SOILS OF THE CHUKA-SOUTH AREA, KENYA

by

T. DE MEESTESTER & D. LEGGER (Eds)

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ABSTRACT

T. de Meester & D. Legger (Eds.)
1988 Soils of the Chuka-South Area
Kenya.

The Chuka-South Area, named after the Chuka Division, is east of the Mount Kenya. The area surveyed covers about 1500 km^2 and includes big parts of the Embu and Meru Districts and a small part of Kitui District. Altitude ranges from 2200 m in the north-west to about 400 m in the east. Geology, geomorphology, hydrology, soil fertility, erosion hazard, climate and agro-ecological zones are described and presented in maps and figures. Soils are defined by physiography and taxonomy and depicted on a soilmap of scale 1:100 000. Factors in their formation are also discussed. There is a full chapter on Land-use and Vegetation with a map on 1:100 000. There is also a chapter on Agriculture and one on Landevaluation describing existing land utilization types in detail. A detailed account is given of the rating procedures on the basis of land qualities.
Free descriptors: Landevaluation, soil suitability, land qualities, farm type, ecological zone, soil formation, geology, geomorphology, land-use, vegetation, climate, Kenya.

Soil correlation excursion by TPIP students and senior staff of KSS (Basement Complex). Photo T. de Meester.

Field instruction first group TPIP students (deep humic Nitisols on pyroclastic rocks, Lahar Complex). Photo A. Veldkamp.

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PREFACE

This report with soil map covers the Southern half of mapsheet 122 (CHUKA-SOUTH) of the Reconnaissance Soil Map of Kenya at scale 1:100000. It has been prepared by the Training Project in Pedology (T.P.I.P.) of the Agricultural University of Wageningen, The Netherlands. The Kenya Soil Survey (KSS), Nairobi, has done the northern half and will also prepare the final map and report of the entire mapsheet 122 (R16, Soils of the Chuka Area). This procedure required a close cooperation between the surveyors, soil correlators and editors of the two participating organizations.

The Training Project in Pedology was approved by the government of Kenya in 1973. It operated in Kisii between 1973 and 1979. It then moved to Kilifi where it operated between September 1979 and November 1982. After a spell of 2 years, it moved to the Chuka Area (between Embu and Meru) in March 1985.
The project was established jointly by the Agricultural University of Wageningen, The Netherlands, the Ministry of Agriculture of Kenya and the Faculty of Agriculture of the University in Nairobi. Its main aim has been the training of students of the Agricultural University, Wageningen, in soil survey, land evaluation and related subjects. Several MSc-students of the University of Nairobi have participated as well.

The cooperation between the Kenya Soil Survey and the Training Project in Pedology, which was started already in 1973, has certainly culminated in the Chuka-Project, as explained above. However, the activities of the T.P.I.P. in Kenya came to a full stop in August 1986 because the Agricultural university of Wageningen decided to re-arrange its oversea's projects and to leave Kenya, after thirteen years of fruitfull collaboration with the Kenyan Government.

Both the Training Project in Pedology and the Kenya Soil Survey are confident that this report and its map will serve as a source of information on soils and landuse in the Chuka Area and that it will contribute to the agricultural development of the eastern slopes of Mount Kenya.

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SUMMARY AND CONCLUSIONS

The Chuka-South Area covers the southern half of the Quarter Degree Sheet 122 of the Survey of Kenya. This is about 154.000 hectares. Altitude ranges from 2.200 m in the north-west to about 450 m in the east. Average annual rainfall ranges from approximately 2.400 mm in the western part to about 600 mm in the east and average annual evaporation ranges from 1.650 mm to 2.220. The middle and eastern parts have two marked wet seasons: a "long" one from March to May and a "short" one from October to December. The "long" wet season predominates going west with some intermediate rains in between. As result of the pronounced gradient in altitude and climate between west and east, the area shows a regular succession of agro-climatic zones in the same sense. Respectively forest (LH0), Tea-dairy (LH1); coffee (UM2); sun flower-maize (UM4); cotton (LM3) and livestock-millet (LM5 and IL5).

The Chuka-South Area can be separated geologically into two halves: the volcanic western part and a basement-system eastern part. The volcanic part has Footridges on the middle and lower slopes of Mount Kenya separated by major and minor valleys. Here and there are High Level Uplands and a Plateau area extends at the foot of the lowest slopes. The transition to the basement-system is a steep major scarp in the south and gradual north of it. The eastern (basement-system) part is less sloping than the western area and shows several different land forms such as (low level) Mountains, Hills, (low level) Uplands, Minor Scarps, Plateaus and Valleys.

The soils of the footridges derived from volcanic parent material, mainly consolidated pyroclastic rock (lahar-type), are very deep, permeable uniforms red clays, almost irrespective of relief class. The very narrow valley bottems have waterlogged clays. The soils of the volcanic plateau's are also derived from pyroclastic rock, but they are a moderately deep to shallow yellowish clayey complex and predominantly pisoferric.
Special features in the plateau-area are isolated circular or oval depressions (bottomlands) with waterlogged soils.

Landuse on the volcanic soils is forest, tea and dairy, coffee and maize, differentiated in zones according to altitude as mentioned before. The farming type is mainly smalholder, permament farming.

The soils of the various landforms in the basement-system area are derived from basement-rock of various origin: granitoid gneisses, gneisses rich in ferromagnesium minerals and undifferentiated banded gneisses. Such soils are predominantly complex, moderately deep to shallow, very stony yellowish red loam to clayloam. Permeability is low, mainly as result of crusting and compaction of the surface soil. Erosion is common in this area. Mountains and hills have very shallow and rocky soil. Here and there are remnants of old riverterraces, often with patches of deep, dark calcareous cracking vertic clays.

Landuse in the basement-system area is cotton, maize, millet and extensive grazing, differentiated according to the ecological zone as mentioned before. The farming type is mainly smallholder shifting cultivation and livestock farming.

The present natural vegetation is strongly connected with soil, altitude, relief and climate. The seven main vegetation landscapes of the Chuka-South area are named after their common, or characteristic plant species (including the common tree-crops coffee and mango). The present vegetation map has contributed to a slight revision of the current agro-ecological map.

The farming, the landuse and the farming systems of the area were studied in study-area's traversing the major agro-ecological zones and the four major farming systems encountered were duly described viz: tea-coffee dairy farming, coffee-maize-beans farming, cotton-maize-pidgeonpea farming and livestock-millet-cotton farming. The major foodcrops in the area are maize and beans, the major cash crops tea, coffee and cotton.

The land of the area was evaluated and classed for a number of relevant Land Utilization Types defined by various attributes according to the FAO-framework for land evaluation as modified and adapted by the Kenya

Soil Survey. Results are summarized in Tables 47 and 48.

The major physical constraint in the wet volcanic part seems nutrient availability, in the dry basement area moisture availability, low erosion resistance and also nutrient availability.

Improvements by a general upgrading of farm management seem physically feasible in the wetter areas, but are much counteracted by an ever increasing fragmentation of farms as result of overpopulation. In the drier area's better use of river-water for irrigation, improved livestock keeping, soil conservation, waterconservation, the introduction of improved (drought-resistant) food crops and the introduction of credit-backed fertilizer programmes seem real possibilities for improvement.

1. THE ENVIRONMENT

1.1 SITUATION, COMMUNICATION AND POPULATION

The survey area is covered by two topographic mapsheets at scale 1:50,000 i.e. Chuka (122/3) and Ishiara (122/4), together comprising the southern half of quarter-degree sheet 122 (Chuka) of the soilmap of Kenya at scale 1:100,000. See Fig. 1 and 2. The extend of this area, hereafter called "Chuka-South Area" is approximately 154 000 ha. It is bounded by latitudes 0° 15' S and 0° 30' S, and by longitudes 37° 30' E and 38° 00' E.

The elevation of the area ranges from about 2200 m in the north-west to about 450 m in the east. Figure 2 shows also that the gradient is gradual. However, a difference in altitude of about 1800 m within some 60 km causes strong gradients in climate, and hence in landuse and living conditions. The western part of the area is high, cool and wet and densely populated, whereas the east is low, hot, dry and rather deserted.

The area is well accessible by a large number of murram roads and tracks, mainly running west-east. A major and partly recently constructed tarmac road, connecting Embu and Meru runs south-north through the west part of the area (the so-called upper-road). Another major (murram) road runs west-east-south-north through the east part, connecting Embu and Meru via Ishiara (the so-called lower road).

The project headquarters were located in Kivuria, Kyeni location (Runyenjes Division, Embu District). There were subcamps in Ishiara, Kaanwa and Kanjuki.

Administratively the Chuka-South Area belongs to three districts, Embu, Meru and Kitui. It is subdivided in locations and sub-locations. In Appendix 6.6 a list of the locations and sub-locations in the area is given together with some details on population and area. It also contains a map showing the existing sublocations.

The area is densely populated. One has estimated the population in 1979 between 240000 and 270000 persons (Population Census 1979).

Fig. 1. Situation of the Chuka-South Area.

As the size of the area is 1,543 km^2, this amounts to an average density of 155 to 175 persons per km^2. With an assumed population growth of 4.0% per year, the 1985 population density may be between 196 and 221. These, however, are average densities for the area. Settlement is very much concentrated in the ecologically more favourable zones, roughly along the Embu-Meru road, but also west of it between the road and the forest. Population density ranges here from 300-700 persons per km^2. In the lower and drier zone, population density can be as low as 30 persons per km^2.

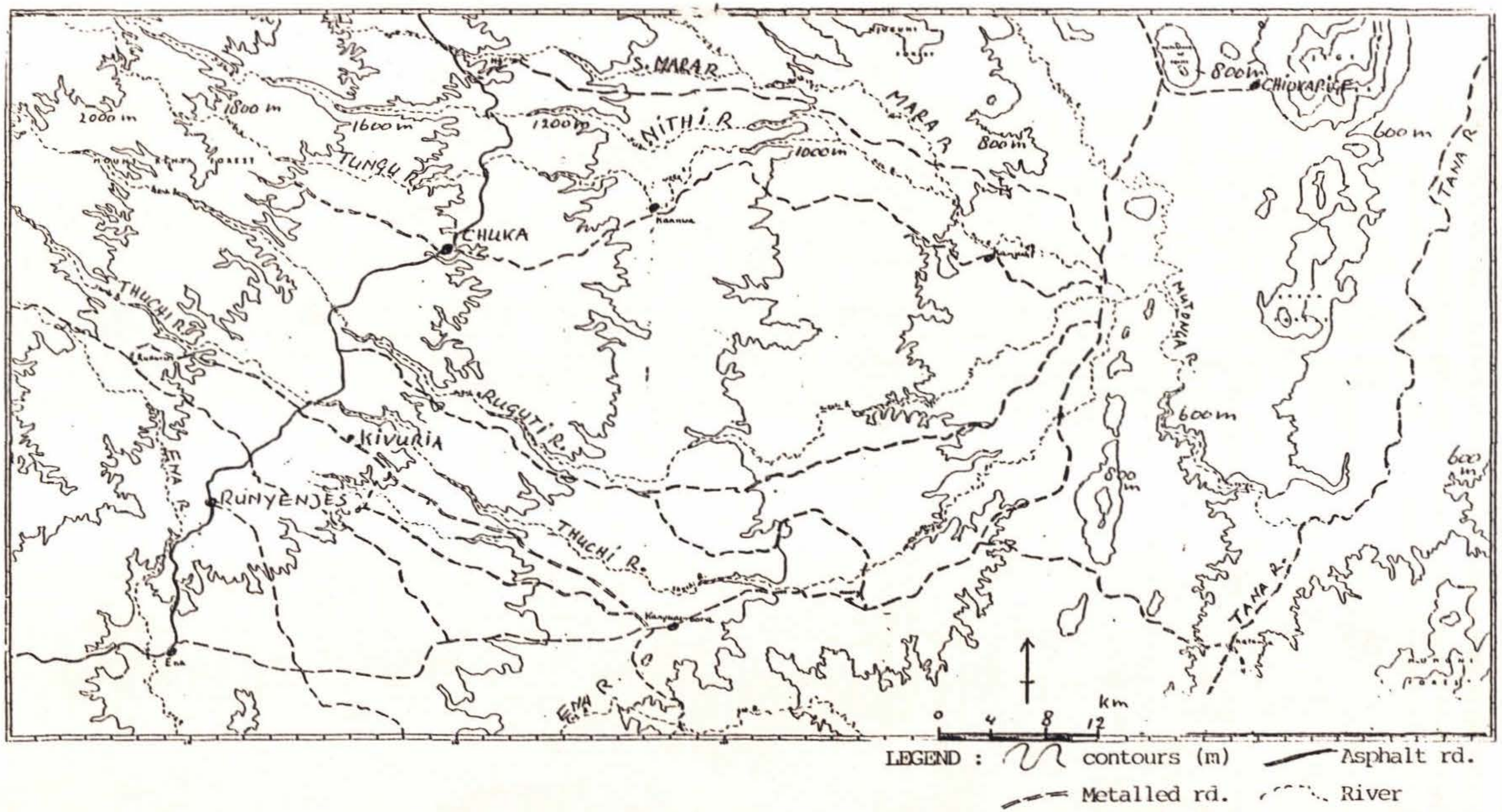


Fig. 2 The Chuka-South Area. Main towns, villages, rivers and contour lines (altitude in m.).

Two district names also indicate the major tribes: Embu and Meru. The Akamba are in Kitui. In the higher parts of Embu and Meru sub-tribes are living along the interfluves between the main rivers. These interfluves coincide with one or two of the present locations. In the low and dry parts of Embu and Meru, other (sub)tribes are living: in the east of the project area, in the Embu part, the Mbeti people, while in the Meru part Tharaka people live.

The Chuka-South Area is well provided with primary and secundary schools, hospitals (Kyeni), clinics, dispensaries and churches, and Ishiara has a monastry.

1.2. CLIMATE AND AGRO-CLIMATIC ZONATION

1.2.1. Introduction

The natural environment is determined by factors, such as climate, geology, geomorphology, hydrology, soils and vegetation. Climate influences the different possibilities for specific kinds of land use very strongly.
With respect to the possibilities of agricultural production in the Chuka area, the extent and variation of rainfall, evapo(transpi)ration and temperature are of overriding importance.
Data were acquired from four main sources, viz. Kenya Meteorological Department at Nairobi, Jaetzold and Schmidt (1983), Braun, in Sombroek et al. (1982) and local rainfall recording stations.

1.2.2. Rainfall

Average annual rainfall

The area is located at the windward side of Mt. Kenya and is characterized by large differences in average annual rainfall, see Table 1 and Fig. 3. The rainfall gradient shows a strong east-west tendency due to differences in altitude; it is increasing in an east-west direction towards the mountain. Hills like Kijege and Kibiro hills cause local disturbances in the general rainfall pattern, especially in the eastern part of the area.

Within the Chuka area the average annual precipitation ranges from 2400 mm at 2150 m in the north-western part to about 550 mm at 700 m in the eastern part near the Tana river. The driest area near Tana river is in the rain shadow of Mumoni hills (1750 m), which affect the amount of rainfall at this site strongly. This dry area is localized on basis of rainfall data, field observations and a satellite image indicating the distribution of biomass over the area.

Table 1. Rainfall data of several stations in the Chuka area (averages, 60% reliability) in mm.

	Station	Alt.	yr		J	F	M	A	M	J	J	A	S	O	N	D	Total
9037034	Chuka County Council farm	1492m	16	Av.	55	40	130	426	153	21	44	27	30	264	386	109	1685
	0 20'S 37 38'E			60%	11	8	109	327	124	5	14	18	13	162	321	58	1170
9037122	Runyenjes D.O.'s office	1477m	8	Av.	25	42	128	410	170	29	43	38	24	225	269	66	1442
	0 26'S 37 34'E																
9037123	Chogoria forest station	1600	11	Av.	62	54	160	518	237	36	41	33	43	278	390	158	2010
	0 17'S 37 37'E			60%	12	43	75	528	203	25	25	29	27	216	385	100	1668
9037161	Ishiara, Embu	853m	11	Av.	31	31	87	268	45	8	3	3	11	81	221	68	857
	0 27'S 37 47'E			60%	4	7	48	240	25	0	0	0	0	44	190	62	620
9037187	Chiokarige D.O.'s office	822m	11	Av.	36	29	103	251	50	15	0	3	6	115	222	105	935
	0 16'S 37 45'E			60%	0	0	76	180	30	0	0	0	0	46	153	60	545
9037198	Mumbuni primary school	1096m	9	Av.	51	31	105	385	108	9	3	6	28	204	318	102	1350
	0 17'S 37 44'S																
9037199	Kibugua Chief's office	1461m	8	Av.	46	52	145	401	163	25	33	27	23	225	317	79	1536
	0 22'S 37 37'E																
9037232	Karua Mutonga	700m	15	Av.	19	17	95	133	31	3	1	0	4	64	125	52	544
	0 22'S 37 45'E			60%	0	0	19	81	5	0	0	0	0	30	68	44	247

Note: 60% reliability according to Weibull (FAO, 1975).

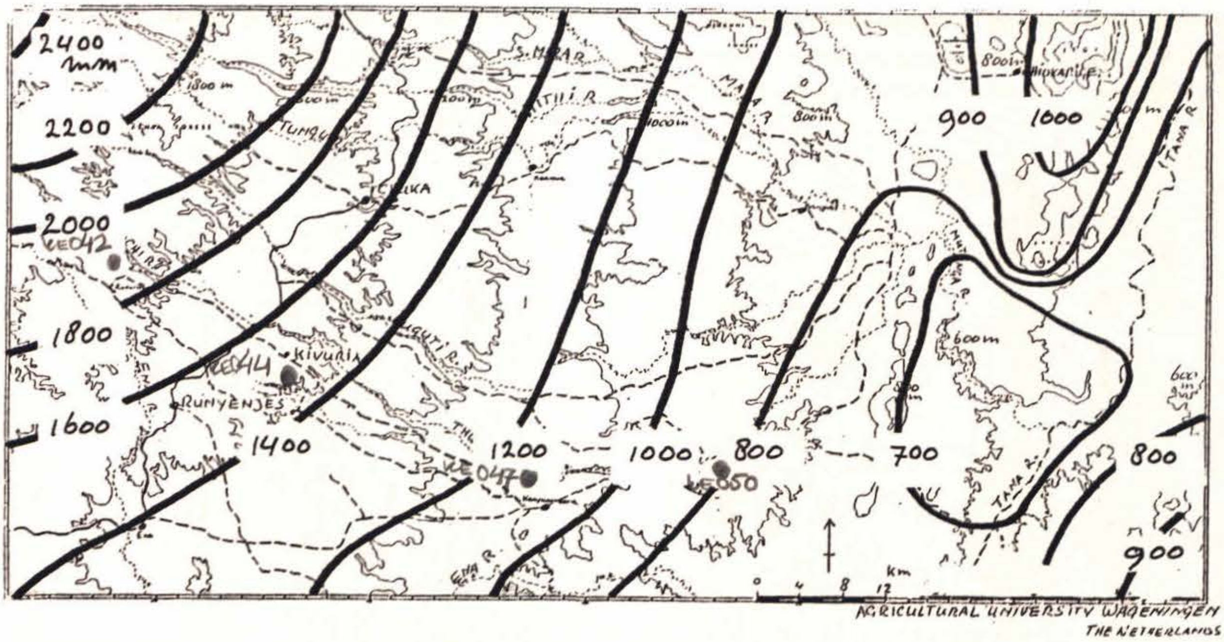


Fig. 3. Average annual rainfall in the Chuka-South Area.

Distribution of rainfall during the year

The distribution of rainfall over the year is not equal, but has a bimodal character in the whole area; see Table 1 and Fig. 4. This strongly influences the agricultural potential.
The first and long rainy season lasts from March up to May and the second, short rainy season from October up to December, with the bulk of the seasonal rainfall concentrated in the months April and November. The distinction between long and short is based on the duration of the rainy season, especially in the wetter areas. There is no significant difference in the amount of rainfall during the first and second season.
The intermediate dry spells are short during January and February and long from June up to September. In general the probability of a single shower is much higher during the short dry season. The outmost western part of the area is characterized by some intermediate rain, see Fig.5.

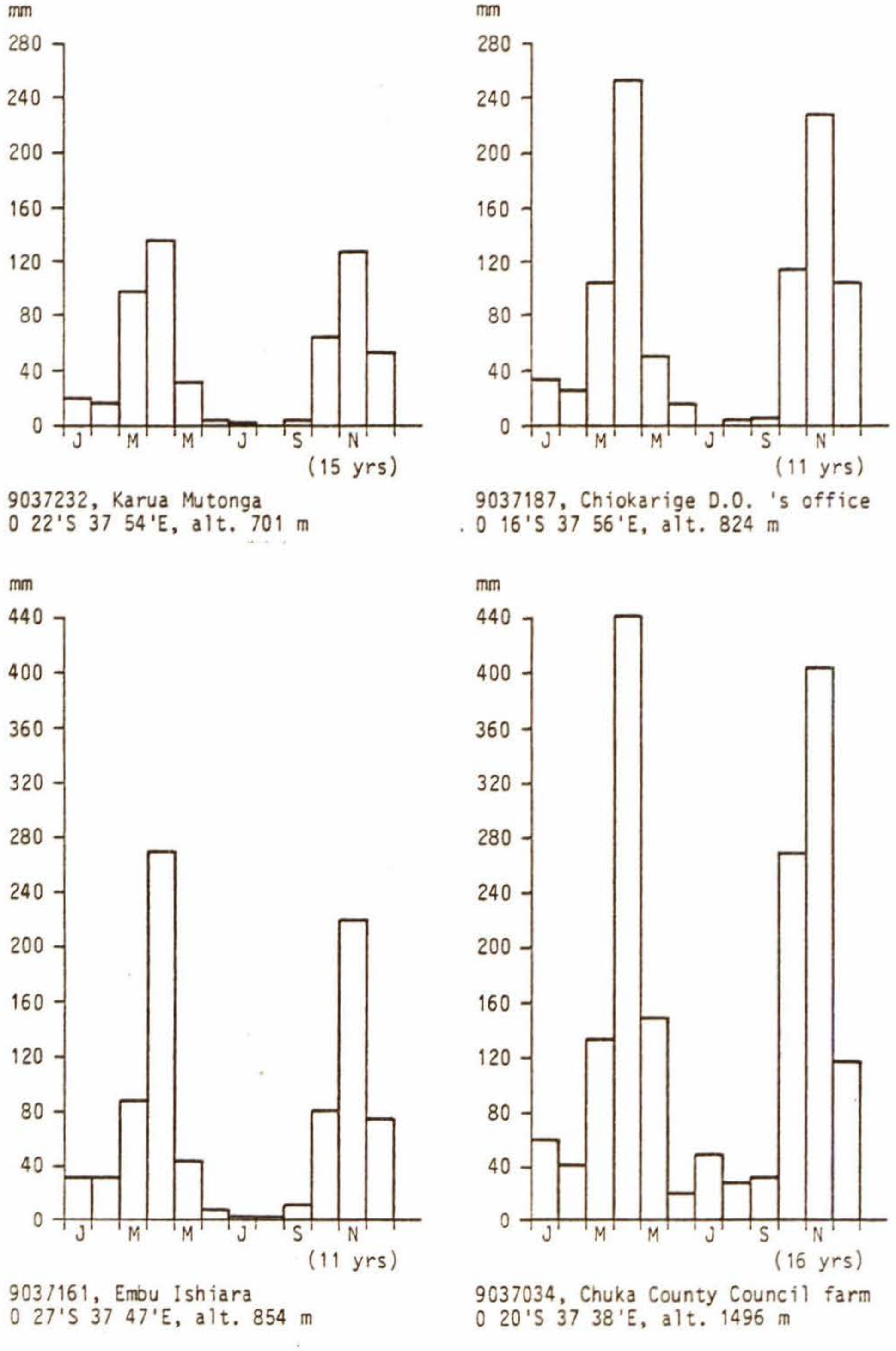


Fig. 4. Distribution of monthly rainfall at four stations in the area.

Probability of rain

In addition to average annual rainfall and its distribution during the year, the probability of rainfall is of great interest to agricultural production, especially in semi-arid regions which are characterized by small and variable amounts of rainfall.
The annual rainfall exceeded in 6 out of 10 years (60% reliability), has been calculated for those stations having records of at least 10 consecutive years. It should be remarked that, the variation in annual rainfall is relatively higher when the average annual rainfall is smaller. See Table 1 and Fig. 6.
Also the rainfall intensities are higher in the dry eastern part of the area than in the moist western zones.

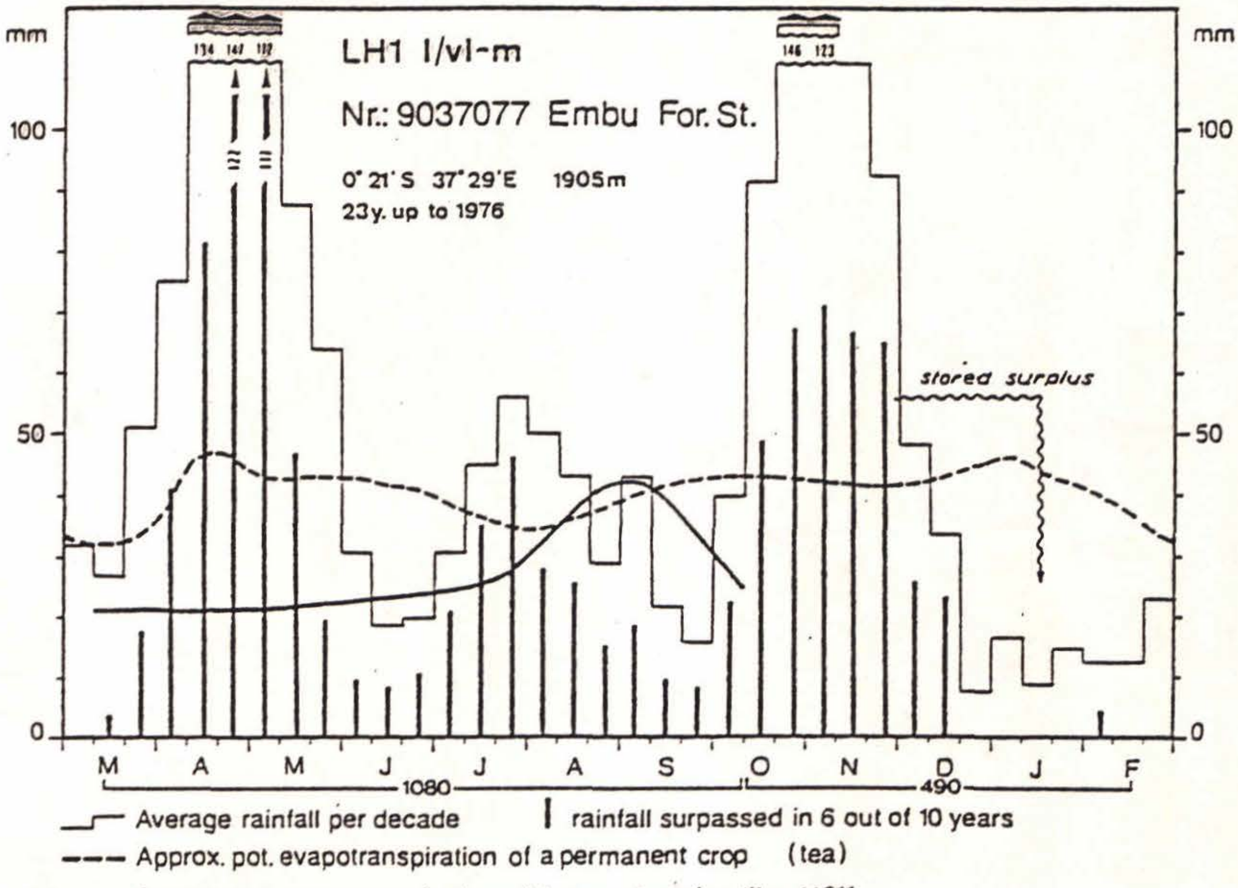


Fig. 5. Climatic data at Embu Forest station, slightly outside the west part of the Chuka-South Area.

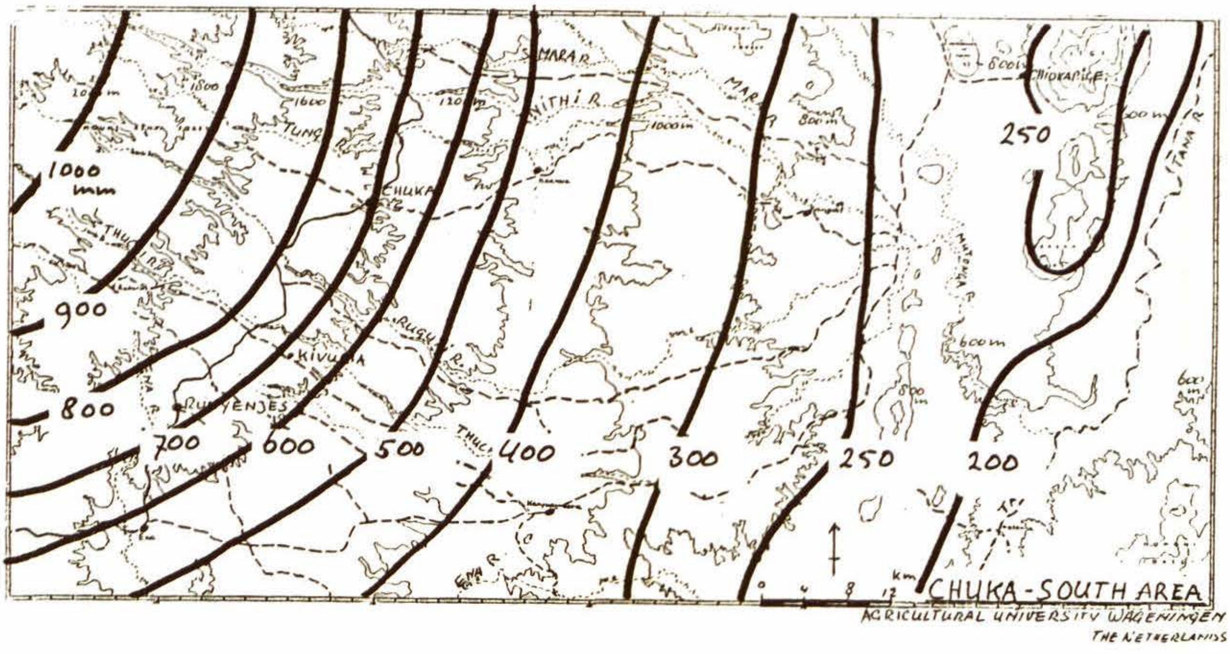


Fig. 6A. Average rainfall in the first rainy season.

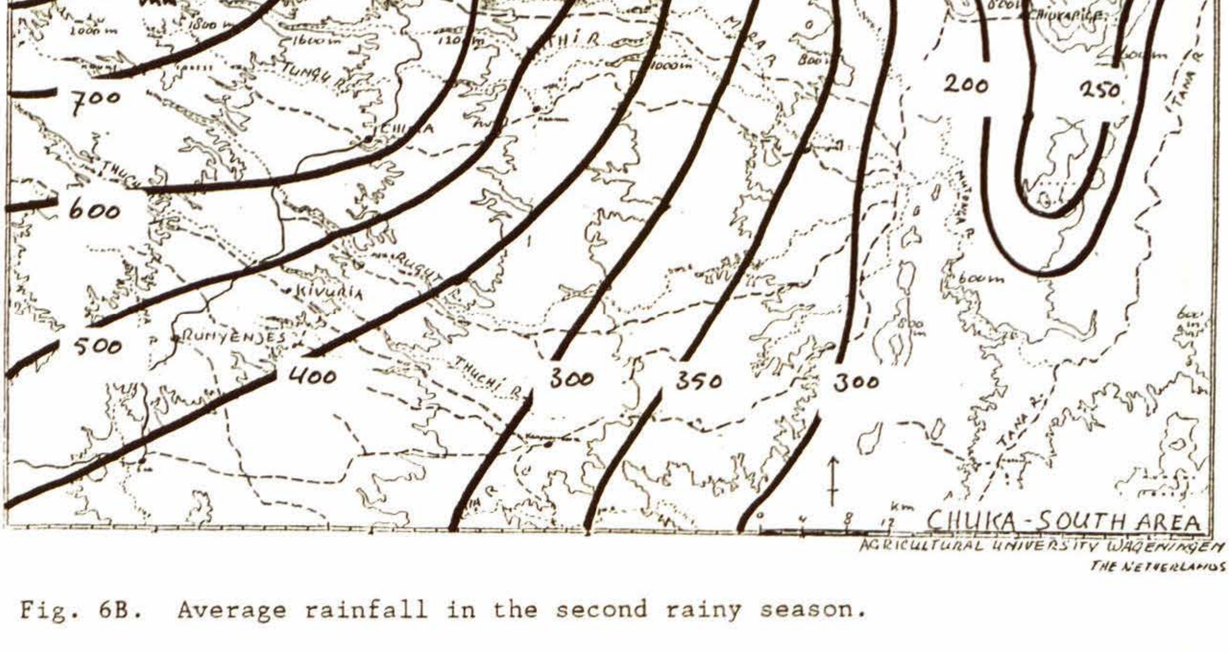


Fig. 6B. Average rainfall in the second rainy season.

1.2.3. Potential evaporation

Braun (Sombroek et al., 1982) calculated the average annual evaporation for Kenya according to the equation:

$$Eo = 2422 - 0.358h$$

in which Eo = evaporation in mm and h = altitude in m (Woodhead, 1968).
In the Chuka area the average annual potential evaporation varies from about 2225 mm at Tana river to 1650 mm in the north-western part (see Table 2.). Compared to rainfall, the potential evaporation is fairly constant throughout the year at different sites, due to only slight variations in temperature, air humidity and wind.

Table 2. Average annual potential evaporation in mm

Station	Eo(mm)
9037034 Chuka County Council farm	1900
9037122 Runyenjes D.O.'s office	1900
9037123 Chogoria forest station	1850
9037161 Ishiara, Embu	2100
9037187 Chiokarige D.O.'s office	2150
9037198 Mumbuni primary school	2050
9037199 Kibugua Chief's centre	1900
9037232 Karua Mutonga	2150

source: Woodhead (1968)

1.2.4. Temperature

In general temperature is correlated with altitude. Therefore temperature shows a strong east-west tendency (Fig. 7): a warm part in the lowlands in the eastern half of the area and cooler zones higher up the mountain in the western part.

To determine the temperatures in the area a specific relation was derived, according to Braun (1986). The following relations between mean, mean maximum, mean minimum temperature (T) and altitude (h) were applied.

Mean temperature (^{o}C) $T = 29.3 - 0.0066h(m)$

Mean maximum (^{o}C) $T = 35.0 - 0.0064h(m)$

Mean minimum (^{o}C) $T = 23.5 - 0.0068h(m)$

Table 3. The temperature zones (after Braun in: Sombroek et al., 1982)

Zone	Mean temp.(^{o}C)	Mean max.(^{o}C)	Mean min.(^{o}C)	Climatic designation
1	24-29	30-35	18-24	fairly hot to very hot
2	22-24	28-30	16-18	warm
3	20-22	26-28	14-16	fairly warm
4	18-20	24-26	12-14	warm temperate
5	16-18	22-24	10-12	cool temperate
6	14-16	20-22	8-10	fairly cool

Throughout the year the temperature is quite constant ($<4^{o}C$ difference). The warmest period of the year is from January to March .

1.2.5 Other climatic parameters

-Solar radiation

Daylength is constant during the year.

Except for the clouds during rainy days, insolation is only limited during the cloudy period in June and July, especially in the western half of the area.

-Winds

The area is characterized by monsoon winds coming from the Indian Ocean and moving in the direction of Mt.Kenya. Winds are not harmful with regard to the cultivation of crops.

1.2.6. Agro-climatic zonation

For the determination of the agro-climatic zones in the area two approaches were used. Firstly the agro-climatic classification of the Kenya Soil Survey (KSS) (Braun in Sombroek et al., 1982) and secondly the so called agro-ecological classification of Jaetzold and Schmidt (1983).

-According to Braun

"The purpose of an agro-climatic zone map is to provide a tool for assessing which areas are climatically suitable for various land use alternatives, with particular emphasis on the suitability for crops".

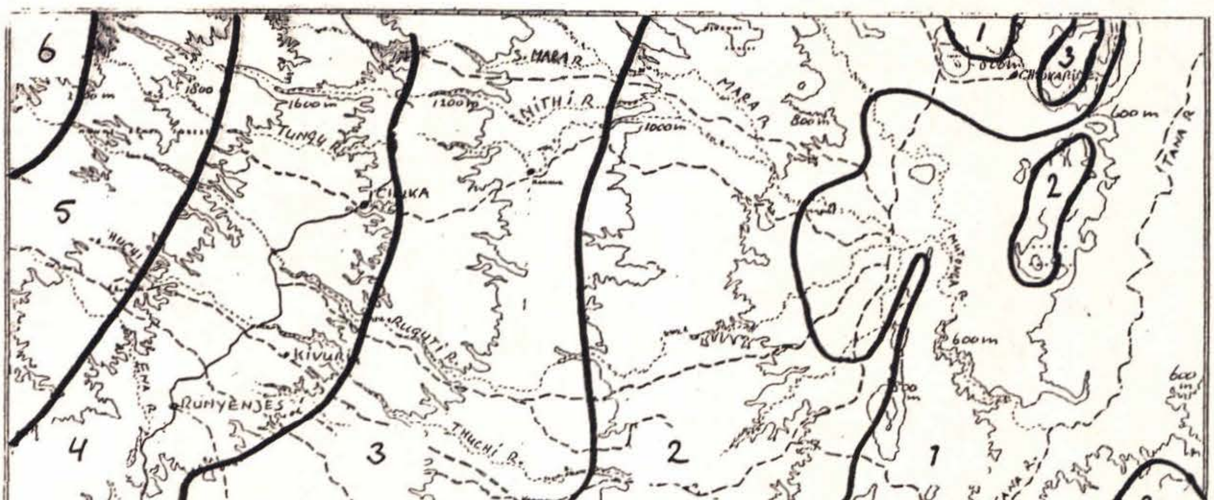


Fig. 7. Temperature zones 1-6.
For legend see Table 3.

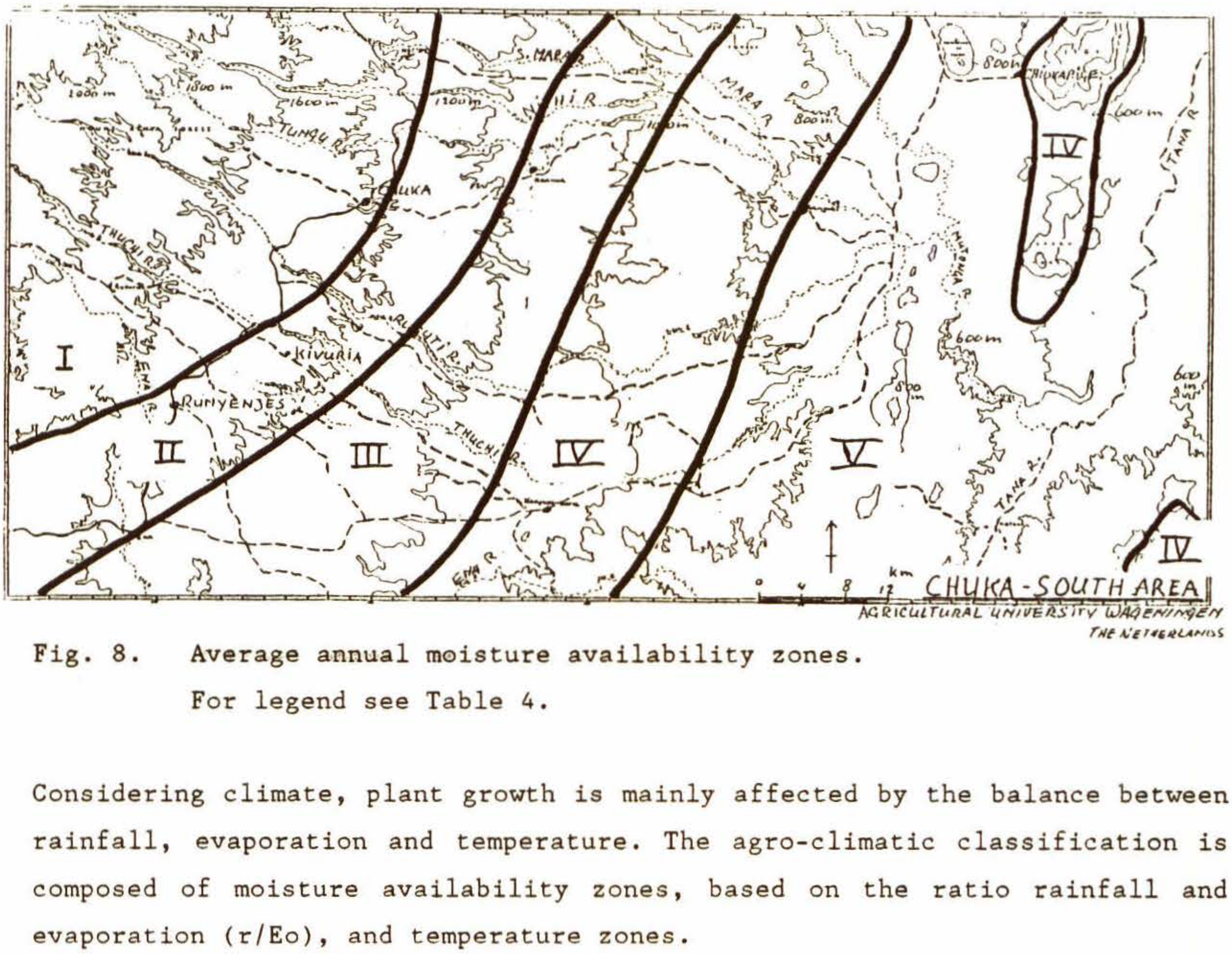


Fig. 8. Average annual moisture availability zones.
For legend see Table 4.

Considering climate, plant growth is mainly affected by the balance between rainfall, evaporation and temperature. The agro-climatic classification is composed of moisture availability zones, based on the ratio rainfall and evaporation (r/Eo), and temperature zones.
As the original Braun classification was carried out on a small scale, the classification of the Chuka area is refined according to the same principle using additional data. The temperature zones are explained in paragraph 1.2.4. The criteria for the soil moisture availability zones can be found in Table 4.

Table 4. Soil moisture availability zones (after Braun in: Sombroek et al., 1982)

Zone	r/Eo ratio	Climatic designation
I	>0.8	humid
II	0.65-0.8	sub-humid
III	0.50-0.65	semi-humid
IV	0.40-0.50	semi-humid to semi-arid
V	0.25-0.40	semi-arid
VI	0.15-0.25	arid
VII	<0.15	very arid

The entire area is covered by five soil moisture availability zones. Fig. 8 shows the adapted map of soil moisture availability zones for the Chuka area and Table 5 the different zones for the recording stations.

Table 5. The agro-climatic zones of the recording stations (after Braun in: Sombroek et al, 1982)

Station	Agro-climatic zone Soil moist.-temp.
9037034 Chuka County Council farm	I-4
9037122 Runyenjes D.O.'s office	II-4
9037123 Chogoria forest station	I-4
9037161 Ishiara, Embu	IV-2
9037187 Chiokarige D.O.'s office	IV-2
9037198 Mumbuni primary school	II-2
9037199 Kibugua chief's centre	I-2
9037232 Karua Mutonga	V-1

The soil moisture availability zones are each subdivided by two or three temperature zones. Hence, the area is characterized by a succession of agro-climatic zones in east-west direction, varying from semi-arid (almost arid), fairly hot to hot lowland in the eastern part to humid, cool temperate/fairly cool highland in the north-western part of the area. This strong climatical variation makes it possible to cultivate a wide range of crops in the area.

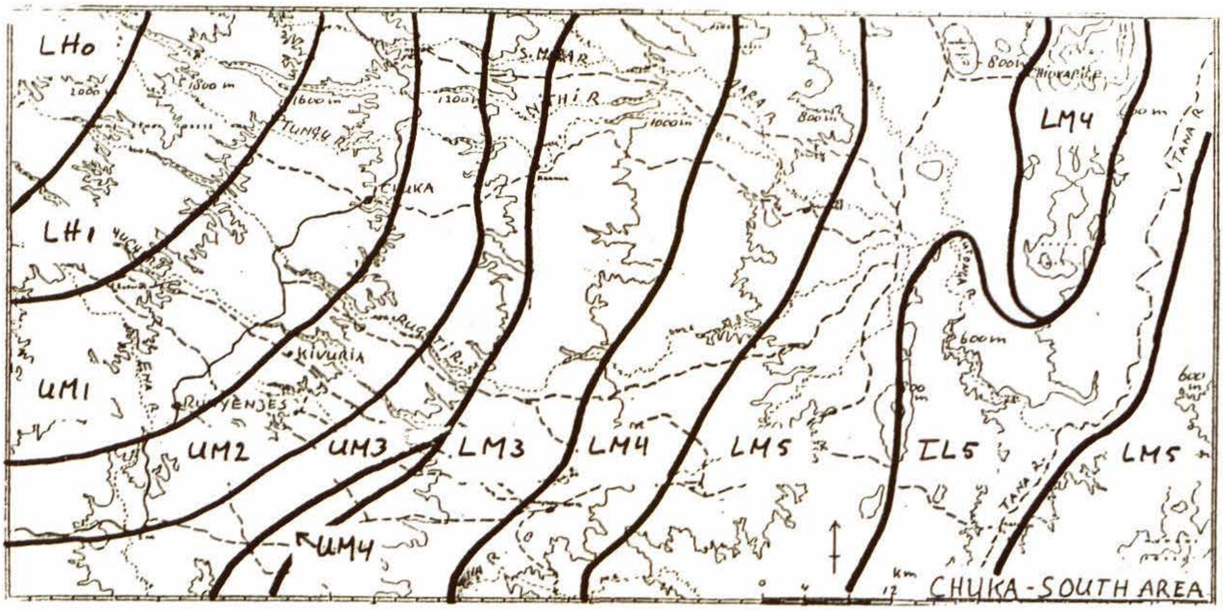


Fig. 9. The agro-ecological zones of the Chuka-South Area. For explanation see text and Table 6.

-According to Jaetzold

The agro-ecological zonation of Jaetzold and Schmidt (1983) is based on the probability of meeting the temperature and water requirements of the main crops. In that sense the zones are parallel with Braun's agro-climatological zones, but in addition the length of growing period is taken into account.

The names of the occurring zones refer to leading crops with a subdivision indicating the length of the growing season. In Table 6 the agro-ecological zones are defined. Fig. 9 shows the main agro-ecological zones in the project area.

Table 6. The agro-ecological zones of Jaetzold

Main zones	Sub zones
LH0 Forest zone	-
LH1 Tea-dairy zone	l/vl-m
UM1 Coffee-tea zone	flim
	m/l + m/s
UM2 Main coffee zone	m + s/m
UM3 Marginal coffee zone	m/s + s
UM4 Sunflower-maize zone	s/m + s
LM3 Cotton zone	s/m + s
	s + s
LM4 Marginal cotton zone	s + s/vs
	s/vs + s/vs
LM5 Livestock-millet zone	s/vs + vs/s
	vs/s + vs
IL5 Livestock-millet zone	vs/s + vs/s
	vs + vs
	vs + i or i + vs

Explanation of the zones:

Main zones

LH Lower Highland zone	0 per-humid
UM Upper Midland Zone	1 humid
LM Lower Midland Zone	2 sub-humid
IL Inner Lowland Zone	3 semi-humid
	4 transitional
	5 semi-arid

Subzones length of growing period exceeded in 6 out of 10 years (60% probability.

l/vl long to very long, 215-234 days

flim fully long, intermediate rains, medium season, 115-174 - 135-154 days

m/l medium to long, 155-174 days

m	medium, 135-154 days
m/s	medium to short, 115-134 days
s/m	short to medium, 105-114 days
s	short, 85-104 days
s/vs	short to very short, 75-84 days
vs/s	very short to short, 55-74 days
vs	very short, 40-54 days
i	intermediate rains (at least 5 decades > 0.2 Eo) i.e. moisture conditions are above wilting point for most crops.

The agro-ecological classification of Jaetzold is based on the same climatic parameters as the classification of Braun. However it is more specific with respect to the cultivation of crops.

1.3 GEOLOGY AND GEOMORPHOLOGY

1.3.1 Geology

The subsurface materials of the Chuka-South area consist mainly of volcanic and metamorphic rock types.

The lithology of the Chuka-South area has been established during the geological survey of the country between Embu and Meru (Schoemann, 1951). A photogeological map of the Chuka-South area (1:100.000) was also prepared during the soil survey (Veldkamp & Visser, 1986) See Appendix 6.2. This map was used during the reconnaissance soil survey as a parent material map.

The two major features of the geology of Kenya, the Precambrian Basement System and the Tertiary Rift Valley, have determined the geology of the Chuka-South area.

The Basement System rocks form the lower, eastern part of the area. Volcanics related to the Rift processes cover the higher, western part of the area. These differences have caused a clear division of the area into two almost equal parts.

The Basement System comprises most of the Precambrian rocks of Kenya, and form parts of the Mozambique Belt. The rocks of the Mozambique Belt originate from sediments deposited in a geosyncline during the Precambrian. The sediments have been metamorphised, invaded by intrusive bodies, uptilted, folded, and sheared. The Basement System rocks are of Katangan age.

In the Basement System of the Chuka-South area four main units were distinguished:

1: *The banded gabbroic-ultramafic complex.* This complex comprises mainly hornblende gabbros and hypersthene bearing granulites. In some units also talc-tremolite rock, peridotite and chromite were found. The units of this complex are intrusions of mainly hornblende gabbros. The intrusions are accompanied by the high-grade metamorphic granulites and intrusive talc, tremolite, peridotite and chromite.

2: *The granitoids.* These units are build up by granites,

granodiorite, gneissose granites and granitoid gneisses. The granites form large intrusive bodies and are accompanied by surrounding granitoid gneisses. The granodiorite also forms an intrusive body and is surrounded by migmatites.
The granite intrusions are accompanied by many pegmatite and aplite vein intrusions which intersect all other Basement System units.

The other two main units are the metamorphised sediments:

3: *The banded migmatitic gneisses complex.* This complex consists mainly of hornblende gneisses and one unit is build up by mainly hornblende and biotite gneisses. The gneisses are dissected by many doleritic, pegmatite and aplite veins. In one unit also granulites are common next to the gneisses and migmatites.

4: *The quartzites and muscovite schists.* This small unit is only found as a part of the Basement System islands in the southern part of the western volcanic area. The metamorphic grade of these meta-sediments is considerably lower than that of the other meta-sediments. The quartzites originate from a band of sandy sediments in the mostly shaly sediments which now form the migmatitic gneisses.

The volcanic rocks in the Chuka-South area are closely related to the Rift Valley development. During the Pliocene numerous volcanoes were active at the margins of the Rift Valley. In this period the broad shield volcano Mt. Kenya, one of the volcanoes along the Rift Valley was built up. Contemporaneous with the eruption activity of Mt. Kenya also the multicentre volcano of the Nyambeni range was formed. The main activity of the Mt. Kenya volcano was from 3.5 to 2 my BP. The activity of the Nyambeni multicentre volcano was from 4.5 to 0.5 my BP. Both volcanic centres delivered volcanic deposits in the Chuka-South area, with Mt. Kenya delivering the bulk. Most of these deposits are lahars, the consolidated mudflows which ran down the slopes of the volcanic body as erosive, destructive, hot masses of pyroclastics, water and enormous boulders of various origins. The deposits of the Nyambeni range are basalts which are found only in the eastern Basement System area, along the Mutonga river.

The deposition of the volcanics has taken place in three main phases:

- The first phase was during the main activity of Mt. Kenya (Upper Pliocene). In this period some phonolite flows and many metres of lahars were deposited in the area. The lahars which covered the relatively flat landsurface also have a flat topography and form the so called "plateau-like lahars". The younger lahars from this phase partly cover the plateau-like lahars and are part of the slopes of Mt. Kenya.

- The second phase was during the activity of the so called parasitic cones on the north-eastern flank of Mt.Kenya (Plio-Pleistocene). In this period lahars from the parasitic cones area entered the area from the north-west and covered an area east of and in between the lahars from the first phase. In this period also the basalts from the Nyambeni range entered the area. The basalts entered the area from the north and flowed by the Mutonga river valley to the Tana river valley.

- The third phase (Pleistocene) is also related to the activity of the parasitic cones of Mt. Kenya. During this most recent phase only a minor amount of lahars entered the area. These lahars flowed from the north-west through the valleys of the major rivers cut into the lahars from the other two phases and were deposited in the Basement System area, in and along the valleys.

Also many river terraces were formed in the Chuka-South area but most of these terraces have been eroded. In areas which were covered with terraces, the remnants of the deposits can be found at some spots. During the most recent part of the geological history of the area colluvium is deposited along the steepest slopes in the area.

1.3.2 Lithology

The following parent materials were distinguished during the reconnaissance soil survey:

G granites and gneissose granites

I phonolites

B (in MB and HB) gabbroic-ultramafic rocktypes

B (in LB and HB) basalts

P lahar complex deposits

Q predominantly granitoid gneisses and migmatites

F gneisses rich in Fe-Mg minerals, predominantly hornblende gneisses

U undifferentiated banded gneisses, usually partly migmatitic

X various parent materials, mainly colluvium

V undifferentiated volcanic sediments

A Pleistocene alluvial deposits

G Granites and gneissose granites:

Granites are coarse-grained and have a granitic texture. The granites of the Kirimiri forest are the most coarse-grained granites. These granites consist mainly of quartz and pink feldspar while the other finer-grained granites consist of equal amounts of quartz and white feldspar with a smaller amount of hornblende.

Gneissose granites resemble the granites macroscopically in composition and texture. However in this type of rock more micas with a preferred orientation occur.

I Phonolites:

Phonolites have a dark blueish black ground mass with many phenocrysts. Sometimes the phenocrysts form half of the bulk of the rock. The ground mass is very dense and very fine granular. It is built up from parallel plagioclase lathes. The phenocrysts are large nepheline and sanidine crystals. The phonolites from the phonolite flows are not very vesicular, contrary to the phonolite boulders from the lahars which can have many vesicles, sometimes with calcite fillings.

B Gabbroic-ultramafic rocktypes (in MB and HB):

They consist of granulites, hornblende gabbros, talc-tremolite and peridotite

Granulites in this unit are fine grained light grey rocks. The weathered surface is sometimes covered with rusty knobs. The rocks contain hypersthene, feldspars and quartz.
Towards the centre of the unit the granulites become darker and the rusty spots disappear. This type of granulite seems to contain much more hypersthene and less feldspars.

Hornblende gabbros are black rocks, with greenish-blue weathering colours, and consist almost completely of hornblende crystals. The average size of the hornblende grains is about 5 mm and their form rather angular. Plagioclase does occur in these rocks.

Talc-tremolite rock type contains possibly also chlorite. This soft silky irregular weathering rock with greyish green colours appears at the lower parts of the unit. The talc and tremolite (and chlorite?) is crystallized in flake like crystals up to 1 cm in diameter.

Peridotite is locally abundant in this unit. The weathered surface is brown to black. The rock itself is medium grained. The fresh cleavage surface is irregular through. The olivine crystals are shiny, glassy, brownish-greenish olive coloured. The olivine crystals form the bulk of this rock. The diameter of the crystals is about 3 mm.

B Basalts (in LB and HB):

Nyambeni basalts show a columnar structure. They are dark grey and have sparse phenocrysts (greenish brown olivine). The phenocrysts are mostly smaller than 0.5 mm but some are found up to 2 mm. There are minute vesicles which sometimes contain a zeolite like material. The groundmass is dark grey. Extremely small brown mineral grains of groundmass size appear in the ground mass.

P Lahar complex:

This complex of volcanic deposits consist of lahars, phonolites and trachytes

Lahars can be devided into loose, porous lahars and firm, dense lahars. The latter have the appearance of a lava flow, and form outcrops with a rounded off surface. The loose, porous lahars which have a more mudflow like appearance, become instable when saturated with water.
The firm dense lahar is the most prominent one. This rocktype shows a large variation in composition. The ground mass is usually dark grey to brownish grey and extremely fine grained. The dense groundmass probably originates from ashes. The groundmass contains angular and rounded fragments of other rock types with diameters ranging from a few mm to a few meters. These fragments are predominantly phonolite and trachyte but locally also Basement System rocks clay and wood occur. Locally vesicles with zeolite and calcite fillings occur.

Phonolites are descriped above under I

Trachytes in the lahars contain microphenocrystics and have a fluidal structure with interstitial glass between the plagioclase lathes. The microphenocrysts are composed of basic plagioclase, olivine and augite. The trachytes can be slightly vesicular.

Q Predominantly granitoid gneisses and migmatites:

They consist of the following rock types: Augengneisses, migmatites and granitoid gneisses. At Karue hill also quartzites and muscovite schists.

Augengneisses consist of medium- to coarse- grained quartz and feldspar with more or less orientated hornblendes and biotites and scattered through the rock are larger feldspar megacrysts.

Granitoid gneisses are composed of fine grained quartz and pinkish white feldspar with no preferred orientation. Scattered through the rock there are parallel streaks of well orientated micas, predominantly biotite.

Migmatites tend to form rock outcrops and tors with smoothly weathered surfaces and spheriodal boulders. The migmatites consist of narrow bands with amphibolitic composition succeeded by light bands mainly consisting of quartz and plagioclase. The migmatites have a medium fine grain size. These rocks show a very bizarre folding and warping.

Quartzite is a medium fine grained, low grade metamorphic rock, which is mainly composed of quartz grains. The quartzites resemble a single band of sand in the Precambrian sedimentary series. It is composed of a series of bands of rock which forms one prominent outcrop in the area at Karue hill.

Muscovite schist is mainly composed of thin flakes of muscovite. Scattered through the whole rock small garnets occur. Like quartzite this schist is also a low grade metamorphic rock. It is very easily weathered and very brittle and soft. The only outcrops are found inbetween the quartzite bands (Karue hill).

F Gneisses rich in Fe-Mg minerals, predominantly hornblende gneisses:

These rocks consist of granulites, migmatites and hornblende gneisses

Granulites have a fine grain size and are dark grey.They consists of hypersthene, clinopyroxeen,hornblende, biotite, plagioclase and quartz. Some granulites have narrow bands rich in dark minerals with a prefered orientation.

Migmatites are very dark and have a fine granular texture. In the normal type of migmatites the dark hornblende rich bands are very thin

and are succeeded by thin bands consisting of quartz and feldspar. Both types of bands are intensely folded.
Large parts of the migmatites are more granitic. These parts are more coarse grained and irregular.
Although the hornblendes still have a preferred orientation, the banded character is disturbed by larger patches of the quartz-feldspar mixture. Locally the granitoid-like migmatites have a granulitic appearance. These parts tend to form outcrops like tors.

Hornblende-plagioclase gneisses are relatively soft and easily weathered. This makes it difficult to find fresh specimens of this rock type. In the field it can be seen in river incisions and in road cuts as rounded, blue- greenish, clayey weathered rocks. The rock is fine grained and consists of an alternation of very thin hornblende and quartz-plagioclase bands.

U Undifferentiated banded gneisses, usually partly migmatitic:

These rocks consist of granitoid gneisses, biotite-, hornblende-biotite and other gneisses

Granitoid gneisses are coarse grained and contain only small amounts of ferro-magnesian minerals. Sometimes muscovite is abundant. Among the minerals, quartz and plagioclase are the most important. The rock has a granitic structure but the ferromagnesian minerals and micas have a prefered orientation. These gneisses are medium fine grained. The dark biotite- plagioclase bands alternate with light quartz-feldspar bands. The latter are more coarse grained. The quartz can form clods up to 7 mm in the light bands

Other gneisses in this unit are e.g. quartz- feldspar-muscovite gneisses, which also contain sillimanite. Also sillimanite-garnet-muscovite-biotite are found. Except a large amount of sillimanite and garnet this rock probably also contains some graphite.

X Various parent materials, mainly colluvium :

Colluvium consists of many boulders, stones and gravel of various sources. The boulders are usually phonolite,basalt or mafic boulders derived from the surrounding higher area. The gravel is usually murram.

V Undifferentiated volcanic sediments :

Mixture of lahar, colluvium and probably ashes.

A Pleistocene alluvial deposits :

Conglomerates are with the Mount Kenya volcanics (more than 90%) the main components of the terrace deposits. The deposits are usually large boulders and stones with intermediate layers of sand and gravel. Deposits rich in pyroclastics are found along the Tana river. The deposits are well sorted but contain some larger pumice bombs. The Basement System component in the deposits comprises only a few percents.

1.3.3 Geomorphology

The geomorphology of the area is closely related to the geology and geological history of the area. The bisection of the area is also very clear in the different landscapes of the area. There is a volcanic landscape and a Basement System landscape.
For the purpose of soil mapping, the landforms have been described in terms of major land units and miscellaneous land types, according to the standard definitions used by the Kenya Soil Survey (van de Weg, 1978).
The following major landforms were mapped in the Chuka-South area.

- Mountains and Major Scarp (M)
- Hills and Minor Scarps (H)
- Footridges (F)
- Plateau (L)
- Uplands (U)
- Plain (P)
- Bottomlands (B)
- Valleys (V)

Note: Fig. 10A-D and Fig. 11 A-E illustrate the geomorpholgy of various major landforms and show their characteristic drainage pattern.

The Mountains (M), are the highest parts in the Basement System area. They have a relief intensity of more than 300m and their slopes are generally >30%. The upper parts of the granite Mountains like the Kijegge and Mumoni consist of bare rock and have the common sugar-loaf appearance of an inselberg. The mountain which consists of the gabbroic-ultramafic complex rocktypes has not the appearance of an inselberg.

The Major Scarp (M), forms a boundary between the volcanic landscape and the Basement System landscape. The scarp slope is usually a few hundred percent and the slope of the underlying colluvial deposits (footslope) is 10-20%.

The Hills (H), are the higher parts in the Basement System area with a relief intensity less than 300m. The hills often differ in shape. The more rounded hills usually consist of granitoids and ultramafics. The more oval, elongated hills consist mainly of granulites and gabbros. Generally the rounded hills have steeper slopes, usually with shallower soils. The slopes vary from 10->50% (see Fig. 11 D and E).
The hill (HP)is a higher part in the volcanic landscape. This higher position is caused by Basement System rocks which only have a very shallow volcanic cover (see Fig. 10C). The overall slope of the crest is 1-4% and the slopes downhill are 20-35%.

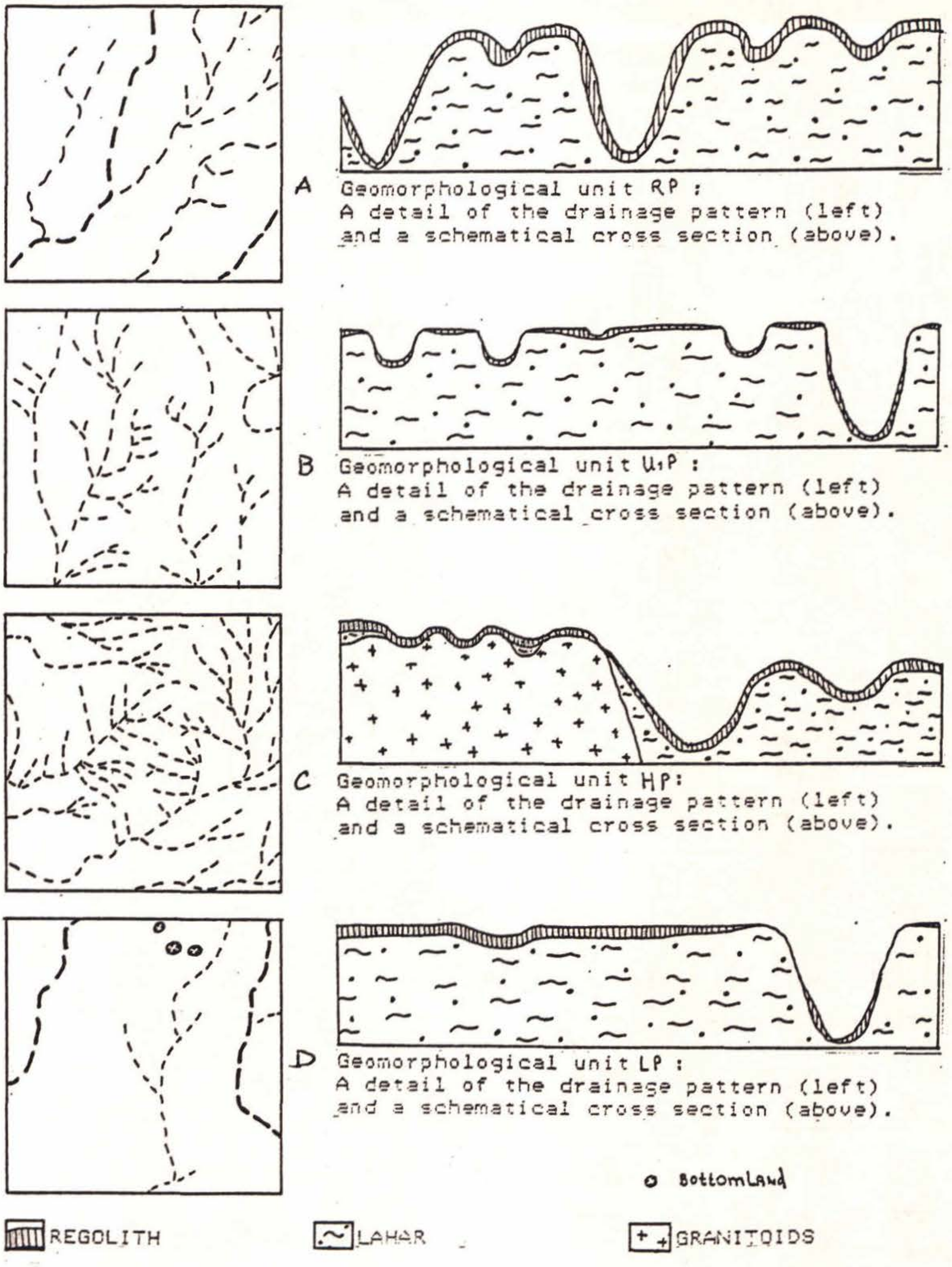


Fig. 10 A-D. Details of the drainage pattern and schematic cross sections through four landscapes of the volcanic area (scales drainage pattern maps 1:100.000, cross section 1:40.000).

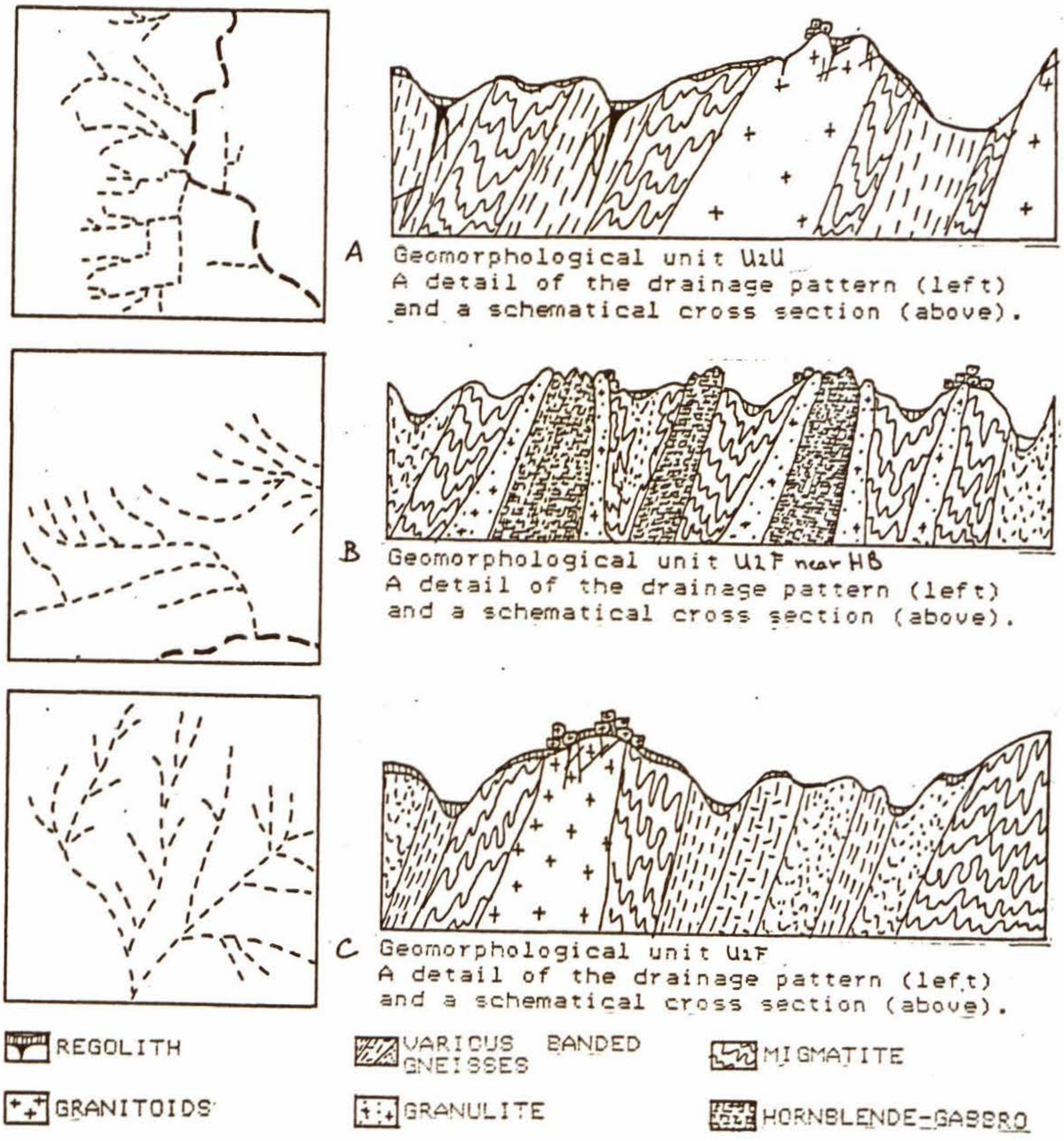
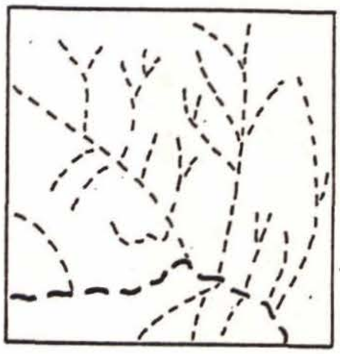
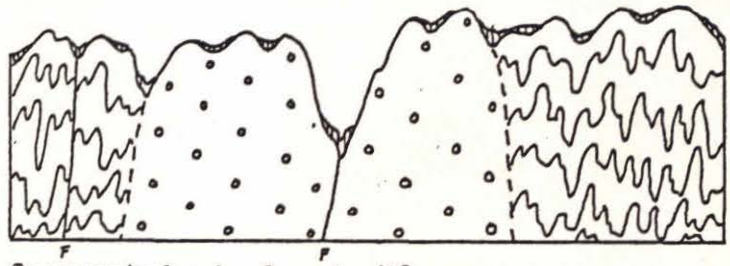


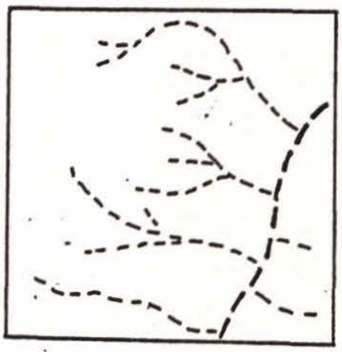
Fig. 11 A-E. Details of the drainage pattern and schematical cross sections through five landscapes of the basement area.

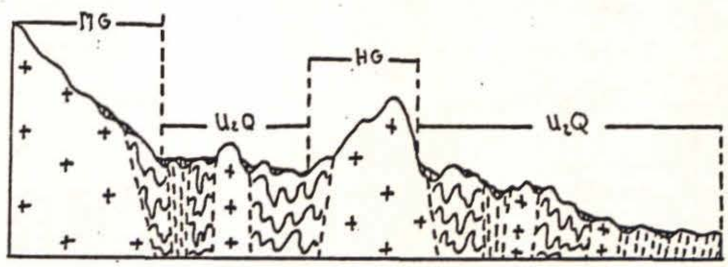
p.t.o





D Geomorphological unit HQ
A detail of the drainage pattern (left) and a schematical cross section (above).





E Geomorphological units MG, HG and U2Q
A detail of the drainage pattern (left) and a schematical cross section (above).

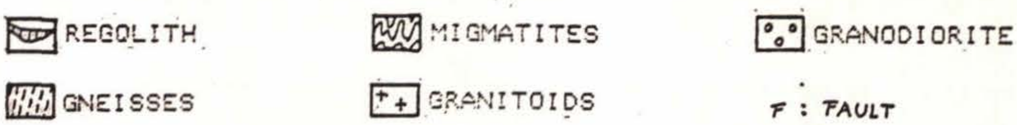


Fig. 11. Continuation

The Minor Scarps (H) n the Basement System landscape narrow elongated ridges occur which were caused by an isolated basalt or phonolite flow. The flow followed a river valley which caused the elongated shape of the Ridges. The relief of these flows has inverted in time.
The crests of the ridges have an overall longitudinal slope of 2-5%. The whole ridge consists mainly of transversal steep slopes (50 to more than 100%). These steep slopes are mapped as minor scarps.

The Footridges (R), contain the middle and lower slopes of the large Mount Kenya volcanic body. They are characterised by an overall longitudinal slope of 5-6% (NW to SE), and are strongly dissected. The crests have slopes of 1- 5% and are usually long and narrow. The valley slopes in this unit have slopes up to 80%. The valley slopes are longer than the crest slopes (see Fig. 10A). The relief intensity is 50-100 m. The parallel dissected parts are stronger and steeper dissected than the subdendritically dissected volcanic uplands.

The Plateau area (L), (overall slope 1-4%) comprises the most south-eastern lahar deposits of Mount Kenya. Its eastern boundary is a very steep scarp but its western and northern boundaries are very gradual transitions to the high level uplands (see Fig. 10D).
Some isolated volcanic landtypes in the Basement System landscape are also plateaus. These plateaus have the same origin as the ridges.

Uplands are divided into two major levels. The lower level uplands have an altitude less than about 900 m, and a relief intensity less than 50 m (slopes 0-16%). They are mainly of Basement System origin.
The higher level uplands have an altitude over about 900 m, and a relief intensity less than 50 m (slopes 0-16%). They are mainly of volcanic origin.

The High Level Uplands (U1), are situated on the less steeper parts of the Mount Kenya body. The crests of this unit are flatter (0-4%) and more extended (see Fig.). The main rocktype is the lahar rock. This unit is often incised by the minor valleys. The transition to the major lahar plateau is very gradual and these uplands can be looked upon as a strongly dissected plateau area.

The Lower Level Uplands (U2), form the lower parts of the Basement System landscape. The main rocktype in the uplands are the various gneisses described in Chapter 1.3.1. The uplands have an overall slope of 3-5% from their western to their eastern boundaries, but the local relief is usually rolling, local slopes are usually 1-30%. The uplands show many gullies, ridges and small hills. Tors are also common in some parts of the uplands, especially where granitoids occur.

The uplands can be subdivided into 3 sub units according to their local relief.

the flat Uplands	(overall slope 1-5%)
the rolling Uplands	(overall slope 5-20%)
the hilly Uplands	(overall slope 5-30%)

The flat uplands show some local dissections like erosion gullies, but the main character is flat. These areas are usually situated along rivers and are former river terraces. Locally remnants of the fluviatile deposits are found in this unit.

The rolling uplands are subdivided into three more sub-landtypes according to the local drainage pattern. These drainage patterns are closely related to the rockstructures and -types.
The rectangular dissected part is an area with a rectangular drainage pattern which is caused by the joints and fractures of this predominantly granitoid gneisses area.
The subparallel dissected part is an area with a subparallel drainage pattern which is caused by parallel granulite and migmatite ridges in this area.
The subdendritically to subparallel dissected parts is an area with a mixture of drainage patterns, this area has a complex build up and comprises many elements of the other landtypes.

The hilly uplands also can be subdivided.
One part has a dendritical drainage pattern. This area is generally situated higher than the surrounding uplands. The main rock types in this area are granodiorites and their accompanying migmatites (see Fig. 11E).
The other unit has a more subparallel drainage pattern. This area is found along the Kijegge Mountains and has a footslope like appearance. It is the transition zone from the Mountains to the other uplands.

The Plain (P), is characterised by an almost flat surface (0-2%) and has only a few shallow incissions. The rocks which are commonly exposed excist of consolidated lahar. This lahar deposit is the youngest deposit in the Chuka- South area and has therefore hardly any inversion height at its boundaries with the surrounding Basement.

The Bottomlands (B), are oval concave depressions which are usually found in clusters in the footridges and the plateau.
These depressions have different drainage and soil qualities. Some of them are almost always well drained while others form permanent swamps. Their slopes vary from 0 to 4%. These depressions are well described in a special survey on this subject (van Hees & de Roo, 1986). See App. 6.7, Plate 6.

The Valleys (V), are divided into two units. The major valleys have a relief intensity of 50-100 m, and slopes of the valley-sides are 8-30%. The minor valleys have a relief intensity less than 50 m, slopes of valley- sides are 8-30%.

The Major Valleys (V1), comprise deep (more than 50 m deep), steep, V-shaped valleys of the largest perennial rivers of the Chuka-South area. These rivers originate near the summit of Mount Kenya in former glacier valleys.
Since the present rivers are far too small to have caused these large valleys (misfitted rivers) the formation of these valleys is certainly related to the more glaciated periods of Mount Kenya. Other causes of the formation of these valleys are probably the lahars which almost certainly have caused the steep and deep valley of Nithi river.
The slopes of the valleys are often over 100% and the overall slope of the valley profiles is 4-6%.

Minor Valleys (V2), are contributaries to the major valleys, and have a relief intensity less than 50 m. The slopes vary between 8-30%. See App. 6.7, Plate 3. These valleys are also misfitted but the rivers are not always perennial.

Relation landscape-lithology.
In the past the area has known various climates. Humid and semi arid climates have been alternating many times.
Under more humid climatic conditions, due to differential weathering of contrasting rocktypes, the weathering front showed different depths.

During semi arid conditions the saprolite was stripped off and this is still happening in the drier parts. This cycle repeated several times and caused the landforms of the Basement System landscape. As a matter of fact the Basement System landscape should be looked upon as an etch plain.

The different landforms described, usually comprise different rocktypes. For example the mountains and the hills (in the Basement) contain predominantly granites, granitoid gneisses and rocks from the gabbroic-ultra mafic complex. The fact that these rocktypes are almost exclusively found in the higher parts of the Basement System landscape indicates a relative slower rate of weathering of these rocks compared to the surrounding rocktypes.

1.4 HYDROLOGY

The Chuka-South area is situated in the upper-Tana basin. The Tana river is traversing the eastern part of the survey area from South to North.

The drainage system is determined by the radial drainage pattern of Mount Kenya. The Mount Kenya is drained by many major deeply incised perennial rivers.

The Ena, Tungu, Rugutti and Mara rivers have their origin on the slopes of Mount Kenya, but the Mutonga, Nithi and Thuchi rivers originate from the partly glaciated top of Mount Kenya.

All these rivers drain into Tana river which is the largest river of Kenya.

The Tana river has also some large intermittend contributaries (especialy in Kitui district). These intermittend rivers, Konyu and Kalange, have only water immediately after heavy rainfall.

Only at Ishiara the water of the perennial Thuchi river is used for irrigation purposes. This irrigation scheme was established in 1948.

1.4.1 The water-supply.

Four sources of water are of importance in the survey-area. These sources are surface water, near-surface water, groundwater and rainwater.

Surface water is taken from the perennial rivers. This water is fetched with gourds or other containers. Most water-pipe lines have their inlets in these rivers. Most taps from water pipe-lines are found in the western part of the area.

The surface water from the perennial rivers can be contaminated by the time it reaches the eastern part of the area. The best locations (with respect to the infection danger) for the water-inlets of pipe-lines are in the uninhabited areas of the Mt.Kenya forest or in wells in the riverbed beside the river.

Near-surface water is taken from handdug wells, which are in the volcanic area usually a number of metres deep in the regolith. This water is usually free of contaminations.

In the eastern part of the area many shallow wells are dug in the riverbeds of wadis. At some spots these shallow wells supply water throughout the whole year. The shallow wells are easily contaminated. Groundwater is taken from a few bore-holes in the lahars and from some springs in the lahars and granites. This water is usually free of contaminations except when the spring-water is collected in small pools.

Rainwater is caught in the eastern part of the area in large tanks which collect the rainwater from the roofs of schools and other large buildings. This water can be a fairly safe supplement or source of water. This way of water-conservation is new in the survey area and not very wide-spread yet.

1.4.2 The potential groundwater resources.

The Chuka-South area was hydrogeologically surveyed in 1985 (Veldkamp & Visser, 1986). This hydrogeological survey resulted in a map 100:000, (see Appendix 6.2).

The occurence of groundwater-bodies in the rocks in both parts of the survey area, (the Basement System area and the Volcanic area,) is largely determined by the fractures of the rocks. This means the higher the amount of fractures in the rocks, the higher the chance of occurence of groundwater in the rocks. In the Basement System area the regolithes of the rocks are in general too thin and too little continuous to contain groundwater bodies of considerable extensions.

In the banded migmatitic gneisses complex (X) the best possibilities for finding groundwater are found in unit X2. This unit shows a dense pattern of joints of which the rectangular, strongly jointed or faulted zones are the most distinct. This unit forms a low area between the high mountain complexes comprised by unit G1. This favours the developement of extended groundwater bodies in this unit. The second best chance of occurences of groundwater in the gneisses are found in unit X5, especially in the zone which seems to be a continuation of a fault in an adjacent G1-unit. The less favourable possibilities of finding groundwater in the X-units are in unit X1, the small granulite hills. A problem in the whole gneisses area is the poor permeability of the regolith. The top soil tends to form impermeable crusts which favours extremely high run-off percentages. The little amount of rain-water which infiltrates into the regolith usually does not percolate deeper than 50 cm. The major part of this water is evaporated during the dry season or transported to the riverbeds of the luggas in a through-flow. Only very small amounts of the rain-water will percolate through the regolith into the fracture system of the underlying rock. Also lateral addition of water to the groundwater in the fracture systems of the gneisses is very limited. In general this does not favour the occurence of large amounts of groundwater in the X-units.

Unit Q has a topographic position and structure which make the possibility of finding groundwater in this also unit very limited.

The occurence of groundwater in unit G1 is limited to the faults in this unit. That these faults do carry water is demonstrated near Chiokariga, where a spring is fed by a fault. Unit G2 offers almost no possibilities for groundwater bodies. The unit merely consists of small hills which are isolated and not well fractured. The water running off the hills of unit G1 and G2 partly feeds the water in the fractures in unit G3. This best jointed granitoid unit also has the most favourable topography to offer the best chances of all G-units to contain groundwater bodies. Also the feeding of the fracture systems of the granitoids with water percolating through the regolith is not such a problem as it is in the gneisses areas. The shallow regolith is more sandy and better permeable.

The M-units offer little scope to find groundwater in these units. The topography of these units, the shallow, poorly permeable regolith and the lack of well developed fractures do not favour the chances of finding groundwater here. Very limited amounts of groundwater may be found in the fairly wide granulite border zones around the largest M-units, although granulites do not contain very good aquifers in general.

The lavas do not contain aquifers. All lava flows (V) are single flows which are too thin and too well drained to contain groundwater.

The lahars mostly form very thick deposits with very thick and permeable regolithes. In the regolithes of the L-units as well as in the lahars themselves large amounts of groundwater can be found. The thickest lahar deposits and most aquifers are found in sub-unit L1a. Large amounts of groundwater can be found here. The further eastwards one goes in sub-unit L1b, the smaller the chances of occurences of aquifers become. Almost no groundwater can be expected at the eastern border of the lahars, where the lahar thickness is almost nil.

Unit L2 comprises areas where a thick regolith originating from lahars is covering granitoids. Some water can be expected in these regolithes during the rainy season, but the shallow granitoids prevent the occurences of important aquifers in this unit.

The colluvial deposits (C) do contain some water which easily infiltrates into these deposits forming the foot-slopes of the volcanics and some of the ultra-mafics. The colluvium around the lava flows and the ultra-mafics is not very liable to contain large amounts of groundwater. More important amounts are found in the colluvium bordering the lahars. Locally a lateral supply of water from the lahars causes the occurence of considerable amounts of groundwater in the colluvium. This is reflected by the tillage of crops needing a constant supply of water.

Some of the fluviatile deposits also offer good possibilties or occurences of groundwater. The terrace deposits in unit F1 do not contain extended amounts of groundwater, but the areas which were formerly covered with these deposits and now form the largest part of this unit, are covered with thick regolithes and have a flat topography, so the infiltration of rain-water into the regolithes and the underlying rock is favoured. These units will contain very probable higher amounts of groundwater than the surrounding X- units.

Unit F2 comprises a few very large riverbeds. One riverbed is that of Tana river. Of course the riverbed of this perennial river is always saturated. The other F2-units are the riverbeds of large wadis. These riverbeds usually contain water at various depths.

At one of these wadis, Konyu, a spot with a very shallow watertable was surveyed in detail. Konyu wadi is an intermittent contributary of Tana river. A small part of this wadi was surveyed with geoelectrical instruments to gain insight in the build up of the wadi and to explain the local shallow water table at the survey spot. This water table is very important for the local people and their cattle.

Schlumberger soundings and measurements along Wenner arrays were carried out. As reference and to check the measurements also augerings were done. The soundings were processed into cross sections and apparent resistivity maps which gave insight in the build up of the wadi at the survey spot. The depth of the riverbed deposits varies from

about 10m upstream to about 2m in the right-angled bend of the wadi. This decrease of valley fill can be considered as a natural sub-surface dam. This is one important reason by which the shallow water table can be explained. Another aspect of the wadi is a straight gully in the bedrock under the deposits. This gully follows the straight course of the largest part of the Konyu at the survey spot. This suggests a fault or strongly jointed zone in the rock under the deposits. From this fault zone, the most down-stream end is at the survey spot. Seeping of water into the riverbed deposits is assumed. This is a another explanation for the shallow water table. It shows also why the water table usually, also during extreme dry periods, is above the top of the natural sub-surface dam.
A rough estimate indicates an amount of water in this valley fill, which is enough to supply water to the local users (people and animal) during a period of about one year without rain.

1.4.3 Possible improvements of the water supply.

Improvements can be made with respect to the public-health e.g. the type and location of inlets of the water-pipe lines and information supply.
In general an increase of the amount of available water wil not always give an improved situation. Often the area (esspecially in the less dense populated eastern area) involved will attract more people and cattle than it can support. This will lead to a severe overgrazing and overuse of the natural carrying capasity of that area.
The amount of the water in the wadis can be increased by building sub-surface dams or earth dams. The protection of the wells as well in the volcanic as in the Basement System area is important.
An increased amount of bore-holes which deliver save water also can be an improvement, but the drilling of bore-holes and the maintenance of these bore-holes and pumps demand considerable amounts of money and skill of the local people.

1.5. VEGETATION AND LANDUSE.

1.5.1. Working methods.

Introduction.

Vegetation and landuse of the Chuka-south area was surveyed by applying the landscape guided (=physiographic) method as developed by the ITC (International Institute for Aerial Survey and Earth Sciences, (Gils & Zonneveld, 1982).

This method is based on the use of aerial photographs to delineate landunits on physiographic basis and on a lower level on vegetation and landuse differences. During the fieldwork these units are sampled in a so called stratified random way: sampling activity is distributed over all the units of the aerial photo interpretation map (API-map), with an equal attention to each unit.

Air Photo Interpretation.

Aerial photographs on a scale of 1:50.000 were the basis for the interpretation map. However these photos showed the situation of 20 years ago, in the meantime major changes have taken place.

The aerial photographs were interpretated, firstly on basis of major landscape differences, bases on general landform differences (Van de Weg, 1978). On a lower level differences in individual landforms and vegetation/landuse were used to differentiate the major API units. Some landscapes could not be divided in any detail (the Mountain Rain forest) and there more fieldwork was needed to find correlations between aerial photograph characteristics and vegetation differences. However for the majority of the area no such problems were encountered. In this way an API-map on scale 1:100.000 was made and used to prepare for the fieldwork (sample places and routes).

Field sampling.

Parts of the area were visited and subsequent API-units were sampled. Especially those units were visited which were adjacent to each other (the cluster aspect of the method).

During the fieldwork the differences in vegetation and landuse between

1968 and present (1985) became a problem. Especially in the eastern part of the area units could consist of high bushland which were previously bare farmland (and vice versa). In these cases sampling was not that much related to the specific place as it was elsewhere. A total of 180 samples have been taken, distributed over 30 API-units. Each of them consists of a relevee of the vegetation, an augering and general remarks on landscape and landuse.
Vegetation relevees were of different size, depending on the vegetation structure. They varied from larger than $1000m^2$ (Wooded Grassland), $400m^2$ (Woodland or Bushland) till $25m^2$ (Grassland).

In each relevee all plant species were noted down and an estimation was made of the external- and internal coverage of the individual plantspecies, as well as their abundancy. The majority of the plants have been recognised in the field, the remaining were sampled and send to the East African Herbarium in Nairobi to be determined.

Field sample processing.
Much confusion is caused by the numerous physiognomic classifications. A term like "savanna" is so often used in so many different ways that it does not have much meaning anymore. We have chosen for the simple physiognomic classification as given by White (1983). This classification is used in the legend. In case of cultivated land, the physiognomic classification is not used but the term Farmland and the degree of cultivation.

The final legend of the map is based on the floristic classification made of the 180 vegetation relevees. Mapping units consist of (mostly) complexes of vegetation types which are characterised by sociological types. The relevee data were processed according to the Braun-Blanquet tabulation method (Gils & Zonneveld, 1982).

Final map preparation.
After the field work was done the entire area was re-interpretated with aid of the 1:50.000 aerial photographs. Some differences were found compared to the first interpretation. Especially in landscape 6 many units were changed. The first interpretation was too much based on

differences in bush fallow stages. The final interpretation consists of larger units with many complexes of different vegetation types. However one has to realise that aerial photographs of 1968 are the basis of this map, and that not all units could be adapted to the present situation. The final map was prepared by reducing the interpretation-map by the means of a sketchmaster to a 1:100.000 map.
The legend is based on the importance of the different vegetation types in the complex. It is based on the physiognomic- as well as on the physiographic classification. General geology is indicated for each landscape and only for each mapping unit if it differs from the majority of the landscape.

1.5.2. The seven main landscapes.

A total of seven landscapes were distinguished in the Chuka-south area based on differences in vegetation, landuse and physiography. Each landscape is named after two plantspecies; the first one is a characteristic one, the second is a dominant plant.

Landscape 1: *Ocotea usambarensis - Strombosia scheffleri.*
Mountain Rain Forest on Mountain Footridges, developed on Mt. Kenya volcanics.
The higher parts of the forest are still virgin but especially the lower four kilometers of forest has been heavily exploitated (fuelwood, timber), See App. 6.7, Plate 1.

Landscape 2: *Croton megalocarpus - Coffea arabica.*
Very intensively cultivated land on Mountain Footridges, developed on Mt. Kenya volcanics, See App. 6.7, Plate 3.

Landscape 3: *Dombeya rotundifolia - Mangifera indica.*
Intensively cultivated land on Plateau and (volcanic) Uplands, developed on Mt. Kenya volcanics.

Landscape 4: *Combretum zeyheri - Combretum binderianum.*
Extensively cultivated Bushland and Woodland on Plateau

and (volcanic) Uplands, developed on Mt. Kenya volcanics.

Landscape 5: *Hyparrhenia sp. - Heteropogon contortus.*
Very extensively cultivated Wooded Grassland on Hills and Mountains developed on (basic) intrusives in Basement System, See App. 6.7, Plate 9.

Landscape 6: *Acacia senegal - Commiphora africana.*
Complex of extensively and intensively cultivated Thicket, Bushland, and Woodland in Uplands, developed on Basement System.

Landscape 7: *USP 10 - Ochna ovata.*
Scrub forest on Mountains, developed on intrusives in Basement System (granites and granitoides).

1.5.3. Plant communities.

The 180 field samples (vegetation relevees) resulted in the formation of 30 sociological groups and 22 plant communities. The formation of them is related to geological and climatical conditions and to human influence. Ten plant communities were found on the volcanic deposits of Mount Kenya, ten on the Basement System Rocks and two on Intrusives. See the lists below.

On Mt. Kenya volcanics:

A	*Podocarpus milanjianis*	-	*Galiniera coffeoides*
B	*Ocotea usambarensis*	-	*Strombosia scheffleri*
C	*Prunus africana*	-	*Celtis africana*
D	*Pteridium aquilinum*	-	*Camellia sinensis**
E1	*Digitaria scalarum*	-	*Coffea arabica**
E2	*Newtonia buchani*	-	*Croton megalocarpus*
F	*Dombeya rotundifolia*	-	*Mangifera indica**
G	*Vernonia aemulans*	-	*Lantana camara.*
H	*Combretum molle*	-	*Combretum binderianum*
J	*Terminalia brownii*	-	*Combretum zeyheri*
K	*Themeda triandra*	-	*USP 2*

On Basement System Rocks:

L	*Tephrosia uniflora*	-	*Tephrosia villosa*
M	*Pupalia lappaceae*	-	*Aristide adscensoinis*
N	*Commiphora africana*	-	*Acacia tortilis*
O	*Acacia brevisica*	-	*Acacia tortilis*
P	*Delonix elata*	-	*Sterculia rhynchocarpa*
Q	*Acacia nilotica*	-	*Terminalia brownii*
R	*Hyphaene thebaica*	-	*Cassia longiracemosa*
S	*Pennisetum typhoides**	-	*Sorghum bicolor**
T	*Lawsonia inermis*	-	*Sphaeranthus sp.*
U	*Combretum sp.*	-	*Commiphora africana*

On Intrusives:

I	*Hyparrhenia sp.*	-	*Heteropogon contortus*
V	*Ochna ovata*	-	*USP 10*

* cultivated plants or not indigenous trees.

For a detailed description of the plant communities see Oostveen & Scholte (1987).

1.5.4. Mapping unit description.

(See Vegetation and Landuse map, Appendix 6.3).

Ocotea usambarensis - Strombosia scheffleri Ls.

Climate and Soil.

This landscape is situated in te highest north-western part of the study area where the altitude ranges from 1600-2100 m. Several hundred meters higher (outside our area) it borders the bamboo zone. It is also the wettest part of the area with an annual rainfall of 1800-2200 m.
The area is covered by several lahar flows, which form several layers causing a step-like appearance. Soils are deep-weathered Nitisols* and Acrisols, with a decreasing humic topsoil going downwards.

Past, Present and Future.

The majority of the forest is still virgin and differs not much from the forest in the past. However the boundaries of the forest (especially mapping unit 1.3) and the forest near the tracks have been heavily exploited. Forestry has practised intensive selective felling to cut timber trees like Campher (*Ocotea usambarensis*) and Podo

(*Podocarpus milanjianus*). Only near the tracks these trees are cut, remaining only useless trees (often secondary species like *Croton* sp. or very old Camphers). Near the boundaries of the forest large parts of it are cut for the use of fuelwood.

1.1. *Podocarpus milanjianus - Galiniera coffeoides*
Vegetation types: A (80%), B (20%)

1.2. *Ocotea usambarensis - Strombosia scheffleri*
Vegetation types: B (80%), A (10%) and C (10%)

1.3. *Prunus africana - Celtis africana*
Vegetation types: C (80%) and B (20%)
Most heavily influenced part of the Forest

1.4. *Ensete ventricosum - Newtonia buchani*
Vegetation types: C (70%), B (20%) and A (10%)
Only in the steepest valleys a different vegetation is found (with slopes of over 100%). A large part of this unit is covered by the *Prunus - Celtis* vegetation type with a *Newtonia buchani* Woodland along the rivers. On the steepest slopes with shallow soils also wild bananas (*Ensete ventricosum*) and tree ferns (*Cyathea sp.*) occur.

Croton megalocarpus - Coffea arabica Ls.

Climate and Soil.

This landscape stretches from the boundaries of the Rainforest to the *Combretum* Woodland and spans an area with an average annual rainfall of 1200-1600 mm. More important is the length of the growing season (with also influence of evaporation).
Obviously the soils in the cultivated area near the Forest have a darker topsoil than the soils in the lower part of the Forest. In all their other properties they are more or less similar. Going downwards soils are having more structure, shiny pedfaces become more pronounced and finally, in the extreme eastern part, the profiles become less deep. All are Nitosols.

Past, Present and Future.

The area near the Rainforest (at least unit 2.1.) is quite recently (last century) deforestated. There used to be a forest like the *Prunus africana - Celtis africana* vegetation type. Downwards a lower and opener forest with species like *Erythrina abyssinica* and *Dombeya rotundifolia* will have occured (see next landscape).

With the present high population pressure which is increasing with 4% per year, this landscape will change rapidly. Especially in unit 2.2. the change might be tremendous because the present ecologically adapted landuse system has to change as well (see unit description).

2.1. *Pteridium aquilinum - Camellia sinensis.*
Vegetation types: D (85%), E1 and E2 (10%) and C (5%)
The highest and wettest part of landscape 2 with a very typical landuse which is reflected already in the name Jaetzold & Schmidt (1983) gives for this agro-ecological zone: Tea - Dairy zone. Near the homesteads, on the ridges, small pastures of ± 1/5 ha are situated and some gardens with foodcrops (maize, beans). Elsewhere tea plantations occur.

2.2. *Croton megalocarpus - Coffea arabica.*
Vegetation types: E1 and E2 (80%), C, D and F (20%)
One of the most extended mapping units with a lot of variation in slopes, valleys and landuse. However one major component can be recognised in all of them and is the typical unit of this landscape: Farmers have their foodcrops near the homesteads on land without slope, the coffee is planted on terraces build on the often steep slopes and in the valley bottom bananas are planted. Especially near the homesteads trees are abundant (E2).

2.3. *Eucalyptus camaldulensis - Pinus raddiata.*
Plantation forest which is planted some 20 years ago.

2.4. *Albizia gummifera - Newtonia buchani.*
Vegetation types: E1/2 (50%), C (30%) and D (20%)
Valleys with still an abundant tree vegetation, remnants of the former and comparable to the lower part of unit 1.4. Often forest is cleared on the ridges earlier than in the valleys.

2.5. *Albizia gummifera - Newtonia buchani.*
Vegetation types: E1/2 (50%), D (40%) and C (10%)
The whole valley is cultivated but remnants of the forest can be found along the rivers.

2.6. *Musa sp. - Coffea arabica.*
Vegetation types: E1/2 (100%)
The smaller valleys where the banks of the streams are cultivated with bananas.

Dombeya rotundifolia - Mangifera indica Ls.

Climate and Soil.

Subhumid climate, with an annual average rainfall of ± 1300-1100 mm. Nitisols dominate in the western part and Acrisols with an argillic horizon (caused by the variation in soil moisture content) dominate in the eastern part of this landscape.

Past, Present and Future.

In the past a forest dominated which was much opener and lower than the present Rain forest. Towards the east this forest gradually becomes a kind of Woodland with more drough resistent trees.

Although the pressure on the land is high, small areas can be found with a fallow vegetation with an age of five or more years (veg. type H). But the majority of the land is cultivated with, in contrast to the previous landscape, fallow periods of up to two years (grass-or weed fallow).

3.1. *Mangifera indica - Zea mays.*
Vegetation types: F (70%), E1/2 (25%) and G (15%)

3.2. *Dombeya rotundifolia - Mangifera indica.*
Vegetation types: F (50%), E1/2 (30%) and G (20%)

3.3. *Lantana camara - Zea mays*
Vegetation types: G (40%), F (30%) and E1/2 (30%)

3.4. *Albizia gummifera - Newtonia buchani.*
Vegetation types: F (50%), E1/2 (30%), C (10%) and G (10%)

3.5. *Musa sp. - Zea mays.*
Vegetation types: F (60%), E1/2 (30%) and G (10%)

Combretum zeyheri - Combretum binderianum Ls.

Climate and Soil.

The majority of this landscape is sub-humid with an average annual rainfall of ± 900-1200 mm and a prolonged dry season. In the eastern part of the area the limitations of the soil become important. The majority of these soils are quite deep Acrisols with a moderate fertility and moderate physical properties. But near the edge of the plateau (in the southern part of the area) they become much shallower and more gravelly. Within one meter depth murram (iron - manganese concretions) can be found and finally at the edge of the plateau the soils become less than 20 cm deep (Lithosols). Although the majority of this landscape is of volcanic origin, in some valleys Basement System rocks are the parent material for soils which causes many similarities with landscape 6.

Past, Present and Future.

Especially north of the Thuchi river (Meru district) this landscape is quite extended. It is relatively undisturbed, which is striking when going down on the slopes of Mt. Kenya through its intensively cultivated land (landscape 2, 3 and 6). This can be explained by its buffer position between the lands of different (sub)tribes: the Chuka (highlands, Ls 2 and 3) and the Tharaka (lowlands, Ls 6) people. Only recently this area became safe enough to start cultivation. The vegetation is influenced by an extensive burning regime which caused the dominance of *Heteropogon contortus* but saved the tree layer. In future much more cultivation will be practised in the northern part of this landscape, in the southern part most of the suitable places are already cultivated. A Bushland is left which is grazed, and offers little opportunities to cultivate due to it's very shallow soils.

4.1. *Combretum zeyheri - Heteropogon contortus.*
Vegetation types: H (70%) and F (30%)

4.2. *Combretum zeyheri - Zea mays.*
Vegetation types: H (50%) and F (50%)

4.3. *Aloe secundiflora - Euphorbia nyikae.*

4.4. *Heteropogon contortus - Euphorbia nyikae.*

4.5. *Zornia apiculata - Ocimum basilicum.*
Vegetation types: L (90%) and K (10%)
On some places flows of Lahar streamed further away from Mt. Kenya. One of these probably reached a depression in the Basement System and formed a plain. Soils are very shallow and moderately fertile there. Small areas with soils of heavy clay soils (Vertisols) occur, developed in a poorly drained environment as can be expected on these flat areas. They have a characteristic vegetation type (K).

4.6. *Combretum zeyheri - Terminalia brownii.*
Vegetation types: J (100%)
This Woodland is found on the Materi basalt Plateau and on the Plain of lahar where also unit 4.5. is situated. Both locations are surrounded by Landscape 6, which illustrates the importance of the parent material. Compared to unit 4.5. this unit has a much less human- influenced vegetation type (especially burning).

4.7. *Euphorbia nyikae - Acacia brevispica.*
Vegetation types: F (60%), G (20%) and O1 (20%)

Valleys with locally shallow soils, which are partly derived from Basement System rocks which has its influence relativelly far to the west.

4.8. *Combretum binderianum - Combretum zeyheri.*
Vegetation types: H (40%), G (30%) and S (30%)
No Basement System influences.

Hyparrhenia sp. - Heteropoqon contortus Ls.

Climate and Soil.

Volcanic influences no longer dominate the three eastern situated landscapes. This change in geology goes together with a steadily decreasing amount of rainfall, in this landscape about 1000 mm a year. This landscape occurs only in the north-eastern part of the Chuka-south area and has slopes of over 20%. Soils are moderately deep, often with murram.

Past, Present and Future.

Probably this landscape used to be covered by a kind of Bushland, similar to unit 5.1. Fire is the main factor which has caused this Wooded Grassland. The fire tolerant *Heteropogon contortus* dominates here. Due to the steep slopes, shallow soils and demographic factors (see Ls4) this landscape has never been cultivated to any extend. Main landuse is grazing (mainly cattle). During the dry season the Hills are covered by a layer of "standing hay" with a very low food quality. For a more detailed discussion about the grazing situation in this landscape see Scholte 1986[a].

5.1. *Gardenia jovis-tonantis - Heeria reticulata.*
Vegetation types: Q (90%) and I (10%)
Vegetation type Q is dominant, but some open places (especially in the Mutharanga forest near Chiokarige) occur. Fire is not important, only the fringe of the scrub forest is burned regularly.

5.2. *Heeria reticulata - Heteropogon contortus.*
Vegetation type: I (100%)

5.3. *Gardenia jovis-tonantis - Heeria reticulata.*
Vegetation types: Q (90%) and I (10%)

5.4. *Hyparrhenia sp. - Heteropogon contortus.*
Vegetation type: I (100%)

Acacia senegal - Commiphora africana Ls.

Climate and Soil.

This landscape occupies most of the eastern part of the Chuka-south area, the lowest and driest part of this area with an annual average rainfall of 900-600 mm. It belongs to the Basement System which stretches several hundred kilometers to the east and is covered by an endless sea of thornbush. Each part of this area has once been cultivated, so vegetation is a reflection of the stage in the bush-fallow system. This often obscures the difference in environmental circumstances.

The majority of the soils are Chromic Luvisols, developed on gneisses rich in ferro-magnesium minerals, which are quite deep and moderately fertile (chemically) but have a very low organic matter content. They are all eroded and have lost their humic topsoil. This caused the sealing of the bare soil surface.

Past, Present and Future.

In 1938 Maher, then Soil Conservation Officer for Kenya wrote a report about Embu district based on four weeks of field investigations. He writes about the *Acacia senegal - Commiphora africana* landscape: "Bare granitic rocks and scanty sands in semi-arid country situated at low altitudes reflect back a pitiless sun. Stunted animals and poverty-stricken inhabitants seek sustenance in a barren semi-desert where all hope of progress is futile and where famine is ever waiting at the door - the most promising method of dealing with these people appears to be to move them, lock, stock and barrel, leaving their present land to regenerate to bush and to become once again the haunt of the elephant, the rhinoceros and the buffalo - abandonment of the land to the slow but sure healing of Nature is the only practicable remedy". (Maher, 1938).

Nearly fifty years later the physical situation seems to be much the same. No discussion has to be held about the severety of the degradation, but the report of 1938 leads to questions about the rate of it.

Due to the availability of permanent water and easily exploitable land, this landscape has been cultivated already a long time ago. Shortly

afterwards degradation became more and more serious till the situation in 1938 and nowadays.
See Scholte (1986b) for a reconstruction of the former vegetation and the change into the present situation.

Present Landuse.
In the majority of the area bush-fallow agriculture is practised. People start cultivation by clearing a particular bush, usually a few hectares large. Not all trees are cut, especially *Sterculia rhynchocarpa*, *Delonix elata* and *Adansonia digitata* are spared, *Commiphora africana* and *Acacia senegal* and *A. tortilis* trees are often only cut, remaining a one meter high stem. A few months after clearing everything is burned, usually just before the expected onset of the rains.

Cultivation starts with the major foodcrops millet, sorghum and green grams. Most important cash crop is cotton. On favourable places which receive more moisture, maize is grown.

After two or three years of cultivation, land is left fallow. The first year only heavily grazed annual grasses and herbs grow. Trees which were spared during cultivation, grow up and are the centres of a slowly recovering vegetation. Depending on the amount of depletation of the soil and the grazing pressure, regeneration may occur. If not the land remains bare, the soil surface seals and any regeneration will be unlikely. The situation is often worsened due to grazing animals for which this area is very attractive (see Scholte 1986a).
The regenerating trees slowly grow out of reach from cattle and goats, and within several years a dense thicket is formed, which after 10-20 years can become a Scrub Forest (7 m high trees). This stage is hardly reached anymore, because before that moment trees are already cut for a new cultivation stage. Nowadays especially the transition from bare soils with outgrowing trees into bushland is hindered. More exhausted soils and a higher grazing pressure are responsible for this. Although landclearing as such is not accelerating, the amount of older *A. senegal* - *C. africana* bush decreases due to a decrease in development of bush after cultivation (see Scholte 1986a, 1986b).

6.1. *Bauhinia tomentosa - Acacia brevispica.*
Vegetation type: O (100%)
Thicket and Bushland on the footslopes of the scarp between Ls 4 and 6. This rather luxuriant vegetation contrasts with the sparse vegetation upwards (unit 4.3.). Here the moisture availability is very high due to seepage of groundwater from the plateau. Many similarities exist between this landscape and landscape 7.

6.2. *Commiphora holziana - Commiphora africana.*
Vegetation type: N (100%)
Mainly Scrubforest on a ridge in the centre of this landscape.

6.3. *Acacia senegal - Commiphora africana.*
Vegetation types: O1 and O2, P
On a few places extended areas Bushland and Woodland can be found. This unit is heterogenous, but the majority consists of relative old Bushland.

6.4. *Pennisetum typhoides - Commiphora africana.*
Vegetation types: N (25%), S (20%), M (20%), P (15%), O (15%), F (5%).
The most common mapping unit in this landscape.

6.5. *Pennisetum typhoides - Commiphora africana.*
Vegetation types: N (40%), M (30%), S (20%), P (5%), L (5%), F (5%).
In many aspects comparable to unit 6.4., but not the conspicious chess-board pattern of thicket and farmland.

6.6. *Pennisetum typhoides - Aristida adscensionis.*
Vegetation types: S (30%), N (30%), M (20%), O (20%).

6.7. *Pennisetum typhoides - Acacia tortilis.*
Vegetation types: S (40%), O (30%), M (15%), L (15%).
Farmland with *Acacia tortilis* Woodland along the watercourses and in general a high tree cover.

6.8. *Terminalia brownii - Hyphaene thebaica.*
Vegetation types: N (30%), S (20%), O (20%), Q (20%), M (10%).

6.9. *Pennisetum typhoides - Gossypium sp.*
Vegetation types: S (50%), L (30%), M (10%).

6.10. *Tephrosia sp. - Cassia longiracemosa.*
Vegetation types: S (60%), L (30%) and R (10%).
Along several rivers extended river-terraces have been formed, which due to their fertility are all intensively cultivated. The majority of this unit is presently cultivated or fallow (usually less than 2 years). Only small patches of less intensively used land occur.

6.11. *Acacia rovumae - Cassia longiracemosa.*
Vegetation types: S (40%), L (30%), R (25%) and T (5%).

6.12. *Acacia mellifera - Acacia senegal.*
Vegetation types: 02 (100%).
Old riverterrace with Bushland, 5 m high, with a very low ground cover due to the heavy grazing pressure.

USP 10 - Ochna ovata Ls.

Climate and Soil.

In the extreme eastern part of the Chuka-south area a range of mountains is situated which rises more than 500 m above the surroundings. This altitude causes a lifting of airmasses from the east, resulting in a nearly doubling of the annual rainfall (1200 versus 700 in the surroundings). Soils range from shallow to moderately deep (especially on the footslopes), their fertility is moderate. In the footslopes soil moisture conditions are relative favourable.

Past, Present and Future.

These Mountains were attractive during times that nomads crossed the area, people fled into the Mountains and stayed long after. In 1945 the British colonial goverment decided to protect the heavily exploited Mountains and all cultivation and inhabitation of these Mountains was forbidden with exception of the Kibiro Hills. Remarkable is that after independance (1963) the forests remained unoccupied in contrast to an overall tendency in Kenya to neglect colonial anti-erosion measures.

Up to this moment no cultivation and grazing has been practised in these gazetted Mountains. In 40 years a dense Scrub Forest developed above which baobabs (*Adansonia digitata*) rise, remnants of the cultivation land.

The Kibiro hills which were never gazetted, probably show the situation of the Mountains before gazetting: a stone-rich bare soil with an occasional shrub and no cultivation anymore. Only some grazing is practised by herds of people living near the Tana river.

The boundary of the gazetted forests can be found as sharp lines in the landscapes. Long before the time of cultivation, these Mountains were covered by a high forest. Especially on the higher slopes this might

have resembled the Mt. Kenya forest. Nowadays only on the highest peak of Mumoni forest "real" forest can be found (less than 5 acres).
The majority of the Scrub Forest is formed by the *Ochna ovata - Acacia brevispica* vegetation type, characteristic for a recovering environment with a not too shallow soil and slopes of less than 50%. Baobab trees form the upper layer (15 m high). On steeper slopes other vegetation types occur. On the top of rockfaces (with a very shallow soil) *Euphorbia nyikae* is dominant together with some *Commiphora* species. Under these rockfaces a dense thicket, evergreen, ± 1.5 m high stands, benefitting of the availability of rain water running off the rocks.

7.1. *Ochna ovata - Acacia brevispica.*
Vegetation type: V (100%).
The majority of this landscape is formed by the *USP 10 - Ochna ovata* vegetation type which occurs on the slopes. On the footslopes an *Acacia tortilis* Woodland can be found. Patches of grassland occur, especially on the western side of the range (*Hyparrhenia sp. - Heteropogon contortus* vegetation type).

7.2. *USP 10 - Ochna ovata.*
Vegetation types: V (80%) and U (20%).
The Scrub forest on Mumoni mountain differs from that of Kijege in having a slightly different species composition. The majority of the footslopes has been cultivated in Mumoni forest. On the peak of Mumoni (1700 m) Mountain Rainforest occurs.

7.3. *Canthium phyllanthoideum - Boerhavia erecta.*
Vegetation type: M (100%).
The only not gazetted "forest" shows clearly the effect of not being protecting during more than 40 years. It is covered with a sparse fallow vegetation and a few scattered *Balanites aegyptica* shrubs.

1.6. SOIL FAUNA.

1.6.1. Introduction.

The activity of the soil fauna is often an important soil forming process, because it is of help in the decomposition of plant remains, and creates channels by which soil physical properties are influenced. Therefore, attention was paid to the study of the soil fauna in the Chuka area. Because of earlier experiences in the Kisii area in Kenya an emphasis was laid on the activity of termites.

Termites (order *Isoptera*) are principal inhabitants of tropical and sub-tropical semi-arid regions. They belong to the "social insects" (like the *Hymenoptera* (bees)), which live in colonies in nests of their own construction. These nests serve to house and protect the colony, store food and maintain an optimal environment. Subterranean galleries and covered runways or sheetings are used when the termites are searching for requisites, as food collected by the workers is the basic energy source of the colony. Depending on the species of termite it consists of plant material, either living, dead, partially or almost entirely decomposed (wood, grass, herbs and plant litter, humus and fungi).
Termites have an impact on both vegetation and soil:

- By feeding activities and subsequent decomposition, termites affect the cycling of organic matter and nutrients.
- By building nests, mounds, subterranean galleries and sheetings, termites cause a redistribution of soil particles, resulting in altered physical and chemical soil properties (Lee and Wood, 1971).

The sub-family *Macrotermitinae* is a dominant group in the research area. Termites of this sub-family construct special structures with faecal material, the "fungus combs", in their nests. On these combs various fungi are grown, continuously eaten by the termites and replaced with fresh material. The fungus combs are of importance by providing nitrogenous materials and vitamins to the termite (Lee and Wood, 1971).

In general the fungus growers (*Macrotermitinae*) are very efficient in decomposing organic matter. Nearly all material transported to the nest is utilized, leaving a very small fraction undigested.
Return to the ecosystem takes place only as:

- salivary secretions (for cementing soil particles)
- termite corpses (annual flights of alates)
- predation on termites (e.g. by birds, lizards, ants)
- faeces (in *Macrotermitinae* little or no return via faeces; only available when nest is abandoned) (Wood, 1975).

The construction of termite mounds and therewith the movement of big quantities of soil has been the research subject of several soil scientists. In some cases bringing of subsoil material to the surface is expected as beneficial to soil fertility (Arshad, 1982; Miedema and Van Vuure, 1977). Wood and Sands (1978) on the other hand found that erosion of structures built by *Macrotermitinae* often added soil of a lower nitrogen content compared with the topsoil. Also the low organic matter content of the subsoil material is supposed unfavourable because this should imply an acceleration of erosion (Lee and Wood, 1971).
The dense network of galleries built by termites must affect porosity and aeration, but these effects have not yet been measured (Lee and Wood, 1971). Pomeroy (1983) tried to summarize the effects of *Macrotermitinae* in grazing lands of a semi-arid area in Kenya. He concluded that beneficial and harmfull effects - insofar it is possible to compare them- could well be of similar magnitude.
The construction of sheetings around "food" before this is transported to the nest can be seen as an adaptation to climatic conditions that are unfavourable for termites. Soil particles are cemented together with salivary secretions and this means a contribution of organic matter to these soil constructions (Wood, 1975; Robinson, 1958; Wood and Sands, 1978). An enormous quantity of soil is treated in this way: Bagine (1984) estimated for *Odontotermes* for an arid area in Kenya (200 mm rain annually) a translocation of 1059 kg of soil to sheetings per hectare per year. Looking at the enormous amount of soil translocated, the addition of organic matter in the form of saliva is possibly of importance regarding soil fertility. However this has never been quantitatively described untill now.

In the different zones of the Chuka Area also the abundance and activity of termites change. A very preliminary survey was carried out to obtain an idea of the termite activity in the different zones. After that a more intense study was made on effects of termites on the soil, with either emphasis on the chemical or the physical aspects, or both. In the forest zone the termites are active, mostly decomposing wood (*Odontotermes* species), but also some humus feeders are found. In the tea zone at about 1700 m altitude, the soil is mostly a Nitosol, termite activity was not very high, and termite sheetings were only found on fencepoles and on the stems of the trees.

In the coffee zone at about 1400 m altitude more termites were active. Here the chemical aspects of termite activity were more intensively studied. In one plot in a well kept coffee field, samples were taken from a soil pit. Separate samples were taken from the basic structure elements (rounded blocks) and from the clearly termite influenced aggregates, for example found in termite galleries. The samples were chemically analysed. No significant differences in contents of C, N and Ca could be detected but the number of samples was low and the variation large. (Aalders, 1987 and Nobbe, 1987).

In the cotton zone at about 900 m altitude many termite nests both of *Odontotermes* and *Macrotermes* are found. Here a rather elaborate studie was carried out, the results of which will be discussed below. (Bongers, 1987 and Kools, 1987).

In the livestock zone (the eastern half of the area) termites seem to be the only soil fauna surviving, huge *Macrotermes* mounds being abundant, See App. 6.7, Plate 9. Here an experiment was carried out, trying to use termite activity to physically improve the crusted soils of this region. The results indicate that this approach to the problem is viable (Scholte, 1986b).

1.6.2. Soil fauna cotton zone - methods.

A maize field with a *Macrotermes* mound was chosen as an experimental site. It was situated on a 0-2% slope, on soil unit LP1AB (chromic and humic Acrisols), and in vegetation unit 3.3.: *Lantana camara - Zea mays*. Ten plots, each 100 m^2 (10 x 10 metre) located at various distances from the *Macrotermes* mound were studied.

For the estimation of litter production all litter was collected from three specific sites of 1 m^2 whenever material was found.

The foraging acitivity of *Macrotermes aff. subhyalinus* can be measured by counting each month during 24 hours the number of foraging holes open (Lepage, 1979). This could not be done in our sample plot, but presence and dimensions (in cm) of newly build sheetings, still wet, were noted in the morning. Doing this was considered a way to describe the foraging activity. With a conversion factor the amount of transported soil can be calculated. Sampling was at first done every three weeks for three successive days. Later this was done more frequently.

Observations were carried out on a transect of 200 x 1 metre in the maize field. Litterbags were installed to estimate the amount of litter consumed by termites and its seasonal variation and the amount of soil transported in relation to the amount of litter. The litterbags consisted of coated iron gauze (mesh width 0.5 x 0.5 cm), thus permitting termites to penetrate the bags. They were both used aboveground and underground. For aboveground foraging litter collected from 1 m^2 was laid on top, the soil removed as much as possible with a brush. The litter was weighed in the field; a moisture content sample was taken and dry weight calculated. The 20 aboveground litterbags were inspected every week: from the moment the termites started eating the litter and began to build sheetings to cover it, it was kept for two weeks. Subsequently the remaining litter and soil were taken and new material was exposed on the same spot. From the remaining litter the dry weight was measured again and the sheeting was collected for weighing and analysis on CEC, base saturation, pH, C and N content.

The method used for measuring litter consumption by aboveground litterbags includes an estimation of the amount of litter present on the ground, during the experimental period (litter availability). For underground consumption 10 gauze envelopes (30 x 30 cm) were dug in at a depth of 10-15 cm. They contained 25 g fresh litter from the field. A subsample was taken for water content measuring, for knowing the dry weight. In advance a scheme was made, according to which the litterbags would be taken out. This consisted of cycli of 7 weeks, built up by 1, 2 and 4 weeks in varying order. Loss in dry weight was determined.

1.6.3. Results.

Termites were determined with the use of a determination key of Bouillon, (1965). In the cotton zone one species of *Macrotermes*, *Pseudocanthotermes*, *Ancistrotermes* and *Microtermes* was found. Two *Odontotermes* species (A and B) were found: species A on the maize plot and species B on other fields in the cotton zone. On the maize plot *Macrotermes* was very numerous, also *Microtermes* was often found. Less often *Odontotermes* sp. A were seen. The name of both species could not be determined. Incidentally *Pseudocanthotermes* and *Ancistrotermes* were found.

From the three litter collecting sites an average litter production of 400 ± 67 g/m^2 was estimated for the maize field (cotton zone) for the experimental period (24 weeks). The litter availability data as derived from the litterbag experiments are combined in table 7.

Table 7: Litter availability in g/m^2 as calculated from the in-weight from the aboveground litterbags, maize and cottonzone (1985-1986)

	Nov.	Dec.	Jan.-Febr.	Mrch.-Apr.
Maize	162 ± 89	79 ± 30	29 ± 9	73 ± 22

Litter production measurements give an estimate of how much litter is produced, while litter availability is an estimation of the amount of litter present on the ground. Despite inaccuracies in the methods a coarse estimation about aboveground consumption can be made from both figures: about 327 g/m^2 disappeared, in other words is consumed by termites.

The litterbags experiments made it also possible to estimate litter consumption by termites. Although some big differences in amount eaten from the above ground litterbags occur, an average value is calculated. From the 68 ± 23 g offered on the litterbag 28 ± 15 g is eaten.

With the assumption that the amount eaten is a constant factor, independent of the amount litter available (using the above mentioned averages for maize 59%) and the average area foraged by termites per week (0.05 ± 0.06 m^2/m^2) a very coarse approach about the amount of litter left in the field can be made. It should be noted that the obtained data about litter consumption for maize are mainly based on the litterbags B, C and D, at short distance of the *Macrotermes* mound. During the growing season a pool of 400 ± 67 g litter/m^2 was present during the 24 weeks of our experiment. With above mentioned assumptions after 24 weeks 101-217 g/m^2 is still present at the maize field. This means that both methods yield the same consumption figures.

Consumption from underground litterbags is not so easily interpretable. Expected differences in foraging quantity between bigger and smaller termites (in this experiment resp. *Macrotermes* and *Odontotermes* versus *Microtermes*) cannot be concluded with this method. Collecting the litterbags occurs independent of visible eating signs by termites (in contrast with the aboveground litterbags). The time during which termites are active in the litterbag is therefore unknown. If for example bigger termites are present for a short time then only a small loss in weight of the litter will be found.
From underground litterbags on average 5.9 ± 5.0 g disappeared. The big variance is mainly due to foraging by different termite species (in general: bigger and smaller eaters) and by the unknown foraging time.
The presence of *Microtermes* in the maize field is remarkable: once present, these termites stay at a specific site, only driven out temporary by the bigger *Macrotermes* or *Odontotermes*. Another feature which becomes clear from the underground litterbag data is the presence of *Macrotermes* in litterbags B, C, D and F; *Odontotermes* in litterbags F, H and J and *Microtermes* foraging at all sites. For *Macrotermes* and *Odontotermes* this is in agreement with the aboveground activity observations.
Kooyman & Onck (1987) also found *Microtermes* to increase under agriculture. The small, diffuse underground nests are relatively unaffected by agricultural practises. In litter consumption *Microtermes* would not be unimportant, especially due to the area they inhabit (in 5 weeks 9 of the 10 underground litterbags were foraged by *Microtermes*).
In our experiment with litterbags with fixed positions, consumption

estimates for a situation with *Microtermes* present can be done: on average 1-5 g/week. This estimate will be too optimistic, because searching and colonization will take time (dependent among others from population density in the field).
Calculations about the amount of litter consumption per m^2 by *Microtermes* are not so easily made, because there are no data about nest or population density. A reliable probability of presence cannot be accepted, because the termites stay at a specific site after colonization.

The amount of sheetings (cm^2/m^2/day) were observed in relation to the position in the field.
Three periods of foraging activity are distinguished:

a. the (short) rainy season: the start of the experiment in November till the end of December, including the last rain of 24/12/1985.
b. the dry season: January, February and the first week of March.
c. the (long) rainy season: starting with the first rain at 7/3/1986, till the end of the experiment in April.

Although the three periods were not sampled in exactly the same way the results are interpreted as if they were entirely comparable.
The plots near the termite mound are more often visited by termites than the more distant plots. In the dry season the termites forage at the shortest distance from the nest. In March/April the largest distance is found. Because of the big heterogeneity both in distance and amount of sheetings formed on the transects an estimate of the soil replaced to kgs per hectare is a guess. However, a coarse estimate can be made by applying a simplified zonation (active zones and inert zones). For all zones an average sheeting quantity in cm^2/m^2/day is calculated. With help of a conversion factor (found by collecting soil of measured sheetings and weighing it) the soil quantity replaced in g/m^2/day can be calculated. An estimate of the overall quantity of soil replaced on the whole experimental plot is calculated from the relative area fraction of the active zones. See Table 8.

Table 8: Calculated amount of soil replaced by termites from activity measurements in $g/m^2/day$ (1985-1986).

termite species	area	season					
		Nov./Dec.		Jan./Mrch.		Mrch./Apr.	
		m^2	$g/m^2/d$	m^2	$g/m^2/d$	m^2	$g/m^2/d$
Macrotermes	active zone	300	5	330	2	287	21
						112	13
						40	9
						200	5
	whole plot	1000	1.5	1000	0.7	1000	9
Odontotermes	active zone	150	0.02	100	0.06	274	2
	whole plot	1000	0.003	1000	0.006	1000	0.6

Conversion factor for Macrotermes sheetings : 1 cm^2 1.0 ± 0.8 g.
Odontotermes sheetings: 1 cm^2 0.09 ± 0.04 g.

For the 24 weeks the experiment lasted, this means that 491 g soil/m^2 is replaced by *Macrotermes*; 25 g/m^2 by *Odontotermes*, holding for the experimental plot.
Because of the close relation of distance to the termite mound and litter availability (both amount and distribution) it is of importance to be cautious when interpolating these results to bigger areas.

Eaten aboveground litterbags are related to the total amount of litterbags available per week, resulting in a ratio of 0.05 ± 0.06. In spite of the big variance these averages give a slight indication about the area foraged by termites per unit of time. For example: a ratio of 0.05 means: on a part of 0.05 m^2 of a total area of 1 m^2 is foraged in 1/0.05 = 20 weeks.

In Table 9 and 10 the data of some chemical analyses on %C, %N, C/N and Cation Exchange Capacity (CEC) for a soil profile very close to the experimental plot and for some sheetings collected at the maize plot are shown.

Table 9: Chemical analyses on C, N and CEC for profile 122/3-116 (soil unit LP1/AB)

depth	%C	%N	C/N	CEC
0- 5	2.44	0.26	9.4	154
5- 10	1.64	0.25	6.6	139
15- 20	2.17	0.23	9.4	133
25- 30	1.97	0.21	9.4	128
35- 40	1.82	0.16	11.4	113
50- 55	0.65	0.14	4.6	99
95-100	0.71	0.09	7.9	74

In general the C/N ratio for the sheetings is higher than for the soil (both surface and deeper layers), mainly due to a low N-content of the sheetings. The sheetings-CEC is lower than the CEC for the topsoil.

1.6.4. Conclusions and discussion.

These studies were carried out during the short dry season (January-March) and in periods of the "short" and the "long" wet season. Especially for conclusions concerning litter availability and consumption by termites the long dry period (May-October) is of special interest. Consumption during periods of litter shortage can be of great importance, in particular when the termites start eating the crops.
From activity measurements and litter consumption data a high termite activity beyond a radius of about 20 metres from the *Macrotermes* mound in the maize field became apparent. On the experimental field also a zone of activity by *Odontotermes* (from which the nest is unknown) exists, resulting in the overall estimate for quantity of soil translocated of 491 g/m^2 for *Macrotermes* and 25 g/m^2 for *Odontotermes*, holding for this location. Because of the dependence of termite activity to distance from the mound and the big heterogeneity in distribution of the sheetings (connected with litter distribution and availability) some caution must be practised with interpolation of these results to bigger areas.
Microtermes, a small termite, also member of the fungus growing *Macrotermitinae* appears to be numerous in the maize field, especially foraging underground. Only 1-5 gramme per week is foraged by

Microtermes, but together with the high probability of presence (in 5 weeks 9 of the 10 underground litterbags were inhabited by *Microtermes*) these termites seem to be important in underground litter consumption. Because of the lack of a reliable probability of presence for *Microtermes* (after a first colonization these termites tend to stay at that specific site, resulting in only a few data) comparison of litter consumption by bigger and smaller termites is not possible.

The litter consumption from aboveground litterbags (mainly by *Macrotermes*) and some rather crude hypotheses concerning the foraging rate, the amount eaten by termites and the amount of litter present, resulted in the very coarse estimate of 102-217 g/m^2 still present after the 24 experimental weeks. With regard to the litter production for this period some 180-300 g/m^2 disappeared during this period. From the litter availability calculations follows a consumption of 327 g/m^2 for the same period. Although both calculations must be seen as very coarse estimates, it is remarkable that the order of magnitude corresponds. Very generally 3/4 part of the available litter has been consumed by termites in the 24 week experimental period.

The higher C/N ratio and the lower Cation Exchange Capacity (CEC) from the sheetings, compared with the (top)soil both indicate possible unfavourable influence of termites in an agricultural situation.

Termite activity may influence soil physical properties (e.g. porosity), but research concerning this in the same area has not yet been completed (Bongers, 1987). Concluding from the results described in this report termite sheetings do not contribute to an increased soil fertility. Combined with the high litter consumption it seems that termite presence does not affect agricultural conditions favourably.

Table 10: Chemical analysis about C, N and CEC for some collected sheetings (for Macrotermes and Odontotermes).

termite	date	%C	%N	C/N	CEC
Macrot.	16/11	1.47	0.12	12.3	57
Macrot.	16/1	2.12	0.12	17.7	116
Macrot.	6/2	1.49	0.13	11.5	115
Macrot.	19+27/2	2.12	0.11	19.3	104
Macrot.	19+26/3	1.95	0.13	15.0	109
Macrot.	10/4	2.09	0.13	16.1	118
Macrot.	20/3	2.01	0.14	14.4	110
Macrot.	8/4	4.62	0.28	16.5	167

2 METHODS

2.1 INTRODUCTION

This chapter provides information on methods applied for the soil survey, the laboratory testing of soil samples and the cartography. The methods that have been practised for the studies on vegetation, farming and land-use and land evaluation have been described in the chapters in question.

2.2 OFFICE METHODS

Prior to the fieldwork all available aerial photographs, topographic and geological maps, reports and other literature about the Chuka Area were collected and studied.

The area is covered by topographic maps from the Survey of Kenya at a scale of 1:50.000, viz. the sheets 122/3 (Chuka) and 122/4 (Ishiara). Together these two sheets form the southern half of quarter degree sheet 122 (Chuka) of the soil map of Kenya, to be published at scale 1:100.000.

The aerial photographs cover the area at a scale of approximately 1:50.000. Certain selected Sample Areas, to be discussed in the following paragraph, are covered by aerial photographs at a larger scale, mainly approximately 1:12.500.

All aerial photographs were acquired from the Survey of Kenya, except those of an area near Ishiara, which were borrowed from a private firm. Most of the photography was done in 1963, which in some areas brought about confusion, due to changes in roads, land-use etc.

A geological map of the area at a scale 1:250 000 existed (Schoeman, 1951). Moreover, the project made a preliminary geological map (1:50000), which was presented to the Ministry of Mines and Geology. (Veldkamp, and Visser, 1987).

2.3 FIELD METHODS

As a first step in the reconnaissance survey a general inventory on soils, vegetation and land-use was implemented on basis of aerial photo-interpretation and 3 weeks of fieldwork by 4 surveyors and their assistants.

Results have been published by Van Oostveen et al. (1985). The soil inventory map was then used to select two so-called sample strips, indicated on a map in Appendix 6.8.

Between May 1985 and June 1986 a number of surveyors worked on these areas in detail and/or semi-detail. After having accomplished the sample strip surveys, a much larger area adjacent to and including the sample strip was surveyed and mapped on a reconnaissance basis (1:50.000). In general, the same surveyor worked on both subjects. In each survey, numerous routine augerings were made with an Edelman soil auger (mostly clay-type), in general to a depth of 120 cm. The sites were chosen from aerial photographs and pinpointed on the photo and the fieldmap. Properties of land, soil and vegetation were recorded on standard forms of the Kenya Soil Survey (KSS), that are based on forms used by FAO (1977). Some 130 soil pits have been described and sampled. Profile descriptions and analytical data of samples from 44 soil pits which can be regarded as representative for the soil unit concerned, as well as their location and serial number are given in Appendix 6.8.

The separate reconnaissance soil maps were finally compiled into the actual mapsheet Chuka-South and reduced to 1:100.000.

A few profiles have been selected by the International Soil Research and Information Centre (ISRIC), Wageningen, The Netherlands, for further analysis and study, particularly including micromorphology. Of these profiles soil monoliths have been prepared for display, reseach and training at ISRIC, KSS and the AUW.

Apart from the soil surveys, a number of related soil, vegetation and crop studies have been carried out by post-graduate students.

All reports are available for restricted use at het KSS, Nairobi.

2.4 LABORATORY METHODS

Most determinations for soil characterization were done at the National Agricultural Laboratories (NAL) in Nairobi. The procedures are summed up below. Moreover, a number of soil samples have been analysed at the TPIP laboratory in Chuka. Especially moisture retention (pF) and pH were determined, partly on behalf of the survey, partly for the benefit of soil research subjects. Most soil mineralogy analysis has been done at the laboratory of the department of Soil Science and Geology of the AUW.

The samples received the following treatments:

Texture

NAL. Treat mechanically to remove cementing agents; shake overnight with sodium hexametaphosphate and sodium carbonate in an end-over-end shaker.

Measure silt and clay (<0.05 mm) with a hydrometer after 40 s and clay (<0.002 mm) after 6.4 h. The difference represents sand (0.05-2 mm).

pH and electrical conductivity

NAL. For soils with an electrical conductivity (EC) >120 mS at 25°C, prepare a saturation extract (paste) for measurement of pH (paste) and EC. Measure pH (H_2O) in a soil-water suspension and pH (KCl) in a suspension of soil in aqueous KCl (concentration 1 mol/l) of volume ratio 1:1.

Mass fraction of carbon

NAL. Walkley and Black method (Black, 1965, p. 1372-1376) for the A-horizon only. No correction factor was used to compensate for recovery.

Mass fraction of nitrogen

NAL. Semi-micro Kjeldahl on a horizon only (Black, 1965, p. 1374-1375).

Substance content of exchangeable cations

NAL. Leach soil with ammonium acetate (content. 1 mol/l) of pH 7.0. Estimate Na, K and Ca by emission spectrometry and with addition of lanthanum chloride for calcium. Estimate Mg by atomic absorption spectrometry.

Cation-exchange capacity

NAL. After leaching out exchangeable cations, wash the soil with aqueous ethanol (volume fraction 0.95) and percolate with acidified NaCl. Steamdistill off the ammonia and titrate against HCl (concentration 10 mmol/l) (Houba et al., 1979).

Exchangeable acidity

NAL. Extract soil with $BaCl_2$ (concentration 300 mmol/l), not buffered at any pH and titrate (Mehlich et al., 1962).

Mass fraction of available nutrients

NAL. Soak for 1 h with acid (concentration of HCl 100 mmol/l and of H_2SO_4 12.5 mmol/l) in a volume ratio 1:5 and shake for 10 min.
Estimate Ca, K and Na in the extract by emission spectrometry after anion resin treatment to counteract precipitation of Ca-salts. Estimate Mg by atomic absorption spectrometry with thiazol yellow, P with vanadomolybdophosphoric yellow, and Mn with phosphoric acid and potassium periodate (Mehlich et al., 1962).

Bulk density (volumic mass)

Dry a known volume of soil core at 105°C and weigh (Richards, 1954).

Moisture tension

TPIP. Estimate mass fraction of moisture in saturated soil and soil after equilibration with sandbox to pF 0.4, 1.0, 1.5 and 2.0 and kaolin box (for pF 2.3 and 2.7). pF 3.0, 3.7 and 4.2 (Stakman et al., 1969) were determined at the NAL.

2.5 CARTOGRAPHIC METHODS

For the area surveyed, a base map on scale 1:100.000 was not available. So two adjoining sheets (122/3 and 4) of the Survey of Kenya on scale 1:50.000 were assembled to cover the area. Each sheet was simplified. Additional information was collected during fieldwork and from aerial photographs and added, for instance the new tarmac road.
The soil map (Appendix 6.1) was transferred onto a radex-red transparent copy of the basemap and produced in black and white only.

KSS will in due course use this map to compile its final, coloured soilmap of the entire Chuka-mapsheet 122.

3. THE SOILS.

3.1. PREVIOUS WORK.

Gethin-Jones and Scott (1959) prepared a 1:3.000.000 soil map of Kenya for the first edition of the National Atlas of Kenya. It was reprinted in 1962 (2nd edition) and 1970 (3d edition). The authors recognized the following soil units within the survey area:

- "Strong-brown loams (ando like soils)", which coincide roughly with unit RP2 of the volcanic Footridges (mainly Cambisols)

- "Red friable clays with and without a humic topsoil (latosolic soils)", which cover unit RP1h and U1P1h of the volcanic footslopes for about 90% (mainly Nitisols and Acrisols)

- "Red friable clays (latosolic soils from volcanic and basement complex)", which cover roughly the transitional zone with units U1P LP and U2F, of the Volcanic Uplands, Plateaus and of the gneisses rich in ferromagnesian minerals (mainly Acrisols, Luvisols, Cambisols and Lithosols)

- "Complex of:
  - yellow-red loamly sands (podsolic soils from basement upper slopes)
  - dark brown sandy loams (podsolic soils from sediments and basement)
  - very pale brown mottled loamy sands (groundwater laterite from valley bottom"

This complex covers the major part of the U2 soils on various gneisses, colluvium and pleistocene sediments of the basement complex (mapping units U2F, U and X, P, B and V2)

- "Shallow stony soils and rock outcrops", which cover the units M and H.

The survey area is also covered by the Exploratory Soil Map (Scale 1:1.000.000) prepared by the Kenya Soil Survey (Sombroek et al 1982). While comparing the section of this map which covers the Chuka-South Area with the soilmap of that area (Appendix 6.1) the following remarks can be made:

- The M2-unit coincides well with the RP2-unit of the survey area, but its classification (Andosols) does not. RP2 has dystric and chromic Cambisols, and humic Acrisols.

- Unit R1 and R2 coincide well with unit RP1h of the survey area, and its classification (humic Nitisols) as well.

- Unit R3 coincides roughly with unit U1P1h, U1P2 and U1PC and partly also its classification (eutric Nitisols, Cambisols and Acrisols, pisoferric phase).

- Unit L1 coincides well with unit LP1, LP2P and LPC (Plateau) of the Survey area. Its classification (Ferralsols) does not. These volcanic Plateau Soils are chromic and ferric Acrisols, dystric Cambisols (pisoferric) and partly Lithosols.

- Unit Um6 and Um20 coincide with the various U2 (Upland) units on gneisses, colluvium of the basement complex. Their classification (Ferralsols) does not. The U2 unit soils are mainly chromic and calcic Luvisols and also Acrisols Cambisols Regosols and Lithosols.

- Unit Pd3 partly coincides with unit U2UC of the survey area. Its classification does not. The U2UC soils are a complex of chromic Luvisols, ferric Acrisols and eutric Regosols.

- Unit H13 coincides well with MQC (Mountains).

Parts of the Chuka-South Area have been studied and/or surveyed and evaluated by the Kenya Soil Survey (Van der Pouw et al 1977, Braun and Nyandat 1972, Michieka and Siderius 1978, Gachene, 1983).

The previous work mentioned, especially the Exploratery Soil Map of Kenya, the site evaluation of Ishiara and the survey of the Evurore catchment has provided useful information.

3.2. GENERAL PROPERTIES OF THE SOILS.

The soils of the Chuka South Area represent a wide range of profile characteristics. Differences in parent material, age drainage condition, moisture retention etc. have delivered an array of soils from high to low agricultural potential.

With reference to Chapter 1.3 and to Appendix 6.1 and 6.5 the following subdivisions into major landforms were made

- Mountains
- Hills and Minor Scarps
- Footridges
- Plateaus
- Uplands
- Plains
- Bottomlands
- Valleys

3.2.1. Mountains (M).

The Mountains are prominent in the extreme eastern part of the survey area with peaks of about 1700 m in the north-east (Kijege forest) and 1500 m in the south-east (Mumoni forest). The soils of these mountains are complexes, developed mainly on migmatites, granitoid gneisses and granites. The forested areas have a fair percentage moderately deep soils, the bare parts are very shallow and rocky.
Along the northern edge of the area are mountains (Njuguni forest) with soils on basic and ultrabasic rocks.

3.2.2. Hills and Minor Scarps (H).

The Hills cover relatively small but prominent features in the area with a relief intensity of about 100 m and slopes of 8-30%. They are scattered over mostly the eastern part of the survey area where the Kiburu ridge is most prominent. The soils there are developed on basement-complex: granitoid gneisses (Q), basic to ultrabasic rocks (B) or on undifferentiated gneisses (U). In the volcanic footslope area in the south-west of the area, hills of granitoid gneiss protrude through the volcanic lahars at several places. Most prominent there are Karue Hill and Kirmiri Forest west of the main Embu-Meru road. Hills with soils developed on consolidated pyroclastic rocks are in the extreme west of the area.

Minor Scarps are running roughly north-south in the middle of the area, forming the transition between the volcanic footslopes of the western half and the lower basement in the east. This abrupt transition by scarps is fading out towards the north. The parent rock of the very shallow, stony and rocky soils of the scarps is mainly undifferentiated or granitoid gneisses, and the slopes are steep.

3.2.3. Footridges (R).

Footridges are the dissected middle slopes of Mount Kenya, a volcanic mountain. Relief intensity is 50-100 m and the slopes of the dissecting valley sides are 5-16%. The volcanic Footridges cover about one-third part of the survey area, in the (north) west, and are dissected by numerous small valleys with an U-shaped crossection (the bigger valley, having a V-shaped section are mapped as Major and Minor Valleys). See App. 6.7, Plate 3.

The soils of the Footridges are developed on consolidated pyroclastic rocks of the Lahar complex. These rocks vary considerably in composition and hardness. The soils however are very deep and uniform.

The ridges between the valleys (slope class AC) have extremely deep permeable soils, classified as dystric and humic Nitisols* (RP1h/AC). The valleys of the Footridges (slopeclass DF) have Nitisols on the upper and middle slopes, and here and there dystric Acrisols on the lower slopes. The flat but narrow valley bottoms are predominantly waterlogged gleyic Acrisols or Gleysols. A small area in the extreme north-west corner of the area, above 1600 m alitude has Footslope soils, classified as dystric and chromic Cambisols (RP2).

3.2.4. Plateaus (L).

Plateaus are comparatively flat area's (slopes 0-8%) of certain extent, commonly bound on at least one side by an abrupt descent (scarp). See App. 6.7, Plate 5. The largest plateau-area is in the south part between the volcanic footslopes and the basement complex. The parent rock is consolidated pyroclastic rock. This volcanic plateau-area possibly represents the lowest and oldest lahar deposits. It is dissected by Minor Valleys. The soils (LP) are moderately deep Acrisols in the higher western part becoming more and more shallow, rocky, pisoferric and complex towards the scarp. Murram quarries are abundant in this area.

In the north eastern half of the survey area exist several very small plateaus, which are remnants of lava flows. These plateaus are prominent features in the landscape especially the one of Materi-mission. They are bounded by a descent on more than one side because the underlying basement complex has been protected from erosion by the phonolite layer on top. The soils are mainly Acrisols and Cambisols.

3.2.5. High level Uplands (U1).

Uplands are dissected areas with a relief intensity of 50 m or less and slopes of 0-16%. The High Level Uplands are located west of the descent to the basement system i.e. in the higher half of the survey area (higher than about 900 m). The parent material there is entirely of volcanic origin: consolidated pyroclastic rocks. The largest area of high level uplands is at the lower end of the volcanic footslopes in the northern middle part of the area. The transition to the lower basement area is gradual here (not with a scarp). The soils are mainly deep to moderately deep Nitisols* and Acrisols (U1P1h and U1P2). Near the fringe the soils are complex and often shallow Cambisols, Acrisols and Lithosols (U1PC).

3.2.6. Lower level Uplands (U2).

The Lower Level Uplands are all situated in the eastern part of the survey area (altitude less than about 900 m) consisting of basement system rocks. Except for the mountains, the hills, some plateau's and a small plain, this part is all Uplands. The majority of the soils is developed on basement rock of various origin: granitoid gneisses (U2Q), gneisses, rich in ferro-magnesian minerals (U2F) and undifferentiated banded gneisses (U2U). Uplands bordering Mountains or Hills often have soils on colluvium (U2X1) and there are two strips of Upland soils on pleistocene alluvial material (U2X2), possibly old terraces of the Thuchi and Ruguti rivers, containing small basin area's with Vertisols (too small to be mapped separately). The vast majority of the Lower Upland Soils are orthic or chromic Luvisols, predominantly shallow to moderately deep, alternating with smaller area's of very shallow stony and rocky soils (Regosols and Lithosols). Such area's had to be mapped as soil-complexes.

3.2.7. Plains (P).

Plains are flat or very gently undulating area's. There is only one such area mapped, with soils developed on a thin sheet of pyroclastic material (PPC). This mapping unit is a complex of orthic Luvisols and Lithosols.

3.2.8. Bottomlands (B).

Bottomlands are area's with a concave topography (slight depressions) lacking an outlet, which causes groundwater and surface water to accumulate. The Bottomlands of the surveyed area are in fact "volcanic sinkholes". They occur mainly on the volcanic Plateau (LP) in the south-west of the area. A few are located in the Upper Level Uplands, also in the finge area of the volcanic footslopes, i.e. the oldest lahar deposits. Their origin and genesis is rather obscure. The most acceptable theory is that during the deposition of the lahar a large amount of water drains out of the mudflow to the surface, concentrates and forms little lakes and ponds. After consolidation of the volcanic mud and the disappearance of the water, depressions stay behind. (van Hees and de Roo 1987). At present these bottomlands have an oval or circular shape, varying in diameter from 100-400 m. Few are larger. They have a complex of ferric Acrisols (on the fringes) and plintic and vertic Gleysols, or pellic Vertisols (on the bottom). See App. 6.7, Plate 6.

3.2.9. Major Valleys (V1).

Major Valleys are large valleys of perennial rivers from Mount Kenya traversing the Footridge area from north-west to south-east. Relief intensity is 50-100 m and the valley side slopes are 8-30%. The soils are developed on consolidated pyroclastic rocks. The mapping unit (V1PC) is complex, consisting of Nitisols* on the upper slopes, chromic Luvisols and Acrisols on the lower slopes, scattered with shallow patches and rock outcrops.

3.2.10. Minor Valleys (V2).

Minor Valleys are smaller valleys with a relief intensity of less than 50 m and valley-side slopes of 8-30%. See App. 6.7, Plate 3 and 4. They are the valleys of short, intermittant rivers and occur mainly in the transitional zone between the volcanic footslopes and the basement complex, roughly in the middle part of the survey area. The Minor Valley-soils are also mainly developed on consolidated pyroclastic rocks and are classified as dystric and humic Nitisols*, and plintic Acrisols (lower slopes) (V2P). The smallest of the minor valleys are complex units with Lithosols and scattered rock outcrops. Some valleys have soils developed on various parent materials (V2XC), classified as Acrisols, Cambisols and Lithosols, with scattered rock outcrops.

3.3. DESCRIPTION OF MAPPING UNITS.

3.3.1. Codes and terminology.

Soil mapping units are units of land with a particular soil. They can be separated spatially in the field, can be shown on maps, and can be used for land evaluation purposes. All mapping units have been briefly described in the legend to the soil map and have been indicated as such on the map by a code (Appendix 6.1 and 6.5).

The legend has been set as follows: the main subdivision is based on physiography (first character), the second entry is the parent rock or parent material with indication of geological formation (second character), and at the third level soil properties are diagnostic, in particular texture class soil drainage and soil depth. Subdivision of the mapping units according to slope classes introduces further detail.

Physiography	Character
Mountains	M
Hills and Minor scarps	H
Footridges	R
Plateaus	L
High Level Uplands	U1
Lower Level Uplands	U2
Plains	P
Bottomlands	B
Major Valleys	V1
Minor Valleys	V2
Parent material and/or rock.	
Granitoid gneisses	Q
Gneisses, rich in ferro-magnesian minerals	F
Undifferentiated gneisses	U
Phonolites	I
Basic to ultrabasic rocks	B
Pyroclastic rocks (Lahar Complex.)	P
Various parent materials	X
Soil characteristics.	
Humic surface soils	h

Second serial number.

For soils with similar major characteristics a serial number (1, 2, 3) is given, to express minor variations in drainage condition, soil depth, soil texture, soil colour, etc.

Depth class.

The depth classes have only been indicated, if the major part of the soil unit has shallow soils (<50 cm) over rock (P) or moderately deep soils (50-80 cm) over rock (p).

Slope class		Character
0- 2%	flat to very gently undulating	A
2- 5%	gently undulating	B
5- 8%	undulating	C
8-16%	rolling	D
16-30%	hilly	E
>30%	steeply dissected	F

Slope class is not part of the unit codes. On the soil map, however, slope classes have been indicated in capitals. A soil unit may be subdivided into several sections of different relief. Example of mapping unit code.

$\frac{\text{U1P2hp}}{\text{DF}}$

U = physiographic unit (Uplands).
1 = first serial number (High Level).
P = parent rock (pyroclastic).
2 = second serial number.
h = soil characteristic (humic).
p = soil depth class (moderately deep over rock).

In the legend, the various characteristics of the mapping units are listed in the following order: drainage condition, soil depth range, soil colour (moist) range, mottling (if any), soil consistence (moist), soil texture range, inclusions (if any, e.g. 'in places saline and/or sodic'), texture of surface soil ('underlying....'), texture of subsoil ('overlying...').

The descriptions denote the characteristics of the subsoil (usually the B-horizon) above 100 cm. Whenever the surface soil and/or the deeper subsoil differ(s) from the subsoil by two or more textural classes, they are also described. In case of a textural change within 150 cm, the texture of the deeper subsoil is also given.

The terminology of the legend is according to the definitions given in the 1962 supplement of the Soil Survey Manual (Soil Survey Staff, 1951), and to the FAO Guidelines for Soil Profile Description (1977). The colour indications are based on the Munsell Color Charts (1975) and are given for moist conditions. The same holds for the description of the individual soil mapping units and for the profile descriptions given in Appendix 6.8. The soils are classified according to the Legend of the FAO/Unesco Soil Map of the World (1974).
Modifications and additions to this system are indicated by an asterisk (Siderius & van der Pouw, 1980).

3.3.2. Comprehensive description of mapping units.
The reconnaissance soil map of the Kilifi Area comprises 34 mapping units. In this paragraph, the units have been described comprehensively. The sequence, in which the details have been

presented, is according to the KSS-practice.

The following order is maintained throughout the paragraph:

- parent material	- range of characteristics
- macro relief	- chemical properties
- Erosion	- diagnostic properties
- Rockiness/stoniness	- classification (FAO and USDA)
- Land use	
- Soils, general	- Representative profile

M -Soils of the Mountains and Major Scarps

Mapping Unit: MQC

Parent material		: Granitoid gneisses and granites
Macro relief		: Hilly to mountaineous
Erosion		: Moderate to severe sheet, slight rill and gully erosion
Rockiness/stoniness		: Very gravelly, stony to very stony, bouldery; in places rocky
Land use		: Partly protected forest; dense bushland to wooded bushland; extensive grazing; charcoal exploitation
Soils, general		: Complex of well drained, shallow, in places deep, brown to reddish brown, loose to friable, sand to sandy clay loam soils, gravelly,
Range of characteristics		
-Colour	A	: Dark brown to dark yellowish brown
	B	: Brown to reddish brown
-Texture	A	: Sand to sandy clay loam, gravelly
	B	: Sand to sandy clay, gravelly
-Structure	A+B	: Medium granular to medium subangular blocky
-Consistence	A+B	: Loose to friable when moist; non to slightly sticky and non to slightly plastic when wet
Chemical properties		: See Analytical data of representative profile
Diagnostic properties		: Argillic B-horizon; cambic B-horizon; in places lithic phase
Classification		: orthic LUVISOLS,eutric REGOSOLS,EUTRIC CAMBISOLS and LITHOSOLS
Representative profile no		: 1
Remarks		: No

Mapping Unit: MBP

Parent material	: Mafic intrusives mixed with migmatites and gneisses
Macro relief	: Mountainous to steeply dissected
Erosion	: Slight to moderate sheet and rill erosion
Rockiness/stoniness	: Very gravelly and stony, bouldery and rocky
Land use	: Grazing only
Soils, general	: Complex of somewhat excessively drained, shallow to moderately deep, dark brown to dark reddish brown, friable, sandy clay loam to sandy loam soils
Range of characteristics	
-Colour	A : Dark brown
	B : Dark reddish brown to dark brown
-Texture	A+B: Sandy clay loam to sandy loam
-Structure	A+B: Subangular blocky
-Consistence	A+B: Friable when moist; slightly sticky and slightly plastic when wet
Chemical properties	: Not available
Diagnostic properties	: Non continuous hard rock within 25 cm depth
Classification	: eutric REGOSOLS and LITHOSOLS (10%)
Representative profile no	: none
Remarks	: no

H- Soils of the Hills and Minor Scarps

Mapping Unit HQC

Parent material	: Granitoid gneisses and granites
Macro relief	: Steeply dissected
Erosion	: Moderate rill and gully erosion
Rockiness/stoniness	: Stony and rocky
Land use	: Grazing; cropping of maize, sorghum and cotton. Locally timber production and natural forest.
Soils,general	: Complex of somewhat excessively drained, extremely shallow to deep, strong brown, loose, sandy clay loam soils, partly gravelly or stony, with an AB and a BC sequence of horizons.
Range of characteristics	:
-Colour	A+B: Strong brown to dark reddish brown
-Texture	A+B: Sandy clay loam, partly gravelly or stony.
-Structure	A : Weak, fine to medium, single grain structure
	B : Moderate, medium single grain structure
-Consistence	A : Loose when moist, slightly sticky and slightly plastic when wet.
Chemical properties	: See analytical data of representative profiles.
Diagnostic properties	: Cambic B-horizon or argillic B-horizon. Partly with continuous hard rock within 25cm depth.
Classification	: eutric CAMBISOLS and LITHOSOLS and chromic

LUVISOLS. Locally chromic ACRISOLS and eutric REGOSOLS.

Representative profile no's	: 2 and 3
Remarks	: no

Mapping Unit: HUC

Parent material		: Gneisses rich in ferro-magnesian minerals
Macro relief		: Rolling to hilly
Erosion		: Slight sheet and rill erosion
Rockiness/stoniness		: Gravelly and slightly stony
Land use		: Grazing; cropping of millet and cotton
Soils,general		: Complex of somewhat excessively drained, extremely shallow to moderately deep, dark yellowish brown to dark reddish brown, loose sand to sandy clay loam soils.
Range of characteristics		
-Colour	A+B	: Dark yellowish brown to dark reddishh brown
-Texture	A+B	: Sand to sandy clay loam
-Structure	A+B	: Weak, fine to moderate single grain or subangular blocky structure.
-Consistence	A+B	: Loose to very friable when moist; non sticky and slightly plastic when wet.
Chemical properties		: See analytical data of representative profile
Diagnostic properties		: Cambic B-horizon and sometimes continuous hard rock within 25 cm depth.
Classification		: eutric CAMBISOLS, eutric REGOSOLS and LITHOSOLS
Representative profile no		: 4
Remarks		: 20% of this unit consists of bare rock and another 10% out of LITHOSOLS. Flat hilltops may include LUVISOLS on lahar remnants.

MAPPING UNIT: HIC

Parent material		: Phonolite
Macro relief		: Steeply dissected
Erosion		: Slight, rill and gully erosion
Rockiness/ stoniness		: Very stony
Land use		: Grazing.
Soils general		: Complex of somewhat excessively drained, very shallow, to moderately deep, dark brown, friable, sandy clay to silty clay soils, mostly an AC sequence.
Range of characteristics		:
-Colour	A	: Dark brown
-Texture	A	: Clay to silty clay
-Structure	A	: Medium, moderate subangular blocky structure
-Consistence	A	: Friable when moist; slightly sticky and slightly plastic when wet.
Chemical properties		: No data available
Diagnostic properties		: Cambic B-horizon; hard continuous rock within 25 cm.
Classification		: Complex of dystric CAMBISOLS, dystric

		REGOSOLS and LITHOSOLS.
Representative profile(s)	:	None
Remarks	:	Every named soil unit has an acreage of about 30% of the whole unit. The soils of this unit resemble those of unit HUC.

Mapping Unit: HBC

Parent material	:	Mafic intrusives mixed with migmatites and gneises
Macro relief	:	Hilly to steeply dissected
Erosion	:	Slight to moderate sheet and rill erosion
Rockiness/stoniness	:	Very gravelly and stony, bouldery and rocky
Land use	:	Grazing only
Soils general	:	Somewhat excessively drained, shallow to moderately deep, dark brown to dark reddish brown, friable sandy clay loam to sandy loam soils.
Range characteristics	:	
-Colour	A :	Dark brown
	B :	Dark reddish brown to dark brown
-Texture	A+B:	Sandy clay loam to sandy loam
-Structure	A+B:	Subangular structure
-Consistence	A+B:	Slightly sticky and slightly plastic when wet; friable when moist.
Chemical properties	:	No data available
Diagnostic properties	:	Non continuous hard rock within depth of 25cm
Classification	:	eutric REGOSOLS and LITHOSOLS(10%)
Representative profiles no	:	None

Mapping Unit: HPC

Parent material	:	Lahar/ phonolite
Macro relief	:	Hilly to mountainous, slope > 8 %
Erosion	:	Slight to moderate sheet and rill erosion, slight gully erosion, common measurement against soil erosion is making thrashlines
Rockiness / stoniness	:	Rocky and stony on slopes, few rocks and stones on valley bottom
Land use	:	Annual crop cultivation, maize and beans at parts where soil depth is shallow or deeper. Unproductive land, occasionally used for grazing, occurs at parts where soils are very shallow or very rocky
Soils, general	:	This unit is a complex of well drained, very shallow to very deep, dark brown to dark red, friable to firm, clayey soils with an ABCR-horizon sequence, the B- and CR-horizon are often mixed, clayskins are present in the B-horizon. The deeper soils occur on the upper slope and in the valley bottom.
Range of characteristics	:	

-Colour	A :	Dark brown to dark reddish brown
	B :	Dark brown to dark red
-Texture	A+B:	Clay at places slightly gravelly to gravelly
-Structure	A+B:	Moderate to strong, fine to coarse, (sub)angular blocky
-Consistence	:	Hard to very hard when dry, friable to firm when moist, slightly sticky and slightly plastic when wet
Chemical properties	:	See analytical data of representative profile
Diagnostic properties	:	ochric or umbric A, argillic B for ACRISOLS, continuous hard rock within 25cm of the surface for LITHOSOLS
Classification	:	ACRISOLS and LITHOSOLS
Representative profile no	:	5
Remarks	:	No

R- Soils of the Footridges

Mapping Unit: RPlh (slopeclass AC)

Parent material	:	Lahar / phonolite
Macro relief	:	Mountainous in the western part, rolling to hilly in the eastern part, slopes 0-5%
Erosion	:	Slight splash and sheet erosion Rockiness / Stoniness: Nil
Land use	:	Cropping of annual and perennial crops, main foodcrops grown at higher altitudes are maize, beans and potatoes. Maize, beans, cassava, cowpea and pigeon pea are grown at lower altitudes. In the western part of this unit the main cash crop is tea, going down the slope of Mt. Kenya coffee is becoming more and more important till coffee is the main cash crop. The area contains many trees which are used for the production of firewood, timber, fodder and fruits. At higher altitude cattle is grazing on pasture, at lower altitude people practise zero-grazing.
Soils,general	:	Well drained, extremely deep, dark reddish brown to dark red, friable, clay, having an AB horizon-sequence with 20 to 40 cm humic topsoil. Shiny pedfaces are present in the B-horizon. Under natural forest the humic A-horizon is very shallow and the B-horizon has only few shiny pedfaces
Range of characteristics		
-Colour	A :	Dark reddish brown
	B :	Dark reddish brown to dark red
-Texture	A+B:	Clay
-Structure	A :	Moderate, fine granular to coarse subangular blocky
	B :	Moderate to strong, fine to coarse, subangular to angular blocky

-Consistence		: Friable when moist, slightly sticky and slightly plastic when wet
Chemical properties		: See analytical data of representative profiles
Diagnostic properties		: ochric or umbric A, nitic B
Classification		: dystric and humic NITISOLS*; ACRISOLS in the lower slopes
Representative profileno's		: 6, 7, 8 and 9
Remarks		: No

Mapping Unit:RPlh (slope class DF)

Parent material		: Lahar / phonolite
Macro relief		: Hilly to mountainous, slopes > 8 %
Erosion		: Nil
Rockiness/stoniness		: Nil
Land use		: As in unit RPlh/AC
Soils, general		: As in unit RPlh/AC, but less deep and with a different colour
Range of characteristics		
-colour	A	: Dark reddish brown to yellowish red.
	B	: Yellowish red to dark red
Chemical properties		: See analytical data
Diagnostic properties		: As in unit RPlh/AC
Classification		: As in unit RPlh/AC, more ACRISOLS
Representative profile no's		: 10, 11 and 12

Mapping Unit: RP2

Parent material		: Pyroclastic agglomerates
Macro relief		: Flat to rolling
Erosion		: Nil
Rockiness/stoniness		: Nil
Land use		: Forest trees; timber
Soils, general		: Well drained, very deep, dark reddish brown, very friable, clay, with an AB horizon sequence
Range of characteristics		
-Colour	A	: Dark reddish brown
	B	: Dark reddish brown to yellowish red
-Texture		: Clay
-Structure		: Medium angular blocky
-Consistence		: Slightly sticky and slightly plastic
Chemical properties		: no data available
Diagnostic properties		: ochric epipedon, cambic B horizon or argillic horizon
Classification		: Complex of dystric and chromic CAMBISOLS and humic ACRISOLS.
Representative profile no's		: 13
Remarks		: The highest part of the survey area (>1900 m above sea level).

L- Soils of the Plateaus

Mapping Unit: LP1

Parent material		: Undifferentiated various igneous rocks, predominantly consolidated lahars.
Macro relief		: Flat to gently undulating
Erosion		: Nil
Rockiness/stoniness		: Nil
Land use		: Grazing; cropping of maize, beans, cotton and sisal.
Soils, general		: Well drained, very deep, dark reddish brown, friable, silty clay to clay. The soils have an AB sequence of horizons.
Range of characteristics		
-Colour	A	: Dark reddish brown to dark red
	B	: Dark red to brown
-Texture	A+B	: Clay to silty clay
-Structure	A	: Moderate medium granular
	B	: Moderate coarse subangular blocky
-Consistence	A+B	: Friable when moist, slightly sticky and slightly plastic when wet
Chemical properties		: See analytical data of representative profiles.
Diagnostic properties		: Argillic B-horizon, Base sat.< 50%
Classification		: ferric, chromic and humic ACRISOLS
Representative profile no's		: 14, 15 and 16
Remarks		: The topsoil tends to decrease in thickness towards the East. In this unit humic and gleyic ACRISOLS are found. These soils are imperfectly to moderate well drained.

Mapping Unit: LP2P

Parent material		: Mainly consolidated lahars
Macro relief		: Flat
Erosion		: Slight splash erosion
Rockiness/stoniness		: Rocky and stony in the whole unit
Land use		: Grazing; bushland with Acacia, Combretum and Euphorbia candelabrum.
Soils, general		: Somewhat excessively drained, extremely shallow to very shallow, dark brown, very friable, very gravelly, sandy loam to sandy clay loam. The soils have an AC sequence of horizons.
Range of characteristics		
-Colour	A	: Dark brown
-Texture	B	: Gravelly to very gravelly, sandy clay loam to sandy loam.
-Structure	A	: Fine subangular blocky structure
-Consistence	A	: Very friable when moist, slightly sticky and non plastic when wet.
Chemical properties		: See analytical data of representative profile.
Diagnostic properties		: Continuous hard rock within 25cm
Classification		: LITHOSOLS, pisoferic phase
Representative profile no		: 17

Remarks : Around 20% of this unit consists of bare rock.

Mapping Unit: LPC

Parent material : Lahar complex
Macro - relief : Flat to gently undulating, slopes 0-5%
Erosion : Nil
Rockiness/stoniness : Very gravelly, at places rocky
Land use : Grazing, cropping of cotton, maize, pigeon peas and sorghum
Soils, general : Complex of well drained, very shallow to deep, brown to dark reddish brown, very gravelly, very friable, sandy clay over petroplinthite (murram)/ rock. The soils have an AB sequence of horizons.
Range of characteristics
-colour A : Dark brown
B : Dark brown to dark reddish brown
-texture A+B: Very gravelly sandy clay
-consistence A+B: Very friable when moist, slightly sticky and slightly plastic when wet
Chemical properties : See analytical data of representative profile.
Diagonostic properties : cambic B-horizon, more than 40% murram within 100 cm of the surface, at places continuous hard rock within 25 cm of the surface
Classification : dystric CAMBISOLS, pisoferric phase and LITHOSOLS
Representativeprofiles no : 18
Remarks : no

Mapping Unit: LIC

Parent material : Phonolite
Macro relief : Flat to gently undulating (crest of phonolite flow)
Erosion : Nil
Rockiness/stoniness : Fairly stony and rocky
Land use : Grazing; cropping of sorghum and millet
Soils, general : Complex of somewhat excessively drained, very shallow to deep, dark reddish brown to brown, very friable, very gravelly sandy clay loam to sandy clay. The soils have an AC sequence of horizons.
Range of characteristics:
-Colour A : Reddish brown
-Texture A : Sandy clay loam to sandy clay
-Structure A : Moderate, fine granular and subangular blocky structure
-Consistence A : Very friable when moist, slightly sticky and non plastic when wet.
Chemical properties : No data available
Diagnostic properties : Cambic B-horizon and continuous hard rock

		within 25cm.
Classification	:	dystric CAMBISOLS and LITHOSOLS
Representative profile(s)	:	None
Remarks	:	20% of this unit consists of dystric CAMBISOLS, the rest of this unit is bare rock (20%) and LITHOSOLS (60%).

Mapping Unit: LB

Parent material	:	Basalts and Pleistocene fluvial terraces rich in basalts
Macro relief	:	Flat to gently undulating at borders.
Erosion	:	Slight sheet; at borders slight rill erosion
Rockiness/stoniness	:	Nil; partly gravelly and stony, in places bouldery.
Land use	:	Cropping of milet, cotton, greengrams; wooded bushland, grazing. In places murram exploitation.
Soils, general	:	Well drained, deep, reddish brown to red sandy clay loam to clay, gravelly, friable soil.
Range of characteristics		
-Colour	A :	Dark reddish brown
	B :	Red
-Texture	A :	Silty clay to clay
	B :	Silty clay to clay, gravelly (Fe/Mn concretions)
-Structure	A :	Fine and medium subangular blocky
	B :	Medium granular and subangular blocky
-Consistence	A+B:	Friable when moist; slightly sticky to sticky and slightly plastic to plastic when wet
Chemical properties	:	See analytical data of representative profile.
Diagnostic properties	:	Argillic B-horizon; ferric properties
Classification	:	ferric ACRISOLS and ferric LUVISOLS
Representative profile no	:	19
Remarks	:	"LB" soils of Materi-plateau have deeper soils than "LB" soils of other plateaus

Soils of the high level Uplands (volcanic origin)

Mapping Unit: UlPlh

Parent material	:	Undifferentiated, various volcanic rocks, mainly consolidated lahars.
Macro relief	:	Gently undulating to undulating
Erosion	:	Splash and rill erosion are common during the rainy season. Gully erosion is not very common because many terraces against erosion have been constructed.
Rockiness/stoniness	:	Nil
Land use	:	The main food crops are maize, beans, bananas. The main cashcrop is coffee. The less important crops are cassavas, sweet potatoes, pigeon peas, napier grass, mangoes, lemons and firewood. Except for coffee, which is always a

		single crop, intercropping is practized.
Soils, general		: Well drained, very deep, dark reddish brown to dark red, friable, silty clay to clay. The soils generally have an AB sequence.
Range of characteristics		
-Colour	A :	Dark reddish broown to dusky red
	B :	Dark red to dark reddish brown
-Texture	A+B:	Clay to silty clay
-Structure	A :	Granular
	B :	Subangular blocky
-Consistence	A+B:	Slightly sticky and slightly plastic when wet, friable when moist.
Chemical properties		: See analytical data of representative profile.
Diagnostic properties		: Base saturation <50%; argillic B-horizon. Sometimes an umbric A-horizon.
Classification		: dystric and humic NITISOLS*
Representative profile no		: 20
Remarks		: no

Mapping Unit: U1P2p

Parent material		: Consolidated lahars
Macro relief		: Undulating
Erosion		: Moderate sheet erosion and slight rill erosion.
Rockiness/stoniness		: None
Land use		: Cropping of pigeon peas, maize, millet, and sorghum.
Soils general		: Well drained, moderately deep to deep, dark red to dark reddish brown, friable, clay.
Range of characteristics:		
-Colour	A :	Dark reddish brown
	B :	Dark red to dark reddish brown
-Texture	A+B:	Clay
-Structure	A :	Medium granular structure
	B :	Medium subangular blocky structure
-Consistance	A+B:	Slightly sticky and slightly plastic when wet, friable when moist.
Chemical properties		: See analytical data of representative profile.
Diagnostic properties		: Argillic B-horizon
Classification		: chromic and humic ACRISOLS
Representative profiles no		: 21
Remarks		: no

Mapping Unit: U1PC

Parent material	: Undifferentiated various igneous rocks, predominantly consolidated lahars.
Macro relief	: Flat to rolling
Erosion	: Slight sheet and moderate rill erosion
Rockiness/stoniness	: Gravelly and at spots rocky and stony
Land use	: Grazing; cropping of cotton, maize, pigeon peas and sorghum.

Soils, general	:	Complex of somewhat excessively drained, very shallow to deep, dark reddish brown to brown, very gravelly sandy clay to clay soils, usually with an AB sequence of horizons.
Range of characteristics		
-Colour	A :	Very dark grey to dark brown
	B :	Dark reddish brown to brown
-Texture	A+B:	Clay to sandy clay, locally very gravelly
-Structure	A+B:	Moderate, medium, angular blocky structure
-Consistence	A+B:	Friable when moist, slightly sticky and non-plastic when wet.
Chemical properties	:	See analytical data of representative profiles.
Diagnostic properties	:	Cambic B-horizon, argillic horizon and in places continuous hard rock within 25cm.
Classification	:	dystric CAMBISOLS and LITHOSOLS, piso-ferric phase, in places ACRISOLS
Representative profile no's	:	22 and 23
Remarks	:	The LITHOSOLS (30% of the unit) are mainly found at the boundary of this unit

Soils of the lower level Uplands (Basement System)

Mapping Unit: U2Q1p

Parent material	:	Granitoid gneisses
Macro relief	:	Gently undulating to undulating
Erosion	:	Moderate sheet, in places severe rill and gully erosion
Rockiness/stoniness	:	Slightly gravelly to gravelly; in places fairly stony or rocky.
Land use	:	Shifting cultivation of millet, cotton, greengrams; extensive grazing.
Soils, general	:	Well to somewhat excessively drained, moderately deep, in places shallow or rocky, dark reddish brown to red, friable sandy clay to clay.
Range of characteristics		
-Colour	A :	Dark brown to dark reddish brown
	B :	Yellowish red to red
-Texture	A+B:	Sandy clay to clay, in places gravelly
-Structure	A+B:	Medium subangular blocky
-Consistence	A+B:	Friable when moist, slightly sticky to sticky and slightly plastic to plastic when wet.
Chemical properties	:	No data available
Diagnostic properties	:	Argillic B-horizon, in places ferric properties.
Classification	:	chromic LUVISOLS, ferric ACRISOLS
Representative profile no	:	None
Remarks	:	ferric ACRISOLS, moderately deep over murram, are found in flat parts.

Mapping Unit: U2Q2P

Parent material		: Plagioclase, granitoid and quartz feldspar gneisses
Macro relief		: Undulating to rolling
Erosion		: Moderate to severe sheet and rill erosion
Rockiness/stoniness		: Gravelly and at spots very gravelly and stony, and rockoutcrops.
Land use		: Grazing and shifting cultivation (millet)
Soils, general		: Well drained, shallow, dark reddish brown, firm, clay.
Range of characteristics		
-Colour	A+B:	Dark reddish brown
-Texture	A :	Sandy loam to clay
	B :	Gravelly clay
-Structure	A :	Medium granular
	B :	Medium subangular blocky
-Consistence	A+B:	Slightly sticky and slightly plastic when wet, firm when moist.
Chemical properties		: See analytical data of representative profiles
Diagnostic properties		: argillic B-horizon
Classification		: chromic LUVISOLS and chromic, in places calcic, CAMBISOLS and LITHOSOLS
Representative profile no's		: 24 and 25
Remarks		: no

MAPPING UNIT: U2QC

Parent material		: Granitoid gneisses
Macro relief		: Undulating to rolling
Erosion		: Severe sheet, moderate rill; in places moderate gully erosion
Rockiness/stoniness		: Gravelly, fairly stony; in places bouldery (tors)
Land use		: Shifting cultivation of millet and cotton; extensive grazing, locally charcoal exploitation.
Soils, general		: Well drained, shallow to deep, dark reddish brown to red, friable clay.
Range of characteristics		
-Colour	A+B:	Dark reddish brown to red
-Texture	A+B:	Loamy sand to clay; in places gravelly
-Structure	A+B:	Medium subangular blocky
-Consistence	A :	Very friable when moist, slightly sticky and non to slightly plastic when wet.
	B :	Friable when moist, slightly sticky to sticky and slightly plastic to plastic when wet.
Chemical properties		: No data available
Diagnostic properties		: Argillic B-horizon
Classification		: chromic LUVISOLS
Representative profile no		: None
Remarks		: No

Mappping Unit: U2F1

Parent material		: Gneisses rich in ferro magnesian minerals.
Macro relief		: Flat to undulating, in places rolling.
Erosion		: Moderate rill, slight gully and slight sheet erosion.
Rockiness/stoniness		: At spots fairly gravelly
Land use		: Grazing; cropping of millet, sorghum, maize, cotton and pigeon pea
Soils, general		: Well to somewhat excessively drained, deep to very deep, dark red to dark reddish brown, friable, sandy clay to clay
Range of characteristics:		
-Colour	A:	Dark reddish brown
	B:	Dark red to dark reddish brown
-Texture	A+B:	Sandy clay to clay
-Structure	A:	Fine subangular blocky
	B:	Medium to coarse subangular blocky
-Consistence	A+B:	Slightly sticky and slightly plastic when wet, friable when moist.
Chemical properties		: See analytical data representative profile
Diagnostic properties		: Argillic B-horizon
Classification		: orthic and chromic LUVISOLS.
Representative profile no		: 26
Remarks		: No

Mapping Unit: U2F2p

Parent material		: Gneisses rich in ferromagnesian minerals, migmatites
Macro relief		: Flat to undulating, in places rolling.
Erosion		: Moderate rill and sheet erosion and slight gully erosion
Rockiness/stoniness		: Fairly stony and gravelly, in places rocky
Land use		: Grazing; cropping of cotton, cow peas, sorghum and millet.
Soils general		: Somewhat excessively to well drained, moderately deep, dark red to dark brown, friable, clay to sandy clay loam
Range of characteristics:		
-Colour	A:	Dark brown
	B:	Dark red to dark brown
-Texture	A+B:	Clay to sandy clay loam
-Structure	A:	Fine subangular blocky structure
	B:	Medium subangular blocky structure
-Consistence	A:	Slightly sticky and non plastic when wet, friable when moist
	B:	Slightly sticky and slightly plastic when wet, friable when moist
Chemical properties		: See laboratory data representative profiles
Diagnostic properties		: Argillic B-horizon
Classification		: orthic and chromic LUVISOLS
Representative profile no's		: 27 and 28
Remarks		: no

Mapping Unit: U2F3P

Parent material	: Gneisses rich in ferro-magnesian minerals
Macro relief	: Hilly
Erosion	: Slight rill erosion
Rockiness/stoniness	: Fairly stony and rocky
Land use	: Grazing; cropping of millet, sorghum, beans and cotton
Soils, general	: Somewhat excessively drained, shallow, red to dark reddish brown, friable, sandy loam to sandy clay loam. The soils have a BC sequence of horizons
Range of characteristics	
-Colour	B: Red to dark reddish brown
-Texture	B: Sandy loam to sandy clay loam
-Structure	B: Medium subangular blocky
-Consistence	B: Friable when moist, slightly sticky and non-plastic when wet.
Chemical properties	: No data available
Diagnostic properties	: Argillic B-horizon, continuous hard rock within 25 cm
Classification	: chromic LUVISOLS
Representative profile(s)	: None
Remarks	: LITOSOLS cover about 10% of the area.

Mapping Unit: U2FC1

Parent material	: Gneisses rich in ferro-magnesian minerals
Macrorelief	: Gently undulating to undulating
Erosion	: Moderate rill and gull erosion
Rockiness/stoniness	: Gravelly and fairly stony
Land use	: Grazing; cropping of maize, millet and cotton
Soils, general	: Complex of well drained, shallow to deep, strong brown to dark reddish brown, friable, sandy clay to clay soils with an ABC sequence of horizons.
Range of characteristics	
-Colour	A: Dark brown
	B: Strong brown to dark reddish brown
-Texture	A+B: Sandy clay to clay
-Structure	A: Coarse subangular blocky
	B: Coarse subangular blocky to coarse prismatic
-Consistence	A+B: Friable to firm when moist; slightly plastic and sticky when wet.
Chemical properties	: See analytical data representative profiles
Diagnostic properties	: ArgillicB-horizon
Classification	: humic and chromic LUVISOLS in places calcic LUVISOLS and CAMBISOLS
Representative profile no's	: 29 and 30
Remarks	: no

Mapping Unit: U2FC2

Parent material	: Gneisses rich in ferro-magnesian minerals
Macro relief	: Undulating to rolling
Erosion	: Moderate rill and severe gully erosion
Rockiness/stoniness	: Fairly stony and rocky, partly gravelly
Land use	: Grazing; maize, millet, sorghum and beans
Soils, general	: Complex of somewhat excessively drained, shallow to moderately deep, yellowish red to dark brown to dark reddish brown, friable, loamy sand to clay. The soils have an AB or BC sequence of horizons.
Range of characteristics	
-Colour	A+B: Dark brown to dark reddish brown, partly yellowish red
-Texture	B: Loamy sand to clay loam
-Structure	B: Medium, subangular blocky
-Consistence	B: Friable when moist, slightly sticky and non plastic when wet
Chemical properties	: See analytical data of representative profiles.
Diagnostic properties	: Cambic B-horizon, partly argillic horizon
Classification	: eutric CAMBISOL, REGOSOLS and LUVISOLS
Representative profile no's	: 31 and 32
Remarks	: Less than 10% of this unit consists of bare rock and LITHOSOLS

Mapping Unit: U2UC

Parent material	: Undifferentiated Basement System gneisses; a varied succession of granitoid gneisses and gneisses rich in ferromagnesian minerals, with many pegmatite vein intrusives
Macro relief	: Gently undulating to undulating, undulating to rolling, rolling to hilly
Erosion	: Severe sheet, moderate rill and slight gully erosion; in places more severe water erosion
Rockiness/stoniness	: Gravelly to very gravelly fairly stony; in places fairly bouldery and fairly rocky
Land use	: Dense bushland; few shifting cultivation of millet; charcoal exploitation; extensive grazing
Soils, general	: Complex of somewhat excessively drained, shallow to moderately deep, red, friable, sandy clay loam to sandy clay.
Range of characteristics	
-Colour	A: Dark brown to reddish brown
	B: Dark reddish brown to red
-Texture	A: Sand to loamy sand; in places gravelly
	B: Loamy sand to clay; in places slightly gravelly to gravelly
-Structure	A+B: Weak to moderate fine to medium subangular blocky
-Consistence	A: Loose to very friable when moist; non to slightly sticky, non to slightly plastic when

		wet
	B:	Very friable to friable when moist; slightly sticky to sticky, slightly plastic to plastic when wet
Chemical properties	:	See analytical data of repprersentative profiles
Diagnostic properties	:	Argillic B-horizon; in places paralithic phase
Classification	:	chromic and orthic LUVISOLS and REGOSOLS, in places lithic phase.
Representative profile no's	:	33 and 34
Remarks	:	no

Mapping Unit: U2X1C

Parent material	:	Colluvium derived from basalts and pleistocene fluviatile terraces and gneisses rich in ferro-magnesian minerals.
Macrorelief	:	Undulating to hilly; minor scarps are included in this unit.
Erosion	:	Moderate to severe sheet, moderate rill erosion.
Rockiness/stoniness	:	Gravelly, very stony and very bouldary; in places excessively stony.
Land use	:	Extensive grazing; wooded bushland
Soils, general	:	Complex of excessively drained, shallow to deep, dark brown to red friable gravelly clay soils.
Range of characteristics		
-Colour	A:	Very dark brown to dark reddish brown.
	B:	Dark brown to red
-Texture	A+B:	Sandy clay to clay
-Structure	A+B:	Fine to medium subangular blocky
-Consistence	A+B:	Friable when moist; slightly sticky to sticky and slightly plastic to plastic when wet.
Chemical properties	:	No data available
Diagnostic properties	:	Argillic B-horizon, ferric properties
Classification	:	chromic and ferric LUVISOLS, ferric ACRISOLS and eutric REGOSOLS, partly lithic phase.
Representative profile(s)	:	None
Remarks	:	No

Mapping Unit: U2X2p

Parent material	:	Pleistocene alluvial sediments of various sources over Basement Complex.
Macro relief	:	Flat to undulating
Erosion	:	Moderate, in places severe, rill and gully erosion.
Rockiness/stoniness	:	Slighty stony
Land use	:	Grazing; cropping of millet, maize and sorghum
Soils,general	:	Well drained, moderately deep to deep, yellowish red to dark reddish brown, friable

	to very friable, sandy clay loam to clay. The soils usually have an BC sequence of horizons
Range of characteristics	
-Colour	B: Yellowish red to dark reddish brown
-Texture	B: Sandy clay to clay
-Structure	B: Coarse subangular blocky
-Consistence	B: Friable to very friable when moist, slightly sticky and slightly plastic when wet.
Chemical properties	: See analytical data of representative profiles.
Diagnostic properties	: Argillic B-horizon
Classification	: ferric and chromic LUVISOLS, partly calcic
Representativeprofile no's	: 35 and36
Remarks	: In this unit the calcic LUVISOLS (20%) are found in the lower parts, especially near the river or erosion gullies. At very small spots calcaro-pellic VERTISOLS occur. These VERTISOLS have a sodic phase (see profile 6)

P- Soils of the Plains

Mapping Unit: PPC

Parent material	: Consolidated pyroclastic rocks (Lahar complex)
Macro relief	: Flat to gently undulating
Erosion	: Slight sheet, rill and gully erosion
Rockiness/stoniness	: Rocky, at places gravelly and stony
Land use	: Grazing; lahar stone production at boundary of this unit.
Soils, general	: Complex of well drained, shallow to moderately deep, dark reddish brown to dark brown, friable, sandy clay to clay.
Range of characteristics	
-Colour	A: Dark brown
	B: dark brown to dark reddish brown
-Texture	A+B: Sandy clay to clay
-Structure	A: Medium granular
	B: Medium subangular blocky
-Consistence	A+B: Non-sticky and non-plastic when wet, friable when moist.
Chemical properties	: See analytical data representative profile
Diagnostic properties	: Argillic B-horizon or continuous hard rock within 25cm.
Classification	: orthic LUVISOLS and LITHOSOLS (50%)
Representative profile no	: 37
Remarks	: vertic LUVISOLS (10%) occur at lower spots

B-Soils of the Bottomlands

Mapping Unit: BPC

Parent material	: Lahar / phonolite
Macro relief	: Gently undulating to undulating, slope 0-5%
Erosion	: Nil

Rockiness / stoniness	: None to very few rocks
Land use	: Occasionally ponded, grazing, rotation of annual crops like maize, beans, cocoyam, sweet potato. Lower parts are used for grazing.
Soils, general	: Complex of poorly to well drained, shallow to very deep, dark reddish brown to dark red and dark grey, mottled, very friable, clay, having an AB horizon sequence, overlying petroplinthite (murram) or rotten rock with a humic topsoil of 15-60cm thick.
Range of characteristics	
-Colour	A: Dark reddish brown
	B: Dark reddish brown to dark red
-texture	A: Clay
	B: Clay, at places gravelly
-structure	A: Moderate, fine, granular
	B: Fine to medium, subangular to angular blocky
-consistence	: Very friable when moist, slightly sticky and slightly plastic when wet
Chemical properties	: See analytical data representative profiles.
Diagnostic properties	: umbric A, argillic B, at places having a pisoferric phase or hydromorphic properties within 50 cm of the surface
Classification	: gleyic, ferric and humic ACRISOLS and plinthic GLEYSOLS.
Representative profile no's	: 38 and 39
Remarks	: no

V1- Soils of the Major Valleys

Mapping Unit: V1PC

Parent material	: Undifferentiated, various volcanic rocks, mainly consolidated lahars.
Macro relief	: Moderately steep to steep
Erosion	: Moderate splash and moderate rill erosion are common. Gully erosion is limited because of the presence of terraces, constructed for coffee cultivation.
Rockiness/stoniness	: At places boulders
Land use	: The main food crops are maize, beans and bananas. The main cashcrop is coffee. The less important crops are cassavas, sweet potatoes, pigeon peas, napier grass, mangoes, lemons and firewood. In the highest NW corner of the area landuse of this unit is tea or forest. Except for coffee and tea, which are always single crops, intercropping is practized.
Soils, general	: Well drained, very deep, dark reddish brown to dark red, friable, silty clay to clay. The soils generally have an AB sequence of horizons.
Range of characteristics	
-Colour	A: Dark reddish brown to dusky red

	B:	Dark red to dark reddish brown
-Texture	A+B:	Clay to silty clay
-Structure	A:	Granular
	B:	Subangular blocky structure
-Consistence	A+B:	Slightly sticky and slightly plastic when wet, friable when moist.
Chemical properties	:	See analytical data representative profiles.
Diagnostic properties	:	Base saturation <50%, argillic B-horizon. Sometimes an umbric A-horizon.
Classification	:	dystric and humic NITISOLS* (50% each)
Representative profile no's	:	40 (slope) 41 (valley bottom)
Remarks	:	-A minor part of this unit (approx. 2%) comprises of valley bottom soils -The representative profiles are fromthe tea-zone (approx. 1700m)

V2- Soils of the Minor Valleys

Mapping Unit: V2P

Parent material	:	Undifferentiated, various volcanic rocks, mainly consolidated lahars.
Macro relief	:	Steep (Valley slopes)
Erosion	:	Moderate splash and rill erosion are common. Gully erosion is limited because of construction of terraces.
Rockiness/stoniness	:	At some places rock outcrops occur.
Land use	:	The main food crops are maize, beans and bananas. The main cashcrop is coffee. The less important crops are cassavas, sweet potatoes, pigeon peas, napier grass, mangoes, lemons and firewood. Except for coffee, which is always a single crop, intercropping is practized.
Soils, general	:	Well drained, very deep, dark reddish brown to dark red, friable, silty clay to clay. The soils generally have an AB sequence of horizons.
Range of characteristics		
-Colour	A:	Dark reddish brown to dusky red
	B:	dark red to dark reddish brown
-Texture	A+B:	Clay to silty clay
-Structure	A:	Granular
	B:	Subangular blocky
-Consistence	A+B:	Slightly sticky and slightly plastic when wet. Friable when moist
Chemical properties	:	See analytical data of representative profiles.
Diagnostic properties	:	Base saturation < 50%, argillic B-horizon. Sometimes umbric A-horizon.
Classification	:	dystric and humic NITISOLS* and plinthic ACRISOLS, partly humic ACRISOLS.
Representative profile no's	:	42 (valley slope) and 43 (valley bottom)

Remarks : A minor part of this unit (approx. 5%) comprises of valley bottom soils.

Mapping Unit: V2PC

Parent material	: Complex of various volcanic rocks
Macro relief	: Rolling to hilly
Erosion	: Slight rill erosion
Rockiness/stoniness	: Fairly rocky and stony
Land use	: Cropping of maize, cotton and cocojam
Soils, general	: Complex of well drained, very shallow to deep, dark red to dark brown, friable, at places gravelly, sandy clay loam to sandy clay. The soils usually have an AB or BC sequence of horizons.
Range of characteristics	
-Colour	A+B: Red to dark brown
-Texture	A+B: Sandy clay loam to sandy clay
-Structure	A: Medium granular structure
	B: Coarse granular to fine subangular blocky structure.
-Consistence	A+B: Very friable to friable when moist, slightly sticky and slightly plastic when wet.
Chemical properties	: No data available
Diagnostic properties	: Argillic B-horizon, ferric properties, calcic properties.
Classification	: chromic, ferric and calcic LUVISOLS and LITHOSOLS.
Representative profile(s)	: None
Remarks	: 10% of this unit consists of LITHOSOLS

Mapping Unit: V2XC

Parent material	: Complex of various volcanic rocks.
Macro relief	: Steep (Valley slopes)
Erosion	: Moderate rill and gully erosion
Rockiness/stoniness	: Stony and rocky, at places rock outcrops.
Land use	: Grazing; cropping of millet, sorghum and cotton.
Soils, general	: Complex of well drained, extremely shallow to deep dark red to dark brown, friable, very gravelly sandy clay loam to sandy clay. The soils have an AB or BC sequence of horizons.
Range of characteristics	
-Colour	B: Dark red to dark brown
-Texture	B: Sandy clay loam to sandy clay
-Structure	B: Coarse medium subangular blocky structure
-Consistence	B: Friable when moist; slightly sticky and slightly plastic when wet.
Chemical properties	: No data available
Diagnostic properties	: Argillic B-horizon; cambic B-horizon; at places continuous hard rock within 25cm.
Classification	: Complex of ferric ACRISOLS, dystric CAMBISOLS

and LITHOSOLS

Representative profile(s) : None

Remarks : 30% consists of bare rock, 30% out of ferric ACRISOLS and 30% out of dystric CAMBISOLS.

3.4. SOIL GENESIS AND CLASSIFICATION.

3.4.1. Soil genesis aspects.

The basis for soil classification is provided by the combined action of soil forming factors. Some obvious trends in soil genesis of the Chuka-South Area are summarized in this section. As its position is very close to the Kindaruma Area, reference is made to the corresponding chapter of the report on that survey (van de Weg and Mbuvi 1975).

Climate.

Climate is one of the most important soil forming factors in the survey area and there is a strong gradient in temperature and rainfall from west to east. In the middle-section of the area, where organic matter content is rapidly decreasing one can observe the sequence humic Acrisols --> dystric Acrisols --> chromic Acrisols. West of this zone are mainly humic Nitisols*, except for the extreme NW corner which has Cambisols and Acrisols.

East of the middle-section are mainly Luvisols and Cambisols. The presentday rainfall, both the annual amount and seasonal distribution would not be able to cause this type of soil formation. It seems likely that a former, more humid climate, relatively short lasting, has contributed to the present situation. In the very dry eastern part are Luvisols with (more recently formed ?) calcic properties.

Parent material.

The influence of different parent material is quite strong, when comparing the western half with pyroclastic (volcanic) rocks, and the eastern half with rocks belonging to the basement system. Within each of these area's differences in soils are mainly caused by climate and topography.

Landform (topography) and age.

All soils, of volcanic as well as of basement origin are extremely old and well weathered. Topographic position however causes strong local differences. In relatively flat area's (Plateau) drainage is hampered resulting in extensive formation of petro-plinthite (murram). Topography (slope length and steepness) is of little influence in the very permeable and stable soils of the western part, whereas it causes strong denudation, rejuvination and deposition by erosion, in the east of the area.

Drainage condition.

In the western part the soils are well drained, the ridges as well as the valley slopes. In the eastern part there is much run-off, causing excessive drainage conditions in the higher area's and deposition in the lower area's. Murram formation in the poorly drained Plateaus was mentioned above. At present however the evidence of poor drainage there is limited, and ironstone formation is not an active process anymore. The soils of the valley-bottoms of the western part as well as the bottoms of the volcanic depressions (mapped as Bottomlands) have hydromorphic properties.

Man.

In the eastern part shifting cultivation with a short fallow-period and overgrazing are becoming common-practice because of increasing population pressure. This causes depletion of the topsoil and often even soil-loss by excessive erosion.

In the volcanic part the population pressure is mounting very much as well, resulting in fragmentation of farmland and cultivation on steeper slopes. Although the soils are much less vulnerable to erosion and terracing for coffee is common practice, loss if the humic topsoil is observed more and more. Also gully formation, terrace decline and flooding of the valleyland is on the increase as result of lack of protection by cultivated or natural vegetation, footpaths and asphalt roads.

3.4.2. Major classification units.

Nitisols.*

These are strongly weathered and strongly leached soils with an AB-horizon sequence. An ochric or umbric epipedon overlies an argillic B-horizon of which at least a part has a base saturation below 50%. The argillic B has a clay distribution such that the percentage of clay does not decrease form its maximum by as much as 20% within 150 cm of the surface. This argillic horizon is characterized by shiny pedfaces on at least some of the ped surfaces (Kenyan Concept).

In the survey area are humic Nitisols*, having a dark (umbric) topsoil relatively rich in acid, humic material. See Plate on page 4. Also a large area is covered by dystric Nitisols*, having a more red topsoil with less organic matter. The humic Nitisols* are found mostly in the area covered by the Mt. Kenya forest where they have a high organic matter content in the B-horizon. The dystric Nitisols* cover the mountain footridges between about 1400 and 1800 m. See App. 6.7, Plate 3.

Acrisols.

These are strongly weathered and strongly leached soils with an AB-horizon sequence. An ochric or umbric epipedon overlies an argillic B-horizon of which at least a part has a base saturation of less than 50%.

Several subunits are found in the survey area. The humic Acrisols have an umbric epipedon, which is rich in acid, humic material. On the Plateau the humic Nitisols* transform into humic Acrisols, in eastern direction. In the ferric Acrisols the argillic horizon overlies petroplinthite (murram), which indicates at least imperfectly drained conditions, now or in the past. Some Acrisols with an umbric epipedon have ferric properties too. As they key out as humic first, they are called humic (ferric)* Acrisols (Kenyan Concept). The chromic ones have a reddish colour, with hues being redder than 5YR (Kenyan Concept). Chromic Acrisols can transform to Ferralsols, containing more low activity clay. These soils are called ferral-chromic* Acrisols (Kenyan Concept). They follow in the sequence of humic Acrisols, chromic Acrisols to ferral-chromic Acrisols. The gleyic Acrisols are found in the bottomlands. They develop under moderately well drained conditions and show hydromorphic properties within 50 cm of the surface.

Luvisols.

In principle these are moderately weathered soils with an AB-horizon sequence. An ochric or umbric epipedon overlies an argillic B-horizon that has consistently a base saturation higher than 50%.
Chromic, calcic and orthic Luvisols are encountered in the survey area.

The chromic ones have a reddish colour with a hue redder than 5YR (Kenyan Concept). They are very common in the area of soils developed on Basement System rocks. Calcic Luvisols have concretions of soft powdery lime or a calcic horizon. Their appearance is mostly associated with (recent or ancient) streams. Orthic Luvisols are those without any of the specific characteristics for the other subunits.

Cambisols.
These are young and limited weathered soils. They have an AB-horizon sequence, in which the B-horizon is not pronounced enough to qualify as an argillic. There are many weatherable primary minerals in these soils.

The subunits dystric, eutric and gleyic are encountered in the survey area. The dystric Cambisols have no umbric epipedon, and the base saturation of the B-horizon is less than 50% at least in some part of the B-horizon. The eutric ones have no umbric epipedon, but the base saturation of the B-horizon is consistently above 50%. Gleyic Cambisols show hydromorphic properties because of moderately well drained conditions. They are found mostly in the valley bottoms in the western part of the survey area.

Lithosols.
These are shallow soils with an AR-horizon sequence. An ochric epipedon overlies a layer of continuous coherent hard rock within 25 cm (Kenyan Concept) of the surface. There is no B-horizon whatsoever.

The lithosols developed on ferro-magnesian rocks are eutric, having a high base saturation. The Lithosols appear especially at places with severe erosion such as those at very small ridges of hard rock and at the scarp of the volcanic plateau.

3.4.3. Remarks.

Kenyan Concept.
The use of the FAO/UNESCO Legend terminology for soil surveys of more detail than the legend was intended for, has revealed the need for greater detail in the existing classification framework. This has led

to adaptations of the first and second level terminology, as well as the introduction of the 'unit' (third level terminology).

The deviations from and the additions to the FAO/UNESCO classification system as applied by the Kenya Soil Survey are known as the 'Kenyan Concept' (Siderius & van der Pouw, 1980). They were applied in the 'Exploratory Soil Map of Kenya' (Sombroek et al., 1982), 'Soils of the Kisii Area' (Wielemaker & Boxem, 1982) and in Soils of the Kilifi Area (Boxem et al. 1987), and are indicated with an asterix*.

The following deviations are of particular relevance for the Chuka-South Area:

- intergrades between Great Groups,
- an adjusted Lithosol and Nitosol concept,
- diagnostic properties.

Intergrades between Great Groups.

In some parts of the Chuka-South Area soils occur that do not satisfy the existing first level definitions. These soils are intergrades between two Great Groups, viz. Luvisols/Acrisols on the one hand and Ferralsols on the other hand. The soils possess properties that refer to both an argillic and an oxic B horizon: there exists an increase in clay content with depth, high enough to meet the requirements of an argillic horizon, but outspoken signs such as cutans are not or hardly visible. At the same time the soil meets requirements of an oxic horizon, which, however, are not fully met either. An exhaustive list of criteria is given by Siderius and Van der Pouw (1980, p. 4-5). As mentioned in 342 one intergrade has been recognized: the FERRAL-chromic* ACRISOLS.

Lithosols.

The depth limitation for Lithosols (hard rock within 10 cm of the surface) was found to be too narrow for Kenya conditions and has been set at 25 cm. In addition, Lithosols can be subdivided into dystric and eutric subgroups if necessary.

Nitosols.

The present definition of the Nitosols in the FAO/UNESCO Legend would have given a considerable extend of dystric Nitosols because soils with a slight increase in clay content meet the requirements of an argillic horizon. The thickness requirement is also met. Shiny ped faces, however, the features that gave the Nitosol its name, do not occur at all in these soils. Therefore, a nitic B horizon is proposed by Siderius & Van der Pouw (1980, p. 18-19).

Diagnostic properties.

The definition of ferric properties is slightly altered. The original concept of ferric is used in connection with Luvisols and Acrisols, showing one or more of the following:

1. many coarse mottles with hues redder than 7.5YR or chromas more than 5, or both,
2. discrete nodules, up to 2 cm in diameter, the exteriors of the nodules being enriched and weakly cemented or indurated with iron and having redder hues or stronger chromas than the interiors,
3. a cation exchange capacity (from NH_4Cl) of less than 24 me/100g (= 240 mmol/kg) clay in at least a subhorizon of the argillic B horizon. According to the Kenyan Concept, the term ferric is used exclusively for the features mentioned under 1 and 2, and does not embrace the CEC requirement.

The Revised FAO-UNESCO Legend.

In 1987, a draft of a revised legend for the FAO-UNESCO Soil map of the world was issued, with amendments proposed related to the diagnostic horizons, the definitions of major soil groupings and of soil units, the introduction of third level soil units and the phases. Although the proposed amendments of this draft legend are not mentioned in the soil mapping unit descriptions and/or the profile descriptions, a few remarks as to the applicability in the Chuka-South area seem appropriate.

First of all about the new first-level addition: Lixisols, which are soils with an argillic B-horizon, high base saturation, but low clay activity. The latter characteristic separates them from Luvisols which will then be soils with high clay activity. This means that all

Luvisols in the Chuka-South area will become Lixisols.
A similar separation has been made by splitting the Acrisols into Acrisols now defined as soils with low activity clay and Alisols with high activity clay. This means that the soils in the survey area, which are now classified as Acrisols, will remain Acrisols.

Another relevant proposal is to rename the "stony phase" into the term rudic. This means for the survey area that many soils in the eastern part will become "rudic".

3.5 SOIL FERTILITY

3.5.1 Introduction

Fertility of the soils of the Chuka Area has been evaluated by means of soil analysis only. The fertility assessment has been carried out according to the Quantitative Evaluation of the Fertility of Tropical Soils (QUEFTS), a modification of the Kisii and Kilifi systems (Guiking et al., 1982, Janssen et al., 1988). In the absence of field data the validity of this system for the Chuka area could not be tested. However it was developed on data obtained from Kisii (Wielemaker and Boxem, 1982) an area with soils similar to those of the Western part of the survey area and it also proved to be valid in Kilifi (Boxem, De Meester and Smaling, 1987) where the soils have properties comparable with those of the Eastern part. Still, uptake relations used in the QUEFTS model being empirical, care must be taken when using data obtained by this model when it has been applied under circumstances differing from the original (or checked) ones, as is the case in this report.
The availability of nutrients , i.e. chemical soil fertility of the area, was done in two different ways:

- chemical soil fertility as a mapping unit characteristic
- chemical soil fertility as a spatial variable

3.5.2 Methodology

At the end of the field survey composite samples were collected at random in a way that -together with the fertiliy samples collected

around representative profiles- roughly every 20 ha of the survey area was represented by at least one sample. From each location a sample was collected from a depth of 0-20cm. This sample was obtained by mixing soil, from the given depth ranges, of six augerings each at about 4 m from each other.
Subsequently these samples were send to the NAL for the analysis of the available nutrients (Mehlich et al, 1962).

The available nutrients data were, together with the coordinates of each sample location, fed to a computer. Consequently, nutrient limited yields were calculated with the QUEFTS model (Janssen et al, 1988) for each location. QUEFTS calculates dry yields of maize from data on pH-H2O, total organic C and N (k/ha), P-Olsen (mg/kg) and exchangeable K (mmol/kg) and is mainly based on previous research data obtained in both Surinam and Kenya. To obtain the fresh yields a correction factor of 1.25 has to be applied.
For use of the QUEFTS model the original data had to be adapted as follows. The P-Mehlich figures were divided by 3 to get data comparable with P-Olsen figures; C data were multiplied with a factor of 12 (1.2 to transfer C- Walkley-Black to total C); N and K data were multiplied with a factor 10 to obtain the right dimensions. The model uses either organic C or organic N data as N source. When organic C data are used a C/N ratio of 10 is assumed. In this study both C and N data were used after which the yields were calculated as the average of the two.
The survey area was divided in 56 by 27 regular grid cells, each cell covering an area of 1 km^2. Values of the different variables were estimated for each grid cell from neighbouring data points, by the method of strict kriging (Corsten, 1985). In this study it was assumed that there is no surface trend, i.e. the expectation for each variable is a constant, and that the covariance structure is isotropic, i.e. the same in every direction. The construction of the semi-variogram was done with SPATANAL a programm written by A. Stein (Agric. Univ. Wageningen). This semi-variogram was approximated by linear equation.
Next the original data were transferred to a regular data set and plotted on a map by UNIRAS (European Software Contractors, 1986). In the kriging procedure the search radius was 9 km and the maximum number of the neighbouring observations was 24.

3.5.3 The QUEFTS system

The QUEFTS system is based on the interrelations between:

- the uptake of N, P and K by a maize crop during one growing season
- the corresponding grain yield levels
- chemical soil properties measured in samples of unmanured soil and suited as N, P and K availability indices.

For each of the nutrients of N,P and K, four levels of availability were distinguished corresponding with maize yield levels as indicated in Table 11.

Generally plant growth is restricted by lack of N, P or K, however other nutrients, which have not been considered in this system, certainly can affect plant growth. Therefore the calculated yields rather have a relative than an absolute value.

For further information on the system is referred to the Kilifi report (Boxem, De Meester and Smaling, 1987)

Table 11. Levels of nutrient availability, corresponding maize yields and uptake of N, P and K.

Availability level	Yield (tons/ha)	Uptake (kg/ha) N	P	K
1	> 5.0	> 120	> 16	> 120
2	2.5 -5.0	61 -120	9 -16	71 -120
3	1.25-2.5	30 - 60	5 - 8	40 - 70
4	< 1.25	< 30	< 5	< 40

3.5.4 Fertility appraisal.

Chemical soil data were available for 28 of the 37 mapping units of the soil map. Average chemical soil data, average estimated maize yields, number of observations most limiting nutrient for the different mapping units are presented in Table 12.

The grouping of the mapping units into fertility classes according to their maize yield is presented in Table 13 and Figure 12.

The large area occupied by unit RP1h makes its estimated yield of 2.5 -

3.0 Mg/ha (= Mega-gramme equals one tonne) the most common one. In general yields in the eastern part of the area are rather low, although the lowest yields occur in unit U2FC1. It is clearly shown that the highest yields occur on the pyroclastic materials (P). The behaviour of the soils on gneisses rich in ferro-magnesian minerals (F) is striking: yields of units U2F1 and U2F2p are relatively high, but yields of units U2FC1 and U2FC2 are the lowest.

Table 12. Number of observations (n), average chemical soil data, estimated maize yield and the most limiting nutrient (N or P or K) of soil mapping units.

Map	n	pH-	C	N	P	Ca	Mg	K	Yield	lim.
Unit		H2O	%		mg/kg	cmol(+)/Kg			kg	factor
MQC	1	6.7	0.3	.06	314	4.8	0.6	0.4	1539	N
HGC	1	5.7	1.7	.22	18	2.4	1.3	0.6	3776	P
HQC	3	5.7	1.0	.13	21	4.6	1.6	0.3	2047	N
HUC	2	6.8	0.5	.08	72	6.6	2.8	0.2	1659	N
HBC	1	6.9	1.7	.19	31	7.6	7.8	0.1	1222	K
HPC	2	5.4	3.2	.28	13	0.0	0.4	0.2	2182	K
RP1h	66	5.2	2.8	.35	17	2.6	1.8	0.6	2835	P
RP2	1	5.4	6.4	.99	25	0.0	0.8	0.5	2128	K
LP1	15	5.8	2.1	.17	18	4.5	2.9	1.0	3785	P
LPC	2	5.7	1.9	.14	25	4.8	2.6	1.2	3961	N
LB	1	6.2	1.9	.11	6	2.8	1.3	0.6	2836	P
U1P1h	5	5.9	1.9	.24	18	4.0	3.7	1.0	4066	P
U1P2	5	5.6	1.6	.16	9	5.3	2.6	0.9	2968	P
U1PC	3	6.1	2.3	.19	15	8.9	3.9	0.8	4101	P
U2Q2p	1	8.0	0.4	.10	207	2.4	1.8	0.2	1152	K
U2QC1	1	7.3	0.2	.06	51	6.8	2.4	0.2	1365	N
U2F1	7	6.6	0.8	.10	78	7.5	3.1	0.5	2549	N
U2F2p	4	6.4	0.6	.12	67	11.2	3.7	0.5	2587	N
UU2FC1	8	6.8	0.6	.08	46	13.8	1.9	0.2	967	N
U2FC2	5	6.1	0.8	.09	51	8.4	2.5	0.2	1411	K
U2UC	6	6.8	0.2	.08	87	4.8	2.9	0.4	1500	N
U2XC	1	6.6	0.9	.08	6	0.8	2.5	0.3	1647	P
U2Ap	3	6.4	1.1	.11	25	11.7	4.7	0.5	2151	P
PPC	1	5.7	1.8	.14	34	14.4	4.8	0.1	2258	K
BVC	1	5.2	1.6	.10	38	5.2	1.4	0.3	2486	N
V1PC	6	5.0	2.3	.40	16	1.9	3.0	1.0	2868	P
V2P	3	5.5	2.5	.23	59	3.6	4.1	0.9	4246	N
V2PC	2	5.6	1.9	.19	25	9.3	4.6	0.7	2933	N

Table 13. Classification of mapping units according to their estimated maize yields.

Class	Yield (Mg/ ha)	Maping units
1	4.0 - 4.5	U1P1h, U1PC, V2P
2	3.5 - 4.0	HGC, LP1, LPC
3	3.0 - 3.5	-
4	2.5 - 3.0	LB, RP1h, U1P2p, U2F1, U2F2p, V1PC, U2PC
5	2.0 - 2.5	BVC, HPC, HQC, PPC, RP2, U2App
6	1.5 - 2.0	HUC, MQC, U2UC, U2XC
7	1.0 - 1.5	HBC, U2FC2, U2Q2P, U2QC1
8	0.5 - 1.0	U2FC1

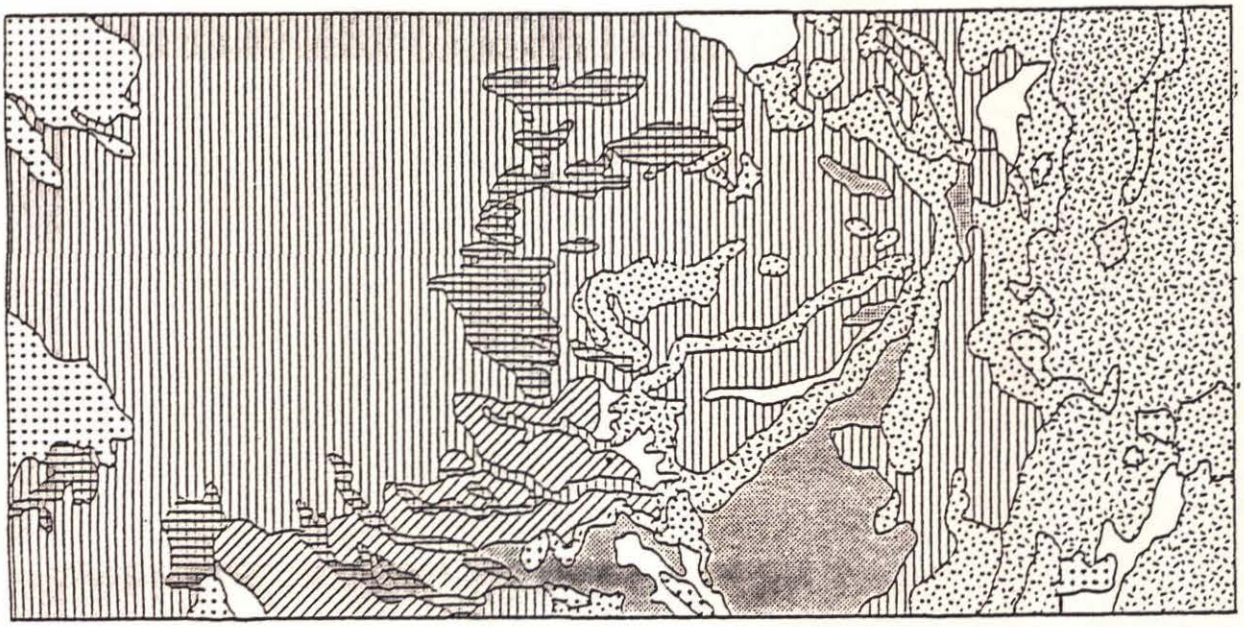


Figure 12. Nutrient limited yields of maize (dry matter), averaged per mapping unit.

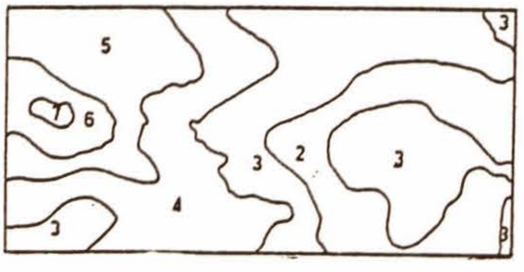
3.5.5. The spatial distribution of the pH and various soil nutrients

The spatial distribution of the various soil characteristics will be discussed briefly as it is best shown by the various maps.

pH-H2O

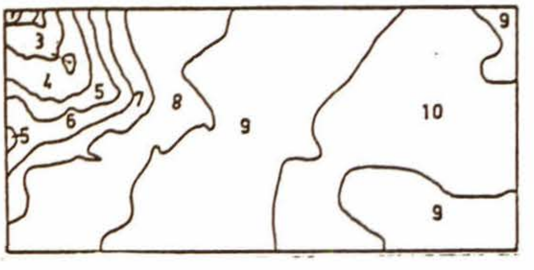
The pH-H2O values increase gradually from West to East and seem to be negatively related to the rainfall which increases with increasing altitude. As a result nutrients are leached out at higher locations - giving low pH values - and transported to the lower ones, where more calcareous horizons are found (see Figure 13).

pH Values below 5.5 are associated with base saturations of less than 50% and with the presence of exchangeable (and toxic!!) aluminium. Especially in the area with values below 4.5 these aluminium levels will result in yield reductions of non resistant crops and the yields of all crops will be reduced as a result of the virtual absence of the major nutrient elements Ca and K and of several metallic trace elements.



1 = 7.0 - 7.5
2 = 6.5 - 7.0
3 = 6.0 - 6.5
4 = 5.5 - 6.0
5 = 5.0 - 5.5
6 = 4.5 - 5.0
7 = 4.0 - 4.5

Figure 13. Estimated pH-H2O values



1 = 0.9 - 1.0
2 = 0.8 - 0.9
3 = 0.7 - 0.8
4 = 0.6 - 0.7
5 = 0.5 - 0.6
6 = 0.4 - 0.5
7 = 0.3 - 0.4
8 = 0.2 - 0.3
9 = 0.1 - 0.2
10 = 0.0 - 0.1

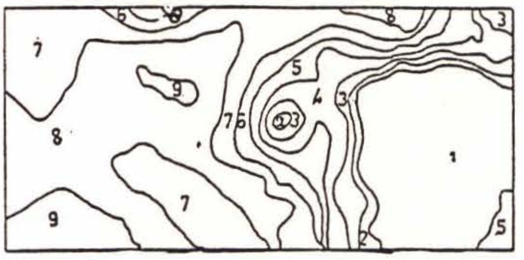
Figure 14. Estimated Nitrogen percentages

Organic nitrogen

Contrary to the increasing temperature and decomposition rate of organic matter, the organic nitrogen contents decrease downslope (see Figure 14). However the C/N ratios increase from West to East, aggrevating the N deficiency of the soils of the Basement System Rocks to some extent.

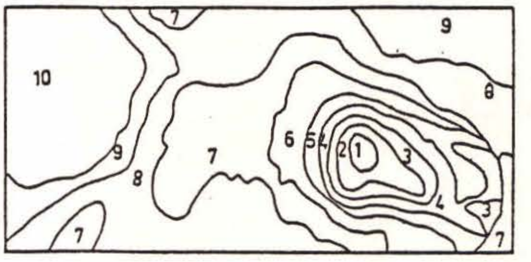
Phosphorus

P figures increase rapidly towards the East and reach very high values (up to 220 mg/kg). Very likely this is caused by favourable pH conditions (low adsorbtion rates) at places possibly combined with relatively high concentrations in the parent material (see Figure 15).



1 = > 80
2 = 70 - 80
3 = 60 - 70
4 = 50 - 60
5 = 40 - 50
6 = 30 - 40
7 = 20 - 30
8 = 10 - 20
9 = 0 - 10

Figure 15. Estimated P concentrations (mg/kg)



1 = 18 - 20
2 = 16 - 18
3 = 14 - 16
4 = 12 - 14
5 = 10 - 12
6 = 8 - 10
7 = 6 - 8
8 = 4 - 6
9 = 2 - 4
10 = 0 - 2

Figure 16. Estimated Exchangeable Calcium (mmol(+)/Kg)

Calcium

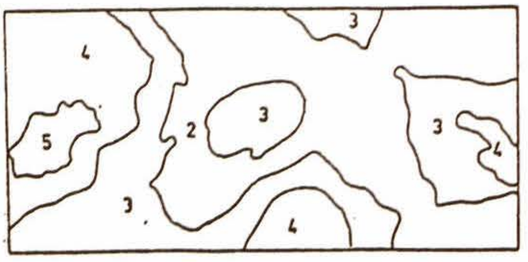
The Ca contents are strongly related with pH values. Next to the leaching, respectively accumulation effects, as discussed before, also the parent material matters. The latter can be concluded out of the fact that the highest values are found near basic and ultrabasic rocks (see Figure 16). The distribution of Ca supports those of pH values to a high degree.

Magnesium

Although the same tendency in distribution pattern can be observed as mentioned for Ca both the differences in value and the pattern itself are much less pronounced (see Figure 17). This can be explained as follows. On weathering magnesium is released from the clay minerals. By this the concentration of magnesium in exchangeable form will not drop as dramaticallly as is the case with calcium which does not make up part of the clayminerals.

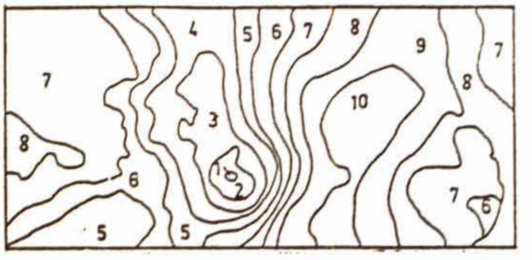
Potassium

The highest potassium concentrations are found on the Plateaus and high level Uplands of volcanic origin. Probably the original K concentrations of the pyroclastic rocks were high, but decreased in the Western part of the area as a result of leaching. K-Contents in the Eastern part of the area are low, either as a result of low contents in the parent material or by excessive weathering of the Basement System Rocks combined with very low accumulation rates caused by the high solubility of K compared to those of Ca and Mg (see Figure 18)



1 = 4 - 5
2 = 3 - 4
3 = 2 - 3
4 = 1 - 2
5 = 0 - 1

Figure 17. Estimated Exchangeable Magnesium (cmol(+)/Kg)



1 = 11 - 12   6 = 6 - 7
2 = 10 - 11   7 = 5 - 6
3 = 9 - 10   8 = 4 - 5
4 = 8 - 9   9 = 3 - 4
5 = 7 - 8   10 = 2 - 3

Figure 18. Estimated Exchangeable Potassium (mmol(+)/ kg)

Trace elements

As a result of strong leaching in the Western part of the survey area, deficiencies of several trace elements are axpected there, often combined with Aluminium toxicity.

In the Eastern part ultramafic intrusions rich in Cr, Ti and other heavy metals are found (Veldkamp and Visser, 1987). On weathering, these metals will be released at places resulting in toxic concentrations in the soils. At these places only a vegetation poor in species can grow. From a public health point of view it may be advisable to diiscourage farming at these sites. Further research on this subject is still required.

3.5.6. Yield potentials

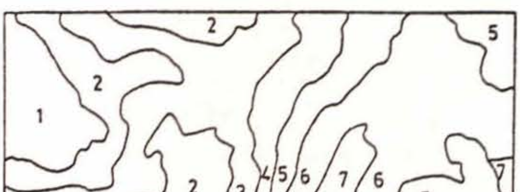
Potential maize yields

The highest potential maize yields are found on soils developed on pyroclastic rocks, reaching a maximum at the outer part of the Volcanic Footridges.

In terms of most limiting nutrient, as far as it concerns the elements N, P and K, the area can roughly be divided in two parts: a Western half in which phosphorus is the most limiting element and an Eastern part in which nitrogen is the most limiting one. Areas in which potassium is the most limiting nutrient are scattered over the whole survey area and coincide with the lowest overall yields (see Figure 19 and 20).

Water limited yield potentials.

Next to nutrients, crops also require water. To compare the relative effects of an improved water supply over an improved fertilisation a water-limited yield map (Figure 21) was produced (Veldkamp, 1987). From figures 19 and 21 it can be concluded that the present moisture supply is enough for roughly twice or three times as high a cropyield as is actual possible because of the low fertility. This does not take into account the amount of run-off.



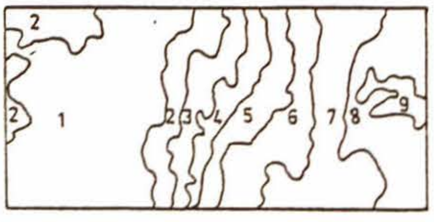
1 = 4.0 - 4.5
2 = 3.5 - 4.0
3 = 3.0 - 3.5
4 = 2.5 - 3.0
5 = 2.0 - 2.5
6 = 1.5 - 2.0
7 = 1.0 - 1.5
8 = 0.5 - 1.0
9 = 0.0 - 0.5

Figure 19. Estimated nutrient limited yields of maize (Mg/ha)

1 K is most limiting nutrient
2 P ,, ,, ,, ,,
3 N ,, ,, ,, ,,

Figure 20. Map of most limiting nutrient

However, in the eastern half of the survey area run-off rates of 50% have been measured. Only in these cases water may become more limiting than nutrients.



1 = > 8 Mg (dry)maize/ha
2 = 7 -8 ,,
3 = 6 -7 ,,
4 = 5 -6 ,,
5 = 4 -5 ,,
6 = 3 -4 ,,
7 = 2 -3 ,,
8 = 1.5-2 ,,
9 = >1.5 ,,

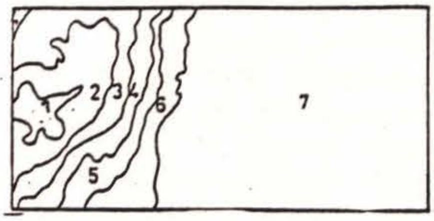
Figure 21. Water limited yield potential of maize

Actual maize yields

All figures presented above give potential yields. To check their practical use they were compared with figures obtained with actual yield data. Figure 22 gives the actual cropyields calculated from published data of control fields of fertilizer trials that were conducted over a three years period by the FAO (FAO, 1975). Figure 23 was obtained by using cropyield data collected during the second rains in 1985 (Ooms, 1987).

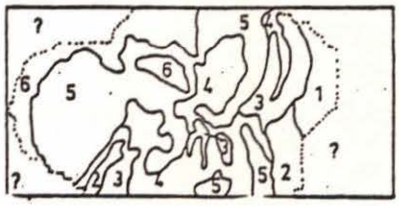
Some remarkable differences can be observed which partly can be explained as follows. Potential yields are entirely based on the fertility status of the soils. In case of the actual crop yields the crops were fertilized, especially in the Eastern part (some cowdung close to each maize seed). Furthermore the longer growing season in the Western part (lower temperatures) and different maize varieties influence the final results.

Finally the FAO data were based on soil mapping units which within the survey area have a different nutrient status from the ones on which the trials were run. Finally most data of Ooms are located in the Eastern half and those from the FAO in the Western half of the survey area.



1 = > 3.25 Mg/ha
2 = 3.00 - 3.25 ,,
3 = 2.75 - 3.00 ,,
4 = 2.50 - 2.75 ,,
5 = 2.25 - 2.50 ,,
6 = 2.00 - 2.25 ,,
7 = < 2.00 ,,

Figure 22. Nutrient limited yields of maize (FAO, 1975).



1 = 3.00 - 3.25 Mg/ha
2 = 2.75 - 3.00 ,,
3 = 2.50 - 2.75 ,,
4 = 2.25 - 2.50 ,,
5 = 2.00 - 2.25 ,,
6 = < 2.00 ,,

Figure 23. Actual maize yields second rains 1985 (Ooms, 1987)

3.5.7 Recommendations

The very low fertility levels in the dry eastern half indicate that with the introduction of irrigation alone no major cropyield increases can be expected. It should also be realised that the physical aspects of these soils are unfavorable (low infiltration rates, poor aeration and high erodibility, all aspects related to a low structure stability). Their low percolation rates require a very high level of soil management because it increases their susceptibility to salinisation and, probably more dangerously, to sodification. Without the right management the Exchangeable Sodium Percentage (ESP) of these soils, with their low CEC values, very soon can increase to levels at which the clay peptises, leading to a further decrease in structure stability. At best these soils should be left under bush fallow (extensive grazing, wild life).

On the other hand one should realise that all maps give a generalized picture. This means that even within the poorest units plots of a few acres may exist with a much higher yield potential at which agriculture certainly is feasible. For example some of the river terraces.

The better structured soils in the western half of the survey area are more acid and in many cases require liming to increase their fertility. Liming will increase the pH and CEC but also decrease the AEC of these soils with variable charge characteristics. This will result in a drop of the allready low structure stability so in lower infiltration rates, lower aeration, higher erodibility and lower biological activity, all finally leading to cropyield reductions. Only the application of fertilizers at very low and often repeated rates (split applications), which should be monitored very closely on their (negative) effects on the structure stability, and the use of organic fertilizers, which, considering the presence of dairy farming and the moderate decomposition rates, seems possible, could improve the situation considerable.

3.6 EROSION AND LAND DEGRADATION

3.6.1 Introduction

Erosion hazard depends on the interaction of the following factors (Hudson,1971; Morgan, 1979):

- erosivity, or the tendency of the eroding agent to cause erosion.
- erodibility, or the susceptibility of a soil to detachment and transport.
- slope and slope length
- soil cover
- conservation practices and mangement

Erosion can occur as superficial sheet (or splash), rill or as deep gully erosion. Splash and rill erosion are easily obliterated by tillage. In some soils a certain degree of annual soil loss does not significantly affect productivity. This is called permittable or tolerable soil loss.

Besides hazard and susceptibility for loss of soil by erosion, there are related processes causing deterioration of the soil for sustained production, e.g. soil compaction, crust formation, salinization, removal of soluble nutrients, fixation etc. The term soil degradation is commonly used for these processes.
The susceptibility to erosion of the soils of the survey area was estimated by combining the effects of the land characteristics related to climate (erosivity), soil (erodibility) and relief.
These land characteristics were studied in detail at selected, representative sites in the Chuka - South area.
One of these studies resulted in a report on the subject at Marimanti (Scholte, 1986b).
The estimated characteristics were used to compile a single value map on the erosion hazard after clearing.

3.6.2 Factors controlling erosion

Erosivity

Only rainfall erosivity will be discussed, as wind erosivity is not important in the Chuka-South area. It depends on the intensity, duration, and frequency of rainstorms.

In the survey area the erosivity of the rainstorms decreases with the altitude.

The erosive rainstorms have the most disastrous effect when the soil of the cultivated fields has no vegative cover, which is at the start of the rainy season.

The project gauges recorded the highest intensities in the eastern part of the area (Marimanti), where the majority of the rain falls with an intensity of $\pm$ 50 mm/hr or more (up to 90 mm/hr).

Erodibility

The susceptibility of a soil to detachment and transport by rainsplash and run off is called erodibility.

The erodibility of a soil is determined by a large number of soil characteristics, such as soil stability, infiltration rate, soil materials and grade, size of the structure.

Table 14, Aggregate stability and infiltration rate in relation to soil, landuse and organic matter content (Emerson, 1966).

Mapping unit	Classification (FAO) (general)	landuse/ vegetation	aggregate stability Emerson	final rate infiltration mm/min	organic content %
RP2	humic Nitisol*	tea	8	1.57	1.6
RP2	orthic Nitisol*	tea	8	2.4	1.5
RP1h	humic Nitisol*	coffee	6-8	1.74	1.8
V2PC	humic Acrisol	dairy/grass	5	5.5	1.3
LP1	chromic Ferralsol	tobacco	5-8	2.5	1.6
U1P2	plintic Acrisol	maize	8	1.95	1.7
U2FC	chromic Luvisol	millet/fallow	3	0.1-0.5	0.2
U2FC	calcic Luvisol	bush fallow	3-5	1.1	0.5

In Table 14 the estimated values of these characteristics are listed. The least erodible soils in the area are the deep red Nitisols* which are used for tea cultivation. The most erodible soils are the chromic Luvisols used in a bush fallow cycle.

These chromic Luvisols also show the lowest infiltration rates. The extreme low infiltration rates are caused by severe crusting, which is very common on these Luvisols.

The highest steady state infiltration rates are also found on the Nitisols* in the so called coffee zone. These Nitisols* are characterised by many small cracks which cause the fine angular blocky structure.

Organic matter content has a positive effect on structural stability. The aggregate stability was estimated by the Emerson test (Emerson, 1966). Class 8 are the most stable aggregates, class 1 the most instable aggregates.

Topography

Erosion normally increases with increased slope-steepness and slope-length, as a result of enhanced velocity and volume of surface runoff. Running water is, however, often slowed down by obstacles like hedges and stones ("stone mulch").

Crusting

Another form of degradation that occurs in the Chuka-South area is crust formation. Esspecially the Luvisols in the eastern Basement System area are vulnerable to this type of degradation. Crust formation is caused by rainsplash on overgrazed and "overcultivated"land.

The final stage is an area with a bare surface and with a massive top structure with hardly any vegetation left (See App. 6.7, Plate 10).

Vegetation cover

It is generally recognised and accepted that the effect of vegetation cover overrules all other factors causing erosion. The major role of vegetation is the interception of rain drops. Their energy is reduced by the plant rather than passed to the soil.

Vegetation that directly covers the soil reduces the velocity of surface runoff. Moreover, a root system, organic matter and biological activity in an area under vegetation cover opens up the soil and increases its infiltration capacity. Hence, soil erodibility is reduced.

In Scholte (1986b), a more detailed discussion is held about the influence of vegetation on soil properties like porosity, infiltration capacity and degree of sealing. This is illustrated by soil moisture measurements during the rains. On sealed areas less than 20% of the rainwater can infiltrate, compared to ± 50% in case of soils covered by grasses and 100% when the soil is covered by dense shrubs (all data at an average rainfall intensity of 50 mm/hr.).

3.6.3 Soil erosion hazard after clearing

A map was prepared showing the erosion hazard after clearing. This map (Fig. 24) indicates the susceptibility of the areas to erosion hazard. The factors described under 2, except vegetation, were taken into account when preparing this map.

The following legend was used:

1 slight splash erosion
2 moderate splash and slight to moderate gully erosion
3 moderate rill and slight to moderate gully erosion
4 moderate to severe rill and moderate gully erosion
5 severe rill and moderate to severe gully erosion
6 severe splash and sligth rill and gully erosion
7 severe splash and moderate rill and gully erosion
8 severe splash, rill and gully erosion

These classes indicate a gradual increase from almost no erosion to severe erosion. The worst classes are 5 and 8.
Classes 1 and 2 indicate the areas where erosion is not expected to become a major problem after clearing.
Many boundaries are the same as on the soil map. The soil map translated to these 8 classes yields Table 15.

The map indicates clearly that erosion is a serious problem in the Basement System area and on the very steep slopes in the volcanic area.

CHUKA SOUTH AREA

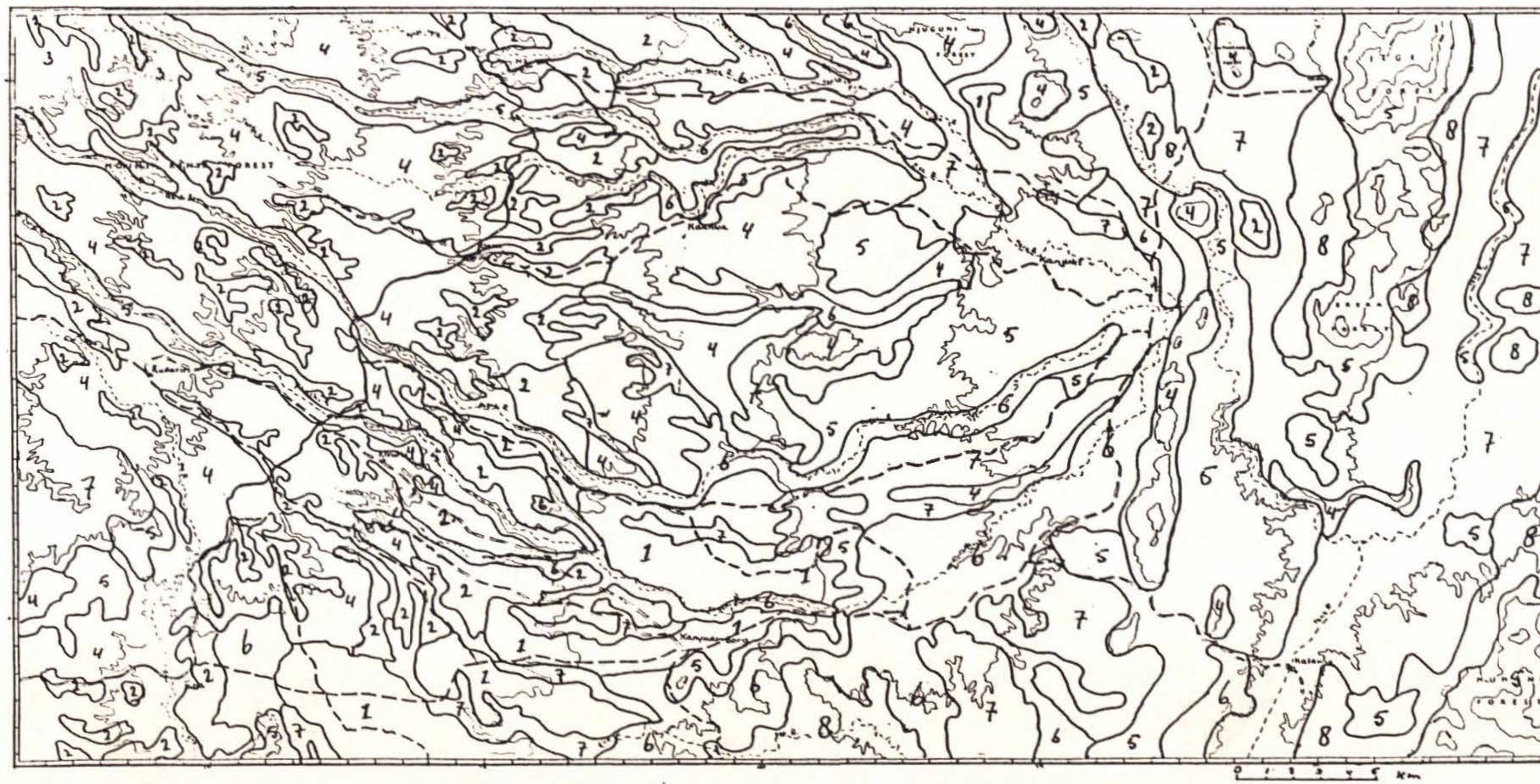


Fig 24 Erosion hazard map. For explanation see text Ch. 3.6.3

LEGEND : Contours (m) Asphalt road Metalled rd. Track River (bed)

To prevent erosion it is prohibited to cultivate on the mountains and most hills in the Basement System area. It is obvious from the map that this rule should not be abandoned.

3.6.4 Present status of erosion

Severe splash, rill and gully erosion are common on steep slopes, scarps, hills, mountains, ridges and steep-sided valleys. These areas should be kept under permanent vegetation.
The well drained deeper soils of the footridges and the plateau area are not so susceptible to erosion, except under poor management. The moderately deep red soils in the U2 uplands are susceptible to crust formation and erosion. In the whole area roads and footpaths, especially if running downhill are usually deeply gullied and are a hazard to adjoining cultivated areas (See App. 6.7, Plate 8).

3.6.5 Conservation practices

During the soil survey several farming system research studies have been carried out. Around 150 farmers were interviewed, (Abdullah et al., 1986; De Haan 1986; Van Der Donk & Helder 1986). One of the subjects of these studies was erosion. These results are listed in table 16.
The large amount of terraces (with or without grasslines) used in the coffee and tea zone is very striking. This is simply explained by the fact that the Kenian Coffee Cooperation KCC, makes it obligatory to cultivate coffee on terraces.
The large amounts of stonelines in the marginal cotton and livestock-millet zone can be explained by the many stones in these areas and the habit of stone clearing.
The grasslines are mostly used in areas where zero grazing is common. The fodder for the cattle is cultivated on these grasslines.
In some areas (especially in the tea zone) many farmers do not use any soil conservation measures at all. This absence of conservation practises has its origin in the farmer perception of erosion.
The perception of the interviewed farmers is listed in table 17.

Table 15. The major soil units and their erosion hazard after clearing.

Major soil unit	erosion hazard class (after clearing)
MG	5
MB	4
HG	5
HQ	5
HU	5
HI	4
HB	4
HP	7
RP1	2-4
RP2	2-3
LP	1
LI	2
LB	2
U1P	3-4
U2Q	6-7
U2F	6-8
U2U	6-7
U2X	5-6
U2A	5-6
PP	2
BV	1
V1P	5-6
V2P	6-7

Table 16. The answers of 150 farmers in percentage related to conservation practices in different agro-ecological zones.

Conservation practises	tea zone	major coffee zone	marginal coffee zone	cotton zone	marginal cotton zone	livestock millet zone
terraces	30%	30%	31%	62%	5%	5%
terraces + grasslines	25%	45%	47%	20%	-	-
grasslines	10%	40%	50%	35%	15%	2%
trashlines	-	-	7%	65%	90%	100%
stonelines	-	-	-	25%	70%	20%
none	65%	10%	20%	5%	-	-

Table 17. The perception of 150 farmers answers asked for conservation practices in different agro-ecological zones.

perception livestock	teazone	major coffee zone	marginal coffee zone	cotton zone	marginal cotton zone	millet zone
Negligible	80%	30%	33%	24%	15%	31%
slight problem	19%	23%	23%	29%	41%	36%
major problem	1%	47%	45%	47%	44%	33%

The data presented in Table 17 explain why most of the farmers in the tea zone do not take any conservation practises: they do not consider erosion as a problem there.

Table 17 shows also that in general erosion is considered as a problem. Striking is that only one third of the farmers in the strongly eroded livestock-millet zone consider erosion as a major problem. These farmers all use conservation practises, but the major goal is probably water harvesting. An explanation of this phenomena is the different farming system which is practised in the livestock-millet zone.

In this zone bush-fallow farming is practised, while in the other zones permanent farming is common. Lack of sufficient attention by the extension service can also be considered as a reason for the low perception of erosion.

Nowadays the bush-fallow cultivation practise is intensifying and changes gradually into permanent farming. These changes cause an increased erosion problem. A clear example is found near Ishiara where the erosion problem is most serious.

It might be advisable for the extension service to give more attention to the livestock-millet zone since erosion there is expected to become a serious problem in the future.

4 FARMING AND LANDUSE

4.1 INTRODUCTION

The agricultural production of the project area depends much on its population (see Chapter 1.1) climate (see Chapter 1.2) and soils (see Chapter 3). Most important are the differences in altitude and rainfall over relatively short distances, which make the area ecologically very diversified. The agro-ecological zones (according to Jaetzold, see also Chapter 1.2) are listed in Table 18, which also presents their approximate equivalents to the former Kenya system of ecological regions (Bernard, 1971; for Meru only).

Field observations suggest that the major agro-ecological units in the area are conveniently aggregated into 5 groups, A through E, to be used in this report only.
The dominant vegetation type in group A is montane tropical rain forest; this land is not used for arable farming. Within groups B through E, the following four farming systems occur:

AGRO-ECOL. GROUP	FARMING SYSTEM
B	Tea-coffee-dairy system
C	Coffee-maize-beans system
D	Cotton-maize-pigeon pea system
E	Livestock-millet-(cotton) system

Farming in the project area can be characterized as rainfed mixed farming by small-holders. Most farmers combine cropping with some kind of livestock production but the proportions of these two components differ among farms. Also, farms differ in their orientation towards the market. Both market-oriented and subsistence-oriented farms occur, but almost all farmers produce their own food.

The different farming systems will be elaborated later in this chapter. First, attention will be given to the development of agriculture in the project area since the beginning of the 20th century.

Table 18. Agro-ecological subdivision of the Chuka-South area.

Agro-ecological group	Agro-ecological zones according to Jeatzold & Schmidt (1983) symbol	name	characteristic crop(s)	Approximate equivalent of ecological regions, see Bernard (1971)
A (forest)	LH 0	Lower Highland, per humid	forest	(montane rain) forest
B (tea-coffee-dairy)	LH 1	Lower Highland, humid	tea-dairy	Kikuyu grass zone (upland zone)
	UM 1	Upper Midland, humid	coffee-tea	
C (coffee-maize-beans)	UM 2	Upper Midland, sub-humid	main coffee	Star grass zone (homestead zone)
	UM 3	Upper Midland, semi-humid	marginal coffee	
	UM 4	Upper Midland, transitional	sunflower-maize	
D (cotton-maize-pigeon peas)	LM 3	Lower Midland, semi-humid	cotton	Grass woodland zone
	LM 4	Lower Midland, transitional	marginal cotton	*Acacia-Combretum* zone (seed crop zone)
E (livestock-millet cotton)	LM 4	Lower Midland, semi-arid	livestock-millet	*Acacia-Commiphora* (lowland)
	IL 5	Inner Lowland, semi-arid	livestock-millet	

4.2 AGRICULTURAL DEVELOPMENT IN THE 20th CENTURY

4.2.1 Situation at the beginning

Different ecological conditions have led to different farming practices in the highland parts of Embu and Meru, and in the lowland part of the project area. Highland and lowland are roughly separated by the 915 m contour line. Some 90 percent of all people in the project area live in the highlands.

Highland people are traditionally at home in agro-ecological group C, the homostead zone; their houses are concentrated along the road from Embu to Meru. Each household possessed grazing land in the uplands, agro-ecological group B. The land around the house was used for the production of root and tuber crops such as yam, taro, sweet potatoes and cassava, and for other crops like bananas, gourds, sugar cane and miraa. Bananas and sweet potatoes were of special importance as they made up the greater part of the people's calory intake.

In agro-ecological group D, the seed crop zone, the land was used for the production of small grains, pulses, and for the growing of tobacco and sweet potatoes.

The land was essentially communal property but was entrusted to individual clans, families or households for long periods of time. The average household cultivated between 1 and 2 hectares, situated in different zones. This differentiation made the highland systems diverse, stable and relatively secure.

Agriculture in the lowlands, confined to agro-ecological group E, had a less sedentary character than in the highlands; shifting cultivation was common. Local variations in the terrain (associated with rivers, hills, depressions, soil variation, rockiness, slope of the land, etc.) determined the cultivation pattern. Depending on the natural fertility of the land, fields were cropped for 2 to 7 seasons. A period of occupation was usually followed by a 10 to 20 years fallow.

Millets, sorghum, cow peas, and black and green gram were important crops in the lowlands -as in the highlands- together with castor beans, gourds and tobacco.

Animal husbandry was practized throughout the project area but the animals were not used in land preparation. Cattle, sheep and goats were grazed away from the homestead; special pastures were not prepared and the manure was hardly used. Cattle, and to a lesser degree also sheep and goats, had great social significance. To possess animals meant wealth, and the wealth of a household was generally measured in "cattle units". The animals were given away as dowries or slaughtered on special social or religious occasions. They were also kept as a reserve for times of famine, when people could exchange them for other food. Sheep and goats outnumbered cattle, particularly in the lowlands. The cattle was mostly of the Zebu type, hardy beasts that survive serious shortage of water or fodder and relatively resistant to a number of debilitating diseases (Bernard, 1971).

Although most farms were self-supporting, trade links existed between the highlands and the lowlands for a few special commodities and services. Miraa and tobacco, produced in the highlands, were exchanged for honey from the lowlands. Surplus quantities of common food crops were traded as well, especially in times of famine. Highlanders were skilled blacksmiths who produced arrow heads, swords, spear blades, knives, hoes, axes, pincers and bells; their woman were renowned for producing outstanding pottery. In the lowlands, the Tharaka people excelled in the production of baskets and mats, woven from local Doum palm fibre.

4.2.2 Development until 1950.

The colonial government stimulated the production of cash crops and has built markets and roads. It has also introduced new crops, developed new cultivars of traditional crops, promoted the use of new tools and cultivation techniques and furthered the expansion of crop land. However, severe droughts, poor infrastructure and the economic crisis of the thirties frustrated the success of this programme.

Of the then introduced crops, "European" maize is the most important. There existed a local maize type in the area, but it was small and low yielding and enjoyed little popularity (Bernard, 1971). The new maize seeds were distributed free of charge and were readily accepted by the farmers (after initial reluctance). By the early 1950's, it had become one of the most important export crops in Meru and challenged the position of millet as the traditional staple food, especially in the highlands. Other successful introductions in the highlands were new cultivars of beans, millet (in zones LM5, IL5 and LM4; see Table 18), sorghum, cassava and sweet potatoes. English potatoes, cabbages and carrots were also introduced in that period.

Not every attempt to introduce a new crop was successful. Wheat, for example, never became a success. Other failures were groundnut, linseed and coriander.

The introduction of new crops was much less successful in the lowlands. An exception is cotton, which was grown in the lowlands albeit on a much smaller scale than in the seed-crop zone of the highlands. It had entirely disappeared from Meru by 1940, predominantly because of low world market prices. Attempts to introduce pure cash crops like tea and coffee (in the late thirties) were frustrated by white settelers elsewhere in Kenya who disliked competition by native growers. Nonetheless, Arabica coffee became established in Meru but only at a small scale and mainly because of the determination of the Local Native Council; a few more areas were planted by the missions in Meru and Chogoria. These efforts would prove immensely valuable for the later development of coffee farming in Kenya.

The colonial administration was quite successful in its efforts to introduce new implements. An example is the introduction of the steel hoe, or "jembe", which replaced the traditional digging stick and thus eliminated a major constraint to the expansion of food crops in the area. With a jembe, a woman can cultivate 3 to 4 times more land than with a digging stick.

The administration's measures also influenced animal husbandry in the area. As traditional exchanges and ceremonial slaughtering were curbed, livestock grew in number. Cattle raiding was stamped out and cattle diseases were brought under control. The eventual result of all this was serious overstocking and erosion of the land. Plans to correct the situation through the improvement of pastures, cultivation of fodder crops, stall feeding and promotion of non-ceremonial meat consumption could not keep livestock numbers from increasing. Faced with a concurrent increase in population pressure, greater parcel fragmentation and shortening fallow periods, the administration pressed for conserving farming practices which maintain soil structure and fertility and reduce erosion (Bernard, 1971, Clayton, 1964). Unfortunately, measures like the construction of wash stops, grazing control and reafforestation were not always adopted by the local farming communities.

4.2.3 Development after 1950.

Four important developments have taken place since 1950:

(i) Land consolidation and adjudication.

(ii) Introduction of coffee, tea and some other cash crops such as cotton and tobacco.

(iii) Introduction of grade cattle for milk production.

(iv) Replacement of millet by maize as the main staple.

In the highlands, land consolidation and adjudication was necessary to be able to feed an increasing population and a prerequisite for the development of coffee and tea production.
The land consolidation programme was executed in the sixties. It proved impossible to provide each family with 10-12 acres of land (4-5 hectares) as was originally planned. Instead, most farms range between 1 and 3 hectares. The consolidation and adjudication of land is now completed in agro-ecological groups B and C but is still going on in group D.

The introduction of coffee in the fifties and sixties, and of tea in the sixties and seventies were very important changes.
Cooperative unions were instrumental in the rapid diffusion of coffee in Meru and Embu. They supervise planting, cultivation, processing, transportation and marketing. The introducing of tea was promoted by the Kenya Tea Development Authority. At present, there are some 5000 to 8000 tea growers in the area, all served by the Rukuriri tea factory. The third important cash crop in the (lower) highlands is cotton; it is of much less importance than coffee or tea. Tobacco, mainly used for snuff, is increasingly grown in recent years. Efforts to introduce

castor, groundnuts and sisal failed as was the case in the thirties. The replacement of millets by maize is most obvious in the highlands but occurred also in the lowlands where maize is now a valued ingredient of people's diet. Maize is a marginal crop in the lowlands but is grown by 40 percent of the farmers there.
Even short duration and drought resistant varieties like Katumani and dryland composites perish from time to time. Even so, maize has certain advantages over millet and sorghum: it is probably less labour demanding (not susceptible to bird damage), it produces well in a good season and it can be used in many ways. Sorghum and, especially, millets continue to be the main staple-food in the lower parts of the project area.

The introduction of grade cattle (mostly Guernseys) was highly successful in agro-ecological group B and to a lesser extent also in group C. Unfortunately, grade cattle forms only a tiny fraction of all cattle in the area. The majority, especially in the lowlands, are traditional Zebu type cattle.

4.3 THE FARMING SYSTEMS

On the basis of the District Development Plans for Embu and Meru, 1984-1988, agricultural land use in 1982 is estimated as follows:

CROP GROUP		COMMODITY (percent)	FRACTION OF THE AREA (percent)
grain crops:			44
	maize	83	
	millet/sorghum	17	
pulses:			23
	beans	89	
	pigeon peas	5	
	grains	4	
	cow peas	2	
root and tuber crops:			4
	English potatoes	88	
	sweet potatoes	10	
	cassava	2	
other annual crops:			7
	cotton	87	
	sunflower	12	
	tobacco	1	
permanent crops:			22
	coffee	62	
	tea	24	
	pyrethrum	1	
	bananas	12	
	mangoes	1	
		Total	100

The above figures indicate that maize and beans are the most important food crops in the project area while coffee, tea and cotton are the main cash crops. As this break-down gives no insight in the different farming systems practiced in the project area, these will be described in some detail in the following.

4.3.1 Tea-coffee-dairy farming

The tea-coffee-dairy farming system is a form of permanent cultivation with emphasis on production for the market. Where possible, maize and

beans are also grown for home consumption. Holdings (1.1-4.1 hectares in extent) are consolidated and adjudicated. Renting of land is rare.
The tea-coffee-dairy system is practiced in an area of some 150 km^2 with a total population of some 70,000 people or a population density of 300 to 600 persons per km^2. This farming system is confined to agro-ecological group B, zones LH1 and UM1. The altitude of the land is between 1590 and 2200 metres; the average annual temperature varies between 16 and 19 C°. See App. 6.7, Plate 2.
An average holding has 2.3 hectares of land of which about 2 hectares are farmed (De Haan, 1986). The various LUTs in this farming system and their basic economic data are presented in Table 19.
Food and cash crops both cover about half the cultivated area; tea and coffee are the major income generating crops. Tea and coffee are grown on equal areas of land (0.4-0.5 hectares per farm) but tea produces about two times the income from coffee.

Although dairy is an important activity, providing both milk for home consumption as cash income through the sale of milk, it is difficult to quantify its importance because of lack of reliable data.
Table 19 implies an average gross margin of about Ksh 21,000 from the main cropping activities. The margin is about Ksh 10,000 per hectare-year, or about Ksh 8,000 per person-year. The main resources of the Tea-coffee-dairy system are:

Land:
average holding: 2.3 hectares
range: 0.8 - 4.8 hectares

People:
average household size: 6.8 persons
normative labour force: 1.4 female adult and 1.2 male adult

Animals:
average herd: 2.4 cattle, 2.6 goats and sheep and 9 chicken,
animal traction is rare, except for transport.

Land is in short supply and starts to to become more fragmented now, as the second generation (after consolidation and adjudication of the land) takes up farming. Farming is already very intensive, while most of the land is on slopes.

Table 19. LUT components of the Tea-Coffee-Dairy farming system and their basic economic data.

LUTs	% of farmed land	Average size (ha) (all farms)	Yield per ha (kg)	Price per kg (ksh.)	Value of Production (ksh.)	Variable costs per ha (ksh.)	Labour days per ha (days)	Gross margin per ha (ksh.)	Gross margin per labour day (ksh.)
1st rains									
Maize	10	0.2	1500-2000	1.94	3300	600	100-150	2700	18-27
Maize + beans	5	0.1	1500+ 400	1.95/4.30	4600	700	120-160	3900	24-33
Beans	10	0.2	800-1000	4.30	3900	700	130-170	3200	19-25
Eng. potatoes, cassave, yams	10	0.2	8000	0.70	5600	2200	190	3200	17
Fruits, vegetables (cabbages)	5	0.1	5000	0.90	4500	400	170	4100	24
2nd rains									
Maize	5	0.1	1000-1500	1.94	2300	600	100-150	1700	11-17
Beans	5	0.1	800-1000	4.30	3900	700	130-170	3200	19-25
Eng. potatoes, cassave, yams	5	0.1	6000	0.70	5600	2200	190	3200	17
Fruits, vegetables (cabbages)	5	0.1	5000	0.90	4500	400	170	4100	24
Permanent crops									
Tea	20	0.4	4000[1]	7.05	28200	1500	250	26700	107
Coffee	25	0.5	700[2]	20.00	14000	3000	300-400	11000	31
Bananas	5	0.1	6000	2.00	12000	1000	20	11000	550
Pasture/forage	10	0.2	Small plots of Kikuyu around the homestead. Stumps of Napier grass along side the coffee plot or elsehwere.						
Fallow land and trees		0.3	Woody biomass like trees around the house and in crop land, hedges, wood lots and bush.						
Other crops			Sweet potatoes, arrow root, pumpkin, pineapple, avocados, sugarcane, English fruits.						
Annual Husbandry - Types and numbers:	90% of farmers possess cattle, 60% goats, 30% sheep and 90% chickens. Average farmer keeps 2.1 cows, 0.3 calves, 1.8 goats, 0.8 sheep and 9 chickens.								
- Feed	Mainly zero grazing: Kikuyu grass and Napier grass plus 'dairy meal', maize stalks, banana leaves/stems, vines, etc.								
- Purpose/Production	- producing milk and meat (2-6 litre milk/day, for home consumption and sales, guestimated) - producing dung - traction purposes - savings-bank and social aims								
- Integration with farming	Mainly through eating of crop residues and by provision of manure, cattle is also used as traction mainly for transport.								

(1) Tea yields in kg green leaves, average 5th-20th year.

(2) Coffee yields in kg dry beans, average 5th-20th year.

In spite of the good infiltration capacity of most soils and of soil conservation measures like terracing and the construction of grass lines and trash lines, farming on steep slopes has led to increasing soil degradation. With respect to this, especially coffee cultivation can cause problems although tea stands with an interrupted canopy are also associated with soil erosion. During coffee harvests, labour shortage is often a problem.

4.3.2 Coffee-maize-beans farming

The coffee-maize-beans system is best characterized as permanent cultivation of (mixed) annual crops (maize, beans) and tree crops (coffee, bananas). Cattle is kept for milk (zero grazing). Coffee is the main cash crop; maize, beans and bananas are grown for home consumption with the surplus sold. The holdings (1.3 - 5.0 hectares in extent) are consolidated and adjudicated. Renting of land is not an important habit. See App. 6.7, Plates 4 and 5.

The coffee-maize-beans system is practiced in an area of some 290 km^2 with a population of approximately 160.000 people and a population density between 400 and 700 people per km^2. This farming system is typical of agro-ecological group C, zones UM2, UM3 and UM4. The altitude of the land is between 1280 and 1680 metres; the average annual temperature varies between 19 and 22 °C.

An average holding includes 2.4 hectares of farm land (Abdullah et al., 1986). The various LUT's in this farming system (and their basic economic data) are given in Table 20.

Table 20 implies an average gross margin of Ksh 15,000 per year from the main crop activities. The margin is about Ksh 8,000 per hectare-year or Ksh 5,000 per person-year. The main resources of the system are detailed below:

Land:

average holding: 2.7 hectares
range: 1.0 - 5.0 hectares

People:

average household size: 9.2 persons
normative labour force: 3.1 adults

Animals:

livestock units per farm: 2.0 - 2.8; animal traction is rare.

Table 20. LUT components of the Coffee-Maize-Beans farming system and their basic economic data.

LUTs	% of farmed land	Average size (ha) (all farms)	Yield per ha (kg)	Price per kg (Ksh.)	Value of Production (Ksh.)	Variable costs per ha (Ksh.)	Labour days per ha	Gross per ha (Ksh.)	Margin per labour day (Ksh.)
Annual crops									
1st Rains									
Maize	17	0.4	900-1600	1.94	2300	600	100-150	1700	11-17
Maize + Beans	13	0.3	1000+ 400	1.94/4.30	3700	700	120-160	3000	19-25
Beans	13	0.3	600- 800	4.30	3000	700	130-170	2300	14-18
2nd Rains as first rains									
Permanent crops			(1)						
Coffee	21	0.5	800-900	20.00	17000	3000	300-400	14000	43-47
Bananas	13	0.3	6000	2.00	12000	1000	20	11000	550
Pasture/forage		0.1	Napier grass/Bana grass						
Agro-forestry		0.2-0.3	Woody biomass like trees around the house and in crop land, hedges wood lots and bush.						
Other crops	Occurrance: (% of farms)	76-100%:	cassave						
		51- 75%:	English potatoes, sweet potatoes, paw paw						
		26- 50%:	vegetables, mangoes, macademia, citrus, yams, sorghum						
Animal Husbandry:									
- Types and numbers:	70-90% of farmers possess cattle and/or goats/sheep; 2.0-2.8 livestock units per farm; 70% of cattle is improved breed								
- Feed	: mainly by zero grazing; main source: napier grass, other: kericho grass, 'dairy meal', maize stalks, banana leaves/stems, vines, grazing.								
- Purpose/ Production	: Cattle for milk and cash reserve; 1-5 litre milk/day for home consumption and sales; if sold earnings around Ksh. 4000 per year.								
- Integration with farming	: mainly through eating of crop residues and by provision of manure (coffee).								

(1) Coffee yield in dry beans, average 5th-20th year.

With regard to these resources, the same problems as for the tea-coffee-dairy farming exist:
Land is in short supply and starts to become more fragmented now that the second generation (after consolidation and adjudication of the land) takes up farming. Farming is already very intensive, even on sloping land. In spite of the good infiltration capacity of most soils and of soil conservation measures like terracing and the construction of grass lines and trash lines, farming on steep slopes has led to increasing soil degradation (See App. 6.7, Plate 8). About half of the farmers report this as a major problem. Another pressing problem is the severe labour shortage during the coffee harvest.
The coffee berry disease (CBD) is another point of concern; it is detrimental to the quantity and quality of the coffee yield, especially in the wetter parts of the UM1 and UM2 zones.

4.3.3 Cotton maize-pigeon pea farming

The cotton-maize-pigeon peas system is based on bush fallow with (mixed) annual food crops such as maize, millets, sorghum, pigeon peas and cow peas, and with cash crops (cotton, tobacco). See App. 6.7, Plate 5.
Subsistence farming is the producer's first goal. Animals (Zebu cattle, sheep and goats) are kept as a cash reserve and for the meat, partly on the holding and partly herded. Holdings (1.0-4.0 hectares) are only in part adjudicated; renting of land occurs only incidentally.
The area used for cotton-maize-pigeon peas production totals some 440 km^2 and carries a population of some 80,000 people. The population density is between 100 and 400 persons per km.

This farming system is confined to agro-ecological group D, zones LM3 and LM4. The altitude of the land ranges from 760 to 1280 meters; the average annual temperature is 22-25 °C. Donk & Helder (1986) report that the average holding in the Marianni and Kanyuki locations was 1.9 hectares in 1985. The various LUT's in this farming system (and their basic economic data) are presented in Table 21.

Table 21. LUT components of the Cotton-Maize-Pigeon peas farming system and their basic economic data.

LUTs	% of farmed land	Average size (ha) typical size	all farms	Yield per ha (kg)	Price per kg (Ksh.)	Value of Production (Ksh.)	Variable costs per ha (Ksh.)	Labour days per ha	Gross per ha (Ksh.)	Margin per labour day (Ksh.)
Annual crops										
1st rains										
Maize	16	0.3	0.3	1000	1.94	1900	200	110-150	1700	12-15
Sorghum	11	0.2	0.2	500	1.10	600	100	110-210	500	2- 5
Millet	5	0.2	0.1	500	1.25	600	100	110-130	500	4- 5
Pigeon peas	11	0.3	0.2	400	2.25	900	100	100-130	800	6- 8
2nd rains as 1st rains plus										
Cotton (1)	5	0.5	0.1	400	5.00/2.45	1800	500	130-170	1300	8-10
Tobacco	1	0.1	0.02	700	12.50	8800	100	200	8700	44
Pasture/forage			0.4	Bana grass, napier grass						
Agro-forestry			0.1-0.2	Woody biomass like trees around the house and in crop land, hedges, wood lots and bush. Bush becoming more important.						
Other crops	Occurrance : (% of farms)		76-100%: cow peas 51- 75%: beans, green gram 26- 50%: sunflower, coffee					unknown %: mango, paw paw, castor, pumkpin, cassave, arrow root sweet potatoes, banana.		
Intercropping	Occurrence : (% of instances)		pure cropping (30%)					: cotton, maize		
			two crop combinations (55%)					: maize/sorghum/millet + legume, millet + sorghum		
			three or four crop combinations (15%)					: millet + sorghum + legume		
Animal husbandry										
- Types and numbers:	50-70% of farmers possess cattle and/or goats/sheep hard sizes: cattle: mean 4, range 2-12; goats/sheep: mean 5, range 3-16									
- Feed	: Some zero-grazing/'rope' grazing towards eastern part, otherwise herding									
- Purpose/ Production	: Mostly as cash reserve and security: some milk for home consumption; cattle is hardly eaten, goast/sheep more often									
- Integration with crop production	: Little except for use of crop residues and use of manure (only partly) and as part of bush-fallow system. Very little ox-ploughing.									

(1) Manual land preparation, the cultivation extends into first rains.

Table 21 suggests an average gross margin of Ksh 2,000 per year from the main cropping activity, or some Ksh 1,800 per hectare-year. The margin per adult amounts to some Ksh 1,000 per person-year. The main resources of the cotton-maize pigeon peas system are:

Land:
average holding: 4.7 hectares
range: 2.2 - 13.8 hectares

People:
average household size: 8.1 persons
normative labour force: 1.1 female adult + 0.7 male adult

Animals:
average herd: 4 heads of cattle + 5 goats or sheep. Animal traction is rare.

Part of the land in use for cotton-maize-pigeon peas farming is hilly and rocky, or has a low fertility status or a low water-holding capacity (Luvisols). Erosion is a major problem on some 40 percent of the fields and erosion control measures such as terraces (20 percent of the farmers), trash lines (60%), trees (40%) and stonelines (30%) are common.

4.3.4 Livestcok-millet-(cotton) farming.

The livestock-millet-(cotton) system can be described as mainly bush-fallow, ranging from permanent agriculture to shifting cultivation with (mixed) annual crops such as millets, sorghum, maize, green gram and cow peas, and some cash crops (cotton). Emphasis is on subsistence production. There is extensive grazing of cattle, goats and sheep. The holdings are not adjudicated.

The area used for livestock-millet-(cotton) farming totals some 530 km^2. With a total population of about 30,000 people, the population density ranges between 30 and 100 persons per km^2. This farming system is confined to agro-ecological group E, zones LM5 and IL5. The altitude of the land is between 630 and 1130 meters, the average annual temperature is 24-30 °C.

The size of the average holding is about the same in this farming system as in the cotton-maize-pigeon peas type. The figure of 1.9 hectares reported by Donk & Helder (1986) confirms the one published by ICRA (1985). The various LUT's of this farming system (and their basic economic data) are presented in Table 22.

Table 22. LUT components of the Livestock-Millet-Cotton farming system and their basic economic data.

LUTs Animal crops	% of farmed land	Average size (ha) typical size	 all farms	Yield per ha (kg)	Price per kg (Ksh.)	Value of Production (Ksh.)	Variable costs (Ksh.)	Labour-days per ha	Gross per ha (Ksh.)	Margin per labour day (Ksh.)
1st rains										
Millet	11	0.3	0.2	700	1.25	900	100	100-130	800	6- 8
Sorghum	11	0.3	0.2	500	1.10	600	100	110-210	500	2- 5
Maize	11	0.3	0.2	1000 (2)	1.94	1900	200	110-150	1700	12-15
Green gram	11	0.2	0.2	500	2.78	1400	100	120-160	1300	8-11
Cow peas	5	0.3	0.1	500	2.50	1300	100	120-160	1200	8-10
2nd rains as 1st rains plus cotton (1)	37	0.9	0.7	500	5.00/2.45	2300	500	110-140	1800	13-16
Pasture/forage				None; animals are herded						
Agro-foresting				None; wood is collected in bush; income from charcoil making						
Other crops	Occurrance (% of farms)	: 76-100% none 51- 75% pigeon peas 26-50 % sunflower					unknown %: mango, pawpaw, caston, pumkin			
Intercropping	Occurrance (% of farms)	: pure cropping (50%) two crop combinations (30%) three crop combinations (20%)					: green gram, cotton, maize, sunflower : millet/sorghum, green gram + sorghum : millet + sorghum + cow peas			

Animal husbandry:

- Types and numbers: Between 70 to 90% of rural households have livestock.
  Average herd sizes: cattle 4-12 heads; goats 25-35 heads; sheep 5-15 heads.
- Feed : grazing only (herding).
- Purpose/production : 1) cash reserve/security, 2) social obligations, 3) milk
- Integration with crop production : - use of fallow land or grazing
  - oxen are used for ploughing

(1) ox-ploughed, cultivation extends into first rains.

(2) high risks, causing highly variable yields.

Table 22 indicates an average gross margin of Ksh 3,200 per year from the main cropping activity, or some Ksh 2,000 per hectare-year. If the average number of adult persons per household is set at 2, the gross margin per person amounts to some Ksh 1,000 per person-year. The main resources of the livestock-millet-(cotton) system are as follows:

Land:
size of average holding: 5 hectares

People:
average household size: 8.1 persons
normative labour force: between 1 and 3 persons in 75% of all households

Animals:
average herd size: 4-12 heads of cattle + 25-35 goats + 5-15 sheep. Oxen are used for plowing.

There are indications of seasonal labour shortages. The land has normally a low natural fertility level. "Capped" soils, especially chromic Luvisols which constitute about 70% of all arable land, suffer from low infiltration rates (See App. 6.7, Plate 10). Much of the precious rainfall is therefore not stored in the soil but is lost as run-off and causes erosion in the process. Ninety percent of all farmers recognized erosion as a serious problem and took measures: trash lines (60%), stone lines, wood (20%) and ridging (10%). Overgrazing of the land is a common phenomenon. It is estimated that 60 percent of all households possess an equivalent herd of 6 heads of cattle, 30 goats and 10 sheep, totalling 8.5 livestock units. If it is assumed that 30,000 persons live in this ago-ecological group, with an average 5.6 persons per household, more than 3,000 households would possess livestock. This adds up to an estimated 25,000 livestock units in this agro-ecological group! Agro-ecological group E covers some 530 km^2, of which 78%, or 413 km appears to be in use as arable land. If 90 percent of all households cultivate an average 1.9 hectares per households, the total area used for arable farming in one particular year amounts to 90 km^2.

This leaves 323 km^2 for grazing at a density of 77 livestock units per km^2, or 57 per km^2 if all non-arable areas are included in the potential grazing area. If it is assumed that crop lands can be used for grazing during 50% of the year, the livestock unit density drops to

51 per km^2, still twice the permissible density of 25 livestock units per km^2.

Overgrazing is not the only cause of soil degradation in the area. Overcropping depletes soil fertility and furthers erosion as well. The yearly cropping of 90 km^2 out of a total of 414 km^2 arable land corresponds with a cultivation factor, "R", of 22. With an average occupation period of 3 years, this permits a fallow period of about 11 years. Note that this estimate is based on averaged figures; certain areas are much more intensively used. An ICRA survey in Tharaka revealed that 23 percent of all farmers observed a fallow period between 5 and 20 years, 56 percent used fallows between 2 and 5 years, 12 percent used a 1 to 2 years fallow and the remaining 9 percent observed no fallow period at all (Abella et al., 1984). If an equivalent occupation period of 3 years is assumed, the average cultivation factor R would be between 45 and 50 percent. This indicates serious pressure on the crop land.

Scholten (1986b) reports that land (especially land with chromic Luvisols) that is grazed immediately after cropping, looses its vegetation which leads to "capping" of the soil. Then, it becomes very difficult for the natural vegetation to re-establish itself. Scholten recommends a two years period of rest before grazing of the land can start. Such a measure would reduce the permissible number of livestock units in the area from 12,000 to about 11,000.

4.4 THE LAND UTILIZATION TYPES

In this report, Land Utilization Types (LUT's) are defined as single crops produced at a certain technology level (extensive grazing is an obvious exception). A LUT is determined by its "key attributes of land use", conveniently divided into management/technology attributes and crop specifications. Therefore, the technological means of the producers will be outlined first, followed by a description of the crops/varieties grown and their requirements. This section will be concluded with a summary table (Table 23) of all important LUT's and their occurrence in each of the distinguished farming systems. The information presented is largely compiled from data by Donk & Helder

(1986), Ooms (1987), De Haan (1986), Abella et al. (1984), Abdullah et al. (1986) and from a number of internal reports and communications of older data.

4.4.1 Technology levels

For practical reasons, only two broad levels of technology are defined. Agriculture practiced at technology level II is associated with higher yields than agriculture at level I. The higher input levels and better cultivation practices at level II will normally go with higher ratings for one or more land qualities.

The broad management/technology levels are roughly as follows:

Technology level I is characterized by the use of traditional production methods. The farmers apply no or only little fertilizer and plant protection is minimal, except for coffee and tea. Farmers produce their own seeds, except for maize where hybrid seeds are purchased. Land preparation is done by hand (hoeing), especially in agro-ecological groups B, C and D; draught animals are used in agro-ecological group E.

At technology level II, the farmers use improved implements and methods, also aimed at soil and water conservation, and apply fertilizers and crop protection agents as needed. Land preparation is predominantly done by hand but draught animals are used as well.

4.4.2 Crops and their requirement

Tea:

Cultivars: The Assam Jat variety is most suitable for East African conditions. About 25 subvarieties (clones) are existing and the growers are provided with at least two clones. Since 1966, tea is multiplied exclusively through vegetative propagation.

Labour requirements: man power only (about 250 labour days per hectare-year). Labour peaks during the rainy periods, April to July (51% of the yearly requirements) and November and December (22% of the yearly requirements) because of picking.

Plant density/intercropping: 8650 trees per hectare (3500 trees per acre); no intercropping.

Topography/soil conservation: some 20% of all tea is grown on flat land, some 20% on gentle slopes and nearly 60% on steep slopes. Erosion

is not a major problem, except where canopy closure is incomplete. Care is taken to cover the soil with mulch after pruning (every third year).
Pruning: pruning is done to prevent the bush from growing too high and to prevent decline of yields. After four years, the first pruning is done at 55 cm above the ground, three years later the bush is pruned at a level 5 cm above the previous pruning. Pruning is done every three years by almost all farmers. Only 10% of the farmers prune every two years and another 10% prunes less frequently. Those who prune their tea every third year divide their tea plot into three blocks that are pruned in rotation.
Fertilizers/manure: Farmers are advised to apply 600 kg of NPK (21% N) per hectare-year but the actual fertilizer use is close to 370 kg per hectare-year. About 40% of the farmers apply their fertilizer in two applications and 60% applies only one dressing. An estimated 40% of all farmers use manure on their tea plot.
Weeds/herbicides: Weeds are a problem along the edges of plots and in places within a tea field where the canopy is not closed. The most common weeds are black jack (muchege) (*Bidens pilosa L.*) and couch grass (Kithamgari) (*Digituria scalarum L.*).
Most weed control is done using panga's or forked jembes.
Pest/diseases: The only important disease in the area is Armillaria Root Rot, or 'malaria' as it is called by the farmers. About 20-30 percent of all farmers have symptoms of this disease in their plots. The disease is caused by a fungus: *Armillaria mellea*. Armillaria is prevented by ensuring that no stumbs or pieces of wood are left on the field after clearing of the forest. Affected tea bushes have to be removed. Other diseases do occur in the area as well but they are hardly noticed by the farmers, like: mycosis or mite born diseases (Red crevice tea mite, Red spider mite and Tea purple mite), Black Tea Thrips, Kangaita weevil, *Phomopsis thea* and *Hypoxylon* wood rot.
Harvest/yields: Tea is picked throughout the year but more intensively during the rainy periods. Yields vary among subareas and with the amount of precipitation. Data from 1983/84 (a dry year) point at yields of 0.2 to 0.6 kg per tree per year, while in 1984/85 (a more or less normal year) the yield of green leaves was generally between 0.3 and 0.8 kg per tree. Per hectare yields of some 3900 kg green leaves are normal for the area; the yields range from 2500 kg to 5600 kg.

Coffee:

Cultivars: K7 (80% of all farms), SL28 (50%) and SL34 (50%).

Labour requirement: Man power only (300-400 labour days per hectare-year). Labour peaks in harvest time (April to June, 40% of yearly requirement, and November-December, 25%).

Plant density/intercropping: 1325 trees per hectare of which 85% bears fruits; no intercropping.

Topography/soil conservation: Some 30 percent of all coffee is grown on flat land, 30% on gentle slopes and 40% on steep slopes. Erosion is seen as a major problem by 50 percent of the farmers. The following soil conservation measures are taken: terracing (30 percent of the farmers), terracing + grass lines (50%), grass lines only (negligible). Terracing is obligatory on sloping land.

Pruning: multiple stem pruning is applied directly after harvesting. Two or more main stems are left; they are replaced by suckers every 3-5 years. The laterals bear fruits two times before being pruned. As a consequence of this method of pruning, many trees are tall or bend over which interferes with spraying and harvesting.

Fertilizers/manure: Animal manure is widely used as well as chemical fertilizers. Calcium Ammonium Nitrate (CAN) is used by 60 percent of the farmers, often together with Diammonium Phosphate (DAP).

The application rate is about 280 kg per hectare.

Weeds/herbicides: Weeding is done 1-3 times per year. It is recommended to keep the immediate vicinity of the trees weed-free but this is only rarely done in practice. Weeding is the most labour demanding operation after harvesting. Some 30 percent of the farmers use herbicides (glycophosphate, Paraquat).

Pests/diseases: the commonest diseases in the area are Coffee Berry Disease (CBD) and leaf rust. They occur mainly in the wet seasons, especially in wet/cool areas. Spraying is common practice in the area but it is done at lower rates than recommended. Coffee leaf miner and thrips are common pests, the latter is more prominent in the drier/warmer parts of the area.

Harvest/yields: Coffee is harvested from April till June and in November and December. The yields are of the order of 800-900 kg green beans per hectare (4,400-5,000 kg berries at a conversion rate of

1:5.5). The quality of the harvested produce is better in wet/cool areas than in the warmer and drier parts. Processing is done at the many cooperative factories in the region (See App. 6.7, Plate 4).

Maize:

Cultivars: Hybrid H611/612, H511/H512 and Katumani. Only 40 percent of the farmers buys new seeds every year.

Season: first and second rains.

Labour requirement: Human labour is widely used (panga and jembe) at 110-150 labour days per hectare-season, except in agro-ecological group E where some 70 percent of the land is ploughed with oxen. In the other agro-ecological groups, some 30 percent of the land is ploughed with oxen. Land preparation is done in February/March and in August/September.

Plant density/intercropping/sowing: 25-35 kg seeds are used per hectare. The plants are in lines, 70-100 cm apart with a 40-60 cm spacing in the line. Seeding is done at 2 seeds per hole.

Maize is grown as a single crop on 30-50 percent of the fields. Mixed cropping with beans is common in agro-ecological groups B and C. In group D, mixed cropping with cow peas, chick peas, millet and sorghum occurs also. Maize is sown in March and September, just before the onset of the rains.

Topography/soil conservation: Maize is normally grown on flat to gently sloping land. Some 40 percent of all maize growers regard soil erosion as a major problem. The control measures taken differ among agro-ecological groups; grass lines are applied by 50 percent of the farmers in groups B and C, 20 percent of the farmers in group C use terraces and 10 percent use trash lines. In groups D and E, the same measures are taken but in different proportions: 20 percent grass lines and terraces, and 60 percent trash lines. Stonelines are used by 30 percent of the farmers in groups D and E.

Fertilizers/manure: Fertilizers are applied during land preparation or at the time of sowing. More fertilizer is used in agro-ecological groups B and C than in groups D and E. Normal application rates are between 60 and 120 kg CAN or NPK 20:20:0 per hectare.

Weeding: Weeds are controlled twice per season (with panga or jembe). Labour shortage is a common problem. Herbicides are not used.

Pests/diseases: The maize stalk borer (*Busseola fusica*) and worms are the commonest pests. Between 30 and 80 percent of the farmers use chemicals. Alternatively, a mixture of soil and ash is used. Farmers in groups D and E reported ants, termites, grasshoppers and monkeys as serious pests.

Harvest/yields: Harvest time is 3 to 5 months after seeding, depending on temperature and variety. The yields are between 300 and 1600 kg per hectare-season, with 1000 kg as a "normal" average, also in the case of intercropping with beans.

Beans:

Cultivars: Roso Coco and Canadian Wonder

Season: First and second rains

Labour requirement: as for maize; 120-160 labour days per hectare-season.

Plant density/spacing: 40-50 kg seeds per hectare. Single planting on 50 percent of the fields, else intercropping with maize.

Topography/soil conservation: as for maize

Fertilizers/manure: Not used

Weeds/herbicides: as for maize

Pest/diseases: Bean fly (*Melanagromyza phaseoli*) damage to young seedlings is common. No plant protection.

Harvest/yields: The yields lie between 500 and 900 kg per hectare-year for single crops and around 400 kg in the case of intercropping with maize.

Cotton:

Cultivars: UKA/59/240, UKA/59/540, UKA/59/520 or Babika 75; UKA/59/240 is most widely used.

Season: second rains but often into the following first rainy season.

Labour requirement: Oxen are used for land preparation on 70 percent of the land. Where ox ploughs are used, 110-140 hours/ha labour is done in August and September.

Plant density/intercropping/sowing: 9 kg seeds are used per hectare with 3-5 seeds per hole and 40-80 cm between holes. Seeding is done in October. About two thirds of the cotton area is grown to single cotton, the rest is intercropped with maize or pigeon peas.

Topography/soil conservation: as for maize

Fertilizers/manure: Not used

Weeds/herbicides: Hand weeding with a panga; 4-6 times a year

Pests/diseases: Two-thirds of all farmers apply chemicals to control insects. *Calidea dregii* is the major pest besides other insects and worms.

Harvest/yields: Harvesting is done entirely by hand. The harvest periods are from July till September and in February/March. The first harvest yields about half as much as the second; yields are between 150 and 675 kg per hectare with 450 kg as an average. The Cotton Board collects the harvest 4 times per year in several villages in each location. Two qualities are distinguished (AR and BR) which the farmers keep apart. The cotton balls are processed in local ginneries.

Tobacco:

Cultivars: local, sometimes Virginia

Season: first and second (growing period extends over two seasons).

Labour requirement: All work is done by hand; some 200 labour days are needed per hectare-season.

Plant density/intercropping/sowing: The seeds are sown on a finely tilled seed bed, mostly in a nursery near a river. The seedlings are transplanted at the onset of the rains in October. Most farmers produce their own seeds. Plant spacing is normally 50x10 cm if tobacco is grown as a single crop; intercropping with maize (alternating rows) is not uncommon.

Topography/soil conservation: as for maize

Fertilizers/manure: Manure is used by 90 percent of the farmers; commercial fertilizers are used where tobacco is grown for the market.

Weeds/herbicides: Two weedings per season, to a total of four weedings. Herbicides are not used.

Pests/diseases: Chemicals are not used; ash is occasionally applied to reduce damage by insects.

Harvest/yields: Two harvests per year, at irregular intervals. The first harvest takes place between January and March, the second between June and October. Harvesting is done by hand. The upper leaves are of better quality than the lower ones. Flowers and tops are normally removed to suppress generative growth. Yields are about 700 kg per hectare. After drying, the leaves are cut and fermented; oil is sometimes added to get a mild taste. The produce is ground to snuff and sold on the local market.

Sorghum

Cultivars: Two cultivars are widely grown:

a) Red-White, a two season crop which is planted in the second season and ratooned in the first season.

b) Compact Panicle, planted twice a year in either season. More drought resistant than Red-White.

Labour requirement: as for maize, 110-210 labour days are required per hectare-season.

Plant density/intercropping/seeding: Cultivar a) is mostly intercropped (75-90%) in rows with one row of sorghum and 2-4 rows of other crops, mostly millet (35 percent), millet and cow peas (25 percent), or green gram (25 percent). Occasionally, sorghum is grown in combination with maize and millet. Sorhum never dominates a crop combination.

Topography/soil conservation: as for maize

Fertilizers/manure: not commonly used

Weeds/herbicides: Two weedings per growing season, with panga or morro.

Pests/diseases: With minimal crop protection measures applied, pests (insects) and diseases (*Coletotrichum, Helminthosporium*, and *Claviceps microphala*, or "honey disease") are common. The latter disease is controlled by smearing honey on the panicles.

Harvest/yields: Harvesting is done three or more times. The red/white cultivar produces some 1000 kg of grain in two seasons; the compact cultivars produce some 500 kg per hectare-season.

There is a considerable variation in yields (200-2500 kg per hectare).

Millet

Cultivars: Local (bulrush) millet, selected from farmer's stock

Season: First and second

Labour requirement: as for maize, but 100-130 labour days required per hectare-season.

Plant density/intercropping/seeding: Spaced at 85x100 cm, with 10-20 tillers per tussock when single cropped. More commonly intercropped with sorghum (30 percent), with sorghum and cow peas (30 percent) or with other crops (10 percent). Millet is sown directly after the rains, in March and October.

Topography/soil conservation: as for maize

Fertilizers/manure: Not used.

Weeds/herbicides: Two weedings per season, with panga or morro.

Pests/diseases: Monkeys, squirrels and birds are severe pests, as well as various insects and worms. Only a minority of the farmers use chemicals. Honey disease is the main fungal disease; see also under Sorghum.

Harvest/yields: harvesting takes place in June-July and in January-February. The spikes are cut off and removed, the stalks remain on the land. Yields are commonly of the order of 500 kg grain per hectare-season.

4.4.3. Extensive grazing.

Geographical area: Of the southern Chuka mapsheet extensive grazing is confined to the agro-ecological group E.

Animal types: The main animal types are cattle, goats and sheep.

Produce: The main types of produce are meat, skins and live animals (young as well as adult ones).

Production aims: The main production aims are subsistence, cash income, security for droughts and social purposes, like dowries and social parties.

Producion methods: Nearly all families herd their own livestock, except at the end of the dry season when some familes keep the animals around the homestead.

Herds:

.sizes per type and in total.

Herds are normally composed of cattle, goats and sheep. The sizes of the herds vary, but are on the average in the following ranges:

- -cattle, 4-12;
- -goats, 25-35;
- -sheep, 5-15.

A somewhat different herd composition has been found around Kaara-Ka-Mbabu with relatively less goats and sheep, with an average herd composition of about 7 cattle and 9 goats/sheep (Donk & Helder, 1986).

.grades of livestock types.

The goats are known as East African Goat. Cattle are mostly local zebu (short-horned, 'small East African Zebu), but some 'Kenyan Boran', a larger sub-type of zebu are also present. Sheep are of the fat-tailed Masai type.

.livestock units.

If one assumes an average herd size of 6 heads of cattle, 30 goats and 10 sheep, am average herd consists 8.5 'livestock units'.

Grazing:

.vegetation.

Most of the area is in the *Acacia-Commiphora* landscape, but an important part is in the *Heeria-Enteropogon* landscape. The area with this savanna type can be found for example around Kaara-Ka-Mbabu. For details on vegetation see Chapter 1.5 and Scholte (1986a).

.system.

Usually small boys are responsable for the grazing of the animals during the day, only in cases of large herds (more than 10 cattle and 50 goats) older men take care of the animals. The boys often join their herds and enable themselves in this way to stay and play together. They leave with the animals at approximately 10 AM and return usually at 6 PM. In the dry season they stay longer in the field, the total grazing time however decreases due to the longer reposes without much available feed in the surroundings.

.composition of fodder (species per season) per animal type.

The following account is a near quotation from Scholte (1986) and based on a detailed study of an area south of Isharia. It only gives the most important species, while in fact tens of species are eaten by the animals, for details see Scholte (1986a). Start of 'quotation': "For an evaluation of the importance of the consumed plant species and their habitats a comparison has to be made between the relative abundance of the plants in the area and the number of minutes spent on eating them. No intensive research was done to determine the abundance of the several plant species. However with the knowledge of the area and the comparison between the foodhabitats, the information on the detailed map and the description of the units, an estimate can be made of the importance of several plant species and their environment. One has to realise that the number of minutes spent on eating from a plant is not the same as the amount of food intake. The importance of a plant is not only determined by the abundancy but also by the quality and the time of availability. It is not easy to quantify all these factors. Therefore we limit ourselves by giving only a rough estimate in descriptive form of the importance of the plant species and their habitats in the study area in the period June to December 1985.

Although the wet season seems to be the time of abundance and thus of few constraints, the amount and quality of food determine the condition of the animals and thus of their chance to survive during the dry season.

Important is that not all available plant material is eaten, but that part of it remains for worse times. Striking was that many species which were already completely consumed in the Ishiara area, were still available at the end of the dry season in the protected areas (e.g. *Grewia villosa*).

Not all material can be eaten without exhausting the system, a plant which looses all its leaves a few days after they have grown has little chance to survive. Also the system itself needs a certain amount of material to maintain itself (e.g. biomass for termites which maintain soil porosity).

Not one landscape is on the fore with regard to the wet season plant production. However taking into consideration their relative size, bush on the rockoutcrops is the most important wet season grazing. These areas are relatively undisturbed during decades of clearing and burning, and are covered by a high ground vegetation which consists of species like *Triumfetta flavencens*, *Barleria eranthomides* and *Pentas sp*. But also more disturbed areas, can provide large amounts of food, like for instance the river terrace along the river Ena which is responsable for the high amount of *Cyperus bulbosus* shortly after the onset of the rains in October.

At the end of the wet season and the beginning of the dry season the amount and especially the quality of litter is responsable for the condition with which the animals can survive the dry season. The majority of litter is produced by *Commiphora africana* (and the other *Commiphora* species) and is of a rather poor quality. Only the litter of

Acacia mellifera is of a slightly higher quality (the litter of the other *Acacia* species is too small to be eaten from the ground). The other litter producing plants all grow in the well developed bush along water courses. In the present situation no danger of exhausting this resource seems to exist. However by decreasing the proportion of this vegetation (especially in the bush along dry rivers) problems will arise and cause food shortages early in the dry season. No information about a proper use factor of this resource exists. A special case form the rockoutcrops with *Sterculia rhynchocarpa* and the *Terminalia* species, which remain isles of litter till the end of the dry season.

From halfway the dry season to the end of the dry season *Acacia senegal* pods form the most important food for livestock in the area. Its habitat is not very specific and at the moment a major decrease of this tree does not seem likely. However 1985 was an extraordinary year for the production of *A.senegal* pods, in drier years like 1982, 1983 and 1984 the pod production seemed to be only a fraction of that in 1985. In spite of the high production in 1985 the majority of the pods were eaten at the end of the dry season. In those drier years only some litter is left (with a low quality) and the *Acacia tortilis* pods. They have a high food quality and are highly desired by all animals. This caused a shortage of high quality food in September 1985, especially for cattle which cannot eat the young leaves which appear at this time of the year on the trees and shrubs. The producion of *Acacia tortilis* pods seems to be very regular and is the only quality food in drier years. In this way *A. tortilis* can be considered as the ultimate base of animal husbandry in these regions. The majority of the *A.tortilis* pods is produced by the large trees (more than six meters high), not by the more common smaller trees. They grow along the (dry) rivers and are always able to obtain water (surface water which seepages slowly through the rotten rock). However along many water courses no *A. tortilis* trees are growing anymore. During clearing of land these trees are cut or at least lopped. They compete with crops for the available water due to their extensive root system. Charcoal production is also responsable for the disappearance of large *A. tortilis* trees. Almost certainly this activity will destroy in this way a store of animal food during the dry season.

Acacia tortilis and *A. senegal* as well as *Commiphora africana* are also important leaf producing species. They provide valuable food at the very end of the dry season (*A. tortilis* even a few weeks before the onset of the rains). Especially the easely available leaves of the cut or lopped trees (dwarf shrubs), growing on the fallow land, is heavely browsed by goats and sheep. It is not clear if these trees are able to survive and grow up to form bushland and close the bush-fallow circle in this way.

Comparison of the study area south of Ishiara with other areas of the Ishiara mapsheet leads to the following observations:
The *Heeria-Enteropogon* landscape (very extensively cultivated Wooded Grassland) showed a quite different diet for the three types of animals. The much larger content of grasses in particular in the diet of cattle is remarkable, *Hyarrphenia* species, *Enteropogon macrostachys* and *Heteropogon contortus* are the most important ones. People burn parts of the area at the end of the dry season and then after the onset of the rains a real mat of young palatable grasses is formed on these places. This high quality forage is the main grazing resource in the rain season. Shrubby herbs like the many *Papilionaceae* species (*Indigofera atriceps*, *Crotalaria sp.* etc) are also important, especially later in the rain season and in the beginning of the dry season. Their quality is relatively high as is their palatability. Occasional observations in the dry season showed a high grazing intensity on the grasslands of the hills. At this time grasses are flowering and have a crude fibre content which is too high for consumption. In the extended grasslands only the shrubby herbs are still eaten. In contrast with this are the valleys where even in the dry season an undergrowth of herbs is available and trees provide litter and fruits during the whole dry season.

No fundamental differences were found between other areas of the *Acacia commiphora* landscape in the Ishiara mapsheet and the area studied. However due to different extensions of the various landforms differences in grazing patterns can be found. Different in other areas is for example the importance of the footslopes which, with a relatively high soil fertility and lateral flow of surface water, are important dry season grazing areas, and where *Acacia tortiles* is the dominant tree. In some more intensive agriculture areas differences occur due to shorter fallow periods, but also here grazing depends on bushes and other less intensively used land, as for example the river terrace along the Tuchi river, between Ishiara and Mutonga. The study area south of Ishiara further differs from the remaining areas of the mapsheet in being more intensively used in the past which caused extensive sealed soil areas. Furthermore the area studied has more variations in landforms, soils and vegetation than many other parts of the mapsheet. In spite of all these minor differences the same requirements and bottlenecks of the existing 'extensive grazing' land use type as outlined for the area studied can be found for the other areas". (End of 'quotation').

Recommended maximum livestock density per km^2:
Jeatzold and Schmidt (1983) recommend a maximum density of 25 livestock units per km^2. The carrying capacity of the Chuka-South Area has not been determined, due to lack of time and data (Scholte, 1986a).

Table 23. LUT's and farming systems in the project area.

LUT		FARMING SYSTEMS			
Crop	Technol. level	Tea-coffee-dairy.	Coffee-maize-beans.	Cotton-maize-pigeon peas.	Livestock-millet-(cotton).
Tea	I/II	+	-	-	-
Coffee	I/II	+	+	-	-
Maize	I/II	+	+	+	-
Beans	I/II	+	+	+	-
Potatoes	I/II	+	+	-	-
Vegetables	I/II	+	+	-	-
Fodder	I	+	+	+	-
Bananas	I/II	+	+	+	-
Cassava	I/II	-	+	+	-
Cotton	I/II	-	-	+	+
Sunflower	I/II	-	+	+	-
Sorghum	I/II	-	+	+	+
Millet	I/II	-	-	+	+
Tobacco	I/II	-	-	+	-
Pigeon peas	I/II	-	+	+	+
Cow peas	I/II	-	+	+	-
Green gram	I/II	-	-	+	+
Grazing	I	-	-	-	+

4.5 COST-BENEFIT ANALYSES

Table 24 specifies for each LUT, i.e. for each combination of crop and teachnology level, the unit price of the marketable produce, the transport costs per kilogram or unit, and the normative yield in kg per hectare. These reference data are used for calculating the agro-economic results of each LUT at a specific land suitability level. Tables 25 through 27 give the expected yields, the value of the produce, the labour requirement and the gross margins per hectare or per labour day for the various LUT's at the suitability levels S1 (good), S2 (fair) and S3 (poor). Tables 25 through 27 will be presented without much comment on the economic data themselves; the column headings are explained in the following.

As regard Table 24 (Reference data per Land Utilization Type):

"Labour days per hectare": the number of labour days per hectare at the normative yield level. The estimates are based on the crop budgets of the Farm Management Unit of the Ministry of Agriculture. One day is considered to consist of 6 working hours; the calculated labour requirement is rounded to the nearest 10 days.

"Variable costs per hectare": the costs of the required material inputs per hectare, excluding costs for the transport of the produce and labour costs. The estimates are based on the crop budgets of the Farm Management Units of the Ministry of Agriculture. Variable costs are based on input levels as required for the normative yield and are the same for suitability levels S1, S2 and S3.

"Price per kg": the average or usual market or factory/cooperative price, per kg or unit produce. The years 1985-1986 are reference years.

"Transport costs per kg": the average or usual costs of transport, per kg or unit produce, from the farm gate to the market or factory/cooperative.

Table 24. Reference data per land utilization type.

Land Utilization Type: Crop	Technology level	REFERENCE DATA: Labour days per ha	Variable costs per ha	Price per kg or unit Ksh.	Transport costs per kg or unit Ksh.	Normative yield kg	Source*
1. Tea	I	230	1,800	7.05	.35	5,000	1
2.	II	260	3,000	7.05	.35	6,000	2
3. Coffee	I	430	2,300	20.00	1.00	800	3
4.	II	630	7,000	20.00	1.00	1,600	4
5. Maize	I	140	500	1.94	.10	2,500	5
6.	II	150	1,600	1.94	.10	4,000	
7. Beans	I	150	400	4.30	.10	1,000	6
8.	II	160	1,900	4.30	.10	1,800	
9. Potatoes	I	240	2,800	.80	.10	10,000	7
10.	II	280	4,300	.80	.10	20,000	
11. Cabbages	I	200	500	.90	.10	6,000	8
12.	II	330	1,100	.90	.10	18,000	
13. Fodder (napier and/ or bana grass)	I		no data			4,700	
14.	II		no data			10,000	
15. Bananas	I	30	1,400	2.00	.10	12,000	9
16.	II	100	4,000	2.00	.10	20,000	
17. Cassave	I	no data	200	.60	.10	4,000	10
18.	II	no data	1,100	.60	.10	7,500	
19. Cotton	I	200	200	4.62	.10	400	11
20.	II	230	1,700	4.75	.10	900	12
21. Sunflower	I	110	400	3.30	.20	700	13
22.	II	110	800	3.30	.20	1,000	14
23. Sorghum	I	200	200	1.10	.10	2,000	15
24.	II	200	600	1.10	.10	3,100	
25. Millet (Bulrush)	I	110	200	1.25	.10	700	16
26.	II	110	300	1.25	.10	1,500	
27. Tobacco	I		no data				
28.	II		no data				
29. Pigeon Peas	I	120	200	2.22	.10	450	17
30.	II	120	400	2.22	.10	900	
31. Cow peas	I		no data				
32.	II		no data				
33. Green gram	I	130	300	2.78	.10	400	18
34.	II	140	400	2.78	.10	1,000	

* For sources see next page.

Table 24 (continued).

Sources.

The following Crop Budgets of the Farm Management Unit of the Ministry of Agriculture have been used.

source number	district	agro-ecological zone * symbol	sub-zone * symbol	date	page
1	Embu	UM 1	lim	10/04/86	4
	Embu	LH 1	l/v-m	10/04/86	1
2	Embu	UM 1	lim	10/04/86	5B
3	Meru	UM 1	m/l+m/s	10/04/86	1
4	Embu	UM 1	m+s/m	10/04/86	3B
5	Embu	UM 2	m+s/m	10/04/86	3
6	Embu	UM 1	lim	10/04/86	5
7	Meru	LH 1	l/vl-m	10/04/86	3
8	Meru	LH 1	l/vl-m	10/04/86	6
9	Embu	UM 1	lim	10/04/86	7&8
10	Embu	LM 4	s/sv+vs/s	10/04/86	8
11	Meru	LM 4	s+s	10/04/86	7
12	As source 11, but intrapolation of level I and II, in combination with information from Jeatzold & Schmidt (1983) and Helder & Donk (1986).				
13	Meru	UM 2	m+s/m	10/04/86	8
14	Meru	UM 2	m+m	10/04/86	7
15	Meru	UM 3	m/s+m/s	10/04/86	6
16	Embu	UM 3	s+s	10/04/86	5
17	Embu	LM 3	s+s	10/04/86	12
18	Embu	LM 3	s+s	10/04/86	13
	Meru	LM 3	s+s	10/04/86	9

* For explanation of zonation and symbols see Jeatzold & Schmidt (1983).

considered to consist of 6 working hours; the calculated labour requirement is rounded to the nearest 10 days.

"Variable costs per hectare": the costs of the required material inputs per hectare, excluding costs for the transport of the produce and labour costs. The estimates are based on the crop budgets of the Farm Management Units of the Ministry of Agriculture. Variable costs are based on input levels as required for the normative yield and are the same for suitability levels S1, S2 and S3.

"Price per kg": the average or usual market or factory/cooperative price, per kg or unit produce. The years 1985-1986 are reference years.

"Transport costs per kg": the average or usual costs of transport, per kg or unit produce, from the farm gate to the market or factory/cooperative.

"Normative yield": the yield obtained with the specified technology under optimum ecological conditions (rainfall, temperature and soil conditions). It is important to note here, that the normative yield refers not necessarily to optimal, or even "the best", management conditions. The available management conforms to the applicable technology level(s).

As regard Tables 25 through 27 (Agro-economic results per Land Utilization Type at suitability levels S1, S2 and S3):

"Yield": marketable produce, in kg or unit per hectare, obtainable at the various suitability levels. The following assumptions were made:

suitability level		range of yield relative to normative yield	point estimate relative to normative yield (*)
"Good"	S1	76% - 100%	90%
"Fair"	S2	51% - 75%	65%
"Poor"	S3	26% - 50%	40%
"Not"	N	<26%	--

(*) used as a basis for further calculations.

"Normative yield": the yield obtained with the specified technology under optimum ecological conditions (rainfall, temperature and soil conditions). It is important to note here, that the normative yield refers not necessarily to optimal, or even "the best", management conditions. The available management conforms to the applicable technology level(s).

As regard Tables 25 through 27 (Agro-economic results per Land Utilization Type at suitability levels S1, S2 and S3):

"Yield": marketable produce, in kg or unit per hectare, obtainable at the various suitability levels. The following assumptions were made:

suitability level		range of yield relative to normative yield	point estimate relative to normative yield (*)
"Good"	S1	76% - 100%	90%
"Fair"	S2	51% - 75%	65%
"Poor"	S3	26% - 50%	40%
"Not"	N	<26%	--

(*) used as a basis for further calculations.

"Value of Production": the value of the produce in KSh per hectare, calculated as follows: point estimate of yield multiplied by price per kg less transport costs per kg. The figures presented are rounded to the nearest KSh 100,-.

"Labour days per hectare": as in Table 24 but adjusted for the different yields at the various suitability levels and rounded off to the nearest 10 days.

"Gross margin per hectare": the value of the production per hectare less variable costs per hectare as given in Table 24. The gross margin per hectare is an indication of the economic return to the land, exclusive of the costs of labour and other production factors.

"Value of Production": the value of the produce in KSh per hectare, calculated as follows: point estimate of yield multiplied by price per kg less transport costs per kg. The figures presented are rounded to the nearest KSh 100,-.

"Labour days per hectare": as in Table 24 but adjusted for the different yields at the various suitability levels and rounded off to the nearest 10 days.

"Gross margin per hectare": the value of the production per hectare less variable costs per hectare as given in Table 24. The gross margin per hectare is an indication of the economic return to the land, exclusive of the costs of labour and other production factors.

"Gross margin per labour day": the gross margin per hectare divided by the number of labour days. The gross margin per labour day is an indication of the economic return to labour. The figures are expressed in KSh.

Note: The data presented in Tables 24 through 27 are indicative only. They are meant for comparing alternative LUT's rather than for use in an absolute way.

Tables 25 through 27 suggest that a LUT at a lower level of suitability might be economically more attractive that a LUT at a higher suitability level, either because of a higher gross margin per hectare or per labour day or both. Which yardstick to use depends on the relative scarcity of land and/or labour as reflected in the price or scarcity value of these production means. The prices of outputs and inputs and the (implied) prices of land and labour can change over time. Before more specific or binding conclusions can be drawn with regard to the relative attractiveness of a cartain LUT, the suitability of the various LUT's must be analyzed from an ecological point of view also. This ecological evaluation will be discussed in some detail in Chapter 5.

Table 25. Agro-economic results per land utilization type at suitability level S_1 ('good').

Land Utilization Type		SUITABILITY LEVEL S_1 (76-100% of normative yield)				
		Yield	Value of	Labour days	Gross margin	
Crop	Technology level	90%	production	per ha	per ha	per labour day
		Kg	Ksh.		Ksh.	Ksh.
1. Tea	I	4,500	30,200	210	28,400	135
2.	II	5,400	36,200	236	33,200	141
3. Coffee	I	720	13,700	400	11,400	29
4.	II	1,440	27,400	580	20,400	35
5. Maize	I	2,250	4,100	137	3,600	26
6.	II	3,600	6,600	145	5,000	34
7. Beans	I	900	3,800	147	3,400	23
8.	II	1,620	6,800	155	4,900	32
9. Potatoes	I	9,000	6,300	235	3,500	15
10.	II	18,000	12,600	270	8,300	31
11. Cabbages	I	5,400	4,300	197	3,800	19
12.	II	16,200	13,000	221	11,900	54
13. Fodder (napier grass and/ or bana grass)		4,230	no data			
14.		9,000	no data			
15. Bananas	I	10,800	20,500	27	19,100	708
16.	II	18,000	34,200	95	30,200	318
17. Cassave	I	3,600	1,800	no data	1,400	
18.	II	6,750	3,400	no data	2,100	
19. Cotton	I	360	1,600	197	1,400	7
20.	II	810	3,800	224	2,100	9
21. Sunflower	I	630	2,000	109	1,600	15
22.	II	900	2,800	109	2,000	18
23. Sorghum	I	1,800	1,800	191	1,600	8
24.	II	2,790	2,800	190	2,200	12
25. Millet	I	630	700	109	500	5
26.	II	1,350	1,600	108	1,300	12
27. Tobacco	I		no data			
28.	II		no data			
29. Pigeon Peas	I	405	900	119	700	6
30.	II	810	1,700	118	1,300	11
31. Cow Peas	I		no data			
32.	II		no data			
33. Green Gram	I	360	1,000	129	800	6
34.	II	900	2,400	137	2,000	15

Table 26. Agro-economic results per land utilization type at suitability level S_2 ('fair').

Land Utilization Type		SUITABILITY LEVEL S_2 (51-75% of normative yield)				
		Yield	Value of	Labour days	Gross margin	
Crop	Technology level	65%	production	per ha	per ha	per labour day
No.		Kg	Ksh.		Ksh.	Ksh.
1. Tea	I	3,250	21,800	160	21,800	125
2.	II	3,900	26,100	184	26,100	126
3. Coffee	I	520	9,900	330	9,900	23
4.	II	1,040	19,800	460	19,800	28
5. Maize	I	1,625	3,000	128	2,500	20
6.	II	2,600	4,800	131	3,200	24
7. Beans	I	650	2,700	141	2,300	16
8.	II	1,170	4,900	144	3,000	21
9. Potatoes	I	6,500	4,600	222	1,800	8
10.	II	13,000	9,100	245	4,800	20
11. Cabbages	I	3,900	3,100	189	2,600	14
12.	II	11,700	9,400	298	8,300	28
13. Fodder (napier and/ or bana grass)		3,055	no data			
14.		6,500	no data			
15. Bananas	I	7,800	14,800	20	13,400	671
16.	II	13,000	24,700	84	20,700	246
17. Cassave	I	2,600	1,300	no data	900	
18.	II	4,875	2,400	no data	1,100	
19. Cotton	I	260	1,200	190	1,000	5
20.	II	585	2,700	207	1,000	5
21. Sunflower	I	455	1,400	107	1,000	9
22.	II	650	2,000	105	1,200	11
23. Sorghum	I	1,300	1,300	170	1,100	6
24.	II	2,015	2,000	160	1,400	9
25. Millet	I	455	500	107	300	3
26.	II	975	1,100	103	800	8
27. Tobacco	I		no data			
28.	II		no data			
29. Pigeon Peas	I	293	600	116	400	3
30.	II	585	1,200	112	800	7
31. Cow Peas	I		no data			
32.	II		no data			
33. Green Gram	I	260	700	126	400	3
34.	II	650	1,700	131	1,300	10

Table 27. Agro-economic results per land utilization type at suitability level S_3 ('poor').

Land Utilization Type		SUITABILITY LEVEL S_3 (26-50% of normative yield)				
		Yield	Value of	Labour days	Gross margin	
Crop	Technology level	40%	production	per ha	per ha	per labour day
		Kg	Ksh.		Ksh.	Ksh.
1. Tea	I	2,000	13,400	120	11,600	97
2.	II	2,400	16,100	142	13,100	92
3. Coffee	I	320	6,100	270	3,800	14
4.	II	640	12,200	350	5,200	15
5. Maize	I	1,000	1,800	120	1,300	11
6.	II	1,600	2,900	118	1,300	11
7. Beans	I	400	1,700	135	1,300	10
8.	II	720	3,000	133	1,100	8
9. Potatoes	I	4,000	2,800	210	200	1
10.	II	8,000	5,600	220	1,500	7
11. Cabbages	I	2,400	1,900	182	1,600	9
12.	II	7,200	5,800	276	4,900	18
13. Fodder (Napier and/ or bana grass)	I	1,880	no data			
14.	II	4,000	no data			
15. Bananas	I	4,800	9,100	13	7,700	594
16.	II	8,000	15,200	72	11,200	156
17. Cassave	I	1,600	800	no data	600	
18.	II	3,000	1,500	no data	400	
19. Cotton	I	160	700	183	500	3
20.	II	360	1,700	191	0	0
21. Sunflower	I	280	900	104	500	5
22.	II	400	1,200	102	400	4
23. Sorghum	I	800	800	140	600	4
24.	II	1,240	1,200	130	600	5
25. Millet	I	280	300	104	100	1
26.	II	600	700	98	400	4
27. Tobacco	I	no data				
28.	II	no data				
29. Pigeon Peas	I	180	400	113	200	2
30.	II	360	800	106	400	4
31. Cow Peas	I	no data				
32.	II	no data				
33. Green Gram	I	160	400	124	100	1
34.	II	400	1,100	125	700	6

5 LAND EVALUATION

5.1 INTRODUCTION

Land evaluation is the process of assessing land suitability for a specified purpose. It involves the interpretation of data on land forms, soils, vegetation, climate and other aspects of land, in order to compare alternative kinds of land use in terms applicable to the objectives of the evaluation (FAO, 1976).
The socio-economic context should be taken into account to identify non- physical limitations to agricultural production. Problem-oriented land evaluation studies can not be successful without integration of the sociological and economic aspects of land and its use (Boxem, De Meester & Smaling, 1987)
Consequently, a land evaluation is generally carried out in two stages, a purely physical land evaluation followed by a socio-economic analysis, an approach which entails a multi-disciplinary effort (Beek, 1978).
In this chapter, the procedure and results of the physical ("ecological") land evaluation are discussed only.
An ecological land evaluation comprises the following main activities:

a) Selection of relevant land utilization types (LUTs) in relation to the physical, social and economic conditions of the area and the development objectives.
The identification of LUTs forms the backbone of the land evaluation. The LUTs are characterized by "key attributes", which reflect those biological, socio-economic, technical etc. aspects of the production environment that are relevant to the productive capacity of a land use system (LUS).
This land evaluation has been carried out for 15 LUTs described in Chapter 4.

b) Determination of the requirements of the relevant land utilization types.
Each crop has minimum needs to survive and produce, and higher needs to reach optimum production. A demanding crop has higher

requirements than a less demanding crop and thus the land unit under consideration might show a lower suitability for some crops and a higher suitability for other crops.
Requirements are basically separated into physical and management requirements.

c) Identification of relevant land units, their land qualities and land characteristics.
Land units (LUs) are areas possessing specified land qualities and land characteristics. (FAO, 1984).
Each land unit consists of one or more soil mapping units with the same land quality ratings. One soil mapping unit can occur in more than one land unit, e.g. if it covers more than one relief class or when it occurs in more than one agro-ecological zone.
Land characteristics are attributes of land that can be measured or estimated, e.g. slope gradient, soil depth, average annual rainfall.
Land characteristics do not affect the suitability of land for a certain use in an indiscriminate way. Therefore, land characteristics are mostly aggregated to clusters, the land qualities (LQs), which cover distinct basic requirements of land use.

d) Matching of land qualities and land use requirements and classification of the land suitability.
The comparison of the needs of a LUT, the land use requirements, and the rated land qualities, is commonly referred to as matching. The results of a matching procedure are indications of the suitabilities of a certain LU for the (proposed) LUT. In this report, the suitability indications are comprised in four classes:

S1 Physically highly suitable: Land with no or slight limitations for the sustained cultivation of the defined crop. Yields are 76 to 100% of the normative yields.

S2 Physically moderately suitable: Land with moderate limitations for the sustained cultivation of the defined crop. Yields are only 51-75% of the normative yields

S3 Physically poorly suitable: Land with severe limitations for the sustained cultivation of the defined crop. Yields are 26-50% of the normative yields.

N Physically non suitable: land with limitations which preclude successful sustained cultivation of the defined crop. Yields are below 25% of the normative yields.

The following remarks must be made before discussing the procedures and evaluation results in some more detail:

- This land evaluation is done according to the revised edition (20-02- 1987) of "Rating of Land Qualities in Kenya", third approximation of the Kenya Soil Survey (Weeda, 1987).
- This land evaluation refers to the "present situation". Any assessment of the effects of future developments (fertilizer application, irrigation, erosion control) requires adjustment of the suitability ratings. This will conceivably result in a different, more favourable, suitability classification.
- This land evaluation has a strictly physical basis. Interpreting the physical suitabilities in a socio-economic context may well show a different picture of the overall outlook of the farmer.
- Intercropping systems are not rated as such. Normative yields from such systems could be inferred from the projections for individual crops, if adjusted for lower plant densities. Possible positive or negative interferences between the different crops are ignored, although there are indications that intercropping affects the yields.
- Ratings of land qualities and associated suitability classifications may need adjustment when more detailed research on the land characteristics and land qualities, e.g. on the climate and fertility, is completed.

5.2 LAND QUALITIES

In this section, a number of land qualities are discussed. These land qualities, and the land characteristics which have been used to determine the land qualities, are presented in Table 28.

Three major environmental limitations to crop production are recognized in the Chuka-South area:

- -Temperature
- -Moisture availability
- -Nutrient availability

The temperature variation in the Chuka-South area spans the temperature zones 1 through 6, i.e. from very hot to fairly cool. This broad temperature range poses limitations to the regional extent of land (zones) suitability for a given crop (see section 5.2.1.).
The Chuka-South area extends over several agro-climatic zones, varying from humid to semi-arid. About half of the area is situated in the semi-humid to semi-arid transition zone and the semi-arid zone. Here, moisture stress is to be expected.
Apart from climatic factors, also the unsatisfactory moisture storage of many soils may hamper crop performance. In addition, the low level of natural soil fertility is a serious limitation to crop production in large parts of the Chuka-South area (see section 5.2.3.).
In each of the following paragraphs, one land quality and its ratings will be discussed. Some land qualities are of importance to a few LUTs in particular; the land qualities discussed in the last paragraphs are important to any LUT.

The conversion tables (as given in Table 46a-o) used in matching LQ's and LUR's are compiled from data on crop requirements supplied by Sombroek et al, 1982; Ackland, 1977; Purseglove, 1986; Buol et al, 1975; Ooms, 1987 and de Haan, 1986 and obtained through personal communication with various specialists.

5.2.1. The temperature regime

The three most important climatic factors in the Chuka-South area are temperature, precipitation and evapotranspiration.

Table 28. Land qualities and land characteristics considered in this land evaluation

Land qualities/limitations:	Land characteristics used to determine the land qualities:
1. Temperature	Mean annual temperature (Mean maximum temperature) (Mean minimum temperature) (Absolute min. temperature)
2. Moisture availability	Average monthly rainfall (P) Surface run-off coefficient (C) Average monthly evaporation (Et) Soil moisture storage capacity for easily available soil moisture (S)
3. Nutrient availability	CEC (cmol(+)/Kg soil) Organic Carbon (%) Exchangeable K, Ca, and Mg (cmol(+)/Kg soil)
4. Resistance to erosion	Agro-climatic zone (KSS) Slope class and slope length "Erodibility" of the soil
5. Availability of oxygen for root growth	Soil drainage class
6. Ease of cultivation	Slope class Stoniness/rockiness of the top soil Depth of the soil Soil consistence Width and length of the field
7. Absence of hindrance by vegetation	Physiognomic type
8. Availability of foothold for roots	Rootable depth

The temperature zones suggested by Sombroek et.al., 1982, are used as a basis for rating the temperature characteristics; these temperature zones are indicated on the agro-climatic zone map of Kenya by Braun (in Sombroek et al, 1982). A more precise identification of these zones is pursued in ongoing research on the climate (Pulles, 1987); his preliminary results were used to determine the temperature zones in which the various land units are located.

The temperature zones vary from zone 6 in the north-westerly corner of the area to zone 1 in the eastern half of the area. This implies that mean annual temperatures in the area vary between 14-16 °C and 24-30 °C.

Not only the relation between the bulk of the crop yields and the temperature zone should be taken into account but also the quality of the product should be looked at. This is especially true for products as tea and coffee. Tea for example, could be grown in temperature zones 1 and 2, but its quality would be too poor to make tea growing an economic proposition.

Table 29. Rating of the land quality Temperature (Source:Weeda, 1987.)

Temp. zone	mean annual temp. °C	mean max. temp. °C	mean min. temp. °C	absolute min. temp. °C
6	14-16	20-22	8-10	0-2
5	16-18	22-24	10-12	2-4
4	18-20	24-26	12-14	4-6
3	20-22	26-28	14-16	6-8
2	22-24	28-30	16-18	8-10
1	24-30	30-36	18-24	10-16

Chances of night frost have been left out of this table since this characteristic is not applicable to the Chuka-South area.

Data as the mean maximum and mean minimum temperatures and the absolute minimum temperature play a minor role in the determination of land suitabilities for most crops, mainly because little is known about the influence of these factors on crop production.

5.2.2 Moisture availability

Moisture availability is first and foremost a matter of climate and soil characteristics. Apart from those, other factors such as run-off/run-on, deep percolation and seepage play a part in the water balance of the soil. Water losses by deep percolation are of importance to some of the RP-map units. Replenishment/depletion of available soil moisture by lateral water flow occurs at the fringes of the lahar areas, especially at the scarps. Run-off and run-on is mainly restricted to the soils of the Basement System area.

These factors, together with precipitation, evapotranspiration and water uptake by plantroots, determine the amount of available soil moisture at any moment in the growth cycle of the crop. Deep percolation, seepage and run-on are not considered in this excercise.

Here the availability of water for plant growth is expressed in terms of the potential length of the growing season(s). The growing season is the period during which the plant has enough available soil water to survive. It is identified with a simplified water balance (on a monthly basis and for specific soil units).

The following basic data are needed:

-The average rainfall (P): The average monthly rainfall sum from the nearest representative rainfall station.

The average rainfall data of stations in and near the Chuka-South area have been calculated. Due to the great influence of the relief on the rainfall distribution in the Chuka-South area, the nearest representative rainfall station can not be determined directly. First, 5 rainfall zones have been determined with rainfall data from all stations. Within each rainfall zone, the most representative rainfall stations are determined with the help of Thiessen polygons for each unit.

In this method, monthly rainfall averages are used. Especially for semi-arid regions, where the rainfall is unevely distributed, this may introduce rather serious errors.

-The surface run-off coefficient (C):

Reliable run-off estimations are available for parts of the Chuka-South area. For the other parts, the run-off rates were estimated with the help of Table 2.1 in Weeda (1987), although for some texture groups the approximate run-off coefficients appeared to be rather low.

-The average monthly evaporation (Et):

Since no data are available on the actual evaporation (Et) in the Chuka- South area, Et had to be estimated from the potential evaporation (Eo) with the formula:

$$Et = 2/3\ Eo$$

For each unit in the Chuka-South area the potential annual evaporation is calculated with Woodhead's formula. The distribution of the total evaporation per month (in % of the annual evaporation sum) is determined from data on decade basis (Pulles, 1987).
For reasons of simplicity, evaporation figures were not calculated for each indiviual crop or group of crops. Hence, the water balance is not crop specific.

-The soil moisture storage capacity for easily available soil moisture (S):
Easily available soil moisture is retained by the soil with a suction that corresponds with pF values between 2.3 and 3.7. These pF values are thought to represent most Kenyan soils at field capacity (pF 2.3) and the moisture content at which moisture stress starts to hamper the production of most crops (pF 3.7).
This figure could partly be determined with laboratory data (pF values), but estimates had to be made for most units. These estimates are based on texture analyses and on Table 2.2 in Weeda (1987).
The storage capacity S, is reduced proportionally with the amount of stones and gravel present in the soil mass. S is calculated for three different soil depth classes, taking into account the rooting patterns of the plants under consideration. (The "effective" rooting depth is the depth over which the plant develops 80% of its roots.)
Soil depth classes:

designation:	depth (cm):
shallow	0-50
moderate	50-80
deep	80-120

The adopted criteria for good plant growth are as follows (Weeda, 1987):

if $(PE + dS)/Et > 1$	then this month is a full growing month.
if $0.5 < (PE + dS)/Et < 1$	then there is enough water available for the germination and ripening of annual crops during this month. For perennial crops this period usually signifies a period of reduced growth. This month is counted as half a growing month.

in which
PE = Effective Rainfall = P - C (mm)
dS = Surplus of soil water balance from the previous month (mm) (not exceeding the maximum soil moisture storage capacity)
Et = actual evapotranspiration (mm)

The actual number of growing months corresponds with the overall rating factor for water availability (Rw) as presented in Table 30.

Table 30. Rating for number of months growing season (Source:Weeda, 1987).

Rating (Rw)	Month(s) per growing season
1	> 11
2	9.5 - 11
3	6 - 9
4	4 - 5.5
5	3 - 3.5
6	2 - 2.5
7	< 2

Since the rainfall pattern in most of the Chuka-South area is bi-modal, two potential growing seasons are identified and analyzed separately.

5.2.3 Availability of nutrients

The basic information on which the rating of this land quality is founded is routinely determined at the National Agricultural Laboratory, Nairobi, for soil survey and soil fertility purposes. The components are:

-CEC (cmol(+)/Kg soil)
-Organic carbon (%)
-Exchangeable K, Ca, and Mg (cmol(+)/Kg soil)
-pH-H2O 1:2.5

A table has been constructed for the application of the most limiting factor method on these components:

Table 31 Rating the availability of nutrients for plant growth. Source: Weeda (1987).

Rating(Rn)	CEC cmol/Kg	%C temp. zone* 1,2,3	%C temp. zone* 4,5,6	exch K cmol(+)/Kg	exch Ca cmol(+)/Kg	exch Mg cmol(+)/Kg	pH-H2O (1:2.5)
1. High	>16	>2.0	>2.5	>0.5	>6.0	>3.0	5.6-6.8
2. Moderate	6-16	1.1-2.0	1.6-2.5	0.21-0.5	3.0-6.0	1.1-3.0	4.8-5.5 6.9-7.5
3. Low	3-5.9	0.5-1.0	1.0-1.5	0.10-0.20	1.0-2.9	0.5-1.0	4.0-4.7 7.6-8.7
4. Very low	<3	<0.5	<1.0	<0.10	<1.0	<0.5	<4.0 >8.7

Rating for pH-H2O for tea only:

1. 5.0-5.6
2. 4.3-4.9 or 5.7-6.0
3. 4.0-4.3 or 6.1-7.3
4. <4.0 or >7.3

* See Agro-climatic zone map of Kenya (Sombroek et al, 1982)

The amount of available P is not taken into consideration here for the reasons that the P-Olsen or P-Mehlich is not determined for all units and the method of analysis is not always mentioned with the analysis results. Furthermore, there is still no good method of determining the amount of P which can be taken up by the plant and therefore the figures of available P have no real value.

On the whole, organic carbon contents correlate positively with the amount of nitrogen in the soil. The interpretation of organic carbon figures varies with the temperature zones in which the area is situated. The temperature zones mentioned here are those from the agro-climatic zones map of the Kenya Soil Survey (Sombroek et al, 1982).
In the case of "chemically inactive components coarser than 2mm", like stones and gravel, the analysis data have been corrected to account for the volume taken up by these components (apart from pH).
The final rating is determined by the lowest sub-rating of the topsoil (0-20 cm), except when the final rating of the subsoil (20-50 cm) differs more than one unit from the final topsoil rating. In this case the final rating of the topsoil is graded up or down one class, thus obtaining the final rating of the profile.

5.2.4 Resistance to erosion

In the Chuka-South area, only water erosion is of importance. The resistance of the land to erosion depends on many factors. Some of these factors are "environmental" factors, others are entirely soil factors. Some of the most important environmental factors are the climate and slope of the land. The climate determines the amount and intensity of rainfall and therewith the kinetic energy of the rain drops that fall on the soil. The slope determines, to some extent, the infiltration of water into the soil. The soil factors determine the infiltration characteristics of the soil and the stability of the soil structure. An attempt to attribute ratings to these soil factors that, together, determine the "erodibility" of the soil, is made in Weeda (1987). In this study, the lack of basic data precluded to use this erodibility rating procedure. Instead, rating of the erodibility is substituted by a soil structure stability rating (the Emerson test). The structure stability seems to be very important as it determines the rate of infiltration and it indicates how easily soil particles are detached from the soil mass. A good relationship between soil erodibility and the soil structure stability proved to exist for the soils in the Kilifi area, Kenya (Boxem, De Meester and Smaling, 1987).

The erosion problem is most severe in the Basement System area where soil stability tends to be low. There is almost no erosion in the Mt. Kenya forest area or the adjacent "Tea zone" although very steep slopes occur there. Some erosion was observed in the "Coffee zone" where the soil stability is lower and also steep slopes occur also. See App. 6.7, Plate 8. The same holds for the "Volcanic Uplands", in the map units group UIP. There, soil stability is about the same as for the soils of map unit group LP, but with the very gentle slopes that occur within LP units there is almost no erosion. In the Basement System area, almost all soils are very erodible. The different resistance against erosion in this part of the Chuka-South area is mainly due to differences in slope class and vegetation.

-The climate factor:

According to Weeda (1987), the erosivity of the rain in Kenya is strongly related to the kinetic energy of 15 minute showers with rainfall intensities of over 25 mm/hr ($KE_{15}>25$).The $KE_{15}>25$ classification and the corresponding ratings for the various KSS agro-climatic zones are presented in Table 32.

Table 32 Climate factor ratings (Source:Weeda, 1987)

Rating	$KE_{15}>25$	Agro-climatic zone (KSS)
1	<5000	VI, VII
2	5000-10000	II,IV,V
3	>10000	I,II

-Slope factor:

The slope class and the slope length are combined in the slope factor. Whenever intermediate or compound slope classes are met, the rating is not obtained by interpolation, but by giving the unit a compound rating of minimum and maximum ratings for the slope classes. This results sometimes in single final ratings, but usually in compound final ratings, see Table 33.

Table 33. Slope factor ratings (Source: Weeda, 1987).

slope class :	A	B	C	D	E	F	G
slope % :	0-2	2-5	5-8	8-16	16-30	30-45	>45
slope length (m)							
<50	1	1	3	3	3	5	7
50-100	1	3	3	5	5	7	9
100-200	1	3	5	5	7	9	9
>200	1	3	5	5	7	9	11

-The soil factor:

The soil factor rating is based on the soil structure stability (Emerson test) as presented in Table 34 (Emerson, 1967).

Table 34. Soil factor rating (Source: Weeda, 1987).

Rating:	Soil structure stability:
1	High
3	Medium
5	Low

-The final rating of the land quality "resistance against erosion":

The final rating (Re) is obtained by the summing the subratings for the individual factors climate, slope and soil. The final rating is presented in Table 35.

Table 35. Land quality Resistance against erosion (Source: Weeda, 1987)

Rating (Re):	Sum factors:
1.	3-7
2.	8-11
3.	12-14
4.	15-19

5.2.5 Availability of oxygen for root growth

Persistent waterlogging limits the amount of oxygen available to growing roots. This limitation is closely related with the drainage class of the soil.

Most of the soils in the Chuka-South area are well to excessively drained, but the soils of map units BPC (LU 39) are imperfectly to very poorly drained. Some soils of map unit LP1 (LU 21) are less well drained due to the flat topography of the area. The valley bottoms, which form part of the valley complexes, are also imperfectly to very poorly drained. See Table 36.

Table 36. Land quality availability of oxygen for root growth. (Source: Weeda, 1987)

Rating (RO)	Soil drainage class
1. Very high	Well to excessively drained
2. High	Moderately well drained
3. Moderate	Imperfectly drained
4. Low	Poorly drained
5. Very low	Very poorly drained

5.2.6 Ease of cultivation

Land preparation in the Chuka-South area is done entirely by hand or with the use of oxen. For these two main types of cultivation, a suitability classification was made with respect to the land quality "ease of cultivation".

The ease of cultivation depends largely on the following factors:

1 the steepness of the slope,

2 the surface stoniness and rockiness,

3 the soil consistence or workability,

4 the depth of the soil and

5 the size and shape of the field.

The last factor is of importance only if a tractor is used. This factor is not considered in our ratings, because tractors are not used in the Chuka- South area. In some cases, the dry consistence is more limiting than the moist consistence. In parts of the Basement System area, tillage by hand is almost impossible, because of the hardness of the soils at the end of the dry season.

The first four factors mentioned are rated according to Tables 37 to 40. The final rating (Rc) is determined with the help of Table 41 for cultivation by hand and oxen. The most limiting factor determines the final suitability classification and the final rating of the land quality "ease of cultivation".

Except for some very rocky units, all land units were deemed suitable for cropping if judged by their ease of cultivation. Every unit can be worked by hand, although sometimes at the cost of a fairly high input of labour.

The map units LP2P and PPC (LU 22 and 38) consist almost entirely of bare rock. There, of course, cultivation is impossible.

Table 37. Sub rating steepness of slopes. (Source: Weeda, 1987)

Sub rating	Slope class	Slope %
1.	A, B, C	0-8
2.	CD, D	8-16
3.	DE, E	16-30
4.	F	30-70
5.	G	>70

Table 38. Subrating stoniness/ rockiness of the topsoil. Source: Weeda, 1987).

Subrating	Stoniness	%	Rockiness	%
1.	non	<0.01	non	<2
2.	fairly stony	0.01-1	fairly rocky	2-10
3.	stony	0.1-3	rocky	10-25
4.	very stony	3-15	very rocky	25-50
5.	exceedingly stony	>15	extremely rocky	>50

Table 39. Subrating depth of soil to rock (or any other consolidated material). (Source: Weeda, 1987)

Subrating	Depth to rock (cm)	
1.	deep	>50
2.	shallow	25-50
3.	very shallow	<25

Table 40. Subrating workability of the soil (ease of action), based on the consistency of the topsoil (0-25 cm) (Source: Weeda, 1987).

Subrating	Plasticity Wet	Stickiness Wet	Moist	Dry
1. High	non to slightly plastic	non to slightly sticky	very friable, friable, loose	soft, slightly hard, loose
2. Medium	plastic	sticky	firm	hard
3. Low	very plastic	very sticky	extremely firm	very hard

The final rating for the land quality "ease of cultivation" is determined by the most limiting factor method.

Table 41. Final rating land quality Ease of cultivation for LUTs with power of hand and oxen. (Source: Weeda, 1987).

Rating (Rc):	Steepness of slope	Stoniness/ rockiness	Depth of soil	Workability of soil
1.	1	1	1	1
2.	2	2	1	2
3.	3	3	1	2
4.	4	4	2	3
5.	5	5	3	3

5.2.7 Absence of hindrance by vegetation

This land quality is of importance only for the Basement System area, where shifting cultivation still is practised, and also for the edge of the volcanic area and the Mt. Kenya Forest. All other areas are entirely under permanent cultivation.

In some cases, the vegetation can hinder the cattle, e.g. when a more intensive type of grazing is practised, or it can be used as a feed. In this paragraph, only the "ease of land clearing" is discussed.

Table 42. Rating of the land quality Absence of hindrance by vegetation. (Source:Weeda, 1987).

Rating (Rv):	Physiognomic type
1	grassland (G)/cultivated land bushed wooded grassland (BWG) wooded grassland (WG)
2	bushed grassland (BG) wooded bushed grassland (WBG)
3	bushland (B) wooded bushland (WB) bushed woodland (BW) woodland (W)
4	dense bushland (Bd) dense wooded bushland (WBd) dense bushed woodland (Bwd) dense woodland (Wd) bushland thicket (Bt) wooded bushland thicket (WBt) forest (F)

5.2.8 Availability of foothold for roots

This land quality is used for forestry and silvicultural land utilization types only. The present land evaluation does not consider such LUTs, but since forestry already plays an important role in parts of the Chuka-South area and forestry and silviculture may become more important LUTs in the near future, this land quality is considered here.

The criterium to determine the sufficiency of foothold for the crop or vegetation is the effective soil depth (cm).

Table 43. Rating of the land quality Availability of foothold. (Source: Weeda, 1987).

Rating (Rf):	Rootable depth (cm):	Depth class:
1. High	>120	Very deep
2. Moderate	50-120	Moderately deep to deep
3. Low	<50	Shallow to very shallow

Table 43. Rating of the land quality Availability of foothold. (Source: Weeda, 1987).

Rating (Rf):	Rootable depth (cm):	Depth class:
1. High	>120	Very deep
2. Moderate	50-120	Moderately deep to deep
3. Low	<50	Shallow to very shallow

5.3 THE LAND UNITS AND THEIR RATINGS (Legend for Appendix 6.4).

For all 115 combinations of soil mapping unit, relief class, temperature zone and rainfall/agro-climatic zone, sets of ratings as discussed in section 5.2 were determined. Next, sub-units with identified ratings were formed. These homogeneous sub-units are "land units" of which 47 appeared to exist in th Chuka-South area. (Land units are areas possessing specified land qualities and land characteristics. FAO, 1984). The correlation of mapping units and land units is shown in Table 44.

Table 44. Correlation of the mapping units and the land units

MAPPING UNIT	LAND UNITS	MAPPING UNIT	LAND UNITS	MAPPING UNIT	LAND UNITS
MQC	1	LPC	23, 24	U2FC1	33,34,36,37
MBP	2	LIC	22	U2FC2	31,33,35,36
HQC	4, 5, 6	LB	25	U2X1C	31, 33
HUC	7	U1P1h	26, 27, 28	U2X2p	31, 33, 34
HIC	8	U1P2p	27,28	U2UC	31
HBC	4, 9	U1PC	29,18,28,30	PPC	38
HPC	10	U2Q1p	31	BPC	39
RP1h	11, 12, 13,	U2Q2p	31, 37	V1PC	40,41,42,43
	14, 15, 16,	U2QC	31, 34, 35	V2PC	42, 43, 44
	17, 18	U2F1	31, 32		45, 46
RP2	19, 20	U2F2p	31, 32, 33,	V2XC	47
LP1	21		34, 35, 36		
LP2P	22	U2F3p	35, 36		

Note: L.U. 3 does not exist.

The location of the land units in the Chuka-South area is shown in Fig. 5.1. The ratings of the land qualities of all 47 landunits are depicted on a map (Appendix 6.4).

Table 45: The ratings of the land qualities

L.U.	Rt	Rw				Rn	Re	Ro	Rc	Rv	Rf
		growing season									
		first		second							
		rooting depth									
		A	B	A	B						
1	1+2	6	7	6	6	4	3-4	1	4-5	1-4	2-3
2	2	6	6	5	6	4	3-4	1	3-5	1-4	2-3
3	this land unit does not exist										
4	1	6	7	6	7	3-4	3-4	1	3-5	1-4	2-3
5	2	6	7	6	7	3-4	3-4	1	3-5	4	2-3
6	4	4	4	5	6	3-4	4	1	3-5	4	2-3
7	1+2	5	6	5	6	4	3-4	1	2-3	2-4	2-3
8	1	6	7	6	7	4	3	1	2-5	4	2-3
9	2	5	6	5	5	4	3-4	1	3-5	1-4	2-3
10	4	4	4	5	6	2-3	3	1	3-5	1	1-3
11	5	(i)				3	1-2	1	1-2	1	1
12	5	(i)				3	2-3	1	3-5	1	1
13	4	(i)				3	1-2	1	1-2	1	1
14	4	(i)				3	2-3	1	3-5	1	1
15	2+3	(i)				3	1-2	1	1-2	1	1
16	2+3	(i)				3	2-3	1	3-5	1	1
17	2	6	6	6	6	3	1-2	1	1-2	1	1
18	2	6	6	6	6	2-3	2-3	1	3-5	1	1-3
19	6	(ii)				?	1-2	1	1-2	4	1
20	6	(ii)				?	2-3	1	3-5	4	1
21	2	5	6	5	6	2-3	1-2	1-2	1	1	1
22	1+2	7	7	7	7	?	1-2	1	2-5	2-4	2-3
23	1+2	6	6	6	6	3-4	1-2	1	3-5	2-4	3
24	1	5	6	5	6	3-4	1-2	1	3-4	2-4	3
25	1	6	6	5	6	2	1-2	1	2-3	1-3	2
26	3+4	4	4	5	6	2-3	2	1	1-2	1	1
27	2	(iii)				2-3	1-2	1	1-2	1-4	1-2
28	1+2	5	6	5	5	2-3	1-2	1	1-3	1-4	1-3
29	3	(iv)				2-3	2-3	1	3	1	2-3
30	1	6	6	6	6	2-3	2	1	2-3	1	2-3
31	1+2	6	6	6	6	3-4	2-3	1	2-3	1-4	2-3
32	1	7	7	7	7	3-4	2-3	1	2-3	1-4	1-2
33	2	5-6	6	5-6	5-6	3-4	2-3	1	2-3	1-4	1-3
34	1	7	7	6	6	3-4	2-3	1	2-3	1-4	1-3
35	1	6	6	6	7	3-4	3	1	2-3	1-4	2-3
36	1	6	6-7	5	6	3-4	2-3	1	2-3	1-4	2-3
37	1	6	7	6	6	4	2-3	1	2-3	2-4	2-3
38	1	7	7	7	7	3	1-2	1	2-5	1	2-3
39	2	(v)				3-4	2-3	3-5	2-4	1-4	1-3
40	6	(ii)				3-4	2-3	1*	2-4	1-4	1-3
41	2-5	(i)				3-4	2-3	1*	2-5	1-4	1-3
42	2	5	6	5	6	3-4	2-3	1*	2-5	1-4	1-3
43	1	6	6	6	6	3-4	2-3	1*	2-4	1-4	1-3
44	1+2	6	6	5	5	3-4	2-3	1*	2-5	1-4	1-3
45	2	(iii)				3-4	2-3	1*	2-5	1-4	1-3
46	2	5	6	6	6	3-4	2-3	1*	2-5	1-4	1-3
47	2	7	7	6	6	3-4	2-3	1*	2-5	1-4	1-3

Notes

Rt: Ratings for the land quality "temperature".

Rw: Ratings for the land quality "availibility of water (for plant growth)".

Rn: Ratings for the land quality "availibility of nutrients (for plant growth related produce)".

Re: Ratings for the land quality "resistance against erosion".

Ro: Ratings for the land quality "availability of oxygen in the rootzone".

Rc: Ratings for the land quality "ease of cultivation".

Rv: Ratings for the land quality "absence of hindrance by vegetation".

Rf: Ratings for the land quality "availability of foothold for roots".

Rooting depth A: Moderately deep to deep

B: Shallow to moderaterly deep

(i): This Land Unit knows only one growing season. The rating for water availability to moderately deep to deep rooting crops is 3; for shallow to moderately deep rooting crops 5.

(ii): This Land Unit knows only one growing season. The rating for water availability to moderately deep to deep rooting crops is 1; for shallow to moderately deep rooting crops 2.

(iii): This Land Unit knows only one growing season for moderately deep to deep rooting crops. The rating for water availability to these crops is 3. The rating for water availability to shallow to moderately deep rooting crops is 5 for both growing seasons.

(iv): For moderately deep to deep rooting crops there is only one growing season in this Land Unit. The rating for water availability to these crops is 2. The rating for water availability to shallow rooting crops is 4 in the first growing season and 5 in the second growing season.

(v): This Land Unit knows only one growing season for all crops. The rating for water availability to shallow to moderately deep rooting crops is 3; for water availability to deep rooting crops 2.

1*: The rating of the land quality "availability of oxygen in the rootzone" is 1 in most of this unit. An exception forms the valley bottom which has rating 5.

5.4 THE MATCHING PROCEDURE AND THE SUITABILITY CLASSIFICATIONS.

After identification of relevant land units and their ratings, these ratings were compared to the land use requirements of the 15 LUTs under consideration. The matching procedure makes use of conversion tables (table 46.a to 46.o). In these tables, the suitability class for a LUT can be judged from the ratings for each individual land quality. The final suitability of the land unit for a specified LUT is then determined by the most limiting land quality.
The results of the matching procedure are given in Table 47, where the suitability class of each land unit is given for all LUTs considered. table 48 shows in which land units certain suitabilities for given LUTs occur.

Table 46a-o: Conversion tables for the LUTs and land qualities considered

Table 46-a. TEA

	Rt	Rw	Rn	Re	Ro	Rc	Rv
S1	1-3	1+2	1	1-3	1	1+2	1+2
S2	4+5	3+5	2+3	4	2	3	3
S3	6	4+5	3+4		3	4+5	4
N							

Table 46-b. COFFEE

	Rt	Rw	Rn	Re	Ro	Rc	Rv
S1	2+3	1-3	1+2	2	1	1+2	1+2
S2	1+4	4+5	2+3	3	2	3	3
S3	4+5	5	3+4	4	2	4+5	4
N	6	6+7	4		3-5	5	

Table 46-c. BEANS

	Rt	Rw	Rn	Re	Ro	Rc	Rv
S1	1-4	1-5	1+2	1+2	1	1+2	1
S2	4+5	5+6	3	3	2	3	2
S3	5	6	4	4	2	4+5	3
N	6	7			3-5	5	4

Table 46-d. MAIZE

	Rt	Rw	Rn	Re	Ro	Rc	Rv
S1	1-3	1-5	1+2	1	1	1+2	1
S2	4	5+6	2+3	2	1	3	2
S3	5+6	6	4	3	2	4+5	3
N		7		4	3-5	5	4

Table 46-e. BANANA

	Rt	Rw	Rn	Re	Ro	Rc	Rv
S1	1+2	1+2	1	1	1-3	1	1
S2	3+4	3	2+3	2	4	2	2
S3	5+6	4	3	3	5	3	3
N		5-7	4	4		4+5	4

Table 46-f. CASSAVA

	Rt	Rw	Rn	Re	Ro	Rc	Rv
S1	2	1-4	1+2	1+2	1	1	1
S2	1+3	4+5	2+3	2+3	2	2	2
S3	4	6	4	3	2	3	3
N	5+6	7		4	3-5	4+5	4

Table 46-g. COTTON

	Rt	Rw	Rn	Re	Ro	Rc	Rv
S1	1+2	1-4	1	1	1+2	1+2	1
S2	3	4+5	2+3	2	2	3	2
S3	4	6	4	3	3	4+5	3
N	5+6	7		4	4+5	5	4

Table 46-h. SUNFLOWER

	Rt	Rw	Rn	Re	Ro	Rc	Rv
S1	1-3	1-5	1+2	1	1	1+2	1
S2	4	5	2+3	2	1	3	2
S3	5+6	6	4	3	2	4+5	3
N		7		4	3-5	5	4

Conversion table cont'd

Table 46-i. SORGHUM

	Rt	Rw	Rn	Re	Ro	Rc	Rv
S1	1+2	1-4	1+2	1	1+2	1+2	1
S2	3+4	5+6	2+3	2	3	3	2
S3	5	7	4	3	3	4+5	3
N	6	7		4	4+5	5	4

Table 46-j. MILLET

	Rt	Rw	Rn	Re	Ro	Rc	Rv
S1	1+2	1-5	1+2	1	1	1+2	1
S2	3	6	2+3	2	2	3	2
S3	4	7	4	3	2	4+5	3
N	5+6	7		4	3-5	5	4

Table 46-k. SWEET POTATO

	Rt	Rw	Rn	Re	Ro	Rc	Rv
S1	1+2	1-5	1+2	1+2	1+2	1	1
S2	3+4	5+6	3	3	3	2	2
S3	5+6	6	4	4	4	3	3
N		7			5	4+5	4

Table 46-l. TOBACCO

	Rt	Rw	Rn	Re	Ro	Rc	Rv
S1	1+2	1-5	1	1	1	1+2	1
S2	3	5+6	2	2	2	3	2
S3	4	6	3	3	3	4+5	3
N	5+6	7	4	4	4+5	5	4

Table 46-m. PIGEON PEAS

	Rt	Rw	Rn	Re	Ro	Rc	Rv
S1	1+2	1-5	1+2	1+2	1	1+2	1
S2	3	5	3	3	2	3	2
S3	4	6	4	3	3	4+5	3
N	5+6	7		4	4+5	5	4

Table 46-n. COW PEAS

	Rt	Rw	Rn	Re	Ro	Rc	Rv
S1	1+2	1-5	1+2	1	1+2	1+2	1
S2	3	5	3	2	3	3	2
S3	4	6	4	3	4	4+5	3
N	5+6	7		4	5	5	4

Table 46-o. GREEN GRAM

	Rt	Rw	Rn	Re	Ro	Rc	Rv
S1	1+2	1-5	1+2	1	1	1+2	1
S2	3	5+6	3	2	2	3	2
S3	4	6	4	3	3	4+5	3
N	5+6	7		4	4+5	5	4

Table 47. The suitability classifications

LAND UNIT	TEA	COFFEE	BEANS	MAIZE	BANANA	CASSAVA	COTTON	SUNFLOWER	SORGHUM	MILLET	SW. POTATO	TOBACCO	PIGEON PEA	COW PEA	GREEN GRAM
1*	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
2*	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
3	land unit 3 does not exist														
4	N	N	S3	S3	N	S3	S3	iv	iv	iv	N	N	S3	S3	S3
5	N	N	S3	N	N	N	S3	N	iv	iv	N	N	S3	S3	S3
6	S3	S3	S3	N	N	N	N	N	N	N	S3	N	N	N	N
7	N	N	S3	S3	N	S3	S3	S3	iv	iv	S3	N	S3	S3	S3
8	N	N	S3	N	N	N	S3	N	S3	S3	N	N	S3	S3	S3
9	N	N	S3	S3	N	S3	S3	S3	iv	iv	S3	N	S3	S3	S3
10	S3	S2	S2	S3	S3	N	S3	S3	S3	S3	S3	S3	S3	S3	S3
11	ii	S3	S2	S3	S3	N	N	S3	S3	N	S3	N	N	N	N
12	ii	S3	S3	S3	S3	N	N	S3	S3	N	S3	N	N	N	N
13	ii	ii	S2	S2	ii	S3	S3	S2	S2	S3	S2	S3	S3	S3	S3
14	ii	ii	S3	ii	ii	S3	S3	ii	ii	S3	S3	S3	S3	S3	S3
15	ii	S2	S2	S2	ii	S2	S2	S2	S2	S2	S2	S3	S2	S2	S2
16	ii	S2	S3	ii	ii	S3	ii	ii	ii	ii	S3	S3	ii	ii	ii
17	N	N	S2	S3	N	S3	S3	S3	S2	S2	S3	S3	S3	S3	S3
18	N	N	S3	S3	N	S3	S3	S3	ii	ii	S3	S3	S3	S3	S3
19*	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
20*	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
21	S3	S3	S2	S2	N	ii	S2	S3	ii	S2	S3	S3	ii	ii	ii
22	N	N	N	N	N	N	N	N	iv	iv	N	N	N	N	N
23	N	N	S3	S3	N	S3	S3	S3	ii	ii	S3	S3	S3	S3	S3
24	N	N	ii	ii	N	S3	ii	S3	ii	ii	S3	S3	ii	ii	ii
25	N	N	ii	ii	N	S3	S3	S3	S2	S2	S3	S3	ii	ii	S3
26	S3	S2	i	S2	iv	ii	ii	ii	S2	ii	S2	ii	ii	ii	S2
27	S2	S2	i	S2	ii	S2	S2	S2	S2	S2	S2	ii	S2	S2	S2
28	iv	S3	i	S2	N	ii	S2	ii	S2	S2	S2	ii	S2	S2	S2
29	S2	S2	i	ii	ii	ii	ii	ii	S2	ii	S2	ii	S2	S2	S3
30	N	N	ii	S3	N	S3	S3	S3	S2	S2	S3	S3	S3	S3	S3
31	N	N	S3	S3	N	S3	S3	S3	ii	ii	S3	S3	S3	S3	S3
32	N	N	N	N	N	N	N	N	iv	iv	N	N	N	N	N
33	N	N	ii	ii	N	S3	S3	S3	ii	ii	S3	S3	ii	ii	S3
34	N	N	S3	S3	N	S3	S3	iv	ii	ii	N	S3	S3	S3	S3
35	N	N	S3	S3	N	S3	S3	iv	ii	ii	S3	S3	S3	S3	S3
36	N	N	S3	S3	N	S3	S3	S3	ii	ii	S3	S3	ii	ii	S3
37	N	N	S3	S3	N	S3	S3	S3	S3	S3	S3	N	S3	S3	S3
38	N	N	N	N	N	N	N	N	iv	iv	N	N	N	N	N
39	iv	iv	ii	ii	iv	ii	ii	ii	ii	ii	ii	iv	ii	ii	ii
40*	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
41	S3	S3	ii	ii	iv	iii	iii	ii	ii	ii	ii	iv	ii	ii	ii
42	S3	S3	ii	ii	N	ii	ii	S3	ii	ii	S3	iv	ii	ii	ii

43	N	N	S3	S3	N	S3	S3	S3	ii	ii	S3	iv	S3	S3	S3
44	N	N	ii	ii	N	S3	S3	S3	ii	ii	ii	iv	ii	ii	ii
45	S3	S3	ii	ii	iv	ii	ii	ii	ii	ii	ii	iv	ii	ii	ii
46	N	N	ii	ii	N	ii	S3	S3	ii	ii	S3	iv	ii	ii	ii
47	N	N	S3	S3	N	S3	S3	S3	ii	ii	iv	iv	S3	S3	S3

* These units are located in protected forest areas. This fact makes them unsuitable for all the kinds of land use taken in consideration.

i = S1-S2
ii = S2-S3
iii = S2-N
iv = S3-N

Table 48. The suitability areas for the LUTs under consideration

LUT	suitability class	land units showing this suitability
Tea	S2	27,29
	S3	6,10,21,26,41,42,45
	S2-S3	11-16
	S3-N	28,39
	N	1,2,4,5,7-9,17-20,22-25,30-38, 40,43,44,46,47
Coffee	S2	10,15,16,26,27,29
	S2-S3	13,14
	S3	6,11,12,21,28,41,42,45
	S3-N	39
	N	1,2,4,5,7-9,17-20,22-25, 30-38,40,43,44,46,47
Beans	S1-S2	26-29
	S2	10,11,13,15,17,21
	S2-S3	24,25,30,33,39,41,42,44-46
	S3	4-9,12,14,16,18,23,31,34-37,43,47
	N	1,2,19,20,22,32,38,40
Maize	S2	13,15,21,26-28
	S2-S3	14,16,24,25,29,33,39,41,42,44-46
	S3	4,7,9-12,17,18,23,30,31,34-37,43,47
	N	1,2,5,6,8,19,20,22,32,38,40
Banana	S2-S3	13-16,27,29
	S3	10-12
	S3-N	26,39,41,45
	N	1-9,17-25,28,30-38,40,42-44,46,47
Cassava	S2	15,27
	S2-S3	21,26,28,29,39,42,45,46
	S2-N	41
	S3	4,7,9,13,14,16-18,23-25,30,31, 33-37,43,44,47
	N	1,2,5,6,8,10-12,19,20,22,32,38,40
Cotton	S2	15,21,27,28
	S2-S3	16,24,26,29,39,42,45
	S2-N	41
	S3	4,5,7-10,13,14,17,18,23,25,30,31, 33-37,43,44,46,47
	N	1,2,6,11,12,19,20,22,32,38,40
Sunflower	S2	13,15,27
	S2-S3	14,16,26,28,29,39,41,45
	S3	7,9-12,17,18,21,23-25,30,31,33,36, 37,42-44,46,47
	S3-N	4,34,35
	N	1,2,5,6,8,19,20,22,32,38,40

Table 48. Cont'd

LUT	suitability class	land units showing this suitability
Sorghum	S2	13,15,17,25-30
	S2-S3	14,16,18,21,23,24,31,33-36,39,41-47
	S3	8,10-12,37
	S3-N	4,5,7,9,22,32,38
	N	1,2,6,19,20,40
Millet	S2	15,17,21,25,27,28,30
	S2-S3	16,18,23,24,26,29,31,33-36,39,41-47
	S3	8,10,13,14,37
	S3-N	4,5,7,9,22,32,38
	N	1,2,6,11,12,19,20,40
Sweet potato	S2	13,15,26-29
	S2-S3	39,41,44,45
	S3	6,7,9-12,14,16-18,21,23-25,30,31, 33,35-37,42,43,46
	S3-N	47
	N	1,2,4,5,8,19,20,22,32,34,38,42
Tobacco	S2-S3	26-29
	S3	10,13-18,21,23-25,30,31,33-36
	S3-N	39,41-47
	N	1-9,11,12,19,20,22,32,37,38,40
Pigeon pea	S2	15,27-29
	S2-S3	16,21,24-26,33,36,39,41,42,44-46
	S3	4,5,7-10,13,14,17,18,23,30,31,34, 35,37,43,47
	N	1,2,6,11,12,19,20,22,32,38,40
Cow pea	S2	15,27-29
	S2-S3	16,21,24-26,33,36,39,41,42,44-46
	S3	4,5,7-10,13,14,17,18,23,30,31,34, 35,37,43,47
	N	1,2,6,11,12,19,20,22,32,38,40
Green gram	S2	15,26-28
	S2-S3	16,21,24,39,41,42,44-46
	S3	4,5,7,10,13,14,17,18,23,25,29-31, 33-37,43,47
	N	1,2,6,11,12,19,20,22,32,38,40

6. APPENDICES

APPENDIX 6.5 LEGENDS OF LOOSE MAPS

LEGEND OF THE RECONNAISSANCE SOIL MAP.

See Appendix 6.1 (loose) and simplified soil map (Fig. 25)

M MOUNTAINS
(reliëf intensity over 300 m, slopes over 30%)

MQ Soils developed on migmatites, granitoid gneisses and granites.
MQC complex of well drained, reddish brown to brown soils of varying depth, texture and rockiness
(orthic LUVISOLS, eutric REGOSOLS, CAMBISOLS and LITHOSOLS)

MB Soils developed on basic to ultrabasic rocks.
MBP somewhat excessively drained, shallow to moderately deep, dark reddish brown to dark brown, sandy loam to sandy clay loam
(eutric REGOSOLS and LITHSOLS)

H HILLS AND MINOR SCARPS (reliëf intensity 100 m, slopes 8-30%).

HQ Soils developed on granitoid gneisses.
HQC complex of somewhat excessively drained, dark reddish brown to strong brown, friable soils of varying depth, texture, stoniness and rockiness
(eutric CAMBISOLS, chromic LUVISOLS, chromic ACRISOLS, eutric REGOSOLS, partly lithic phase, and LITHOSOLS)

HU Soils developed on undifferentiated gneisses.
HUC complex of well drained, dark reddish brown to brown, gravelly soils of varying depth, texture, stoniness and rockiness
(eutric and dystric CAMBISOLS, eutric REGOSOLS and LITHOSOLS)

HI Soils developed on phonolites.

HIC complex of well drained, very shallow to deep, dark reddish brown to brown, friable sandy clay loam to sandy clay; in places very gravelly or rocky
(dystric CAMBISOLS, dystric REGOSOLS and LITHOSOLS)

HB Soils developed on basic to ultrabasic rocks.

HBC complex of somewhat excessively drained, shallow to moderately deep, dark reddish brown to dark brown, gravelly soils of varying texture, stoniness and rockiness
(eutric and calcaric REGOSOLS and LITHOSOLS)

HP Soils developed on consolidated pyroclastic rocks (Lahar Complex).

HPC complex of well drained, dark red to brown, friable clay soils of varying depth, with an acid humic topsoil of varying thickness
(chromic and orthic ACRISOLS, locally LITHOSOLS)

R <u>FOOTRIDGES</u> (dissected middle slopes of volcanic mountains, relief intensity 50-100 m, slopes on valley sides 5 to 16%).

RP Soils developed on consolidated pyroclastic rocks (Lahar Complex).

RP1h well drained, very deep, dark reddish brown to yellowish red and dark red, friable clay with an acid humic top soil
(dystric and humic NITISOLS*, partly dystric ACRISOLS)

RP2 well drained, very deep, dark reddish brown, friable clay
(dystric and chromic CAMBISOLS and humic ACRISOLS)

L <u>PLATEAUS</u> (reliëf intensity less than 50 m, slopes 0-8%).

LP Soils developed on consolidated pyroclastic rocks (Lahar Complex).

LP1 well drained to moderately well drained, very deep, dark reddish brown, friable clay
(chromic and humic ACRISOLS, in low areas ferric ACRISOLS)

LP2P well drained, very shallow, dark brown, friable, very gravelly, stony and rocky, sandy loam to sandy clay loam
(LITHOSOLS)

LPC complex of well drained, dark reddish brown to brown, very gravelly, sandy clay loam to sandy clay soils of varying depth, consistancy, stoniness and rockiness
(dystric CAMBISOLS, pisoferric and partly lithic phase)

LI Soils developed on Phonolite.

LIC complex of well drained dark reddish brown to brown, friable, very gravelly sandy clay loam to sandy clay soils of varying depth, stoniness and rockiness
(dystric CAMBISOLS, LITHOSOLS and rock outcrops)

LB Soils developed on basic to ultrabasic rocks.

LB well drained, deep, red to dark reddish brown, gravelly and stony, friable sandy clay loam to clay soils
(ferric ACRISOLS, partly pisoferric phase)

U <u>UPLANDS</u>.

U1 <u>HIGH LEVEL UPLANDS</u>, volcanic origin (altitude over about 900 m, reliëf intensity less than 50 m, slopes 0-16%).

U1P Soils developed on consolidated pyroclastic rocks (Lahar Complex).

U1P1h well drained, very deep, dark red to dark reddish brown, friable clay, with acid humic topsoil
(dystric and humic NITISOLS*)

U1P2 well drained, moderately deep to deep, dark red to dark reddish brown, friable clay
(chromic ACRISOLS)

U1PC complex of somewhat excessively drained, dark reddish brown to brown, gravelly sandy clay to clay soils of varying depth, stoniness and rockiness
(dystric CAMBISOLS, ferric ACRISOLS, partly lithic phase, and LITHOSOLS)

U2 <u>LOWER LEVEL UPLANDS</u>, basement system.
(altitude less than about 900 m, reliëf intensity less than 50 m, slopes 0-16%)

U2Q Soils developed on granitoid gneisses.

U2Q1p well drained, mainly moderately deep, dark reddish brown, gravelly sandy clay loam to clay
(chromic LUVISOLS, in places ferric ACRISOLS)

U2Q2P well drained, shallow, dark reddish brown, gravelly and stony, sandy clay loam to clay; in places rocky
(chromic LUVISOLS, and CAMBISOLS partly lithic phase, in places calcic, and LITHSOLS)

U2QC complex of well drained, red to dark reddish brown, gravelly, sandy clayloam to clay soils, of varying depth, stoniness and rockiness
(orthic and chromic LUVISOLS and eutric REGOSOLS, partly lithic phase)

U2F Soils developed on gneisses, rich in ferro-magnesian minerals.

U2F1 well drained, deep to very deep, dark reddish brown to dark red, friable, sandy clay to clay in places gravelly
(orthic and chromic LUVISOLS)

U2F2p well drained, moderately deep, dark red to darkbrown, friable sandy clayloam to clay; in places fairly gravelly and stony or calcareous; occasional rock outcrops
(orthic and chromic LUVISOLS, partly calcic LUVISOLS)

U2F3P well drained, shallow, red to dark reddish brown, friable sandy loam to sandy clay loam; in places fairly stony and rocky
(chromic LUVISOLS and partly LITHOSOLS)

U2FC1 complex of dark red to strong brown, gravelly sandy clayloam to clay soils of varying depth, stoniness and rockiness
(orthic, chromic and calcic LUVISOLS, and CAMBISOLS, and humic and ferric ACRISOLS)

U2FC2 complex of well drained, very gravelly, stony and rocky soils of varying depth, colour, consistance and texture
(eutric REGOSOLS, CAMBISOLS and LUVISOLS, partly lithic phase and LITHOSOLS)

U2U Soils developed on undifferentiated banded gneisses

U2UC complex of somewhat excessively drained, red to dark reddish brown, very gravelly loamy to clayey soils of varying depth, stoniness and rockiness
(chromic LUVISOLS, eutric REGOSOLS, in places lithic phase, and LITHOSOLS)

U2X1 Soils developed on various parent materials (mainly colluvium)

U2X1C Complex of well drained, red to dark brown, gravelly very stony and bouldery clay soils of varying depth (chromic and ferric LUVISOLS, ferric ACRISOLS and eutric REGOSOLS, partly lithic phase)

U2X2 Soils developed on pleistocene alluvial sediments over basement complex

U2X2p well drained, moderately deep to deep, red to dark reddish brown, slightly gravelly, sandy clayloam to clay; in places calcareous
(ferric and chromic LUVISOLS, partly vertic and calcic LUVISOLS)

P PLAINS
(relief intensity less than 10 m, slopes 0-5%).

PP Soils developed on consolidated pyroclastic rocks (Lahar Complex).

PPC complex of well drained, dark reddish brown to dark brown, rocky, friable sandy clay soils of varying depth and stoniness
(orthic LUVISOLS and LITHOSOLS)

B BOTTOMLANDS ("volcanic sinkholes")
(relief intensity less than 5 m, slopes less than 2%.

BP Soils developed on consolidated pyroclastic rocks (Lahar Complex)

BPC complex of mottled clay soils of varying drainage condition, depth and colour; in places overlying petroplintite (murram)
(gleyic and ferric ACRISOLS, plintic and vertic GLEYSOLS and pellic VERTISOLS)

V VALLEYS

V1 MAJOR VALLEYS

(relief intensity 50-100 m, slopes of valley-sides 8-30%)

V1P Soils developed on consolidated pyroclastic rocks (Lahar Complex)

V1PC Complex of well drained, dark reddish brown, friable clay soils of varying depth and rockiness
(dystric NITISOLS*, humic and chromic ACRISOLS, chromic LUVISOLS, partly petroferric phase, LITHOSOLS and rock outcrops)

V2 MINOR VALLEYS

(relief intensity less than 50 m, slopes of valley-sides 8-30%)

V2P Soils developed on consolidated pyroclastic rocks (Lahar Complex)

V2P Well drained, deep, dark red to dark reddish brown, friable clay; in places rock outcrops
(dystric and humic NITISOLS*, and humic, and plintic ACRISOLS)

V2PC complex of well drained, dark reddish brown, friable clay soils of varying depth, stoniness and rockiness
(chromic, ferric and calcic LUVISOLS, partly lithic phase, and rock outcrops)

V2X Soils developed on various parent materials.

V2X Complex of well drained, dark red to dark brown, very gravelly, loamy and clayey soils of varying depth, stoniness and rockiness
(ferric ACRISOLS, dystric CAMBISOLS, LITHOSOLS and rock outcrops)

CHUKA SOUTH AREA

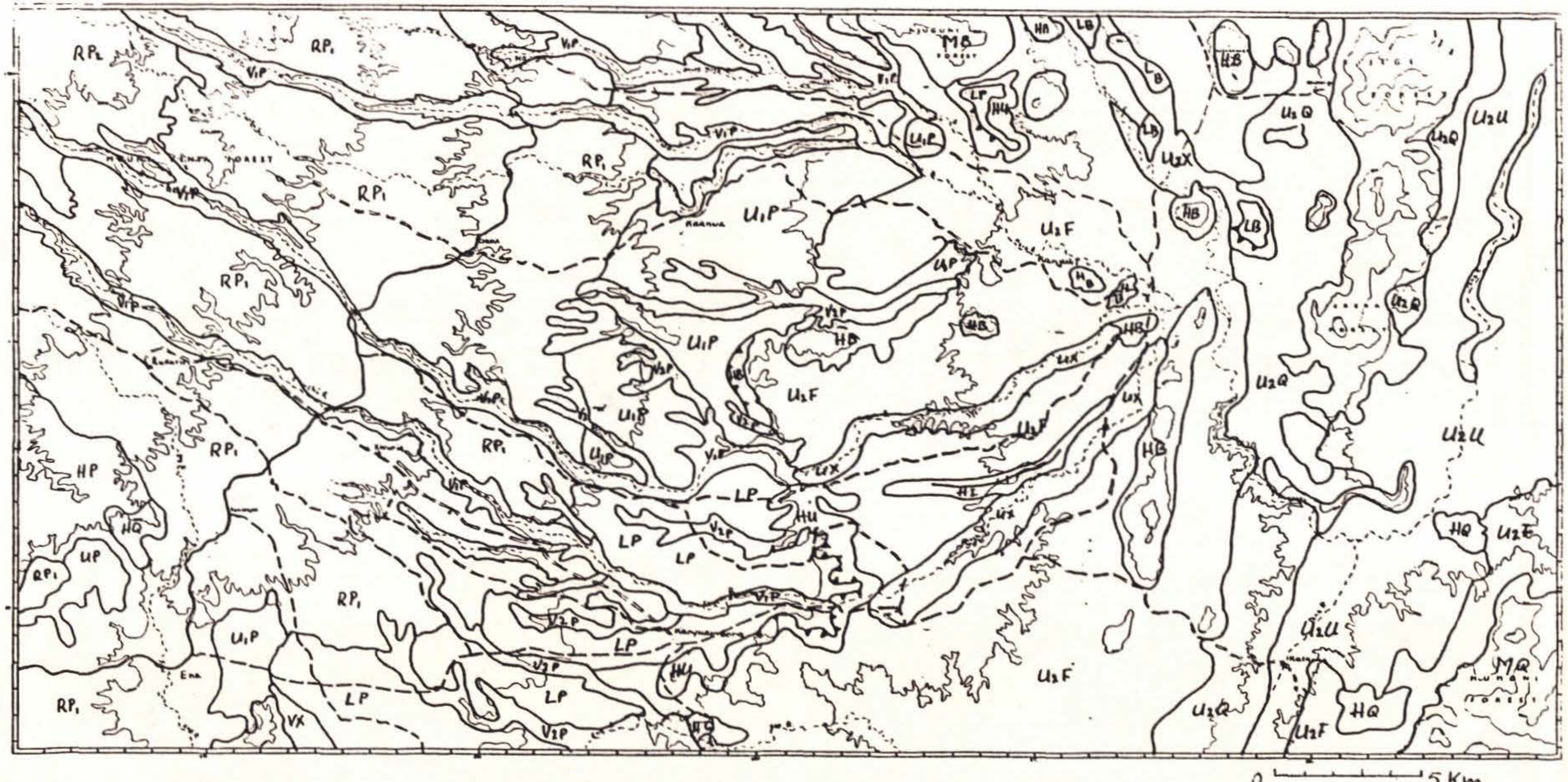


Fig. 25 Simplified soil map. For explanation see text of soil legend App. 6.5

LEGEND : contours (m) Asphalt rd. Metalled rd. River

THE LEGEND OF THE MAP OF GEOLOGY AND HYDROLOGICAL PROPERTIES.

See Appendix 6.2 (loose)

Quaternary

Colluvial deposits: C

: Non sorted mixture of clay, sand, gravel, and boulders of various origin. Locally springs and near surface water occur at contact zones with underlying rocktypes.

Fluviatiel deposits: F

F1: Terrace deposits : Flat areas with a generally thicker saprolite, sometimes a poorly sorted mixture of gravel and stones occurs. locally small springs from conglomerates occur, no extended groundwater bodies.

F2: Riverbed deposits : Poorly sorted fairly isotropic sandy deposits with extended groundwater bodies at various depths.

Tertiary and Quarternary

Lava flows: V

: Basalt and phonolite lava flows with columnar jointing. These deposits have only a limited thickness and are too well drained to contain a groundwater body.

Lahar complex: L

Llb: Sloping lahars : Predominantly sloping lahars with some enclosed lava flows. These lahars show a dense pattern of joints.
Always aquifers between 50-100 m and sometimes near surface water in the thick regolith zone. Sometimes springs occur in steep valleys.

Lla: Plateau like lahars : Predominantly flat lahar deposits with some enclosed lava flows. These lahars show a dense pattern of joints. Aquifers to be expected between 50-100 m in the western part of this unit and always near surface water in the thick regolith zone during the rainy seasons. Springs at steep valleys and at scarps.

L2: Lahars overlying granitoids : Predominantly a thick regolith zone originating from lahar deposits overlying granitoid rocks with near surface water in this regolith zone and no water to be expected in the fractures of underlying roctypes.

Pre-Cambium

Gabbroic-ultramafic complex: M

: Complex of gabbros, granulites and other ultramafic rocktypes. These rocks have only a few tight fractures and one fault. These fractures probably only contain some very limited amounts of water.

Granitoids: G

G1: Granites and Granodiorites : Mountainous granite and granodiorite massives with many undeep fractures but locally with major joints and faults. Groundwater in fractured zones along major faults and joints.

G2: Gneissose granites : These gneissose granites and augengneises show an intermediate dense jointing pattern. These hilly units are too small to contain extended aquifers.

G3: Granitoid gneisses : These anisotropic granitoid gneisses show a dense jointing pattern. This unit probably contains larger groundwater bodies, especially along the inselbergs of unit G1.

Banded migmatic gneisses complex: X

X1: Granulites	: These impermeable granulites show only very tight jointing. There is no groundwater to be expected in these hilly units.
X2: Succession of various banded gneisses with granitoids	: This banded complex of gneisses shows extended major granitoid bands and a rectangular jointing pattern. This unit is liable to contain large groundwater bodies especially along the inselbergs of unit G1.
X3: Banded gneisses rich in gabbro veins and granulites	: This complex shows only undeep very frequent fracturing. No groundwater bodies are to be expected in this unit.
X4: Hornblende-plagioclase gneisses with migmatitic and granulitic bands	: This complex shows usually undeep fracturing. Along the granulites more fractured zones are found which probably contain some groundwater. Gneisses in general better fractured than in unit X3. Small groundwater bodies more probable than in previous X-units.
X5: Hornblende-, biotite- and hornblende-biotite gneisses and migmatites	: This gneiss complex has usually undeep fractures. The area along the G1 unit is rich in migmatites. Most migmatites show only some very tight fractures. The gneisses show in general the best developed joint system of all X-units. Expecially extension zone of the fault in the adjacent G1-unit is very liable to contain groundwater.

Quartzites and Muscovite-schists: Q

: This banded quartzite schist complex shows only some tight fractures. especially the schists are very impermeable. Therefore this unit is not very liable to contain considerable amounts of water.

Strike outcrops :

Fault :

Lineament :

Scarp :

Depression :

Strike and dip :

Wells :

Springs :

Seepage zone :

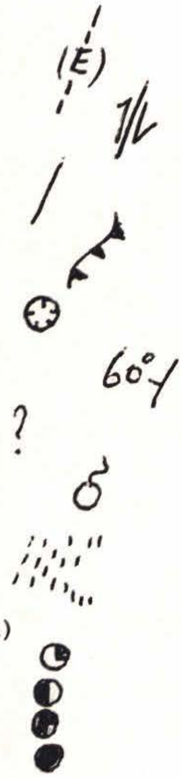
Electrical conductivity (S/cm)

0-250 (low) :

250-750 (medium) :

750-2250 (high) :

>2250 (very high) :



THE LEGEND OF THE VEGETATION AND LANDUSE MAP OF THE CHUKA-SOUTH AREA.

See Appendix 6.3 (loose)

1. *Ocotea usambarensis - Strombosia scheffleri Ls.*
Mountain Rain Forest on Mountain Footridges, developed on Mt. Kenya volcanics.

1.1. *Podocarpus milanjianus - Galiniera coffeoides.*
Montane Rain Forest above 1950 m on Mountain Footridges.

1.2. *Ocotea usambarensis - Strombosia scheffleri.*
Sub-montana Rain Forest 1700-1950 m on Mountain Footridges.

1.3. *Prunus africana - Celtis africana.*
Transitional Rain Forest ± 1600-1700 m on Mountain Footridges.

1.4. *Ensete ventricosum - Newtonia buchani.*
Forest in steep Valleys of Mountain Footridges.

2. *Croton megalocarpus - Coffea arabica Ls.*
Very intensively cultivated land on Mountain Footridges, developed on Mt. Kenya volcanics.

2.1. *Pteridium aquilinum - Camellia sinensis.*
Intensively cultivated land with tea plantations and small dairy pastures on Mountain Footridges.

2.2. *Croton megalocarpus - Coffea arabica.*
Intensively cultivated land with coffee plantations, on Mountain Footridges.

2.3. *Eucalyptus camaldulensis - Pinus radiata.*
Plantation forest on Mountain Footridges.

2.4. *Albizia gummifera - Newtonia buchani.*
Woodland along the river and scattered in the whole Valley with Farmland.

2.5. *Albizia gummifera - Newtonia buchani.*
Farmland with Woodland along the river in Valley.

2.6. *Musa sp. - Coffea arabica.*
Farmland without trees in Valley.

3. *Dombeya rotundifolia - Mangifera indica Ls.*
Intensively cultivated land on Plateaus and (volcanic) Uplands, developed on Mr. Kenya volcanics.

3.1. *Mangifera indica - Zea mays.*
Intensively cultivated Farmland with a treecover < 20%, on strongly dissected Plateaus.

3.2. *Dombeya rotundifolia - Mangifera indica.*
Farmland, less intensively cultivated than 3.1, same tree cover on Plateaus.

3.3. *Lantana camara - Zea mays.*
Farmland and Fallowland in chess-board form, on volcanic Uplands.

3.4. *Newtonia buchani - Albizia gummifera.*
Woodland along the river and farmland in Valleys.

3.5. *Musa sp. - Zea mays.*
Farmland in Valleys.

4. *Combretum zeyheri - Combretum binderianum Ls.*
Extensively cultivated Bushland and Woodland on Plateaus and volcanic Uplands, developed on Mt. Kenya volcanics.

4.1. *Combretum zeyheri - Heteropogon contortus.*
Homogeneous Bushland extensively cultivated (< 30% Farmland) on Plateau and volcanic Uplands.

4.2. *Combretum zeyheri - Zea mays.*
Farmland (1/2) and Bushland (1/2) in chess-board form in volcanic Uplands.

4.3. *Aloe secundiflora - Euphorbia nyikae.*
Thicket and Bushland on often very shallow soils at the edge of the Plateau.

4.4. *Heteropogon contortus - Euphorbia nyikae.*
Complex of 4.1. (75%) and 4.3. (25%).

4.5. *Zornia apiculata - Ocimum basilicum.*
Grassland with shrubby herbs on Plains (lahar) and Plateaus.

4.6. *Combretum zeyheri - Terminalia brownii.*
Woodland on Plateaus (basalt) or Plains (lahar).

4.7. *Euphorbia nyikae - Acacia brevispica.*
Farmland and Thicket in Valleys with shallow soils, partly developed of Basement System.

4.8. *Combretum binderianum - Combretum zeyheri.*
Bushland in Valleys.

5. *Hyparrhenia sp. - Heteropogon contortus Ls.*
Very extensively cultivated Wooded Grassland on Hills and Mountains, developed on (basic) Intrusives in Basement System.

5.1. *Gardenia jovis-tonantis - Heeria reticulata.*
Scrub forest with a tree cover < 75%, on Mountains or Hills.

5.2. *Heeria reticulata - Heteropogon contortus.*
Wooded Grassland with a treecover < 25% on Mountains or Hills.

5.3. *Gardenia jovis-tonantis - Heeria reticulata.*
Bushland on Footslopes transition to landscape 6.

5.4. *Hyparrhenia sp. - Heteropogon contortus.*
Wooded Grassland on Footslopes, transition to landscape 6.

6. *Acacia senegal - Commiphora africana Ls.*

6.1. *Bauhinia tomentosa - Acacia brevispica.*
Thicket on the Footslope of the Plateau and areas which are highly influenced by the colluvium and water from it.

6.2. *Commiphora holziana - Commiphora africana.*
Thicket on Hills and Mountains.

6.3. *Acacia senegal - Commiphora africana.*
Thicket in Uplands.

6.4. *Pennisetum typhoides - Commiphora africana.*
Mosaic form of Farmland (50%) and Thicket (50%), typical bush-fallow system.

6.5. *Pennisetum typhoides - Commiphora africana.*
Thicket (50-75%) and Farmland (25-50%), no mosaic form.

6.6. *Pennisetum typhoides - Aristida adscensionis.*
Farmland and bush along the streams.

6.7. Farmland (75%) and Bushland and Woodland, large areas of both types without changes.

6.8. Farmland (75%) and a relative high treecover.

6.9. *Pennisetum typhoides* - cotton.
Farmland in Uplands.

6.10 *Tephrosia sp. - Cassia orientalis.*
Intensively cultivated Farmland on River-terrace.

6.11 *Acacia rovumae - Hyphaene thebaica.*
Farmland and Woodland along the river on Riverterras.

6.12 *Acacia mellifera - Acacia senegal.*
Bushland on River-terrace.

7. USP - *Ochna ovata Ls.*

7.1. *Ochna ovata - Acacia brevispica.*
Forest and Thicket on Kijegge - Kiere mountains.

7.2. USP - *Ochna ovata.*
Forest on Mumoni mountains.

7.3. Intensively cultivated area on mountains.

THE LEGEND TO THE MAP OF LAND UNITS FOR LAND EVALUATION.

(See Appendix 6.4) Please see Chapter 5.3 for full explanation.

APPENDIX 6.6: LIST OF ADMINISTRATIVE UNITS, DATA ON AREAS AND POPULATION AND MAP WITH LOCATIONS (Fig. 26) (Source: Population Census 1979).

Embu District

Division	Location	Sublocation	Population	Households	Area	Population Density
			numbers	numbers	km^2	people/km^2
Runyenjes	Gaturi-	.Kavulturi	4743	812	11	420
	North	.Kevote	4670	764	11	418
		.Kianjuki	3529	551	6	541
		.Makengi	3955	695	7	531
			12942			
	Gaturi-	Nembure	3301	518	7	425
	South	.Gatunduri	5028	810	13	382
		.Ena	3046	549	10	281
		.Githimu	4931	891	16	300
		Kithegi	3782	715	22	166
			20088			
	Kagaari-	.Nbuijeru	4116	704	13	298
	North	.Kianjokoma	2558	470	7	351
		.Kanja	4045	719	11	351
		.Gitare	2265	373	5	442
		.Mukuuri	3848	702	11	331
			16832			
	Kagaari-	.Gikuuri	5218	848	6	820
	South	.Kigaari	3733	672	11	339
		.Gichiche	3834	649	8	453
		.Gichera	4065	753	39	103
		.Kahanjara	2398	485	10	222
		.Nthagaiya	3933	776	23	166
		.Runyenjes TC	1566	454	1	932
			24747			

Division	Location	Sublocation	Population	Households	Area	Popu.Dens
	Kyeni-	.Rukuriri	3447	570	8	424
	North	.Kiangungi	3886	661	7	533
		.Mufu	2900	445	8	337
		.Kathari	5316	743	12	439
			15579			
	Kyeni-	.Kathanjuri	4833	799	8	569
	South	.Karuromo	3241	579	17	182
		.Kigumo	3028	488	11	261
		.Kathunguri	3736	681	16	220
		.Kasafari	558	107	8	66
			15396			
Siakago	Evurori	.Nguti	6173	1303	55	111
		.Evurore	4031	755	53	74
		.Thambu	2600	544	65	39
		.Kamarandi	2496	562	96	25
		Kathera	3756	917	69	54
			19056			
Total Embu District		Upper limit[1]	124610			
		Lower limit[2]	111132			
Meru District						
Nithi	Mangumoni	.Thuita	7366	1116	17	421
		.Mwonge	3651	563	5	620
		.Kabuboni	4096	655	8	476
		.Mukuuni	5703	991	22	249
		.Rubate	3425	579	9	378
		.Kamwimbi	3965	904	63	62
			28206			

Division	Location	Sublocation	Population	Households	Area	Popu.Dens
	Karingari	.Mugiritwa	6318	1004	14	426
		.Chuka	2040	347	5	408
		.Chuka TC	1361	454	1	829
		.Ndagani	7121	1151	21	329
		.Mwiro	5034	835	10	495
		.Gitarene	6136	1017	21	288
		.Marianni	3655	735	34	108
		.Kithangani	2318	504	37	62
			33983			
	Kanjuki	.Kanjuki	3960	694	59	66
		.Kaimande	1674	350	28	58
		.Mutino	3439	667	37	93
			9113			
	Muthambi	.Iringa	2785	488	10	276
		.Igamura	2580	446	6	410
		.Gatua	5339	875	15	346
		.Chamunga	3953	659	8	457
		.Kadunga	2735	542	22	119
		.Karimba	4984	854	18	275
			22376			
	Upper-Mwimbi	.Muligi	10492	1576	27	379
	Kiera/Mwimbi	.Mugumango	12637	2065	33	372
		Magutuni	12529	2353	94	131
			25202			
Tharaka	South-Tharaka	.Chiokariga	4859	1038	88	54
		.Kamanjuki	3554	615	137	26
			8443			
Total Meru District		Upper limit[1]	137815			
		Lower limit[2]	125250			

Division	Location	Sublocation	Population	Households	Area	Popu.Dens
Kitiu District						
Far North	Tharaka	Gakombe	1382	2658	16	11
		Kamaindi	2586	450	141	18
	Katze	.Mugunga-Ikonga	2246	379	93	24

Total Kitui District	Upper limit[1]	6214
	Lower limit[2]	2246
Total Map Sheets	Upper limit[1]	268639
Total Map Sheets	Lower limit[2]	238628

1. Upper Limit includes population of all mentioned locations and sublocations.
2. Lower Limit includes only population of those location and sub-locations marked with a point.

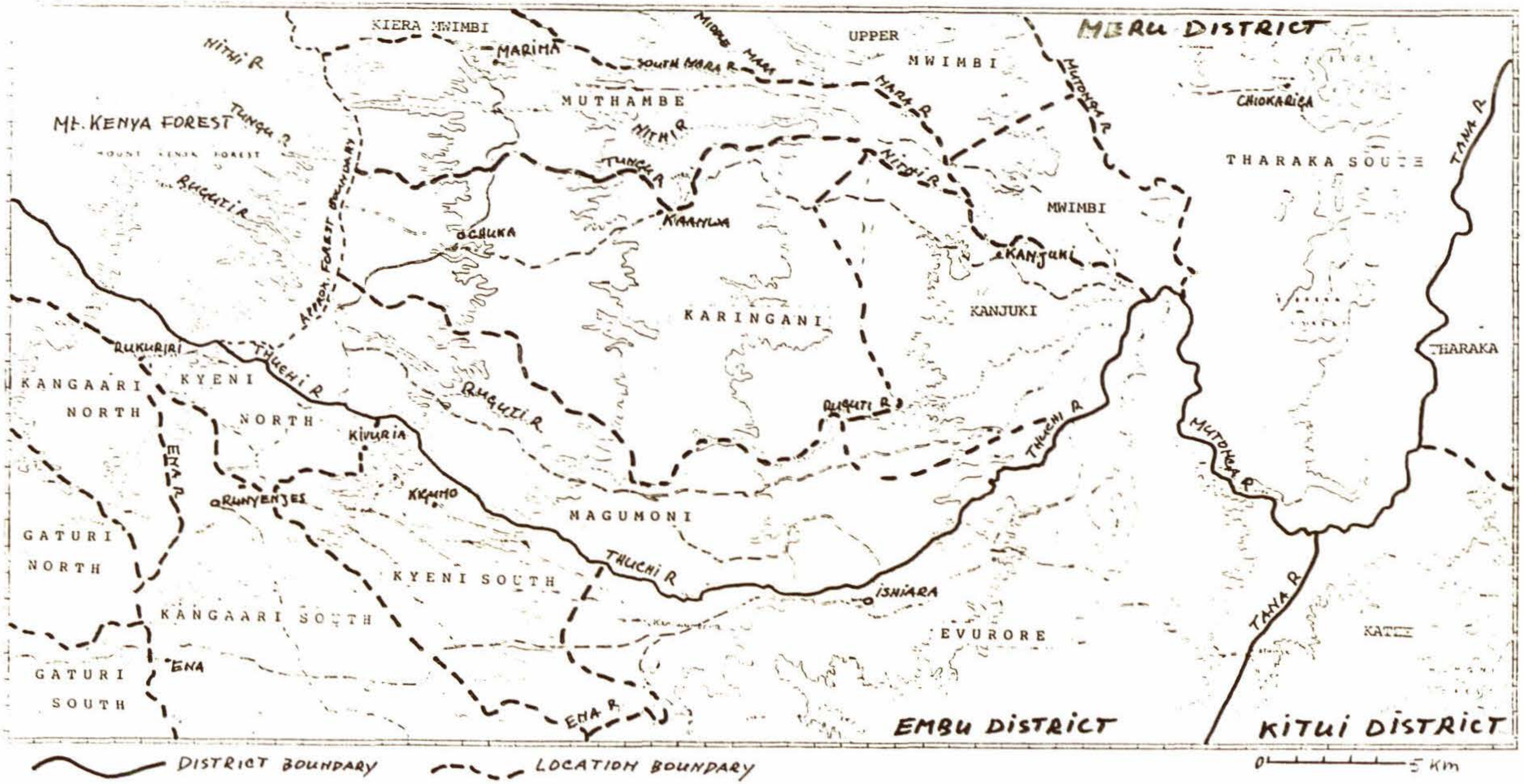


Fig. 26 The Chuka-South Area. Administrative boundaries of Districts and Locations.

APPENDIX 6.7: COLOR PLATES OF THE CHUKA-SOUTH AREA

Plate 1. Forest road in Mt.Kenya forest.
NW corner of Chuka-South Area
(photo A. Veldkamp).

Plate 2. Tea zone. Mt.Kenya forest at background. Soils are dystric and humic Nitisols*
(photo A. Veldkamp).

Plate 3. Volcanic Footridges, dissected by valleys. Coffee zone. View in Eastern direction. Soils are dystric and humic Nitisols* (photo T. de Meester).

Plate 4. Minor Valley in Coffee zone, near Runyenjes (photo T. de Meester).

Plate 5. Tobacco farm on Volcanic Plateau. Soils are chromic and humic Acrisols (photo T. de Meester).

Plate 6. Volcanic sinkhole in Volcanic Plateau area. Soils are mainly gleyic and ferric Acrisols (photo A. Veldkamp)

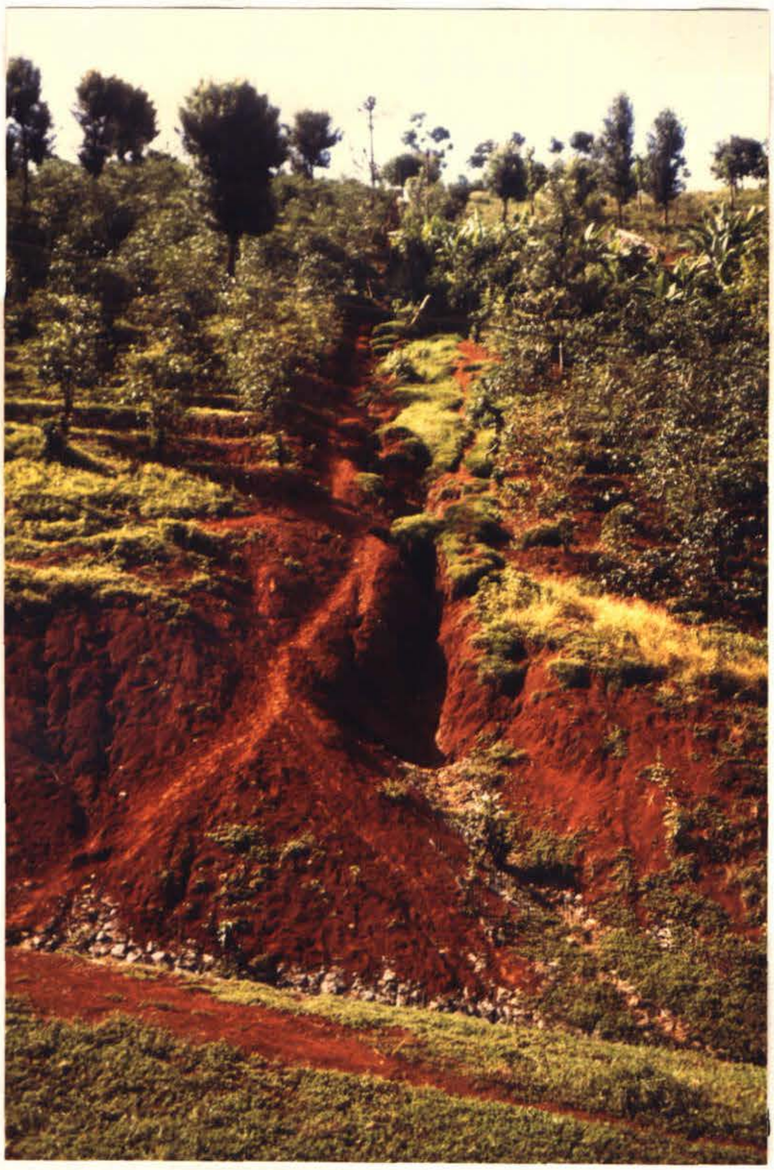


Plate 7.
Roadcut in Volcanic Footridges. Note bedrock and rotten rock in lower left corner (photo A. Veldkamp).

Plate 8.
Gully erosion in terraced coffee farm, clearly induced by down slope footpath between fields. Volcanic Footridges. (photo T. de Meester)

Plate 9. Scrub vegetation on Basement Complex soil (chromic Luvisols). Note termite mound (photo A. Veldkamp).

Plate 10. Sealed soil surface on overgrazed and overcultivated Basement ~~Computer~~ soils (chromic Luvisols) (photo T. de Meester).
Complex

APPENDIX 6.8: DETAILED DESCRIPTIONS OF REPRESENTATIVE PROFILES 1-43.

For situation see Fig. 27

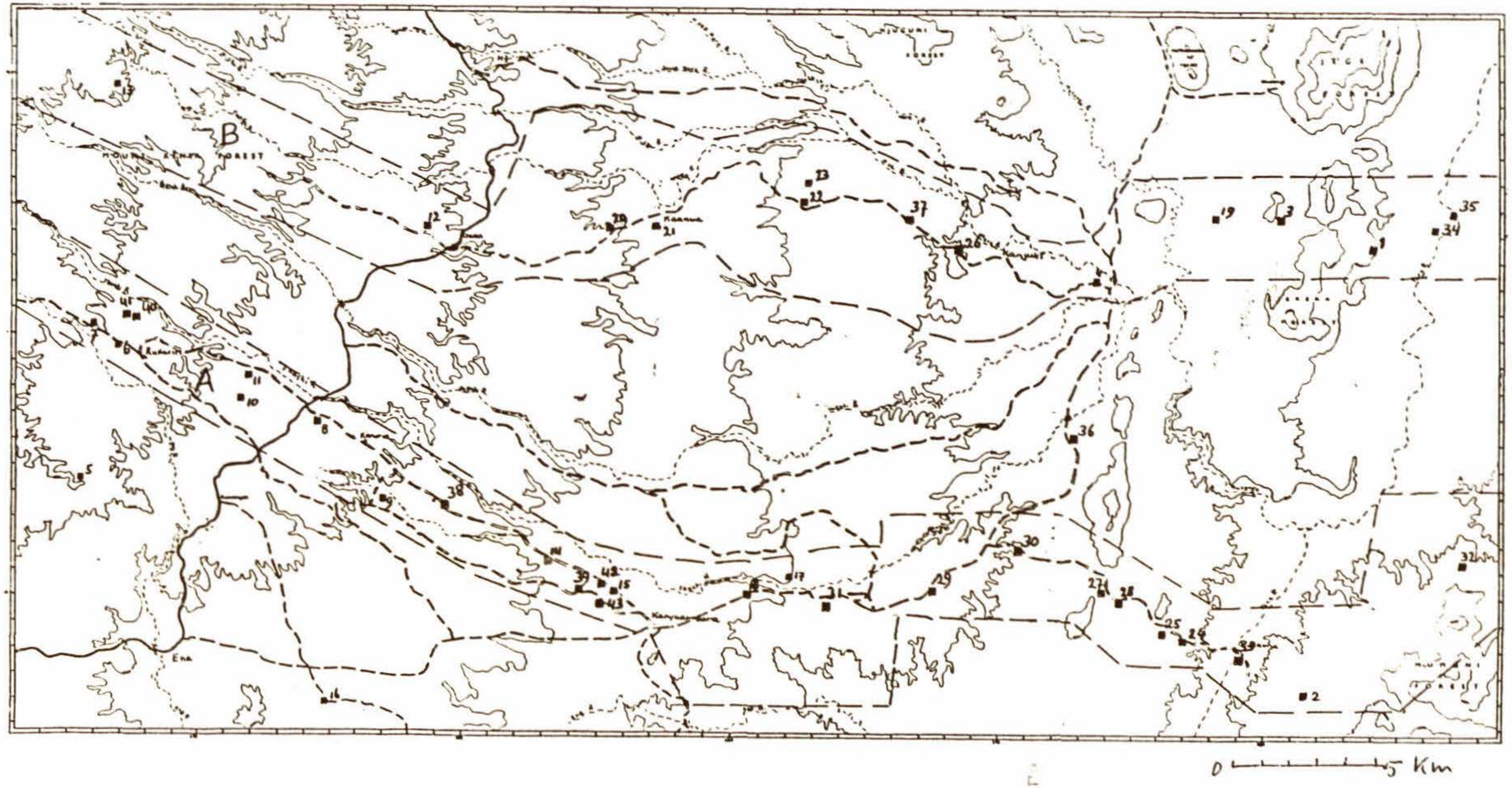


Fig 27 Situation of the representative soil profile pits 1-43.

Legend : Contours — Tarmac road — metalled rd — track — River (bed) — Limit of sample areas A and B

PROFILE 1

Date/ season	: 12/02/1986; dry season
Sheet-observation no	: 122/4-114
Coordinates	: 3865 E, 99635 N
Elevation	: 740 m
Authors	: J. Pulles
Soil mapping unit	: MQC
Soil classification (FAO/KSS)	: orthic LUVISOL
(USDA)	: ultic Haplustalf
Geology	: minor intrusives Basement System
Local petrography/ parent material	: granitoid gneisses
Physiography	: uplands
Macro-relief	: rolling to hilly
Slope (length, shape, pattern)	: 200 m, convex, irregular
Slope gradient	: moderately steep (23%)
Position on slope	: upper slope
Meso- and micro-relief	: nil
Vegetation/ Landuse	: wooded bushland; charcoal exploitation; shifting cultivation of millet
Erosion	: severe sheet, slight rill erosion
Rock outcrops	: rocky
Surface stoniness	: gravelly, stony and bouldery;in places very bouldery
Overwash	: nil
Surface runoff	: rapid
Surface sealing/ crusting/cracking	: slight thin crust
Drainage class	: somewhat excessively drained
Flooding	: nil
Groundwater level (actual)	: always deep
Presence of salts/ alkali	: nil
Soilfauna influences	: some biopores present
Expected rooting depth	: moderately deep

Horizons:

Ah	0 - 10 cm	Dark brown to brown (7.5 YR 4/2) when moist; sand, slightly gravelly; weak fine to medium subangular blocky structure; soft, very friable, non sticky and non plastic; no cutans; few fine, few very fine pores; gradual and smooth transition to
AB	10 - 20 cm	Dark brown (7.5 YR 3/4) when moist; sand, slightly gravelly; weak fine to medium subangular blocky structure; slightly hard, very friable, non sticky and non plastic; some clay bridging; few fine, few very fine pores; clear and wavy transition to
Bt	20 - 40 cm	Reddish brown (5 YR 4/4) when moist; sandy clay loam, slightly gravelly; weak fine to medium subangular blocky structure; slightly hard, friable, slightly sticky and slightly plastic;

	patchy thin clay skins and clay bridging; few medium, few fine, few very fine pores; clear and wavy transition to
B+CR 40 - 60 cm	Reddish brown (5 YR 4/4) when moist; sandy clay loam, very gravelly; predominantly rock structure; slightly hard, friable, slightly sticky and slightly plastic; patchy thin clay skins and bridging.

LABORATORY DATA OF PROFILE DESCRIPTION NO.: 1

Field Observation No.: 122/4-114

Lab. no. .../86	2150	2151	2152	2153
Horizon designation	Ah	AB	Bt	B+CR
Depth (cm)	0-10	10-20	20-40	40-60
pH-H2O (1:2.5)	6.8	6.4	6.1	6.3
pH-M KCl (1:2.5)	5.8	5.1	4.8	5.2
EC (mS/cm; 1:2.5)	0.04	0.03	0.03	0.05
C (%)	0.6	0.4	0.4	0.4
N (%)	0.07	0.06		
C/N	9	15		
CEC cmol(+)/Kg, pH 7.0	3.8	3.4	5.8	6.0
Exch. Ca (cmol(+)/Kg)	1.7	1.0	1.8	2.2
,, Mg ,,	0.8	0.7	1.2	1.7
,, K ,,	0.5	0.4	0.2	0.1
,, Na ,,	0.1	0.1	0.1	0.1
Sum cations	3.6	2.2	3.3	4.1
Base sat. at pH 7.0	95	65	57	68
ESP at pH 7.0	3	3	2	2
Gravel% >2mm				
Sand% 2-0.05mm	84	84	78	72
Silt% 50-2 um	7	7	5	7
Clay% <2 um	9	9	17	21
Texture class	LS	LS	SL	SCL
CEC clay (cmol(+)/Kg)			19	

FERTILITY ASPECTS

Depth (cm)	0-20
Lab. no. .../86	2154
Ca cmol(+)/Kg	1.5
Mg ,,	0.9
K ,,	0.2
Mn ,,	-
Exch. acid. ,,	-
P ug/g	?
C %	0.4
N %	0.11
pH-H2O (1:2.5)	6.5

PROFILE 2

Date/season	: 11/12/85, rainy season
Sheet observation no	: 122/4-98
Coordinates	: 3813 E, 99467 N
Elavation	: 732 m
Author	: Richard Kraayvanger
Soil mapping unit	: HQC
Soil classification (FAO/KSS)	: chromic LUVISOL
(USDA)	: ustic Dystropept
Geology	: precambrian metamorfites
Local petrography/ parent material	: muscovite-feldspar-quartz gneisses
Physiography	: hill
Macrorelief	: rolling
Slope (lenght, shape and pattern)	: 200m, convex and regular
Slopegradient	: moderately steep
Position on slope	: middle slope
Meso and microrelief	: gullies
Vegation/landuse	: densewood-bushland, grazing and shifting cultivation
Erosion	: moderate gully erosion
Rockoutcrops	: fairly rocky
Surface stoniness	: exceedingly stony, and bouldery
Overwash	: -
Surface runnoff	: medium
Surface sealing/crusting/cracking	: -
Drainage class	: exc. well-drained
Flooding	: -
Groundwaterlevel	: >200cm
Presence of salt/alkali	: -
Soilfauna influences insects	: ants, few termites and other
Expected roooting depth	: 40 cm

Horizons:

Ah	0-25cm	Dark brown (7.5YR 3/2) when moist; moderate medium granular and crumb structure; many medium and fine pores; gravelly and stoney loamy sand; firm, non sticky, non plastic; gradual and wavy transition to
B+CR	25-60cm	Dark reddish brown (5YR 3/4) when moist; moderate medium subangular blocky structure; commom medium and fine pores; gravelly and very stoney sandy clay loam; firm, slightly sticky, slightly plastic; gradual and irregular transition to
CR	>60 cm	Rockstructure.

LABORATORY DATA OF PROFILE DESCRIPTION NO.: 2

Field Observation No.: 122/4-98

Lab. no. .../86	595	596
Horizon designation	Ah	B+CR
Depth (cm)	0-25	25-60
pH-H2O (1:2.5)	7.1	6.4
pH-M KCl (1:2.5)	5.9	5.2
EC (mS/cm; 1:2.5)	0.10	0.04
C (%)	0.9	<0.1
CEC cmol(+)/Kg, pH 7.0	10.3	10.9
Exch. Ca (cmol(+)/Kg)	5.4	3.0
,, Mg ,,	2.9	2.8
,, K ,,	0.5	0.2
,, Na ,,	0.4	0.1
Sum cations	9.2	6.1
Base sat. at pH 7.0	89	56
ESP at pH 7.0	4	1
Gravel% >2mm		
Sand% 2-0.05mm	70	66
Silt% 50-2 um	14	8
Clay% <2 um	16	26
Texture class	SL	SCL
CEC clay (cmol(+)/Kg)	38	

PROFILE 3

Date/ season	: 15/01/ 1986
Sheet observation no	: 122/4-107
Coordinates	: 381E, 9965N
Elavation	: 765 meters
Author	: R. Kraayvanger
Soil mappingunit	: HQC
Soil classification (FAO/KSS)	: chromic LUVISOL
(USDA)	: udic Rhodustalf
Geology	: major intrusives
Local petrography/ parentmaterial	: quartz-feldspar-granitiod gneiss
Physiography	: hill
Macrorelief	: mountanous
Slope(lgth., shape and pattern)	: 400m, linear and regular
Slopegradient	: very steep
Position on slope	: middle slope
Meso and macrorelief	: -
Vegetation/landuse	: bushland, grazing
Erosion	: slight rill erosion
Rockoutcrops	: Rocky
Surface stoniness	: exceedingly stony
Overwash	: -
Surface runnoff	: slow
Surface sealing crusting	: -
Drainage class	: excessivly well drained
Flooding	: -
Groundwaterlevel	: >200cm
Presence of salts/alkali	: -
Soilfauna influences	: ants and insects
Expected rooting depth	: moderately deep

Horizons:

Ah	0-10cm	Dark reddish brown(5YR 3/3) when moist; medium granular structure; many medium and fine pores; very gravelly loamy sand; loose, non sticky, non plastic; clear and smooth transition to:
B+CR	10-60 cm	Dark reddish brown (2.5YR 3/6) when moist; medium subangular blocky structure, CR material has a rockstructure; many medium and fine pores; gravelly sandy loam; firm, slightly sticky, slightly plastic; few, thin clayskins; clear and diffuse transition to:
CR	>60 cm	Rock

LABORATORY DATA OF PROFILE DESCRIPTION NO.: 3

Field Observation No.: 122/4-107

Lab. no. .../86	2174	2175
Horizon designation	Ah	B+CR
Depth (cm)	0-10	10-60
pH-H2O (1:2.5)	7.4	7.2
pH-M KCl (1:2.5)	6.9	5.2
EC (mS/cm; 1:2.5)	0.07	0.04
C (%)	0.6	0.3
CEC cmol(+)/Kg, pH 7.0	6.9	6.3
Exch. Ca (cmol(+)/Kg)	3.8	3.1
,, Mg ,,	2.4	2.3
,, K ,,	0.4	0.1
,, Na ,,	0.1	0.1
Sum cations	6.7	5.6
Base sat. at pH 7.0	97	89
ESP at pH 7.0	1	1
Gravel% >2mm		
Sand% 2-0.05mm	76	76
Silt% 50-2 um	10	6
Clay% <2 um	14	18
Texture class	SL	SL
CEC clay (cmol(+)/Kg)	27	

PROFILE 4

Date/ season	: 18/5/85; end rainy season
Sheet-observation no	: 122/4-7
Coordinates	: 3733 E, 99622 N
Elevation	:
Authors	: Willy Simons
Soil mapping unit	: HUC
Soil classification (FAO/KSS)	: eutric REGOSOL
(USDA)	: lithic Ustropept
Geology	: Basement System
Local petrography/ Parent material	: hoornblende gneisses
Physiography	: Hill
Macro-relief	: hilly
Slope (length, shape and pattern)	: 40 m, concave, regular
Slope gradient	: 20%
Position on slope	: lower slope
Meso- and micro-relief	: nil
Vegetation/ Landuse	: grassland, probably used for grazing
Erosion	: nil
Rock outcrops	: nil
Surface stoniness	: rubble land
Overwash	: nil
Surface runoff	: very rapid
Surface sealing/crusting/cracking	: nil
Drainage class	: well drained
Flooding	: nil
Groundwater level (actual)	: always deep, > 2m
Presence of salts/ alkali	: nil
Soilfauna influences	: extreme
Expected rooting depth	: shallow

Horizons:

Ah	0-10/20 cm	Dark reddish brown (5YR 3/2) when moist; common medium distinct yellowish brown mottles (10YR 5/6) when moist; slightly gravelly sandy loam; strong fine subangular blocky structure; friable, non sticky and non plastic; many medium and fine pores; frequent fine and few medium roots; clear and broken transition to:
CR/B	10/20-80 cm	Dark reddish brown (2.5YR 3/4) when moist; no roots; clear and smooth transition to:
CR	80-150+ cm	Rotten rock; frequent hard carbonate concretions, ∅ 0-10 mm, in joints.

LABORATORY DATA OF PROFILE DESCRIPTION NO.: 4

Field Observation No.: 122/4-7

Lab. no. .../85	4945
Horizon designation	Ah
Depth (cm)	0-10/20
pH-H2O (1:2.5)	7.4
pH-M KCl (1:2.5)	6.9
EC (mS/cm; 1:2.5)	0.07
C (%)	0.7
CEC cmol(+)/Kg, pH 7.0	8.0
Exch. Ca (cmol(+)/Kg)	3.8
,, Mg ,,	3.0
,, K ,,	0.1
,, Na ,,	0.6
Sum cations	7.5
Base sat. at pH 7.0	94
ESP at pH 7.0	8
Gravel% >2mm	
Sand% 2-0.05mm	77
Silt% 50-2 um	11
Clay% <2 um	12
Texture class	SL
CEC clay (cmol(+)/Kg)	38

FERTILITY ASPECTS

Depth (cm)	0-20
Lab. no. .../85	4972
Ca cmol(+)/Kg	8.8
Mg ,,	3.4
K ,,	0.1
Mn ,,	0.3
exch. acid. ,,	-
P ug/g	134
C %	0.3
N %	0.07
pH-H2O (1:2.5)	6.9

PROFILE 5

Date/ season	: 12/03/'86
Sheet-observation no	: 122/3-128
Coordinates	: 3352E, 99544N
Elevation	: 1740 m
Authors	: Nicole Bongers
Soil mapping unit	: HPC
Soil classification (FAO/KSS)	: orthic ACRISOL
(USDA)	: typic Paleudult
Geology	: Mt. Kenya series
Local petrography/ parent material	: lahars
Physiography	: hill
Macro-relief	: mountainous
Slope (length, shape and pattern)	: 50 m, straight, regular
Slope gradient	: 55%
Position on slope	: upper slope
Meso- and micro-relief	: nil
Vegetation/ Landuse	: perennial crop cultivation; coffee
Erosion	: moderate sheet and rill erosion
Rock outcrops	: nil
Surface stoniness	: nil
Overwash	: nil
Surface runoff	: medium
Surface sealing/crusting/cracking	: nil
Drainage class	: well drained
Flooding	: nil
Groundwater level (actual)	: always deep
Presence of salts/ alkali	: nil
Soilfauna influences	: limited
Expected rooting depth	: very deep, >1.50 m

Horizons:

AB 0 - 40 cm	Dark brown to brown (7.5YR 4/4) when moist; clay; strong fine angular blocky structure; friable, slightly plastic and non-sticky; patchy thin clayskins; many medium and common fine pores; many very fine and fine roots, common medium and very few coarse roots; clear and smooth transition to:
Bt1 40 - 85 cm	Strong brown (7.5YR 4/6) when moist; clay; strong fine angular blocky structure; friable, slightly plastic and non sticky; patchy thin clayskins; many medium and common fine pores; few fine and medium, very few coarse roots; clear and smooth transition to:
Bt2 85- 150 cm	Strong brown (7.5YR 4/6) when moist; clay; friable, slightly plastic and slightly sticky; common thin clayskins; many medium and common fine pores; few fine and medium, very few coarse roots.

LABORATORY DATA OF PROFILE DESCRIPTION NO.: 5

Field Observation No.: 122/3-128

Lab. no. .../86	4112	4113	4114	4115
Horizon designation	AB	Bt1	Bt2	Bt2
Depth (cm)	0-40	40-85	85-110	110-150
pH-H2O (1:2.5)	4.9	4.6	4.4	5.3
pH-M KCl (1:2.5)	4.1	4.1	4.1	4.1
EC (mS/cm; 1:2.5)	0.03	0.03	0.03	0.03
C (%)	0.8	0.5	0.4	0.3
CEC cmol(+)/Kg, pH 7.0	16.5	15.0	13.2	12.5
Exch. Ca (cmol(+)/Kg)	0.9	0.7	0.6	0.8
,, Mg ,,	0.2	0.1	0.1	0.3
,, K ,,	0.1	0.1	0.1	<0.1
,, Na ,,	0.1	0.1	0.1	0.2
Sum cations	1.3	1.0	0.9	1.3
Base sat. at pH 7.0	8	7	7	10
ESP at pH 7.0	1	1	1	2
Gravel% >2mm				
Sand% 2-0.05mm	14	16	14	16
Silt% 50-2 um	12	16	16	18
Clay% <2 um	74	68	70	66
Texture class	C	C	C	C
CEC clay (cmol(+)/Kg)	17			

FERTILITY ASPECTS

Depth (cm)	0-20	40-60
Lab. no. .../86	4088	4089
Ca cmol(+)/Kg	<0.1	<0.1
Mg ,,	<0.1	<0.1
K ,,	0.1	0.2
Mn ,,	0.1	0.1
Exch. acid. ,,	1.4	1.0
P ug/g	14	11
C %	2.1	n.d.
N %	0.18	n.d.
pH-H2O (1:2.5)	5.2	5.1

PROFILE 6

Date/ season	: 27-8-85; end of cold season
Sheet and Observation no	: 122/3-13
Coordinates	: 3365 E, 99598 S
Elevation	: 1780m
Authors	: Willy Simons & Nicole Bongers
Soil mapping unit	: RP1H/AC
Soil Classification (FAO/KSS)	: humic NITISOL*
(USDA)	: typic Palehumult
Geology	: Mt. Kenya series
Local petrography/ parent material	: pyroclastic agglomerates/phonolite
Physiography	: volcanic Footridge
Macro-relief	: hilly
Slope (length, shape & pattern)	: convex, regular
Slope gradient	: 2%
Position on slope	: summit
Meso- and micro-relief	: nil
Vegetation/ Landuse	: annual crop cultivation; maize, tea
Erosion	: nil
Rock outcrops	: nil
Surface stoniness	: nil
Overwash	: nil
Surface runoff	: slow
Surface sealing/crusting/cracking	: weak sealing, 2mm thick
Drainage class	: well drained
Flooding	: nil
Groundwater level (actual)	: always deep , > 2m
Presence of salts/ alkali	: nil
Soilfauna influences	: moderate
Effective rooting depth	: extremely deep

Horizons:

Ah 0-20 cm	Dark reddish brown (5YR 3/3) when moist; silty clay; weak fine granular structure; loose, non sticky and non plastic; no clayskins; many medium pores, few fine pores; very frequent very fine, few medium and coarse roots; charcoal; clear and smooth transition to:
AB 20-45 cm	Dark reddish brown (2.5YR 3/4) when moist; clay; moderate medium subangular blocky structure; friable, slightly sticky and slightly plastic; continuous thin clayskins, shiny pedfaces; common medium pores, few fine pores; few fine, very few medium and coarse roots; clear and smooth transition to :
Bt 45-145+ cm	Red (2.5YR 4/6) when moist; clay; moderate coarse subangular blocky structure; friable, slightly sticky and slightly plastic; patchy thin clayskins; common medium and fine pores; few fine, very few medium and coarse roots.

LABORATORY DATA OF PROFILE DESCRIPTION NO.: 6

Field Observation No.: 122/3-13

Lab. no. .../85	5794	5795	5796	5797
Horizon designation	Ah	AB	Bt	Bt
Depth (cm)	0-20	20-45	45-90	90-140
pH-H2O (1:2.5)	4.6	4.2	4.3	4.5
pH-M KCl (1:2.5)	4.4	4.0	4.2	4.3
EC (mS/cm; 1:2.5)	0.06	0.07	0.05	0.03
C (%)	2.3	1.5	1.1	0.4
CEC cmol(+)/Kg, pH 7.0	20.5	23.2	21.5	18.2
Exch. Ca (cmol(=)/Kg)	1.7	1.4	1.4	1.0
,, Mg ,,	0.8	0.6	0.7	0.4
,, K ,,	0.3	0.1	0.1	0.1
,, Na ,,	<0.1	<0.1	<0.1	<0.1
Sum cations ,,	2.8	2.1	2.2	1.5
Base sat. at pH 7.0	14	9	10	8
ESP at pH 7.0	<1	<1	<1	<1
Gravel% >2mm				
Sand% 2-0.05mm	32	6	10	8
Silt% 50-2 um	24	18	8	8
Clay% <2 um	44	76	82	84
Texture class	C	C	C	C
CEC clay (cmol(+)/Kg)	20			

FERTILITY ASPECTS

Depth (cm)	0-20	40-60
Lab. no. ..../85	5801	8416
Ca cmol(+)/Kg	<0.1	<0.1
Mg ,,	<0.1	0.1
K ,,	0.2	0.2
Mn ,,	0.9	0.7
Exch. acid. ,,	1.1	3.7
P ug/g	38	14
C %	4.9	n.d.
N %	0.43	n.d.
pH-H2O (1:2.5)	4.3	4.2

PROFILE 7

Date/ season	: 27/8/85; cold season
Sheet-observation no	: 122/3-14
Coordinates	: 3359 E, 99604 N
Elevation	: 1820
Authors	: Willy Simons & Nicole Bongers
Soil mapping unit	: RP1h/AC
Soil classification (FAO/KSS)	: dystric NITISOL*
(USDA)	: orthoxic Palehumult
Geology	: Mt. Kenya series
Local petrography/ Parent material	: lahar / phonolite
Physiography	: Mountain Footridges
Macro-relief	: rolling
Slope (length, shape and pattern)	: regular
Slope gradient	: 1 %
Position on slope	: summit
Meso- and micro-relief	: nil
Vegetation/ Landuse	: forest
Erosion	: nil
Rock outcrops	: nil
Surface stoniness	: nil
Overwash	: nil
Surface runoff	: very slow
Surface sealing/crusting/cracking	: nil
Drainage class	: well drained
Flooding	: nil
Groundwater level (actual)	: always deep, > 2 m
Presence of salts/ alkali	: nil
Soilfauna influences	: moderate
Expected rooting depth	: extremely deep

Horizons:

O	4-0 cm	abrupt and smooth transition to:
Ah	0-20 cm	Dark reddish brown (2.5YR 3/4) when moist; clay; weak coarse granular structure; very friable, slightly sticky and slightly plastic; common thin clayskins; many medium and few fine pores; frequent fine and medium, common coarse roots; gradual and smooth transition to:
Bt1	20-100 cm	Reddish brown (2.5YR 4/4) when moist; clay; moderate medium subangular blocky structure; friable, slightly sticky and slightly plastic; few thin clayskins and shiny pedfaces; many medium, common fine pores; very few fine and medium roots; gradual and smooth transition to:
Bt2	100-150+ cm	Dark reddish brown (2.5YR 3/4) when moist; see Bu1.

LABORATORY DATA OF PROFILE DESCRIPTION NO.: 7

Field Observation No.: 122/3-14

Lab. no. .../85	8027	8028	8029	8030
Horizon designation	Ah	Bt1	Bt1	Bt2
Depth (cm)	0-20	20-60	60-100	100-150
pH-H2O (1:2.5)	4.4	4.3	4.5	4.7
pH-M KCl (1:2.5)	3.9	4.1	4.1	4.1
EC (mS/cm; 1:2.5)	0.05	0.03	0.03	0.02
C (%)	1.6	1.0	0.7	0.7
CEC cmol(+)/Kg, pH 7.0	12.5	11.0	8.5	8.5
Exch. Ca (cmol(+)/Kg)	0.5	0.5	0.2	0.2
,, Mg ,,	0.1	<0.1	0.1	0.1
,, K ,,	0.3	0.1	0.1	0.1
,, Na ,,	<0.1	<0.1	<0.1	0.1
Sum cations	0.9	0.6	0.4	0.4
Base sat. at pH 7.0	7	5	5	5
ESP at pH 7.0	<1	<1	<1	1
Gravel% >2mm				
Sand% 2-0.05mm	15	11	11	13
Silt% 50-2 um	21	13	9	15
Clay% <2 um	64	76	80	72
Texture class	C	C	C	C
CEC clay (cmol(+)/Kg)		7		

FERTILITY ASPECTS

Depth (cm)	0-20	40-60
Lab. no. .../85	5802	8417
Ca cmol(+)/Kg	<0.1	<0.1
Mg ,,	0.2	<0.1
K ,,	0.3	0.1
Mn ,,	1.4	1.1
Exch. acid. ,,	4.6	2.6
P ug/g	27	11
C %	4.5	n.d.
N %	0.49	n.d.
pH-H2O (1:2.5)	4.0	4.6

PROFILE 8

Date/ season	: 1/6/85; end rainy season
Sheet-observation no	: 122/3-22
Coordinates	: 3443 E, 99567 N
Elevation	: 1480 m
Authors	: Hans Nobbe and Inge Aalders
Soil mapping unit	: RP1h/AC
Soil classification (FAO/KSS)	: dystric NITISOL*
(USDA)	: orthoxic Palehumult
Geology	: Mt. Kenya series
Localpetrography/ Parent material	: lahar / phonolite
Physiography	: Mountain Footridges
Macro-relief	: undulating
Slope (length, shape and pattern)	: 100 m, concave, regular
Slope gradient	: 4 %
Position on slope	: summit
Meso- and micro-relief	: nil
Vegetation/ Landuse	: coffee and perennial crops
Erosion	: very slight splash and sheet
erosion	
Rock outcrops	: nil
Surface stoniness	: nil
Overwash	: nil
Surface runoff	: slow
Surface sealing/crusting/cracking	: nil
Drainage class	: well drained
Flooding	: nil
Groundwater level (actual)	: always deep
Presence of salts/ alkali	: nil
Soilfauna influences	: limited
Expected rooting depth	: very deep

Horizons:

Ap 0-16 cm	Dark reddish brown (5YR 3/3) when moist; clay; moderate very fine granular structure; friable, slightly sticky and slightly plastic; many fine pores; few very fine, common fine and few medium roots; gradual and smooth transition to:
BA 16-25 cm	Dark reddish brown (5YR 3/3) when moist; clay; moderate very fine subangular blocky and fine granular structure; friable, slightly sticky and slightly plastic; broken thin clayskins; many fine pores; few very fine, common fine and few medium roots; gradual and smooth transition to:
Bt1 25-60 cm	Dark reddish brown (2.5YR 3/4) when moist; clay; strong to moderate fine subangular blocky structure; broken thin clayskins; friable, slightly sticky and slightly plastic; many fine pores; very few very fine, very few medium and very few coarse roots; gradual and smooth transition to:

Bt2 60-160+ cm — Dark red (2.5YR 3/6) when moist; clay; moderate to weak fine subangular blocky structure; friable, slightly sticky and slightly plastic; patchy thin clayskins and shiny pedfaces; very few very fine, very few medium and very few coarse roots.

LABORATORY DATA OF PROFILE DESCRIPTION NO.: 8

Field Observation No.: 122/3-22

Lab. no. .../85	5783	5784	5785	5786
Horizon designation	Ap	BA	Bt1	Bt2
Depth (cm)	0-16	16-25	25-60	60-160
pH-H2O (1:2.5)	4.9	5.0	5.0	5.0
pH-M KCl (1:2.5)	4.4	4.7	4.6	4.6
EC (mS/cm; 1:2.5)	0.07	0.05	0.05	0.06
C (%)	2.1	1.4	0.8	0.5
CEC cmol(+)/Kg, pH 7.0	18.2	16.0	11.0	9.5
Exch. Ca (cmol(+)/Kg)	1.3	2.0	1.1	1.1
,, Mg ,,	1.0	1.4	1.2	1.7
,, K ,,	0.6	0.3	0.1	0.1
,, Na ,,	<0.1	<0.1	<0.1	<0.1
Sum cations	2.9	3.7	2.4	2.9
Base sat. at pH 7.0	16	23	22	31
ESP at pH 7.0	<1	<1	<1	<1
Gravel% >2mm				
Sand% 2-0.05mm	10	10	8	4
Silt% 50-2 um	18	14	14	12
Clay% <2 um	72	76	78	84
Texture class	C	C	C	C
CEC clay (cmol(+)/Kg)	9			

FERTILITY ASPECTS

Depth (cm)	0-20	40-60
Lab. no. .../85	8424	8425
Ca cmol(+)/Kg	1.2	0.4
Mg ,,	3.8	2.8
K ,,	0.3	0.2
Mn ,,	1.3	1.3
Exch. acid. ,,	0.6	0.4
P ug/g	14	14
C %	2.2	n.d.
N %	0.07	n.d.
pH-H2O (1:2.5)	5.0	5.1

PROFILE 9

Date/season	: 25/07/85; cold season
Sheet observation no	: 122/3-44
Coordinates	: 3468 E, 994539N
Elavation	: 1330m
Author	: Jan Kuyper
Soil mappingunit	: PRlh/AC
Soil classification (FAO/KSS)	: orthic Acrisol
(USDA)	: typic or ustic Tropohumult
Geology	: Mt Kenya-series
Local petrography/ parent material	: alluvium/colluvium (pyroclastic material)
Physiography	: valley
Macrorelief	: undulating
Slope (lenght, shape and pattern)	: 150m, concave, regular
Slopegradient	: 2%
Position on slope	: lower slope
Meso and microrelief	: nil
Vegation/landuse	: smallscalegroundwater-fed,bananas, sugarcane, maize and napir grass.
Erosion	: nil
Rockoutcrops	: nil
Surface stoniness	: nil
Overwash	: nil
Surface runnoff	: very slow
Surface sealing/crusting/cracking	: nil
Drainage class	: imperfectly to moderately well drained
Groundwaterlevel	: 105cm
Presence of salt/alkali	: nil
Soilfauna influences	: moderate
Expected roooting depth	: 105 cm

Horizons:

Ah 0-20cm	Dark reddish brown (2.5YR 3/4) when moist; clay; moderate very fine medium granular-subangular blocky structure; soft, very friable, slightly sticky and slightly plastic; gradual and wavy transition to:
Bt 20-60 cm	Dark reddish brown (5YR 3/3) when moist; clay; weak to moderate very fine medium subangular blocky structure; slightly hard, very friable, slightly sticky, slightly plastic; patchy thin cutans; smooth and gradual transition to
Btg 60-105 cm	Dark reddish brown (2.5 YR 3/4) when moist; many fine distinct clear black mottles; silty clay; very fine to medium moderate subangular blocky structure; slightly hard, very friable, slightly sticky and slightly plastic; broken thin cutans; few medium manganese concretions; smooth and gradual transition to:

Bg 105-140 cm	Dark brown (7.5YR 4/4) when moist; many tubular iron (rootrust) mottles (7.5YR); silty clay; moderate fine to very fine angular blocky structure; very friable, sticky and plastic; smooth and gradual transition to:
C1 140-160 cm	Greyish brown (10YR 5/2) when wet
C2 160-185 cm	Grey (5Y 5/1) when wet
C3 185-200 cm	Dark grey (10YR 4/1) when wet
C4 200+ cm	Greyish green (5G 5/2) when wet

Rermark: Depth of soil pit was 140 cm. Observations beyond this depth are from augerings.

LABORATORY DATA OF PROFILE DESCRIPTION NO.: 9

Field Observation No.: 122/3-44

Lab. no. .../85	3686	3687	3688	3689
Horizon designation	Ah	Bt	Btg	Bg
Depth (cm)	0-20	20-60	60-105	105-140
pH-H2O (1:2.5)	5.7	5.6	5.7	6.0
pH-M KCl (1:2.5)	5.4	5.3	5.3	5.3
EC (mS/cm; 1:2.5)	0.07	0.07	0.06	0.06
C (%)	1.5	1.4	0.7	0.6
N (%)	0.22	n.d.	n.d.	n.d.
CEC cmol(+)/Kg, pH 7.0	30.9	29.8	24.4	23.2
Exch. Ca (cmol(+)/Kg)	4.5	4.9	4.1	4.5
,, Mg ,,	2.0	2.7	2.0	3.5
,, K ,,	0.4	0.3	0.1	0.1
,, Na ,,	0.2	0.2	0.2	0.2
Sum cations	7.1	8.1	6.4	8.3
Base sat. at pH 7.0	23	27	26	36
ESP at pH 7.0	1	1	1	1
Gravel% >2mm				
Sand% 2-0.05mm	20	20	18	24
Silt% 50-2 um	18	20	20	16
Clay% <2 um	62	60	62	60
Texture class	C	C	C	C
CEC clay (cmol(+)/Kg)	35			

FERTILITY ASPECTS

Depth (cm)	0-20	40-60
Lab. no. ..../85	8443	8444
Ca cmol(+)/Kg	1.6	0.8
Mg ,,	3.1	3.6
K ,,	0.5	0.4
Mn ,,	2.0	3.7
Exch. acid. ,,	0.6	0.8
P ug/g	14	8
C %	1.4	n.d.
N %	0.19	n.d.
pH-H2O (1 : 2.5)	5.2	5.2

PROFILE 10

Date/ season	: 4/9/85; dry season
Sheet-observation no	: 122/3-50
Coordinates	: 3417 E, 99578 N
Elevation	: 1570 m
Authors	: Nicole Bongers
Soil mapping unit	: RP1h/DF
Soil classification (FAO/KSS)	: humic NITISOL*
(USDA)	: orthoxic Palehumult
Geology	: Mt. Kenya series
Local petrography/ parent material	: lahar / phonolite
Physiography	: Mountain Footridges
Macro-relief	: mountainous
Slope (length, shape and pattern)	: 100 m, convex, regular
Slope gradient	: 32 %
Position on slope	: middle slope
Meso- and micro-relief	: nil
Vegetation/ Landuse	: coffee and perennialcrops
Erosion	: nil
Rock outcrops	: nil
Surface stoniness	: nil
Overwash	: nil
Surface runoff	: rapid
Surface sealing/crusting/cracking	: nil
Drainage class	: well drained
Flooding	: nil
Groundwater level (actual)	: always deep, > 2 m
Presence of salts/ alkali	: nil
Soilfauna influences	: none to limited
Expected rooting depth	: extremely deep

Horizons:

Ah	0-30 cm	Dark reddish brown (2.5YR3/4), when moist; clay; weak medium subangular blocky falling apart to fine subangular blocky structure; very friable, slightly sticky and non plastic; common thin clayskins; many medium and fine pores; frequent very fine, few fine and medium roots; clear and wavy transition to:
Bt	30-145+ cm	Dark red (2.5YR3/6), when moist; clay; moderate medium subangular blocky structure; friable, slightly sticky and slightly plastic; continuous thin clayskins and shiny pedfaces; common macropores and many biopores; very few fine medium and coarse roots.

LABORATORY DATA OF PROFILE 10

Field Observation No.: 122/3-50

Lab. no. .../85	8037	8038	8039	8040
Horizon designation	Ah	Bt	Bt	Bt
Depth (cm)	0-30	30-70	70-110	110-150
pH-H20 (1:2.5)	5.3	4.8	4.8	5.0
pH-M KCl (1:2.5)	4.2	4.1	4.2	4.2
EC (mS/cm; 1:2.5)	0.04	0.06	0.06	0.03
C (%)	1.5	1.3	0.2	0.1
CEC cmol(+)/Kg, pH 7.0	12.5	11.3	5.0	4.3
Exch. Ca (cmol(+)/Kg)	0.8	0.5	0.3	0.1
,, Mg ,,	0.3	0.2	0.1	0.1
,, K ,,	0.5	0.1	0.1	0.1
,, Na ,,	0.1	0.1	0.1	0.1
Sum cations	1.7	0.9	0.6	0.4
Base sat. at pH 7.0	14	8	12	9
ESP at pH 7.0	1	1	2	2
Gravel% >2mm				
Sand% 2-0.05mm	9	7	7	7
Silt% 50-2 um	9	7	7	7
Clay% <2 um	82	86	86	86
Texture class	C	C	C	C
CEC clay (cmol(+)/Kg)		5		

FERTILITY ASPECTS

Depth (cm)	0-20	40-60
Lab. no. .../85	8463	8464
Ca mmol/100g	<0.1	<0.1
Mg ,,	0.4	0.2
K ,,	0.4	0.2
Mn ,,	0.1	0.1
Exch. acid. ,,	3.7	2.8
P ug/g	34	21
C %	n.d.	n.d.
N %	1.0	n.d.
pH-H20 (1:2.5)	4.3	4.5

PROFILE 11

Date/ season	: 19/8/85; end of cold season
Sheet-observation no	: 122/3-51
Coordinates	: 3416 E, 99580 N
Elevation	: 1550 m
Authors	: Nicole Bongers
Soil mapping unit	: RPlh/DF
Soil classification (FAO/KSS)	: dystric NITISOL
(USDA)	: aeric umbric Tropaquult
Geology	: Mt. Kenya series
Local petrography/ parent material	: pyroclastic agglomerates
Physiography	: Valley in mountain Footridge
Macro-relief	: mountainous
Slope (length, shape and pattern)	: 80 m, convex, regular
Slope gradient	: 10%
Position on slope	: lower slope
Meso- and micro-relief	: nil
Vegetation/ Landuse	: annual crop cultivation; maize
Erosion	: nil
Rock outcrops	: nil
Surface stoniness	: nil
Overwash	: nil
Surface runoff	: rapid
Surface sealing/crusting/cracking	: nil
Drainage class	: moderately well drained
Flooding	: nil
Groundwater level (actual)	: always moderately deep
Presence of salts/ alkali	: nil
Soilfauna influences	: none to limited
Expected rooting depth	: moderately deep

Horizons:

Ah	0-60 cm	Dusky red (2.5YR3/2), when moist; clay; moderate coarse subangular blocky structure; friable, slightly sticky and slightly plastic; patchy thin clayskins; common medium and fine pores; clear and wavy transition to:
Bg	60-75 cm	Weak red (2.5YR4/2), when moist; many fine distinct red (2.5YR5/8) mottles; clay; strong very coarse subangular blocky structure; friable, slightly sticky and slightly plastic; common thin clayskins; common medium and fine pores; clear and smooth transition to:
BG	75-80+ cm	Dark gray (5Y 4/1), when moist; common fine prominent reddish yellow (5YR6/8) mottles (along rootchannels); clay; strong very coarse subangular blocky structure; friable, slightly sticky and slightly plastic; patchy thin clayskins; few macro- and biopores; no roots.

LABORATORY DATA OF PROFILE 11

Field Observation No.: 122/3-51

Lab. no. .../85	7684	7685
Horizon designation	Ah	Bg
Depth (cm)	0-60	60-75
pH-H2O (1:2.5)	5.8	5.7
pH-M KCl (1:2.5)	4.1	3.8
EC (mS/cm; 1:2.5)	0.02	0.02
C (%)	1.0	0.6
CEC cmol(+)/Kg, pH 7.0	22.9	18.7
Exch. Ca (cmol(+)/Kg)	0.6	0.2
,, Mg ,,	0.4	0.2
,, K ,,	0.2	0.2
,, Na ,,	<0.1	<0.1
Sum cations	1.2	0.7
Base sat. at pH 7.0	5	4
ESP at pH 7.0	<0.1	<0.1
Gravel% >2mm		
Sand% 2-0.05mm	13	15
Silt% 50-2 um	15	13
Clay% <2 um	72	72
Texture class	C	C
CEC clay (cmol/K100g)	23	

Depth (cm)	5-10	40-45
pF 0	71.5	70.1
pF 2.0	40.8	41.5
pF 2.3	38.7	40.1
pF 3.7	29.4	29.5
pF 4.2	27.6	28.1

FERTILITY ASPECTS

Depth (cm)	0-20	40-60
Lab. no. .../85	8465	8466
Ca cmol(+)/Kg	<0.1	<0.1
Mg ,,	1.0	0.8
K ,,	0.5	0.2
Mn ,,	0.7	0.9
Exch. acid. ,,	2.5	3.4
P ug/g	16	8
C %	2.5	n.d.
N %	0.4	n.d.
pH-H2O (1:2.5)	4.1	4.3

PROFILE 12

Date/ season	: 5/8/85; cold season
Sheet-observation no	: 122/3-59
Coordinates	: 3483 E, 99639 N
Elevation	: 1460 m
Authors	: Enav Oren
Soil mapping unit	: RP1h/DF
Soil classification (FAO/KSS)	: dystric NITISOL
(USDA)	: orthoxic Palehumult
Geology	: Mt. Kenya series
Local petrography/ parent material	: lahar
Physiography	: Mt. footridges
Macro-relief	: mountainous
Slope (length, shape and pattern)	: 120 m, convex, regular
Slope gradient	: 16%
Position on slope	: upper slope
Meso- and micro-relief	: -
Vegetation/ Landuse	: coffee
Erosion	: slightly to moderate sheet erosion
Rock outcrops	: nil
Surface stoniness	: nil
Overwash	: nil
Surface runoff	: medium
Surface sealing/crusting/cracking	: moderately crusting
Drainage class	: well drained
Flooding	: nil
Groundwater level (actual)	: always deep, >1.50 m
Presence of salts/ alkali	: nil
Soilfauna influences	: moderate termites activity
Expected rooting depth	: very deep, >1.50 m

Horizons:

Ah 0-15 cm	Dark reddish brown (2.5YR2.5/4) moist; clay; strong fine angular blocky structure; very friable, slightly sticky and slightly plastic; common medium and few fine pores; few fine and few medium roots; abrupt and smooth transition to:
Bt1 15-40 cm	Dark red (2.5YR 3/6) moist on peds, dark reddish brown (2.5YR 3/4) moist in peds; clay; strong fine angular blocky structure; friable, sticky and plastic; common medium and fine pores; broken moderately thick clayskins; few fine and few medium roots; clear and smooth transition to:
Bt2 40-55 cm	Dark red (10YR 3/6) moist; moderate medium angular blocky structure; patchy moderately thick clay skins; very friable, slightly sticky and slightly plastic; few medium and fine fine pores; few fine and few medium roots; clear and smooth transition to:

BC 55-150 cm — Dark red (10YR 3/6) moist; weak very coarse prismatic structure; patchy thin clay skins; very friable, slightly sticky and slightly plastic; few medium pores; very few fine roots.

LABORATORY DATA OF PROFILE 12

Field Observation No.:122/3-59

Lab. no. .../85	7709	7710	7711	7712
Horizon designation	Ah	Bt1	Bt2	BC
Depth (cm)	0-15	15-40	40-55	55-150
pH-H2O (1:2.5)	4.8	4.9	4.7	4.4
pH-M KCl (1:2.5)	3.7	3.9	3.8	3.7
EC (mS/cm; 1:2.5)	0.03	0.03	0.03	0.04
C (%)	1.3	0.8	0.7	1.3
CEC cmol(+)/Kg, pH 7.0	13.5	10.0	8.2	13.5
Exch. Ca (cmol(+)/Kg)	2.7	1.5	1.1	1.8
,, Mg ,,	1.0	0.7	0.8	1.4
,, K ,,	1.3	0.7	0.8	1.0
,, Na ,,	0.2	0.1	0.1	0.2
Sum cations	5.2	3.0	2.8	4.4
Base sat. at pH 7.0	39	30	34	32
ESP at pH 7.0	2	1	1	2
Gravel% >2mm				
Sand% 2-0.05mm	12	10	8	8
Silt% 50-2 um	11	7	7	5
Clay% <2 um	77	83	85	87
Texture class	C	C	C	C
CEC clay (cmol(+)/Kg		8		

FERTILITY ASPECTS

Depth (cm)	0-20	40-60
Lab. no. .../85	7676	7677
Ca cmol(+)/Kg	0.6	0.4
Mg ,,	1.2	1.3
K ,,	0.6	0.4
Mn ,,	1.1	0.9
Exch. acid. ,,	0.6	0.4
P ug/g	8	6
C %	2.1	0.7
N %	0.26	n.d.
pH-H2O (1:2.5)	4.8	4.5

PROFILE 13

Date/ season	: 11/10/85; end of dry season
Sheet-observation no	: 122/3-75
Coordinates	: 3364 E, 99696 N
Elevation	: 2035 m
Authors	: Enav Oren
Soil mapping unit	: RP2
Soil classification (FAO/KSS)	: humic ACRISOL
(USDA)	: typic or orthoxic Palehumult?
Geology	: Mt. Kenya series
Local petrography/ parent material	: lahar
Physiography	: Mt. footridges
Macro-relief	: mountainous
Slope (length, shape and pattern)	: 200 m, convex, regular
Slope gradient	: 10%
Position on slope	: upper slope
Meso- and micro-relief	: -
Vegetation/ Landuse	: forest trees; timber
Erosion	: nil
Rock outcrops	: nil
Surface stoniness	: nil
Overwash	: nil
Surface runoff	: slow
Surface sealing/crusting/cracking	: nil
Drainage class	: well drained
Flooding	: nil
Groundwater level (actual)	: always deep, >1.50 m
Presence of salts/ alkali	: nil
Soilfauna influences	: moderate termites activity
Expected rooting depth	: very deep, >1.50 m

Horizons:

Ah1	0- 5 cm	Dark reddish brown (5YR3/3) when moist; clay; weak fine subangular blocky structure; very friable, slightly sticky and slightly plastic; abundant fine and many medium roots; abrupt, wavy transition to:
Ah2	5- 30 cm	Dark reddish brown (2.5YR3/4) when moist; clay; strong fine subangular blocky structure; very friable, slightly sticky and slightly plastic; abundant medium and many fine pores; many fine and many medium roots; clear smooth transition to:
Bt1	30-110 cm	Dark red (2.5YR3/6) when moist; clay; strong coarse and medium angular blocky structure; patchy thick clay skins; very friable, slightly sticky and slightly plastic; common medium and fine pores; common fine and medium roots; diffuse, wavy transition to:
Bt2	110-150 cm	Yellowish red (5YR4/6) when moist; clay; moderate very coarse angular blocky structure; broken thick

clay skins; very friable, slightly sticky and slightly plastic; very few medium pores; very few fine roots.

Of profile 13 no laboratory data are available.

PROFILE 14

Date/ season	: 14/5/85; rainy season
Sheet-observation no	: 122/3-3
Coordinates	: 3531 E, 99514 N
Elevation	: 1190 m
Authors	: Willy Simons
Soil mapping unit	: LP1
Soil classification (FAO/KSS)	: humic ACRISOL
(USDA)	: orthoxic Palehumult
Geology	: Mt. Kenya series
Local petrography/ Parent material	: pyroclastic agglomerates / phonolite
Physiography	: Plateau
Macro-relief	: gently undulating
Slope (length, shape and pattern)	: linear, regular
Slope gradient	: 2%
Position on slope	: upper slope
Meso- and micro-relief	: nil
Vegetation/ Landuse	: annual crop cultivation; maize, tobacco and cassava
Erosion	: slight splash and sheet erosion
outcrops	: nil
Surface stoniness	: nil
Overwash	: nil
Surface runoff	: slow
Surface sealing/crusting/cracking	: nil
Drainage class	: well drained
Flooding	: nil
Groundwater level (actual)	: always deep, > 2m
Presence of salts/ alkali	: nil
Soilfauna influences	: limited
Expected rooting depth	: very deep

Horizons:

Ap	0-15 cm	Dark reddish brown (5YR 3/2) when moist; clay; weak fine subangular blocky and granular structure; loose, slightly sticky and non plastic; many medium and common fine pores; common fine roots; clear and smooth transition to:
Ah	15-40 cm	Dark reddish brown (5YR 3/2) when moist; clay; moderate coarse subangular blocky structure; loose, slightly sticky and non plastic; many medium and common fine pores; very few medium roots; gradual and smooth transition to:

Bt1 40-70 cm — Dusky red (2.5YR 3/2) when moist; clay; weak medium subangular blocky structure; loose, slightly sticky and non plastic; few thin clayskins; many medium and common fine pores; very few medium roots; gradual and smooth transition to:

Bt2 70-160+ cm — Dark reddish brown (2.5YR 3/4) when moist; clay; moderate medium subangular blocky structure; very friable,moist, slightly sticky and non plastic; few thin clayskins; many medium and few fine pores; very few medium roots.

LABORATORY DATA OF PROFILE 14

Field Observation No.: 122/3-3

Lab. no. .../83	4930	4931	4932	4933
Horizon designation	Ap	Ah	Bt1	Bt2
Depth (cm)	0-15	15-40	40-70	70-160
pH-H2O (1:2.5)	5.7	6.0	6.2	5.7
pH-M KCl (1:2.5)	4.9	5.3	5.6	5.3
EC (mS/cm; 1:2.5)	0.07	0.07	0.06	0.07
C (%)	2.1	1.3	0.9	0.5
CEC cmol(+)/Kg, pH 7.0	27.7	24.0	20.0	18.8
Exch. Ca (cmol(+)/Kg)	9.7	8.7	7.3	5.6
,, Mg ,,	4.0	3.0	2.3	1.2
,, K ,,	0.9	0.7	0.7	0.7
,, Na ,,	0.2	0.1	0.1	0.1
Sum cations	14.8	12.5	10.4	7.6
Base sat. at pH 7.0	53	52	52	40
ESP at pH 7.0	<1	<1	<1	<1
Gravel% >2mm				
Sand% 2-0.05mm	16	14	10	6
Silt% 50-2 um	24	28	18	12
Clay% <2 um	60	58	72	82
Texture class	C	C	C	C
CEC clay (cmol(+)/Kg)	30		21	

FERTILITY ASPECTS

Depth (cm)	0-20
Lab. no. .../85	4968
Ca cmol(+)/Kg	9.8
Mg ,,	3.9
K ,,	0.8
Mn ,,	0.6
exch. acid. ,,	-
P ug/g	45
C %	2.1
N %	0.2
pH-H2O (1:2.5)	5.8

PROFILE 15

Date/ season	: 21/6/85; end rainy season
Sheet-observation no	: 122/3-26
Coordinates	: 3554 E, 99504 N
Elevation	: 1140 m
Authors	: Willy Simons
Soil mapping unit	: LP1
Soil classification (FAO/KSS)	: ferral-humic ACRISOL
(USDA)	: orthoxic Paleustult
Geology	: Mt. Kenya series
Local petrography/ Parent material	: lahar / phonolite
Physiography	: Plateaus
Macro-relief	: gently undulating
Slope (length, shape and pattern)	: -
Slope gradient	: 0 %
Position on slope	: summit
Meso- and micro-relief	: nil
Vegetation/ Landuse	: annual crop cultivation; sweet potato
Erosion	: nil
Rock outcrops	: nil
Surface stoniness	: nil
Overwash	: nil
Surface runoff	: very slow
Surface sealing/crusting/cracking	: weak sealing
Drainage class	: well drained
Flooding	: nil
Groundwater level (actual)	: always deep
Presence of salts/ alkali	: nil
Soilfauna influences	: moderate
Expected rooting depth	: very deep

Horizons:

Ap	0-15 cm	Dark reddish brown (5YR 3/3) when moist; clay; moderate medium granular structure; very friable, slightly sticky and slightly plastic; many medium and few fine pores; common fine roots; clear and smooth transition to:
Ah	15-35 cm	Dark reddish brown (2.5YR 3/4) when moist; clay; moderate medium subangular blocky structure; friable, slightly sticky and slightly plastic; many medium and few fine pores; few fine roots; gradual and smooth transition to:
Bt1	35-85 cm	Dark red (2.5YR 3/6) when moist; clay; moderate medium subangular blocky structure; friable, slightly sticky and slightly plastic; many medium and few fine pores; few fine roots; diffuse and smooth transition to:
Bt2	85-130+ cm	Dark red (2.5YR 3/6) when moist; clay; moderate coarse subangular blocky structure; friable, slightly sticky and slightly plastic; patchy thin clayskins; many medium and few fine pores; few fine roots.

LABORATORY DATA OF PROFILE 15

Field Observation No.: 122/3-26

Lab. no. .../85	6738	6739	6740	6741
Horizon designation	Ap	Ah	Bt1	Bt2
Depth (cm)	0-15	15-35	35-85	85-130
pH-H2O (1:2.5)	5.4	5.1	5.2	5.2
pH-M KCl (1:2.5)	4.7	4.5	4.9	4.9
EC (mS/cm; 1:2.5)	0.04	0.04	0.04	0.04
C (%)	1.6	1.2	1.0	0.5
CEC cmol(+)/Kg, pH 7.0	16.5	14.5	13.9	10.9
Exch. Ca (cmol(+)/Kg)	4.1	2.8	2.5	2.1
,, Mg ,,	2.4	2.4	2.5	1.9
,, K ,,	0.6	0.6	0.1	0.1
,, Na ,,	0.2	0.2	0.1	0.1
Sum cations	6.3	6.0	5.2	4.2
Base sat. at pH 7.0	38	41	37	39
ESP at pH 7.0	1	1	1	1
Gravel% >2mm				
Sand% 2-0.05mm	15	13	11	9
Silt% 50-2 um	19	15	15	9
Clay% <2 um	66	72	74	82
Texture class	C	C	C	C
CEC clay (cmol(+)/Kg)		12		

Depth (cm)	0-5	25-30	55-60	95-100	130-135
pF 0	68.2	65.9	65.2	62.6	63.2
pF 2.0	38.1	38.8	40.0	41.5	42.6
pF 2.3	33.8	35.7	35.9	35.0	35.7
pF 3.7	26.4	25.1	26.7	24.4	25.0
pF 4.2	23.8	24.6	24.5	23.4	25.0

FERTILITY ASPECTS

Depth (cm)	0-20	40-60
Lab. no. .../85	6499	8430
Ca cmol(+)/Kg	1.2	<0.1
Mg ,,	2.0	3.1
K ,,	0.7	0.5
Mn ,,	1.0	1.7
Exch. acid. ,,	0.2	0.4
P ug/g	6	11
C %	1.2	n.d.
N %	0.12	n.d.
pH-H2O (1:2.5)	5.2	5.3

PROFILE 16

Date/ season	: 05/03/'86; end of dry season
Sheet-observation no	: 122/3-125
Coordinates	: 3448 E, 99448 N
Elevation	: 1270 m
Authors	: Nicole Bongers
Soil mapping unit	: LP1
Soil classification (FAO/KSS)	: ferral chromic ACRISOL
(USDA)	: typic or ustic Palehumult
Geology	: Mt. Kenya series
Local petrography/ parent material	: lahars / phonolite
Physiography	: plateau
Macro-relief	: gently undulating
Slope (length, shape and pattern)	: straight, regular
Slope gradient	: 0%
Position on slope	: summit
Meso- and micro-relief	: nil
Vegetation/ Landuse	: fallow; *lantana* bush
Erosion	: very slight
Rock outcrops	: nil
Surface stoniness	: nil
Overwash	: nil
Surface runoff	: nil
Surface sealing/crusting/cracking	: nil
Drainage class	: well drained
Flooding	: nil
Groundwater level (actual)	: always deep
Presence of salts/ alkali	: nil
Soilfauna influences	: termites; moderate influence
Expected rooting depth	: > 1.50 m

Horizons:

Ah 0 - 20 cm	Dark reddish brown (2.5YR 2.5/4) when moist; clay; moderate very fine subangular blocky to moderate fine granular structure; loose, friable, non-plastic and slightly sticky; many medium and few fine pores; common fine and few medium roots; clear and smooth transition to:
ABt 20 - 60 cm	Dark reddish brown (2.5YR 3/4) when moist; clay; moderate very fine subangular blocky structure; hard, friable, non-plastic ans slightly sticky; continuous thin clayskins; many medium and few fine pores; very few fine, medium and coarse roots; clear and smooth transition to:
Bw 60 - 135+ cm	Dark red (2.5YR 3/6) when moist; clay-loam; weak very fine subangular blocky structure; slightly hard, friable, non-plastic and slightly sticky; many medium and few fine pores; very few fine, medium and coarse roots.

LABORATORY DATA OF PROFILE 16

Field Observation No.: 122/3-125

Lab. no. .../86	4102	4103	4104	4105
Horizon designation	Ah	ABt	Bw	Bw
Depth (cm)	0-20	20-60	60-100	100-135
pH-H2O (1:2.5)	6.3	6.4	6.7	6.4
pH-M KCl (1:2.5)	5.0	5.4	5.5	5.5
EC (mS/cm; 1:2.5)	0.02	0.02	0.02	0.01
C (%)	1.5	1.4	0.7	0.7
N (%)	0.23		0.24	
CEC cmol(+)/Kg, pH 7.0	26.8	26.2	22.7	22.0
Exch. Ca (cmol(+)/Kg)	5.7	3.5	2.7	3.3
,, Mg ,,	3.1	2.6	2.3	1.9
,, K ,,	0.6	0.5	0.8	0.6
,, Na ,,	0.4	0.3	0.2	0.2
Sum cations	9.8	6.9	6.0	6.0
Base sat. at pH 7.0	37	26	26	27
ESP at pH 7.0	2	1	1	1
Gravel% >2mm				
Sand% 2-0.05mm	18	14	14	10
Silt% 50-2 um	16	14	12	12
Clay% <2 um	66	72	74	78
Texture class	C	C	C	C
CEC clay (cmol(+)/Kg)		24		

FERTILITY ASPECTS

Depth (cm)	0-20
Lab. no. .../86	4091
Ca cmol(+)/Kg	2.0
Mg ,,	1.8
K ,,	0.4
Mn ,,	0.6
Exch. acid. ,,	<0.1
P ug/g	6
C %	1.4
N %	0.11
pH-H2O (1:2.5)	5.7

Remark: pH-H2O of fertility sample differs consirable from that of the horizon samples. CEC clay values are higher than could be expected from the pH and base saturation values.

PROFILE 17

Date/ season : 6/7/85; dry season
Sheet-observation no : 12/3-37
Coordinates : 3612 E, 99502 N
Elevation : 1010 m
Authors : Tom Veldkamp and Philip Visser
Soil mapping unit : LP2P
Soil classification (FAO/KSS) : LITHOSOL (eutric)
(USDA) : lithic Ustorthent
Geology : Mt. Kenya series
Local petrography/ Parent material: lahar / phonolite
Physiography : Plateaus
Macro-relief : flat
Slope (length, shape and pattern) : > 100 m, straight, regular
Slope gradient : 1 %
Position on slope : -
Meso- and micro-relief : nil
Vegetation/ Landuse : bushland with *Acacia, Combretum* and *Euphorbia candelabrum*
Erosion : slight sheet erosion
Rock outcrops : rocky
Surface stoniness : rubble land
Overwash : nil
Surface runoff : slow
Surface sealing/crusting/cracking : nil
Drainage class : excessively drained
Flooding : nil
Groundwater level (actual) : always deep
Presence of salts/ alkali : nil
Soilfauna influences : limited
Expected rooting depth : very shallow

Horizons:

ABcs 0-20 cm Dark reddish brown (5YR 3/4) when moist; slightly stony and very gravelly sandy loam; moderate fine granular and subangular blocky structure; friable, slightly sticky and non plastic; no cutans; many medium and fine pores; very frequent hard iron and manganese concretions, Ø 5-15 mm; clear and wavy transition to:

R 20+ cm Rotten rock.

LABORATORY DATA OF PROFILE 17

Field Observation No.: 122/4-37

Lab. no. .../ 85	7372
Horizon designation	ABcs
Depth (cm)	0-20
pH-H2O (1:2.5)	5.6
pH-M KCl (1:2.5)	4.9
EC (mS/cm; 1:2.5)	0.03
C (%)	1.0
CEC cmol(+)/Kg, pH 7.0	7.2
Exch. Ca (cmol(+)/Kg)	0.5
,, Mg ,,	1.1
,, K ,,	0.7
,, Na ,,	0.2
Sum cations	2.5
Base sat. at pH 7.0	35
ESP at pH 7.0	3
Gravel% >2mm	45
Sand% 2-0.05mm	68
Silt% 50-2 um	7
Clay% <2 um	25
Texture class	SCL
CEC clay (cmol(+)/Kg)	9

FERTILITY ASPECTS

Depth (cm)	0-20
Lab. no. .../85	7350
Ca cmol(+)/Kg	<0.1
Mg ,,	1.1
K ,,	1.4
Mn ,,	0.1
Exch. acid. ,,	-
P ug/g	15
C %	1.4
N %	0.10
pH-H2O (1:2.5)	5.6

PROFILE 18

Date/ season	: 18/5/85; end rainy season
Sheet-observation no	: 122/3-4
Coordinates	: 3604 E, 99501 N
Elevation	: 1060 m
Authors	: Willy Simons
Soil mapping unit	: LPC
Soil classification (FAO/KSS)	: dystric CAMBISOL
(USDA)	: Dystropept
Geology	: Mt. Kenya series
Local petrography/ Parent material	: lahar / phonolite
Physiography	: Plateaus
Macro-relief	: gently undulating
Slope (length, shape and pattern)	: -
Slope gradient	: 2 %
Position on slope	: -
Meso- and micro-relief	: nil
Vegetation/ Landuse	: thicketsused forextensive grazing
Erosion	: nil
Rock outcrops	: nil
Surface stoniness	: fairly stony (boulders)
Overwash	: nil
Surface runoff	: slow
Surface sealing/crusting/cracking	: nil
Drainage class	: well drained
Flooding	: nil
Groundwater level (actual)	: always deep, > 2 m
Presence of salts/ alkali	: nil
Soilfauna influences	: moderate
Expected rooting depth	: very deep

Horizons:

Ah 0-25 cm	Very dark grey (5YR 3/1) when moist; clay; moderate medium angular blocky structure; friable, slightly sticky and non-plastic; many medium and fine pores; gradual and smooth transition to:
Bcs 25-50 cm	Dark reddish brown (5YR 3/3) when moist; very gravelly sandy clay loam; moderate medium angular blocky structure; friable, slightly sticky and non plastic; very frequent hard iron concretions, Ø 5 mm; many medium and fine pores; common medium roots; gradual and smooth transition to:
BCcs 50-60 cm	Reddish brown (5YR 4/3) when moist; common prominent very dark grey and few prominent red mottles; very gravelly sandy loam; structureless; firm, non sticky and non plastic; few medium pores; very frequent hard iron and manganese concretions, Ø 5-10 mm; few fine roots; clear and smooth transition to:

Ccs1 60-100 cm	Dark reddish brown (2.5YR 3/4) when moist; many prominent red and common prominent yellow mottles; very gravelly sandy clay; strong coarse granular structure; firm, non sticky and non plastic; few medium pores; very frequent hard iron and manganese concretions, Ø 5-10 mm; few fine roots; gradual and smooth transition to:
Ccs2 100-160+ cm	Reddish brown (5YR 4/3) when moist; many prominent yellow mottles; very gravelly clay; strong very coarse granular structure; friable, non sticky and non plastic; many medium and fine pores; very frequent soft iron and manganese concretions, Ø 10-20 mm; few fine roots.

LABORATORY DATA OF PROFILE 18

Field Observation No.:122/3-4

Lab. no. ....../85	4934	4935	4936	4937	4938
Horizon designation	Ah	Bcs	BCcs	Ccs1	Ccs2
Depth (cm)	0-25	25-50	50-60	60-100	100-160
pH-H2O (1:2.5)	5.8	5.4	5.3	5.5	5.9
pH-M KCl (1:2.5)	5.0	4.8	5.1	4.8	4.6
EC mS/cm (1:2.5)	0.07	0.02	0.02	0.02	0.03
C%	1.4	0.7	0.5	0.5	0.5
CEC cmol(+)/Kg, pH 7.0	23.2	13.2	7.9	14.7	14.0
Exch. Ca cmol(+)/Kg	9.5	3.8	2.2	2.3	2.4
,, Mg ,,	4.0	2.5	1.2	2.2	2.8
,, K ,,	1.1	0.3	0.2	0.2	0.2
,, Na ,,	0.1	0.1	0.1	0.1	0.1
Sum	14.7	6.7	3.7	4.8	5.5
Base saturation, pH 7.0	63	51	47	33	39
ESP at pH 7.0	<1	<1	1	1	1
Gravel % > 2mm					
Sand % 2-0.05 mm	28	60	76	46	36
Silt % 50-2 um	18	8	6	10	12
Clay % < 2 um	54	32	18	44	52
Texture class	C	SCL	SL	SC	C
CEC clay (cmol(+)/Kg			30		

FERTILITY *

Depth (cm)	0-20
Lab. no. .../ 85	4969
Ca cmol(+)/Kg	9.6
Mg ,,	4.2
K ,,	1.1
Mn ,,	0.8
Exch. acid. ,,	tr
P ug/g	34
C %	1.8
N %	0.18
pH-H2O (1:2.5)	5.8

*Composite sample from at least 5 locations

PROFILE 19

Date/ season	: 15/01/1986
Sheet-observation no	: 122/4-106
Coordinates	: 3778 E, 99648 N (Materi plateau)
Elevation	: 665 m
Authors	: R. Kraayvanger
Soil mapping unit	: LB
Soil classification (FAO/KSS)	: ferric LUVISOL
(USDA)	: ustoxic Tropohumult (or Plintohumult)
Geology	: Nyambeni basalts
Local petrography	: Basalts
Physiography	: plateau
Macro-relief	: flat
Slope (length, shape, pattern)	: -
Slope gradient	: -
Position on slope	: -
Meso- and micro-relief	: few termite mounds
Vegetation/ Landuse	: grazing and some shambas with cowpeas
Erosion	: nil
Rock outcrops	: -
Surface stoniness	: nil
Overwash	: -
Surface runoff	: very slow
Surface sealing/crusting	: slight crusting
Drainage class	: excessively well drained
Flooding	: -
Groundwater level (actual)	: > 200 cm
Presence of salts/ alkali	: -
Soilfauna influences	: ants, termites and millipedes
Expected rooting depth	: 100 cm

Horizons:

Ah	0 - 15cm	Dark reddish brown (2.5 YR 3/2) when moist; clay; medium granular to fine subangular blocky structure; firm, slightly sticky, slightly plastic; many medium and fine pores; clear and smooth transition to
Bt	15 - 50cm	Dark reddish brown (2.5YR 3/4) when moist; clay; medium granular to fine subangular blocky structure; firm, slightly sticky, slightly plastic; common thin clayskins; smooth and clear transition to
Bcs	50 - 100 cm	Dark reddish brown (2.5YR 3/4) when moist; clay; common medium pores; dominant ferromanganese (murram) concretions, ϕ 10 mm.

LABORATORY DATA OF PROFILE 19

Field Observation No.: 122/4-106

Lab. no. .../86	2180	2181	2182
Horizon designation	Ah	Bt	Bcs
Depth (cm)	0-15	15-50	50-100
pH-H20 (1:2.5)	6.8	6.2	6.2
pH-M KCl (1:2.5)	5.5	4.6	5.0
EC (mS/cm; 1:2.5)	0.04	0.02	0.02
C (%)	1.3	0.8	0.4
CEC cmol(+)/Kg, pH 7.0	14.3	13.9	9.5
Exch. Ca (cmol(+)/Kg)	5.6	4.4	4.0
,, Mg ,,	4.8	3.0	2.2
,, K ,,	0.9	0.2	0.1
,, Na ,,	0.2	0.2	0.2
Sum cations	11.5	7.8	5.5
Base sat. at pH 7.0	80	56	58
ESP at pH 7.0	1	1	2
Gravel% >2mm			
Sand% 2-0.05mm	32	28	48
Silt% 50-2 um	18	12	4
Clay% <2 um	50	60	48
Texture class	C	C	SC
CEC clay (cmol(+)/Kg)		16	

PROFILE 20

Date/ season	: 18/5/85; end rainy season
Sheet-observation no	: 122/3-12
Coordinates	: 3552 E, 99638 N
Elevation	:
Authors	: Willy Simons
Soil mapping unit	: UlPlh
Soil classification (FAO/KSS)	: humic NITISOL
(USDA)	: typic or rhodic Paleudult
Geology	: Mt. Kenya series
Local petrography/ Parent material	: pyroclastic agglomerates
Physiography	: volcanic Footridge
Macro-relief	: undulating
Slope (length, shape and pattern)	: straight, regular
Slope gradient	: 2%
Position on slope	: middle slope
Meso- and micro-relief	: nil
Vegetation/ Landuse	: grasses with *lantana* bushes and trees used for grazing and (fire)wood production
Erosion	: nil
Rock outcrops	: nil
Surface stoniness	: nil
Overwash	: nil
Surface runoff	: slow
Surface sealing/crusting/cracking	: nil
Drainage class	: well drained
Flooding	: nil
Groundwater level (actual)	: always deep, > 2m
Presence of salts/ alkali	: nil
Soilfauna influences	: extreme
Expected rooting depth	: very deep

Horizons:

Ah 0-15 cm	Dark reddish brown (5YR 3/2) when moist; clay; moderate medium granular structure; very friable, sticky and slightly plastic; many medium pores; very frequent fine and frequent medium roots; clear and smooth transition to:
AB 15-30 cm	Dark reddish brown (5YR 3/3) when moist; clay; moderate medium subangular blocky structure; continuous thin clayskins (shiny pedfaces); friable, sticky and slightly plastic; common medium and many fine pores; very frequent fine and frequent medium roots; gradual and smooth transition to:
Bt1 30-65 cm	Dark reddish brown (2.5YR 3/4) when moist; clay; moderate coarse subangular blocky structure; continuous thin clayskins (shiny pedfaces); friable, sticky and slightly plastic; many fine pores; frequent fine roots; gradual and smooth transition to:

Bt2 65-100 cm — Dark reddish brown (2.5YR 3/4) when moist; clay; moderate coarse subangular blocky structure; continuous thin clayskins (shiny pedfaces); friable, sticky and slightly plastic; many fine pores; common fine roots; clear and smooth transition to

Bt3 100-130+ cm — Dark reddish brown (2.5YR 3/4) when moist; clay; moderate coarse subangular blocky structure; continuous thin clayskins (shiny pedfaces); friable, sticky and slightly plastic; many fine pores; common fine roots.

LABORATORY DATA OF PROFILE 20

Field Observation No.: 122/3-12

Lab. no. .../85	4960	4961	4962	4963	4964
Horizon designation	Ah	AB	Bt1	Bt2	Bt3
Depth (cm)	0-15	15-30	30-65	65-100	100-130
pH-H2O (1:2.5)	5.5	5.3	5.0	5.3	5.3
pH-M KCl (1:2.5)	4.8	4.6	4.6	4.9	5.0
EC(mS/cm; 1:2.5)	0.04	0.07	0.04	0.04	0.04
C (%)	1.4	1.0	0.6	0.3	0.4
CEC cmol(+)/Kg, pH 7.0	25.6	26.0	22.5	20.6	22.5
Exch. Ca (cmol(+)/Kg)	4.1	2.5	1.5	1.2	1.2
,, Mg ,,	2.9	1.7	1.2	1.0	1.1
,, K ,,	1.3	0.9	0.8	0.2	0.1
,, Na ,,	0.1	0.1	0.1	0.1	0.1
Sum cations	8.4	4.2	2.6	1.5	1.5
Base sat. at pH 7.0	33	16	12	7	7
ESP at pH 7.0	<1	<1	<1	<1	<1
Gravel% >2mm					
Sand% 2-0.05mm	9	7	7	9	9
Silt% 50-2 um	21	15	13	7	5
Clay% <2 um	70	78	80	84	86
Texture class	C	C	C	C	C
CEC clay (cmol(+)/Kg)	<- 27	->	<-	24	->

FERTILITY ASPECTS

Depth (cm)	0-20
Lab. no. ...../85	4977
Ca cmol(+)/Kg	8.0
Mg ,,	3.8
K ,,	0.9
Mn ,,	1.5
Exch. acid. ,,	-
P ug/g	36
C %	1.4
N %	0.3
pH-H2O (1:2.5)	5.8

PROFILE 21

Date/ season	: 28/8/85; end of cold season
Sheet-observation no	: 122/2-66
Coordinates	: 3560 E, 99636 N
Elevation	: 1180 m
Authors	: Enav Oren
Soil mapping unit	: UlP2p
Soil classification (FAO/KSS)	: humic ACRISOL
(USDA)	: ultic Haplustalf or ultic Tropudalf
Geology	: Mt. Kenya series
Local petrography/ parent material	: lahar
Physiography	: upland
Macro-relief	: rolling
Slope (length, shape and pattern)	: 200 m, straight, regular
Slope gradient	: 11%
Position on slope	: middle slope
Meso- and micro-relief	:
Vegetation/ Landuse	: permanent cultivation of annual crops like cowpeas, mais, sorgum etc.
Erosion	: slightly water erosion
Rock outcrops	: nil
Surface stoniness	: stony
Overwash	: nil
Surface runoff	: medium
Surface sealing/crusting/cracking	: slightly crusting
Drainage class	: well drained
Flooding	: nil
Groundwater level (actual)	: always deep, >150 cm
Presence of salts/ alkali	: nil
Soilfauna influences	: moderate termites activity
Expected rooting depth	: 85 cm

HORIZONS:

Ap	0-10 cm	Dark reddish brown (5YR3/3) when moist; clay; strong medium subangular blocky structure; common medium and fine pores; soft, very friable; very sticky and plastic when wet, many fine and few medium roots; abrupt smooth transition to:
Ah	10-30 cm	Dark reddish brown (5YR3/3) when moist; clay; strong medium subangular blocky structure; broken moderately thick clayskins; common medium and fine pores; slightly hard, friable, sticky and plastic; many fine and few medium roots; clear wavy transition to:
Bt	30-50 cm	Dark reddish brown (5YR3/4), moist; clay; strong medium angular blocky structure; continuous moderately thick clayskins; few medium and fine pores; firm, sticky and slightly plastic; common fine and very few medium roots; gradual wavy transition to:

BC 50-85 cm — Dark reddish brown (2.5YR3/4), moist; gravelly and stony clay; moderate coarse angular blocky structure; continuous moderately thick clayskins; few medium and fine pores; firm, sticky and slightly plastic; common fine and very few medium roots; abrupt irregular transition to:

CR>150 cm — Rotten rock.

LABORATORY DATA OF PROFILE 21

Field Observation No.: 122/2-66

Lab. no. .../85	8009	8010	8011	8012
Horizon designation	Ap	Ah	Bt	BC
Depth (cm)	0-10	10-30	30-50	50-85
pH-H2O (1:2.5)	5.6	5.7	5.7	5.6
pH-M KCl (1:2.5)	4.7	4.7	4.8	4.9
EC (mS/cm; 1:2.5)	0.04	0.03	0.03	0.05
C (%)	1.4	0.7	0.7	0.4
CEC cmol(+)/Kg, pH 7.0	28.9	25.0	26.1	22.3
Exch. Ca (cmol(+)/Kg)	7.7	5.6	5.9	4.8
,, Mg ,,	3.8	3.5	3.6	3.6
,, K ,,	2.0	1.3	1.2	1.2
,, Na ,,	0.3	0.3	1.2	1.2
Sum cations	13.8	10.7	11.9	10.8
Base sat. at pH 7.0	48	43	46	48
ESP at pH 7.0	1	1	<1	<1
Gravel% >2mm				
Sand% 2-0.05mm	8	6	6	7
Silt% 50-2 um	16	10	10	7
Clay% <2 um	76	84	84	86
Texture class	C	C	C	C
CEC clay (cmol(+)/Kg)	26			

FERTILITY ASPECTS

Depth (cm)	0-20	40-60
Lab. no. .../85	8019	8020
Ca cmol(+)/Kg	6.0	3.8
Mg ,,	3.3	4.2
K ,,	1.2	1.1
Mn ,,	1.3	1.2
Exch. acid. ,,	<0.1	0.4
P ug/g	<1	<1
C %	1.7	1.3
N %	0.16	n.d.
pH-H2O (1:2.5)	5.6	5.4

PROFILE 22

Date/ season	: 16/5/85; end rainy season
Sheet-observation no	: 122/4-10
Coordinates	: 3624 E, 99652 N
Elevation	:
Authors	: Willy Simons
Soil mapping unit	: U1PC
Soil classification (FAO/KSS)	: dystric CAMBISOL
(USDA)	: typic or ustic Humitropept
Geology	: Mt. Kenya series
Local petrography/ Parent material	: pyroclastic agglomerates
Physiography	: Upland
Macro-relief	: undulating
Slope (length, shape and pattern)	: 250m, straight, regular
Slope gradient	: 8%
Position on slope	: middle slope
Meso- and micro-relief	: nil
Vegetation/ Landuse	: bushland used for extensive grazing
Erosion	: slight; splash erosion
Rock outcrops	: nil
Surface stoniness	: stony
Overwash	: very slight
Surface runoff	: medium
Surface sealing/crusting/cracking	: weak sealing
Drainage class	: well drained
Flooding	: nil
Groundwater level (actual)	: always deep
Presence of salts/ alkali	: nil
Soilfauna influences	: none to limited
Expected rooting depth	: moderately deep

Horizons:

Ah	0-15 cm	Very dark gray (5YR 3/1) when moist; few fine distinct yellowish red mottles; slightly stony clay; moderate medium granular structure; very friable, non sticky and slighly plastic; few iron concretions, Ø 4-10 mm; many mediumpo res; frequent fine and few coarse roots; clear and smooth transition to:
AB	15-30 cm	Dark reddish gray (5YR 4/2) when moist; common medium prominent yellowish red mottles; gravelly and stony clay; moderate fine subangular blocky structure; friable, non sticky and slightly plastic; frequent iron concretions, Ø 4-10 mm; many medium pores; common fine and very few medium roots; clear and smooth transition to:
Bw	30-50/80 cm	Dark reddish brown (5YR 3/4) when moist; many coarse prominent red mottles; gravelly and slightly stony clay; moderate fine subangular blocky structure; very friable, non sticky and slightly plastic; frequent iron concretions, Ø 4-10 mm; many medium pores; common fine and very few medium roots; clear and irregular transition to:

BC 50/80-110 cm	Dark reddish gray (5YR 4/2) when moist; many coarse prominent yellowish red mottles; very stony clay; moderate fine subangular blocky structure; very friable, non sticky and slightly plastic; common medium pores; clear and smooth transition to:
CR 110-130+ cm	Rotten rock.

LABORATORY DATA OF PROFILE 22

Field Observation No.: 122/4-10

Lab. no. .../85	4954	4955	4956	4957
Horizon designation	Ah	AB	Bw	BC
Depth (cm)	0-15	15-30	30-50/80	50/80-110
pH-H2O (1:2.5)	6.1	5.6	5.3	5.6
pH-M KCl (1:2.5)	5.2	4.6	4.0	4.1
EC (mS/cm; 1:2.5)	0.08	0.04	0.03	0.03
C (%)	2.1	0.9	0.7	0.4
CEC cmol(+)/Kg, pH 7.0	28.3	23.5	25.5	24.0
Exch. Ca (cmol(+)/Kg)	4.9	2.5	1.9	4.5
,, Mg ,,	6.2	3.2	2.2	4.6
,, K ,,	1.6	1.8	1.6	1.7
,, Na ,,	0.2	0.2	0.3	0.8
Sum cations	12.9	7.7	6.0	11.6
Base sat. at pH 7.0	46	33	24	48
ESP at pH 7.0	1	1	1	3
Gravel% >2mm				
Sand% 2-0.05mm	33	39	27	25
Silt% 50-2 um	23	19	21	19
Clay% <2 um	44	42	52	46
Texture class	C	C	C	C
CEC clay (cmol(+)/Kg)	44			

FERTILITY ASPECTS

Depth (cm)	0-20
Lab. no. .../85	4975
Ca cmol(+)/Kg	6.8
Mg ,,	3.4
K ,,	0.9
Mn ,,	0.5
exch. acid. ,,	-
P ug/g	28
C %	1.8
N %	0.13
pH-H2O (1:2.5)	5.8

PROFILE 23

Date/season	: 22/10/85;beginning of the rainy season.
Sheet-observation no	: 122/4-76
Coordinates	: 3625 - 99659
Elevation	: 850 m
Authors	: Philip Visser and Tom Veldkamp
Soil mapping unit	: U1PC
Soil classifcation (FAO/KSS)	: humic-ferric ACRISOL
(USDA)	: Plinthohumult
Geology	: Mount Kenya Volcanic Series
Local petrography (parent material)	: consolidated lahars
Physiography	: Volcanic Upland
Macro relief	: undulating
Slope (length, shape and pattern)	: 150 m, concave, regular.
Slope gradient	: 6%
Position on slope	: middle slope
Meso- and micro- relief	: some boulders
Vegetation/ land use	: Combretum savanna; dense bush, land use for agroforestry
Erosion	: very slight sheet and rill erosion.
Rock outcrops	: nil
Surface stoniness	: stony and fairly bouldery
Overwash	: nil
Surface runoff	: very slow
Surface sealing/crusting/cracking	: nil
Drainage class	: well drained
Flooding	: nil
Groundwater level	: always deep
Present of salts/alkali	: nil
Soil fauna	: termite burrows and termites active throughout the whole profile.
Expected rooting depth	: very deep (>160 m)

Horizons:

Ah	0-20 cm	Dark reddish brown (5YR 3/2) when moist; slightly gravelly silty clay; moderate porous massive fine subangular blocky structure;thin broken clayskins; friable, slightly sticky and slightly plastic; many medium and fine pores; very frequent fine roots few medium roots and very few coarse roots; clear and smooth transition to:
AB	20-45 cm	Dark reddish brown (5YR 3/3) when moist; clay strong porous massive, fine angular blocky structure; thin broken clayskins; friable, slighly sticky and slightly plastic; many medium and fine pores; frequent fine roots, few medium roots and very few coarse roots; clear and smooth transition to:

Bt 45-90 cm — Dark red (2.5YR 3/4) when moist; clay; strong porous massive medium angular blocky structure; thin broken clayskins; friable when moist; slightly sticky and slightly plastic; many medium and fine pores; frequent fine roots, few medium roots, very few coarse roots; clear and smooth transition to:

Bcs 90-130 cm — Dark red (2.5YR 3/4) when moist; very gravelly clay; 80% hard and angular iron and manganese concretions, size 5 mm; weak porous massive very fine angular blocky structure; thin broken clay skins; friable, slightly sticky and slightly plastic; common medium and fine pores; common medium roots; gradual and broken transition to:

BCR 130-160+ cm — Mostly rotten lahar rock with 10% hard and angular iron and manganese concretions, size (average) 5 mm.

LABORATORY DATA OF PROFILE 23

Field Observation No.: 122/4-76

Lab. no. .../86	1129	1130	1131	1132
Horizon designation	Ah	AB	Bt	Bcs
Depth (cm)	0-20	20-45	45-90	90-130
pH-H2O (1:2.5)	6.1	5.6	5.8	5.8
pH-M KCl (1:2.5)	5.1	4.8	5.2	4.9
EC (mS/cm; 1:2.5)	0.08	0.04	0.05	0.03
C (%)	1.5	1.0	0.9	0.5
CEC cmol(+)/Kg, pH 7.0	25.5	25.7	18.6	23.8
Exch. Ca (cmol(+)/Kg)	7.3	4.3	4.0	4.9
,, Mg ,,	6.7	4.0	3.5	3.3
,, K ,,	1.4	1.0	1.0	0.9
,, Na ,,	0.9	0.7	0.5	0.7
Sum cations	16.3	10.0	9.0	9.8
Base sat. at pH 7.0	64	39	48	41
ESP at pH 7.0	3	3	3	3
Gravel% >2mm				
Sand% 2-0.05mm	24	16	42	14
Silt% 50-2 um	16	12	10	12
Clay% <2 um	60	72	48	74
Texture class	C	C	C	C
CEC clay (cmol(+)/Kg)	<- 29 ->			

PROFILE 24.

Date/ season	: 14/11/85; rainy season
Sheet-observation no	: 122/4-81
Coordinates	: 3768E, 99488N
Elevation	: 650 m
Authors	: John Pulles
Soil mapping unit	: U2Q2P
Soil classification (FAO/KSS)	: chromic CAMBISOL
(USDA)	: typic Ustropept
Geology	: Basement System
Local petrography/ parent material	: gneissesrich in ferromagnesian minerals
Physiography	: Uplands
Macro-relief	: undulating
Slope (length, shape and pattern)	: ca. 150 m, convex, regular
Slope gradient	: sloping (9%)
Position on slope	: middle slope
Meso- and micro-relief	: nil
Vegetation/ Landuse	: shifting cultivation (fallow period)
Erosion	: moderate watererosion
Rock outcrops	: nil
Surface stoniness	: very few stones, slightly gravelly
Overwash	: nil
Surface runoff	: medium
Surface sealing/crusting/cracking	: slight
Drainage class	: well drained
Flooding	: absent
Groundwater level (actual)	: always deep
Presence of salts/ alkali	: nil
Soilfauna influences	: slight
Expected rooting depth	: deep

Horizons:

Bw1	0 - 33 cm	Reddish brown (5 YR 4/4) when moist; moderate medium subangular blocky structure, common crumb; no cutans; few medium, fine and very fine pores; sandy loam to sandy clay loam; slightly hard, friable, slightly sticky and slightly plastic; clear and smooth transition to
Bw2	33-70/80 cm	Reddish brown (5 YR 4/4) when moist; weak fine subangular blocky; few pores; very gravelly sandy clay loam; rounded quartz is present, mixed with different gneisses, probably colluvial material with remnants of old Tana terraces; clear and wavy transition to
2B+CR	70/80-100cm	Reddish brown (5 YR 4/4) when moist; more than 50% rockstructure; sandy clay loam.

LABORATORY DATA OF PROFILE 24

Field Observation No.:122/4-81

Lab. no. .../86	547	548	549
Horizon designation	Bw1	Bw2	2B+CR
Depth (cm)	0-33	33-70	80-100
pH-H2O (1:2.5)	7.3	7.5	8.1
pH-M KCl (1:2.5)	6.3	6.2	6.4
EC (mS/cm; 1:2.5)	0.05	0.07	0.09
C (%)	0.4	0.1	0.3
CEC cmol(+)/Kg, pH 7.0	16.1	11.5	9.1
Exch. Ca (cmol(+)/Kg)	10.0	7.9	10.5
,, Mg ,,	3.7	3.4	3.5
,, K ,,	0.3	0.1	0.2
,, Na ,,	0.2	0.2	0.3
Sum cations	14.2	11.5	14.4
Base sat. at pH 7.0	88	100+	100+
ESP at pH 7.0	1	1	3
Gravel% >2mm			
Sand% 2-0.05mm	67	73	79
Silt% 50-2 um	9	9	9
Clay% <2 um	24	18	12
Texture class	SCL	SL	SL
CEC clay (cmol(+)/Kg)	<-	61	->

FERTILITY ASPECTS

Depth (cm)	0-20	30-50
Lab. no. .../86	3676	3677
Ca cmol(+)/Kg	2.4	2.8
Mg ,,	1.8	1.6
K ,,	0.2	0.6
Mn ,,	0.3	0.2
Exch. acid. ,,	-	-
P ug/g	207	224
C %	0.3	n.d.
N %	0.10	n.d.
pH-H2O (1:2.5)	8.0	7.8

PROFILE 25.

Date/ season	: 26/11/85; rainy season
Sheet-observation no	: 122/4-85
Coordinates	: 3760 E, 99489 N
Elevation	: 685 m
Authors	: John Pulles
Soil mapping unit	: U2Q2P
Soil classification (FAO/KSS)	: calcic CAMBISOL
(USDA)	: typic Ustropept
Geology	: Basement System
Local petrography/ parent materail	: gneisses rich in ferromagnesian minerals
Physiography	: Footslope
Macro-relief	: rolling
Slope (length, shape and pattern)	: 200 m, convex, regular
Slope gradient	: strongly sloping (12%)
Position on slope	: middle slope
Meso- and micro-relief	: nil
Vegetation/ Landuse	: extensive grazing during fallow period, vegetation is wooded bushland.
Erosion	: moderate sheeterosion
Rock outcrops	: nil
Surface stoniness	: slightly gravelly, fairly stony
Overwash	: nil
Surface runoff	: rapid
Surface sealing/crusting/cracking	: moderate thin crust, for about 80% covered with 'algen'crust.
Drainage class	: well drained
Flooding	: nil
Groundwater level (actual)	: always deep
Presence of salts/ alkali	: nil
Soilfauna influences	: not noticable
Expected rooting depth	: > 90 cm

Horizons:

Ah 0 - 20/35 — Dark brown (7.5 YR 3/4) when moist; moderate fine subangular blocky structure; few medium, fine and very fine pores; siltloam; very friable, slightly sticky and slightly plastic; reacts with HCl, calcic mycelia present; clear and irregular transition to

Bck 20/35-90 cm — Strong brown (7.5 YR 4/6) when moist; structure, pores, texture and consistence not determinable; reaction with HCl; very frequent calcium carbonate concretions, Ø 3 to 10 mm; in parts rockstructure still present.

Remarks : The rockstructure consists of dark rotten gneisses, and lighter, more metamorphic (harder) gneisses. The Bck is a pisocalcic phase.

LABORATORY DATA OF PROFILE 25

Field Observation No.: 122/4-85

Lab. no. .../ 86	561	562
Horizon designation	Ah	Bck
Depth (cm)	0-20/35	20/35-90
pH-H2O (1:2.5)	8.4	8.2
pH-M KCl (1:2.5)	6.5	7.0
EC (mS/cm; 1:2.5)	0.12	0.17
C (%)	0.6	0.2
CEC cmol(+)/Kg, pH 7.0	17.5	14.7
Exch. Ca (cmol(+)/Kg)	16.9	17.8
,, Mg ,,	3.2	2.5
,, K ,,	0.1	<0.1
,, Na ,,	0.2	0.2
Sum cations	20.4	20.5
Base sat. at pH 7.0	100+	100+
ESP at pH 7.0	1	1
Gravel% >2mm		
Sand% 2-0.05mm	55	49
Silt% 50-2 um	15	21
Clay% <2 um	30	30
Texture class	SCL	SCL
CEC clay (cmol(+)/Kg)	<- 47	->

PROFILE 26

Date/ season	: 18/5/85; end rainy season
Sheet-observation no	: 122/4-8
Coordinates	: 3681 E, 99636 N
Elevation	:
Authors	: Willy Simons
Soil mapping unit	: U2F1
Soil classification (FAO/KSS)	: orthic ACRISOL
(USDA)	: ultic Paleustalf
Geology	: basement system
Local petrography/ Parent material	: hoornblende gneisses
Physiography	: Upland
Macro-relief	: gently undulating
Slope (length, shape and pattern)	: -
Slope gradient	: 0%
Position on slope	: -
Meso- and micro-relief	: nil
Vegetation/ Landuse	: bushland used for extensive grazing
Erosion	: moderate; pipe and sheet erosion
Rock outcrops	: nil
Surface stoniness	: nil
Overwash	: nil
Surface runoff	: medium
Surface sealing/crusting/cracking	: strong sealing, 7 mm thick
Drainage class	: well drained
Flooding	: nil
Groundwater level (actual)	: always deep, > 2m
Presence of salts/ alkali	: nil
Soilfauna influences	: limited
Expected rooting depth	: very deep

Horizons:

Ah	0-20 cm	Dark red (2.5YR 3/6) when moist; clay; strong fine subangular blocky structure; very hard, non sticky and non plastic; common fine pores; common fine roots; gradual and smooth transition to:
Bt1	20-90 cm	Dark reddish brown (2.5YR 3/4) when moist; clay; strong medium subangular blocky structure; patchy thin clayskins; very hard, sticky and slightly plastic; common medium pores and few fine pores; few fine roots; gradual and smooth transition to:
Bt2	90-120 cm	Dark red (2.5YR 3/6) when moist; clay; strong coarse angular blocky structure; broken thin clayskins; very hard, sticky and slightly plastic; common medium pores and few fine pores; few fine roots; gradual and smooth transition to:
BC	120-150 cm	Dark red (2.5YR 3/6) when moist; clay; strong coarse angular blocky structure; patchy thin clayskins; very hard, sticky and slightly plastic; few fine pores; few fine roots; abrupt and smooth transition to:
CR	150-170+ cm	Rotten rock

Remark: rock fragments throughout the solum.

LABORATORY DATA OF PROFILE 26

Field Observation No.: 122/4-8

Lab. no. .../85	4946	4947	4948	4949
Horizon designation	Ah	Bt1	Bt2	BC
Depth (cm)	0-20	20-90	90-120	120-150
pH-H2O (1:2.5)	6.5	6.5	6.7	7.0
pH-M KCl (1:2.5)	5.4	5.4	5.6	5.6
EC (mS/cm; 1:2.5)	0.07	0.06	0.06	0.17
C (%)	0.5	0.4	0.4	0.3
CEC cmol(+)/Kg, pH 7.0	16.4	17.0	16.1	15.0
Exch. Ca (cmol(+)/Kg)	5.3	5.3	5.3	5.3
,, Mg ,,	3.4	4.1	4.4	4.9
,, K ,,	0.6	0.1	0.1	0.1
,, Na ,,	0.1	0.1	0.1	0.1
Sum cations	9.4	9.6	9.9	10.4
Base sat. at pH 7.0	57	56	62	69
ESP at pH 7.0	1	1	1	1
Gravel% >2mm				
Sand% 2-0.05mm	35	31	31	31
Silt% 50-2 um	9	9	0	15
Clay% <2 um	56	60	60	54
Texture class	C	C	C	C
CEC clay (cmol(+)/Kg)	<-	25		->

FERTILITY ASPECTS

Depth (cm)	0-20
Lab. no. .../85	4973
Ca cmol(+)/Kg	5.0
Mg ,,	3.8
K ,,	0.5
Mn ,,	0.2
exch. acid. ,,	-
P ug/g	34
C %	0.8
N %	0.10
pH-H2O (1:2.5)	6.0

PROFILE 27

Date/ season	: 12/11/85; rainy season
Sheet-observation no	: 122/4-80
Coordinates	: 3739 E, 99503 N
Elevation	: 720 m
Authors	: John Pulles
Soil mapping unit	: U2F2p
Soil classification (FAO/KSS)	: chromic LUVISOL
(USDA)	: lithic Rhodustalf
Geology	: Basement System
Local petrography/ parent material	: gneisses rich inferro-magnesian minerals
Physiography	: Uplands
Macro-relief	: gently undulating
Slope (length, shape and pattern)	: 300 m, straight, regular
Slope gradient	: 3 %
Position on slope	: middle slope
Meso- and micro-relief	: very slight due to water erosion
Vegetation/ Landuse	: fallow land (extensive grazing)
Erosion	: slight rill, severe sheet erosion
Rock outcrops	: nil
Surface stoniness	: stony (boulders)
Overwash	: nil
Surface runoff	: rapid
Surface sealing/crusting/cracking	: moderate thin sealing
Drainage class	: somewhat excessively drained
Flooding	: nil
Groundwater level (actual)	: always deep
Presence of salts/ alkali	: nil
Soilfauna influences	: many small ants, also termite activity
Expected rooting depth	: deep

Horizons:

Bt 0-15/20 cm	Dark reddish brown (2.5 YR 3/4) when moist; slightly gravelly clay; moderate medium to coarse subangular blocky structure, and common crumb; slightly hard, friable, slightly sticky and slightly plastic; broken thin clayskins; few medium and fine pores; clear and wavy transition to:
Bt/CR 15/20 -50/60cm	Dark reddish brown (2.5 YR 3/4) when moist; clay; more than 50% rockstructure, rest moderate fine to medium subangular blocky; slightly hard, friable, slightly sticky and slightly plastic; patchy thin clayskins; few fine, common very fine pores; diffuse and wavy transition to:
CRk 50/60+ cm	Rotten rock; in parts petrocalcic visible; reaction with HCl.

LABORATORY DATA OF PROFILE 27

Field Observation No.: 122/4-80

Lab. no. .../86	544	545	546
Horizon designation	Bt	Bt/CR	CRk
Depth (cm)	0-15	20-50	60-70
pH-H2O (1:2.5)	7.3	7.3	8.1
pH-M KCl (1:2.5)	5.8	6.0	6.9
EC (mS/cm; 1:2.5)	0.10	0.07	0.12
C (%)	0.7	0.3	0.4
CEC cmol(+)/Kg, pH 7.0	18.3	12.2	12.1
Exch. Ca (cmol(+)/Kg)	11.2	8.5	10.3
,, Mg ,,	2.9	2.8	2.6
,, K ,,	0.1	<0.1	<0.1
,, Na ,,	0.3	0.2	0.2
Sum cations	14.5	11.5	13.1
Base sat. at pH 7.0	79	94	100+
ESP at pH 7.0	2	2	2
Gravel% >2mm			
Sand% 2-0.05mm	55	65	67
Silt% 50-2 um	13	11	11
Clay% <2 um	32	24	22
Texture class	SCL	SCL	SCL
CEC clay (cmol(+)/Kg)	<-	46	->

PROFILE 28

Date/ season	: 26/11/85; rainy season
Sheet-observation no	: 122/4-86
Coordinates	: 3742 E, 99501 N
Elevation	: 715 m
Authors	: John Pulles
Soil mapping unit	: U2F2p
Soil classification (FAO/KSS)	: chromic LUVISOL
(USDA)	
Geology	: Basement System
Local petrography/ parent material	: gneissesrichinferro-magnesian minerals
Physiography	: Uplands
Macro-relief	: gently undulating
Slope (length, shape and pattern)	: 400 m, convex, regular
Slope gradient	: 2 %
Position on slope	: upper slope
Meso- and micro-relief	: termite mound at 20 m
Vegetation/ Landuse	: bushland, extensive grazing
Erosion	: severe sheet, moderate rill erosion
Rock outcrops	: nil
Surface stoniness	: gravelly, fairly stony (boulders)
Overwash	: slight overwash
Surface runoff	: medium
Surface sealing/crusting/cracking	: slight thin crust
Drainage class	: somewhat excessively drained
Flooding	: nil
Groundwater level (actual)	: always deep
Presence of salts/ alkali	: nil
Soilfauna influences	: very high termite activity, sheetings
Expected rooting depth	: deep

Horizons:

Bt1 0-48 cm	Dark red (2.5 YR 3/6) when moist; clay; medium prismatic falling apart to moderate fine to medium angular blocky structure; slightly hard, very friable, slightly sticky and slightly plastic; continueous thin clayskins; few coarse, few medium and common fine and very fine pores; clear and smooth transition to:
Bt2 48-64 cm	Dark red (2.5 YR 3/6) when moist; very gravelly clay (in top the gravel is coarser); clear and smooth transition to:
B+CR 64-100 cm	Dark red (2.5 YR 3/6) when moist; clay; more than 50% rock structure; few medium pores; termite activity still present.

LABORATORY DATA OF PROFILE 28

Field Observation No.: 122/4-86

Lab. no. .../86	563	564	565
Horizon designation	Bt1	Bt2	B+CR
Depth (cm)	0-48	48-64	64-100
pH-H2O (1:2.5)	6.2	7.6	6.9
pH-M KCl (1:2.5)	5.0	6.2	5.8
EC (mS/cm; 1:2.5)	0.06	0.15	0.10
C (%)	0.3	0.2	0.2
CEC cmol(+)/Kg, pH 7.0	28.6	8.9	21.8
Exch. Ca (cmol(+)/Kg)	14.9	5.4	11.8
,, Mg ,,	3.8	3.4	4.1
,, K ,,	0.2	0.1	0.2
,, Na ,,	0.2	0.4	0.4
Sum cations	19.1	9.3	16.5
Base sat. at pH 7.0	67	100+	76
ESP at pH 7.0	1	4	2
Gravel% >2mm			
Sand% 2-0.05mm	27	75	39
Silt% 50-2 um	11	7	15
Clay% <2 um	62	18	46
Texture class	C	SL	C
CEC clay (cmol(+)/Kg)	<-	44	->

FERTILITY ASPECTS

Depth (cm)	0-20	40-60
Lab. no. .../86	3678	3679
Ca cmol(+)/Kg	8.6	4.8
Mg ,,	4.0	4.8
K ,,	0.3	0.3
Mn ,,	0.8	1.0
Exch. acid. ,,	<0.1	<0.1
P ug/g	14	42
C %	0.4	n.d.
N %	0.10	n.d.
pH-H2O (1:2.5)	6.0	6.3

PROFILE 29

Date/ season	: 6/7/85; dry season
Sheet-observation no	: 122/4-39
Coordinates	: 3673 E, 99505 N
Elevation	: 845 m
Authors	: Tom Veldkamp and Philip Visser
Soil mapping unit	: U2FC1/BC
Soil classification (FAO/KSS)	: calcic LUVISOL
(USDA)	: typic Paleustalf
Geology	: Basement System
Local petrography/ Parent material	: gneisses
Physiography	: Uplands
Macro-relief	: gently undulating
Slope (length, shape and pattern)	: 20 m, convex
Slope gradient	: 4 %
Position on slope	: upper slope
Meso- and micro-relief	: nil
Vegetation/ Landuse	: dense bushland woodland with *Boscia* and *Acacia tortillis*
Erosion	: moderate sheet, rill and gully erosion
Rock outcrops	: nil
Surface stoniness	: exceedingly stony
Overwash	: nil
Surface runoff	: medium
Surface sealing/crusting/cracking	: weak crusting, 3 cm thick
Drainage class	: well drained
Flooding	: nil
Groundwater level (actual)	: always deep
Presence of salts/ alkali	: nil
Soilfauna influences	: moderate
Expected rooting depth	: very deep

Horizons:

Ah	0-35 cm	Strong brown (7.5YR 4/6) when moist; gravelly sandy clay loam; strong medium subangular blocky structure; friable, sticky and non plastic; patchy thin cutans; few medium and fine pores; very frequent hard calcium carbonate concretions, Ø 20-30 mm; clear and wavy transition to:
Bt	35-130+ cm	Dark yellowish brown (10YR 4/6) when moist; gravelly clay; strong coarse angular blocky structure; friable, sticky and non plastic; broken thin cutans; common medium and few fine pores; very frequent hard calcium carbonate concretions, Ø 20-30 mm;

LABORATORY DATA OF PROFILE 29

Field Observation No.: 122/4-39

Lab. no. .../85	7375	7376
Horizon designation	Ah	Bt
Depth (cm)	0-35	35-130
pH-H2O (1:2.5)	7.3	7.4
pH-M KCl (1:2.5)	6.7	6.7
EC (mS/cm; 1:2.5)	0.14	0.15
C (%)	0.3	0.2
CEC cmol(+)/Kg, pH 7.0	13.5	21.6
Exch. Ca (cmol(+)/Kg)	16.4	31.7
,, Mg ,,	5.3	3.4
,, K ,,	0.3	0.2
,, Na ,,	0.8	0.8
Sum cations	22.8	36.1
Base sat. at pH 7.0	100+	100+
ESP at pH 7.0	5	4
Gravel% >2mm	0	35
Sand% 2-0.05mm	56	42
Silt% 50-2 um	19	13
Clay% <2 um	25	45
Texture class	SCL	C
CEC clay (cmol(+)/Kg)	<- 48 ->	

FERTILITY ASPECTS

Depth (cm)	0-20
Lab. no. .../85	7352
Ca cmol(+)/Kg	12.7
Mg ,,	3.0
K ,,	0.4
Mn ,,	0.2
Exch. acid. ,,	-
P ug/g	5
C %	0.5
N %	0.08
pH-H2O (1:2.5)	7.5

PROFILE 30

Date/ season	: 11/11/85; rainy season
Sheet-observation no	: 122/4-79
Coordinates	: 3706 E, 99517 N
Elevation	: 790 m
Authors	: John Pulles
Soil mapping unit	: U2FC1/CD
Soil classification (FAO/KSS)	: calcic CAMBISOL
(USDA)	: typic Ustropept
Geology	: Basement System
Local petrography/ parent material	: gneissesrich inferro-magnesian minerals
Physiography	: Uplands
Macro-relief	: undulating
Slope (length, shape and pattern)	: 300 m, convex, regular
Slope gradient	: gently sloping
Position on slope	: upper slope
Meso- and micro-relief	: nil
Vegetation/ Landuse	: extensive grazing in fallow period
Erosion	: moderate sheet erosion
Rock outcrops	: nil
Surface stoniness	: fairly stony (boulders)
Overwash	: nil
Surface runoff	: rapid
Surface sealing/crusting/cracking	: moderate crust
Drainage class	: somewhat excessively drained
Flooding	: nil
Groundwater level (actual)	: always deep
Presence of salts/ alkali	: nil
Soilfauna influences	: high termite-activity, krotovinas
Expected rooting depth	: deep

Horizons:

Ah	0-15/20 cm	Dark reddish brown (5 YR 3/3) when moist; loam; moderate fine to medium subangular blocky, common crumb and granules; hard, friable, slightly sticky and slightly plastic; patchy thin clayskins; few fine and medium, common very fine pores; abrupt and wavy transition to:
Bw	15/20-35/50cm	Dark reddish brown (2.5 YR 3/4) when moist; very gravelly loam; more than 50% rockstructure; clear and wavy transition to:
Bck	35/50-80 cm	Dark reddish brown (2.5 YR 3/4) when moist; very frequent calcic concretions, Ø 5-20 mm; clear and wavy transition to:
CR	80+ cm	Rotten rock with some calcareas concretions.

LABORATORY DATA OF PROFILE 30

Field Observation No.: 122/4-79

Lab. no. .../86	541	542	543
Horizon designation	Ah	Bw	Bck
Depth (cm)	0-15	20-35	50-80
pH-H20 (1:2.5)	7.4	8.1	8.1
pH-M KCl (1:2.5)	5.8	6.2	6.7
EC (mS/cm; 1:2.5)	0.11	0.11	0.14
C (%)	0.5	0.5	0.4
CEC cmol(+)/Kg, pH 7.0	17.6	19.3	21.8
Exch. Ca (cmol(+)/Kg)	15.5	15.5	17.7
,, Mg ,,	3.0	4.6	4.3
,, K ,,	<0.1	<0.1	<0.1
,, Na ,,	0.2	0.2	0.2
Sum cations	18.7	20.3	22.2
Base sat. at pH 7.0	100+	100+	100+
ESP at pH 7.0	1	1	1
Gravel% >2mm			
Sand% 2-0.05mm	61	61	55
Silt% 50-2 um	15	11	13
Clay% <2 um	24	28	32
Texture class	SCL	SCL	SCL
CEC clay (cmol(+)/Kg)	<-	60	->

FERTILITY ASPECTS

Depth (cm)	0-20
Lab. No. .../86	3675
Ca cmol(+)/Kg	15.2
Mg ,,	5.5
K ,,	0.1
Mn ,,	0.4
Exch. acid. ,,	<0.1
P ug/g	241
C %	0.6
N %	0.12
pH-H20 (1:2.5)	7.1

PROFILE 31

Date/ season	: 6/7/85; dry season
Sheet-observation no	: 122/4-38
Coordinates	: 3634 E, 99499 N
Elevation	: 885 m
Authors	: Tom Veldkamp and Philip Visser
Soil mapping unit	: U2FC2
Soil classification (FAO/KSS)	: chromic LUVISOL
(USDA)	: rhodic Paleustalf
Geology	: Basement System
Local petrography/ Parent material	: gabbronotite, gneisses, talcum
Physiography	: Uplands
Macro-relief	: gently undulating
Slope (length, shape and pattern)	: > 100 m, complex
Slope gradient	: 4 %
Position on slope	: -
Meso- and micro-relief	:
Vegetation/ Landuse	: dense bushland woodland with *Acacia tortulis* and *Euphorbia sp.*
Erosion	: slight rill erosion
Rock outcrops	: nil
Surface stoniness	: nil
Overwash	: nil
Surface runoff	: very slow
Surface sealing/crusting/cracking	: sealing, 5mm thick
Drainage class	: somewhat excessively drained
Flooding	: nil
Groundwater level (actual)	: always deep
Presence of salts/ alkali	: nil
Soilfauna influences	: moderate
Expected rooting depth	: very deep

Horizons:

Bw1 0-40 cm	Dark red (2.5YR 3/6) when moist; sandy clay; strong coarse angular blocky structure; friable, sticky and plastic; thin broken clayskins; common medium and fine pores; clear and wavy transition to:
Bw240-150+cm	Dark red (2.5YR 3/6) when moist; sandy clay; strong coarse angular blocky structure; friable, sticky and plastic; thin broken clayskins; common fine pores.

LABORATORY DATA OF PROFILE 31

Field Observation No.: 122/4-38

Lab. no. .../85	7373	7374
Horizon designation	Bw1	Bw2
Depth (cm)	0-40	40-150
pH-H2O (1:2.5)	5.5	6.2
pH-M KCl (1:2.5)	5.0	5.5
EC (mS/cm; 1:2.5)	0.04	0.05
C (%)	0.3	0.2
CEC cmol(+)/Kg, pH 7.0	13.0	12.6
Exch. Ca (cmol(+)/Kg)	4.7	4.7
,, Mg ,,	2.8	4.3
,, K ,,	0.3	0.2
,, Na ,,	0.3	0.2
Sum cations	8.1	9.4
Base sat. at pH 7.0	62	75
ESP at pH 7.0	3	2
Gravel% >2mm	0	0
Sand% 2-0.05mm	50	50
Silt% 50-2 um	7	11
Clay% <2 um	43	39
Texture class	SC	SC
CEC clay (cmol(+)/Kg)	<- 28	->

Depth (cm)	5-10	40-45	80-85	125-130
pF 0	35.8	27.1	28.0	29.5
pF 2.0	21.7	21.2	21.8	22.3
pF 2.3	19.4	19.4	19.8	20.4
pF 3.7	12.7	13.1	13.4	14.3
pF 4.2	12.2	12.6	12.9	13.4

FERTILITY ASPECTS

Depth (cm)	0-20
Lab. no. .../85	7351
Ca cmol(+)/Kg	3.6
Mg ,,	1.9
K ,,	0.3
Mn ,,	0.1
Exch. acid. ,,	-
P ug/g	13
C %	0.5
N %	0.09
pH-H2O (1:2.5)	6.0

PROFILE 32

Date/season	: 10/12/85; rainy season
Sheet observation no	: 122/4-95
Coordinates	: 3873 E, 99514 N
Elevation	: 703 m
Author	: Richard Kraayvanger
Soil mapping unit	: U2FC2
Soil classification (FAO/KSS)	: chromic LUVISOL
(USDA)	: typic Haplustalf
Geology	: mayor intrusives
Local petrography/ parent material	: hornblende-biotitegneisses and granitoids
Physiography	: hills
Macrorelief	: hilly
Slope (lenght,shape and pattern)	: 300 m, straight, regular
Slopegradient	: 30%
Position on slope	: middle slope
Meso-microrelief	: slumps
Vegetation/landuse	: forest, extensive grazing and shifting cultivation
Erosion	: very slightly rill erosion
Rockoutcrops	: fairly rocky
Surface stoniness	: very stony
Overwash	: -
Surface runn-off	: medium
Surface sealing/criustin/cracking	: -
Drainage class	: well-drained
Flooding	: -
Groundwaterlevel	: >200 cm
Presence of salts/alkali	: -
Soilfauna influences	: many ants, wormcasts and termite sheetings
Expected rooting depth	: moderately deep

Horizons

Ap 0-15 cm	Dark reddish brown (5YR 3/3) when moist; weak fine and medium crumb and granular structure; many medium and fine pores; gravelly loamy sand; loose, slightly sticky, non plastic; wavy and clear transition to
Bw 15-40 cm	Dark reddish brown (5YR 3/6) when moist; moderate fine and medium subangular blocky structure; commom medium and fine pores; very gravelly sandy clay loam; firm, slightly sticky, slightly plastic; wavy and clear transition to
B+CR 40-100cm	Dark reddish brown (2.5 YR 3/6) when moist; moderate fine and medium subangular blocky structure; few medium pores; very gravelly sandy clay; friable, slightly sticky, slightly plastic.

LABORATORY DATA OF PROFILE 32

Field Observation No.: 122/4-95

Lab. no. .../86	588	589
Horizon designation	Ap	Bw
Depth (cm)	0-15	15-40
pH-H2O (1:2.5)	7.0	5.9
pH-M KCl (1:2.5)	6.6	4.5
EC (mS/cm; 1:2.5)	0.10	0.03
C (%)	1.0	0.5
CEC cmol(+)/Kg, pH 7.0	9.7	9.3
Exch. Ca (cmol(+)/Kg)	3.5	3.4
,, Mg ,,	2.6	2.0
,, K ,,	0.7	0.3
,, Na ,,	0.2	0.2
Sum cations	7.0	5.9
Base sat. at pH 7.0	72	63
ESP at pH 7.0	2	2
Gravel% >2mm		
Sand% 2-0.05mm	74	68
Silt% 50-2 um	10	10
Clay% <2 um	16	22
Texture class	SL	SCL
CEC clay (cmol(+)/Kg)	<- 30	->

PROFILE 33.

Date/ season	: 14/11/85; rainy season
Sheet-observation no	: 122/4-82
Coordinates	: 3787 E, 99481 N
Elevation	: 530 m
Authors	: John Pulles
Soil mapping unit	: U2UC
Soil classification (FAO/KSS)	: chromic Luvisol
(USDA)	: Plinthustalf or Paleustalf?
Geology	: Pleistocene alluvial deposits
Local petrography/ parent material	: Pleistocene alluvium
Physiography	: Alluvial plain
Macro-relief	: undulating
Slope (length, shape and pattern)	: ca. 300 m, straight, regular
Slope gradient	: sloping (7%)
Position on slope	: middle slope
Meso- and micro-relief	: strong mesorelief due to erosion gullies
Vegetation/ Landuse	: extensive grazing
Erosion	: severe sheet- and gully erosion
Rock outcrops	: nil
Surface stoniness	: slightly gravelly
Overwash	: nil
Surface runoff	: rapid
Surface sealing/crusting/cracking	: moderate thin
Drainage class	: somewhat excessively
Flooding	: nil
Groundwater level (actual)	: always deep
Presence of salts/ alkali	: nil
Soilfauna influences	: termite burrow at 60 cm
Expected rooting depth	: deep

Horizons:

Ah	0-15 cm	Dark reddish brown (5 YR 3/4) when moist; moderate fine to medium angular to subangular blocky structure, few crumb; few medium, fine and very fine pores; sandy clay loam; slightly hard, friable, slightly sticky and slightly plastic; clear and smooth transition to
Bt	15-90 cm	Red (2.5 YR 4/6) when moist; moderate medium prismatic and angular blocky, sometimes massive structureless, few crumb; broken thin clayskins; few medium, fine and very fine pores; clayloam; hard, firm, slightly sticky and slightly plastic; gradual and smooth transition to
1C	90-120 cm	Red (2.5 YR 4/8) when moist; weak fine subangular blocky; silt loam; soft, very friable, non sticky and non plastic; frequent, soft, irregular shaped iron-concretions,∅ 10 mm; clear and smooth transition to

2C	>120 cm	Fine, within 20 cm changing to larger, rounded rivergravel.

LABORATORY DATA OF PROFILE 33

Field Observation No.: 122/4-82

Lab. no. .../86	550	551	552	553
Horizon designation	Ah	Bt	Bt	1C
Depth (cm)	0-15	15-50	50-90	90-120
pH-H2O (1:2.5)	6.9	7.1	7.5	8.3
pH-M KCl (1:2.5)	6.0	6.1	6.0	6.4
EC (mS/cm; 1:2.5)	0.07	0.19	0.40	0.20
C (%)	0.5	0.3	0.4	0.2
CEC cmol(+)/Kg, pH 7.0	11.1	14.6	16.3	8.6
Exch. Ca (cmol(+)/Kg)	5.8	8.3	9.8	5.5
,, Mg ,,	3.3	4.7	4.9	4.6
,, K ,,	0.2	0.2	0.2	<0.1
,, Na ,,	0.2	0.2	0.4	0.9
Sum cations	10.5	13.4	15.3	11.0
Base sat. at pH 7.0	95	92	94	100+
ESP at pH 7.0	2	1	2	10
Gravel% >2mm				
Sand% 2-0.05mm	67	61	57	59
Silt% 50-2 um	13	7	9	23
Clay% <2 um	20	32	34	18
Texture class	SCL/SL	SCL	SCL	SL
CEC clay (cmol(+)/Kg)	<-	41		->

FERTILITY ASPECTS

Depth (cm)	0-20	40-60
Lab. no. .../86	3684	3685
Ca cmol(+)/Kg	4.4	2.4
Mg ,,	4.0	3.5
K ,,	0.5	0.2
Mn ,,	0.6	0.6
exch. acid. ,,	<0.1	<0.1
P ug/g	60	28
C %	0.2	n.d.
N %	0.09	n.d.
pH-H2O (1:2.5)	7.1	6.7

PROFILE 34

Date/ season	: 13/02/1986; dry season
Sheet-observation no	: 122/4-112
Coordinates	: 3858 E, 99644 N
Elevation	: 490 m
Authors	: J. Pulles
Soil mapping unit	: U2UC
Soil classification (FAO/KSS)	: chromic Luvisol
(USDA)	: lithic Haplustalf
Geology	: Basement System
Local petrography	: undifferentiated Basement System rocks
(Parent material)	
Physiography	: Uplands
Macro-relief	: undulating to rolling
Slope (length, shape, pattern)	: 75 m, convex, regular
Slope gradient	: gently sloping (3%)
Position on slope	: upper slope
Meso- and micro-relief	: moderate dense very slight meso relief
Vegetation/ Landuse	: charcoal exploitation; extensive grazing; few shifting cultivation of millet
Erosion	: severe sheet, slight rill erosion
Rock outcrops	: in places fairly rocky
Surface stoniness	: gravelly
Overwash	: nil
Surface runoff	: rapid
Surface sealing/ crusting/cracking	: slight crusting
Drainage class	: somewhat excessively drained
Flooding	: nil
Groundwater level (actual)	: always deep
Presence of salts/ alkali	: nil
Soilfauna influences	: many termite sheetings on bush vegetation
Expected rooting depth	: shallow

Horizons:

Bt	0 - 10 cm	Red (2.5 YR 4/6) when moist; sandy clay, slightly gravelly; moderate fine to medium subangular blocky structure; slightly hard, firm, sticky and slightly plastic; few thin clay skins; clear and smooth transition to
B+CR	10 - 45 cm	Red (2.5 YR 4/6) when moist; sandy clay, very gravelly to gravel; predominantly rock structure; sticky and plastic; continuous thin clay skins; gradual and broken transition to
CR	45 - 70 cm	Predominantly rotten rock.

LABORATORY DATA OF PROFILE 34

Field Observation No.: 122/4-112

Lab. no. .../86	2189	2190
Horizon designation	Bt	B+CR
Depth (cm)	0-10	10-45
pH-H2O (1:2.5)	7.2	6.6
pH-M KCl (1:2.5)	5.5	4.7
EC (mS/cm; 1:2.5)	0.05	0.06
C (%)	0.2	0.3
CEC cmol(+)/Kg, pH 7.0	14.3	16.5
Exch. Ca (cmol(+)/Kg)	4.3	4.5
,, Mg ,,	3.5	3.6
,, K ,,	0.4	0.1
,, Na ,,	0.3	0.2
Sum cations	8.5	8.4
Base sat. at pH 7.0	59	51
ESP at pH 7.0	2	1
Gravel% >2mm		
Sand% 2-0.05mm	68	62
Silt% 50-2 um	8	8
Clay% <2 um	24	30
Texture class	SCL	SCL
CEC clay (cmol(+)/Kg)	<- 52 ->	

FERTILITY ASPECTS

Depth (cm)	0-20
Lab. no. .../86	2199
Ca cmol(+)/Kg	4.8
Mg ,,	5.3
K ,,	0.4
Mn ,,	0.5
Exch. acid. ,,	<0.1
P ug/g	46
C %	0.1
N %	0.12
pH-H2O (1:2.5)	6.7

Remark: Exceptional high difference between pH H2O and pH KCl, and a low base saturation in relation with pH H2O.

PROFILE 35

Date/ season	: 13/02/1986; dry season
Sheet-observation no	: 122/4-110
Coordinates	: 3865 E, 99647 N
Elevation	: 480 m
Authors	: J. Pulles
Soil mapping unit	: U2X2P (Tana river terrace)
Soil classification (FAO/KSS)	: chromic Luvisol
(USDA)	: arenic Haplustalf?
Geology	: pleistocene upper Tana deposits
Local petrography	: pleistocene alluvial deposits
Physiography	: floodplain
Macro-relief	: flat
Slope (length, shape, pattern)	: -
Slope gradient	: 0 %
Position on slope	: -
Meso- and micro-relief	: nil
Vegetation/ Landuse	: grassland to wooded bushland; extensive grazing
Erosion	: nil
Rock outcrops	: nil
Surface stoniness	: nil
Overwash	: nil
Surface runoff	: slow
Surface sealing/ crusting/cracking	: nil
Drainage class	: well drained
Flooding	: nil
Groundwater level (actual)	: deep
Presence of salts/ alkali	: nil
Soilfauna influences	: sheetings of termites (*microtermes spp.*)
Expected rooting depth	: deep

Horizons:

Ah	0 - 20 cm	Dark reddish brown (5 YR 3/4) when moist; sand; weak medium subangular blocky structure, with common crumb; soft, loose, non sticky and non plastic; no cutans; few medium, few fine pores; gradual and smooth transition to
Bt	20 - 70 cm	Yellowish red (5 YR 5/6) when moist; loamy sand, slightly gravelly; porous massive structure, strongly coherent; slightly hard, very friable, slightly sticky and non plastic; oriented clay bridges; few fine, common very fine pores; gradual and smooth transition to
BC	70 - 130 cm	Reddish yellow (5 YR 6/6) when moist; sand, slightly gravelly; weak medium to coarse subangular blocky structure; soft, loose, non sticky and non plastic; no pores.

LABORATORY DATA OF PROFILE 35

Field Observation No.: 122/4-110

Lab. no. .../86	2183	2184	2185
Horizon designation	Ah	Bt	BC
Depth (cm)	0-20	20-70	70-130
pH-H2O (1:2.5)	7.0	6.6	6.3
pH-M KCl (1:2.5)	6.1	4.7	4.6
EC (mS/cm; 1:2.5)	0.04	0.02	0.03
C (%)	0.3	0.1	0.2
CEC cmol(+)/Kg, pH 7.0	7.8	2.7	7.3
Exch. Ca (cmol(+)/Kg)	2.5	0.4	2.7
,, Mg ,,	3.1	1.9	2.1
,, K ,,	0.9	<0.1	0.1
,, Na ,,	0.1	0.1	0.1
Sum cations	6.6	2.4	4.0
Base sat. at pH 7.0	85	89	68
ESP at pH 7.0	1	?	1
Gravel% >2mm			
Sand% 2-0.05mm	80	94	80
Silt% 50-2 um	8	2	8
Clay% <2 um	12	4	12
Texture class	SL	S	SL
CEC clay (cmol(+)/Kg)	<-	52	->

FERTILITY ASPECTS

Depth (cm)	0-20	40-60
Lab. no. .../86	2195	2196
Ca cmol(+)/Kg	1.6	3.0
Mg ,,	4.0	2.6
K ,,	1.3	0.2
Mn ,,	0.9	0.3
Exch. acid. ,,	<0.1	<0.1
P ug/g	15	168
C %	1.5	0.2
N %	0.2	0.1
pH-H2O (1:2.5)	5.6	6.5

PROFILE 36

Date/ season	: 15/5/85; end rainy season
Sheet-observation no	: 122/4-6
Coordinates	: 3725 E, 99563 N
Elevation	:
Authors	: Willy Simons
Soil mapping unit	: U2X2p
Soil classification (FAO/KSS)	: pellic VERTISOL
(USDA)	: udic Pellustert
Geology	: basement system
Local petrography/ Parent material	: alluvial deposits
Physiography	: Upland
Macro-relief	: gently undulating
Slope (length, shape and pattern)	: -
Slope gradient	: 0%
Position on slope	: -
Meso- and micro-relief	: nil
Vegetation/ Landuse	: bushland with grasses used for extensive grazing
Erosion	: very slight; sheet erosion
Rock outcrops	: nil
Surface stoniness	: nil
Overwash	: nil
Surface runoff	: slow
Surface sealing/crusting/cracking	: cracks; 50 cm deep, 1 cm wide
Drainage class	: somewhat poorly drained
Flooding	: nil
Groundwater level (actual)	: always deep, > 120 cm
Presence of salts/ alkali	: nil
Soilfauna influences	: none to limited
Expected rooting depth	: moderately deep

Horizons:

Ah 0-15 cm Black (10YR 2/1) when moist; clay; strong medium angular blocky structure; common small slickensides, 1-4 cm2; very friable, slightly sticky and slightly plastic; many medium pores; few very fine roots; gradual and smooth transition to:

Bu 15-60 cm Black (10YR 2/1) when moist; clay; strong coarse angular blocky structure; common small slickensides, 1-4 cm^2; friable, non sticky and slightly plastic; many medium pores; few very fine roots; gradual and smooth transition to:

Buck 60-75 cm Very dark grayish brown (10YR 3/2) when moist; clay; strong coarse angular blocky structure; common small slickensides, 1-4 cm2; friable, non sticky and slightly plastic; few soft carbonate concretions, Ø 5 mm; many medium pores; few very fine roots; clear and smooth transition to:

Cck 75-95 cm Calcic horizon; abrupt and smooth transition to:

Cmk 95-130+ cm Petrocalcic horizon.

LABORATORY DATA OF PROFILE 36

Field Observation No.: 122/4-6

Lab. no. .../85	4942	4943	4944
Horizon designation	Ah	Bu	Bck
Depth (cm)	0-15	15-60	60-75
pH-H2O (1:2.5)	8.1	8.5	8.1
pH-M KCl (1:2.5)	6.9	7.2	7.3
EC (mS/cm; 1:2.5)	0.4	0.7	1.65
C (%)	0.6	0.6	0.5
CEC cmol(+)/Kg, pH 7.0	36.7	36.5	34.0
Exch. Ca (cmol(+)/Kg)	28.5	28.5	21.5
,, Mg ,,	11.0	14.2	11.8
,, K ,,	0.6	0.4	0.4
,, Na ,,	0.9	3.9	7.9
Sum cations	41.0	47.0	41.6
Base sat. at pH 7.0	100+	100+	100+
ESP at pH 7.0	2	11	23
Gravel% >2mm			
Sand% 2-0.05mm	38	36	39
Silt% 50-2 um	14	14	13
Clay% <2 um	48	50	48
Texture class	C	C	C
CEC caly (cmol(+)/Kg)	<-	68	->
Moisture% saturation extract			82
ECe (mS/cm)			4.0
pH paste			8.0

FERTILITY ASPECTS

Depth (cm)	0-20
Lab. no. .../85	4971
Ca cmol(+)/Kg	30.0
Mg ,,	9.4
K ,,	0.1
Mn ,,	0.02
Exch. acid. ,,	-
P ug/g	42
C %	0.6
N %	0.07
pH-H2O (1:2.5)	7.9

PROFILE 37

Date/ season	: 18/5/85; end rainy season
Sheet-observation no	: 122/4-9
Coordinates	: 3663 E, 99646 N
Elevation	:
Authors	: Willy Simons
Soil mapping unit	: PPC
Soil classification (FAO/KSS)	: gleyic ACRISOL
(USDA)	: aquultic Haplustalf
Geology	: Mt. Kenya series
Local petrography/parent material	: pyroclastic agglomerates/ phonolite
Physiography	: Plateau
Macro-relief	: flat
Slope (length, shape and pattern)	: -
Slope gradient	: 0%
Position on slope	: -
Meso- and micro-relief	: nil
Vegetation/ Landuse	: grassland used for extensive grazing
Erosion	: slight; sheetwash
Rock outcrops	: nil
Surface stoniness	: nil
Overwash	: nil
Surface runoff	: very slow
Surface sealing/crusting/cracking	: nil
Drainage class	: moderately well drained
Flooding	: nil
Groundwater level (actual)	:
Presence of salts/ alkali	: nil
Soilfauna influences	: limited
Expected rooting depth	: moderately deep

Horizons:

Ah	0-15 cm	Black (10YR 2/1) when moist; few fine distinct black mottles; slightly gravelly clay; weak medium granular structure; friable, non sticky and non plastic; few manganese concretions, Ø 0-5 mm; common medium pores; common fine roots; clear nd smooth transition to:
Bw	15-25 cm	Dark brown (10YR 4/3) when moist; common fine prominent black mottles; slightly gravelly clay; moderate medium subangular blocky structure; friable, non sticky and non plastic; few manganese concretions, Ø 0-5 mm; common medium pores; common fine roots; clear and smooth transition to:
Bt1	25-50 cm	Dark yellowish brown (10YR 4/6) when moist; common fine prominent black mottles; slightly gravelly clay; moderate medium subangular blocky structure; firm, non sticky and non plastic; few manganese concretions, Ø 0-5 mm; common medium pores; few very fine roots; clear and smooth transition to:
Bt2	50-62 cm	Dark yellowish brown (10YR 3/4) when moist; many fine prominent black mottles; gravelly clay; moderate medium subangular blocky structure; few thin clayskins; very firm, non sticky and non plastic; frequent manganese

concretions, Ø 5-10 mm; common medium pores; few very fine roots; abrupt and smooth transition to:

R 62+ cm Hard rock.

LABORATORY DATA OF PROFILE 37

Field Observation No.: 122/3-9

Lab. no. .../85	4950	4951	4952	4953
Horizon designation	Ah	Bw	Bt1	Bt2
Depth (cm)	0-15	15-25	25-50	50-62
pH-H2O (1:2.5)	6.6	6.6	6.8	7.2
pH-M KCl (1:2.5)	5.5	5.9	6.0	6.0
EC (mS/cm; 1:2.5)	0.12	0.10	0.12	0.15
C (%)	1.3	1.1	0.9	0.5
CEC cmol(+)/Kg, pH 7.0	22.2	21.5	20.2	21.3
Exch. Ca (cmol(+)/Kg)	10.9	10.5	10.5	12.3
,, Mg ,,	4.2	3.9	4.0	5.0
,, K ,,	0.2	0.1	0.2	0.2
,, Na ,,	0.2	0.2	0.4	0.5
Sum cations	15.5	14.7	15.1	18.0
Base sat. at pH 7.0	70	68	75	85
ESP at pH 7.0	1	1	2	3
Gravel% >2mm				
Sand% 2-0.05mm	33	29	27	25
Silt% 50-2 um	15	15	11	11
Clay% <2 um	52	56	62	64
Texture class	C	C	C	C
CEC clay (cmol(+)/Kg)	<-	29		->

FERTILITY ASPECTS

Depth (cm)	0-20
Lab. no. .../85	4974
Ca cmol(+)/Kg	14.4
Mg ,,	4.8
K ,,	0.2
Mn ,,	0.3
Exch. acid. ,,	-
P ug/g	34
C %	1.5
N %	0.14
pH-H2O (1:2.5)	5.7

PROFILE 38

Date/ season	: 1/6/85; end rainy season
Sheet-observation no	: 122/3-17
Coordinates	: 3490 E, 99537 N
Elevation	: 1360 m
Authors	: Inge Aalders and Hans Nobbe
Soil mapping unit	: BPC
Soil classification (FAO/KSS)	: gleyic ACRISOL
(USDA)	: epiaquic Palehumult
Geology	: Mt. Kenya series
Local petrography/ Parent material	: lahar / phonolite
Physiography	: Bottomlands
Macro-relief	: flat
Slope (length, shape and pattern)	: -
Slope gradient	: 2 %
Position on slope	: -
Meso- and micro-relief	: nil
Vegetation/ Landuse	: grazing
Erosion	: very slight sheet and splash erosion
Rock outcrops	: nil
Surface stoniness	: nil
Overwash	: nil
Surface runoff	: very slow
Surface sealing/crusting/cracking	: nil
Drainage class	: moderately well drained
Flooding	: nil
Groundwater level (actual)	: temporarily moderately deep
Presence of salts/ alkali	: nil
Soilfauna influences	: limited
Expected rooting depth	: deep

Horizons:

Ah1 0-35/40 cm	Dark reddish brown (5YR 3/2) when moist; clay; moderate fine granular structure; very friable, slightly sticky and slightly plastic; many fine pores; gradual and wavy transition to:
Ah2 35/40-65/70 cm	Dark brown (7.5YR 3/2) when moist; very few fine faint black mottles; clay; moderate fine subangular and granular structure; very friable, sticky and slightly plastic; many fine pores; abundant medium roots; gradual and wavy transition to:
BA 65/70-105/110 cm	Dark brown (7.5YR 3/2) when moist; clay; few fine faint black, red and yellow mottles; moderate fine subangular blocky structure; friable, slightly sticky and slightly plastic; patchy thin manganese cutans; many fine pores; very few coarse and common fine roots; gradual and wavy transition to:
Btg 105/110-130+ cm	Dark reddish brown (5YR 3/3) when moist; clay; abundant little black concretions; strong medium angular blocky structure; broken thin manganese cutans; very friable, sticky and slightly plastic;

very few coarse and common fine roots.

LABORATORY DATA OF PROFILE 38

Field Observation No.: 122/3-17

Lab. no. .../85	5772	5773	5774	5775
Horizon designation	Ah1	Ah2	BA	Btg
Depth (cm)	0-35	40-65	65-105	110-130
pH-H2O (1:2.5)	5.0	5.0	4.9	5.0
pH-M KCl (1:2.5)	4.4	4.8	4.3	4.1
EC (mS/cm; 1:2.5)	0.04	0.04	0.04	0.03
C (%)	1.6	1.2	1.1	1.0
CEC cmol(+)/Kg, pH 7.0	24.7	23.5	18.7	16.5
Exch. Ca (cmol(+)/Kg)	5.0	3.2	2.0	1.3
,, Mg ,,	1.0	1.0	0.5	0.3
,, K ,,	0.2	0.1	0.1	0.1
,, Na ,,	0.1	0.2	0.1	0.1
Sum cations	6.3	4.5	2.7	1.8
Base sat. at pH 7.0	26	19	14	11
ESP at pH 7.0	<1	1	<1	<1
Gravel% >2mm				
Sand% 2-0.05mm	6	12	8	12
Silt% 50-2 um	36	24	20	14
Clay% <2 um	58	64	72	74
Texture class	C	C	C	C
CEC clay (cmol(+)/Kg)	29 ------------------> 16			

FERTILITY ASPECTS*

Depth (cm)	0-20	40-60
Lab. no. .../85	5792	8418
Ca cmol(+)/Kg	5.2	2.0
Mg ,,	1.4	2.0
K ,,	0.3	0.3
Mn ,,	0.8	1.6
exch. acid. ,,	0.5	0.9
P ug/g	38	17
C %	1.4	n.d.
N %	0.10	n.d.
pH-H2O (1:2.5)	5.2	5.4

* Composite sample of at least 5 locations

Remark: The decrease of the CEC of the clay with depth partly can be explained by an incomplete dispersion of the clay in the topsoil (too low clay%). This being true will result in a CEC clay of around 18 for the full profile.

PROFILE 39

Date/ season	: 21/6/85; end rainy season
Sheet-observation no	: 122/3-30
Coordinates	: 3543 E, 99505 N
Elevation	: 1150 m
Authors	: Willy Simons
Soil mapping unit	: BPC
Soil classification (FAO/KSS)	: phlinthic GLEYSOL
(USDA)	: Plinthaquult or Plinthaquept
Geology	: Mt. Kenya series
Local petrography/ Parent material	: lahar / phonolite
Physiography	: Bottomlands
Macro-relief	: undulating
Slope (length, shape and pattern)	: complex
Slope gradient	: 1 %
Position on slope	: -
Meso- and micro-relief	: nil
Vegetation/ Landuse	: pasture used for grazing
Erosion	: nil
Rock outcrops	: nil
Surface stoniness	: nil
Overwash	: nil
Surface runoff	: ponded
Surface sealing/crusting/cracking	: strong crusting; 5 mm thick
Drainage class	: poorly drained
Flooding	: occasionally
Groundwater level (actual)	: temporarily shallow
Presence of salts/ alkali	: nil
Soilfauna influences	: limited
Expected rooting depth	: moderately deep

Horizons:

Ah	0-8 cm	Black (7.5YR 2/0) when moist; clay; strong fine subangular blocky structure; firm, slightly sticky and plastic; common fine pores; common fine roots; clear and wavy transition to:
Bg	8-25/45 cm	Dark grayish brown (10YR 4/2) when moist; many fine prominent yellowish red mottles; clay; strong coarse subangular blocky structure; firm, slightly sticky and plastic; common fine pores; common medium and fine roots; clear and smooth transition to:
Cgc	25/45-65cm	Dark greyish brown (10YR 4/2) when moist; many fine prominent red mottles; very gravelly clay; strong coarse subangular blocky structure; firm, slightly sticky and plastic; few fine pores; very frequent hard spherical iron concretions, Ø 4-20 mm; common fine roots; clear and smooth transition to:
Cr	65-90+ cm	Dark greyish brown (10YR 4/2) when moist; clay; strongly coherent porous massive structure; firm, slightly sticky and plastic; very few fine pores; no roots.

Remark: ironstone layer at 30-35 cm.

LABORATORY DATA OF PROFILE DESCRIPTION 39

Field Observation No.: 122/3-30

Lab. no. .../85	6757	6758	6759	6760
Horizon designation	Ah	Bg	Cgc	Cr
Depth (cm)	0-8	8-25	45-65	65-90
pH-H2O (1:2.5)	5.1	5.0	5.2	6.1
pH-M KCl (1:2.5)	3.3	3.6	4.1	4.9
EC (mS/cm; 1:2.5)	0.05	0.07	0.05	0.18
C (%)	2.5	0.9	0.6	0.2
CEC cmol(+)/Kg, pH 7.0	24.6	18.5	14.2	12.2
Exch. Ca (cmol(+)/Kg)	2.1	1.9	1.7	4.5
,, Mg ,,	0.7	0.6	0.7	2.6
,, K ,,	0.4	0.2	0.2	0.3
,, Na ,,	0.2	0.2	0.2	0.2
Sum cations	3.4	2.9	2.8	7.6
Base sat. at pH 7.0	14	16	20	62
ESP at pH 7.0	1	1	1	2
Gravel% >2mm				
Sand% 2-0.05mm	23	15	33	13
Silt% 50-2 um	25	15	9	7
Clay% <2 um	52	70	58	80
Texture class	C	C	C	C
CEC clay (cmol(+)/Kg)	<-	20	->	14

FERTILITY ASPECTS

Depth (cm)	0-20	40-60
Lab. no. .../85	6504	8438
Ca cmol(+)/Kg	2.4	2.0
Mg ,,	0.7	1.3
K ,,	0.3	0.2
Mn ,,	1.4	1.2
Exch. acid. ,,	-	-
P ug/g	6	8
C %	1.9	n.d.
N %	0.18	n.d.
pH-H2O (1:2.5)	5.6	5.8

Remark: Note that the top three horizons with the lowest base saturation and pH values have the highest CEC clay value.

PROFILE 40

Date/ season	: 26-8-85 : end of cold season
Sheet and Observation no	: 122/3-48
Coordinates	: 3373 E, 99609 S
Elevation	: 1740 m
Authors	: Willy Simons and Nicole Bongers
Soil mapping unit	: V1PC
Soil Classification (FAO/KSS)	: dystric NITISOL*
(USDA)	: orthoxic Palehumult
Geology	: Mt. Kenya series
Local petrography/ Parent material:	Pyroclastic agglomerates/ phonolites
Physiography	: Valley in mountain Footridge
Macro-relief	: mountainous
Slope (length, shape & pattern)	: 150 m, convex, regular
Slope gradient	: 52%
Position on slope	: middle slope
Meso- and micro-relief	: nil
Vegetation/ Landuse	: perennial crop cultivation; tea
Erosion	: nil
Rock outcrops	: nil
Surface stoniness	: nil
Overwash	: nil
Surface runoff	: rapid
Surface sealing/crusting/cracking	: nil
Drainage class	: well drained
Flooding	: nil
Groundwater level (actual)	: always deep, > 200 m
Presence of salts/ alkali	: nil
Soilfauna influences	: none to limited
Effective rooting depth	: extremely deep

Horizons:

ABt	0-20/30 cm	Dark reddish brown (5YR 3/3) when moist; clay; moderate, medium subangular blocky structure; friable, slightly sticky and slightly plastic; common thin claycutans and shiny pedfaces; common medium and fine pores; common very fine, frequent fine and few medium roots, clear and broken transition to:
Bt	20/30-80 cm	Reddish brown (5YR4/4) when moist; clay; moderate very coarse subangular blocky falling apart to coarse subangular blocky structure; friable, slightly sticky and slightly plastic; common, thin claycutans and shiny pedfaces; many medium and fine pores; few fine and few medium roots.

LABORATORY DATA OF PROFILE 40

Field Observation No.: 122/3-48

Lab. no. .../85	8031	8032
Horizon designation	ABt	Bt
Depth (cm)	0-20/30	20/30-80
pH-H2O (1:2.5)	4.4	4.3
pH-M KCl (1:2.5)	3.9	4.0
EC (mS/cm; 1:2.5)	0.05	0.04
C (%)	1.6	1.0
CEC cmol(+)/Kg, pH 7.0	16.3	12.5
Exch. Ca (cmol(+)/Kg)	1.1	0.7
,, Mg ,,	0.4	0.1
,, K ,,	0.6	0.5
,, Na ,,	0.1	0.1
Sum cations	2.2	1.4
Base sat. at pH 7.0	13	11
ESP at pH 7.0	1	1
Gravel% >2mm		
Sand% 2-0.05mm	17	13
Silt% 50-2 um	13	11
Clay% <2 um	70	76
Texture class	C	C
CEC clay (cmol(+)/Kg)	<- 11 ->	

FERTILITY ASPECTS

Depth (cm)	0-20	40-60
Lab. no. .../85	8455	8456
Ca mmol/100g	<0.1	<0.1
Mg ,,	0.6	0.5
K ,,	0.6	0.3
Mn ,,	1.5	1.4
Exch. acid. ,,	3.6	3.5
P ug/g	26	16
C %	2.8	n.d.
N %	0.6	n.d.
pH-H2O (1:2.5)	4.0	4.1

PROFILE 41

Date/ season	: 26/8/85; end of cold season
Sheet-observation no	: 122/3-49
Coordinates	: 3373 E, 99607 N
Elevation	: 1715 m
Authors	: Willy Simons and Nicole Bongers
Soil mapping unit	: V1PC
Soil classification (FAO/KSS)	:
(USDA)	: typic Tropohumult
Geology	: Mt. Kenya series
Local petrography/ parent material	: pyroclastic agglomerates
Physiography	: Valley in mountain Footridge
Macro-relief	: mountainous
Slope (length, shape and pattern)	: 150m, convex, regular
Slope gradient	: 3%
Position on slope	: valley bottom
Meso- and micro-relief	: nil
Vegetation/ Landuse	: grassland
Erosion	: nil
Rock outcrops	: nil
Surface stoniness	: nil
Overwash	: nil
Surface runoff	: rapid
Surface sealing/crusting/cracking	: nil
Drainage class	: well drained
Flooding	: nil
Groundwater level (actual)	: always moderately deep
Presence of salts/ alkali	: nil
Soilfauna influences	: none to limited
Expected rooting depth	: moderately deep

Horizons:

Ah 0-15 cm	Reddish brown (5YR4/4), when moist; clay; moderate medium subangular blocky structure; friable, slightly sticky and slightly plastic; continuous thin clayskins; few medium and fine pores; few very fine, common fine, few medium roots; gradual and smooth transition to:
Bt 15-50 cm	Reddish brown (5YR4/4), when moist; clay; moderate coarse subangular blocky structure; friable, slightly sticky and slightly plastic; continuous thin clayskins; few medium and common fine pores; common fine roots; abrupt and smooth transition to:
B+CR 50-65+ cm	Reddish brown (5YR4/4), when moist; very gravelly clay; coarse granular structure (size of rock fragments); friable, slightly sticky and slightly plastic; continuous thin clayskins; common medium and fine pores; very few fine roots.

LABORATORY DATA OF PROFILE 41

Field Observation No.: 122/3-49

Lab. no. .../85	7690	7691
Horizon designation	Ah	Bt
Depth (cm)	0-15	15-50
pH-H2O (1:2.5)	6.0	5.7
pH-M KCl (1:2.5)	4.9	3.9
EC (mS/cm; 1:2.5)	0.05	0.04
C (%)	1.6	0.8
CEC cmol(+)/Kg, pH 7.0	20.1	20.7
Exch. Ca (cmol(+)/Kg)	6.5	2.5
,, Mg ,,	3.9	2.4
,, K ,,	1.9	1.3
,, Na ,,	0.5	0.1
Sum cations	12.8	6.3
Base sat. at pH 7.0	63	30
ESP at pH 7.0	3	<1
Gravel% >2mm		
Sand% 2-0.05mm	27	17
Silt% 50-2 um	21	13
Clay% <2 um	52	70
Texture class	C	C
CEC clay (cmol(+)/Kg)	<- 23	->

FERTILITY ASPECTS

Depth (cm)	0-20	40-60
Lab. no. .../85	8459	8460
Ca cmol(+)/Kg	0.4	0.4
Mg ,,	2.2	2.7
K ,,	0.7	1.2
Mn ,,	3.2	3.7
Exch. acid. ,,	0.8	0.9
P ug/g	18	14
C %	2.7	n.d.
N %	1.0	n.d.
pH-H2O (1:2.5)	4.9	4.7

PROFILE 42

Date/ season	: 30-08-1985; dry season
Sheet-observation no	: 122/3-53
Coordinates	: 3552 E, 99502 N
Elevation	:
Authors	: Jan Kuyper
Soil mapping unit	: V2P
Soil classification(FAO/KSS)	: plinthic ACRISOL (ferric ACRISOL)
(USDA)	: Plinthudult or Plintustult
Geology	: Mt. Kenya series
Local petrography/ parent material	: phonolite/lahar
Physiography	: Plateau
Macro-relief	: undulating
Slope (length, shape and pattern)	: 300m, straight, single
Slope gradient	: 7%
Position on slope	: middle slope
Meso- and micro-relief	: nil
Vegetation/ Landuse	: small scale rainfed anual crops, jembe, terrasses, maize, pigeon peas, cotton, locally intensive ranging
Erosion	: nil
Rock outcrops	: few rocks
Surface stoniness	: nil
Overwash	: nil
Surface runoff	: slow
Surface sealing/crusting/cracking	: cracks of 4mm, 40cm apart
Drainage class	: well drained
Flooding	: nil
Groundwater level (actual)	: always deep
Presence of salts/ alkali	: nil
Soilfauna influences	: moderate
Expected rooting depth	: very deep

Horizons:

Ah 0-11 cm	Dark reddish brown (5YR 3/4) when moist; silty clay; moderate medium to very coarse subangular blocky falling apart to fine crumb structure; slightly hard, very friable, sticky and slightly plastic; patchy thin clay cutans; very few medium hard spherical iron manganese concretions; abrupt and smooth transition to:
Bt1 11-90 cm	Yellowish red (5YR 4/6) when moist; silty clay; moderate very coarse subangular blocky structure; slightly hard, very friable, sticky and slightly plastic; broken thin clay cutans; very few medium hard spherical iron manganese concretions.
Bt2 90-130+cm	Yellowish red (5YR 4/6) when moist; very gravelly to gravelly silty clay; weak medium to coarse subangular blocky falling apart into single grain structure; loose, sticky and non plastic; patchy thin clay cutans; dominant medium to large hard spherical iron manganese concretions; few partly weathered phonolites.

LABORATORY DATA OF PROFILE 42

Field Observation No.: 122/3-53

Lab. no. .../86	4104	3694	3695
Horizon designation	Ah	Bt1	Bt2
Depth (cm)	0-11	11-90	90-130
pH-H2O (1:2.5)	6.2	5.2	5.8
pH-M KCl (1:2.5)	5.1	4.9	5.3
EC (mS/cm; 1:2.5)	0.03	0.07	0.03
C (%)	1.7	0.7	0.6
N (%)	0.18	n.d.	
CEC cmol(+)/Kg, pH 7.0	27.6	23.5	16.6
Exch. Ca (cmol(+)/Kg)	4.2	1.2	1.0
,, Mg ,,	3.4	2.5	0.5
,, K ,,	1.7	0.7	0.7
,, Na ,,	0.1	0.2	0.2
Sum cations	9.4	4.6	2.4
Base sat. at pH 7.0	34	20	14
ESP at pH 7.0	<1	1	1
Gravel % >2mm			
Sand% 2-0.05mm	18	14	46
Silt% 50-2 um	16	8	6
Clay% <2 um	66	78	48
Texture class	C	C	SC
CEC clay (cmol(+)/Kg)	<-	28	->

Depth (cm)	70-75
pF 0 (vol%)	64.1
pF 2.0 ,,	42.5
pF 2.3 ,,	37.0
pF 3.7 ,,	25.9
pF 4.2 ,,	25.0

FERTILITY ASPECTS

Depth (cm)	0-20	40-60
Lab. no. .../85	8469	8470
Ca cmol(+)/Kg	2.0	0.4
Mg ,,	7.3	2.9
K ,,	1.4	0.9
Mn ,,	1.8	2.3
Exch. acid. ,,	0.3	0.3
P ug/g	11	8
C%	1.9	n.d.
N%	0.3	n.d.
pH-H2O (1:2.5)	4.9	4.9

PROFILE 43

Date/ season	: 29-08-1985; dry season
Sheet-observation no	: 122/3-54
Coordinates	: 3551 E, 99501 N
Elevation	:
Authors	: Jan Kuyper
Soil mapping unit	: V2P
Soil classification (FAO/KSS)	: plinthic ACRISOL
(USDA)	: plnthic or umbric Paleaquult
Geology	: Mt. Kenya series
Local petrography/ parent material	: pyroclastic material, alluvium, colluvium
Physiography	: minor Valley in Plateau
Macro-relief	: undulating
Slope (length, shape and pattern)	: nil
Slope gradient	: 1%
Position on slope	: valley bottom (inclusion)
Meso- and micro-relief	: irrigation/drainage ditches
Vegetation/ Landuse	: small scale annual crop, banana, sugarcane, cassava
Erosion	: nil
Rock outcrops	: nil
Surface stoniness	: nil
Overwash	: nil
Surface runoff	: very slow
Surface sealing/crusting/cracking	: slightly hard 10mm crust, cracks 4mm width 20cm apart
Drainage class	: moderately well drained
Flooding	: nil
Groundwater level (actual)	: temporarily shallow (170cm)
Presence of salts/ alkali	: nil
Soilfauna influences	: limited
Expected rooting depth	: very deep

Horizons:

Ap 0-25 cm	Dark brown (7.5YR 3/2 moist, 5YR 4/4 dry); weak very coarse subangular blocky structure falling apart to very fine to medium moderate granules and crumbs; patchy thin claycutans; gravelly clay; hard and weakly cemented, friable, slightly sticky and slightly plastic; frequent to very frequent, small to medium, hard spherical iron manganese concretions; clear and wavy transition to:
Ah 25-55 cm	Dark reddish brown (5YR 2.5/2 moist, 7.5YR 3/2 dry); very dark gray (7.5YR 3/0), common distinct sharp mottles; moderate very coarse subangular blocky structure falling apart to moderate very fine to medium crumbs and granules; broken thin claycutans; gravelly clay; hard and weakly cemented, very friable, slightly sticky and slightly plastic; frequent to very frequent, small to medium, hard spherical iron-manganese concretions; gradual and smooth transition to:

Bg1	55-90 cm	Dark reddish brown (5YR 2.5/2 moist, 5YR 3/2 wet); black (5YR2.5/1) many medium distinct sharp mottles; moderate very coarse falling apart to moderate medium subangular blocky structure; broken thin clay-manganese cutans; gravelly clay; hard and weakly cemented, friable, slightly sticky and slightly plastic; few small to medium hard, spherical iron-manganese concretions; gradual and smooth transition to:
Bg2	90-140 cm	Dark reddish brown (5YR 2.5/2 moist); black (5YR 2.5/1) many medium distinct sharp mottles; many very coarse falling apart to medium subangular blocky structure; broken to continuous thin clay-manganese cutans; slightly gravelly clay; hard and weakly cemented, friable, slightly sticky and slightly plastic; few small to medium hard spherical iron- manganese concretions; clear and smooth transition to:
Bg3	140-160 cm	Very dark brown (10YR 2/2 moist); black (10YR 2/1) many medium distinct sharp mottles; moderate very coarse angular blocky structure; continuous thin claycutans; slightly gravelly clay; firm and compact, slightly sticky and slightly plastic; few small to medium hard spherical iron-manganese concretions; clear and smooth transition to:
Bg4	160+ cm	Brown to dark brown (7.5YR 4/2 moist); black (10YR 2/1) common fine distinct sharp mottles; continuous thin claycutans; slightly gravelly; slightly sticky and slightly plastic; few small to medium hard spherical manganese concretions.

LABORATORY DATA OF PROFILE 43

Field Observation No.: 122/3-54

Lab. no. .../86	3690	3691	4096	3692	3693
Horizon designation	Ap	Ah	Bg1	Bg2	Bg3
Depth (cm)	0-25	25-55	55-99	99-140	140-160
pH-H2O (1:2.5)	5.7	5.8	5.9	5.5	5.5
pH-M KCl (,,)	5.4	5.4	5.4	5.3	5.3
EC (mS/cm; 1:2.5)	0.19	0.10	0.09	0.10	0.07
C (%)	2.0	1.4	1.2	0.9	0.6
N (%)	0.20	n.d.	n.d.	n.d.	n.d.
CEC cmol(+)/Kg, pH 7.0	32.6	30.4	25.3	24.8	25.2
Exch. Ca (cmol(+)/Kg)	9.5	9.2	7.3	6.9	5.5
,, Mg ,,	4.9	5.0	4.4	3.5	3.0
,, K ,,	1.1	0.7	1.0	0.8	0.6
,, Na ,,	0.3	0.3	0.4	0.3	0.2
Sum cations	15.8	15.2	13.1	11.7	9.3
Base sat. at pH 7.0	48	50	52	47	37
ESP at pH 7.0	1	1	2	1	1
Gravel% >2mm					
Sand% 2-0.05mm	22	24	26	30	30
Silt% 50-2 um	18	18	24	18	14
Clay% <2 um	60	58	50	52	56
Texture class	C	C	C	C	C
CEC clay (cmol(+)/Kg)	<-		39		->

FERTILITY ASPECTS

Depth (cm)	0-20	40-60
Lab. no. .../85	8471	8472
Ca cmol(+)/Kg	6.4	5.2
Mg ,,	4.4	3.6
K ,,	1.0	0.7
Mn ,,	2.0	1.9
Exch. acid. ,,	<0.1	<0.1
P ug/g	161	27
C %	2.5	n.d.
N%	0.24	n.d.
pH-H2O (1:2.5)	6.0	5.9

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