TRAINING PROJECT IN PEDOLOGY

KISII KENYA

Detailed Soil Survey of the Irigonga area

PRELIMINARY REPORT NO 2

ULTURAL UNIVERSITY

NINGEN - THE NETHERLANDS

DETAILED SOIL SURVEY OF THE IRIGONGA AREA

by D. van Mourik

Preliminary Report nr. 2
December 1974

TRAINING PROJECT IN PEDOLOGY, KISII KENYA.

Agricultural University, Wageningen - The Netherlands.

Contents

Preface

This report of the Training Project in Pedology at Kisii, Kenya, of the Section on Tropical Soil Science of the Agricultural University at Wageningen, The Netherlands, is the second one of a series to be presented to Kenyan officials.

The project started in November 1973 after assent had been granted by the Office of the President of Kenya. It is meant for training of post-graduate students of the Agricultural University at Wageningen and for furnishing research opportunities of the staff. The activities of students and staff are directed to obtaining a better knowledge of the soils and the agricultural conditions of the project area to provide a basis for the further agricultural development of the area.
The project in Kisii is conducted by:
Ir. W.G. Wielemaker, teaching and research
Ing. H.W. Boxem , management.
Visiting specialists from the Agricultural University at Wageningen help to resolve special problems.

This report has been written by Mr. D. van Mourik, who was a paticipating student from 30/12/73 upto 30/6/74.
Mr. H.L.M. van Wissen who participated from 16/12/73 upto 30/4/74, wrote the part about landuse and vegetation.
Ing. H.W. Boxem compiled the report into this presentation.

We do hope to pay back with these reports a small part of the great debt we owe to Kenya in general and to many Kenyans in particular for their valuable contributions to the good fuhctioning of the project.

The supervisor of the project
J. Bennema, Professor of Tropical Soil Science

1. Introduction and acknowledgements

The fieldwork for the soil survey of the Irigonga area was carried out in Januaru and February 1974 in the Kisii District in South West Kenya. This survey is the result of co-operation of two-gradute students of the Agricultural University at Wageningen: Mr. D. van Mourik (fieldwork and writer of this report) and Mr. H.L.M. van Wissen (fieldwork and wirter of chapter "Landuse and Vegetation").
The report is edited by Ing. H.W. Boxem and compiled to this presentation.
The surveyors are greatly indebted to the Kenyan authorities, farmers in the surveyed area and assistants and labourers of the Training Project in Pedology at Kisii.
Moreover they wish to express their thanks towards the staff of the forementioned project for their advise and help.

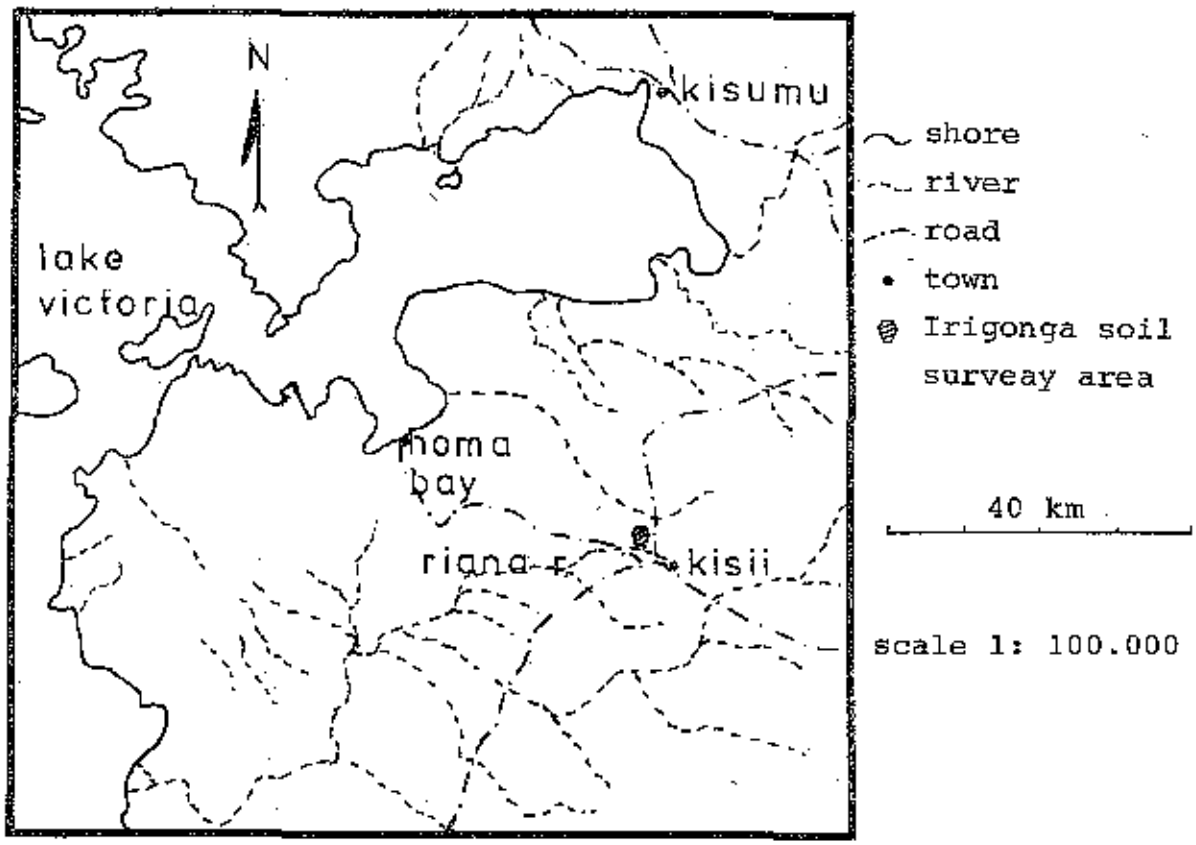


Fig. 1. Location of the Irigonga detailed soil survey area

1.2. Location and Climate

The surveyed area is located between latitudes 0°36' S and 0°39' S and between longitudes 34°43' E. It covers a nearly square area of about 2100 acre (1500 ha) north of the Riana River around Irigonga School (location: Wanjare, district: Kisii, province: Nyanza). Roughly it is situated 60 km. south of Kisumu and 80 km west of Lake Victoria (see. Fig. 1; page 3).

The elevation of the area is between 4800 ft. and 5500 ft. (1440 m and 1650 m.)

The climate according to Koppen-Geiger is an "Aw-climate". The rainfall is bimodal, with the main rainfall peak in April and May (average of 280 and 210 mm. respectively). January and February are the driest months (average of 55 and 70 mm. respectively). The rainfall pattern for the whole year calculated according to the amount of rainfall that is not reached every one in four years is presented in Fig. 2. The total average rainfall is 1675 mm. per year (minimum 1250 mm. and maximum 2000 mm. per year over a period of 30 years).

The temperature is 13° C (annual minimum average) and 26°C (annual maximum average). The monthly temperature averages vary less than one degree during the year.

Table 1: Approximate waterbalance for a moderately deep soil

Approximate Waterbalance (soil depth 50 to 120 cm. and 18% ready available moisture resulting in storagecapacity of 150 mm)

Month:	J	F	M	A	M	J	J	A	S	O	N	D	TOTAL
Average rainfall mm.	75	75	150	250	225	175	100	175	175	125	150	125	AVERAGE 1800
E_p mm.	175	175	175	150	150	150	150	165	175	175	150	160	1945
Change mm	-100	-100	-25	+ 100	+ 75	+ 25	- 50	+ 10	0	- 50	0	- 35	
Storage mm	0	0	0	100	150	150	100	110	110	60	60	25	

It proves that a moderately deep soil has a waterdeficit in Jan. February and March. A shallow soil (soildepth less than 50 cm.) has a waterdeficit in October also, due to a smaller storage-capacity.

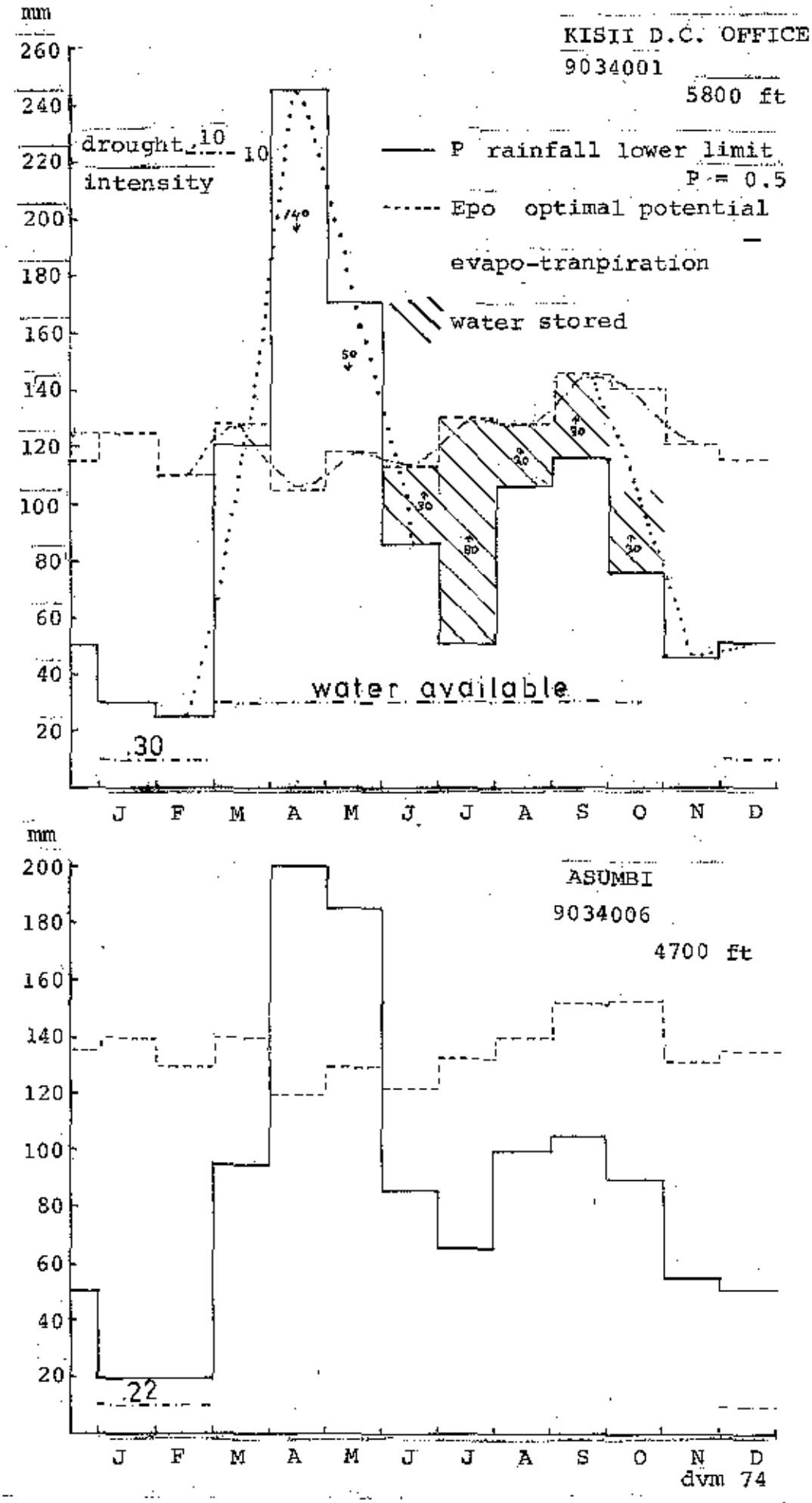
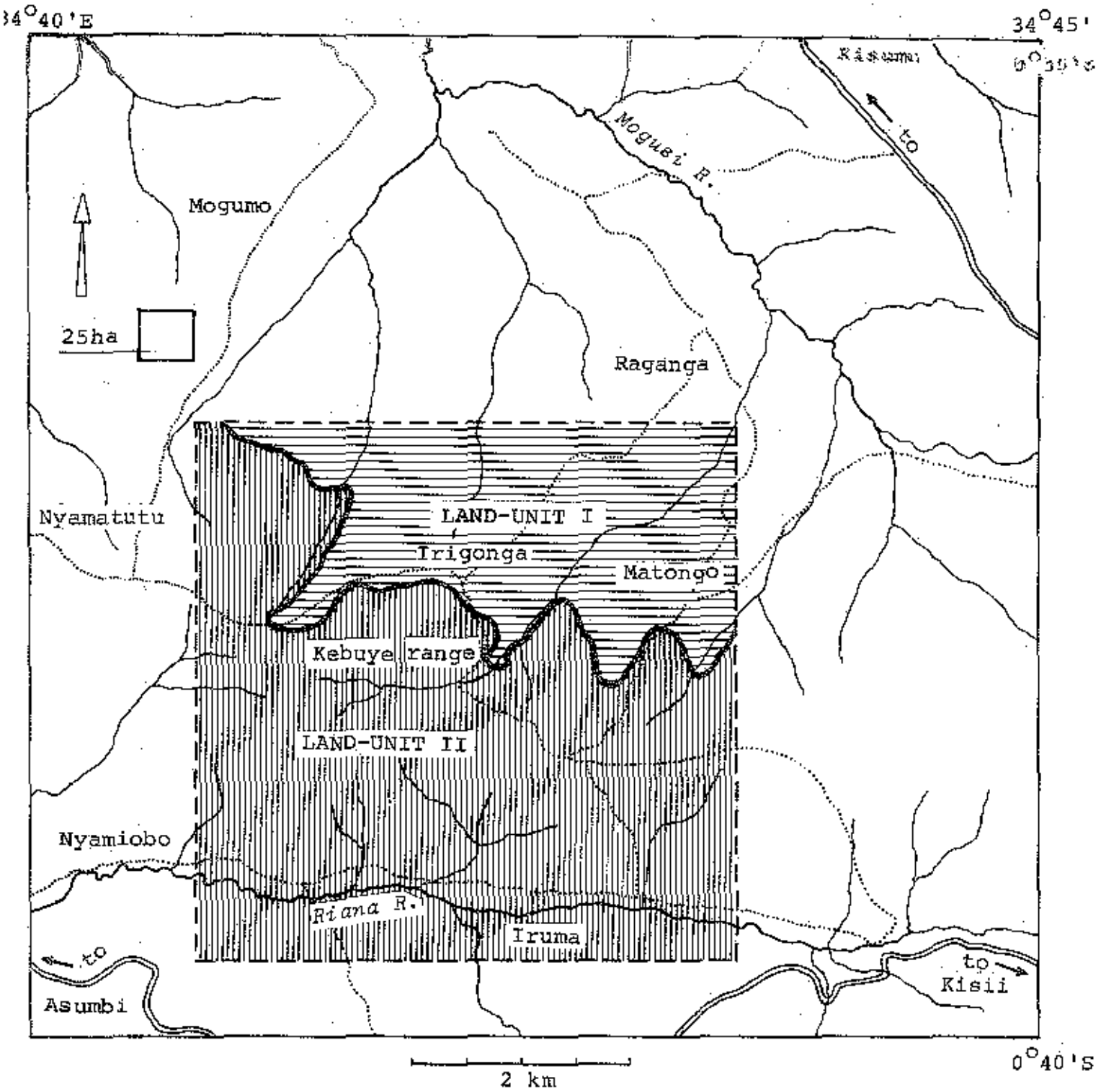


Fig. 2. Availability of water periods (Thornthwaite, mod.)



Legend

- boundary of the detailed Soil Survey of the Irigonga area '74
- land unit boundary (see 1-2)
- river
- primary road
- motorable track (dirt road)
- rural centre (market)

Fig. 3. Physiographic map of land units

1.3. Physiography and Parentmaterial:

The physiographic division of the land in the detailed soil survey consists of two units (Fig. 3).

Landunit I (Fig. 4) consists of rolling to undulating ridges with occasionally an outcrop at the top. The gullies between the ridges or interfluves have small (about 50 m wide) flat hydromorfic valleybottoms. The landunit has mainly moderately deep and deep soils (deeper than 1.20 m) as presented in Fig. 4. The elevation differences between summit of the ridges and the valleybottoms are restricted to 150 feet.

The summit of the ridges are flat to undulating and 200 to 500 m wide. Slopes are 100 to 500 m. long and sloping as presented in Fig. 4 and Fig. 6.

Landunit II consists of steep hills with rolling to hilly ridges. The gullies between the ridges and hills have small and steep valleybottoms. The summits of the hills and ridges consist of tors. Elevation differences between hills and ridges and valleybottoms are 350 to 500 feet. Slopes are 250 to 100 m. long and sloping (about 10%) to moderately steep (about 20%). The summits are undulating to steep and 25 to 50 m. wide as presented in Fig. 5. The landunit has shallow soils (less than 120 cm. deep) and gravelly soils (15 to 50% particles with size of largest dimension of 0.2 to 7.5 cm.).

Both the landunits are situated in the "Wanjare Granite" landscape. The landscape of Wanjare Granite landscape is developed in a highly leucocratic, usually coarse-grained and often porphyritic, pink or pale grey granite, which covers a roughly triangular area of some 50 square miles (15.000 ha.) west of Kisii, Upper Precambrian (Bukoban) invading Precambrian (Nyanzian and Kavirondian) rocks.

The Wanjare Granite landscape consist mainly of heapstructures of individual corestones or woolsacks. These are rounded boulders, which result from imperfect chemical weathering of jointed granite under warm and humid conditions. This corresponds with the lateral waterflow in the formation, which results in numerous wells and joints found in the profile description in the pits 111 and 117 in Appendix 4.

Within the landscape gravelly soils with abrupt horizon boundaries are found next to non-gravelly soils with gradual horizon boundaries Deep gravelly soils are found beside rock outcrops (isolated boulders, tors of woolsacks and massive scarcely jointed rock). This is the result of selective erosion. The smaller particles are removed first and the gravels stay behind.

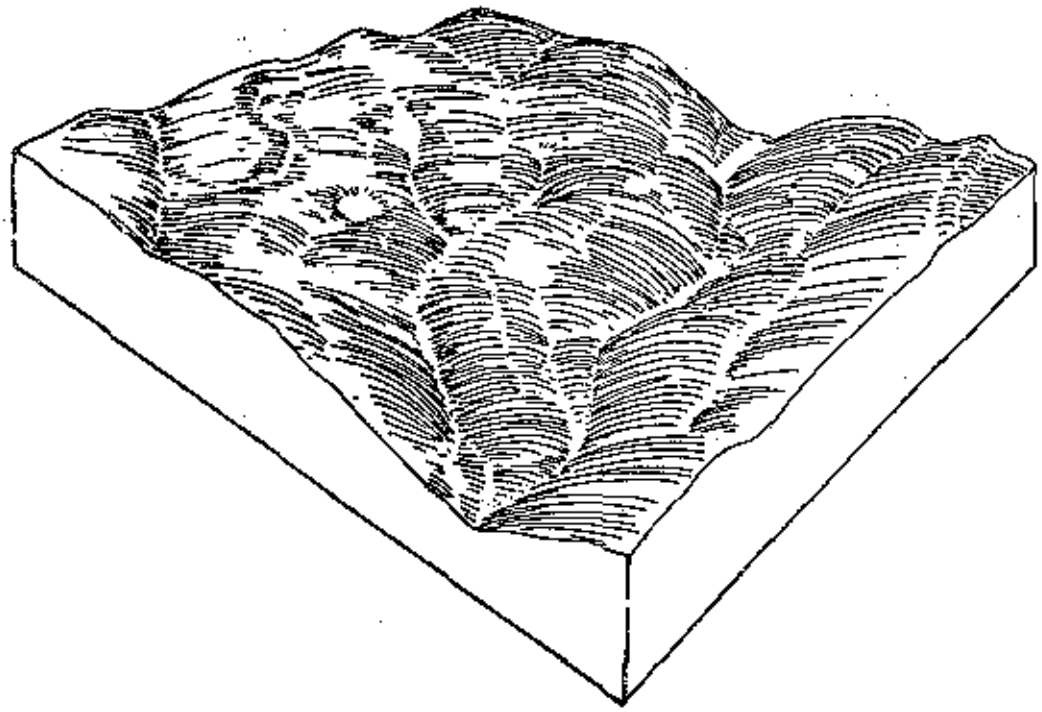


Fig. 4. Three dimensional diagram of land unit I.

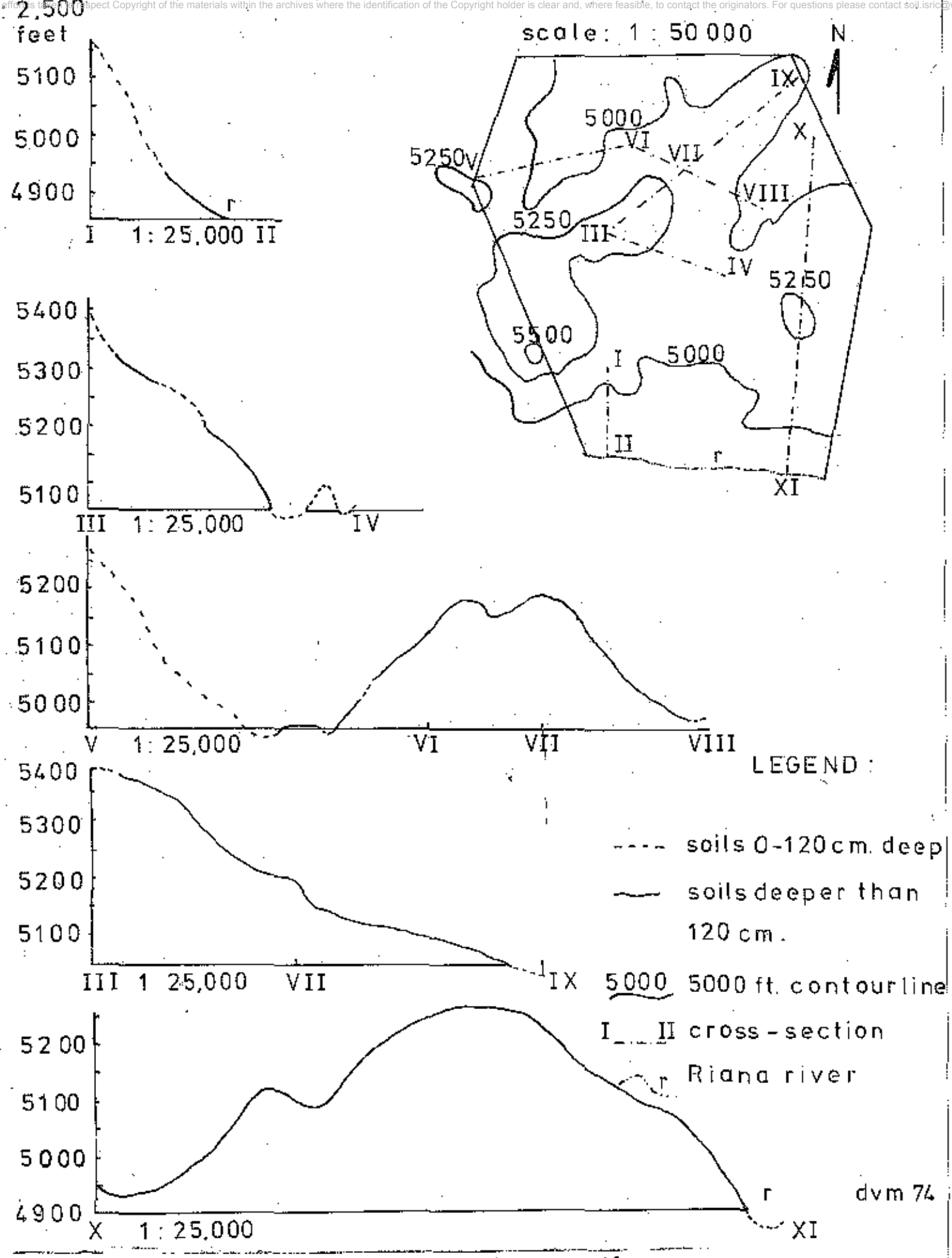
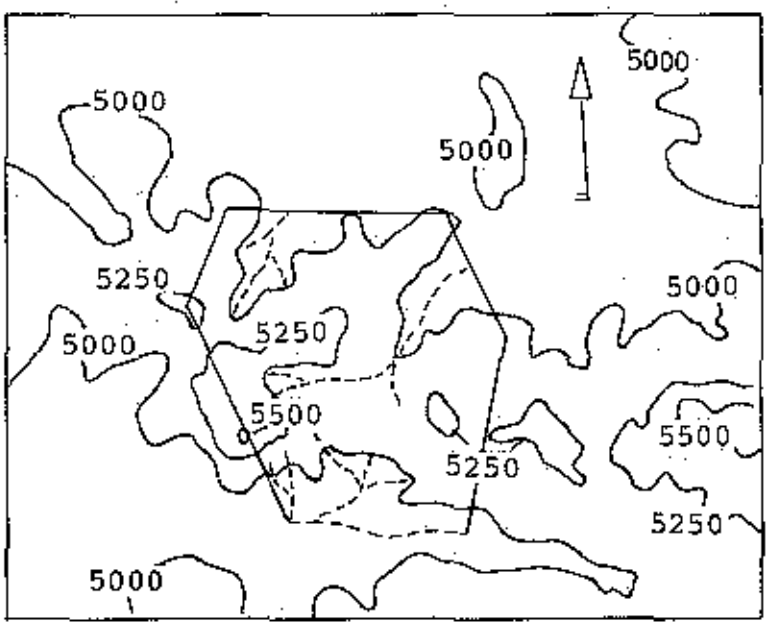


Fig. 5. Soil distribution and slopes, Irigonga soil survey



scale 1 : 100.000

5000 — 5000 ft. contourline

drainage pattern within the soil survey

boundary of the detailed soil survey of Irigonga area

Fig. 6. 250 ft. contourmap. Irigonga soil survey

1.4. Landuse and Vegetation (H.L.M. van Wissen)

Natural Vegetation and Ecology

The expanding cultivation in the Irigonga soil survey area, induced by the increasing population, has caused a complete disappearing of its original vegetation.
According to the vegetation map of Kenya sheet 3, we can divide the area in two vegetation zones:

a) The south-eastern part of the area belonging to the western forest (cultivated Albizia-Bridelia-Vernonia) zone.
b) The north-western part of the area belonging to the Combretum savanna zone (undifferentiated Combretum types including cultivated areas).

Ecologically most of the area is situated within the star grass zone, which is a zone of high potential with adequate rainfall, moderate temperatures and deep soils.

Landuse and Prevailing Farming System

The sample area has a population density between 300 and 350 persons per square Km. and because of this density the farms are rather small, about 1.7 ha. In general the holdings have the typical Kisii lay out:
the homestead, usually on the brow of a ridge and small strip of land running from the top of the ridge to the valley bottom below.
The homestead is usually sorrounded by bananas, cassave, sweet potatoes, maize, beans, passion fruits, pine-apples and tobacco. Near the homestead is normally a coffee plot with bananas as wind break. Between this coffee plot and the valley bottom we find the main strip of maize, groundnuts, sweet potatoes and beans alternating with pasture or fallow. In the valley bottom itself there are usually some bananas and sugarcane. The areas, which are not suitable for agriculture, are often used as communal grazing lands. The area has too much cattle for the relatively small amount of grazing land. This is mainly because cattle is still important for bride-wealth.
The work is divided traditionally according to age and sex;

uninitiated children herd the sheep and goats in the homestead areas, young men herd and raise the cattle, and the middle aged men and the women work in the fields.

Crops and Cropping System

Wimbi (Eleusine) and Sorghum were the most important crops. But their importance decreases sharply after the introduction of hybrid maize in 1964. Coffee is the main cash crop. The variety that is grown here is k7. The yield potential of this variety is not high and it is not resistent to coffee berry disease.

Other cash crops are groundnuts, bananas and passion fruits and especially the importance of the latter is increasing.

Table 2: Agricultural calender

Month	Season	Farm activities
Dec.	dry and hot	landpreparation for long rain
Jan.		crops; dry planting of wimbi;
		planting maize, millet,
Feb.		sorghum.
Mar.	long rains	planting maize, groundnuts,
		sweet potatoes, cabbage, etc.
Apr.	long rains	planting coffee, bananas,
		sugarcane, passion fruits;
May.		three weeks after planting
		weeding of long rain crops.
Jun.		beginning of picking of coffee.
Jul.	intermediate	picking of fly crop coffee;
		mulch coffee.
Aug.	intermediate	harvest long rain crops, starting
		with planting maize.
Sep.	short rains	planting and weeding of short
		rain crops
Oct.	short rains	initiation rituals.
Jan.-Dec. and May-Sep.		major coffee picking

(Data partly from the food research institute survey, preliminary report 2, 1969, Stamford University).

We can divide the crops which are cultivated in the area in food crops and cash crops. Maize is mainly grown as a subsistance crop, but is becoming more and more a cash crop.

The main food crops are: maize, wimbi, sorghum, sweet potatoes

and cassave. Although some of the farmers still grow the local varieties, the acreage is every year decreasing. At the moment about 85% of the farmers grows hybrid maize.
Local maize yield about 400 kg./ha. with a gross margin of Ksh 150/-. The yield of hybrid maize, depending on the husbandry, may go up as high as 2000 kg./ha. (two crops a year).

2. Survey Methods

The soil survey consists of photoanalysis and fieldwork.
With photoanalysis the two divisions of the area in physiographic landunits as presented in Fig. 3 is made. Every landunit represents a specific soilassociation (i.e. a group of defined and named taxonomic units of soil regularly geographically associated in a defined proportional pattern). The defined and named taxonomic soilunits in this study are soilseries (i.e. a group of soils having soil horizons similar in differentiating characteristics and arrangement in the soil profile, except for the texture of the surface soil and developed from a particular type of parentmaterial).
The pattern and properties of the soilseries are found with fieldwork. The soilseries are arranged and described in a legend and presented in table 4 and Fig. 7 in the next chapter.

The fieldwork consists of augering to 1.80 m. deep, where possible, every 200m. or less or more depending on the topography and its relation with the geographical soildistribution as presented in Fig. 4. The fieldwork is carried out in four weeks during the months of December 1973 and January and February 1974, which is the dry season of the area. The soilseries are discerned on base of kind, thickness and arrangement of soil horizons, depth and texture. In every soilseries two or more pits are dug to describe the properties and the range in characteristicts. For the description "Guidelines for soil description of the F.A.O. and the Soil Survey Manual" of the U.S.D.A. are used. The classification is done with the "Soil Taxonomy" of 1970 and the F.A.O. classification. Correlation of series with other soil surveys is done.
Samples are taken from the representative pits, taken from every horizon or from every 50 cm. for laboratory analysis (chemical and micro-morfological).

After the daily fieldwork the boundaries of the soilseries are plotted accurately on the photo with the aid of a stereoscope. These boundaries are transferred with a sketchmaster on a basemap at the end of all the fieldwork. The basemap is prepared with the 1: 12,500 aerial photographs, which are used during the survey, with the slotted template method.

The material, which is used during the survey consists of:

Edelman auger with extension piece to 2.20m.
Munsell colorbook
Topographic map 1:50.000 of the Survey of Kenya
Guidelines for Soil description of the F.A.O.
Soil Survey Manual of the U.S.D.A.
Soil knive
Soil hammer.
Compass
Aerial photographs 1:12,500
Abney level
Pocket altimeter
Mirror stereoscope, Topcon
Sketch-master, Keuffel and Esser

3.1. General Characteristics of the Soils

The soilassociation of landunit I consists of deep to very deep (more than 1.20 m. deep), red, fine clayey soils.
The solum is non-gravelly to slightly gravelly (to 15% particles larger than 2 mm.). The subsolum is gravelly and varies in depth between 20 cm. to deeper than 180 cm.
The A-horizon varies in humus content depending on the site and present landuse. The structure of the A-horizon is weak to moderate. The B-horizon has a moderate to strong structure and has a heavier texture than the A-horizon, but differences are within 10% clay at a total clay content of both horizons of 60%. The texture of the B-horizon is lighter if the solum is gravelly. Humus cutans and clay-humus cutans are found up to deep in the profile (broken to continuous till deeper than 180 cm.). The porosity is common (50 to 200 per square decimeter) up to about 125 cm. deep.

The soilassociation of landunit II consists of shallow to very deep (30 cm. to more than 180 cm. deep), red, gravelly (15 to 50% particles bigger than 2 mm.), loamy to clayey soils. The solum is gravelly from 0 cm. to deeper than 180 cm. The subsolum consists of C-material and its depth varies from 20 cm. deep to deeper than 180 cm. The A-horizon varies in humus content and has a weak structure. The B-horizon has a moderate structure. Humus cutans and humus-clay cutans are found to deeper than 180 cm. and in the C-material. The porosity is few to common till about 125 cm. deep.

Within the landunits on the valley-bottoms hydromorfic soils are found varying in depth and texture.

Table 3: Textural analysis of a gravelly soil (without destruction of the aggregates).

Particle size:	>2 mm.	<2mm particle size:	0.6-2 mm	0.6 mm
Depth 20-40cm:	60 % 40%	depth 20-40 :	66 %	34 %
90-100cm:	47 % 53%	90-100 :	66%	33 %

3.2. Classification

The soils are classified as Ultisols, because of the low saturation and Inceptisols because of the little horizon development.

Within the Ultisols are Humults and Udults depending on humus content. Within the Humults and Udults great groups of Palehumults or-udults are discerned besides Tropohumults and Rhodudults depending on depth of the clay-B. The Pale-great groups with a clay-B deeper than 150 cm. and the Tropo-and Rhodu-great groups with clay-B's less than 150 cm. deep. Within the great groups different subgroups are discerned:
Humoxic and Humic subgroups of the Pale-great groups depending on temperature and humus content, average temperature above 22°C or more than 12 Kg organic carbon in the upper 100 cm. respectively. The Rhodu-great groups are classified as Humoxic and Humic subgroups (see above) and as Typic sub-group, the central concept, and the Flavic sub-group, which has hues over 2.5 YR.

Within the order of the Inceptisols, two sub-orders are discerned: the Aquepts with hydromorfic properties in the upper 50 cm. and the Tropepts without hydromorfic properties in the upper 50 cm. but with an average temperature of more than 22°C.

These sub-orders are classified with the following great-groups: the Tropo-great group with average temperature of more than 22°C (only with the Aquepts), the Humi-great group with a specific organic carbon content and the Dystro-great group with a low base-saturation.

The F.A.O. classification classifies the soils as Nitosols, clay-B deeper than 150 cm. and Acrisols, soils with a clay-B and a low base-saturation.
Within the Nitosols are Distric Nitosols, with a low base-saturation and Humic Nitosols, with organic carbon in the topsoil. The Acrisols in the area are classified as Orthic Acrisols, which is the central concept and Humic Acrisols, with organic carbon in the topsoil.

Table 4 Descriptive Legend:

I Ultisols:

1)very deep (deeper than 180 cm) fine clayey Palehumults soil-series with or without Paleudults:

1.1	Humoxic Palehumults and Humic paleudults on:	
1.1.1.)	granite with non-gravelly solum	GL-F_o^x
1.1.2.)	Granite with gravelly solum	KmG

2)deep (between 120 and 180 cm. deep) fine clayey Palehumults and Tropohumults with or without Paleudults and Rhodudults:

2.1.	Humoxic Palehumults, Humoxic Tropohumults, Humic Paleudults and Flavic and/or Typic Rhodudults: with Typic and Flavic Rhodudults on:	
2.1.1.)	granite with non-gravelly solum	RaG
2.1.2.)	granite with gravelly solum	RiG

3)moderately deep (between 50 and 120 cm.) fine clayey Tropohumults and/or Rhodudults:

3.1.	Humoxic Tropohumults and Typic and/or Flavic Rhodudults: with Typic and Flavic Rhodudults on:	
3.1.1.)	granite with non-gravelly solum	MtG
3.1.2.)	granite with gravelly solum	IrG
3.1.3.)	granite and laterite with solum	Mls-AB**

4)shallow (less than 50 cm. deep) fine clayey Tropohumults and/or Rhodudults:

4.1.	Humoxic Tropohumults, Typic and Flavic Rhodudults on:	
4.1.1.)	granite with non-gravelly solum	KeG

4.1.2.) granite with gravelly solum MiG

4.1.3.) granite and laterite with gravelly solum MIs-AB**

11) Inceptisols complex:

1) very deep, deep, moderately deep and shallow Tropaquepts, Humitropepts, Dystropepts V

* series correlated with the Marongo Ridge detailed soil survey, Kisii 1974. (Preliminary report no. 3)

** series correlated with the soil survey of the East Konyango area, Directorate of overseas survey, 1961.

Explanation of the used symbols:

A	Umbric or Ochric epipedon
A gr	Gravelly Umbric or Ochric epipedon
B2	Fine clayey argillic-B horizon
B2 gr	Gravelly fine clayey argillic-B horizon
B2 gr(C)	Gravelly fine clayey argillic-B horizon with or without a C-horizon or rotten rock or jointed bedrock
B2	Argillic or cambic B-horizon
B2 gr	Gravelly argillic or cambic B-horizon
C	C-horizon or rotten rock or jointed bedrock

The mapping units of this soil survey, consisting of soilseries, are described shortly, for more detailed information a complete profiledescription of a representative pit for each soilseries with its range in characteristics is given in Appendix 4 at the end of the report.

NyG: Nyasoka series, dark reddish brown to red fine clayey, moderately to strongly structured, very deep (> 180 cm.) soils, derived from granite. The soils are well-drained, without stones, with moderate biological activity and are situated on slopes of 2 to 16%. (GL-F_o in Marongo Soil Survey).

RaG: Raganga series, dark reddish brown to red fine clayey, moderately to strongly structured, deep (120-180 cm.) soils, derived from granite. The soil beneath (> 120-180 cm.) consists of gravelly solum or rotten rock of Wanjare Granite. The soils are well-drained, without stones, with moderate biological activity and are situated on slopes of 2 to 16%.

MtG: Matongo series, dark reddish brown to dark red fine clayey, moderately to strongly structured, moderately deep (50-120 cm.) soils derived from granite. The soil beneath (50-120 cm.) consists of gravelly solum or rotten rock of Wanjare Granite. The soils are well-drained, without stones. They are situated on slopes of 8 to 20 %. The soils have a moderate biological activity.

KeG: Kebuye series, dark reddish brown fine clayey, weakly to moderately structured, shallow (0-50 cm.) soils, derived from granite. The soils underneath consists of gravelly solum or rotten rock of Wanjare granite. This soils are moderately well drained, without stones, with moderate biological activity and are situated on slopes of 2 to 20 %.

NmG: Nyamatutu series, dark reddish gray to red gravelly clayey, weakly to moderately structured, very deep soils (more than 180 cm deep) derived from granite. The soils are well drained, have stones which interefere with tillage, have a moderate biological activity and are situated on slopes of 8 to 30%.

RiG: Riana series, dark reddish brown to dark red gravelly clayey, weakly to moderately structured soils. The soils are deep 120-180 cm. and underlain by rotten rock of Wanjare granite.
The soils are well drained, have stones which interfere with tillage have a moderate biological activity and are situated on slopes of 8 to 30%.

IrG: Iruma series, weak red to dark red clayey, weakly to moderately structured soils. The soils are moderately deep (50-120 cm.) and underlain by rotten rock of Wanjare granite. The soils are well-drained, have stones which interfere with tillage, have a moderate biological activity and are situated on slopes of 8 to 30 %.

MiG: Matiti series, dark reddish gray to dark reddish brown gravelly clayey, weakly to moderately structured soils. The soils are shallow (0-50 cm) and underlain by rotten rock of Wanjare granite. The soils are well drained, have stones which interfere with tillage, have a moderate biological activity and are situated on slopes of 8 to 30%.

3.3 Legend of Soil Map and Description of Mapping Units

The legend of the soil map will be given in figure 7 with the diagnostic horizons of the F.A.O. 1970 classification. The series containing laterite are omitted because of the rare occurence within the surveyed area(< 1%). The complex of hydromorfic soils in the valley bottoms is not given, because in the survey no subdivision is made of the complex.

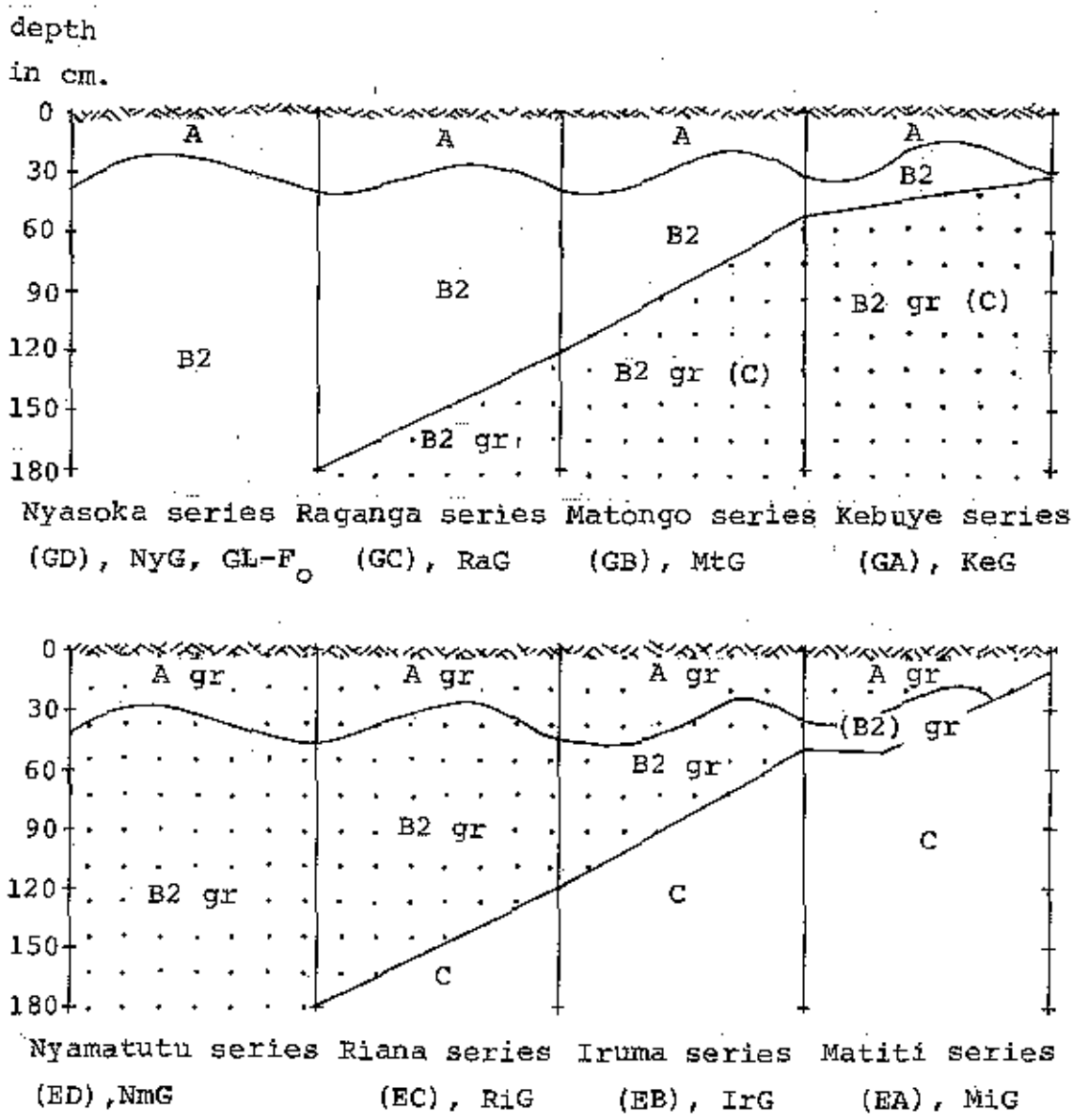


Fig. 7. Schematic legend for explanation of used symbols see next page.

V: Soils in this complex are geographically associated with the valley bottoms. The distribution of the soils is however so scattered at random that the geogr-phic distribution of the soils within the soilassociation is not described. (This unit can be described as an associated complex).
The soils are deep (180 cm.) wet soils with different textures.
On the slopes of the valleys immedistely next to the valley bottom (20 m. distance) shallow soils occur with wetness and shallowness.

4. Landevaluation

Introduction:

The landsuitability is evaluated on different scales dependent on the purpose of the evaluation:
a. for regional or national surveys at small scale (1:150,000)
b. for pre-investment surveys at medium large scale (1:75,000)
c. for feasibility studies at large scale (1:20,000).
The Irigonga soils survey is made at scale (1:12,500) and hence a feasibility study. A feasibility study requires much additional economical research and research in soilfertility, plantbreeding and ecology. On base of this reasearch, the survey area is divided in landdevelopment units. Each land development unit representing an ecological, or economical or administrative units.
Within a land development unit different soils or soilassociations occur.
The Irigonga soil survey is a part of one land development unit.
The landsuitability is evaluated in this study with the following steps:
a. the definition of landuse alternatives which are relevant in the specific land development unit on base of additional agricultural, economical and ecological research.
b. the landquality of relevant landcharacteristics of the tracts of land.
c. the determination of the improvement capacity.
d. the suitability classification
e. the estsblishment of management and improvement specifications.
The last step "the establishment of management and improvement especification", gives the information required for more thorough economical analysis and institutionn building.

The Definition of Landuse Alternatives:

A landuse alternative is a specific sub-division of a major kind of land use (e.g. grassland, irrigated agriculture, rainfed agriculture, forestry, tourism, etc.) serving as the subject of land-evaluation and defined as precisely as practical, in terms of nature of produce, level management, capital input, etc.

In this study four landuse alternatives are described:

1. Forestry, without a further definition because of lack of research. The benefits of forestry are intangible at the moment and mostly in the field of soil conservation, although exploitation for timber and paper is possible in the future.

2. Smallholder, rainfed arable farming low to intermediate technology (present landuse of 90% of the farmers in the Irigonga area data from rough estimates of fieldobservations):

produce: coffee, bananas, hybrid and local maize, finger millet, beans, cassave, groundnuts, sugarcane, sweet potatoes, vegetables and milk.

recurrent inputs: labour (weeding, mulching, pruning, plowing), (minor impr.) little fertilizer, total costs about kes 100/- per ha.

non-recurrent inputs: plough, maize stores and other small sheds (minor and major improvements) tools, contours, total costs (annuity for 10% disconto about kes 50/-)

labourintensity : about 7 man month per ha per year (labour shortage during peak period in march).

farm power : oxen; man.

level of technical know-how: medium extension required for sustained land-use.

farm size : ca. 2 ha (always about 0.5 ha fallow and for cattle)

landtenure : landadjudication for title deeds of customary rights and interests in land by registered freehold landtitles.

local trafficability: dirt or all weather roads with maximum distance to the fields of about 3km.

population density : >0 per square km.

labourstructure : male persons often have outside farm work, children help during peak periods, total avalaible about 2 man (=woman) year/farm.

gross production value: 800/- per ha per year, dependent of price-structure and organisation co-operatives and marketing board (overhead costs).

institutional infrastructure: coffee factories, bananas transport firms, extension, co-operatives and/or marketing boards, outside farm work facilities, agro-industries.

3. Smallholder, rainfed, arable farming, modern technology (present land-use of about the 5% most progressive farmers, data from rough estimates by fieldobservations):

produce: coffee, tobacco, passion fruits, sugar cane, bananas, english potatoes, mixed vegetables, soya beans.

recurrent inputs: maintenance or rent for machines, hired labour (minor improvements) during peak periods, insecticides, pesticides, fungicides, fertilizers, plant material, organic manure (cow-dung or compost from Kisii) fuel and firewood, total cost kes ± 900/- /ha./year.

non-recurrent inputs: nurseries, fences, timber, sheds, barns, pipes, plough, specialised tools, tractors contours, total costs (annuity with 10% disconto kes 250/=)

Labourintensity : about 12- man month per ha. (shortage during peak periods).

farm power : oxen, 2 wheel tractors, 4 wheel tractors.

level of technical know-how: high to very high (much extension from government or other organisations required).

farm size : 1 ha (without fallow and with good crop rotation system).

landtenure : registered freehold titles.

local trafficability: dirt roads (murram in wet spots) or all weather roads with maximum distance to the fields of 1.5 km.

population density: 360 per square km.

labourstructure : hired labour and children during peak periods, about 2 man years available on the farm itself.

gross production value: about 2600/- per ha per year (prices 1973).

institutional infrastructure: marketing boards and cooperatives (machines) extension (fieldwork and exposition), agro-industries, transport and credits.

4. Smallholder, rainfed, arable farming, modern technology: produce: tea, pyrethrum, soya beans, english potatoes, mixed vegetables. (the same as landuse alternative 3; but different land development unit and hence other B/C and other produces and thus another feasibility study).

The landquality classification:

A landquality is a complex attribute of land which acts in a manner clearly distinct from the actions of most other landqualities in its influence on the suitability of land for a specific kind of landuse. The expression of each landquality is determined by a set of interacting single (or compound) landcharacteristics (= attribute of land that can be measured or estimated) having different weight in different environments depending upon the values of all characteristics in the set.
The landqualities are graded in five classes, from high availability or absence of risks (grade 1) to low availability or presence of risks (grade 5).
The different grades of the landqualities are determined by the landcharacteristics, which influence the land quality according to their weight, which is stated behind the landcharacteristic.
The grade of the landquality is found by adding the different grades of the landcharacteristics, multiplied by their specific weight for the landquality.
In this report five landqualities are graded:
Table 5:
1) availability of water:

grading:	landcharacteristics and their weight:			
	soildepth .4	Texture .4	Slope .1	Parentmaterial .1
1	> 180	clay	0 -2 %	Basalt
2	150-180	clay-loam	2- 6 %	Diorite
3	125-150	sandy clay-loam	6-12%	Andesite, Rhyolite
4	50-125	gravelly clay	12-25%	Quartsite
5	< 50		>25%	Granite

2) grading:	C.E.C. .4	Soildepth .4	Organic matter .2
1	20 me/100 gr soil	>180 cm	>8%
2	15-20	150-180 cm	6-8%
3	10-15	120-150	4-6%

2) grading: landcharacteristics and their weight:

	C.E.C. .4	Soildepth .4	Organic matter .2
4	5-10	50-120	2-4 %
5	> 5	0-50	0-2 %

3) availability of oxygen for rootgrowth:

grading	landcharacteristics and their weight:		
	mottles .4	mottles .4	structure .2
1	0-10 % of profile	>120 cm deep	1 and 2 sbk
2	10-25 % of profile	100-120	1 sbk
3	25-50 % "	50-100	1 bk
4	50-5 % "	20-50	prismatic
5	> 65 % "	0-20	coarse pr. and massive

4) resistance towards erosion:

grading	landcharacteristics and their weight:		
	slope .8	soildepth .1	Parent material .1
1	0 - 2 %	180 cm	basalt
2	2 - 6 %	150-180cm	felsite
3	6 -12 %	120-150cm	andesite, rhyolite
4	12-25 %	50-120cm	granite
5	>25 %	0-50 cm	quartzite

5) possibilities of mechanization:

grading	landcharacteristics and their weight:	
	slope .5	stoniness and/or rockiness .5
1	0 - 6 %	0 %
2	6 -12 %	0-1 %
3	12-16%	1-2 %
4	16-25 %	2-10%
5	> 25 %	> 10%

Improvement capacity determination:

In the determination of the improvement capacity the possibilities for obtaining higher yields or gross-benefits with minor (recurrent costs borne by farmer with or without short term credit facilities, or management specifications) Improvements and/or major (= non-recurrent costs borne by farmer or organisation with term credit facilities, or land improvement specifications) is evaluated for every tract of land. This is done with different levels of input requirements:

A) low input reqmirements, costs borne by farmer with occasional credit facilities.

B) medium input requirements, costs borne by farmer with short term credit facilities.

C) high input requirements, costs borne by long term credit facilities.

D) very high initial input requirements normal recurring costs

E) very high initial input requirements + high recurring costs.

Input requirements at level D and E require long term credit facilities and are beyond onfarm development and implies regional planning and development.

In this way it will be possible to evaluate the suitability of the different tracts of land, with the combination of the landqualities with the different levels of input requirements, up to the level of the comprehensive qualities (3 comprehensive landqualities: 1 gross productivity, required recurrent and non-recurrent costs).

It will be clear from the above mentioned that the management and landimprovement specifications determinations takes a central and crucial place in the landevaluation. In this report for 8 tracts of land the improvement capacity will be determinated for four of the five above graded landqualities for two landuse alternatives, with their specific levels of input requirements (e.g. smallholder, rainfed, arable farming intermediate technology with inputlevels A and B; small holder, rainfed, arable farming, modern technology with input levels, C,D,and E).

In the tables the grade of the landquality after the improvement and maintenance at the specific input requirement level will be given. The original condition of the soil will be given at level O. The improvement are specified under the head "establishment of management and improvement specification", the last step of the landevaluation procedure after the landsuitability, and are given at page 27 for the most promising landuse alternatives only. A short list is given here for the suitability determination:

landquality:	rough improvement specification:
resistence towards erosion	contours or terraces
availability of nutrients	chemical and organic fertilizers
possibility of mechanization	stone removal and terraces
availability of oxygen	surface drain construction.

Table 6: Improvement capacity determination:
grades of relevant landqualities for tract of land GC and GD (slope A,B 0-8%)

levels of input requirements	availability of nutrients	absence erosion risk	availability conditions for mechanization	availability of oxygen
O	3	2	1	1
A	2	2	1	1
B	2	1	1	1
C	1	1	1	1
D,E	1	1	1	1
				GC and(C,D) slope 8-30%
O	3	3	2	1
A	2	3	2	1
B	2	2	2	1
C	1	1	2	1
D,E	1	1	1	1
				GB (A,B) 0 -8%
C	4	2	2	-
A	3	2	2	-
B	2	1	1	-
C	2	1	1	-
D,E	1	1	1	-
				GB (C,D) 8-30 %
O	4	4	4	-
A	3	4	3	-
B	2	3	3	-
C	2	2	2	-
D,E	1	2	2	-
				water GA 0 -30 %
O	4	4	3	2
A	3	3	3	2
B	3	3	2	2
C	2	2	2	2
D,E	1	2	1	1

levels of input requirements	availability of nutrients	absence of risk erosion	availability conditions for mechanization	availability of oxy. or water slope
				ED,EC 8-30%
O	3	3	2	2
A	3	2	2	2
B	2	1	1	2
C	2	1	1	2
D,E	2	1	1	1
				EB,EA slope 8-30
O	4	4	4	4
A	4	3	3	4
B	3	2	3	4
C	3	2	2	4
D,E	2	2	2	4
				oxygen V slope 0-8%
O	2	2	1	3
A	2	1	1	2
B	1	1	1	2
C	1	1	1	1
D,E	1	1	1	1

The suitability classification:

The suitability of tracts of land, in this study, is evaluated with conversion tables. Conversion tables convert the grades of the land-qualities in combination with their improvement capacities into suitability classes for a defined land use alternatives.

Table 7. Conversion tables for defined landuse alternatives:

(inputlevel C) FORESTRY

Suitability classes:	Relevant landqualities: resistence erosion	availability nutrients	avail-water	avail. oxygen
S1	2	3	1	1
S2	3	4	2	3
CS3Tt	4/D, t/2	4	4	3
	any grade lower than conditionally marginally suitable.			

The suitability classification: cont.

	(inputlevels A,B)		Smallholder, low to intermediate technology	
S1	2	2	1	1
S2	2	2	2	2
CS3En	3	3/D,e/2	4	2
N1	any grade lower than conditionally marginally suitable.			
S1	1	1	1	1
S2	2	2	1	1
CS3Id	2	2	3/E,i/2	1
	any grade lower than conditionally marginally suitable.			

Table 7 is constructed by reading the relevant grades of landqualities from table 6 at the specific input levels for the different land-use alternatives. The discerned suitability classes are: S1 highly suitable, S2 moderately suitable (i.e. land having limitations reducing output or increasing inputs within the landuse alternative considered), CS3Xx conditionally marginally suitable (i.e. land having limitations reducing severly outputs and increasing considerably inputs and needing inputs, which are not considered in the landuse alternative), N1 presently unsuitable.

The CS3 suitability class has suitability subclasses, which mention with a capital the necessary inputs (T=terraces, E=extension and I=supplementary irrigation) and with a second letter the limitation (t=topography, n=nutrients and d=droughtiness). The capital used in the table itself indicates the input level of the improvement (the improvement is not mentioned in the land usealternative, besause it is introduced as condition from outside). The input levels of those "conditioned improvements are D,E" (see, improvement capacity determination.)
With table 6 it is possible to determine the suitability of a tract of land using table 7 as conversion. This results in table 8 the suitability classification.

Table 8. The suitability classification for three landuse alternatives:

		Landuse alternative		
		FORESTRY	SMALLHOLDER (low to intermediate technology)	SMALLHOLDER(modern technology)
Tract of land (soilseries, slope)				
NyG and RaG (GD and GC)	0 - 8 %	S1	S1	S1
	8 -30 %	S2	CS3En	S1
MtG (GB)	8 -30 %	CS3Tt	CS3En	S2
Keg (GA)	0 -30 %	CS3Tt	CS3En	S2
MmG and RiG (ED and EC)	8 -30 %	S2	S2	S2
Irg and MiG (EB and EA)	8 -30 %	CS3Tt	CS3En	N1
V	0 - 8 %	S2	S2	S1

With plane geometry the agricultural development possibilities (=potential) can be estimated by multiplying the gross margin with the surface for every landuse alternative.

The establishment of the management and improvement specifications.

The management and improvement specification are given for every landuse alternative separate. The description of the landuse alternatives gives the gross margin obtained from a highly suitable tract of land for 1973 prices. It is clear that large price fluctuations in produce and/inputs (especially fertilizer) have distorted the overall economic picture since. The inputlevels for every landuse alternative are given in the landuse alternative description and in the improvement capacity determination of the landqualities of the tracts of land. Comparision of both input levels with the gross margin for every tract of land. The input levels require however upto date economic evaluation because of changing price structures and prices.
In this study the input levels are described and roughly tentative determined (see, the definition of landuse alternatives, page 19).

For the landuse alternative forestry the following management and improvement measures are taken into account:

a) Major improvement measures not defined in landuse alternative at D-(cf. page 21) inputlevel consisted of contour terraces.

b) Management measures consisted of thinning and other normal forestry measures.

The gross margin of this landuse alternative is very low. The only reason for special attention for this landuse alternative is the intangible or difficult to evaluate benefits of soil conservation. The soilconservation needs careful attention in this area.

For the landuse alternative smallholder rainfed arable farming with low to intermediate technology the management specifications and minor improvements as contours are described on page 19 with estimates of costs and benefits.

The major improvements considering the limitation of low natural fertility and sealing are extension at inputlevel D(i.e. very high intial input requirements with normal recurring costs).

It is impossible with this landuse alternative for the farmer to carry high recurring costs because of a lack of credit.

The benefits of this landuse alternative are mainly the employment.

The gross margin is very low and only institution building (cooperatives, marketing board, extension) and a good physical infrastructure (maximum distance field-dirty road 3 KM.) with local centres (cf. Matongo, Nyamatutu, Mogumo, Riana, of Fig. 2) and market centres (Mogumo, Getare, cf. Fig. 2) can provide the area with development possibilities. The intensity of these improvements must depend upon the value of employment, which is given from higher planning levels and the value of the produce, which depend upon the trade possibilities given by transports and institutions.

The landuse alternative smallholder rainfed arable farming modern technology is very dependent of institutions (credit, cooperatives) and infrastructure (trasport) as defined on page 20. The management and minor improvements are given on page 20 with 1973 prices (rough estimates).

It is clear that the physical infrastructure and institution building need to be considered for the specific landdevelopment unit with overall administrative planning, before improvement specifications are determined.

Specific tracts of land with special management specifications can be derived from the improvement capacity determination on page 22 and the suitability classification on page 24. One grade of one landquality lower than highly suitable gives a input of 100/- more or a output of 100/- less.
The major improvement specifications can only be valued which data from regional national (macro) level.

APPENDIX 4:

Profile no. 108: Raganga series (Rag)
Classification : Soil Taxonomy 1970 - fine clayey kaolinitic acid isothermic Humic Paleudult (soilphase: deep)
FAO 1970: Humic Nitosol
Location : Wanjare, Irigonga
Coordinates : 9930.90 N, 690.30 E.
Elevation : 5050 ft.
Described by : van Mourik and van Wissen on 4-2-1974
Geomorfological position: convex slope, middle position.
Parent material: Wanjare Granite
Relief and slope: normal, sloping in rolling landscape
Stoniness : no stones
Erosion : few rills
Drainage : well drained
Moistness : top soil and subsoil dry after two weeks of dry and sunny weather
Biology : few krotovinas, depth of undisturbed soil deeper than 170 cm; common roots mainly at depth of 20 cm.
Landuse : maize

Soil profile:

Ap 0 - 25 cm: Dark reddish brown (5 YR 3/2) dry, fine clay; weak very fine to fine subangular blocky; common very fine, common fine and few medium, imped, continuous random, tubular, open biopores; hard, slightly sticky and slightly plastic; broken, thick, probably humus clay cutans; clear and smooth boundary.

B21 25 - 85 cm: Dark reddish brown (5 YR 3/4) dry, fine clay; strong very fine to fine angular-blocky; common very fine, common fine, few medium imped continous, random, tubular open biopores; hard, friable, slightly sticky and slightly plastic; broken to continuous, thick, probably clay humus iron cutans; diffuse and wevy boundary.

B22 85 -170 cm: Red (2.5 YR 4/6) dry; fine clay; moderate fine to very fine angular blocky; few very fine, common fine and few medium, biopores; hard, friable, slightly sticky and slightly plastic; broken, moderately thick, probably iron clay cutans; clear and smooth boundary.

B23 170 cm: Red (2.5 YR 4/6) dry, loamy clay; moderate very fine to fine angular blocky; few very fine, common fine and few medium biopores; hard firm, slightly sticky and plastic; broken, moderately thick, probably iron-clay cutans; gravelly and slightly stony.

Range in characteristics:

Profile characteristics: The variation in depth of the gravelly B-horizon within the Ragange series lies between 120 and 180 cm. The series represents Typic Rhodudults and Humoxic Tropohumults besides Humic Paleudults and Humoxic Palehumults within the series. This depends on organic matter content in the top of the B-horizon (humults have more organic matter than udults) and depth of the argillic horizon (pale-subgroups have an argillic B-horizon deeper than 150 cm. and trop- or rhodu- subgroups have argillic B-horizons shallower than 150 cm). The colour of the B-horizon varies between red (2.5 YR 4/6 and 3/4-3/8 when dry) and dark reddish brown (5 YR 3/2 - 3/7 when dry). Due to humus content in the A-horizon the colour varies widely.

Environmental characteristics: The series occupies flat to level tops of rigges and sloping slopes in rolling landscapes. Sometimes the series occurs on sloping footslopes. On moderately steep slopes the series occurs due to a tresh-hold in the gully or a protection ridge between the slope and a large gully (Cf. the valley of the Riana river).

Profile no. 109: Matongo series (MtG)
Classification : Soil Taxonomy 1970- fine clayey kaolinitic acid isothermic typic rhodudult (soil phase: moderately deep)
FAO 1970: Orthic Acrisol
Location : Wanjare, Matongo
Coordinates : 9929.25 N, 691.40 E
Elevation : 5150 ft
Described by : van Wissen, van Mourik on 4-2-'74
Geomorfology : concave slope middle position
Parent material: Wanjare Granite
Relief and slope: moderately steep slope in hilly landscape
Stoniness : no stones
Erosion : few rills
Drainage : well drained
Moistness : subsoil moist after two weeks of sunny and dry weather
Biology : few krotovinas, depth of undisturbed soil deeper than 90 cm; common roots mainly at depth of 20 cm
Landuse : fallow for maize with grazing.

Soil profile:

Ap 0 - 20 cm: Dark reddish brown (5 YR 3/4 when dry) fine clay; weak very fine to fine subangular blocky; common very fine common fine and few medium imped continuous random tubular open biopores; hard, slightly sticky and slightly plastic; patchy, thin, probably humus cutans; slightly gravelly; clear and smooth boundary.

B21 20 - 52 cm: Dark red (2.5 YR 3/5 when dry) fine clay; weak to moderately very fine angular blocky; common very fine, common fine and few medium imped, random continuous tubular open biopores; hard, slightly sticky and slightly plastic; broken, moderately thick, probably humus iron clay cutans; slightly gravelly; gradual and smooth boundary.

B22 52 - 92 cm: Dark red (2.5 YR 3/8 when moist) fine clay; moderate angular blocky fine; common very fine, common fine and few medium imped continuous random tubular open biopores; slightly sticky and slightly plastic, broken, thin, probably iron clay cutans; slightly gravelly; clear and wavy boundary.

B23 92 - cm: Dark red (2.5 YR 3/8 when moist) fine clay; moderate angular blocky fine; common very fine, common fine and few medium imped continuous random tubular open biopores; firm, slightly sticky and slightly plastic; broken, thick, probably iron-clay cutans; gravelly, slightly stony and slightly bouldary.

Range in characteristics:

Profile characteristics: The gravelly B-horizon varies between 50 cm and 120 cm. The series contains due to variation in organic matter in the B-horizon Humoxic Tropohumults and Typic Rhodudults. The colour of the B-horizon varies between reddish-brown (5 YR 4/4-3/2) when dry and dark red (2.5 YR 3/3 - 3/8) when dry.

Environmental characteristics: The series occupies moderately steep slopes and level to rolling narrow summits of ridges in hilly landscape.

Profile no. 119: Kebuye series (KeG)
Classification : Soil Taxonomy 1970- fine clayey kaolinitic acid isothermic (flavic) Rhodudult (soilphase:shallow)
FAO: 1970 Humic Acrisol
Location : Gem, Nyakwadha
Coordinates : 681.40 E, 9934.40 N.
Elevation : 4750 ft.
Described by : van Mourik on 27/3/71
Geomorfology : convex slope middle position
Parent material: Wanjare Granite
Relief and slope: hilly landscape with normal relief
Stoniness : fairly stony
Erosion : shallow gullies
Drainage : moderately well drained
Moistness : surface and subsoil moist after some showers in previous days.
Biology : few krotovinas, depth of undisturbed soil more than 50 cm, few roots mainly on a depth of 30 cm.
Landuse : fallow for maize

Soil profile:

Ap 0- 27 cm: Dark reddish brown (5 YR 3/2) moist, fine clay; weak fine subangular blocky; friable, slightly sticky and slightly plastic; common very fine, common fine and few medium biopores; slightly gravelly; few fine faint diffuse red (2.5 YR 5/8) mottles; clear and wavy boundary.

B2 27-50 cm: Dark reddish brown (5 YR 3.5/5) moist, fine clay; moderate fine subangular blocky; slightly sticky and slightly plastic, common very fine, common fine and few medium biopores; broken, moderately thick, probably clay cutans; slightly gravelly; clear and wavy boundary.

C 70 - cm: Yellowish red (5 YR 4/8) and strong brown (7.5 YR 4/8) Wanjare Granite stones and boulders.

Range in characteristics:

Profile characteristics: The series is often well drained. Thickness of the solum varies between 25 and 50 cm. The horizon deeper than 50 cm either consists of a C-horizon or a gravelly B-horizon. The organic matter of the A-horizon and the upper part of the B-horizon varies. Due to the latter fact of the series represents Flavic (i.e. to yellow for typic) Rhodudults, Typic Rhodudults and Humoxic Tropohumults. The colour of the B-horizon varies between dark reddish brown, dusky red and dark red (2.5 YR 3/2-3/7).

Environmental characteristics: The series occurs on sloping slopes of ridges with narrow level or sloping summits, on moderately steep slopes in hilly landscapes and protected positions on summits.

Profile no. 110: Nyamatutu series (NmG)
Classification : Soil Taxonomy 1970: fine clayey skeletal kaolinitic acid isothermic humic Paleudult (soilphase: very deep)
FAO 1970: Dystric Nitosol
Location : Wanjare, Nyamatutu
Coordinates : 9930.40 N, 686.80 E.
Elevation : 5200 ft.
Described by : van Mourik, van Wissen on 7-2-'74
Geomorfology : level summit under outcrop
Parent material: Wanjare Granite
Relief and slope: level summit in hilly landscape with normal relief
Stoniness : fairly stony
Erosion : few rills
Drainage : well drained
Moistness : dry and moist after a shower during the previous day

Biology : few krotovinas, depth of undisturbed soil 180 cm; common roots mainly at a depth of 20 cm.

Landuse : fallow and sweet potatoes.

Soil profile:

Ap 0- 23 cm: Dark reddish gray (5 YR 4/2) dry, fine clay; weak to moderate fine subangular blocky; hard, slightly sticky and slightly plastic, few medium, common fine and common very fine open tubular imped continuous random biopores; patchy, thin, probably humus-clay cutans; very gravelly; clear and smooth boundary.

B21 23-125cm: Red (2.5 YR 4/6) dry, fine clay; moderate fine angular blocky; hard, slightly sticky and slightly plastic, common very fine, common fine and few medium open tubular imped continuous random biopores; broken, moderately thick, clay cutans; gravelly to very gravelly and slightly bouldary; gradual and wavy boundary.

B22 125-160cm: Red (2.5 YR 5/8) moist; fine clay; moderate fine angular blocky; friable, slightly sticky and slightly plastic, common very fine common fine and few medium open tubular imped continous random biopores; broken, thick, probably clay cutans and patchy, black thin, probably humus manganese cutans; gravelly to very gravelly; clear and wavy boundary.

B23 160-310cm: Do; common fine distinct clear reddish yellow (7.5 YR 6/8) mottles.

Range in characteristics:

Profile characteristics: The organic matter content of the topsoil varies. Due to this the series consists of Humic Paleudults and Humoxic Palehumults. The depth of the C-horizon varies between 180 cm and 3.50 m or more.

Environmental characteristics: The series occurs on small level summits of ridge and moderately steep slopes of hilly landscapes.

Profile no. 114: Kiana series (RiG)
Classification : Soil Taxonomy 1970 -clayey skeletal kaolinitic acid isothermic typic rhodudult (soilphase: moderately deep)
FAO 1970: Humic Acrisol
Location : Wanjare, Nyamiobo
Coordinates : 9928.40.N, 688.80 E.
Elevation : 5000 ft.
Described by : van Mourik, van Wissen on 13-2-1974
Geomorfology : concave slope middle position
Parent material: Wanjare Granite
Relief and slope: slope in hilly landscape with normal relief
Stoniness : fairly stony
Erosion : few rills
Drainage : well drained
Moistness : surface soil and subsoil moist after a shower
Biology : few krotovinas, depth of undisturbed soil 140 cm common roots mainly at a depth of 20 cm.
Landuse : maize (ploughed)

Soil profile:

Ap 0 - 27 cm: Dark reddish brown (2.5 YR 3/2) moist; sandy clay; weak very fine to fine subangular blocky; common very fine, many fine and few medium open tubular random continuous biopores; very friable, slightly sticky and slightly plastic, patchy, thin, probably humus clay cutans; gravelly to very gravelly, slightly stony; clear and irregular boundary;

B21 27-70 cm: Dark reddish brown (2.5 YR 3/4) moist, sandy clay; moderate very fine to fine angular blocky; common very fine, common fine and few medium open tubular imped random continous biopores; friable, slightly sticky and slightly plastic; broken, moderately thick, probably clay cutans; few friable broken, moderately thick, probably clay cutans; few medium distinct clear reddish yellow (2,5 YR 6/8) mottles; gravelly; slightly stony; diffuse and wavy boundary.

B22 70 - 144 cm: Dark red (2.5 YR 3/7) moist clay; moderate very fine to fine angular blocky; common very fine, common fine and few medium open tubular random imped continuous biopores; firm, slightly sticky and slightly plastic, broken, thick, probably clay cutans; common medium distinct clear strong brown (7.5 YR 5/8) mottles; gravelly to very gravelly; tongues of Ap continuous, 5 cm wide; abrupt and smooth boundary;

C 144 - cm: Strong brown (7.5 YR 5/6) Wanjare granite rocks; few tongues of Ap material 5 cm wide.

Range in characteristics:

Profile characteristics: Within the series the depth of the B3 or C-horizon is variable between 1,20m and 1,80 m. Due to variation in the depth of the argillic B-horizon the series contains pale- (argillic B deeper than 1,50 m) and tropo- or rhodu- (argillic B shallower than 1,50 m) great groups. Due to variation in organic matter in the topsoil the series contains great groups of the humults (relatively much organic matter in A and top B-horizon) and udults (relatively few organic matter in the A- and top of the B-horizon). The occurence of stonelines within the series varies widely from slightly stony to bouldary. The depth of the stonlines is between 20 and 60 cm. The gravelliness of the profile is 40 to 65 %.

Environmental characteristics: The series occurs on slopes of more than 18% in hilly landscapes near large gullies and on relatively small level to undulating plateau's, downhill from outcrops. The series only exists where a moderate to large sheet or rill erosion occurs.

Profile no. 111 : Iruma series (IrG)
Classification : Soil Taxonomy 1970: loamy skeletal kaolinitic acid isothermic typic rhodudult (soilphase: moderately deep)
FAO 1970: Humic Acrisol
Location : Wanjare, Iruma
Coordinates : 9927,85 N, 689.80 E.
Elevation : 4950 ft.
Described by : van Mourik, van Wissen. on 7-2-'74
Geomorfology : convex slope middle position.
Parent material : Wanjare Granite
Relief slope : sloping slope in hilly landscape with normal relief
Stoniness : fairly stony
Erosion : few rills
Drainage : well drained
Moistness : surface dry and subsoil wet after one shower on previous day.
Biology : few krotovinas and depth of undisturbed soil 1.00m common roots mainly at a depth of 20 cm.
Landuse : fellow after maize

Soil profile:

Ap 0 - 35 cm: Weak red (2.5 YR 4/1) dry loam; weak very fine to fine subangular blocky; common fine, common very fine and few medium biopores; hard, slightly sticky and slightly plastic patchy, thin probably humus - clay cutans; gravelly to very gravelly; clear and wavy boundary.

B21 35- 60 cm: Dark red (2.5 YR 3/6) dry sandy loam; weak to moderate very fine to fine angular blocky; common very fine common fine and few medium biopores; hard; slightly sticky and slightly plastic, broken moderately thick probably clay cutans; gravelly to very gravelly; irregular, clear boundary.

B22 60-100cm: Dark red (2.5 YR 3/8) dry, sandy loam; weak to moderate fine angular blocky; common very fine, common fine and few medium biopores; very hard, slightly sticky and slightly plastic, broken, moderately thick, probably clay cutans; gravelly to very gravelly; abrupt and broken boundary;

B3 100 - 180 cm: Reddish yellow (5 YR 6/8) moist, rotten rock of Wanjare Granite; massive; very few biopores; firm non sticky and non-plastic; tongues of B22 with continuous, thick, probably clay cutans covering about 30% of the surface.

Range in characteristics:

Profile characteristics: Within the series the depth of the B3-horizon or C-horizon or R-horizon (or laterite crust or plinthite cf. Manirida series) layer is variable between 50 and 120 cm. The variation in organic matter content results in the presence of Typic Rhodudults and Humic Tropohumults within the series. Stone layers occur within the series often, mostly between 20 and 50 cm. The series may then contain boulders within the profile. The series is well drained, except on the sloping slopes in landscapes with laterite or plinthite when the soils are moderately well drained.

Environmental characteristics: The series occurs on moderately steep convex and concave slopes mostly on top and middle positions in hilly well drained landscapes and rolling landscapes with large gullies and moderately well drained. The landscapes can be fairly rocky and stony.

Profile no. 117: Matiti series (Mig)
Classification : Soil Taxonomy 1970- fine loam skeletal kaolinitic acid isothermic typic rhodudult (soilphase: shallow)
FAO 1970: Orthic Acrisol
Location : Wanjare, Iruma.
Coordinates : 9928.00 N, 688.80 E.
Elevation : 4875 ft.

Described by : van Mourik, van Wissen on 13-2-'74
Geomorfology : convex slope, lower position
Parent material: Wanjare Granite
Relief and slope: sloping slope in hilly landscape with normal relief
Stoniness : fairly stony
Erosion : few rills
Drainage : well drained
Moistness : surface and subsoil dry after one shower on the previous day.
Biology : few krotovinas, depth of undisturbed soil 50 cm few roots mainly at a depth of 15 cm.
Landuse : Poor range

Soil profile:

A1 0 - 14 cm: Dark reddish gray (5 YR 4/2) dry, sandy loam, weak very fine to fine subangular blocky; common very fine, common fine and few medium biopores; friable slightly sticky and slightly plastic, patchy, thin probably humus, clay cutans; gravelly; slightly clear and wavy boundary.

B2 14 - 48 cm: Dark reddish brown (2.5 YR 3/4) dry, sandy loam; moderately very fine to fine angular blocky; common very fine, common fine and few medium; hard, slightly sticky and slightly plastic; common fine distinct clear (7.5 YR 5/8) mottles; broken, moderately thick, probably clay cutans; gravelly to very gravelly; slightly stony; clear and irregular boundary.

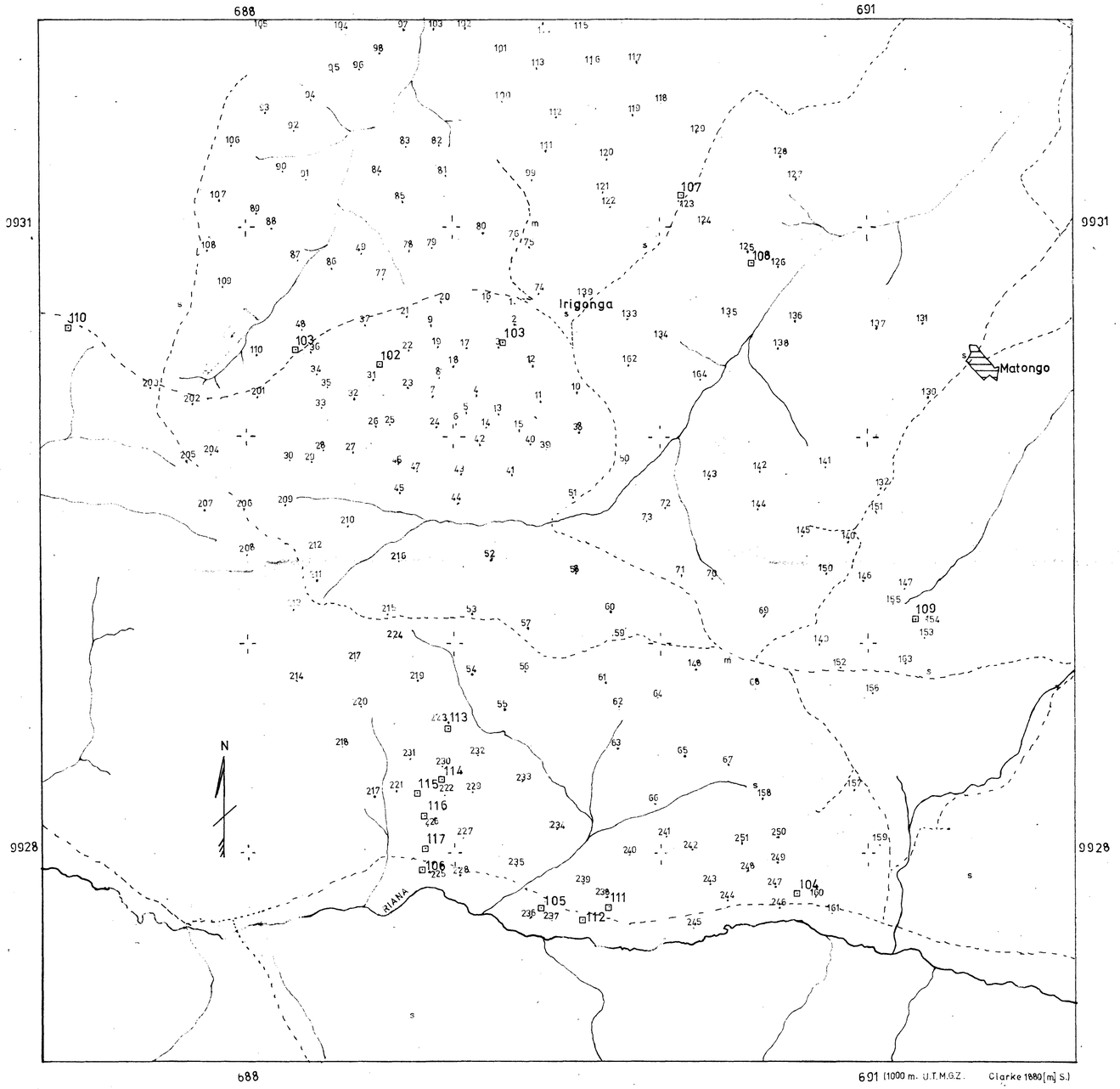
C 48 - cm: Red (2.5 YR 4/6) and reddish yellow (7.5 YR 7/8) rotten rock of Wanjare Granite; massive; hard; 5 cm wide tongues of A1 and B2 material covering 20% of the surface.

Range in characteristics:

Profile characteristics: The depth of the C-horizon varies between 50 and 0 cm. The horizons vary from only an A-horizon, the A-horizon, with a cambic B-horizon and an A-horizon with an argillic B-horizon.

The C-horizon varies from rotten rock, to plinthite and laterite. The humus content varies in a way that the series contains Humoxic Tropohumults and Typic Rhodudults and Humitropepts and Dystropepts. The series contains often stonelines.

Environmental characteristics: The series on top of steep hills, on summits of ridges in hilly landscapes, on steep slopes and sloping slopes under summits of ridges with shallow soil and narrow edges in sloping and hilly landscapes with large gullies.



BASEMAP

ANNEX SOIL PIT AND AUGERHOLE LOCATION MAP FOR THE DETAILED SOIL SURVEY OF THE IRIGONGA AREA (1974).

SCALE 1 : 12.500 (APPR)

LEGEND

- Main tracks (motorable)
- River
- Gully
- Village
- m Market
- s School
- 123 Pit
- 123 Augerhole