI SERIES
Mringaringa	Cordia holstii (Guerke)
Mlandee	Croton megalocarpus (Hutch)
Muliandege	Turrea robusta (Guerke)
Wattle	Acacia mollissima
Meresi	Grevillia robusta
Cypress	Cupressur lusitanica (poor)
	Ground Cover
	Eragrostis tenufolia
	Heteropogon contortus
	Digitaria sp.
	Hyparrhenia sp.
APPENDIX B.33	KOOTI SERIES
Mrilu	Albizzia petersiana (Oliv)
Migunga	Acacia abyssinica (Hochst)
Mwezi	Trema guineensis (Fichab)
	Ground Cover
	Fimbrystylis diphylla
	Eragrostis sp.
	Aristida adscensionis
	Hyparrhenia hirta
	Sporobolus indicus
	Digitaria sp.
	Poor Pyrethrum

Common or Local Name	Scientific Name
APPENDIX B.34	UHINI SERIES
	Artemesia afra (L)
Mnengenenye	Caliniera coeffeoides (Del)
Mneri (Camphor)	Ocotea usambarensis (Engl)
Mwanga	Hagenia abyssinica (Willd)
Mwana	Agauria salicifolia (Hook f. ex Oliv)
Masingo	
Wattle	Acacia mollissima
	Ground Cover
	Eragrostis tenuifolia
	Paspalum sp.
	Cyperus sp.
	Ryparrhenia hirta
	Rhyncheletrum repens
	Dicanthium sp.
	Fimbrstylis diplylla
	Pennisetum clandestium
	Bracken (poor)
	Erica arborea
APPENDIX B.35	MASHIMA COMPLEX
Mfurufuru	Croton macrostachys (Hochst)
Mracha, Mrashe	Conopharyngia holstii (Sapf)
Msenefu	Olea african (Mill)
Muhaa, Mhaa	Macaranga kilimandscharica (Pax)
Ndiri	Xymalos monspora (Harv) (Baill ex Warb)
Menengenenge	Galiniera coffeoides (Del)
Mwana	Agauria salicifolia (Hook f. ex Oliv)
Mseri	Ocotea usambarensis (Engl)
Mwanga	Hagenia abyssinica (Bruce) (J.F. Gmel)
Mtosi	Podocarpus milanjianus (Rendle)
	Cassipourea malossana (Bak Alste)
	Eckebergia ruepelliana (A.Rich)
	Fagaropsis angolensis
Molangi	Allophylus sp. (L)
50' Forest lianas, ferns	
	Albizzia sp. (Durazz)
Giant heather	Erica arborea (L)
APPENDIX B.36	KIMANYATU SERIES
Migunga	Acacia abyssinica (Hochst ex Benth)
Mruka	Albizzia schimperiana (Oliv)
Mfarufuru	Croton macrostachys (Hochst)

Common or Local Name	Scientific Name
APPENDIX B.36 (continued)	
	Ground Cover
	Pennisetum clandestinum
	Eragrostis sp.
APPENDIX B.37	NANJARA SERIES
Mrera	Acacia seyal (Del)
Mfurufuru	Croton macrostachys (Hochst)
Mhesi	Trema guineense (Ficalho)
Mdaka, Mduka	Albizzia gummifera (J.F. Gmel) C.A. Sm
Muaka	Allantlackia stuhlmannii (Engl)
Migunga	Acacia abyssinica (Hochst)
Mriri	Erythrina abyssinica (Lam)
Mnyakata	Acacia polycantha (Willd)
	Ground Cover
	Mexican marigold
	Lantana sp.
	Themeda triandra
	Hyparrhenia filipendula, H. hir
	Eragostis sp.
	Eragostis superba
APPENDIX B.37	
Mriri	Erythrina abyssinica (Lam)
Mnyakata	Acacia polyacantha (Willd)
Mrera	Acacia seyal (Del)
Mfurufuru	Croton macrostachys (Hochst)
Mhesi	Trema guineense (Ficalho)
Mdaka, Mduka	Albizzia gummifera (J.F. Gmel) (C.A. Sm)
	Acacia stuhlmannii (Taub)
	Combretum sp. (Loefl)
	Ground Cover
	Chloris gayana
	Hyparrhenia filipendula
	Eragrostis superba
	Themeda triandra
	Eragrostis sp.
	Lantana sp.
	Mexican marigold

Common or Local Name	Scientific Name
APPENDIX B.38	ALLUVIAL/COLLUVIAL COMPLEX
Mera	Acacia seyal (Del) Lantana salviifolia
	Ground Cover
	Cynodon dactylon Cenchrus ciliaris Eragrostis sp.
APPENDIX B.39	MLOMBEA COMPLEX
Mroma	Cordyla africana
APPENDIX B.40	SAMBALA COMPLEX
	Acacia mellifera (Vahl) (Benth) Acacia stuhlmannii (Taub) Acacia drepanalobium (Harms ex Sjostedt) Acadia nilotica (L) (Willd ex.) Del. Acacia seyal (Del) Combretum sp. (Loefl)
	Ground Cover
	Arista adscensionis Chloris rexpurghiana Digitaria scalarum Eragrostis superba Rhyncheletrum repens Cynodon dactylon Sporobolus fimbriastus

APPENDIX C

METHODS OF SOIL ANALYSIS

The soils were analyzed by the standard procedures in operation at the chemical laboratory, Tengeru. Bases were extracted by leaching the soils with normal ammonium acetate at pH 7.0. Calcium was determined by the oxalate method, magnesium by precipitation with 8-hydroxy-quinoline, manganese colorimetrically after oxidation with potassium periodate, and sodium and potassium using an Eel flame photometer. Exchange capacity was assessed by removal of adsorbed ammonia using normal potassium sulphate and distillation of the displaced ammonia. Organic carbon was assayed by the Walkley and Black Method (1934) assuming 80 percent recovery of carbon and total nitrogen according to Bremner (1960). Mechanical analysis was by the hydrometer method using a mixture of sodium silicate and sodium hexametaphosphate as dispersing agent. Total and organic phosphorus were analysed using the method described by Walker and Adams (1958). The pH was measured in both M/100 in 1:2.5 suspension of calcium chloride and in 1:5 soil/water suspension.

REFER TO
FICHE

4 OF 6

FOR

FIGURE(S):

MAP 1

SOILS

REFER TO FICHE

5 OF 6

FOR

FIGURE(S):

MAP 2

NATURAL VEG. AND

Present LAND USE

REFER TO FICHE

6 OF 6

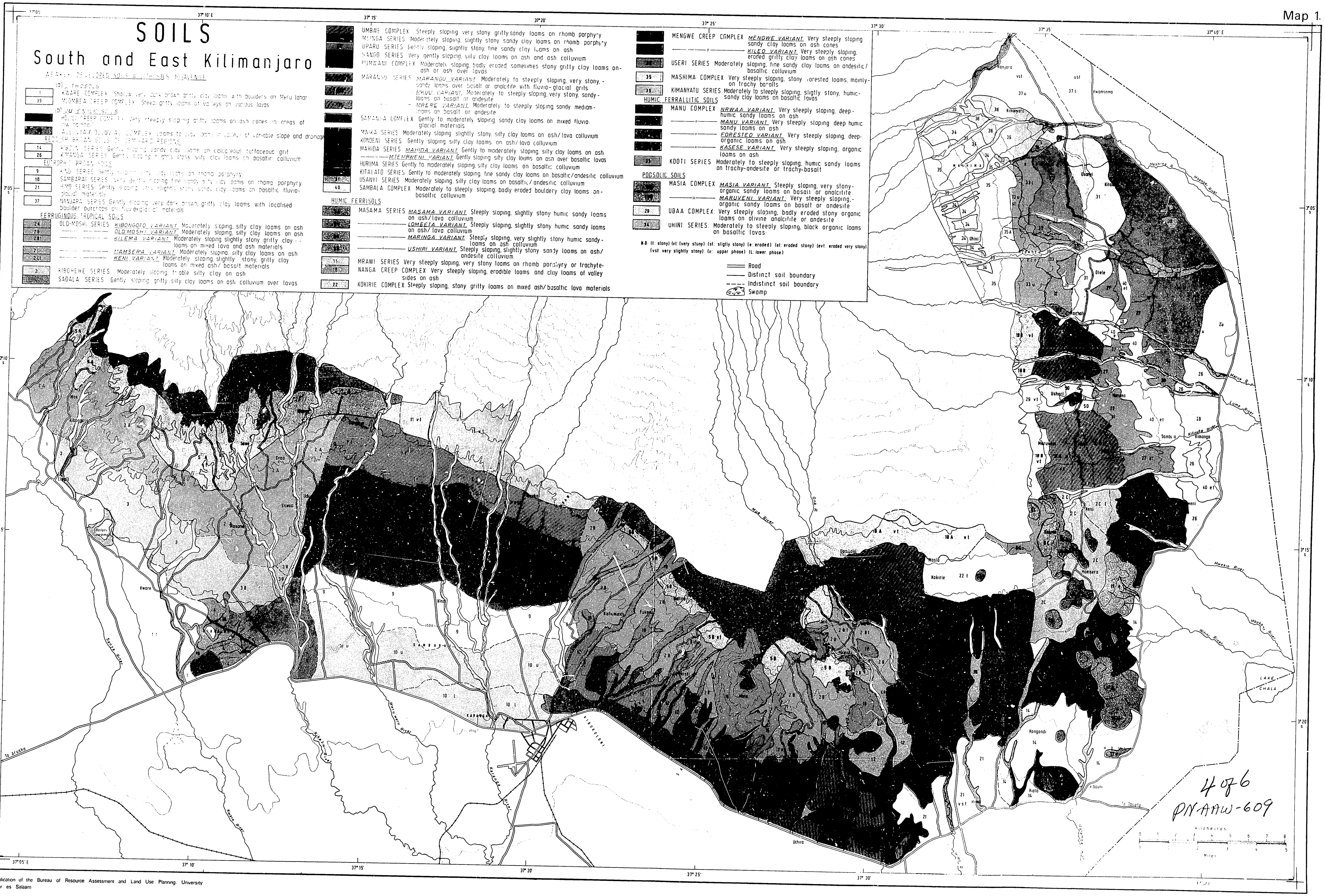
FOR

FIGURE(S):

MAP 3

Land use Potential

Map 1.



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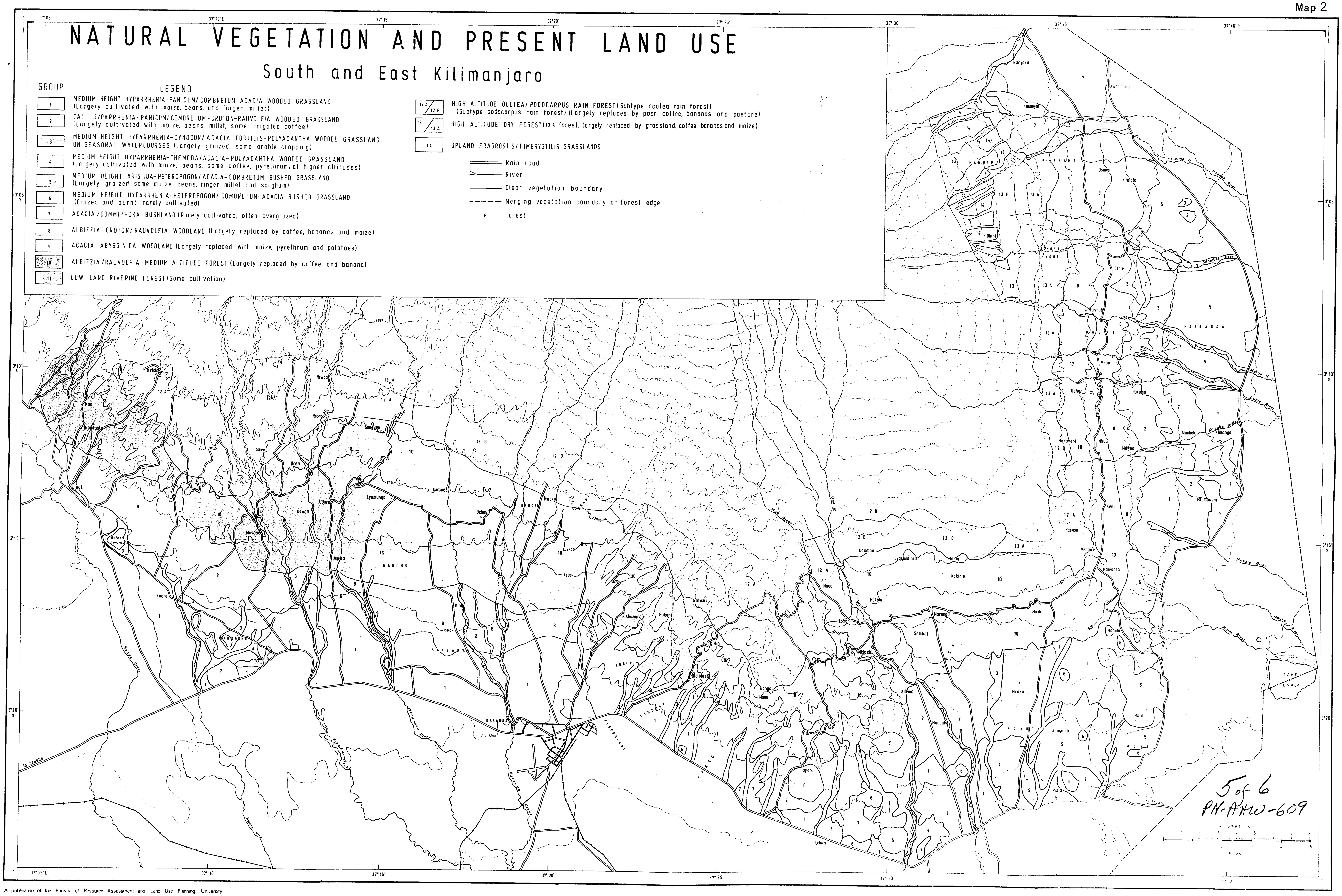
This map accompanies a study by G D ANDERSON



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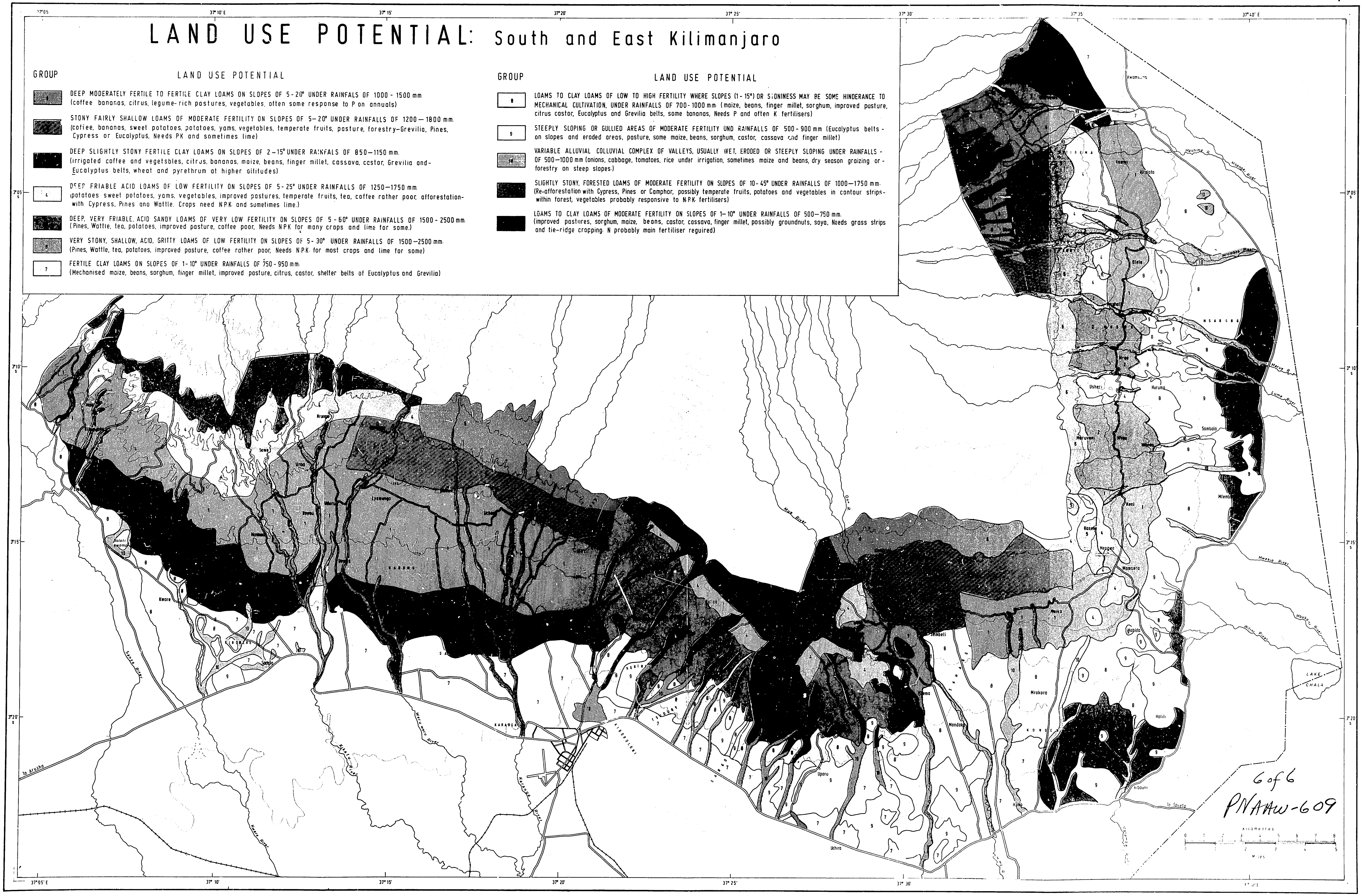
Map 3.



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