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A semi-detailed Soil Survey of the Kisii west area

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A semi-detailed Soil Survey of the Kisii West area

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Training Project in Pedology - Kenya 1974

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PREFACE

From February till the half of April 1974, three students of the Training Project in Pedology - Kenya, from the Agricultural University in Wageningen, have carried out a semi-detailed soil survey (scale 1 : 50.000) of the Kisii West area. This survey was supervised by W.G. Wielemaker and H.W. Boxem.

With the help of field data obtained from the Irigonga and Marongo detailed surveys most of the western Kisii Highlands has been surveyed.

This preliminary report describes the physical environment and the soil associations of the area and their relationship.

1. INTRODUCTION

The Kisii West semi-detailed survey covers the whole western part of the Kisii District and is situated between 0° 35' and 0° 58' S and between 34° 35' and 34° 50' E. It includes partly or completely the subdistricts of Kitutu, Wanjare, Kasipul, Nyarobari, South Mugirango, Bomachoge, Bobasi (Kisii district) and South Nyokal (South Nyanza district). The area covers about 71.800 ha .

Being a transition zone of the Kisii Highlands in ths East to the gently sloping lowlands in the West the area has a gradual decrease in elevation in E - W direction (from about 6000 to 4700 ft). The highest summits are formed by some isolated plateau remnants in the South-Western part and by the Manga scarp in the Eastern part.

The outer limits of the survey area are defined by the long quartsitic Manga scarp in the East, by the Kisii districts-boundary in the south and in the West and the North by the Tanzania road or by physiographic and lithological boundaries.

Important towns and administration centres are Manga in the North, Rongo and Kisii in the centre, the last one is the districts-town, and Ogembo and Kenyenya in the South.

The main rivers are the deeply incised Gucha in the South and the Riana in the North, both running in E - W direction.

The strong growth of the population has resulted in complete removal of the original forest. Nearly the whole area is now under intensive cultivation.

2. ENVIRONMENT

2.1. Climate

2.1.1. Introduction

The climate of the Kisii West area is a transition of the monsoon climate (Am according to Köppen's classification) of the Kisii Highlands and the tropical savannah climate (Aw) of the lower area round Lake Victoria.

The mean annual temperature is about 20°C, temperatures over 30°C rarely occur due to the rather high altitude (1400 - 1800 m), whereas temperatures at night are low (10 - 15°C).
The mean annual precipitation ranges from about 1500 mm in the West to 2.000 mm in the East.

A moderate dry period during january and february is followed by the long rains of april and may, a short dry period in august preceeds the short rains in octobor and novembor. Dry periods are more pronounced in the western part of the Kisii West area.

Climatic data -mainly rainfall data - are taken from all the weather stations in the surveyed area out of the "Summary of Rainfall of Kenya" (1938 - 1971), see fig. 1 the location map of the weather stations. Diagrams of average monthly rainfall and fluctuation of the total annual rainfall have been made, see fig. 3 to 11. In "studies of Potential Evaporation" (T. Woodhead) data were available for the diagram of the mean monthly evaporation (Eo - according Penman), see fig. 2. Mean maximum and minimum temperatures are derived from the Climate and Vegetation map of S.W. Kenya (sheet 3; 1 : 250.000).

Some waterbalances have been calculated to give an idea of the amount of available water for plant growth for all the months.

2.1.2. Calculated waterbalances of soil profiles with different maximum storages of available water for the plant.

Some simplified water input and -output balances in soil profiles have been calculated by using rainfall data of two weather stations in the Kisii West area and calculated evaporation data according Penman (T. Woodhead).

The choosen weather stations - Kisii Coffee Substation and Kamagambo Training School - have a rainfall which is respectively the maximum and minimum total annual rainfall of all the stations in the surveyed area.

Method:

The input-output waterbalance is: $R - r = Ea + D + \Delta S$

R = rainfall

r = runn-off

Ea = actual evapotranspiration

D = drainage in the suhsoil

ΔS = change in the storage of available water in the soil profile

The calculation method used is based on the following assumptions:

$S = So \cdot e^{-\frac{\Sigma(R - Ep)}{So}}$ *

So = maximum storage of available water for the plant in the soil profile.

S = the actual storage of available water.

The exhausting of the storage of available water in the soil profile declines according an negative e-power, so the withdrawing of moisture out of the soil is more difficult when the soil contain less water.

- Eo = Ep, the evaporation of open water is approximately the potential evapotranspiration of soil and plant.
- Maximum storages of available water of some soil profiles are estimated:

  So = 50 mm, is the estimated maximum storage of available water of a very shallow soil (with a depth of about 25 cm)

  So =100 mm, of a shallow soil (depth about 50 cm)

  So =200 mm, of a deep soil (depth about 100 cm)

  So =400 mm, of a very deep soil (depth about 200 cm)
- The considered soil profiles have no water table or the water table is much deeper than the above mentioned soil depths.
- r = 0, the run-off is in this calculated water balances 0, run-off data when available could be easily incalculated.
- Ea = R - ΔS with Ea(max) = Ep, the actuel evapotranspiration is the sum of the rainfall and the change in the storage of available water in the soil profile, Ea is at most as big as Ep.

* cit: cultuurtechniek · Waterhuishouding. deel A Agrohydrologie 1972 LH.

- Sh = Ep - Ea, the shortage of water for optimum plant growth is the difference between potential and actual evapotranspiration.
- $D = R - Ea - \Delta S$ if $R > Ea - \Delta S$
  $D = 0$ if $R < Ea - \Delta S$
  D is the precipitation which cannot be stored in the soil and which is drained in the subsoil.

The waterbalances (see table I and II) could be an indication about the water conditions for plant growth in the Kisii West area, but they must be handled with care because the used calculation method is a simplification of the reality and next to it the evaporation data are rather rough.

Some important reflections when drawing interferences out of the waterbalances are:

- The used potential evapotranspiration (Ep) is not necessary the potential evapotranspiration of a special crop, it may be lower or even higher.
- when the withdrawing of moisture out of soil profiles has passed more than 50% of the maximum storage, the growth of crops will than be considered as decreased.
- the data used are mean data, the fluctuations in the precipitation must be considered, see fig. 4b and 11b.
- for getting moisture out of soil profile of e.g. a depth of 2 meters (400 mm available water), the plant must be a deep-rooted one. It must not be an annual one or in a young phase.

TABEL I - WATER BALANCES OF SOME SOIL PROFILES

KISII COFFEE SUBSTATION 90.34-080

		J	F	M	A	M	J	J	A	S	O	N	D	year
R		73	106	198	286	236	155	103	170	194	148	165	122	1.950
Ep		175	175	185	150	150	130	130	155	160	170	150	160	1.890
R-Ep		-102	-69	13	136	86	25	-27	15	34	-22	15	-38	
-Σ(R-Ep)		147	216					27			22	7	45	
R/Eo		0.42	0.61	1.07	1.91	1.57	1.19	0.79	1.10	1.21	0.87	1.10	0.76	
So= 50mm	S	3	1	14	50	50	50	29	44	50	32	47	20	
	Δ S	-17	-2	13	36	0	0	-21	15	6	-18	15	-27	
	Ea	90	108	185	150	150	130	124	155	160	166	150	147	1.715
	D	0	0	0	100	86	25	0	0	28	0	0	0	239
	Sh	85	67	0	0	0	0	6	0	0	4	0	13	175
So=100mm	S	23	12	25	100	100	100	76	91	100	80	95	64	
	Δ S	-41	-11	13	75	0	0	-24	15	9	-20	15	-31	
	Ea	114	117	185	150	150	130	127	155	160	168	150	153	1.750
	D	0	0	0	61	86	25	0	0	25	0	0	0	97
	Sh	61	58	0	0	0	0	3	0	0	2	0	7	131
So=200mm	S	96	68	81	200	200	200	175	190	200	179	194	160	
	Δ S	-64	-28	13	119	0	0	-25	15	10	-21	15	-34	
	Ea	137	134	185	150	150	130	128	155	160	169	150	156	1.804
	D	0	0	0	17	86	25	0	0	24	0	0	0	152
	Sh	38	41	0	0	0	0	2	0	0	1	0	4	86
So=400mm	S	277	233	246	382	400	400	374	389	400	379	394	357	
	Δ S	-80	-44	13	136	18	0	-26	15	11	-21	15	-37	
	Ea	153	150	185	150	150	130	129	155	160	169	150	159	1.840
	D	0	0	0	0	64	25	0	0	23	0	0	0	112
	Sh	22	25	0	0	0	0	1	0	0	1	0	1	50

- all figures are in mm water
- small deviations in the total annual figures are caused by rounding the monthly figures.

TABEL II - WATERBALANCES OF SOME SOIL PROFILES

KAMAGAMBO TRAINING SCHOOL 90.34-005

		J	F	M	A	M	J	J	A	S	O	N	D	year
	R	55	97	148	234	204	124	85	114	120	125	148	112	1.565
	Ep	175	175	185	150	150	130	130	155	160	170	150	160	1.890
	R-Ep	-120	-78	-37	84	54	-6	-45	-41	-40	-45	-2	-48	
	-Σ(R-Ep)	347	425	462			6	51	92	132	177	179	227	
	r/Eo	0.31	0.55	0.80	1.56	1.36	0.95	0.65	0.79	0.75	0.74	0.99	0.70	
	S	0	0	0	50	50	44	18	8	4	1	1	0	
	ΔS	0	0	0	50	0	-6	-26	-10	-4	-3	0	-1	
So= 50mm	Ea	55	97	148	150	150	130	111	124	124	128	150	113	1.472
	D	0	0	0	34	54	0	0	0	0	0	0	0	88
	Sh	120	78	37	0	0	0	19	31	36	42	0	47	410
	S	3	1	0	84	100	94	60	40	27	17	17	10	
	ΔS	-7	-2	-1	84	16	-6	-34	-20	-13	-10	0	-7	
So=100mm	Ea	62	99	149	150	150	130	119	134	133	135	150	119	1.530
	D	0	0	0	0	38	0	0	0	0	0	0	0	38
	Sh	113	76	36	0	0	0	11	21	27	35	0	41	360
	S	15	9	8	96	150[x]	144	106	81	62	46	45	33	
	ΔS	-18	-6	-2	84	54	-6	-38	-25	-19	-16	-1	-12	
So=200mm[x]	Ea	73	103	150	150	150	130	123	139	139	141	149	124	1.571
	D	0	0	0	0	0	0	0	0	0	0	0	0	0
	Sh	102	72	35	0	0	0	7	16	21	29	1	36	319

So=400mm, the same as So=200mm

x) 150mm is the maximum storage of moisture for lack of enough rainfall for storage above the 150mm.

Conclusions:

The water conditions for plant growth in areas with a total rain fall, a rainfall distribution and a evaporation according to the Kisii Coffee Substation (see table 1) are good for all the months for a soil profile with a depth of 1 meter or more, with an exception for the month February.
This month gives decreased growth on soils with a depth of about 1 m.
Soil profiles less than 1 meter get more water difficulties with diminishing depth of the soil in the months of February, January and December. The first two months show a considerable decreased growth.

The climatic conditions at Kamagambo Training School (see tabel II) are in comparison with Kisii Coffee Substation less favourable for plant growth.
The actuel evapotranspiration ranges from 1.470 to 1.570 mm and the potential evapotranspiration is 1.890 mm, so some crops with a high water demand cannot be cultivated.
There are severe drought months and some growth reducing months.
For a profile of 25 cm depth (50 mm storage) the months of January and February are severe dry while the months of July, August, September, October and December show a reducing growth.
This is also applicable for soil profiles to a depth of 75 cm (150 mm storage), in this situation the months of July to December have now slightly reduced growth conditions.
A profile with a maximum storage capacity of more than 150 mm has no special significance in a year with a rainfall of less than the mean total rainfall of 1.565 mm, for lack of enough rainfall for storing more than 150 mm in the soil.
But in a year with more precipitation the deeper soils has the advantage that they can store the surplus precipitation.

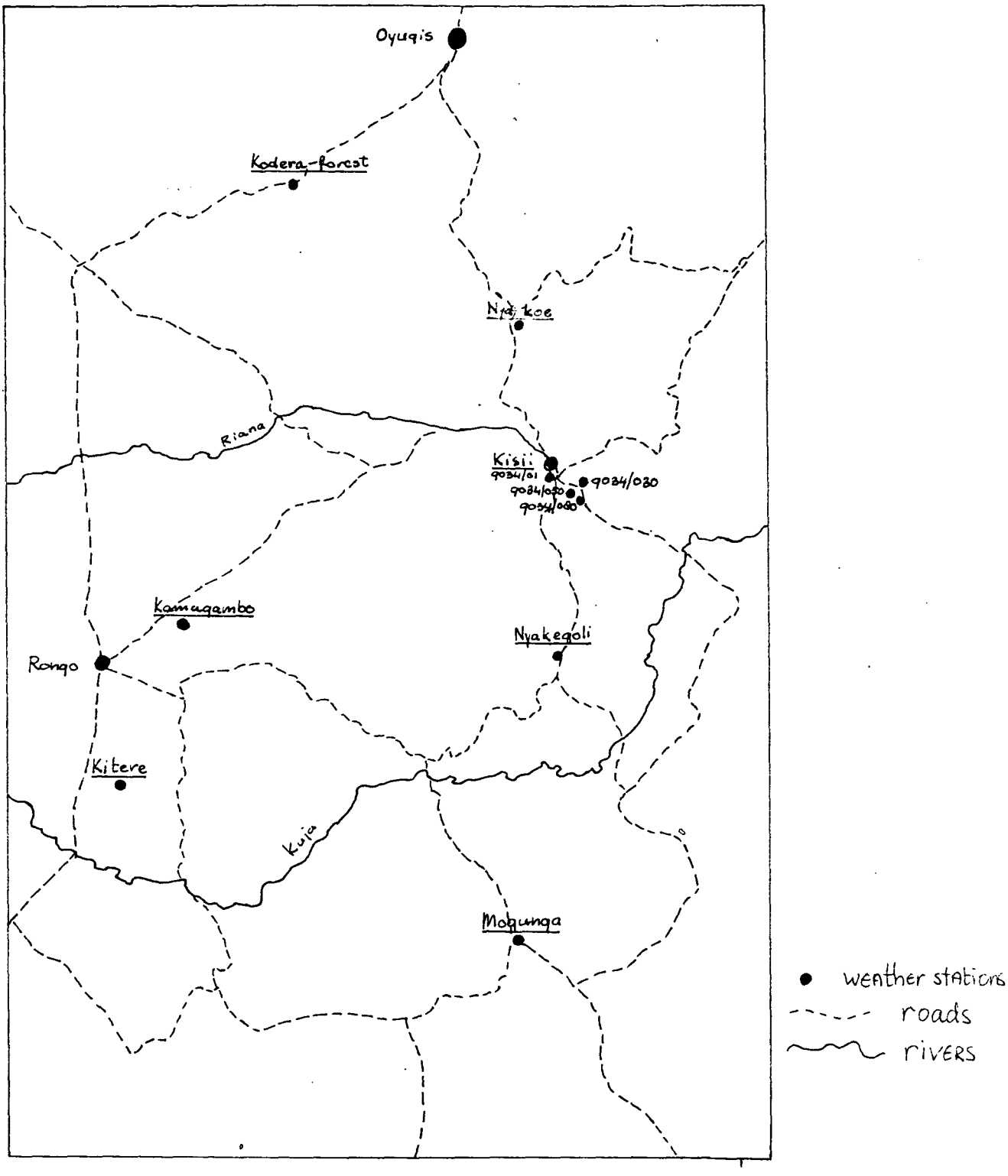


Fig. 1 Location of the weatherstations in the Kisii West area

· Monthly potential evaporation from open water (Penman - E_o) in Kisii - West. *)

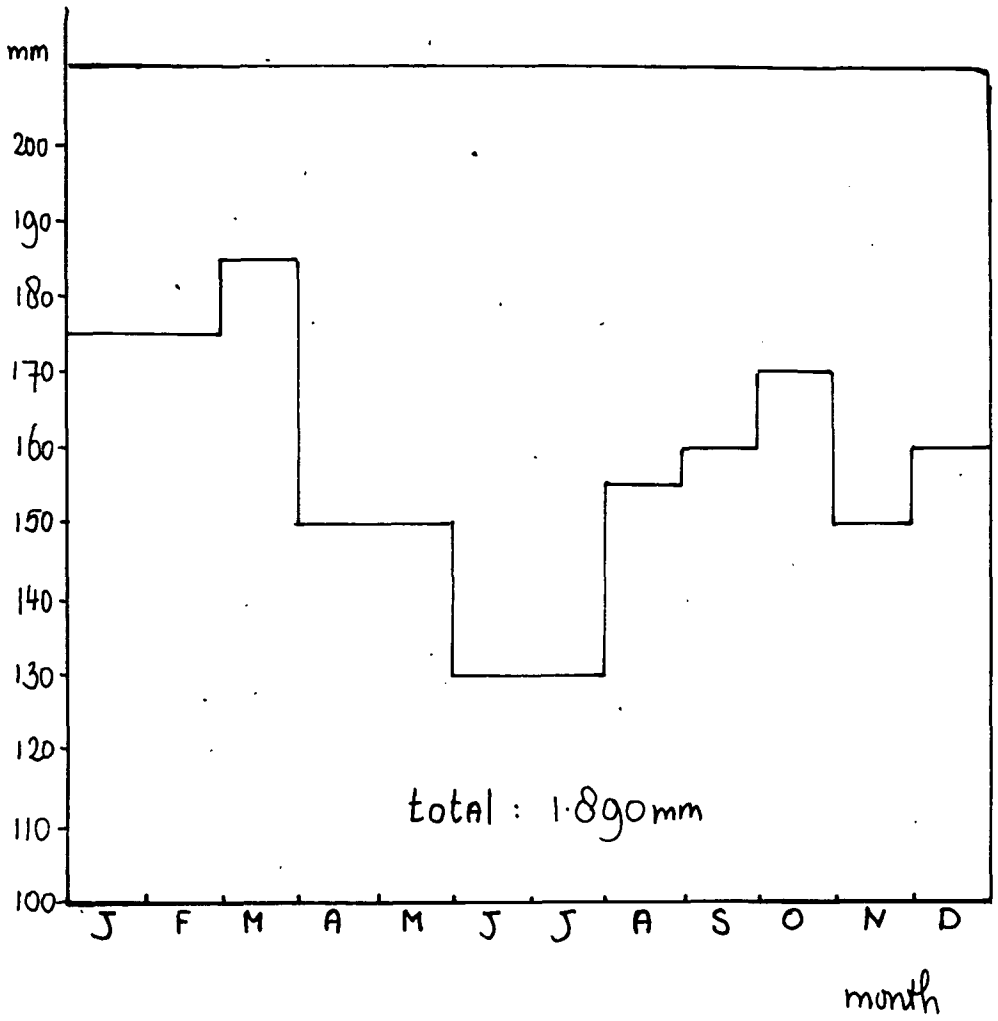


Fig. 2

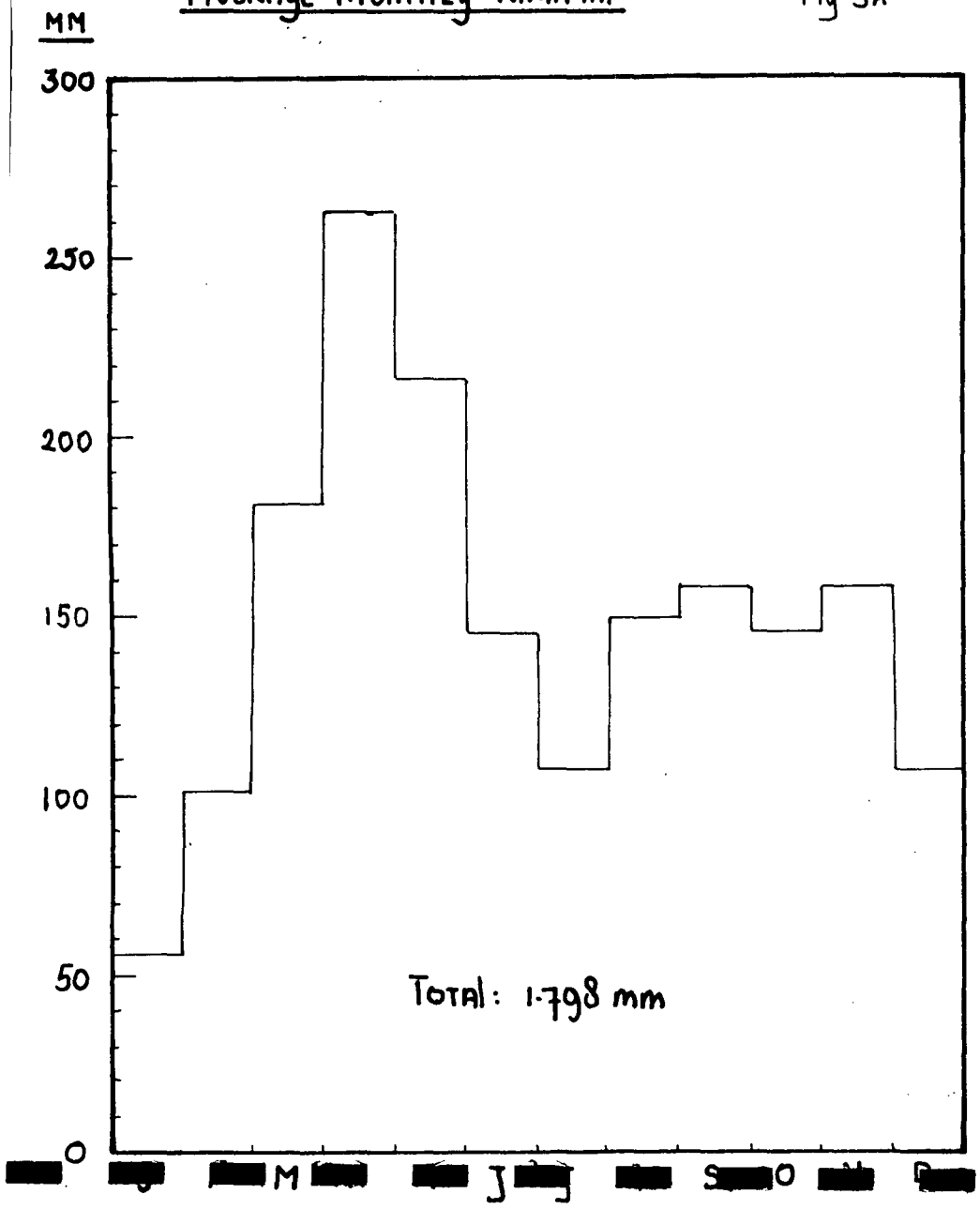
*) Source: studies of potential evaporation in Kenya by T. Woodhead.

Kisii DISTRICT OFFICE, nr. 90-34-001

Coordinates: 0·41S - 34·47E
Altitude: 5800 ft
Period: 1911 - 1971 (60 years)

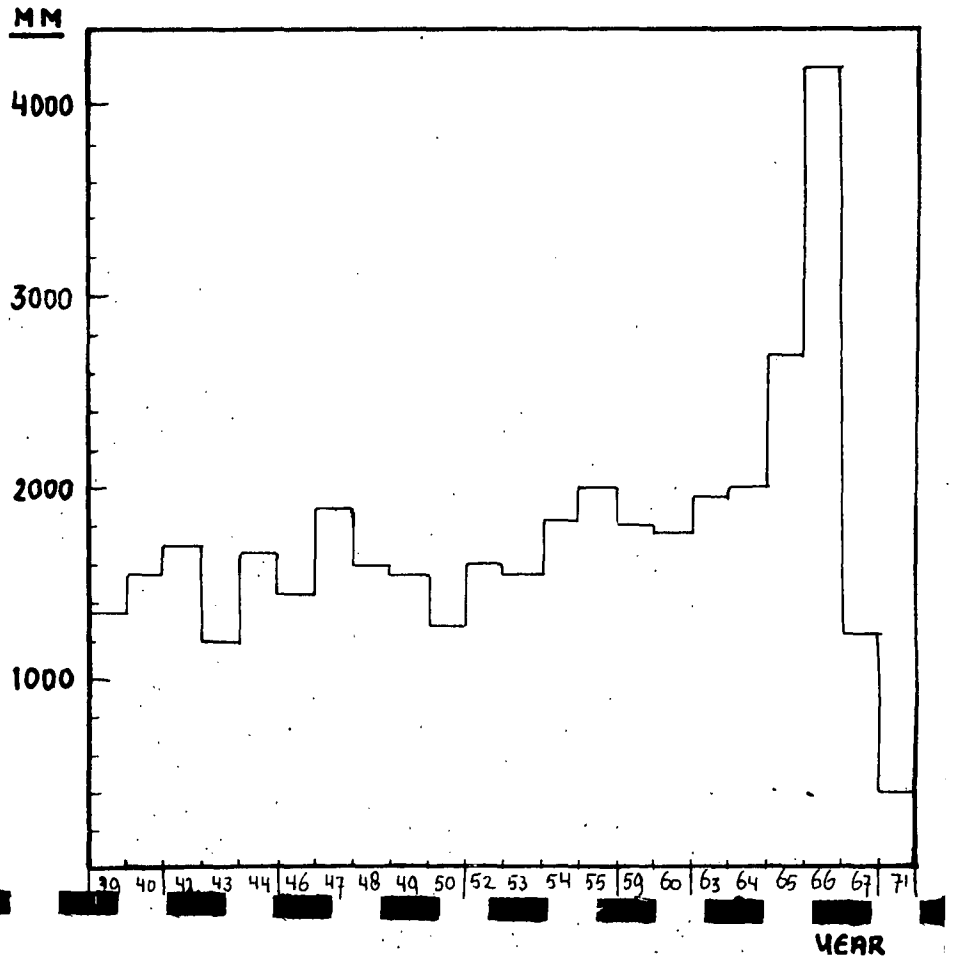
Average monthly rainfall

Fig. 3A



Total annual rainfall

Fig. 3B



Kamagambo school, nr. 90.34-005

Coordinates: 0.45 S - 34.38 E

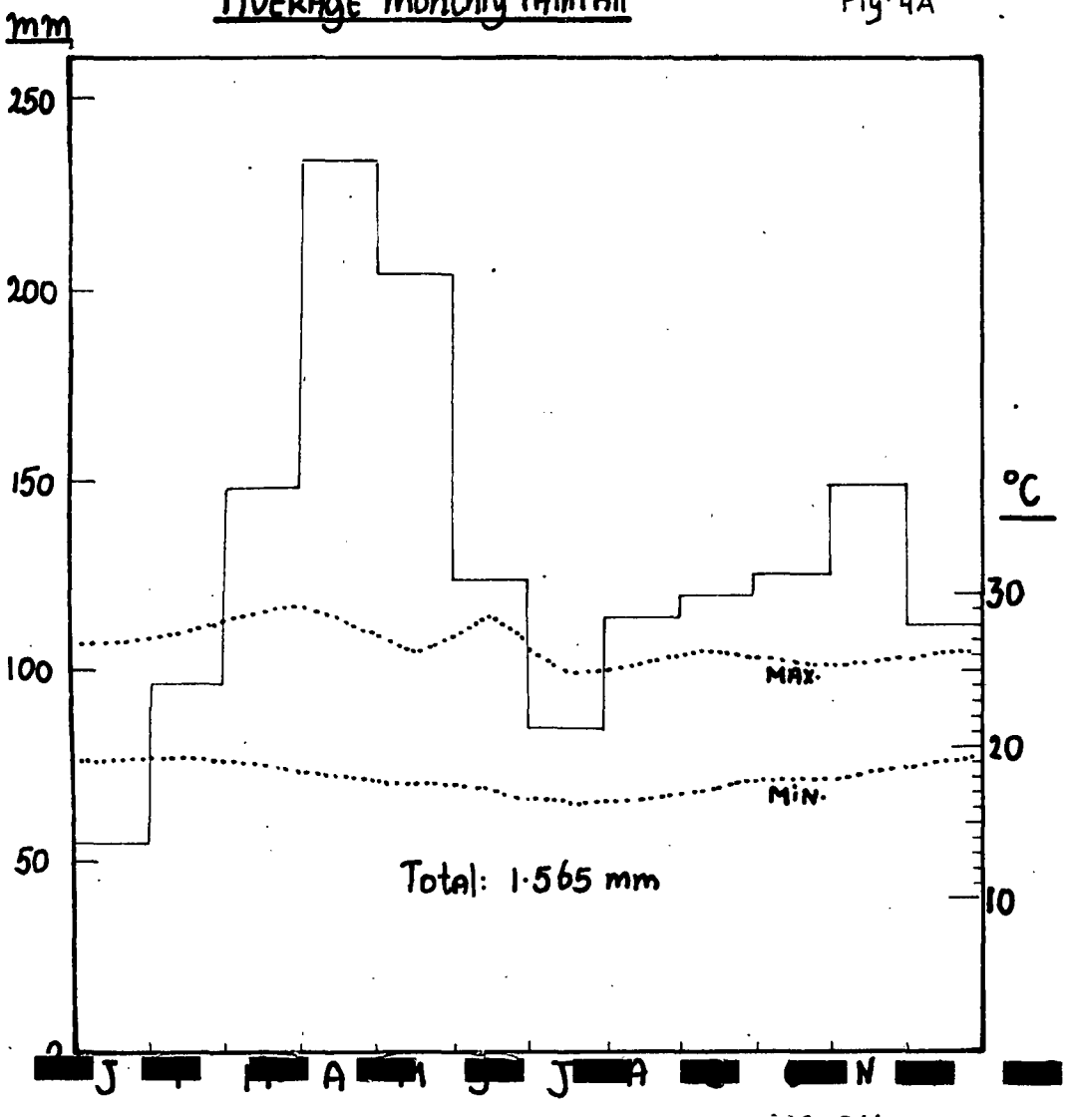
Altitude: 5.000 ft

Period: 1913 - 1967 (29 years)

Average monthly temperature (dotted lines)

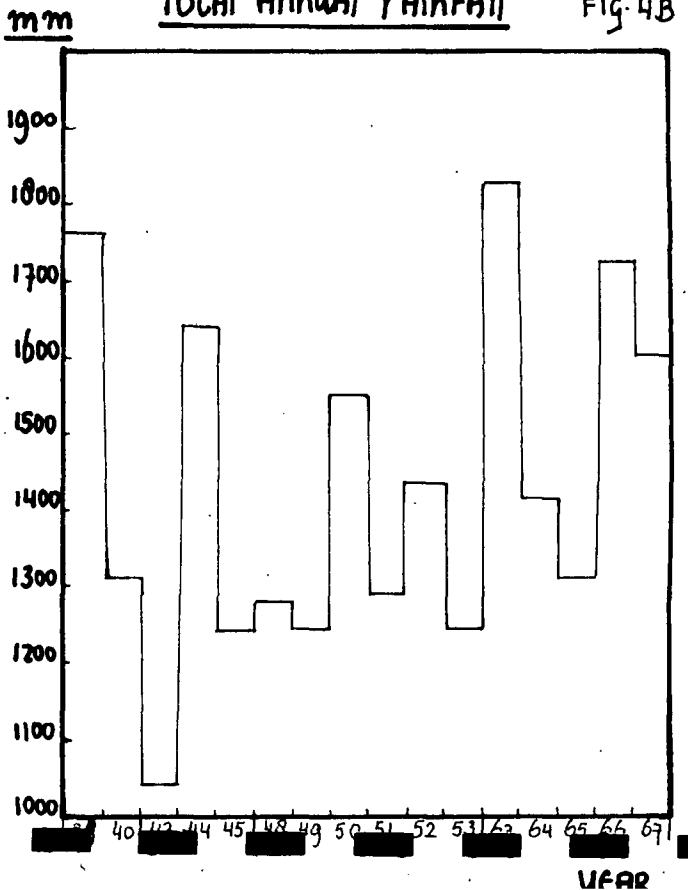
Average monthly rainfall

Fig. 4A



Total annual rainfall

Fig. 4B

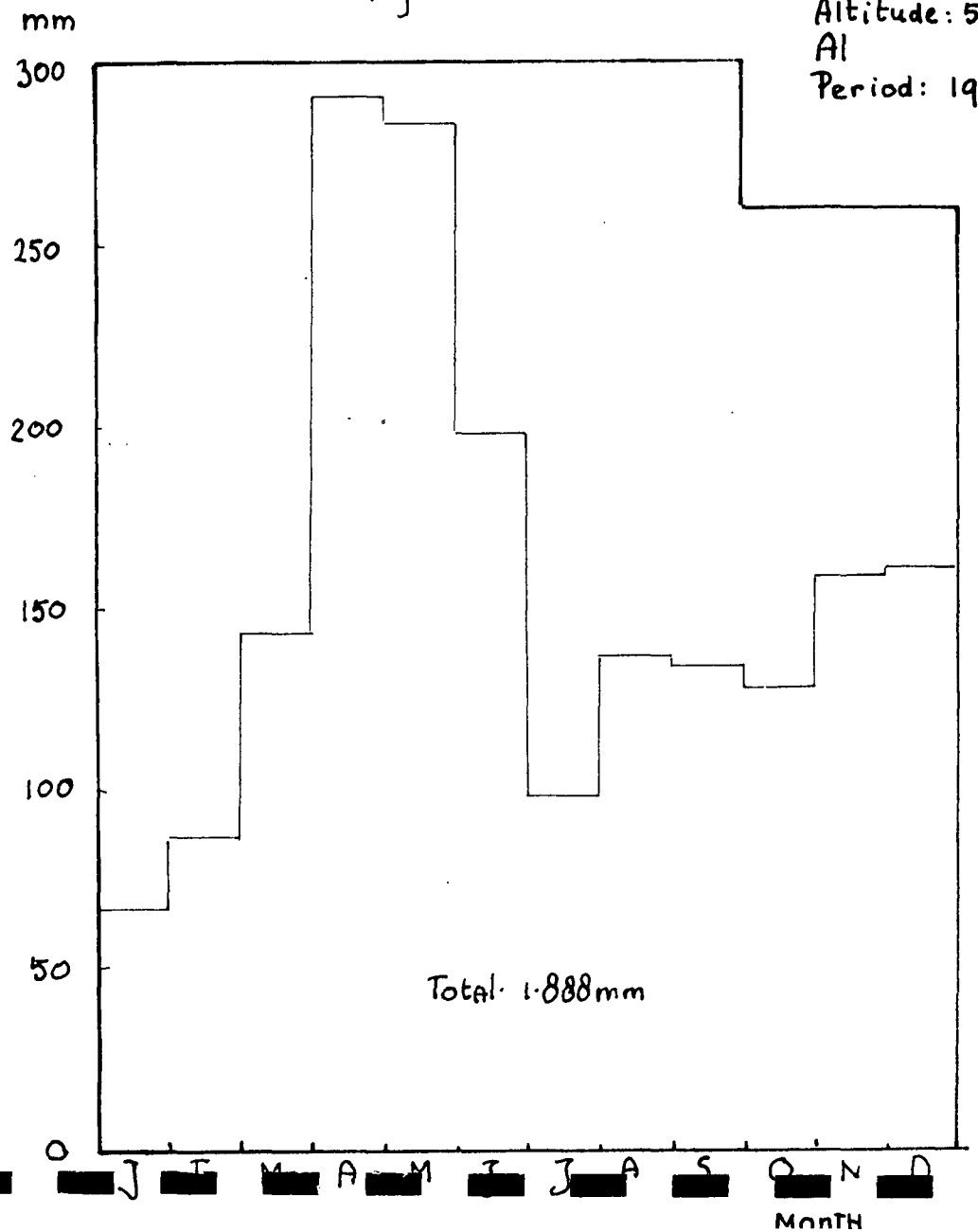


Average monthly rainfall

Fig. 5A

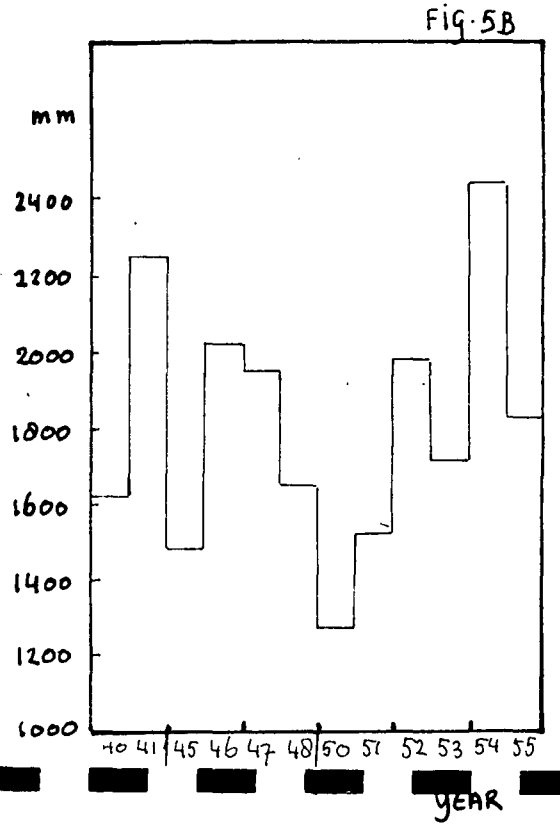
Mogunga 90.34-029

Coordinates: 0.51S - 34.46E
Altitude: 5600 ft
Al
Period: 1940 - 1955 (11 years)



Total annual rainfall

Fig. 5B



KITERE goldfield, nr. 90-34-040

Coordinates: 0·48 S - 34·36 E
Altitude: 5000 ft
Period: 1942 - 1954

Average monthly rainfall

Fig. 6A

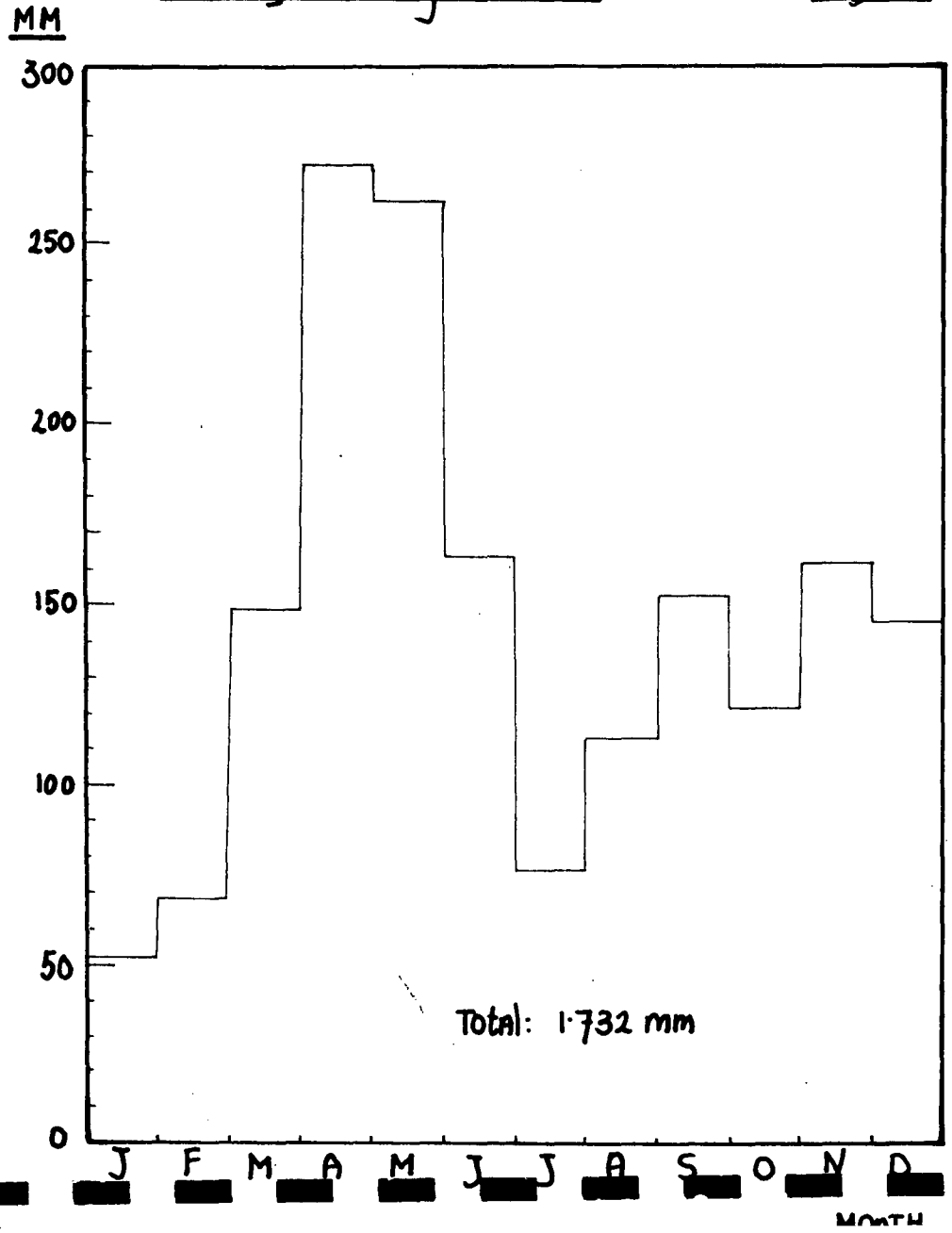
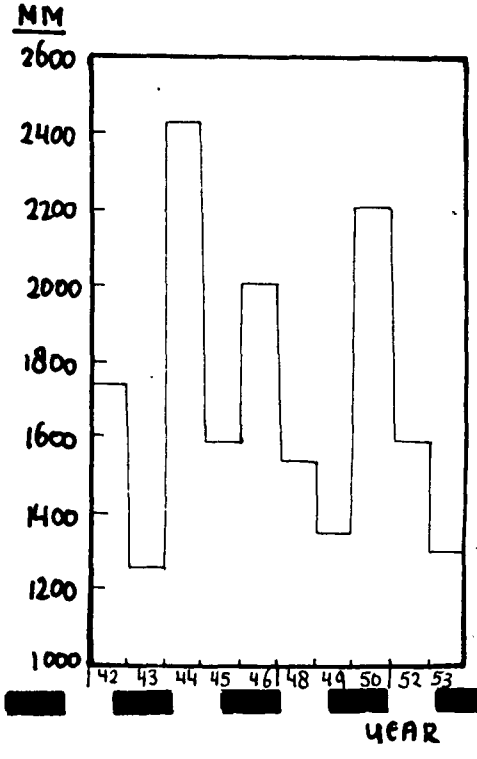


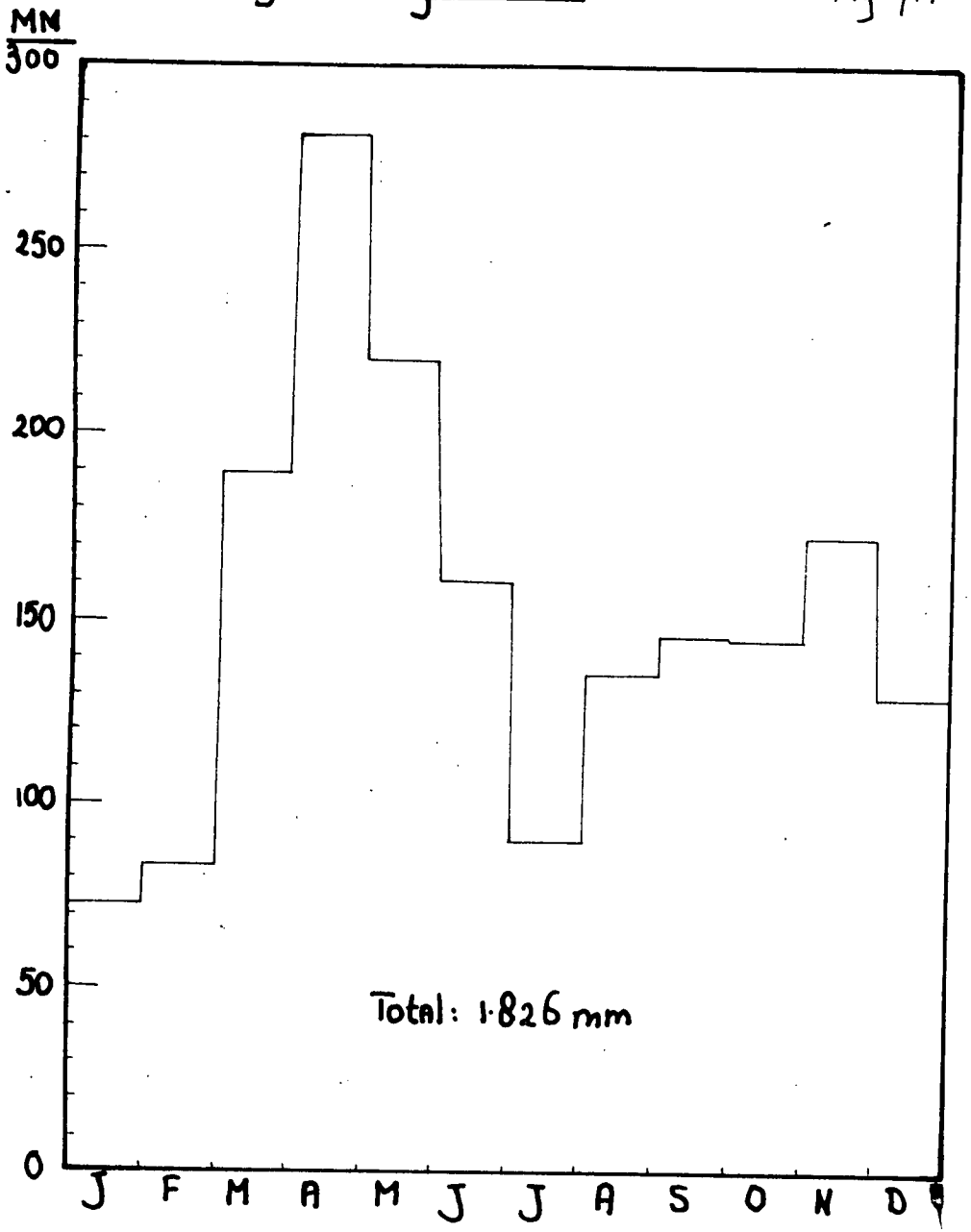
Fig. 6B

Total Annual Rainfall



Average monthly RAINFALL

FIG·7A

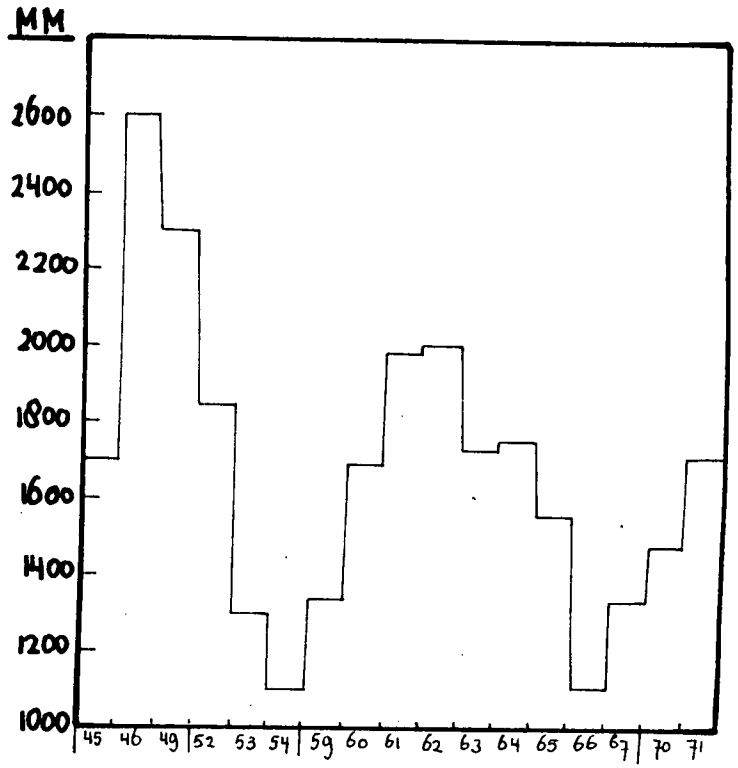


Nyakegoli, nr. 90·34-042

Coordinates: 0·48S – 34·44 N
Altitude 5400ft
Period 1943-1971 (24years)

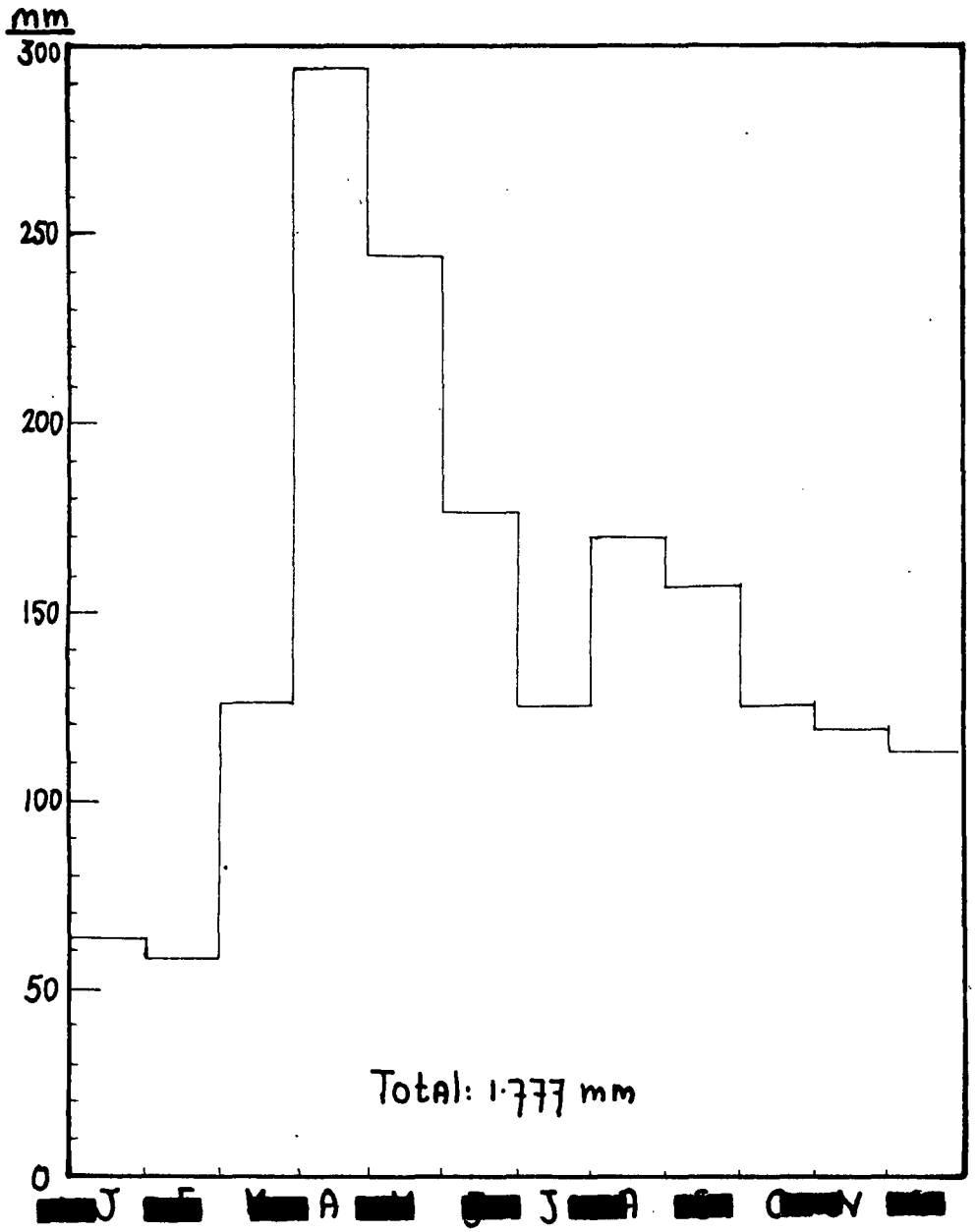
TOTAL Annual RAINFALL

FIG·7B



Average monthly rainfall

Fig. 8A

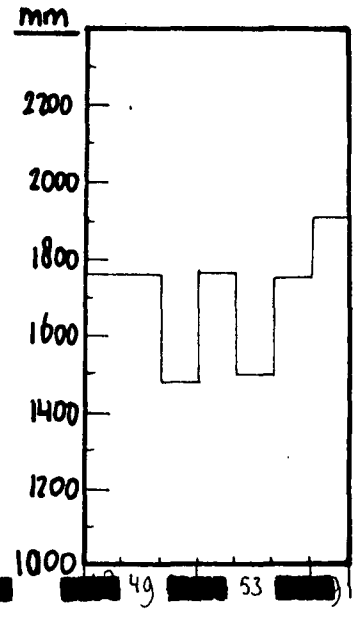


Kisii school, nr. 90·34-050

Coordinates: 0·41 S - 34·46 E
Altitude: 5·300 ft
Period: 1947 - 1959 (11 years)

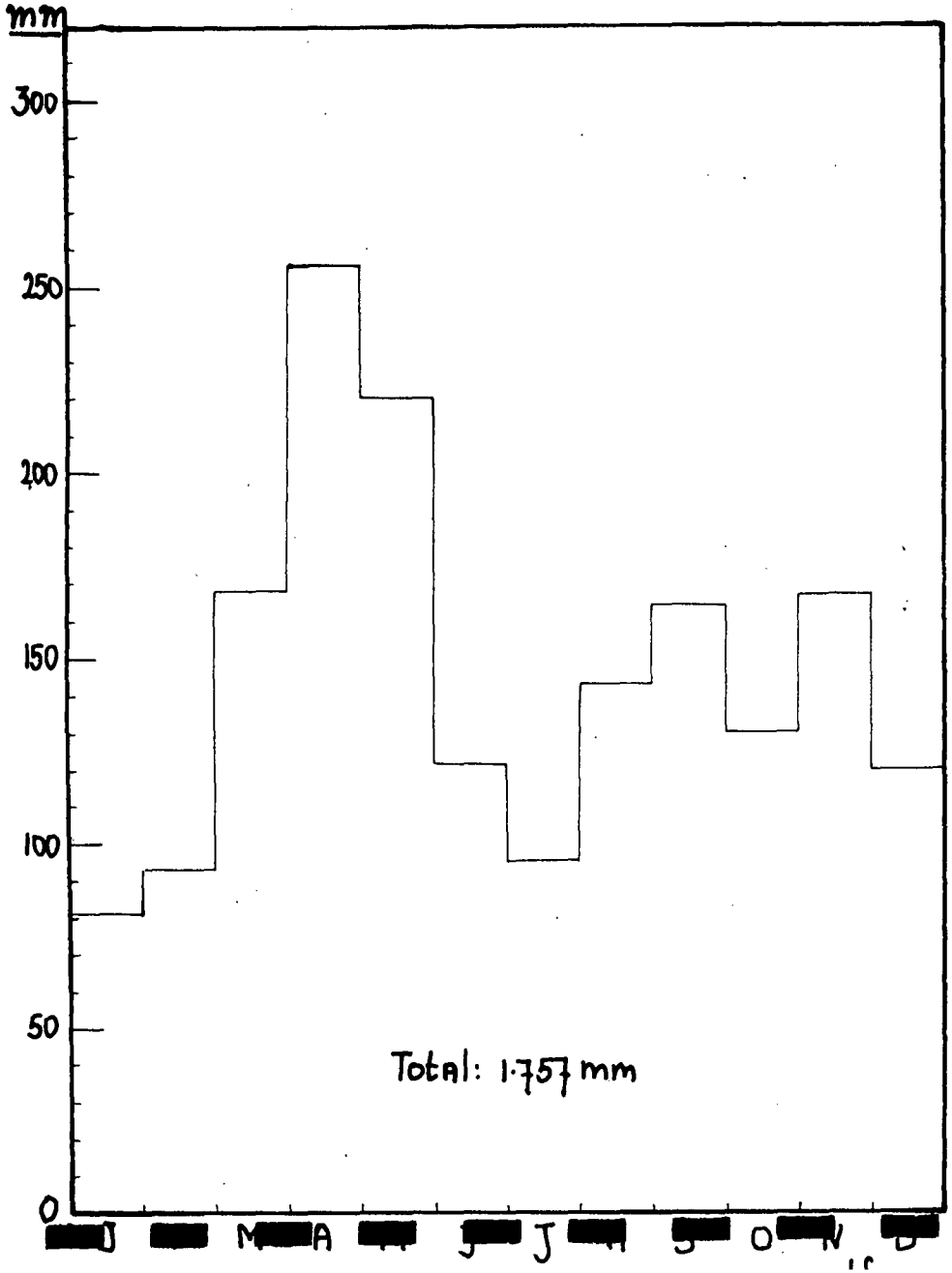
Fig. 8B

Total annual rainfall



Average monthly rainfall

Fig. 9A

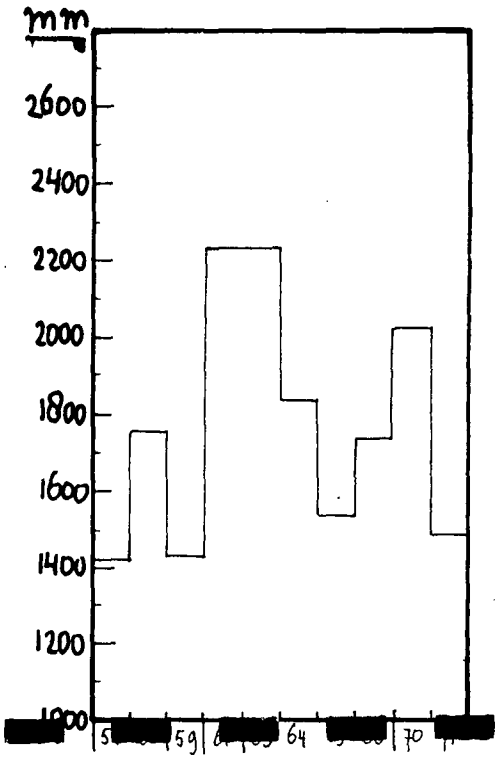


Nyakoe, nr. 90.34-056

Coordinates: 0.38S - 34.44E
Altitude: 5.000 ft
Period: 1951 - 1971 (16 years)

Fig. 9B

Total annual rainfall

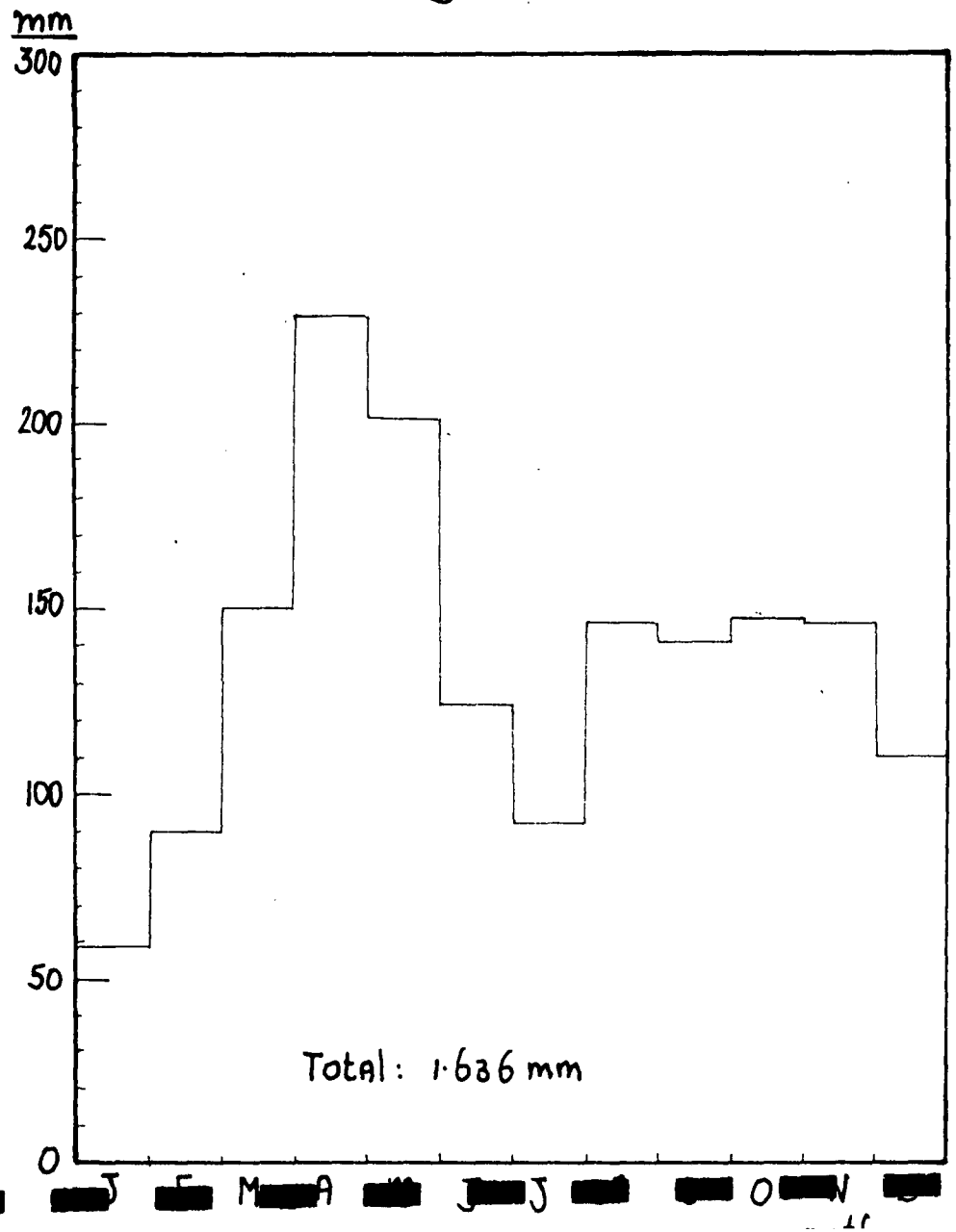


Kodera Forest nr. 9034 - 062

Coordinates : 0.31 S - 34.39 E
Altitude: 4.500 ft
Period: 1952 - 1971 (16 years)

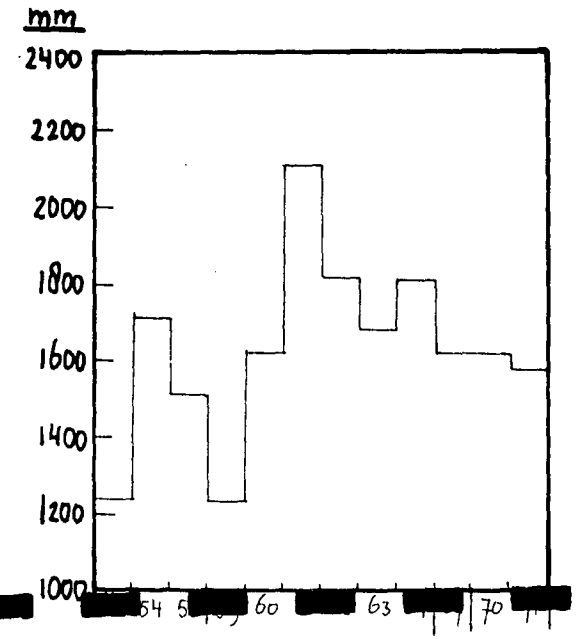
Average monthly rainfall

Fig. 10A



Total annual rainfall

Fig. 10B



Kisii coffee substation, nr. 90·34-080

Coordinates: 0·41 S - 34·47 E

Altitude: 5600 ft

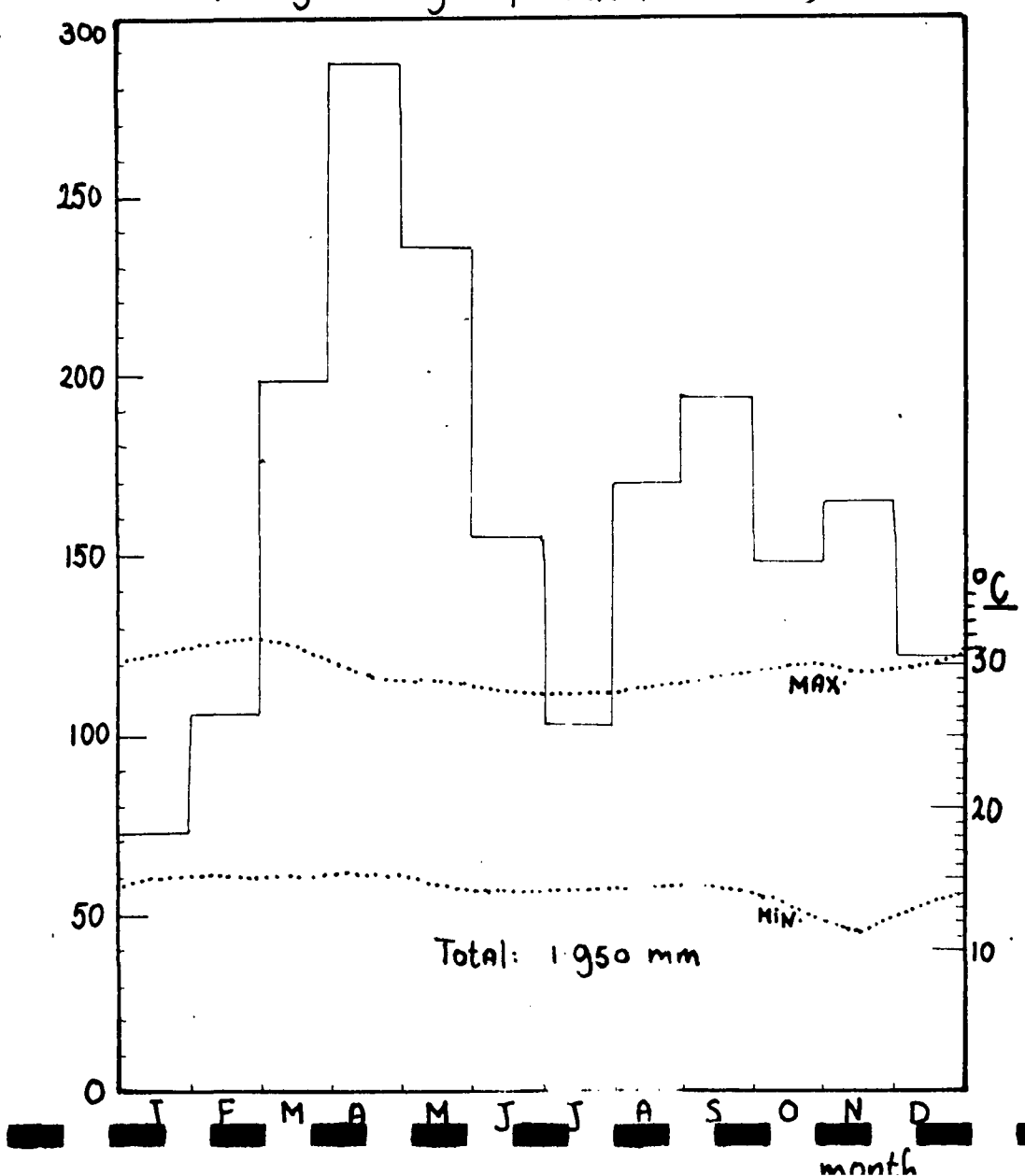
Period: 1940 - 1971 (28 years)

[1940 - 1959 nr. 90·34-030
1960 - 1971 nr. 90·34-080]

Average monthly rainfall

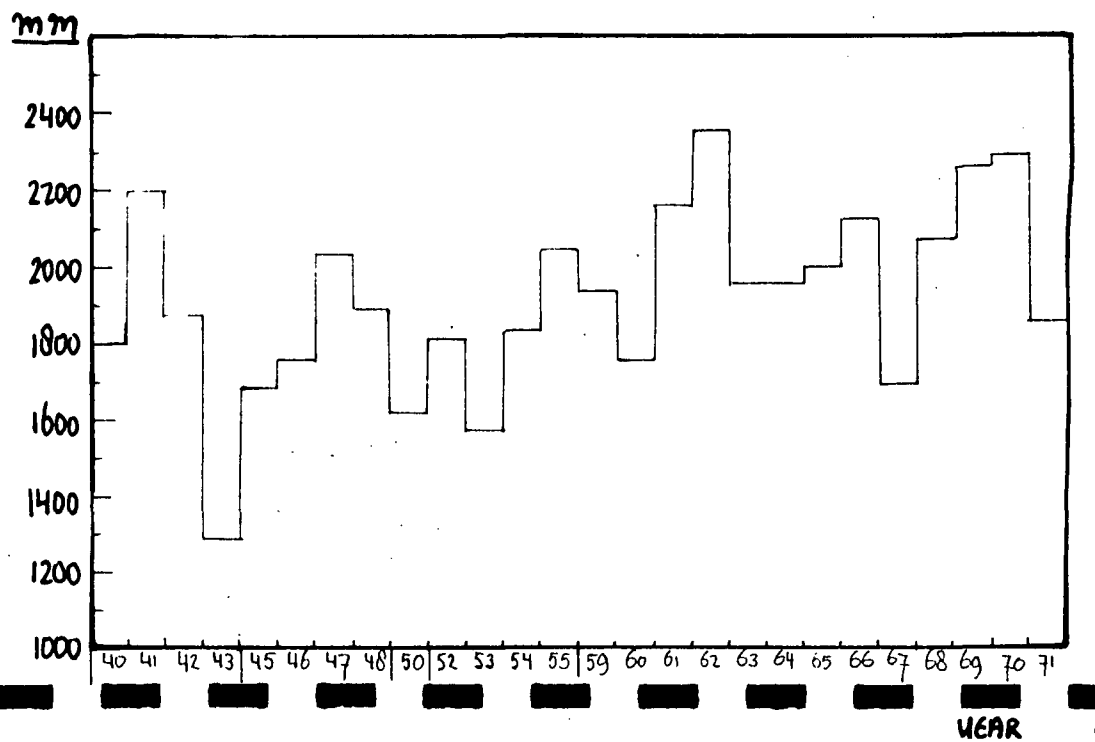
FIG·11A

Average monthly temperature (dotted lines)



Total annual rainfall

FIG·11B



2.2. HYDROLOGY

Nearly the whole area of the Kisii West semi-detailed survey is drained by the Kuja river. Only a small part of the Kisii West area is drained by tributaries of the Awach Tende river, like the Mogusii river (see the contour map).
The rest of the area is drained - more or less - by the Kuja river directly.
The river basins of the most important tributaries of the Kuja river in the Kisii West area are the Riana, the Nyangweta and the Mogunga river (see the contour map). Those river basins are areas less directly drained by the Gucha river in comparison with the area which remains.

Mean fall of the main rivers in the Kisii West area:

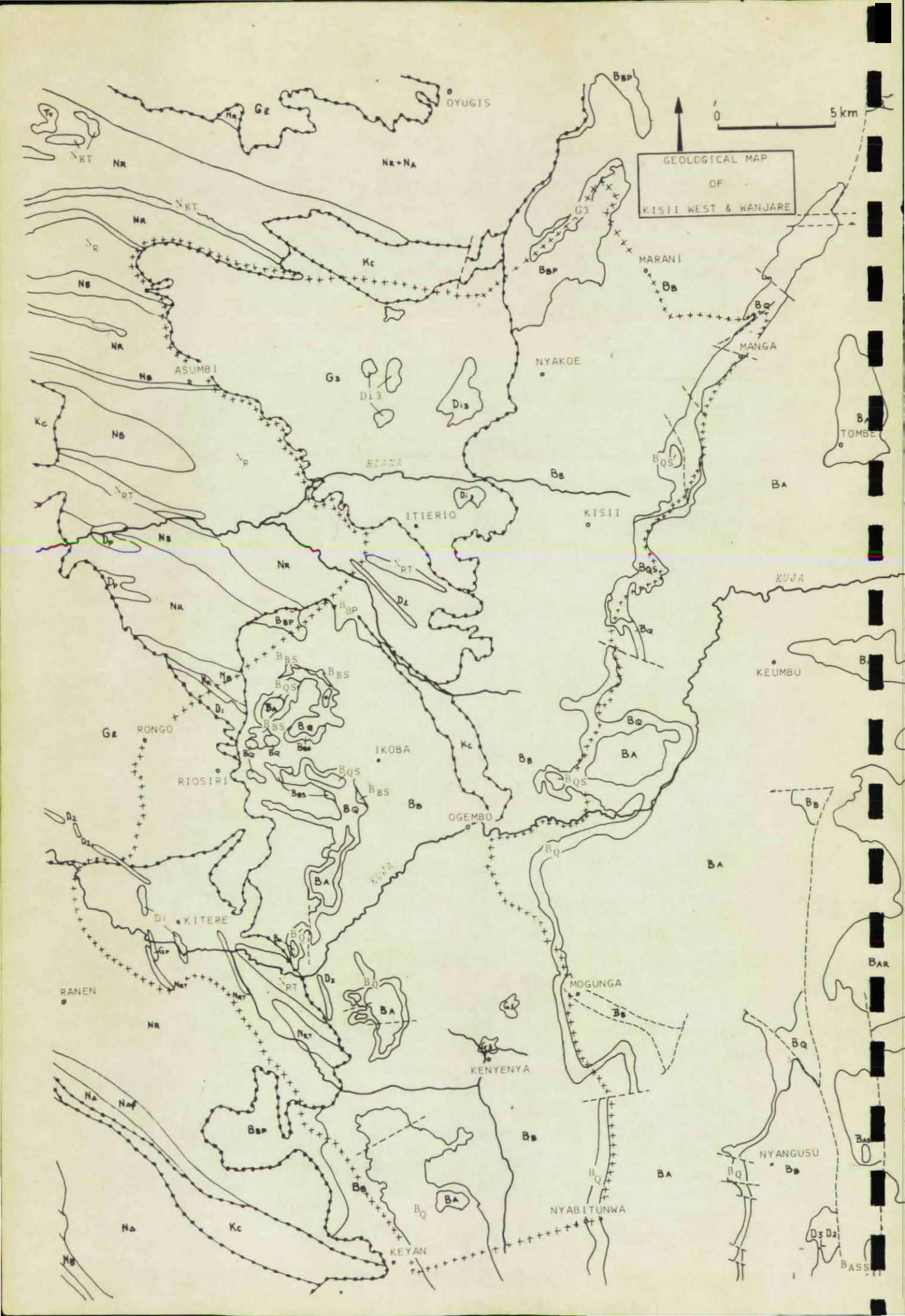
Name of the river	from	to	mean fall (m/100m)
Kuja	Ogembo	Ibencho gorge	1,14
Kuja	Ibencho gorge	Bridge Tanzania road	0,68
Riana	Gesonso market	Riana	0,98
Nyangweta	Mokubo school	Nyangweta	1,86

The smaller streams have in general a much bigger fall than the above mentioned rivers.

Rejuvenation of the Kuja river is evident by the frequent rapids between Ibencho and Ogembo and though below the Ibencho gorge the fall of the river lessens, even here there are also occasional steep sided, deeply incised short gorges.
Clearly to see is the lengthening of the rivers the Riana, the Nyangweta and the Mogunga rivers by the proces of headward erosion.

About 95% of the soils of the Kisii West area are well drained soils. The rest of the soils belongs mainly to the Hydromorphic soils, which are poorly to imperfectly drained. The hydromorphic soils are found in broad valleys, which are filled up with alluvial deposits. These soils are roughly situated in the south-east of the surveyed area and westly of the Sameta hill.

The broad valley bottoms are probably an indication for a stagnation period in the erosive action of the main river Kuja.
In this stagnation period sedimentation could take place in the sharply incised valleys.
Nowadays these broad flat valley bottoms are the remains of this period, which are not yet removed by the erosive action of the lenghthening rivers, the Nyangweta and the Mogunga.


GEOLOGICAL MAP
OF
KISII WEST & WANJARE
0
5 km
OYUGIS
MARANI
MANGA
NYAKOE
ASUMBI
ITIERIO
KISII
TOMBE
KUJA
KEUMBU
RONGO
RIOSIRI
IKOBA
OGEMBO
KITERE
RANEN
MOGUNGA
KENYENYA
NYANGUSU
NYABITUNWA
KEYAN

2.3. Geology

2.3.1. Legend of the geological map

Bukoban System

$B_{AR} + B_{ASS}$	Rhyolites and tuffs with intercalated fine and coarse grained sediments
B_A	Porhyritic and non-porphyritic felsites and andesites
B_{QS}	Cherts
B_Q	Quartzites
$B_B + B_{BS}$	Basalts with Kisii "soapstone", locally developed
B_{BP}	Porphyritic basalts

Post-Kavirondian Intrusives

D3 + D2 + L	Younger dolerites and lamprophyres
G3	Younger granites of Wanjare

Kavirondian System

$K_C + K_G$	Conglomerates and grits

Post-Nyanzian Intrusives

G2	Older granites of Kitere and Oyugis
Di3 + Di2	Quartz-diorites associated with G2 and G3 granites
D1 + Die	Basic minor intrusives; Dolerites (D1), Epidiorites (Die)

Nyanzian System

N_{Bi}	Banded ironstones, cherts and shales
N. N f	Upper andesites (N) with intercalated tuffs and argillaceous felspathic sandstones (N f).
$N_R + N_{RT}$	Rhyolites (N_R) with intercalated tuffs and agglomerates (N_{RT})
N_A	Andesites and dacites

2.3.2. Parent materials

The geological history of the Kisii area has been described in section 1.2.1. of report no.2 "Detailed Survey of the Marongo Area".

The principal rocktypes occurring in the area according to their age-relationship are as below:

6. Quarternary and Tertiary
   - 6.2. Alluvium
   - 6.1. Indurated Ironstones

5. Bukoban System
   - 5.3. Porphyritic and non-porphyritic Felsites and Andesites
   - 5.2. Quartzites and Cherts
   - 5.1.2. Non-porphyritic Basalts with locally developed "soapstone".
   - 5.1.1. Porphyritic Basalts

4. Post-Kavirondian Intrusives
   - 4.1. Wanjare Granites

3. Kavirondian System
   - 3.1. Conglomerates

2. Post-Nyanzian Intrusives
   - 2.2. Kitere Granites
   - 2.1. Quartz-diorites

1. Nyanzian System
   - 1.1. Rhyolites and rhyolitic tuffs

1. Nyanzian System

Nyanzian rocks are the oldest exposed in the area and consist mainly of acid lavas (rhyolites and rhyolitic tuffs), but west of the area basic and intermediate lavas occur (mainly basalts and andesites)

1.1. Rhyolites and Rhyolitic Tuffs: These rocks can be found in the south-western part of the area near Kitere and Nyangweta as white to yellowish grey rotten rock coming to the surface.
They are acid fine-grained volcanic rocks varying in color from pale grey to almost black, when fresh, but white to yellowish grey and soft, when weathered.

Rhyolites lack the strong longitudinal, almost fibrous structure of the tuffs and often contain small quartz vesicles (2-3 mm)
In both rocktypes quartz veins occur.

2. Post-Nyanzian Intrusives

2.1. Quartz-diorites might occur at some places in the Wanjare granite but they are covered normally by very deep soils.
The weathered rock has a black and white mosaic-like appearance.
Strongly weathered white felspars and slightly weathered black hoornblendes are predominant

2.2. Kitere Granites occur in the west of the area near Rongo and Kamagambo, but are almost everywhere covered by a 1 to 2 meter thick pan of indurated ironstone.
Near stream incisions the rock appears at the surface as large round boulders.
It is a fine-grained pale grey rock-type with pink to greenish felspar fenocrysts; the weathered granite is generally pure white.

3. Kavirondian System

3.1. Conglomerates forms the most important rock-type of the Kavirondian system, that is running as a long and narrow belt from Gesonso in south-eastern direction to Kebera (near Sameta Hill).
Especially in the northern part large boulders of conglomerates are present along the Nyanchabo river.

4. Post-Kavirondian Intrusives

4.1. Wanjare Granites are predominant in the north-western part of the area (sub-districts of Wanjare, East Nyokal and Kasipul).
It is covered by deep soils or by indurated ironstone, but in the south near Irigonga granite outcrops occur (Kebuye Range)
The granitic rock consists of coarse-grained pink or blueish grey material with large felspar fenocrysts, but granites tend to be much finer grained near the outer limits of the area
Weathering produces a soft white to pink rock easily desintegrating into slightly weathered quartz grains, weathered felspars and heavy minerals.

5. Bukoban System: The rocks of this system overlying the older Nyanzian rocks cover by far the greater part of the area. With their centre more to the east they extend throughout the whole eastern part to the line Mosocho-Kamagambo-Keyan (N-S).

5.1.1. Porphyritic Basalts: These rocks are locally developed near the edges of the Bukoban system in the South-west (Maroo and Got Muma) and in the North (Mosocho and Gesieko).
They occur as fine-grained dark greyish green rocks with greenish felspar fenocrysts (5-6mm) and sferical quartz vesicles; the weathering is described in the following section.

5.1.2. Non-porphyritic Basalts: occur in a long-drawn belt from Marani down to the Masai-border (Magenche); It is the main rock-type of the area.
The rocks are fine-grained blue-grey to dark grey or dark green with or without quartz vesicles; Normally these vesicles are sferical and filled with chalcedonic silica. Weathering produces spheroidal blocks with thin red-brown skins.
The well-known Kisii "soapstone" is a very locally developed type of rock, that occurs between the quartzites and the underlying basalts (Tabaka with soapstone-factory, Marongo Ridge and Sameta Hill)
Generally the Kisii soapstone is a white soft dense and very fine-grained rock with brown iron-stained surfaces. It consists mainly of kaolinite-sericite derived from basalt, and has been metamorphosised by hydro-thermal action.

5.2. Quartzites and Cherts : The quartzites overlying the basaltic rocks as hard and resistent caps give rise to prominent scarps up to 200 ft (e.g. Manga Ridge); They occur as a discontinuous (due to incision of rivers) belt in the West: Itumbe Hill - Marongo Ridge-Ibencho and Magenche Hill (N-S).or as a long narrow scarp starting in the North (Manga Ridge) via Sameta Hill up to Mogunga, where it passes into a low smooth ridge towards the Masai-border(Nyabitunwa).
Quartzite is a hard fine to medium-grained white to grey rock locally stained by purple iron-oxides; Weathering produces weakly cemented white sandgrains, but is going very slowly.
Cherts is a very fine-grained highly siliceous pale grey to almost black rock often with a very fine layering of iron-stained band ; They overlie or replace the quartzites at some places (Itumbe Hill and between Nyakegogo and the road Kisii-Keroka).

5.3. Porphyritic and Non-prphyritic Felsites and Andesites: are found in the Kisii Highlands to the East of the survey area and on plateaux and summits of Marongo, Gesusu and Ibencho and Itumbi, where they overlie the quartzites.
They are dense, fine-grained rocks with a red to purple, sometimes blue-grey colour with dark green felspathic fenocrysts; Weathering produces round or angular blocks with thick brick-like purple skins.

6. Quarternary and Tertiary

6.1. Indurated Ironstone (Laterite) is mainly found in the area of Rongo and Riosiri in the West and near Asumbi in the North West;It occurs as a nearly continuous layer of 1 - 2 m thickness overlying the rotten rock (Kitere and Wanjare granites).
The ironstone has a mottled appearance: black colours of the more or less vesicular iron-oxide concretions in a light grey to yellowish grey matrix; It is strongly cemented and resistent to weathering, which produces soft rock with small rounded iron-oxide concretions.

6.2. Alluvium occursthroughout the whole area in valleys,where supply of sediments has exceeded the removal; These valleys are flat-bottomed and poorly drained (near Riokindo and Sengera Mission and West of Sameta Hill). The deposits consist of heavy grey mottled plastic clays, with layers of Mn-concretions and plinthite in better drained parts.

2.4. Geomorphology

There is much evidence that the Kisii West area has taken shape through various erosion-cycles: periods of planation and dissection have succeeded eachother, gradually building up the landscape to its present form.

In the south-eastern part of the area the terrain has smooth forms and a low relief, while the valleys are filled with alluvium and are poorly drained. These features are characteristic for a long period of accumulation and of planation (Riokindo landtype - see fig.)

Towards the mainrivers (Kuja-Riana-Nyangweta) dissection and relief are increasing and valleys become better drained; By lowering of the erosion-level or through some other cause rivers have been rejuvenated. Swiftly streaming, deeply incised rivers with many rapids bear witness of this rejuvenation. Due to strong downcutting and the backwearing action of streams the landscape has got a dissected appearance;
The drainage pattern is well developed and dendritic with V-shaped valleys (Kuja landtype - see fig.)
Locally parts of the Riokindo landtype are still untouched.

In the western part of the area a long belt of mesas or table mountains occur arisen from resistent quartzite layers (Marongo Ridge Ibencho Hill, etc.). They are large massives with flat summits forming undulating plateaux, while the quartzite layers have formed steep, rocky escarpments, thus protecting the plateaux against the eroding action of the rivers; They are considered as remnants of an old planation surface (Cretacious) (Marongo landtype - see fig.)

Fig.13. Low flat hills with broad poorly drained valleys (Riokindo landtype near Nyabitunwa).

Fig.14. The deeply incised Kuja valley (Kuja landtype near Kitere).

Fig.15. Insaria Hill, a steep "inselberg" of the Kuja landtype

Fig.16. Ibencho Hill, steep rocky escarpments with undulating plateaux of the Marongo landtype; dissected hills (Kuja landtype) in the front.

Fig.16. Iberoko Hill, steep rocky escarpments with undulating plateaux of the Maronko landtype; dissected hills (Kuja landtype) in the front.

3. SURVEY METHODS

The Kisii West semi-detailed soil survey is based on the detailed surveys of the sample areas Marongo and Irigonga.

The principle of a soil survey based on sample areas is that two areas with the same geology, physiography, climate, vegetation and history include the same soil associations.

The sample areas Marongo and Irigonga (approximately 12.000 ha) are representative for the Kisii West area (approx. 72.000 ha).

The sample areas surveyed with the aid of air photos on scale 1 : 12.500 have been firstly divided in main landtypes and phases with the aid of air photos on scale 1 : 50.000.
A unit is recognizable by its slope, relief, drainage pattern, drainage density and land use.
The division of the landscape of the sample areas gives soil associations of the soil series described in the detailed surveys. Those groups of soils have sufficient correlation with relief, dissection and land use, for use with the semi-detailed soil survey.

The procedure.
The boundaries of the landtypes and phases plotted on the photos with the aid of a mirror stereoscope were checked in the field. On places where deviations in soil distribution and/or physiography occured, new rough boundaries were plotted in the field on the photos, based on augering and analysis of physiography.
In the office these boundaries were plotted more accurately with the help of the mirrorstereoscope.

The relationship between physiography and soil associations is not always a clear one.
The airphoto interpretation needs correction after the field work. In some cases the soil associations of different landtypes or phases are nearly similar. Due to this fact two different maps have been made, a physiognomic interpretation map and a soil association map.

Materials for fieldwork and photoanalysis.

The fieldwork was done with the help of an Edelmanauger, an Abneylevel, a geological compass, Munsell_colorcharts and Guidelines for soildescriptions from the F.A.O.
The airphoto analysis was done with the aid of airial photographs on scale 1 : 50.000 (1960) and a Topcon mirror stereoscope.

Soil sampling.

15 soil pits were dug mostly to a depth of about 2 meters and soil samples were taken of each genetic horizon from representative profiles for chemical analysis at the laboratories of the Agricultural University at Wageningen, the Netherlands.

Map compilation.

The base map for the compilation of the landtypes and phases and soil association maps was the topographical map of Kenya on scale 1 : 50.000 Series Y 731, edition 4 - D.O.S., 1963.
On this map the boundaries of the landtypes and phases and soil associations were transferred from the airial photographs with the help of a Keuffel & Esser vertical sketchmaster.
These provisional maps on scale 1 : 50.000 were reduced by aid of photographical technics to a scale of 1 :100.000, which was decided to be the final publishing scale.

4. THE SOILS

4.1. The photo-interpretation

4.1.1. Introduction

The landscape of the Kisii West area are groupºd into landtypes and landphases according to their appearance in the photo-stereo-image. As little is known of the geomorphological processes which have shaped the terrain, the physiognomic analysis method has been applied: analysis and classification of landtypes and phases based on the external features of the terrain.

The main elements in this photo-interpretation are:

1) slope and relief
2) drainage pattern and density
3) vegetation and landuse

The landtypes constitute the main division of the physiognomic legend and are indicated by capital letters representing the first letter of some geographical name(R, N, M, etc.)
The subdivisions of the landtypes are the landphases e.g. physiognomic mapping units; They have been formed by adding a suffix to the capital of the landtype (Nf, Rh, etc.)

Code system

R = Riokindo landtype
N = Nyakoe ,,
K = Kuja ,,
M = Marongo ,,

h = hill
v = valley
r = ridge
s = slightly dissected
m = moderately ,,
d = deeply ,,
o = outcrop
p = plateau
e = escarpment
fi= footslope irregular
fs= ,, smooth

4.1.2. Description of the physiognomic mapping units

R - RIOKINDO : low hills with broad poorly drained valleys

Relief : 30-75 m
Lithology : Bukoban basalts

Rh - Due to the low relief and smooth landforms the Riokindo land-type has a peneplain-like appearance; It covers large areas in the south-eastern part of Kisii West.
The Rh-landphase consists of low undulating to rolling (less than 16%) hills with convex-concave slopes; No outcrops occur while rockiness or stoniness are absent. It is hardly dissected by rivers and streams.
The whole area is under cultivation.

Rv - Running between the hills are the valleys, filled with slope- or river-alluvium; They appear as large flat to almost flat poorly drained valley-bottoms with narrow meandering stream-channels.
The area is mainly under natural grazing land with a charactoristic widely and regularly spaced bush-vegetation; In drier or better drained parts arable land occurs, the lowest parts of the valleys are dominated by seasonnally flooded swamps with dense river-bushes,reed and sedges.

N - NYAKOE : low flat ridges

Relief : 45-75 m
Lithology : Bukoban basalts, Kitere and Wanjare granites.

Nr - Summits of the ridges are characterized by low to undulating convex slopes, locally with an imperfect drainage where caps of indurated ironstone are present; At those places natural grazing land occurs, but generally arable land is dominating.

Nv - The valleys consist of sloping to moderately steep convex to straight lower slopes and valleybottoms filled with slope-material with an impeded drainage (low mean fall of streams); Apparently many valley slopes have been formed by slump-processes. Drainage patterns are mostly subparallel.
Arable land is predominant on the well drained slopes,valleys are covered by river-bushes or reed, and locally by sugarcane.

K - KUJA : dissected hills

Relief : 90-180 m

Lithology : Bukoban basalts and quartzites, Nyanzian rhyolites Kitere and Wanjare granites

Ko - This landphase includes the cone-shaped outcrops and "inselbergs" with straight moderately steep to steep slopes mostly covered by thick stone- and gravel-layers; Locally clear features of creep action in these layers are visible (rhyolites near Kitere). The Ko-landphase can be considered probably as inselbergs, the last visible remnants of an old surface: Itumbe Hill, Kebuye Range, Insaria and Nyanchua Hill. Natural grazing land and dense shrubs or bushes form the main vegetation.

Ks - The long hillslopes of Ks are slightly dissected, sloping to moderately steep and uniform; It is only locally dissected by rejuvenated rivers and the dendritic drainage pattern is weakly developed.
Intensive cultivation is dominating.

Km - The lower hill- and valleyslopes are moderately dissected, moderately steep and straight to convex; The dendritic drainage pattern is well developed, often with incised V-shaped valleys (slopes up to 50%).
Intensive cultivation is dominating.

Kd - Near the mainrivers (Kuja, Riana etc.) incision and dissection are strongest: deeply dissected V-shaped valleys and gorges with steep convex slopes;The dendritic drainage pattern is well developed everywhere. Especially in places where rivers cut through the resistent quartzites, Kd is common e.g. Ibencho Gorge , where the river Kuja separated Marongo Ridge and Ibencho Hill and near Etago, where the Nyangweta river formed a steep gorge.

M - MARONGO - table land

Relief : 150-240 m

Lithlogy : Bukoban basalts, quartzites and felsites/andesites.

Mp - The summits of the table landscape are formed by plateaux consisting of low undulating to rolling convex.concave hills; A clearly visible drainage pattern is absent, locally depressions without outlets occur
Mp is cultivated intensively.

Me - On the edges of the sharply bounded plateaux there are the escarpments of quartzite with moderately steep to very steep, irregular and rocky slopes, locally reaching a height of 70 m. The Manga Ridge has slopes of more than 300%, consisting of bare rock, but normally the maximum angle does not exceed 70 %.((Marongo Ridge, Ibencho and Sameta Hill)
Me is covered by dense bushes and natural grazing land.

Mfi - Below the escarpment long footslopes occur with moderately steep to steep concave slopes.
The landphase has a rather irregular appearance on the photographs and in the field: small steep gullies and scarps or outcrops of quartzite (slopes up to 50%) are present everywhere; This micro- or meso-relief can be considered as the result of a developing drainage pattern.
Arable land is present with natural grazing land in the steeper parts.

Mfs - If no quartzitic rocks are present, footslopes are smooth, concave with moderately steep slopes
The long slopes of Mfs are under cultivation everywhere.

4.2. The soil associations

4.2.1. Introduction

The soil survey of the Kisii West area is based on the photo-interpretation of the landscape. The experiences from fieldwork show us that there is a relationship between the landscape and the soils.

We have divided the landscape into landtypes and landphases and had given them symbols.(Chapter 4.1.)
In framing the legend of the soil association map we used nearly all these symbols. A soil association is indicated by three characters. The first two (a capital and a small letter) are taken from the physiognomic map, indicating the landphases. The third one (a capital) gives information about the parent material.

A condition for developing a soil association map from a physiognomic map is the rule: "similar soil associations in similar landphases".
There are two important exceptions to this rule in Kisii West.

The first exception to this rule is: "similar landphases but different soil associations".
We divided a landphase into different soil associations when different parent materials were concerned.
In some cases different parent materials in similar landphases caused clearly visible differences in the soils, in other cases the differences are small or not visible.
Yet, we use this subdivision of the landphases based on parent material, due to lack of analytical data of the soil series from the sample areas.
The analytical data must show if e.g. a "well drained, very deep, dark red, clay soil" on basalt and on felsite/andesite are different or similar soil series.

A second exception to the rule is: "different landphases but similar soil associations".
This occurs only once in Kisii West. KsB and RhB turn out to be similar soil associations. We add RhB to the KsB because of this, and the nearly similar external features.

[illegible]

[illegible]

The soil map presents soil associations: groups of defined and named taxonomic units, geographically associated in a defined pattern in the field.
The units are soil series classified in accordance with the 7th Approximation (USDA 1970) down to the level of subgroups (see report nr. 2 of the detailed survey Marongo).

A base for the distribution of soil series in a landphase is the distribution of soil series . such a landphase in the detailed sample areas.
This is an objective base, but it often needs correction after fieldchecks have been carried out.
With a planimeter the areas of the different soil series in a soil association have been calculated in hectares.
In Appendix 2 you may find the distribution of the soil series of all the soil associations of the sample area Marongo in percentages.
The experiences from fieldwork give the final distribution of the soil series in percentages in a soil association, which are mean figures for the Kisii West area.
You may find those percentages in the description of the soil associations (Chapter 4.2.3.)

For the full description of the soil series we refer to the reports nr. 2 and 3, the detailed surveys Marongo and Irigonga, for new soil series to the Appendix 1 of this report.

Soil properties.
In the map legend and the description of the soil associations information is given about several internal and external soil properties, such as slope percentage, drainage condition, soil depth, soil colour, genetic horizons and so on.
Each property is indicated quantitively by means of classes.
In most cases we use the classes as described in the Soil Survey Manual and in the FAO guidelines for soil description.

Slope classes

percentage	single slope	complex slope
0 - 3 %	flat or nearly flat	flat or nearly flat
3 - 8 %	gently sloping	undulating
8 - 15%	sloping	rolling
15 - 30%	moderately steep	hilly
30 - 60%	steep	steep
more than 60%	very steep	very steep

Drainage condition

poorly drained
imperfectly drained
moderately well drained
well drained
somewhat excessively drained
excessively drained

Soil depth

very deep	more than 1,80 m
deep	1,20 - 1,80 m
moderately deep	0,50 - 1,20 m
shallow	0,20 - 0,50 m
very shallow	less than 0,20 m

Soil colour

The soil colours are described by comparison with the Munsell soil colour charts. In general information is given about the colour of the subsoil. In case of a topsoil only the colour of the topsoil is stated.

There are some soil properties which are not mentioned in the description of the soil associations, such as:
texture, clay illuviation and structure.
Some are characteristic for nearly all the soils, while the others are characteristic for two main groups of soils.
To make the report and the map legend more readable and clear we have not mentioned them in all the soil association descriptions.

Texture

Nearly all the soils of the Kisii West area have a texture of very fine to fine clay, only the deviating textures are mentioned in the map legend and the descriptions of the soil associations.

Clay illuviation

Another important property of most soils in Kisii West is the phenomenon of clay illuviation.
In the soil profile you may find a subsoil with clay cutans on soil aggregates, which can be an indication for clay illuviation.

In some soils we don't find clay cutans:
in the soils with an A horizon only and in the poorly drained (hydromorphic) soils, in the latter this is uncertain, there are sometimes slight indications for clay illuviation.

There are differences in the quantity of clay cutans in a soil.
There are in general two groupes of soils:
The soils developed on basalt, felsite/andesite and rhyolite have very clear, continuous clay cutans.
The soils developed on quartzite and granite have less clear, patchy or broken clay cutans.

Structure

We may distinguish two groups of soils with different soil structure.
Soils developed on basalt, felsite/andesite and rhyolite have a moderate to strong structure.
Soils developed on quartzite and granite have a weak structure.
Within these groups the soil structure is influenced by the organic matter content.

Thick topsoil rich in humus

This means a topsoil with a dark brown or black colour (hue and value less than 4) and a thickness of more than 40 cm.
Such a topsoil contains much organic matter and has properties as: a good structure, a good porosity and is not susceptible to surface sealing (has much resistance to erosion).

4.2.2. Legend of the soil association map

Texture

Nearly all the soils of the Kisii West area have a texture of very fine to fine clay, only the deviating textures are mentioned.

RIOKINDO : broad, flat valley bottom

RvA : poorly drained soils with a thin black or locally peaty topsoil and a grey mottled subsoil.

NYAKOE : low flat ridges

Nr : flat to undulating upperslopes of low ridges

NrB : well drained, deep, dark red soils often with a topsoil rich in humus developed on basalt.

NrR : well drained, moderately deep to deep, dark red soils often with a thick topsoil rich in humus developed on rhyolite.

NrW : well drained, deep, dark red soils developed on Wanjare granite.

NrWL: imperfectly drained, moderately deep, red, gravelly soils with indurated ironstone in the subsoil developed on Wanjare granite.

NrKL: well to imperfectly drained, mainly moderately deep, dark red soils with indurated ironstone in the subsoil developed on Kitere granite.

Nv : sloping to moderately steep, slightly convex or straight lower slopes and valleys filled with slope material.

NvB : the hill slope soils are well drained, deep and dark red, developed on Basalt; the valley soils are imperfectly to poorly drained with a dark red colour, developed on recently deposed basaltic slope material.

NvR : the hill slope soils are well drained, mainly moderately deep and dark red, developed on rhyolite; the valley soils are imperfectly to poorly drained with a thin black topsoil and a grey mottled subsoil developed on alluvium.

NvW : the hill slope soils are well drained, deep and dark red, developed on Wanjare granite; the valley soils are imperfectly to poorly drained with a thin black topsoil and a grey mottled subsoil developed on alluvium.

NvWL: the hill slope soils are well drained, moderately deep, red and have a stony, gravelly clay texture with indurated ironstone in the subsoil; the valley soils are imperfectly to poorly drained with a thin black topsoil and a grey mottled subsoil.

NvKL: the hill slope soils are well drained, mainly moderately deep and dark red with indurated ironstone in the subsoil, developed on Kitere granite; the valley soils are imperfectly to poorly drained with a thin black topsoil and a grey mottled subsoil, developed on alluvium.

KUJA : dissected hills

Ko : conical outcrops and "inselbergs" with straight, moderately steep to steep slopes, covered by colluvium.

KoB : somewhat excessively drained, shallow and gravelly, dark brown soils, developed on Basalt.

KoR : somewhat excessively drained, very shallow, gravelly, dark brown soils developed on rhyolite.

KoW : somewhat excessively drained, shallow, gravelly, dark brown soils developed on Wanjare granite.

Ks : slightly dissected, long, straight, sloping to moderately steep hills.

KsB : well drained, very deep, dark red soils often with a thick topsoil rich in humus, developed on basalt.

KsR : mainly well drained, deep, dark red soils, locally with layers of black manganese concretions, developed on rhyolite.

KsW : well drained, moderately deep to deep, red, gravelly clay soils, developed on Wanjare granite.

KsQ : well drained, deep, dark red soils developed on quartzite.

Km : moderately dissected V-shaped valleys and lower hill slopes with moderately steep slopes.

KmB : well drained, deep and dark red soils, sometimes with a thick topsoil rich in humus, developed on basalt.

KmR : well drained, deep, dark red soils locally with gravellayers, developed on rhyolite.

KmQ : well drained, mainly deep, dark red soils developed on quartzite.

KmW : well drained, shallow to deep, dark red, gravelly soils, developed on Wanjare granite.

Kd : deeply dissected steep valley slopes

KdB : well to somewhat excessively drained, shallow to moderately deep, dark red soils developed on basalt

KdR : well to excessively drained, very shallow, gravelly, dark brown soils developed on rhyolite.

KdW : somewhat excessively drained, moderately deep, dark red, gravelly to very gravelly soils developed on Wanjare granite.

MARONGO : table land

Mp : plateau

MpF : well drained, deep, dark red soils often with a thick topsoil rich in humus, developed on felsite and locally on quartzite.

Me : escarpment

MeQ : somewhat excessively drained, very shallow, stony and rocky, dark brown soils with only an A horizon, developed on quartzite.

MeF : somewhat excessively drained, shallow, stony, dark brown soils with only an A horizon, developed on Felsite.

Mfi : footslope with an irregular meso-relief

MfiB : well drained, mainly shallow and dark reddish brown soils developed on basalt mixed with some quartzite.

Mfs : footslope with a smooth relief

MfsB : well drained, deep, dark red soils developed on basalt.

4.2.3. Description of the soil associations

RvA

Geology : Alluvium of probably basaltic origin
Geomorphology : broad, flat to almost flat valley bottoms with narrow meandering streams.

Poorly drained soils with a thin black or locally peaty topsoil and a grey mottled subsoil.
During a part of the year these soils are waterlogged or have the watertable nearby the soil surface.
A narrow transition zone between this soils and the well drained soils of the surrounding hills is characterized by layers of manganese and iron concretions in the soil profile.
The lower parts of the broad valley bottom consist of peat soils, they have a thick topsoil of partly decomposed organic material.
Remarkable is a sharp increase of the texture at a depth of 30 - 50cm although the topsoil and subsoil have a texture of very fine clay, probably due to a change in clay-mineralogy.
Main soil series: 80% MrA, 10% RkB and about 10% peatsoils.

Land use: natural grazing land with sedges, on the better drained parts some arable land and on the drained peat soils some horticulture.
Without drainage these soils are only suitable for natural grazing land.

NrB

Geology : Bukoban Basalt
Geomorphology : flat to undulating upperslopes of low ridges

Well drained, deep, dark red soils often with a thick topsoil rich in humus.
Main soil series: 40% NbB and 40% ChB

Land use: subsistence crops (maize, wimbi, batatas) and cash crops (bananas, coffee and sometimes sugar-cane).
The soils have a high agricultural potential.

NrR

Geology : Rhyolite
Geomorphology : flat to undulating upperslopes of low ridges

Well drained, moderately deep to deep, dark red soils often with a thick topsoil rich in humus.
On level parts the soils have a layer of manganese and iron concretions in the subsoil.
Main soil series: 30% KnR, 30% MnR and 20% NkR

Land use: mainly subsistence crops (maize, wimbi, batatas)
The soils have a medium to high agriculture potential.

NrW

Geology : Wanjare Granite
Geomorphology : undulating summits of ridges

Well drained, deep, dark red soils.
Main soil series: 80% Nyosoka and 20% Matongo

Land use: subsistence crops (maize) and cash crops (bananas, coffee).
The soils have a high agriculture potential.

NrWL

Geology : Wanjare Granite
Geomorphology : gently sloping summits of ridges

Imperfectly drained, moderately deep, red, gravelly soils with an indurated ironstone layer in the subsoil.
Main soil series: 50% Magira and 50% Otela series.

Land use: subsistence crops (maize, cassave and groundnuts)
The soils have a low agricultural potential.

NrKL

Geology : Kitere Granite
Geomorphology : low, flat to undulating ridges

Well to imperfectly drained, mainly moderately deep, dark red soils.
Te soil depth is ranging from very shallow to deep, depending on the position of an indurated ironstone layer in the subsoil.
On the flat top of the ridges this indurated ironstone occurs sometimes at the surface.

The shallow soils with an indurated ironstone layer are moderately well drained and have hues of 5YR in the subsoil.
The soils are susceptible to surface sealing and erosion.
On the flat summit of the ridges sometimes oval depressions occur with poorly drained soils.
Main soil series: 10% MrA, NsG 20%, 15% NdG, PlG 15%, RnL 20%

Land use: natural grazing land on the shallow soils and subsistence crops (maize, wimbi, groundnuts) on the deeper soils, often with the cash crop sisal as a hedge.

The soils have a medium agricultural potential caused by the low water storage capacity of the shallow soils and the susceptibility to erosion.

NvB

Geology : Bukoban Basalt
Geomorphology : sloping to moderately steep, slightly concave or straight lower slopes and valleys filled with slope material.

The lower hill slope soils are moderately well drained, deep and dark red.
The valley soils are imperfectly to poorly drained, however, the colour of the subsoil is often dark red. (probably the soil material has been deposed recently in the valleys)
Main soil series: 50% ChB, 20% MrA and 20% MbB

Land use: river bush, subsistence crops and cash crops.
The soils have a medium agricultural potential.

NvR

Geology : Rhyolite
Geomorphology : sloping to moderately steep, slightly convex or straight lower slopes and valleys filled with slope material.

The hill slope soils are well drained, mainly moderately deep and dark red. They have a layer of manganese and iron concretions mainly at a depth of 30 - 60 cm.
The valley soils are imperfectly to poorly drained with a thin black topsoil and a grey mottled subsoil.
Main soil series: 40% NnR, 20% RkR and 20% OlA

Land use: on the hill slope soils natural grazing land and subsistence crops and on the valley soils often sugar-cane.
The soils have a medium agricultural potential.

NvW

Geology : Wanjare Granite
Geomorphology : sloping to moderately steep lower slopes and valleys filled with slope material.

The hill slope soils are well drained, deep and dark red.
The valley soils are imperfectly drained with a thin black topsoil and a grey mottled subsoil.
Main soil series: 60% Nyasoka, 20% Matonga, 10% MrA)

Land use: subsistence - and cash crops, in the valleys often sugar-cane.
The soils have a high agricultural potential.

NvWL

Geology : Wanjare Granite
Geomorphology : sloping to moderately steep, slightly convex or straight lower slopes and valleys filled with slope material.

The hill slope soils are well drained, moderately deep, red and have a stony, gravelly clay texture.
The valley soils are imperfectly to poorly drained with a thin black topsoil and a grey mottled subsoil.
Main soil series: 60% Otala, 20% Magina and 20% Maraba series.

Land use: grazing land and subsistence crops(cassave, maize, ground nuts).
The soils have a low agricultural potential.

NvKL

Geology : Kitere Granite and Alluvium
Geomorphology : sloping to moderately steep, slightly convex or straight lower slopes and valleys filled with Alluvium

The soils of the lower hill slopes are well drained, mainly moderately deep and dark red.

The hill slope soils have an indurated ironstone layer in the subsoil and sometimes big granite boulders and rotten rock may occur, where the streams have broken through the ironstone layer. The valley soils are imperfectly to poorly drained, with a thin black topsoil and grey mottled subsoil, they are a part of the year waterlogged or have the watertable nearby the soil surface.
Main soil series: 20% Olando, 20% Riosiri, 20% Nyasoka and 20% Paulo.

Land use: on the hill slope soils, natural grazing land on the shallow soils and subsistence crops (maize, wimbi, groundnuts) on the deeper soils. In the valley soils often sugar-cane.
The hill slope soils have a medium agricultural potential and the valley soils have a high agricultural potential for sugar-cane.

KoB

Geology : Bukoban Basalt
Geomorphology : cone shaped outcrops and steepstraight upper slopes, sometimes large boulders occur on top of it.

All the soils are somewhat excessively drained, shallow and gravelly or stony due to presence of a thick colluvial layer (up to 1,5 m) consisting of basaltic and quartsitic gravels and stones. The soils are becoming deeper towards the lower slopes.
Main soil series: 70% Mugirango, 20% Ogembo, and 10% Gucha

Land use: natural grazing land and some subsistence crops (maize, wimbi and sweet potatoes)
The soils have a low agricultural potential due to the susceptibility to erosion and their low water storage capacity.

KoR

Geology : Nyanzian rhyolite
Geomorphology : cone shaped-outcrops with steep straight slopes.

Somewhatexcessively drained, very shallow, gravelly dark brown soils. The dark toplayer overlies a gravellayer (colluvium), below this layer the rotten rock is present. Towards the summit stoniness and rockiness are increasing while the substratum is formed by non-weathered rhyolite.

Main soil series: 70% Kananga and 20% Nyerega.

Land use: mainly bush land, sometimes subsistence crops and locally forest (Nyangweta forest).

The soils have a low agricultural potential due to steepness, rockiness and shallowness.

KoW

Geology : Wanjare Granite

Geomorphology : rock outcrops with tors.

Somewhat excessively drained, shallow, gravelly clay soils with a dark brown colour.

Main soil series: 70% miscellaneous, 20% Kebuye.

Land use: natural grazing land and bush land

The soils have a low agricultural potential.

KsB

Geology : Bukoban Basalt

Geomorphology : long, non- or slightly dissected, uniform, sloping to moderate steep hill slopes.

Well drained, very deep, dark red soils often with a thick topsoil rich in humus.

This association includes also the soils out of the Rh landphase (Chapter 4.1. Riokindo) because they have similar soil series distributions and only slight differences in external features.

Main soil series: 40% Nyaborumbasi, 30% Chang'aa, 10% Muma and 10% $Guch_a$.

Land use: subsistence crops (maize, wimbi, batatas) and cash crops (bananas, coffee and sometimes tea, pyrethrum and sugar-cane)

The soils have a high agricultural potential due to thick topsoil rich in humus, the high water storage capacity and the soils are not susceptible for surface sealing and erosion.

KsR

Geology : Nyanzian Rhyolite
Geomorphology : slightly dissected, mainly sloping convex hills

Mainly well drained, deep, dark red soils, locally with layers of black manganese concretions in the subsoil, where drainage conditions are less.
Main soil series: 50% Nyokal, 20% Kitere and 20% Nerega

Land use: subsistence - and cash crops
The soils have a high agricultural potential.

KsW

Geology : Wanjara Granite
Geomorphology : sloping to moderately steep upper slopes

Well drained, moderately deep to deep, red, gravelly clay soils.
Main soil series: 40% Iruma, 20% Kebuye, 20% Matongo

Land use: maize, ground nuts and sugar-cane
The soils have a medium to low agricultural potential

KsQ

Geology : Bukoban Quartzite
Geomorphology : slightly dissected, sloping to moderately steep slopes.

Well drained, deep, dark red soils.
Main soil series: 60% Myamgori, 10% Kiabigori and 10% Marongo 1.

Land use: subsistence and cash crops
The soils have a medium to high agricultural potential.

KmB

Geology : Bukoban Basalt
Geomorphology : moderately dissected, V-shaped valleys and lower hill slopes with moderately steep slopes.

Well drained, deep and dark red soils, sometimes with a thick topsoil rich in humus. Soils with a thick topsoil rich in humus are less common in comparison with the KsB association.
Main soil series: 10% Nyaborumbasi, 40% Changaa, 30% Gucha

Land use: subsistence - and cash crops
The soils have a medium to high agricultural potential.

KmR

Geology : Nyanzian Rhyolite
Geomorphology : moderately dissected, sloping to moderately steep valley slopes.

Mainly well drained, deep, dark red soils locally with gravellayers in the subsoil, where this association passes into the KoR association.
Main soil series: 50% Nyokal, 10% Nyerega and 20% Kananga.

Land use: subsistence - and cash crops
The soils have a medium agricultural potential as the dark toplayer is partly removed by erosion.

KmQ

Geology : Bukoban Quartzite
Geomorphology : moderately dissected, moderately steep slopes near quartzitic escarpment (MeQ)

Well drained, mainly deep, dark red soils. Texture are mostly more sandy in comparison with soils developed on basalt and rhyolite. Locally near knickpoints and valleys outcrops of quartzite occur, here large amounts of stones are making tillage impracticable.
Main soil series: 40% Nyangori, 10% Kiabigori, 30% Marongo 1.

Land use: subsistence - and cash crops.
The soils have a medium agricultural potential due to locally high rockiness phase and the high erodibility.

KmW

Geology : Wanjare Granite
Geomorphology : middle position of sloping hill slopes

Well drained, shallow to deep, dark red, gravelly clay soils.
Main soil series: 40% Iruma, 20% Kebuye and 20% Matongo.

Land use: maize, groundnuts, sugar-cane
The soils have a low agriculture potential.

KdB

Geology : Bukoban Basalt
Geomorphology : deeply dissected steep valley slopes, occuring near main rivers.

Well drained to somewhat excessively drained, shallow to moderately deep, dark red soils, with a stoniness and rockiness phases which interferes which tillage.
The basaltic underlying rock is weathered to a considerable depth with deep cracks, through the water disappears.
Main soil series: 30% Gucha, 35% Ogembo and 10% Muma.

Land use: mainly natural grazing land and some subsistence crops (maize and wimbi)
The soils have a low agricultural potential due to low water storage capacity in dry periods and their erodibility.

KdR

Geology : Nyanzian Rhyolite
Geomorphology : deeply dissected V-shaped valleys (Kuja) with steep convex slopes.

Well to excessively drained, very shallow, gravelly, dark brown soils. Locally the yellowish white rotten rock appears at the surface as the topsoil is removed by erosion.
On less steep slopes the soils are moderately deep and have a dark red subsoil.
Main soil series: 50% Kananga, 20% Nyerega, 20% Nduru

Land use: mainly subsistence crops (maize, wimbi, batatas)
The soils have a low agricultural potential due to the low water storage capacity, while erosion is a serious danger on the steep slopes.

KdW

Geology : Wanjare Granite
Geomorphology : lower position of sloping hill slopes

Well drained, deep, dark red, gravelly to very gravelly soils.
Main soil series: 40% Matongo, 20% Nyasoka, 20% Iruma.

Land use: natural grazing land and subsistence crops (maize)
The soils have a low agricultural potential.

MpF

Geology : Felsites/Andesites, sometimes mixed with Quartzites
Geomorphology : undulating to rolling, non- to slightly dissected, convex-concave low hills on plateaus.

Well drained, deep, dark red soils, often with a thick topsoil rich in humus.
Only small areas have soils with quartzite influence, e.g. on the Manga ridge and in the north of the Matongo ridge.
The soils developed on quartzite have a thin topsoil rich in humus.
Main soil series: 60% Nyakambene, 10% Skuli and 10% Kiabigori.

Lan use: subsistence crops (maize, wimbi , batatas) and cash crops (coffee and sometimes tea)
The soils have a high agricultural potential.

MeQ

Geology : Quartzites
Geomorphology : moderately steep to very steep, straight scarps.

Somewhat excessively drained, very shallow, dark brown soils, with only an A horizon and rockiness and stoniness phases which makes tillage impracticable.
Main soil series: 80% Marongo 1

Land use: natural grazing land with shrubs
The soils have a low agricultural potential.

MeF

Geology : Felsites
Geomorphology : moderately steep to very steep straight scarps.

Well to somewhat excessively drained, shallow, dark brown soils with only an A horizon and rockiness and stoniness phases which makes tillage impracticable.
Main soil series: 80% Gesusu.

Land use: natural grazing with shrubs
The soils have a low agricultural potential.

MfiB

Geology : Bukoban Basalt mixed with some Quartzites
Geomorphology : moderately steep to steep, long, slightly concave footslopes with an irregular meso-relief.

Well drained, mainly shallow and dark reddish brown soils.
The very shallow soils have only an A horizon.
In this soil association the soil depth is mainly shallow but ranges from very shallow to deep, there is a clear relationship between soil depth and the slope percentage of the meso-relief.
On the steeper parts the rockiness and stoniness phases make tillage impracticable.
Main soil series: 15% Chang'aa, 10% Muma, 20% Mugirango, 15% Ogembo and 20% Marongo 1

Land use: natural grazing land and subsistence crops
The soils have a medium agricultural potential, due to shallowness and irregularity.

MfsB

Geology : Bukoban Basalt
Geomorphology : moderately steep, long, straight to concave, smooth footslopes.

Well drained, deep, dark red soils, sometimes which a stoniness phase which interferes with tillage.
Main soil series: 20% Chang'aa, 20% Nyaborumbasi, 25% Nyangori and 20% Marongo 1.

Land use: mainly subsistence crops (maize, wimbi, batatas).
The soils have a medium to high agricultural potential.

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APPENDIX I

SOIL PROFILE DESCRIPTIONS

Profile no.: 500 Chang'laa series (ChB)

Classification: 7th Approximation 1970 - Humoxic Palehumult

Majoge, Keberi near Sameta, 9913.80 N - 692,47 E

Altitude: 5.550 ft

(R. Henneman, S. Kauffman, 25-3-1974)

Geomorphology	: smooth uniform slope of low hill
Parent material	: basalt - Kavirondian
Relief and slope	: normal relief and slope class 3 (sloping)
Stoniness	: class 0 (no stones)
Drainage	: well drained
Moistness	: topsoil and subsoil moist
Biology	: rootdevelopment deeper than 1.60 m., strongest development in the first 30 cm.
Land use	: coffee

Soil profile:

A1 0 - 15 cm - Dark reddish brown (5 YR 3/3) moist; very fine clay; weak very fine subangular blocky and fine crumbs; many very fine biopores; clear and smooth boundary.

A3 15 - 60 cm - Dark reddish brown (2.5 YR 3/5) moist; very fine clay; weak very fine subangular blocky ; many very fine and common fine biopores; continuous clay cutans; many termite holes, Ø 6 cm; gradual and smooth boundary.

B 60 - 160 cm - Dark red (2.5 YR 3.5/6) moist; very fine clay; weak to moderate subangular blocky, very fine to fine; many very fine and common fine biopores; continuous clay cutans; termite holes up to 1 m., Ø 2 cm.; at a depth of 80-100 cm., very few, rounded, strongly weathered stones.

Profile no.: 501 Riokindo series (RiA)

Classification: 7th Approximation - Oxic Plinthaqult

Majoge, Keberi near Sameta, 9914.00 N - 692.57 E,
Altitude: 1615 m.
(R. Henneman, S. Kauffmann, 25-3-1974)

Geomorphology	: lower slope of a low nill towards a broad valley bottom
Parent material	: basalt
Relief and slope	: flat relief and slope class 1 (gently sloping)
Stoniness	: class 0 (no stones)
Drainage	: imperfectly drained, part of the year water-logged

Moistness : topsoil and subsoil moist
Biology : rootdevelopment up to 80 cm., mainly in the upper 60 cm.
Land use : grassland

Soil profile:

A11 0 - 25 cm. - Black (5 YR 2/1) moist; very fine clay; weak very fine subangular blocky and fine crumbs; many very fine biopores; slightly sticky and slightly plastic; clear and smooth boundary.

A12 25 - 58 cm. - Very dark grey(5 YR 2.5/1) moist; very fine clay; weak to moderate very fine subangular blocky; many very fine biopores; slightly sticky and slightly plastic; many fine manganese concretions with iron-oxide skins (red or yellow)

B21g 58 - 84 cm. - Dark greyish brown(10 YR 4/2) moist; very fine clay; weak very fine to fine angular to subangular blocky; continuous moderately thick clay cutans; many very fine biopores; slightly sticky and slightly plastic; few to many small black manganese concretions slightly cemented by iron-oxides (yellow); many strong brown mottles.

B22g 84 - 100 cm. - Dark gray (10 YR 4/1) moist; very fine clay; weak very fine to fine angular to subangular blocky; many very fine biopores; very many (60%) manganese-iron concretions, 10 mm large, cemented; few, strong brown mottles; ~~clear~~ smooth and smooth boundary; continuous clay cutans.

B23g 100 - 130 cm. - Dark gray (10 YR 4/1) moist; very fine clay; moderate fine angular blocky; many very fine biopores; slightly sticky and slightly plastic ;very few manganese-iron concretions; many yellowish red (5 YR 5/8) mottles; 0-5% stones, non-weathered, rounded, Kavirondian.

B31 130+ cm. - Gray(10 YR 5/1) moist; very fine clay; weak fine angular blocky; common very fine biopores; stainlike, about 5% of the ped surface black mottles.

remarks: abrupt texture increase at 100 cm. depth.

Profile no.: 502 Keberi series (KbA)

Classification: 7th Approximation - Histic Tropaquept

Majoge, Keberi near Sameta, 9914.00 N - 592.65 E.
Altitude: 5310 ft.

(R. Henneman, S. Kauffman, 25-3-1974)

Geomorphology : broad valley bottom
Parent material : alluvial deposit
Relief and slope : flat releif and slope class 1 (level)
Stoniness : class 0 (no stones)
Drainage : poorly drained, part of the year water looged, water table 140 cm.
Moistness : topsoil and subsoil moist
Biology : root distribution mainly in the first 40 cm.
Land use : natural grassland

Soil profile:

O 0 - 15 cm. - Black (7.5 YR 2/0) moist; peat, more than 50 % organic matter; weak fine crumbs, abrupt and smooth boundary.

A 15 - 38 cm. - Dark gray (5 YR 3.5/1) moist; very fine clay; moderately medium prismatic and weak very fine subangular blocky; many very fine and common fine biopores; many fine distinct red mottles; clear and smooth boundary

Cg 38 - 94 cm. - Dark gray (5 YR 4.5/1) moist; very fine clay; moderate to strong subangular blocky, coarse; many very fine and common fine biopores; common very fine distinct red mottles (root-rust); clear and smooth boundary.

CG 94 -140 cm. - Gray (7.5 YR 5/0) moist; very fine clay; weak fine angular blocky; few fine distinct red mottles.

remarks: abrupt texture increase at 38 cm.

Profile no.: 503 Chang'aa series -(ChB)

Classification: 7 th Approximation 1970 - Humoxic Palehumults

Kisii West, West Kitutu, Nyakobari, 9929.75 N,694.00 E,
Altitude 1570 m.
(G.R. Henneman, 30-4-1974)

Geomorphology : lower footslope of steep hill
Parent material : non-porphyritic basalt
Relief and slope : normal relief and slope class 3 (sloping)
Stoniness : class 0 (no stones)
Drainage : well drained
Moistness : topsoil and subsoil moist
Biology : root-development more than 1.70 m., mainly in the upper 25 cm.
Land use : natural grassland

Soil profile:

profile no.: 503 (continuation)

A 0 - 16 cm. - Dark reddish brown (5 YR 3/2½, moist); very fine clay; weak very fine and fine crumbs; very many very fine biopores; clear smooth boundary.

B1 16 - 40 cm. - Dark reddish brown (5 YR 3/4½, moist); very fine clay; weak to moderate subangular blocky ; very many very fine biopores; continuous thin to moderately thin humus-clay cutans; common, spherical termite holes, Ø 2 cm.

B21 40 - 95 cm. - Dark red (2.5 YR 3/6½, moist); very fine clay; moderate to strong, very fine to fine, subangular to angular blocky; many very fine and common fine biopores; continuous and thick clay cutans.

B22 95 - 130 cm. - Dark red (2.5 YR 3/6½, moist); very fine clay; strong, very fine to fine, angular blocky; many very fine and common fine biopores; continuous and thick clay cutans.

Profile no.: 504 Gucha series -(GuB)

Classification: 7 th Approximation 1970: Humoxic Tropohumults

Kisii West, Nyakobari,
Altitude 1,595 m.
(G.R.Henneman, 30-4-1974)

Geomorphology : steep upper slope of hill
Parent material : non-porphyritic basalt, gravels, colluvium
Relief and slope : normal relief and slope class 5 (steep)
Stoniness : 0-5% gravels
Drainage : well drained
Moistness : topsoil and subsoil moist
Biology : root-development to a depth of 1 m., mainly in the upper 20 cm.
Land-use : natural grassland

Soil profile:

A 0 - 22 cm. - Dark reddish brown (5 YR 3/2½, moist); very fine clay; weak fine crumbs; very many, very fine biopores; clear and smooth boundary.

B1 22 - 55 cm. - Reddish brown (5 YR 3.5/4½, moist); very fine clay;moderate very fine subangular and angular blocky;broken and thin humus-clay cutans; very few to few rounded, weathered gravels of basalt and fresh quartzite gravels; very many, very fine biopores.

B2 55 - 134 cm. - Yellowish red (5 YR 4/8, moist); very fine clay; moderate to strong very fine to fine angular blocky; many very fine and common fine biopores; moderately thin, broken or continuous clay cutans; many angular gravels and stones of fresh quartz and few rounded gravels and stones of weathered basalt, occuring in layers - outside the gravel layers many strongly weathered gravels, stones and boulders of basalt.

B3 134 - 180 cm. - Soft rotten rock, light red (2.5 YR 6/8) and reddish yellow (7.5 YR 6/6, moist); broken thin clay cutans.

Profile no.: 505 Marongo I series - MaQ

Kisii West, South Mugirango, Itumbi hill
Altitude:
(S. Kauffman, 29-4-1974)

Classification: 7th Approximation 1970 - Ruptic Lithic Oxic Humitropeptic Troporthent

Geomorphology : uniform upper slope of steep hill
Parent material: colluvium of quartzites and basalts mixed with some soap-stone, overlying non-porphyritic basalt
Relief and slope: excessive relief and slope class 5 (steep, 42 %)
Stoniness : 50 % gravels
Drainage : somewhat excessive drained
Moistness : topsoil and subsoil moist
Biology : root-development to a depth of 1.20 m., mainly in the upper 30 cm.
Land use : fallow grassland

Soil profile:

A11 0 - 10 cm. - Very dark brown (10 YR 2/2) moist; very fine clay; weak very fine crumbs and subangular blocky; many very fine and fine biopores; slightly sticky and slightly plastic; 15 % gravel and stones, quartzites with some basalts and soap-stone, fresh and weathered; smooth and clear boundary;

A12 10 - 45 cm. - Very dark grayish brown (10 YR 3/2) moist; very fine clay; weak very fine subangular blocky; many very fine biopores; slightly sticky and slightly plastic; 50 % gravels and 20 % stones, quartzites with some basalt and soap-stone, fresh and weathered; gradual and smooth boundary;

Profile no.: 505 (continued)

A3 45 - 75 cm. - Dark reddish brown (5 YR 4/6) moist; very fine clay; 50 % gravels and 30 % stones, quartzites with some basalt and soapstones, fresh and weathered; weak very fine sub-angular blocky; gradual and smooth boundary.

B21 75 - 120 cm. - Yellowish red (5 YR 4/6) moist; very fine clay; 40 % gravels and 30 % stones, basalt with some quartzites, weathering colours: red and strong brown; weak very fine sub-angular blocky; patchy and thin clay cutans; gradual and wavy boundary.

B22 120 - 170+ cm. - Dark red (2.5 YR 3/6) moist; very fine clay; more than 70 % rotten rock of basalt, soft, weathering colours red and strong brown; patchy to broken thin clay cutans.

Profile no.: 506 Nyokal series - NyR

Kisii-West - Wanjare, near Gasero along the Tanzania road
Altitude: 1440 m.
Coordinates: 9923.30 N, 686.75 E.
(S. Kauffman, G.R. Henneman, 8-5-'74)

Classification: 7th Approximation - Humoxic Palehumult

Geomorphology	:on low flat-topped hill (NhR, KsR)
Parent material	: rhyolite (Nyanzian)
Relief and slope	: normal, gently undulating
Stoniness	: class 0 (no stones)
Drainage	: well drained
Moistness	: topsoil and subsoil moist
Biology	: root-development to a depth of 130 cm. mainly in the upper 20 cm.
Landuse	: maize

Soil profile:

Ap 0 - 15 cm. Dark reddish brown (5 YR 3/3, moist); very fine clay; weak fine to very fine crumbs; many fine and very fine biopores; slightly sticky and slightly plastic; boundary clear and smooth.

B 21 15 - 80 cm. Dark reddish brown (5 YR 3/4, moist); very fine clay; weak to moderate very fine sub-angular blocky; many fine and very fine biopores; slightly sticky and slightly plastic; many spherical termite holes, Ø= 6 cm.; moderate thick broken clay cutans; boundary clear and gradual.

B22 80 - 135 cm. Dark red (2.5 YR 3/6, moist); very fine clay; weak to moderate fine to very fine subangular blocky; many very fine biopores; thin broken clay cutans; boundary clear and smooth.

B23 135 - 175 cm. Dark red (2.5 YR 3/6, moist); very fine clay; moderately thick continuous clay cutans; many spherical black manganese concretions, non-cemented.

Remarks: depth of pit 175 cm.

Profile no.: 507 Nyangori series - NyQ

Kisii West, Kitutu, Manga ridge (near Esaba)
Altitude: 1870 m.
Coordinates: 9928,40 N, 701.30 E
(S.Kauffman, G.R.Hennemann, 8-5-1974)

Classification: 7th Approximation - Humic Paleudults

Geomorphology : plateau on long quartzite ridge (MpQ)
Parent material : quartzite (Bukoban)
Relief and slope : normal and sloping
Stoniness : class 0 (no stones)
Drainage : well drained
Moistness : topsoil and subsoil moist
Biology : root development to a depth of 1.60 m. mainly in the upper 0.25 m.
Landuse : natural pasture

Soil profile

A1 0 - 10 cm / Dark reddish brown (2.5 YR 3/4, moist); very fine clay; moderatel weak very fine subangular blocky; many very fine and few fine biopores; slightly sticky and slightly plastic; Thin broken humus- and clay-cutans; boundary clear and smooth.

B21 18 - 70 cm / - Dark red (2.5 YR 3/6, moist); very fine clay; moderate fine to very fine subangular blocky; many very fine biopores; thin broken and continuous clay cutans; slightly sticky and slightly platic; boundary diffuse and smooth.

B22 70 - 160 cm / - Dark red (2.5 YR 3/6, moist); very fine clay; moderately weak to weak very fine subangular blocky; common to many very fine biopores; slightly sticky and slightly plastic; thin broken and continuous clay cutans.

Remarks: depth of pit 1.60 m. and depth of bedrock 2.50 m.

Profile no.: 508 Maraba series - MaA

Kisii West, Bomachoge, near Sengera
Altitude: 1713 m.
Coordinates: 9904.02 N, 690.00E.
G.R.Hennemann, 10-5-1974

Classification: 7 th Approximation: Fluventic Tropaquept

Geomorphology	: nearly level alluvial valley-bottom (RvA)
Parent material	: alluvium
Relief and slope	: flat or concave, level to gently undulating
Stoniness	: class 0 (no stones)
Drainage	: imperfectly drained
Moistness	: topsoil and subsoil moist
Biology	: root development to a depth of 0.60 m. mainly in the upper 0.15 m.
Landuse	: natural pasture

Soil profile

A 0 - 6 cm. - Black (5 YR 2/1, moist); very fine clay; weak very fine crumbs; many very fine and few fine biopores; slightly sticky and slightly plastic; boundary clear and smooth

B1g 6 - 30 cm. - Very dark gray (5 YR3/1, moist); very fine clay; weak to moderate very fine angular to subangular blocky; many very fine and few fine biopores;thin broken clay cutans; common to many clear medium dark reddish brown mottles (rootrust); slightly sticky and slightly plastic;boundary clear and smooth

B21g 30 - 43 cm. - Very dark gray (5 YR 3/1, moist); very fine clay; moderate fine to very fine angular blocky; common very fine biopores; moderately thick continuous clay cutans;common clear fine to medium yellow mottles; slightly sticky and slightly plastic; boundary clear and smooth

B22g 43 - 65+cm. - Very dark gray(5 YR3/1, moist); very fine clay; strong fine angular blocky; few very fine biopores;slightly sticky and slightly plastic; moderately thick to thick continuous clay cutans; few to common fine to medium clear yellow mottles.

Remarks: the watertable was present at a depth of 0.30 m., it has been lowered to 0.65 m. to make description of the pit possible.

there is a sharp increase in clay content from the B1g to the B21g-horizon, although both horizons have a texture of very fine clay.

Profile no.: 509 Nyaborumbasi - NbB

Kisii West, Bomachoge, eastly of Ibencho hill
Altitude; 1725 m.
Coordinates: 9919.05 N, 684.30 E
S. Kauffman, 10-5-1974

Classification: 7 th Approximation: Pachic Humoxic Palehumult

Geomorphology : convex upper-slope of low smooth hill (RhB)
Parent material : non-porphyritic basalt (Bukoban)
Relief and slope : normal, strongly sloping
Stoniness : class 0 (no stones)
Drainage : well drained
Moistness ; topsoil and subsoil moist
Biology : root development to a depth of 1.60 m. mainly in the upper 0.30 m.
Land use : maize

Soil profile

Ap 0 - 18 cm. - Dark reddish brown (5 YR 3/2, moist); very fine clay; weak to moderately weak fine crumbs; common fine and many very fine biopores; slightly sticky and slightly plastic; boundary clear and wavy

A3 18 - 42 cm. - Dark reddish brown (5 YR 3/3, moist); very fine clay; moderate fine to very fine angular to subangular blocky; common fine and many very fine biopores; slightly sticky and slightly plastic; few spherical flat-bottommed krotvinas, Ø = 15 cm.; boundary clear and broken

B1 42 - 64 cm. - Dark reddish brown (5 YR 3/4, moist); very fine clay; moderate fine to very fine angular to subangular blocky; common fine and many very fine biopores; slightly sticky and slightly plastic; moderately thick continuous clay- and humus cutans; few spherical termite-holes, Ø = 2 cm.; boundary clear and smooth

B2 64 - 160 cm. - Dark red (2.5 YR 3/6, moist); very fine clay ; moderate to strong very fine angular blocky; common fine and many very fine biopores; slightly sticky and slightly plastic; thick continuous clay and humus cutans.

Remarks: B2-horizon extends to a depth of 2.40 m. (augering)

Profile no.: 510 Riteke series - RiF

Kisii West, Bomachoge, Ibencho Hill near Riteke school
Altitude: 1840 m.
Coordinates: 9904.10 N, 688.20 E
(S. Kauffman, G.R. Hennemann, 10-5-1974)

Classification: 7 th Approximation: Typic Rhodudult

Geomorphology : irregular upper-footslope (MfiB)
Parent material : felsite (Bukoban)
Relief and slope : excessive, steep
Stoniness : class 0 (no stones)
Drainage : well drained
Moistness : topsoil and subsoil moist
Biology : root development to a depth of 130 cm. mainly in the upper 30 cm.
Land use : natural pasture and shrubs

Soil profile

A 0 - 18 cm. - Da rk yellowish red (5 YR 3/6½, moist); very fine clay; moderately weak very fine subangular blocky; many very fine biopores; slightly sticky and slightly plastic; few angular to rounded fresh and weathered gravels of felsite; boundary clear and wavy

B1 18 - 70 cm. - Reddish brown (5 YR 4/6½, moist); very fine clay ; weak very fine subangular blocky; common to many very fine biopores; slightly sticky and slightly plastic; thin broken clay cutans; many to very many angular and rounded fresh to weathered gravels of felsite; boundary clear and smooth

B2 70 - 105 cm. - Red (2.5 YR 4/6½, moist); very fine clay; weak very fine subangular blocky; many very fine biopores; moderately thick broken clay cutans; few gravels and many stones, angular to rounded of fresh or weathered felsite; boundary clear and wavy

B3 105 - 140+cm. - Red (2.5 YR 4-5/6½ moist); dominant strongly weathered rotten rock of felsite; multi-colored, reddish yellow or dark red.

Remarks: depth of the pit 140 cm.

Profile no.: 511 Kananga series - OmR

Kisii West, South Mugurango near Nyangwetta forest
Altitude: 1465 m.
(S. Kauffman, G.R. Henneman, 10-5-1974)
Coordinates: 9902.15 N, 683.25 E

Classification: 7 th Approximation : Ruptic Lithic Toporthentic
Oxic Humitropeptic Dystropept

Geomorphology : straight upper-slope (KoR)
Parent material : rhyolite (Nyanzian)
Relief and slope : excessive, steep
Stoniness : class 0 (no stones)
Drainage : somewhat excessively drained
Biology : root development to a depth of 100 cm.
mainly in the upper 40 cm.
Land use : natural pasture and shrubs

Soil profile

A 0 - 20 cm. - Dark brown (7.5 YR 3/2) moist; very fine clay; weak fine to very fine subangular blocky and crumbs; many very fine biopores; slightly sticky and slightly plastic; many fresh to weathered angular and rounded gravels of rhyolite; boundary clear and broken

A/R 20 - 70 cm. - Dark brown(7.5 YR 3/2) moist; very fine clay; weak very fine sub-angular blocky and crumbs; many very fine biopores; slightly sticky and slightly plastic; dominant weathered angular yellow or multi-coloured gravels and stones (rhyolite) passing into consolidated rotten rock; boundary gradual and wavy

R 70 - 135 cm. - Multi-coloured or yellowish brown weathered consolidated rock; schist-like structure.

Remarks: depth of pit 135 cm.

Profile no.: 512

Hydromorphic soil undifferentiated
Location: Kasipul, Mogumo
Coordinates: 9935.20 N., 687.90 E.
Elevation: 4700ft.

Classification: Soil Taxonomy 1970: Tropaquept
F.A.O. 1970 : Gleysol

Described by D. van Mourik on 27-3-1974

Geomorphological position : level uniform broad valleybottom

Parent material : Wanjare Granite

Level slope in hilly landscape with subnormal relief

No stones with few erosion rills and imperfectly drained

Surface soil moist and subsoil wet

No krotovinas and depth of undisturbed soil 90 cm.

Land use : poor range

Soil profile :

A1 0- 40 cm. Black (5 YR 2/1) moist, clay; moderate fine subangular blocky; common very fine, common fine and few medium biopores; moist, firm, slightly sticky and slightly plastic; few, fine, faint, diffuse, strong brown mottles; clear, wavy boundary

Cg 40- 98 cm. Black to dark reddish brown (5 YR 2/1.5) moist, fine clay; moderate medium prismatic; few very fine, few fine and few medium biopores; moist very firm, non sticky and plastic; many, medium, distinct, clear, strong brown mottles; gradual, smooth boundary

CG 98-145 cm. Grayish brown (10 YR 5/2) moist, fine clay; massive; few fine, few medium biopores; non sticky and plastic; few, faint, fine, diffuse, black and yellow mottles; clear, irregular, boundary; sligh ly gravelly

C 145- cm. Yellow (5 Y 7/6) massive, rotten rock; many medium, faint, diffuse, black mottles.

Profile no.: 513 Otula series

Location : North Nyokal., South-Nyanza

Coordinates : 9935.65 N., 682.75 E.

Elevation: 4800 ft.

Classification: Soil Taxonomy 1970 : Fine clayey skeletal acid isothermic Flavic Rhodudult

F.A.O. 1970 : Humic acrisol

Described by van Mourik on 27-3-1974

Geomorfological position : convex upper slope

Parent material : Wanjare Granite

Sloping slopes in rolling to hilly landscape of ridged interfluves with normal relief

Stony with shallow gullies and moderately well drained

Surface and subsoil moist after showers on the previous day

Few krotovinas and depth of undisturbed soil 108 cm.

Few roots mainly at a depth of 30 cm.

Land use : fallow and cassave

Soil profile :

A1 0- 20 cm. Dark reddish brown (5 YR 2/2) moist, clay; weak fine subangular blocky; common very fine, common fine and few medium biopores; moist friable , slightly sticky and slightly plastic; few, fine, faint, diffuse yellowish red rust mottles; slightly gravelly; smooth, clear boundary

B2' 20- 56 cm. Dark reddish brown (5 YR 3/4) moist, clay; weak fine subangular blocky; common very fine, common fine and few medium biopores; moist friable, slightly sticky and slightly plastic; few, small, soft, spherical, black, iron-manganese nodules; broken, moderately ,thick, probably humus-clay cutans; slightly gravelly; smooth, clear boundary

B3 56-108 cm. Yellowish red (5 YR 4/6) moist, sandy clay; weak fine subangular blocky; few fine, few medium biopores; moist friable, slightly sticky and

no.: 513 (continued)

slightly plastic; very many, large, hard, spherical, black, ironstone nodules; common, medium, faint, clear, reddish yellow mottles; slightly gravelly; abrupt,irregular boundary

R 108- cm. Dark reddish brown, reddish yellow and pink Wanjare Granite

Profile no. : 514 Magina series

Location : North-Nyokal, South-Nyanza

Coordinates : 9936.20 N., 680.40 E.

Elevation : 4700 ft.

Classification : Soil Taxonomy : Fine clayey skeletal acid isothermic Flavic Rhodudult

1 70

F.A.O. 1970 : Humic Acrisol

Described by van Mourik on 27-3-1974

Geomorfological position: convex slope, middle position

Parent material: Wanjare Granite

Sloping slope in hilly to rolling landscape of ridges with normal relief

Fairly stony with few erosion rills, shallow gullies and well drained

Surface and subsoil moist after some showers

Few krotvinas and undisturbed soil deeper than 110 cm.

Many roots, mainly at a depth of 30 cm.

Landuse : poor range

Soilprofile :

no.: 514 (continued)

A1	0- 35 cm.	Dark reddish brown (5 YR 2/2) moist, sandy clay; weak fine angular blocky; common very fine, common fine, and few medium biopores; moist friable, slightly sticky and slightly plastic; slightly stony,and gravelly; clear, wavy boundary
B2	35- 70 cm.	Yellowish red (5 YR 4/6) moist, sandy clay; moderately sub-angular blocky; common very fine and few fine biopores; common,medium, prominent, sharp, black mottles; thin, patchy clay cutans; gravelly; clear, irregular boundary
B3	70-110 cm.	Reddish yellow (5 YR 6/8) moist, sandy clay; weak, fine, angular blocky; few very fine and few fine biopores; moist friable, slightly sticky and slightly plastic; many, large, soft, spherical, black, iron-stone nodules and common, medium, distinct, clear, dark yellowish brown mottles and few, medium, distinct, clear, reddish yellow mottles ; slightly gravelly; clear, wavy boundary
C	110- cm.	Continuous, vesicular pan of indurated plinthite.

APPENDIX II

Distribution of the soil series in the soil associations of the Marongo area (%)

	KsB	KmB	KdB	KoB	KdR	MpF	MeQ	MfiB	MfB	NR	NG
NbB	29	19	3	-	-	-	-	4	18	-	-
ChB	27	40	11	-	-	-	-	9	19	-	-
IkB	4	3	1	-	-	-	-	1	-	-	-
MmB	4	9	11	-	-	-	-	9	2	-	-
GcB	8	10	29	-	-	-	-	6	2	-	-
MgB	3	4	7	72	3	-	5	21	-	-	-
OgB	1	3	27	28	1	-	6	13	1	-	-
MrQ	-	-	-	-	-	-	-	-	-	-	-
MnQ	7	-	-	-	-	5	-	1	27	-	1
KbQ	3	-	-	-	-	8	4	3	3	-	1
ItQ	4	-	-	-	-	3	4	-	7	-	1
MnQ	3	-	2	-	-	2	78	21	17	-	1
NkF	-	-	-	-	-	71	-	-	-	-	-
SkF	-	-	-	-	-	19	-	-	-	-	-
GsF	-	-	-	-	-	10	1	-	-	-	-
KtR	-	-	-	+	1	-	-	-	-	2	-
NkR	3	-	-	-	1	-	-	-	-	11	-
NdR	-	-	-	-	2	-	-	-	-	7	-
NrR	-	-	-	-	10	-	-	-	-	26	-
KnR	4	4	-	-	74	-	-	4	-	32	-
RkR	-	-	-	-	9	-	-	-	-	-	-
NsG	1	-	-	-	-	-	-	-	-	-	19
NdG	-	-	-	-	-	-	-	-	-	-	15
PlG	-	-	-	-	-	-	-	-	-	-	18
RnL	-	-	-	-	-	-	-	-	-	-	21
RsL	-	-	-	-	-	-	-	-	-	-	18
DlA	-	4	6	-	-	-	-	-	-	11	1
MrA	-	-	-	-	-	2	-	-	-	3	3
Av	-	4	11	-	7	1	2	6	3	-	-