

TRAINING PROJECT IN PEDOLOGY

KISII

KENYA



A Detailed Soil Survey of the Magombo market area

PRELIMINARY REPORT NO 9

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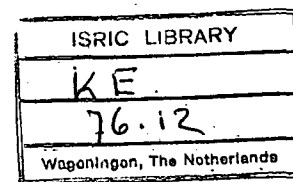
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A DETAILED SOIL SURVEY OF THE

MAGOMBO MARKET AREA

by

S.E. ter Maat

K. van der Torren

D.H. Vuyk

J.H.M. Scholten

Preliminary Report no. 9

April 1976

TRAINING PROJECT IN PEDOLOGY, KISII-KENYA

Agricultural University, Wageningen - The Netherlands

6348

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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 ninth 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 is the result of a detailed soil survey carried out in the surroundings of Magombo market. The text of the original report is written by Messrs. S.E. ter Maat, K. van der Torren, D.H. Vuyk and J.H.M. Scholten.

It is considerably revised and recompiled by Mr. H.W. Boxem.

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 functioning of the project.




The supervisor of the project

J. Bennema, Professor of
Tropical Soil Science.

1. The Environment

1.1. Location of the area

The Magombo Market area in which the detailed soil survey was carried out is located in the Kisii Highlands, east of the Manga Ridge, between 99.23 and 99.29 N, and between 7.09 and 7.15 E (map sheet 130/2, Kisii) with as southern boundary the Gucha river, and as most important village Magombo market. The altitude varies from about 1800 m to about 2100 m. The total surveyed area is 3340 ha.

-  detailed soil survey : Magombo market area
-  reconnaissance soil survey
-  map sheet 130

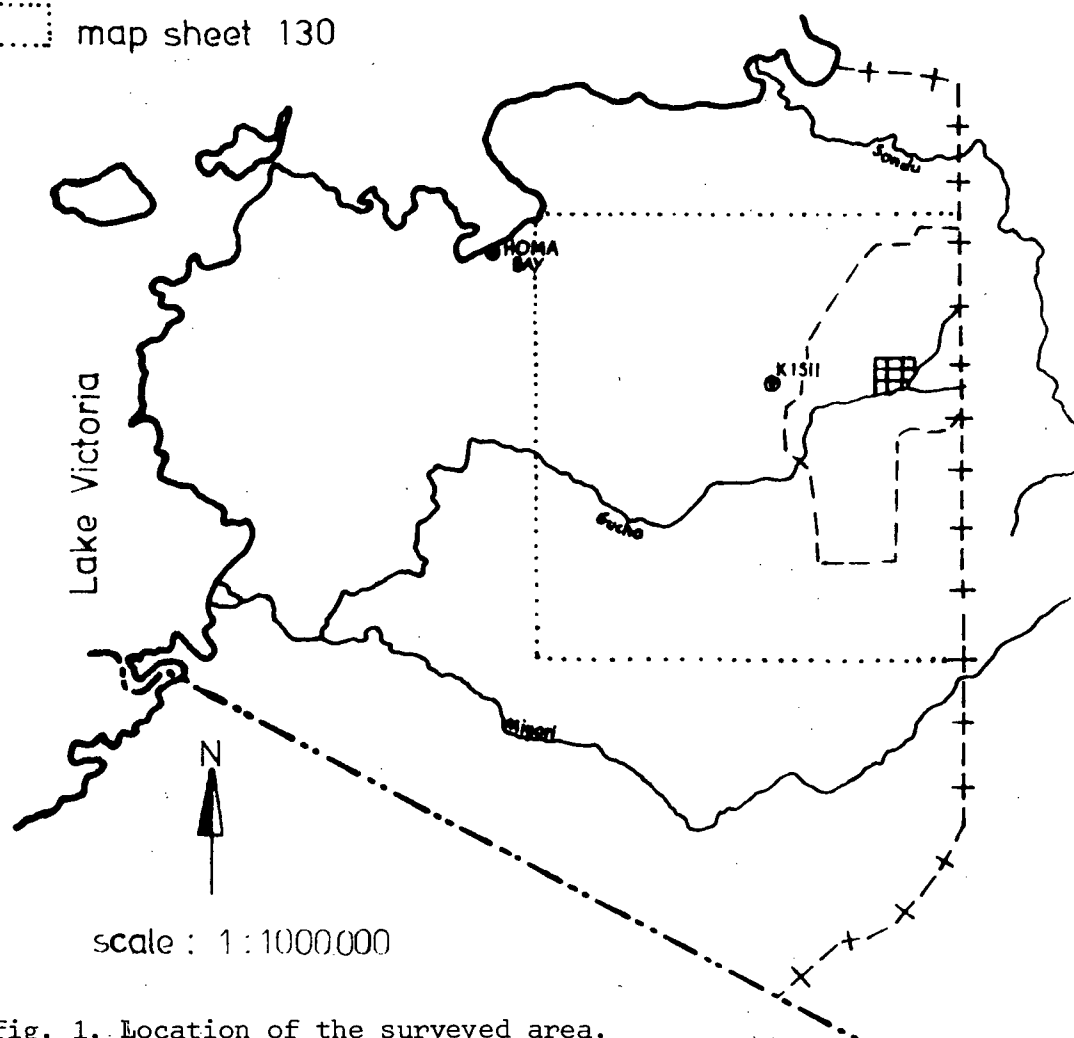


fig. 1. Location of the surveyed area.

1.2 Geology

The Magombo market area belongs geologically to the Bukoban system of late Precambrium age. The dominant rock of the area is andesite,

only in the Northwestern part there is a small area with rhyolite and along the Gucha river South of Magombo market a narrow strip of rhyolites and tuffs with intercalated fine and coarse grained sediments is found. In the andesite a layering can be recognized with a dip of 10-12% to the East-South East.

Locally conglomerate rock is found.

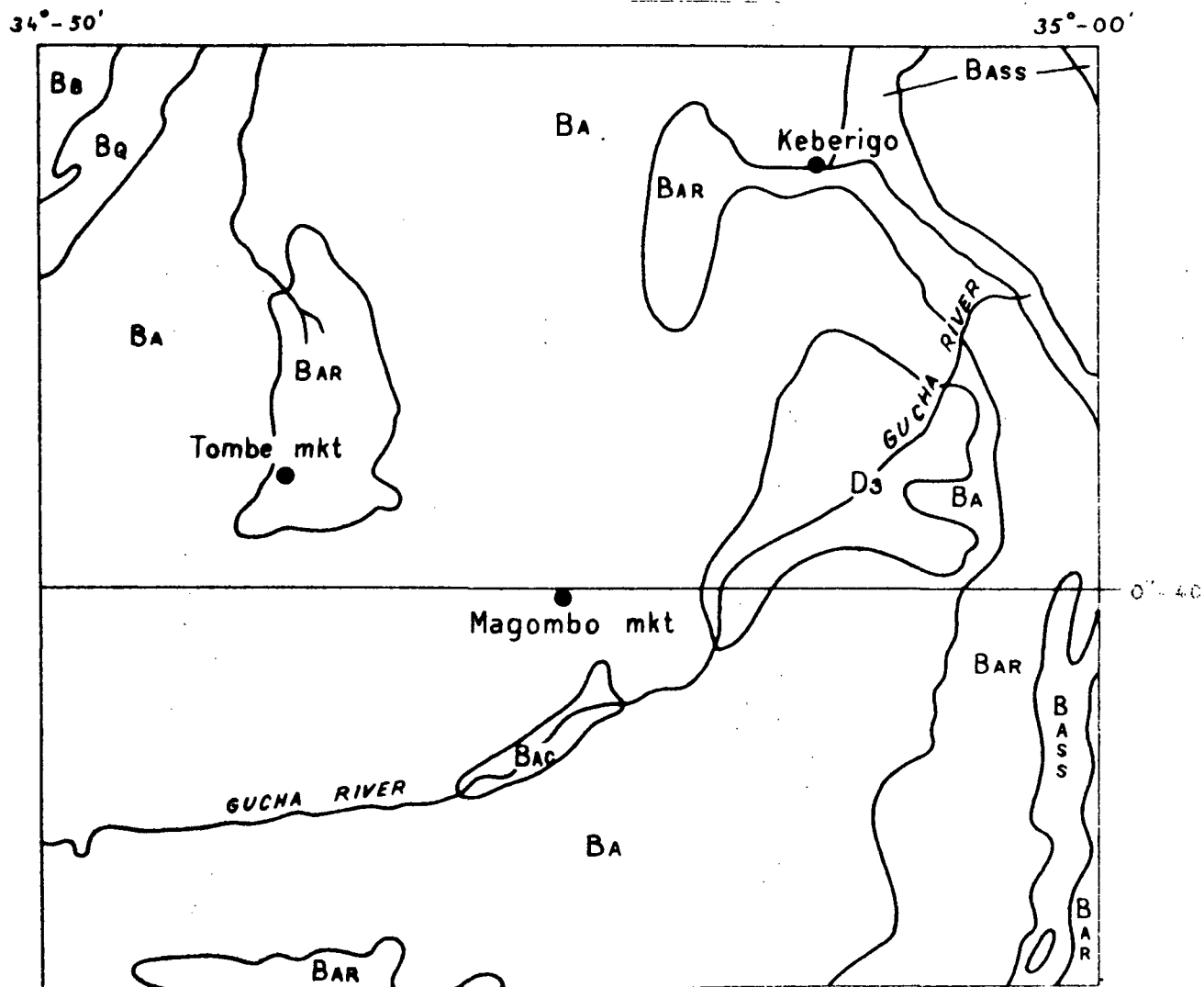


Fig. 2. Simplified geological map Scale 1 : 125,000.

Legend:

Bukoban system.

BA - porphyritica and non-porphyritic felsites and andesite

BAR - rhyolites and tuffs

BASS } - rhyolites and tuffs with intercalated fine and coarse
BAC } grained sediments

BQ - quartzites

BB - basalt

Intrusive

D3 - younger dolerites and lamprophyres (post Bukoban)

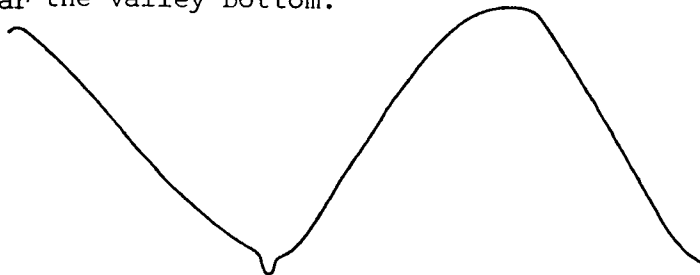
1.3. Geomorphology

The area can be divided in two parts:

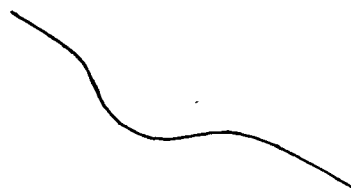
- a. A lower part in the East with convex hills and flat valley bottoms. The convex hillslopes have a gradient of 5 to 15%; near the valley bottoms the slopes are mostly linear with a gradient of 15 to 20%. The height of the hills is about 60 to 100 m. On some places of the valley bottoms a terrace can be recognized 2 till 4 m. above the level of the river.



- b. A higher, steeply dissected part West of Magombo market with steep linear and concave slopes with a gradient of 20 to 40%, and convex hill tops. The valleys are V-shaped. The height of the hills is 80 to 200 m. The highest part of the area is in the Northwest, in the rhyolite area. Of major importance for the shape of the valleys is the appearance of springs in the valley sides. They are cutting backwards V-shaped valleys with slopes of 25-40% going up the hills, or are the cause of steep linear slopes near the valley bottom.



Of interest is the appearance of a kind of round pits, with a diameter of 10-30 meter and 1-5 meter deep, on the slopes and mostly grouped together, from which the people are saying: "that formerly the elephants came to drink here", or: "these pits were formerly cattle boma's". Anyway, most likely is that these pits were formed by human beings, probably people from another tribe because in Kisii history one cannot find anything about it.



1.4. Hydrology

The surveyed area is a part of the catchment area of the Gucha river, running from the North-East to the South-West, which is also the main river in the surveyed area. (PR.14). Although in the dry season the precipitation is very low, the main streams in the wider valleys are never dry. All over the area one can find springs, in the transition hill-valleybottom, but also higher upon the hills.

A great number of them is dry at the end of the dry season.

Important are the "dams" of mostly conglomerate rock at the end of the flat bottomed, wet valleys. On these places the valleys are narrowing, and the streams running through have rapids, sometimes over a length of 50-500 m with a height difference of 10-30 m. In the lower parts of the flat valleybottoms one can find swamp or marshes. The drainage direction of the minor streams is from NW to SE, of the bigger streams from NE to SW. Height differences Gucha river: from 1815 m near Gekano till 1800 m above sealevel South of Miriri market.

1.5. Climate of the Tombe - Magombo area

There is no meteorological station situated in the surveyed area. So we are forced to estimate rainfall, evapotranspiration and temperature from figures of neighbouring stations. These stations are: Nyanturubo 90 34 031, Murumba 90 34 032 and Nyamira.

Three sub-areas can be distinguished although there are no big climatological differences.

For the growth of pyrethrum however, the difference of these sub-areas regarding temperature is important.

- a - Tombe, a higher area between 6500 ft. and 7000 ft., has a pronounced relief (steeply dissected, see soils)
- b - Magombo, a lower area between 6000 ft. and 6500 ft., with a less pronounced relief (hilly) dissected,
- c - the valley bottoms.
- The Magombo area is warmer and drier than the Tombe area
- the valley bottoms are especially during the night colder than the surrounding hills and more vaporous.

The climatic code of the surveyed area on the "Map of Vegetation" by Trapnell, Brunt and Birch - Nairobi 1970 is A2 We3.

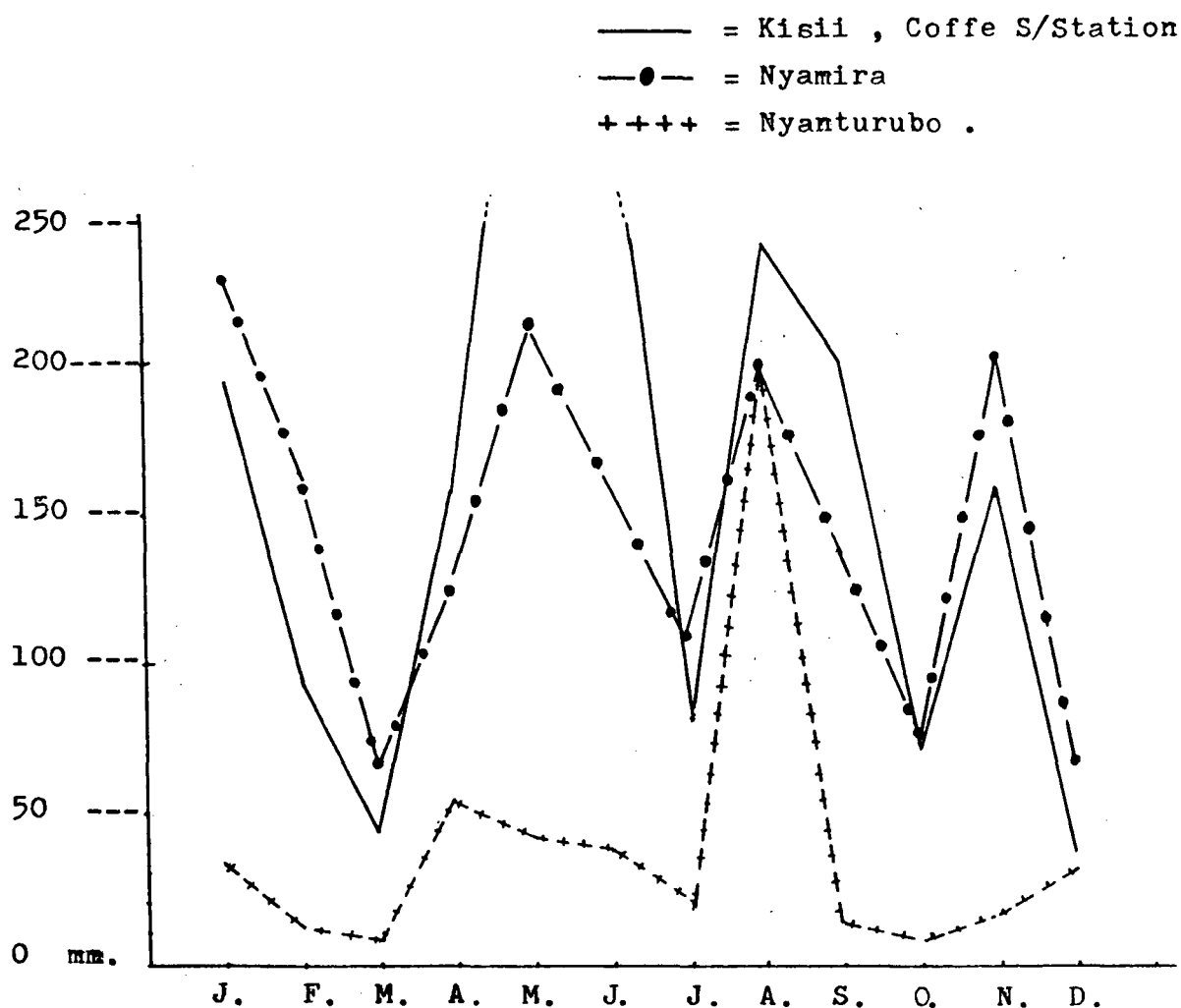


Fig. 3. Rainfall in 1973 measured in three meteorological stations.

Temperature.

Mean minimum temperatures are about 10°C and maximum temperatures can reach 29°C in Magombo.

For Tombe these temperatures may be 1-2 degrees lower because of the altitude effect ($\pm \frac{1}{2}^{\circ}\text{C}$ per 100 m height).

Magombo and Tombe are situated in the higher part of Kisii district, having a cooler climate than the lowlands in the West up to Lake Victoria. The mean daily temperatures are about $16-20^{\circ}\text{C}$.

Rainfall and Evapotranspiration.

The yearly rainfall amounts three out of four years more than 1600 mm. (v. Mourik, PR.6 and PR.1).

The graph above concerning the precipitation in 1973 gives us an idea about the differences in distribution, dependent on time and place.

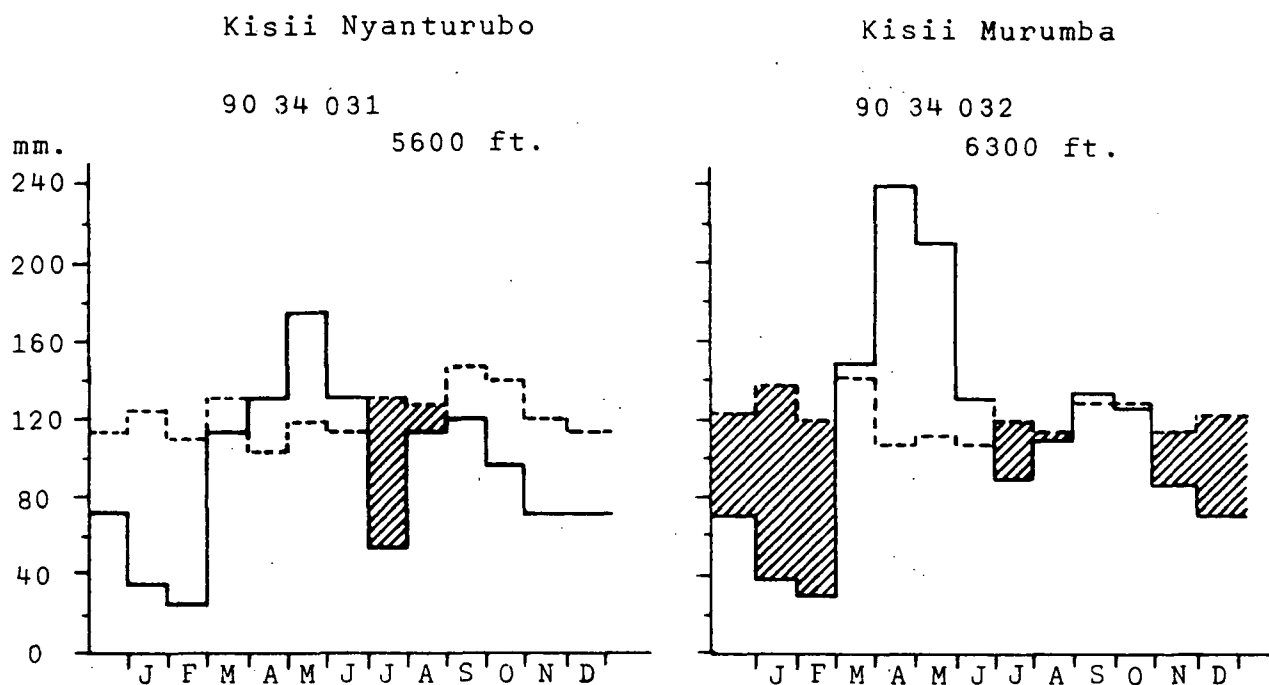


Fig. 4. Rainfall and evapotranspiration in two weather stations.

———— = monthly rainfall in mm

----- = E_{po} : the mean consumptive water use of a crop at the end of the vegetative period with optimal water availability (e.g. a fully closed tea crop).



= estimate of the available stored water for a crop in full production throughout the whole year, e.g. tea.

(For maize: see maize suitability)

E_{po} = 0.82 x the evaporation of an open water surface.

The storage capacity is calculated for a soil with a rootable depth of 1 m and a moisture content of 20% between pF 2 and pF 3.6.

Fig. 4. shows the rainfall and evapotranspiration figures of Nyanturubo (South-West of Magombo) and Murumba (North-West of Magombo).

We can notice that there is

- a dry spell during December, January and February
- a rainy season during March, April, May and June
- a drier month July
- a second rainy season during August, September and October.

2. Soils

2.1. The fieldwork

The fieldwork was done from August to December 1974.

First an interpretation was made on aerial photographs, and then every unit was checked by one or more augerings with the Edelman auger, mostly to a depth of 1.50 m.

In representative units pits were dug to a depth of 1.50-2.00 m, the profiles described according to the outlines of the Soil Survey Manual, The FAO Guidelines for Soil description and the outlines of the Kenyan Soil Survey, and from each horizon disturbed and undisturbed samples were taken for laboratory analysis.

Augerhole Observations.

About 800 augerings were made, and from each augering the following data were noted down:

from the surroundings:

geology and petrography

landform and relief, percentage and position of the slope

from the augering site:

internal drainage and possibility of flooding

rock outcrops and stoniness

overwash/blow, sealing, crusting and cracking

termite mounds.

human influence, landuse

from the augerhole:

depth of horizons

soil colour according to the Munsell soil colour charts

humusdepth, based on differences in soil colours

mottling, texture and stoniness

consistence

concretions

groundwater level

Profile pits

In every soil series at least one profile pit was dug, in order to make a very detailed description and to take soil samples.

The same data as noted down at augerhole observations were collected, but besides these the following:

- location and elevation
- climate
- physiography, landunit
- regional vegetation
- erosion
- soil fauna
- root distribution
- infiltration
- vertical and horizontal permeability
- properties of horizon boundaries
- soil structure
- cutans
- pores
- reaction on hydrochloric acid
- and if of importance: other features.

From each horizon were taken samples, disturbed samples and from important soil series also undisturbed ring samples.

Results of organic matter and pF research are available and from two profiles, East of Magombo market, very detailed analysis are done including texture, pH, free iron and aluminum, X-ray diffraction, CEC, phosphate and micro-morphological research.

Concerning the research done on two profiles East of Magombo market, a preliminary report is in preparation. Anticipating on this report figures are given of organic carbon, bulk density, pH and texture.

2.2. The use of aerial photographs

For the survey the use of aerial photographs was very important because only topographical maps with 1 : 50,000 scale were available. In the surveyed area 26 photographs, spread over four runs, were used. First a base map was made with the help of the slotted template triangulation method, after which the photographs were used in the field as maps, for the first photo-interpretation, and finally for drawing the soil- and soil phase boundaries.

After the fieldwork was done these boundaries just as roads, rivers, streams, schools, villages etc. were drawn from the photographs on the base map with use of a sketchmaster.

photo scale : about 1 : 12,500
photo year : 1969
flying height : 3600 m
focal length : 152.08 mm

2.3. Explanatory legend of the detailed soil map

Division and criterions for division.

The first division is based on drainage and soil material:

1. well-drained, very fine-fine clayey soils.
2. moderately to imperfectly drained, very fine-fine clayey soils.
Water is removed from the soil slowly enough to keep it wet for a small but significant part of the time.
3. Poorly drained very fine-fine clayey soils.
Water is removed so slowly that the soil remains wet for a large part of the time. The water table is commonly at or near the surface.
4. Very poorly drained very fine-fine peaty clay soils.
The water table remains at or on the surface the greater part of the time.
5. Very poorly drained organic soils.
The water table remains at or on the surface the greater part of the time, and there is a layer containing more than 30% organic soil materials and extending from the surface to a depth of 40 cm or more.

The well-drained deeper soils have been a subdivision based on soil-depth.

- 1.1 some rotten rock beginning deeper than 150 cm
- 1.2 some rotten rock beginning between 50 and 150 cm
- 1.3 very gravelly from a depth of less than 50 cm
- 1.4 lithic contact within 50 cm depth

The well-drained deeper soils are divided on humus depth:

- 1.1.1 humus depth less than 80 cm
- 1.1.2 humus depth more than 80 cm.

The field check of humus depth is based on differences in soil colour.

Humus-rich soil material must have one of the following:

if Hue is 2.5 YR, chroma must be smaller than 5 and value smaller than 4.

If Hue is 5 YR, " " " " " 4 and value smaller than 4.

The connection between soil colour and organic matter content was checked by laboratory analysis (see: laboratory results: soil colour-organic matter content, Appendix 1).

The moderately to imperfectly drained soils are distinguished from the poorly drained soils by reduction colours (chroma=2 or smaller) beginning deeper than 20 cm. They must have a layer with 5-50% concretions within 125 cm depth.

3. Poorly drained soils have reduction colours (chroma=2 or smaller) within 20 cm depth; they must have a layer with 5-50% concretions within 125 cm depth too.

4. Very poorly drained soils must have a histic epipedon, more than 50% reduction colours (chroma=2 or more) under the histic epipedon and may not have concretions.

5. Very poorly drained organic soils.

These peat soils may not have concretions, must have more than 30% organic soil materials, and the layer with organic soil materials must extend from the surface to a depth of 40 cm or more.

2.4. Soil phases

Within each soil series there are variations in soil phases. All soil series have the following phases:

humus depth:

1. 0 - 40 cm
2. 40 - 80 cm
3. more than 80 cm

soil depth:

4. 0 - 20 cm 1.100 - 150 cm
3. 20 - 50 cm 0.more than 150 cm
2. 50 -100 cm

Slope:

- A 0 - 3%
- B 3 - 8%
- C 8 - 15%
- D 15 - 30%
- E 30 - 65%

Rockiness:

- R1: 0 - 2%
- R2: 2 - 10%

Stoniness:

- S1: 0 - 3%
- S2: 3 - 15%

slope meter used: the Abney hand level.

Except the well-drained soils they have also the following phase:

reduced zone:

G1 permanent reduced zone on more than 100 cm depth.

G2 permanent reduced zone beginning between 50 and 100 cm depth.

G3 permanent reduced zone beginning between 0 and 50 cm depth.

Rockiness and stoniness are only noted down in the soil code on the map, if they are present.

2.5. Short description of the soil series

1. Well drained, very fine-fine clayey soils.

1.1 Very fine clayey; some rotten rock beginning deeper than 150 cm.

1.1.1 Magombo series: Humus depth less than 80 cm (70.9% of surveyed area).

These red soils occur on the hills and are normally several meters deep. They have a good structure, a high biological activity, a high permeability and are formed by weathering of andesite or rhyolite rock. This is the most important soil series of the area.

Horizon: A1 with organic carbon content of about 2-2.5 vol.%,

B2t horizon with clay cutans.

1.1.2 Nyambaria series: Humus depth more than 80 cm (6.2% of surveyed area).

This series occurs on the bottom of smaller valleys running down large slopes, and contains a lot of humus-rich soil material which accumulated. The structure and the water availability are good and these soils are often used for growing maize.

Horizons: A1 with organic carbon content of about 2 vol.%, B2t horizon.

1.2 Very fine clayey; some rotten rock beginning between 50 and 150 cm depth.

Nyamwanga series: a series occurring on steep convex slopes, near hill-tops and in steep valleys where rock is not deep below the surface.

The steeper slopes are not stable, therefore the soil material of the A1 horizon is moving down and the soil can be described as "cumulic" (7.6% of surveyed area).

1.3 Very fine clayey; very gravelly from a depth of less than 50 cm.

Miriri series: A very fine-fine clayey skeletal soil found near hill-tops on steep convex slopes, and other places liable to erosion.

Roots can go down as far as the depth of the massive rock; the soil will be dry readily because the amount of water stored in the soil is small. (2.7% of surveyed area). Horizons: A1, cambic B,R.

- 1.4 Very fine-fine clayey; with lithic contact within 50 cm depth.

Loudetia series: This soil is very shallow: hardrock within 50 cm from the surface, and is found on places with severe erosion: steep hilltops where the forest has been cut and along streams.

Rooting is difficult and the soil will be dry very readily. The Loudetia series is called after the Loudetia grass, frequently occurring on this soil (2.0% of surveyed area).

Horizons: A1, R.

2. Moderately to imperfectly drained, very fine-fine clayey soils. Reduction colours beginning deeper than 20 cm; a layer with 5-50% concretions within 125 cm depth.

Gekano series: Soils occurring on the transition hill-valley and on higher parts of valley bottoms, consisting of kaolinitic clay laying on montmorillonitic clay with an abrupt boundary on a depth of 50 - 100 cm. Mostly an ironstone pan is present on the transition kaolinitic-montmorillonitic clay. The structure of the upper horizons is good, the structure of the lower montmorillonitic horizons is very dense and this clay will be wet and badly aerated the greater part of the year. Horizons: A1, cambic B (0.9% of surveyed area).

3. Poorly drained, very fine-fine clayey soils. Reduction colours within 20 cm depth; a layer with 5-50% concretions within 125 cm depth.

Nyachogochogo series: Soils occurring on the higher part of valley bottoms but lower than the Gekano series. They have an abrupt change from kaolinite to montmorillonite clay, mostly at a depth of 50-100 cm, and are very wet the greater part of the year but in the dry season the water table can be lower than 100 cm from the surface. This soil is often used as grazing land. Horizons: A1, A2 and B2 (2.4% of surveyed area).

4. Very poorly drained, very fine-fine peaty clay soils: with histic epipedon, more than 50% reduction colours under the histic epipedon and without concretions.

Kenyerere series: Soils found under swamps or marshes in the lower parts of valley bottoms which are wet throughout the year. They have

an abrupt change to montmorillonite clay too.

Horizons: O, A1, B1, cambic B, IIB2. (1.9% of the surveyed area).

5. Very poorly drained organic soils.

With a layer containing more than 30% organic soil materials and extending from the surface to a depth of 40 cm or more.

Kenyamware series: This series is found in the lowest parts of valley bottoms, mostly in swamps. There is a peat layer which can vary in thickness from 40 cm to more than one meter. The soil is wet throughout the year unless it is drained by means of ditches.

Horizons: A0, O2, C IIC. (3.6% of surveyed area).

6. Complex soil units.

Soil complexes have been made when the pattern of some soil series is too intricate to be shown accurately and clearly on the map.

6.1 Complex of Nyachogochogo and Kenyerere series. (1.6% of surveyed area). Mainly occurring along the Gucha river; the meandering river is the cause that the units of the two series are small so that they cannot be shown separately on the map.

6.2 Complex of Gekano and Kenyerere series. (0.2% of surveyed area). A complex occurring on the valley bottom East of Miriri market; the intricate pattern here is caused by landslides and wash down of soil materials into the valley.

2.6 Schematic cross-sections

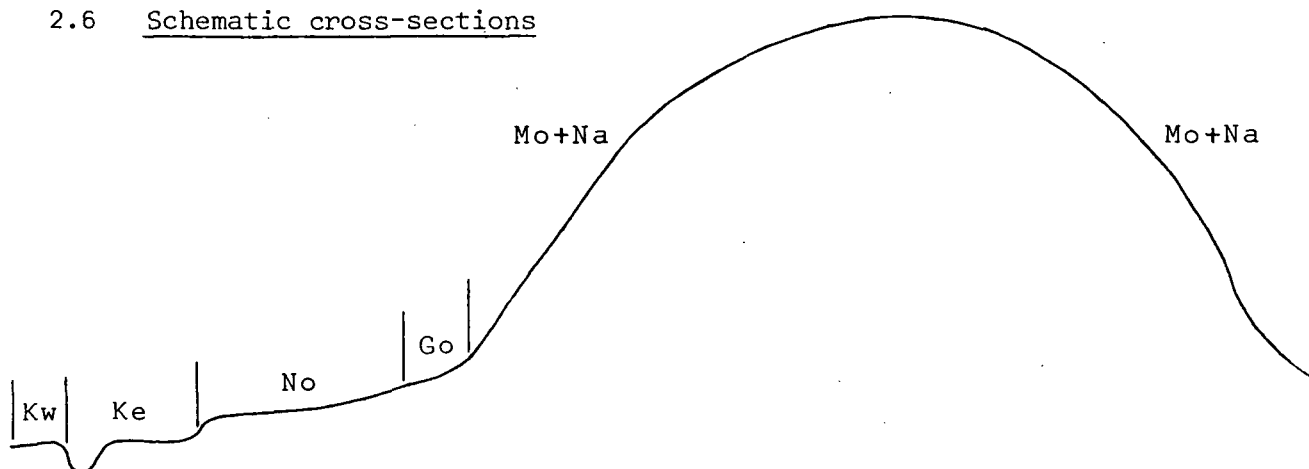


Fig. 5. Schematic cross-section of the lower part in the East with convex hills and flat valley bottoms.

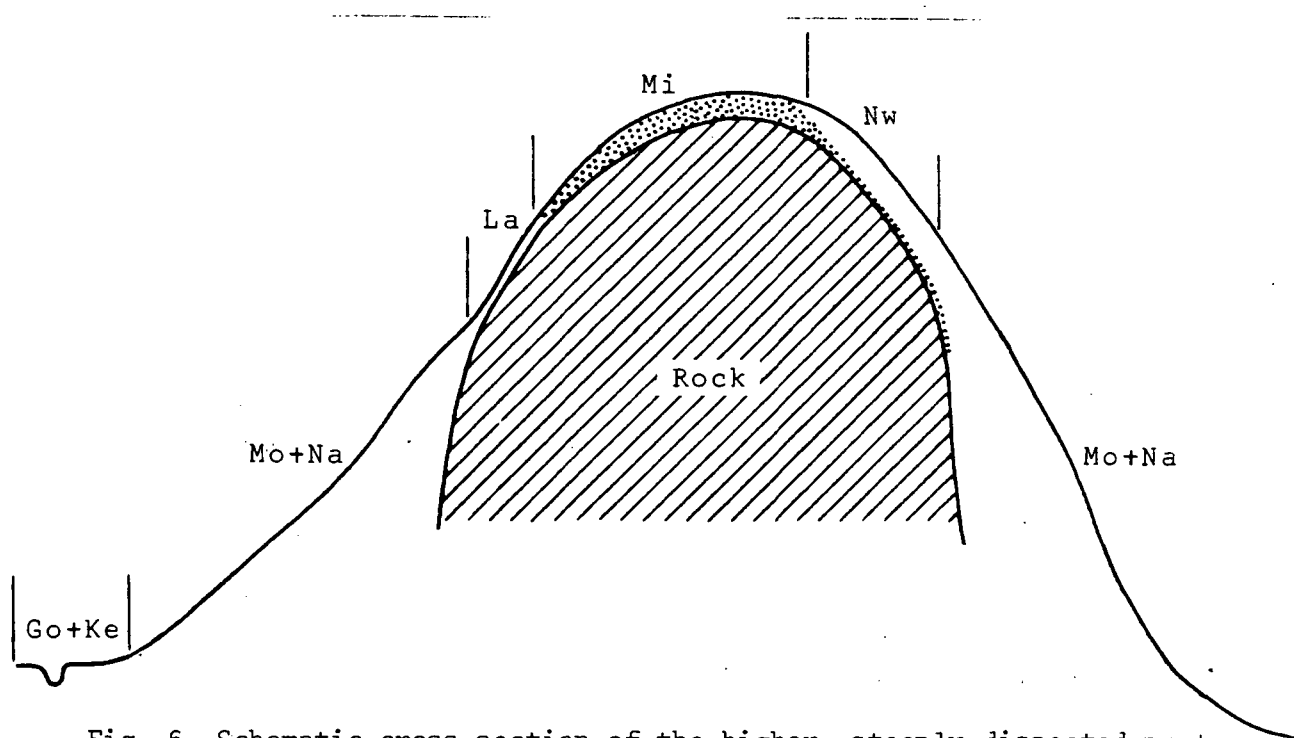


Fig. 6. Schematic cross-section of the higher, steeply dissected part West of Magombo market.

List of abbreviations used in Figs. 5 and 6.

Mo = Magombo series	Go = Gekano series
Na = Nyambaria series	NO = Nyachogochogo series
Nw = Nyamwanga series	Ke = Kenyerere series
Mi = Miriri series	Kw = Kenyamware series
La = Loudetia series	

2.7. Laboratory results

From the profiles nrs. 1, 3, 4, 5, 6 and 7 ring samples are taken in order to measure the bulk density and to find the relation soil moisture tension (PF)/soil moisture content. The measurements, from which the results are shown in figure 10, are all done by Ing. H.W. Boxem. During the survey the field check of humus depth was based on differences in soil colour. A research has been done to correlate soil-colour-organic carbon content. The results are given in a table at the end of Appendix 1 (p.74).

Very detailed research is done on two profiles near Magombo market, all the results will be recorded in a preliminary report: Differences in soil profile development due to a local spring, by J.H.M. Scholten, which is in preparation.

Anticipating on this report some important data are given:

profile.1S: Nyambaria series

profile 3S: Magombo series

- organic carbon content (determination according to Walkley and Black, multiplication factor used: $f = 100/80$).

Bulk density

Texture

pH

All data are to be found in Appendix 1 at the back of this report.

3. Vegetation in the surveyed area

3.1 Vegetation

Hillsides: All the deeper (red) clayey soils are under cultivation; mainly of maize, tea, pyrethrum, and pastures. These include the Magombo, Nyambaria, Nyamwanga, and Miriri series. These cultivation together with the homesteads and the hedges form the main aspect of the area. The original vegetation has been a moist montane forest. Eventhough the settlement of the area is quite recent there are not even secondary forests present, but remniscent elements of these forests can be found, mainly *Polyscias fulva*. On the steeper hills also small forest plantations of *Cupressus* sp. and *Eucalyptus* sp. can be found. The latter can also be found in the valley bottoms. On the most shallow soils (*Loudetia* series) are grasslands of *Loudetia kagerensis* mostly accompanied with *Exothea abyssinica*, the first being dominant. They are sometimes rich in herbs, but sometimes they only consists of the two grasses mentioned above. Economically their only use is for (hay) roof cover. On places where these are locally deeper shrub vegetation arises. The main species are *Maesa lanceolata*, *Pavetta abyssinica*, *Vernonia auriculifera* and *Cassia didymobotrya*.

Valley bottoms: The highest parts of the valley bottoms are also taken in cultivation mainly for maize and pastures (*Gekano* series). This also counts for the *Nyachogochogo* series, especially where they are drained. Where this is not so clump grasslands appear with typical swamp shrubs as *Sesbania Keniensis*, *Gomphocarpus semilunatus*, *Dissotus senegalesis* etc. On the *Kenyerere* and *Kenyamware* series we find reed and sedge swamps; on the latter there are sometimes plantations of *Eucalyptus*, as mentioned above, or sometimes even crops as maize (but then drained).

3.2 Weeds

Maize and horticultural crops: Weeding in maize is done by hoe, usually twice after emergence, but sometimes it is done, irregularly, only once. The main weed species are annuals, being *Ageratum conyzoides*, *Amaranthus* hybrids, *Conyza floribunda*, *Crassocephalum*, *Crepidioides*, *Galynzoga parviflora*, *Oxalis corniculata*, and *Tagetes minuta*. Of these *Galynzoga* forms the greatest problem because of its rapid appearance in great numbers. The most nuisance and difficult to remove

are those weeds which bear underground stolons and bulbils. These are *Digitaria scalarum* and *Commelia benghalesis*. Both have underground stems, but the latter also forms underground flowers producing seed. *Oxalis latifolia*, which possesses bulbils is not very common (more often in tea) but once established it is very difficult to remove due to the many bulbils.

Tea. When the plucking table is closed, weeds do not form a problem, because only grasses, which are then easy to remove, can sometimes grow through. During the settling phase more or less the same situation as above exists, also depending on the previous crop.

Pyrethrum: The same weeds as for maize, but the annuals are more important in the first years as a result of intensive weeding and crop rotation (usually it is preceded by maize in order to remove grasses like *Digitaria*.)

Pastures: Often the pastures are plated with *Pennisetum clandestinum* (Kikuyu grass). They all, however, tend to become grasslands in which again *Digitaria scalarum* is the main species. Besides *Pennisetum clandestinum* also *Cynodon dactylon* is to be found common, but seldom abundant. Other common species in the composition of these pastures are *Hydrocotyle mannii*, *Centella asiatica*, and *Conyza floribunda*. If neglected very much other weeds than *Conyza* appear, for example *Stephania abyssinica*, but also the bushed like *Cassia didymobotrya* etc. *Pteridium aquilinum*, the bracken fern, also tends to become a weed, especially in pastures on rather shallow soils.

4. Land-use in and around the Magombo detailed survey area.

When about a century ago, the Kitutu settled in this part of the Gusii-highlands, they found dense forests, which frustrated their pastoral way of life, but the rich forest-soils, once the forest was cleared, and the reliable rainfall expectation, ensured heavy yields of sorghum, millet, vegetables and bananas. During the last decades, the Kitutu farmers have been changing from food crops to more profitable export crops, such as pyrethrum and tea, and they are inclined to go on specialising in these enterprises.

Looking at the landscape, one can distinguish a pattern of narrow strips from the valley bottoms to the hill tops, separated and divided in small plots by hedges, often of Mauritian-thorn.

In "A precolonial history of the Gusii of Western Kenya" W.R. Ochieng explains these strip formed farms out of the site of the homesteads as follows:

In the past, as in the present day, the Gusii avoided the valleys. Generally flat ridge-tops were popular, as they enabled villagers to espy the activities of their enemies from a safe distance. But not many ridges had flat tops, so that the majority of homesteads, or villages, were sited along the flanks of the ridges. Apart from security reasons, the flat valley bottoms were also avoided because they tended to be unhealthy and prone to temperature inversion at night and in the morning hours. (cit. end).

Farm sizes in this part of East-Kitutu vary from 1 ha to 10 ha, with an average of 2 ha; the average number of persons per farm is 7-8.

The population density accounts ± 450 persons/km².

In the following table the composition of 45 bigger farms in the Western part of East-Kitutu is shown. These figures are extracted from loan application forms from the years 1971-'73; under "proposed", the areas to be realized after loan approval are given. Loans in most cases are applied for obtaining grade dairy cattle or to establish tea or pyrethrum, and in some cases to invest in Irish potatoes or in passion-fruit.

Table 1. Farm composition of 45 bigger farms in Western East-Kitutu.

	Present situation ('71-'73)			Proposed situation		
	Total (ha)	mean per farm (ha)	% of farm	Total (ha)	mean per farm (ha)	% of farm
Pyrethrum	20.03	0.445	11.4	33.60	0.745	19.2
Tea	21.77	0.486	12.5	36.63	0.813	20.9
Maize	48.10	1.068	27.5	26.61	0.591	15.2
Grazing	50.68	1.125	28.9	61.29	1.364	35.1
Bush Trees	23.09	0.514	13.2	5.61	0.125	3.2
Homestead	6.17	0.138	3.5	5.91	0.130	3.3
Other	5.25	0.113	3.0	5.44	0.121	3.1
TOTAL	175.09	3.889	100	175.09	3.889	100

Other crops in the Survey area are: vegetables, passion fruit, Irish potatoes, fruits (pineapples, bananas), sugarcane (for chewing), fruit trees (avocado, orange, loquat), beans and sweet potatoes.

A big part of the tree-areas consists of rather recently planted black wattle, eucalyptus and cypress plots or rows, mostly for use as fuel (in the form of charcoal), building-wood and fencing-poles.

Some of the grasslands in the area carry only a tough, thin low feeding value grass, most of the *Loudetia kagerensis* species, used for thatching. Sometimes *Imperata cylindrica* is cultivated for this purpose, but where possible these thatching-grasslands are improved to grazing-lands, because most of the new buildings are covered by corrugated steel roofs. Where improvement is impossible due to poor soil properties, the land is used as building site, e.g. for schools.

During a K.T.D.A.-survey in 1965/66 the average labour input on an average tea farm was determined by compiling the labour data from 12 farms around Magombo. The next table gives these data:

Table 2. Labour input (hours/year) per farm on domestic & farm work.

Item	farmer	other	women	children	hired	Total(1)	% of total
Tea	478	11	483	271	512	1630	22.3
Other cash crops (2)	114	6	245	240	41	516	7.0
Maize	117	22	370	260	77	715	9.8
Livestock (3)	402	2	360	887	32	1239	16.9
Wimbi	11	2	152	32	11	192	2.6
Other farm work (4)	223	7	298	131	91	686	9.4
Domestic (5)	116	11	1882	592	32	2337	32.0
% of total	20.0	0.8	52.0	16.5 (1)	10.9		

(1) In the totals, children are counted half (man = woman = 2 children)

(2) Mainly pyrethrum, also passion fruit

(3) Indigenous & grade cattle, sheep, goats, herding, spraying (dipping), milking and selling milk

(4) Includes work on vegetables, building & repairs, supervision, etc.

(5) Includes cooking, washing clothes, collecting water and firewood, etc.

For two-thirds of the survey area Magombo is the nearest market, for one-third this is Tombe. Both these markets are also centres for Farmers Cooperative societies, which handle some important products for the farmers.

Table: products handled by Magombo and Tombe FCS (1973)

	Milk			Pyrethrum		
	members	grade cows (est.)	production (kg)	members	production (kg dry fls)	pyrethrins %
Magombo	249	700(+300)	179,622	754	494,288	1.14
Tombe	380	760	125,743	2402	224,721	1.34

Tea is handled directly by the tea factories, supervision of the KTDA, and collected at least weekly, more often twice weekly, at a collecting centre, which is generally at a distance of not more than one mile from the farm.

5. Land evaluation

In this chapter we hope to contribute answers on questions about the valuation of the different soils for several rural purposes.

This land evaluation depends on land qualities like available water etc., but also on socio-economic factors, costs of produce and prices of products.

The land qualities do not change rapidly, but the socio-economic factors do. These changing socio-economic factors make it not useful to define the suitability of a given soil for a given crop system exact in terms of input and output. To evade this difficulties the soil units are valued for a certain crop and a defined management level. The required costs are estimated (1975) but not taken into account. In this way this land evaluation is only based on the land qualities, climate and soil, for three crops, maize, tea and pyrethrum. Also the valleys are described, which gives an direction of possible development of these valleys.

5.1 Method of classification

Each soil unit has specific land qualities, availability of water, nutrients, oxygen, risk of erosion and risk of inundation.

These qualities are graded and in this way each soil unit is characterized by its grading of land qualities and classified in order and class.

There are two orders: 1. the land is suitable for a specific crop,
2. the land is not suitable for that crop.

The number of classes is free.

The most limiting land quality determines order and class in this classification. This can be done more accurate but that will be a loss on clearness and reliability.

The results are visualized on the enclosed maps (App. 3, 4 and 5).

5.2. Maize suitability of the Magombo area

5.2.1 Introduction

The maize grown in the area is for the greater part hybrid maize 612 and 613^C and spotwise local maize derived from local or hybrid maize. These hybrids, introduced the last few years, need a long time from sowing till maturity, 6 up to 8 months.

Variety determining climatic data are - rainfall pattern
- temperature (altitude).

The Magombo area is suitable for the hybrids 612 and 613^C because of its altitude and relatively low temperature, and its rainfall pattern.

5.2.2 Maize growth determining factors

In the first instance potential maize growth is determined by climate and soil. These factors can be utilized more or less efficient, what we call farm management. Therefore it is necessary to define the suitability for a fixed management level.

Climate.

General description: see chapter "climate" in this report.

Temperatures at this altitude of 6000 ft. to 7000 ft. are unfavourable for short growing hybrids. Therefore it is not possible to have two yields of maize per year. The maize is sown in March and harvested about September. In this period the total rainfall amounts to about 1000 mm. The optimal temperature for maize growth is found to be near 26°C. The mean daily temperatures in the area are about 18°C (estimate). This results in suboptimal maize growth.

Clover (2) showed that the optimal rainfall for maize growth in tropical areas is between 625 mm and 875 mm during a 5 months growing period. Dagg made a closer approximation of the effect of rainfall on the maize yield by defining the crop-water requirement in terms of potential evaporation:

month:	March-April-May			-June-July		-August-Sept.-October		
% v.E _{pot} :	45	48	63	87	100	92	67	45

These figures, incorporated in the rainfall and evapotranspiration data of Nyanturubo, show a water shortage in July. This shortage can be supplied by the stored water in the soil. A soil with a storage capacity of 20mm/10 cm needs to be at least 40 cm deep rootable to supply the water shortage of 80 mm (Fig. 7).

In the other months there is a superfluous precipitation of at least 250 mm. This means low potential evaporation, and so water and potential evapotranspiration are not well balanced. The surplus of water also causes an extra cooling of soil and plant and promotes slower growth.

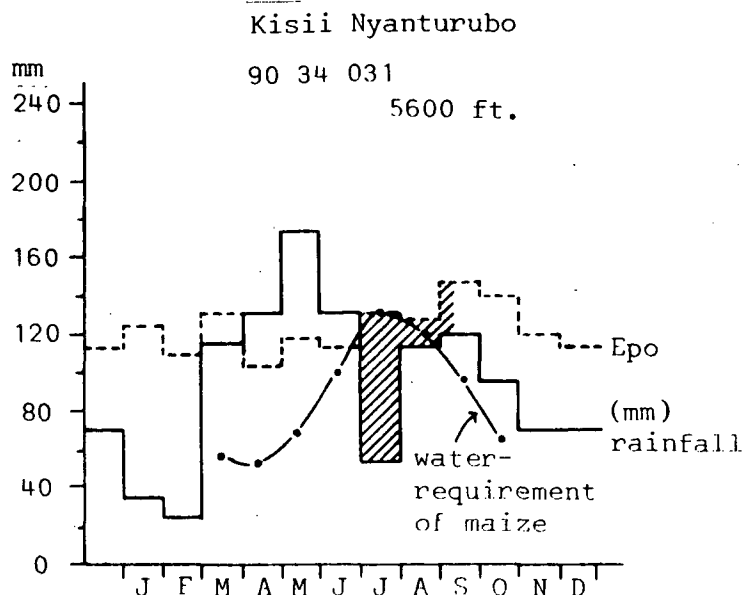


Fig. 7. Climate and water requirements for Maize (Nyanturubo).

The partition of the area in Tombe and Magombo, considering their different altitudes and corresponding difference in temperature of 1°C , is not as important as it is for e.g. Pyrethrum.

Taking all climatic conditions together we can say that they are not optimal for maize growth.

The potential yield of maize H 613^o is lower than it is in Kitale where H 613^c yielded more than 10,000 kg/ha incidentally.

Here the potential yield may be 7000 kg/ha. This is still a respectable yield (estimate).

Soil.

See the general chapter about the soils in this report.

See 'landqualities' in this chapter.

Farm management.

In order to compare and visualize the result of improved management with the present way of farming, two suitability maps for maize cultivation are compiled:

- for the growth of maize under the present conditions p)
- for the growth of maize under the conditions of improved management, marked with f),

the latter having consequence on related aspects as farmpower, labour-intensity and recurrent and non-recurrent costs.

The management will be defined by:

- crop rotation
- land preparation
- seeds, sowing system, fertilizer use
- weed control
- pests and diseases control.

Crop rotation

Maize is a very soil exhausting crop. A maize crop of 6270 kg requires: 168 kg N, 57 kg P_2O_5 and 135 kg K_2O .

It takes from the soil a large amount of nutrients, especially nitrogen and potassium, because of its high dry matter production. Besides this nutrient aspect there is a danger of damaging the soil under a maize crop by rainfall-erosion, because of the rather open growth of maize.

Crop rotation can meet these factors, because

- each crop has its specific nutrient demand; so there is a proportion utilization of nutrients by means of crop rotation;
- this rotation of crops is also a rotation of rootsystems. An alternation between shallow- and deep rooting crops cause a better utilization of the available nutrients in the soil;
- each crop needs a specific care for land preparation. Rootcrops for example need a deep soil preparation, this is beneficial also for other crops by the improved air-water relationship;
- by this alternating (time) land preparation the environment is not continuously favourable for the same weed species, thus oppressing excessive weed growth;
- a well chosen crop rotation, for example between maize and grasses, may maintain a good condition of the soil by means of the specific soil improving properties of certain crops.

p) At present there is nearly no crop rotation.

f) Proposed is a rotation between maize and pasture, possibly in combination with horticultural crops and root crops.

This rotation can best be done in the way of strip cropping.

Well performed strip cropping can be very beneficial in a point of view of soil conservation. Normally a soil covering (water absorbing) crop is planted above a less soil covering crop, thus preventing a big downwards water movement.

The difference in harvest time implies that the slope is never bare.

Land preparation

- p) At present the whole land preparation includes one two three times ploughing. This may be done by hand with the hoe (jembe) or with a simple wooden or iron plough for oxen. This preparation results in rough lumpy topsoil. This rough preparation counteracts erosion and slump. The weeds, however, remain living in the clods.
The land is ploughed in more or less at random directions (no contour ploughing).
- f) Proposed is to plough the land with improved ploughs for oxen, followed by harrowing. Little research is done considering the increase in erosion sensibility and decrease of organic matter.
It is, however, beneficial to prepare a seedbed as fine as possible under given conditions (considering erosion there are limitations, mainly depending on slope).
On slopes the land must be terraced if necessary.
Ploughing is carried out parallel to the contour lines.
- p+f) The valleys are supposed to be drained by means of simple, well suited ditches, prepared by the farmer himself.

Seeds and Sowing

- p) The seed used is H 612 or H 613^C, sown in holes made with a jembe. The holes form irregular rows, the distance between the rows varying per "shamba" from 70 - 110 cm and the plant distance in the rows varying from 50 - 90 cm. Two or three seeds of maize are sown in one hole, later on thinned up to one (or two) plants per hole.
The final number of plants per acre varies thus from 10,000 - 20,000 plants.
- f) Proposed is to sow more accurate on the
- prescribed depth; using something like a planting-stick (8 cm)
 - prescribed distance by using lines etc. (90 x 30 cm)
- In order to oppress erosion the rows are laid out parallel to the contour lines.
The final number of plants per acre will be \pm 15,000 plants.

Fertilizer use

- p) The use of fertilizer is not very well considered by lack of soil-fertility and crop response data.

"Chapa Ndege" and superphosphate are used in more or less at random quantities and often insufficient quantities.

- f) Proposed is to apply at least 50 kg Chapa Ndege per acre, awaiting a more accurate fertilizer-use advice, based on soil and leaf analyses and trial fields (see chapter fertility).
- *) Nothing is known about this expected beneficial effect.
Research on tillage will be necessary, for tillage may also damage the soil, if it is not done with proper methods and implements.
- &) Early planting (at the beginning of the rains) proved to be better than late planting.

Weed control

- p) Normally the fields are weeded three times.
(the weeding of the land preparation is not considered here).
The first weeding takes place about one month after sowing, the second weeding takes place about three months after sowing, and occasionally a third weeding is carried out when the maize starts flowering.
This weeding is done with a jembe. The soil is cutted in clods with the weed-remains inside. Because the clods are often not well turned, the weed roots do not dry out enough to die and the weeds start growing again soon after weeding.
- f) In a fine seed bed it is easier to weed without damaging the maize roots. Not a deep working (and maize root damaging) jembe, but a kind of hoe may be used.
In the case of a rough seed bed (slopes) the jembe is used and the clods are well turned to let weed roots dry out.

5.2.3. Other aspects related to farm management

Farmpower

The implements for the present level of farming are simple and cheap, being: - a jembe for planting, weeding and land preparation,

- a panga for clearing the land and harvesting the cobs,
- (here and there oxen and ploughs).

The implements for the proposed way of farming are somewhat more sophisticated, but can be constructed in the area itself.

- a planting stick to plant rapidly and on equal depth,
- a panga for clearing the land and harvesting cobs,
- well fed oxen,
- a good ox-plough and a harrow to make the topsoil fine granular,
- a hoe to control weed growth.

Labour intensity and capital intensity

The economic data on labour and capital intensity are estimates based on figures of the Kisii Smallholders Credit Scheme, but partly changed to our own insights.

The present and proposed farming systems do not need major capital input. The recurrent costs for the farmer are considered only.

The mean yield of maize under the present way of farming is estimated to be 3000 kg grain per ha, while the mean yield under the proposed way of farming is estimated to be 5000 kg grain per ha. Dr. R. Law (Kitale) reports from Kitale a possible maize yield of 11,000 kg grain per ha, while most farmers obtain a yield of less than 4500 kg per ha. Even when we bear in mind that the potential maize yield in Magombo is much lower than it is in Kitale (e.g. 25%), still a yield of about 8,000 kg grain per ha can be obtained in Magombo.

Table 1. Labour (figures in mandays per hectare)

	present p)	proposed f)
Land preparation	60	30
Planting and fertilizing	25	25
Weeding	75	75
Harvest	<u>30</u>	<u>40</u>
	190	170

Table 2. Recurrent costs (figures in KSh/ha).

	present p)	proposed f)
Land preparation	150	300
Seeds	50	50
Fertilizer	<u>300</u>	<u>600</u>
	500	950

Labour is not expressed in money, unless the farmer has to pay for it.

5.2.4. Major land qualities related to maize growth

These land qualities are used as a diagnostic criterion reflecting limitations to land suitability.

The considered land qualities are:

- availability of water
- availability of nutrients
- availability of oxygen for root growth
- risk of inundation
- erosion resistance.

These qualities are rated and quantified as far as possible.

Exact figures about crop responses to the land qualities in the area are not available, so that the valuation (grading) of the land qualities is subjective and based on experience.

The soil units are classified in suitability orders and groups in accordance with the grading of their land qualities.

Availability of water

As is shown in the part 'climate' the minimum storage of water in the soils to prevent serious drought suffered by maize during July has to be 80 mm. This corresponds with a minimum soil depth of 40-50 cm.

The general rule is: the deeper the soil, the better.

So soils with the rock occurring within 50 cm depth may suffer from drought and are low graded: marginal, series La.

The situation where roots cannot penetrate deeper than 100 cm is called suboptimal, series Mi and Nw - 2.

The situation where roots can penetrate deeper than 100 cm is called optimal, series Na, Mo and Nw - 1.

Availability of nutrients

See chapter "fertility". Summary:

- a) there are three main soil types: deep-, shallow- and valley bottom soils
- b) organic matter and nitrogen content of the leafs are closely related
- c) P-uptake by maize increases with pH
- d) P-sorption depends on parent material and clay content
- e) fertilizer application may be based on P-sorption, pH and crop.

The soil units are not classified according to these properties, but according to (among other properties) soil depth and organic matter. Therefore, only these two properties are used to grade the soil units with respect to fertility at this moment. There are not enough data to correlate the factors pH, P-sorption and base saturation and the soil units.

Regarding the main elements nitrogen and phosphorus (potassium is all over the area sufficiently available) we notice:

1. nitrogen supply depends on the organic matter content,
2. phosphorus supply depends on the (ignoring pH etc.) root volume, and thus on the extension and intension of the root system, (P-diffusion in these soils is probably negligible),
3. phosphorus supply is better and P-sorption is less near the parent rock in the rotten rock, thus in the shallow soils.

2. and 3. are opposites. The shallow soils are mostly found on very steep slopes, and are for this reason not suitable for maize growth.

Considering these facts the soils are graded according to:

- rootable depth
- organic matter content.

The valley bottom soils, with a totally different chemical and physical structure, are also classified according to their rootable depth.

Availability of oxygen

The red clay soils are very well structured. Their internal drainage is excellent.

The soils in the valleys are more or less poorly drained. They form in this way a sequence determined by their relative altitude.

Risk of inundation

This is closely related to the oxygen status of a certain soil type. During the rainy season the soil types Ke and Kw are inundated, also No may be inundated.

Erosion resistance

Slopes steeper than 15% show signs of erosion under the present way of farming. They lose their topsoil by rain splash.

This makes every soil on slopes steeper than 15% unsuitable for sustained use of the land in a maize rotation. Soil units with a slope between 8 and 15% are little affected, soil units with a slope between 0 and 8% are not clearly affected by erosion.

Much can be improved by contour ploughing, strip cropping and terracing (by putting a rim of maize stalks at the lower part of field), thus making slopes up to 30% suitable for maize cultivation.

5.2.5. Land qualities and soil units

The soil units are valuated according to the grading of their land qualities. These land qualities are graded according to their land quality factors (soil depth etc.).

Four grades are distinguished to identify the land qualities of the different soil units: 1 = high grade

2 = medium grade

3 = low grade

4 = very low grade (unsuitable for maize cultivation)

Resulting in next table:

Soil unit	Land quality				
	available water	available nutrients	available oxygen	risk of inundat.	erosion resistance
Na	1	1	1	1	-
Mo ₂	1	1	1	1	-
Nw ₂₋₁	1	1	1	1	-
Nw ₃₋₁	1	1	1	1	-
Mo ₁	1	2	1	1	-
Nw ₁ -1	1	2	1	1	-
Nw -2	2	2	1	1	-
Go/gl	1	2	2	1	-
Mi	2	3	1	1	-
La	3	3	1	1	-
Go/g,2,3	1	3	3	2	-
No	1	3	3	3	-
Ke + Kw	1	3	4	4	-
Slope A,B 0-8%					1
Slope C 8-15%					2
Slope D 15-30%					f) 3 p) 4
Slope E					4

The soil units are classified in orders and classes according to the grading of their land qualities, in such a way that the most limiting land quality determines the final classification in order and class of a certain soil unit.

The land quality "erosion resistance" is considered apart from the other land qualities for practical reasons.

Order 1 = suitable, with class 1 better than class 2 etc.

Order 3 = unsuitable, with class 1: presently unsuitable
with class 3: permanent unsuitable

5.2.6. Final classification

- Soil unit-	Slope	p) o r e s i s t a n c e		f) o r e s i s t a n c e	
		o r d e r	c l a s s	o r d e r	c l a s s
- Na, Mo ₂ , Nw ₂ -1, Nw ₃ -1	A,B	1.1		1.1	
	C	1.2		1.2	
	D	3.1		1.3	
	E	3.3		3.3	
- Mo ₁ , Nw ₁ -1, Nw-2, Go/g1	A,B	1.2		1.2	
	C	1.3		1.3	
	D	3.1		1.4	
	E	3.3		3.3	
- La, Mi, No Go/g2, Go/g3	A,B	1.3		1.3	
	C	1.4		1.4	
		3.1		1.5	
		3.3		3.3	
- Ke, Kw	nr	3.1		3.1	

5.3. Soil suitability for pyrethrum

5.3.1. Conditions for pyrethrum growing in the Magombo area

Crop management

Pyrethrum is generally planted at not too steep plots after a grain crop (maize, wimbi), or on a newly broken pasture. The crop is maintained for 2½-3 years. The spacing is 40-60 cm apart widespread or in rows 20-30 cm apart with an interrow distance of 60-70 cm, which gives 40,000 - 60,000 plants per hectare.

Most farmers weed about every 8-10 weeks, however trials at Keroka indicate that weeding once in 4 weeks should be more profitable. Picking of flowers is done every 2-3 weeks; once a year the old stems are removed.

Labour estimations from Bosuener (GAT-KSHCS) indicate that for an average yearly yield of 400 kg dry flowers per hectare in the first year 325 mandays/ha are needed; 50 for seedbed preparation, 50 for planting, 100 for weeding and 125 for picking; in the following years this becomes 100 for weeding, 200 for picking and 10 for maintenance, which totals 310 mandays/ha.

In 1973/74, the proceeds from 400 kg dry fls. were:

In Tombe, at 1.34% pyrethrins, 489 ct/kg: Ksh. 1956/=

In Magombo, at 1.14% pyrethrins, 417 ct/kg: Ksh 1668/=

Land preparation is mostly done by jembe, weeding ought to be done by forked jembe, but is often done by normal jembe.

Planting material can be bought from the pyrethrum board out of the Nyosia nursery, but is often purchased from neighbours or taken from own old fields.

Altitude and temperature

There is an inverse correlation between temperature and pyrethrins-content; a rise of 300 m generally gives a rise of 0.08% in pyrethrins content, up to 2500 m altitude. Earlier, the recommended lower limit for pyrethrum growing was 1950 m, but this was changed recently to 1650 m, with the introduction of adapted clones for lower altitudes. Bud initiation is influenced by the number of hours in which the temperature is below 15°C, this reduces production during the warm, dry periods of the year. To illustrate the effect of higher altitude, the pyrethrum production figures and pyrethrins-contents of the farmers cooperative societies in the surroundings of the sample are given.

(see next page)

Rainfall

Pyrethrum requires an evenly distributed rainfall of about 100 mm/month. When rainfall and air humidity are too high, the incidence of root rot increases and vegetative growth is vigorous, but when they are too low, risk of early overblowing increases and the tougher stems cause difficulties with picking.

Table 3. Pyrethrum yields and pyrethrins-contents of some farmers cooperative societies in and around Magombo area (for location, see map).

Village	1971/1972		1972/1973		1973/1974	
	% pyr.	tons	% pyr.	tons	% pyr.	tons
	cont.	dry fls.	cont.	dry fls.	cont.	dry fls.
Tinga (2010 m)	1.66	416	1.61	308	1.62	468
Tombe (2040 m)	1.35	287	1.28	176	1.34	225
Makairo (1900 m)	1.28	151	1.32	71	1.36	108
Rigoma (1860 m)	1.24	268	1.17	123	1.18	160
Magombo (1900 m)	1.19	84	1.12	45	1.14	49
Esani (1860 m)	1.16	167	1.11	96	1.14	110

Of course, rainfall can also give cooling, necessary for bud initiation. The yearly total amount of rainfall in the area is sufficient, about 1600 mm, but the distribution is not ideal in most of the years, probably in the area it is better at higher altitudes, where rainfall seems to be slightly higher.

5.3.2. Soil suitability for pyrethrum

Some considerations are given below, which have led to the rating of the land qualities which seem to be important for pyrethrum growing.

Availability of water

Pyrethrum requires an evenly distributed amount of water during the year, and because it is a shallow rooting crop, the water storage capacity, and thus the structure of the top 100 cm of the profile has to be very good.

Risk of erosion

The soil suffers so much from the repeated weeding and trampling in a pyrethrum field and the open structure of the crop, that a very good structure and little slope is required for pyrethrum growing. Soils with a high content of organic matter in the top 80 cm and a slope of less than 8% are most suitable, although structure has to be restored regularly by rotation with pasture to give sufficient resistance against erosion. Land under a slope of more than 30% must be considered absolutely unsuitable.

Availability of nutrients

A fairly rich soil is most suitable for pyrethrum growing, since a very rich soil, such as exists on old dwelling sites, causes excessive vegetative growth and increased incidence of root rot. However, a rather high level of available phosphorus seems to be beneficial. The lower pH limit for pyrethrum is 5.5.

Availability of oxygen

Because pyrethrum has rather weak and shallow rooting system, the top 50 cm of the soil has to be well aireated and well structured.

Risk of inundation

In wet soils the incidence of root rot, caused by fungi (*Sclerotinia* spp.) increases, so pyrethrum does not tolerate any waterlogging, and soils with impeded drainage are unsuitable for growing the crop. The groundwater level has to remain below 50 cm and the drainage of the soil has to be very good.

The following grades of availability or absence of risk can be distinguished:

- | | |
|------------------|--------------------|
| -1- High grade | -3- Low grade |
| -2- Medium grade | -4- Very low grade |

5.3.3. Rating of land qualities for pyrethrum growing of the different soil units.

Soil unit	Av. of water	Risk of erosion	Av. of nutrients	Av. of oxygen	Risk of inundation
Na	1	1	1	1	1
Mo ₂	1	1	1	1	1
Mo ₁	2	2	2	1	1
Nw ₃ ⁻²	1	1	1	1	1
Nw ₂ ⁻²	1	1	1	1	1
Nw ₂ ⁻¹	1	1	1	1	1
Nw ₁ ⁻²	2	2	2	2	1
Nw ₁ ⁻¹	2	2	2	2	1
Mi	3	2	3	3	1
La	4	2	3	4	2

Soil unit	Av. of water	Risk of erosion	Av. of nutrients	Av. of oxygen	Risk of inundation
Go/G ₁	1	1	1	1	2
Go/G ₂	1	1	1	2	3
No/G ₁	1	1	2	2	3
No/G ₂	1	1	2	3	3
Ke	1	1	3	3	4
Kw	1	1	4	4	4
<u>Slope</u>					
0-8%	-	1	-	-	-
8-15%	-	2	-	-	-
15-30%	-	3	-	-	-
30%	-	4	-	-	-

5.3.4. Final classification

Soil unit	Slope class	Classification
Order I. Suitable		
Na, Mo ₂ , Nw ₃ , Nw ₂	0-8% a,b	1.1.Optimal
Na, Mo ₂ , Nw ₃ , Nw ₂	8-15% c	1.2.Suboptimal
Mo ₁ , Nw ₁ , Go/G ₁	0-8% a,b	1.2. "
Na, Mo ₂ , Nw ₃ , Nw ₂	15-30% d	1.3.Marginal
Mo ₁ , Nw ₁ , Go/G ₁	8-15% c	1.3. "
Mi, Go/G ₂ , No	0-8% a,b	1.3. "
Order 3. Unsuitable		
Mo ₁ , Nw ₁	15-30% d	3.1.Presently Unsuitable
Mi	more than 8% b,c,d	3.1. " "
All Units	more than 30% e	3.3.Permanently "
La, Ke, Kw	0-65% a,b,c,d,e	3.3. " "

5.4. Soil suitability for tea growing

5.4.1. Conditions for tea growing in the Magombo area

Crop management

Nearly all tea in the Kisii-district originates from vegetatively propagated Assam-type cuttings, which are planted, according to KTDA-guidelines in rows at 150 x 90 cm (5 x 3 ft.) at a rate of 7,183

stumps/ha. According to modern Assam standards, planting can be done much denser, at a rate of 12,350 stumps/ha.

Tea comes in production 3 years after planting, full production is reached 8-10 years after planting. From tea planting figures one can conclude that the great majority of the Kitutu tea is not yet in full production. According to KTDA estimates for Kitutu (extra high rating), 3 year old tea produces 1500 kg green leaf/ha and 7 year old tea produces 6300 kg green leaf/ha.

In the first years much of the farmer's time is spent on weeding, which becomes less urgent when the plucking table is closed. Special attendance is given to couch grass (*Digitaria scalarum*) which should be eradicated before planting.

Table. 4. Tea planting details in Kitutu division, Kisii district.

Year:	1967	1968	1969	1970	1971	1972	1973	1974
Planted (ha)	124	114	146	100	218	401	266	125
running totals (ha)	434	548	694	794	1011	1412	1679	1803
% increase compared with previous year	40.0	26.2	26.7	14.3	27.4	39.6	18.9	7.4

The most important cultural practices on tea are pruning and tipping, to form and restore the picking table at a height of 50 cm.

The KTDA recommends a fine, hard plucking regime, which means that only two leaves and the bud are plucked to get a fine quality tea, and that plucking should be done quite regular; a plucking round of 5-7 days in the flush season and ± 10 days in the drier periods is recommended. During a 3 year plucking cycle, the table should rise about 30 cm under hard plucking. Any greater rise indicates under-plucking and loss of crop. The following labour profile points out that a greater part of labour spent on tea is used for planting practices, which can be understood from the year of the survey, which was in the starting period of the enormous increase of the Kisii tea area.

One of the determining factors for tea development is the infrastructure. The green leaf, once plucked, must reach the processing factory, in the case of Magombo area Nyankoba, the same day. The aim of the KTDA is, that there is a collecting centre, where leaf officers examine and collect green leaf at least weekly, within a mile distance

of every tea farmer. The connecting roads from the collecting centres to the factories must be all weather roads.

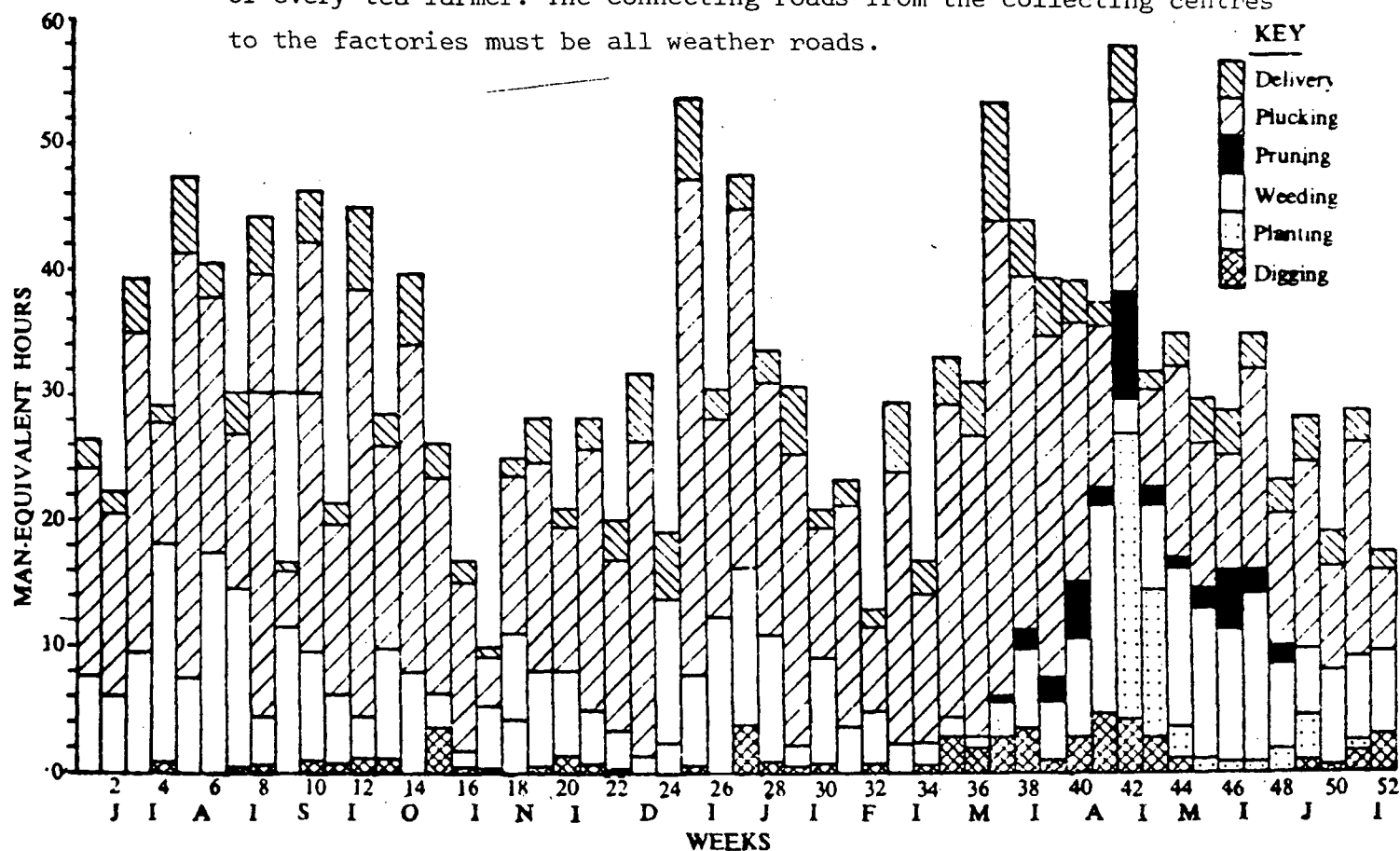


Fig. 8. Labour profile of tea operations on Kitutu farm (Average man-hour per week, 1965/1966)

Climatic conditions for tea

In Kenya, tea can be grown at altitudes between 1500 m and 2200 m.

Under 1500 m rainfall is in most cases inadequate and over 2200 m frost can occur, which is not tolerated by Assam tea.

Mean minimum temperatures should not be below 12°C and maxima not over 30°C. The best quality tea is produced in a cool climate, and so tea growing was prohibited under 1600 m until some years ago.

Tea requires at least 1200 mm rainfall/year, below this it is marginal.

The ideal rainfall should not fall below 50 mm/month.

An even distribution of rainfall and sunshine hours/day over the year causes an evenly distributed labour requirement and production.

The production statistics indicate a production decrease in February, March and April, though this decrease is not severe in Kitutu.

Hailstorms can cause much damage to tea, but in Kisii frequent heavy hailstorms do not occur in the somewhat higher area.

Tea receipt weights (tons green leaf), Kitutu, from file LCT/KIS, leaf collection reports, tea officer, ministry of agriculture, Kisii.

Month	year	1971	1972	1973	1974
1		169	265	417	374
2		123	238	346	163
3		43	211	388	218
4		28	270	247	383
5		156	233	274	372
6		126	248	309	386
7		120	245	264	394
8		190	243	279	375
9		178	230	239	382
10		240	303	469	398
11		194	349	360	486
12		223	353	360	436
total		1857	3187	3953	4367
mean/month		155	266	329	364
ha in prod.		548	694	794	1011
prod. kg/ha		3390	4592	4981	4318

Within Kisii district, Kitutu division (Central & East Kitutu) has the best climatic conditions for tea growing.

5.4.2. Soil suitability for tea

A number of land qualities are selected which are very important for the growth of tea in the Magombo Market area.

The land qualities are:

- availability of water
- availability of nutrients
- availability of oxygen
- risk of inundation
- risk of erosion

Each land quality can be subdivided into land quality factors, and a rating of the land qualities can be made by qualification of the factors.

The following grades of rating have been distinguished:

1	high grade	of availability/absence of risk				
2	medium grade	"	"	"	"	"
3	low grade	"	"	"	"	"
4	very low grade	"	"	"	"	"

5.4.3. Land qualities and rating of the land qualities

Availability of water

land quality factors: - groundwater level
- soil depth
- texture of the soil
- organic matter content
- amount of rainfall
- evapotranspiration

Soil depth, texture and organic matter content are important for the storage of water in the soil.

That the estimated annual transpiration is a good help for estimation of the annual yield will emphasize that water is very important for growing tea.

Because the differences in rainfall and evapotranspiration won't be very big and because no good figures were available, these factors have not been taken into account.

Rating-availability of water.

high grade: - groundwater level within 150 cm depth, or
- soil depth more than 150 cm.

medium grade:

- soils 100-150 cm deep
- soils 50-100 cm deep with a very high organic matter content.

low grade: - soils 50-100 cm deep

very low grade:

- soils which are very gravelly and/or with lithic contact within 50 cm depth.

Availability of nutrients

Land quality factors: - soil depth

- organic matter content
- amount of weatherable minerals
- CEC and base saturation
- texture

Soil depth is very important because tea roots can go down very deep; tea roots have been found on 14-16 m depth; only the availability of phosphorus is better in shallower soils.

Organic matter will function as a storage for nutrients, but under cultivation there will be a loss of organic matter due to mineralization and washing; for this reason mulching is very important.

Unital now there are not enough figures available of CEC and base saturation but probably they will be much higher than is estimated; for the rating they are not taking into account.

Rating availability of nutrients

- | | |
|-----------------|---|
| high grade: | - soils deeper than 150 cm and with humus depth more than 40 cm. |
| medium grade: | - soils deeper than 150 cm and with humus depth 0-40 cm. |
| | - clayey soils 50-150 cm deep and with humus depth about 80 cm or more. |
| | - soils with a very high organic matter content. |
| low grade: | - soils 50-150 cm deep with humus depth less than 40 cm. |
| | - soils which are very gravelly. |
| | - soils with a layer of ferric nodules within 150 cm. depth. |
| very low grade: | - soils with lithic contact within 50 cm depth. |

Availability of oxygen

Land quality factors depth of permanent reduced zone.

The depth of the permanent reduced zone is an indication which part is permanently waterlogged.

Rating availability of oxygen:

- | | |
|------------|---|
| high grade | - permanent reduced zone beginning deeper than 150 cm |
|------------|---|

- medium grade: - -----
low grade: - permanent reduced zone beginning 50-150 cm deep.
very low grade: - permanent reduced zone beginning within 50 cm depth.

Risk of inundation

land quality factor: - the middled highest groundwater table.
There tea roots need oxygen, inundation, even temporarily, will be the cause of severe damage.

Rating risk of unundation

- high grade: - groundwater table deeper than 150 cm.
medium grade: - groundwater table between 100 and 150 cm.
low grade: - groundwater table between 50 and 100 cm.
very low grade: - groundwater table within 50 cm depth.

Risk of erosion

land quality factor: - steepness of the slope.

Erosion can cause severe damage on steep slopes if the surface is not entirely covered with plants that will reduce the speed of raindrops and prevent surface washing. There tea in maturity will cover the surface entirely, the risk is not so serious like in the first four years of establishment. During the establishment period mulching and terracing on steep slopes will prevent erosion.

Rating risk of erosion

- high grade: -slope class a, b and c, slopes between 0 and 15%.
medium grade: - " " d and e, slopes between 15 and 65%.
low grade: -slopes steeper than 65% (do not occur).
very low grade: -----

5.4.4. Other land qualities which have not been rated.

Hail affecting plant growth.

Hail storms, mainly occurring in the wet season, can damage the leaves of tea and so reducing the prices.

Some places, such as hill tops, will be more affected by hail storms than others.

Climate

Although climatic differences are not big, the higher part near Tombe Market and Miriri Market will be cooler and will have a higher total rainfall than the lower part near Magombo market, but the impact of the climate within this area on the growth of tea is not known. (see chapter 1, climate).

5.4.5. The different soil units and the rating of their land qualities.

Soil unit	Av. of water	Av. of nutrients	Av. of oxygen	Risk of inundation	Risk of erosion
Na	1	1	1	1	-
Mo1	1	2	1	1	-
Mo2	1	1	1	1	-
Nw ₁ -1	2	3	1	1	-
Nw ₁ -2	3	3	1	1	-
Nw ₂ -1	2	2	1	1	-
Nw ₂ -2	3	2	1	1	-
Nw ₃ -2	2	2	1	1	-
Mi	3	3	1	1	-
La	4	4	1	1	-
Go/G1	1	3	3	2	-
Go/G2	1	3	3	3	-
No/G1	1	3	3	2	-
No/G2	1	3	3	3	-
Ke	1	2	4	4	-
Kw	1	2	4	4	-
slope class a, b and c					1
slope class d and e					2

1 = high grade

3 = low grade

2 = medium grade

4 = very low grade

5.4.6. Final classification.

Soil unit	Slope class	Classification
Na, Mo2	a,b,c (0-15%)	1.1
	d,e (15-65%)	1.2
Mo1, Nwe-1, Nw3-2	a,b,c,d,e	1.2
Nw1-1, Nw1-2, Nw2-2	a,b,c,d,e,	1.3
Mi,Go/G1,Go/G2, No/G1,No/G2		
Ke,Kw	-----	3.1
La	a,b,c,d,e	3.3

Explanation of the final classification:

order 1. suitable

1.1 optimal suitable

1.2 suboptimal suitable

1.3 marginal suitable

order 2. conditionally suitable. Not taken into account:

order 3. unsuitable

3.1 presently unsuitable

3.3 permanently unsuitable

5.5. Some land use proposals for the valley bottom.

Introduction: In the area the valley bottoms are all more or less unsuitable for crops like tea, pyrethrum, maize etc. This has been shown in the discussion of suitability of the different soils with regard to these crops (see also suitability maps). Because of the land shortage some remarks on making these valley bottoms (more) productive seems to be wise, although one should bear in mind that it is not the solution to the land shortage problem.

The main reason for the unsuitability for the crops mentioned above is their poor drainage property. Nevertheless there is graduation, that is there are soils better drained (Gekano series) to very poorly drained soils (Kenyerere and Kenyamware series). The better drained soils are usually taken in production already, both for arable and pasture lands. Pastures are indeed a possibility, also for the lesser drained soils, and this will be discussed more thoroughly than the

other mentioned possibilities: marginal forestry, poultry, fish ponds, and horticultural crops.

Permanent pastures. Pastures in the valley bottoms can be seen as additional to the pastures on the hillsides. The pastures in the valley bottoms can be permanent, whereas they are rotational on the hillsides. For pastures in the valley bottoms artificial drainage has to be carried out. This can be done by digging ditches on the transition valley bottom-hillside, in order to catch seepage water, and ditches across the valley to the streams. It may also be necessary to build some dams against flooding in the rainy seasons.

Produce. The produce of this utilization type is milk. Since it requires a high know how and management (incl. food concentrates and medical care) for grade cows to be more profitable than local cattle, the assumption is made that local cattle is used in this system. The milk yield can be 750 ltr./cow which equals 1875 ltr./ha, as it is possible to keep one local cow per acre (yields per annum). For this the management must be correct (eq. optimal calving interval = \pm 16 months, also the habit of keeping many bulls must change if this possible quantity of milk is desired). The pastures must be improved by planting grasses like Kikuyu grass (*Pennisetum clandestinum*), bush clearing and drainage systems must be well enough to keep up the grass composition.

Capital intensity: The minor improvements necessary for the produce will lead to non recurring investments. Digging ditches can be done by the farmer. This requires simple equipment and time. There are no figures which can estimate these costs. The recurring costs include minerals (salts), veterinary costs, and the depreciation of cattle. In 1973 these were in the Kisii district:

Depreciation of cattle (over 8 years)	37.50
Veterinary costs	30.00
Minerals	30.00
Diverse investments	15.00
	<hr/>
	112.50/acre = 270.0/ha.

Farm power: entirely manual.

Labour intensity: An estimation of the labour intensity for this

utilization type is given by the Land and Farm Management Division, Small Holder Credit Scheme Kisii. Their estimation is for this 50 mandays per year per acre = 125 md/year/ha. These do not include labour necessary for minor improvements.

Technical know how level: In this utilization type with local cows a know how level is chosen which is regarded as a high level for Kisii (see produce). Know how about the drainage system must be given, but is presently already partially present because some farmers have already started this system.

Land qualities: As stated before different soil types in the valley bottoms have different properties. Land qualities of importance are:

- a) Oxygen availability, is the natural drainage well enough for the utilization system, is artificial drainage possible to the degree necessary for this system?
- b) Flood hazard, is there risk of inundation during the rainy seasons, and if so can the building of dams help?
- c) Subsistence, this may occur on the peaty soils.
- d) Treading down of the pasture by cattle, this may also occur on the peaty soils. If this occurs then grass can be cut and given to the cattle.
- e) Nutrients, this is not discussed here, firstly because there are no figures, and secondly because it is likely that it is sufficient even on the Histosols, since they appear to be of a mesotrophical type.

Soil suitability: For the main 4 land qualities the following grades have been constructed:

oxygen availability	Flood hazard
1 optimal (=high grade)	1 Never flooding (=high grade)
2 suboptimal (=medium grade)	2 seldom flooding (=medium grade)
3 marginal (=low grade)	3 regular flooding (=low grade)
4 extremely marginal (=very low grade)	4 at least 1x a year flooding (= very low grade)

Soil subsistence

- 1 no risk (= high grade)
- 2 moderate risk top layer only
(=medium grade)
- 3 moderate risk (=low grade)
- 4 high risk (=very low grade)

Treading down

- 1 no risk (= high grade)
- 2 low risk (=medium grade)
- 3 moderate risk (=low grade)
- 4 high risk (= very low grade)

Grading of the soils:

a) present situation

Soil unit	Land quality		Flood hazard	Subsistence	Treading down	Suitability code
	Oxygen availability					
2/g1	1		1	1		1.1
2/g2	2		1	1		1.2
3/g1	3		1	1	2	1.3
3/g2	4		2	1	2	3
4	4		4	1	3	3
5	4		4	1	4	3

b) situation after minor improvements (drainage and dams):

Soil unit	Land quality		Flood hazard	Subsistence	Treading down	Suitability code
	Oxygen availability					
2/g1	1		1	1		1.1
2/g2	1		1	1		1.1
3/g1	1		1	1		1.1
3/g2	1		1	1		1.1
4	3		1	2	3	1.3
5	4		1	4	4	3

Evaluation of the grading:

For pastures the soil series 2 and 3 (Gekano and Nyachogochogo series) are suitable, but for 2/g2 and 3 the minor improvements are necessary. Soil series 4 (Kenyerere series) are marginal suitable, because it is not well possible to drain these only by ditches. Also cattle can not graze directly on it because of the treading problem. Grass can be cut though to give it to cattle. This soil could be made suitable with more advanced technical drainage systems, by pumps and drainage pipes,

but they are too expensive for the utilization type, and therefore it is not discussed. The soil series 5 (Kenyamware series) will stay unsuitable because of the subsistence risk, so that in the rainy seasons these soils will be badly drained again, after subsistence.

II Marginal forestry

Except for pastures there are also other possible utilization systems for the valley bottoms. They will be discussed more briefly. First forestry is mentioned because of the demand for local fuel. There are already some Eucalyptus plantations on these soils. Except for the fast growth of these trees another advantage is their water consumption, so that drainage is less a problem. Subsistence (and oxidation) risk prevails though on the peaty soils.

III Poultry

Another possibility for these valley bottoms is the practice of poultry. This though is not possible for chicken, because of their susceptibility to diseases in these marshy areas, but it is possible for birds like ducks etc. Extension must be given on the know how. This utilization type can be practiced on the wettest soil types where drainage is difficult.

IV Fishponds

This is also a thought for the wettest soils, because, obviously there is enough water. For the construction of these, civil engineering studies will be necessary, and also extension. It could be combined with poultry.

V Horticultural crops

Growing of horticultural crops (as vegetables) can be done on those soils which are or can be drained to some extent. Thus roughly spoken the cultivation is more or less possible on those soils where pastures were also possible. The advantage is the higher labour intensity and a more varied production, especially when it is combined with pasture.

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Appendix 1

Profile no. 1: : Nyachogochogo series

Classification : Soil Taxonomy 1970: very fine clayey, kaolinitic,
isothermic, aeric Tropaquept.
FAO 1970: fluvic Gleysol

Location : sheet 130/2 Kisii, 714.3 E, 9928.8 N

Elevation : 1858 m

Described by : H. Scholten, K. van der Torren, S. ter Maat

Landform : medium high part of a nearly flat riverplain
surrounding country hilly

Microtopography : small mounds, probably vegetation rests or biological
activity

Geology : Bukoban

Slope : nearly flat, gradient 1%

Landuse : grazing land, gum tree, maize, (roof deck) grass

Vegetation : 85% grasses, 15% herbs (commelina etc.), few shrubs,
cyperaceae included in grasses, small species, less than 10%

Climate : isothermic

Parent material : alluvial clayey material

Drainage : poorly drained

Moisture : wet throughout the profile

Groundwater : 55 cm below the surface

Root distribution : well distributed throughout the profile

Effective soil
depth : more than 140 cm

Human influence : drained, by means of small ditches.

Soil Profile:

A1,1 0 - 13 cm : Dark greyish yellow (10 YR 3/1) moist; clay; moderate fine
to very fine subangular blocky; friable moist, slightly
sticky, slightly plastic when wet; many fine pores, few very
fine pores; clear smooth boundary.

A1,2 13-33 cm : Light greyish yellow (10 YR 5/1) moist; silty clay; common
fine distinct, light yellowish brown (10 YR 5/8) iron
mottles; moderate fine angular blocky; firm moist, slightly
sticky, slightly plastic when wet; patchy thick clay cutans in
pores and along root pores; common fine to very fine and
few medium pores; gradual smooth boundary.

- A1,3 33-50 cm : Light greyish yellow (10 YR 5/1) moist; silty clay; many fine distinct, light yellowish brown (10 YR 5/8) iron mottles; moderate medium prismatic breaking into fine angular blocky; firm moist, sticky, slightly plastic when wet; continuous thin clay cutans in root pores; common fine pores; few little stones; clear smooth boundary.
- B2,1 50-65 cm : Light greyish yellow (10 YR 5/1) moist; silty clay; moderate fine angular blocky; firm moist, sticky, slightly plastic when wet; continuous thin clay cutans in root pores; common fine thick; clear smooth boundary.
- B2,2 65-78 cm : Light greyish yellow (10 YR 5/2) moist; clay; firm moist, slightly sticky, slightly plastic when wet; common medium distinct light yellowish brown (10 YR 5/8) iron mottles; moderate very coarse angular blocky breaking into medium angular blocky; continuous thick clay and iron-manganese cutans in root pores; few fine pores; very many, small iron nodules; clear smooth boundary.
- B2,3 78-87 cm : Light yellowish brown (10 YR 5/8) moist; silty clay; many coarse distinct light yellowish brown iron mottles; moderate fine angular blocky; very firm moist, slightly sticky, slightly plastic when wet; continuous thick clay and iron-manganese cutans in root pores; few fine pores; dominant, few large and many small, hard, iron-manganese concretions; ironstone; clear smooth boundary.
- B2b1 87-100 cm : Light greyish yellow (10 YR 5/2) moist; clay; many coarse distinct, light yellowish brown (10 YR 5/8) iron mottles; common coarse prominent mottling caused by reduction along roots; weak fine angular blocky; sticky, plastic when wet; continuous thick clay and iron-manganese cutans in root pores; few fine pores; slickensides; clear wavy boundary. note: montmorillonite clay.
- B2b2 100 + cm : Light greyish yellow (10 YR 5/3) moist, montmorillonite clay; common coarse prominent light yellowish brown (10 YR 5/8) iron mottles; weak coarse prismatic with

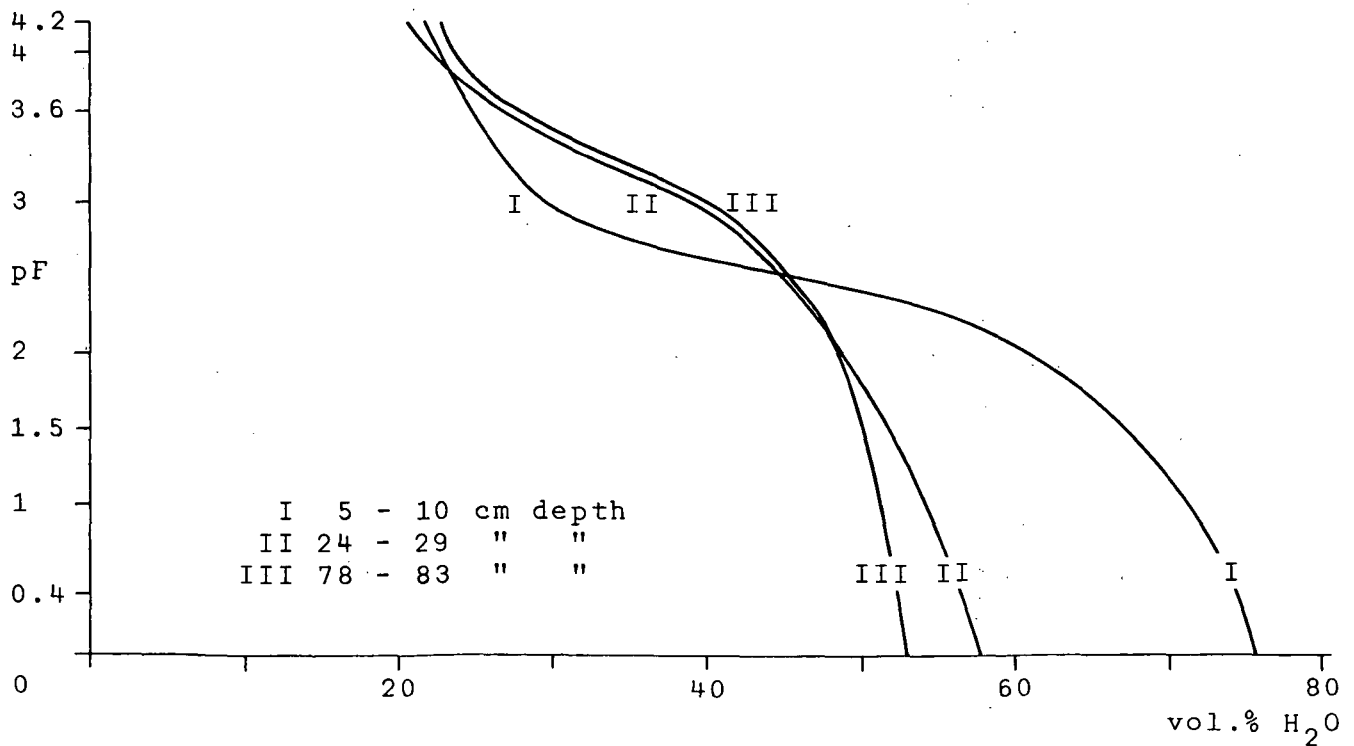
slickensides; sitcky, very plastic when wet;
continuous thick clay and iron-manganese cutans
in root pores; few fine pores.

Core samples : 5-10, 24-29, 78-83 cm.

Analytical data profil 1. Nyachogochogo series:

Depth (cm)	B.D. (g/cm ³)	org C. (weight %)	org C. (vol.%)
5-10	0.69	4.6	3.2
24-29	1.05	2.2	2.3
78-83	1.42	0.3	0.4

pF-curves



Profile no. 2 : Gekano Series

Classification : Soil Taxonomy 1970: very fine-fine clayey, kaolinitic,
isothermic, aeric Dystropept.
FAO 1970: gleyic Cambisol.

Location : Sheet 130/2 Kisii

Coordinates : 714.3 E, 9928.9 N photo IV-394

Elevation : 1890 m

Physiography : transition strip valley bottom-hill, about 20 m width

Described by : H. Scholten, S. ter Maat, K. van der Torren

Landform : hilly

Slope : 2%

Geology : Bukoban

Landuse : grazing land, timber (Black Wattle)

Vegetation : 75% grasses, most Kikuyu and Bermuda grass, 25% herbs;
common black wattle trees and shrubs

Climate : isothermic

Parent material : alluvial kaolinitic material

Drainage : moderately to imperfectly drained

Moisture : moist

Groundwater : 110 cm below the surface

Distribution : very well distributed till 75 cm, few roots below 75 cm

Effective soil depth : more than 150 cm

Infiltration : rapid

Soil fauna : termites in the A1

Human influence : fired clay and charcoal in the A1

Soil profile:

A1,1 0-30 cm : Dark brown (7.5 YR 3/2) moist; silty clay; moderate fine subangular blocky; very friable moist, slightly sticky, slightly plastic when wet; common fine and few medium pores; slightly gravelly; places of pottery and charcoal; clear wavy boundary.

A1,2 30-47 cm : Essentially similar to horizon above, but with few fine distinct iron mottles and very few small iron-manganese concretions; clear wavy boundary.

- B2,1 47-75 cm : Reddish brown (5 YR 4/4) moist; silty clay; moderate very fine angular blocky; friable moist, slightly sticky, slightly plastic when wet; patchy thin clay-iron-manganese cutans on concretions; many fine faint iron mottles; many very fine and common fine pores; slightly gravelly; clear wavy boundary.
- B2,2 75-110 cm : Yellowish brown (10 5/4); moist silty clay with discontinuous vesicular ironstone pan; moderate very fine angular blocky; few very fine and fine pores; many small iron and manganese concretions; abrupt wavy boundary.
- IIB 110 + cm : Brown (7.5 YR 5/4) moist; montmorillonite clay; many medium faint strong brown mottles; very coarse strong angular blocky breaking into strong fine angular blocky; slightly sticky, very plastic when wet; continuous thick clay cutans; intersected slickensides; common very fine and fine pores.

Remarks: Soil occurring on the transition hill-valley and on higher parts of valley bottoms, consisting of kaolinitic clay laying on montmorillonitic clay with an abrupt boundary on a depth of 50-100 cm.

Mostly an ironstone pan is present on the transition kaolinitic-montmorillonitic clay. The structure of the upper horizons is good, the structure of the lower montmorillonitic horizons is very dense and this clay will be wet and bad aerated the greater part of the year.

Profile no. 3	: Magombo series
Classification	: Soil Taxonomy 1970: very fine clayey, kaolinitic isothermic Palehumult FAO 1970: humic Nitosol
Location	: sheet 130/2 Kisii
Coordinates	: 714.8 E., 9928.5 N., near Nyanchochogo school
Elevation	: 1924 m
Described by	: J.H.M. Scholten
Physiography	: on the middle of a convex hill slope
Meso relief	: sloping
Landform	: hilly
Slope	: 12%
Geology	: Bukoban
Landuse	: pasture
Vegetation	: 90% Kikuyu and Bermuda grass
Climate	: isothermic
Parent material	: andesite
Int. drainage	: well drained
Moistness	: moist
Infiltration	: rapid
Groundwater	: -
Soil depth	: much more than 2 m
Distribution	: well distributed throughout the profile
Soil fauna	: few krotovinas
Human influence	: fried clay and charcoal on 5-24 cm depth.

Soil Profile:

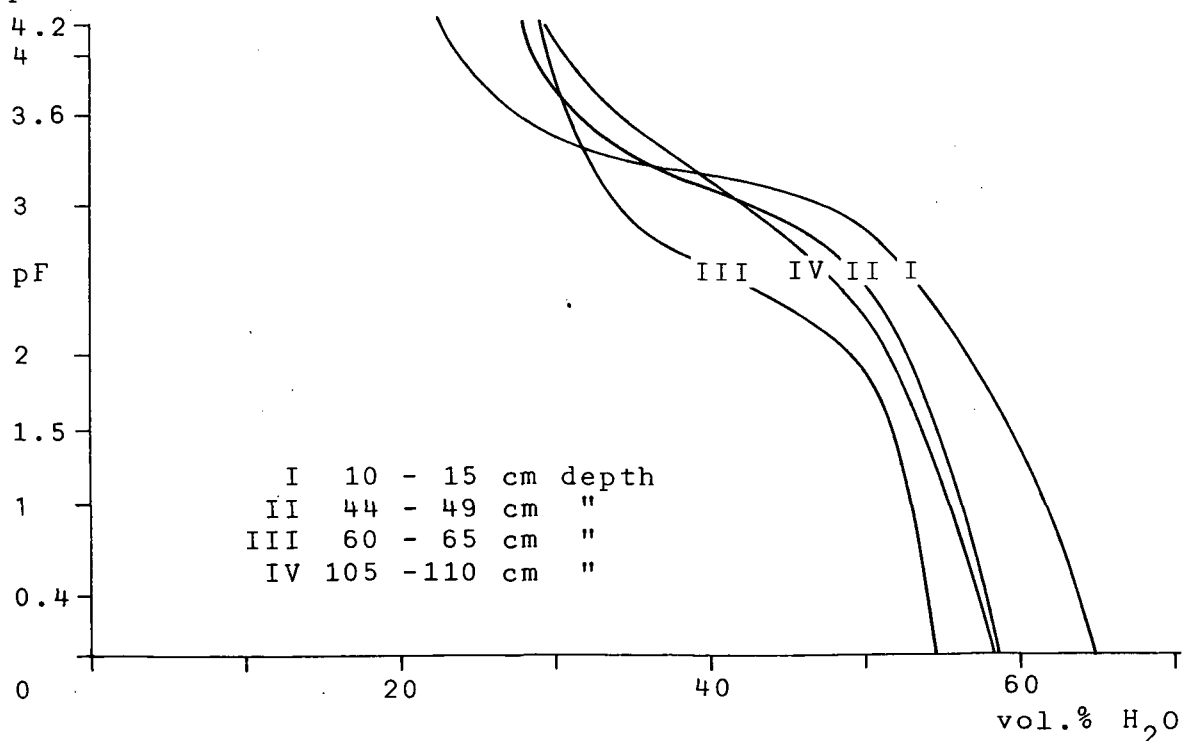
A1,1	0-5 cm	:	Dark reddish brown (5 YR 3/2) moist; very fine clay; moderate fine subangular blocky, friable moist, slightly sticky, slightly plastic when wet; many very fine, fine and medium pores; abrupt smooth boundary.
A1,2	5-24 cm	:	Dark reddish brown (5 YR 3/2) moist; very fine clay; moderate fine subangular blocky; friable moist, slightly sticky, slightly plastic when wet; many very fine, fine and medium pores; friable clay and charcoal rests; gradual smooth boundary

- B1 24-49 cm : Dark reddish brown (5 YR 3/3) moist; very fine clay moderate very fine subangular blocky; friable moist, slightly sticky, slightly plastic when wet; continuous moderately thick clay-organic matter cutans; many fine and very fine pores; occasionally krotovinas about 10 cm diameter with soil colour 5 YR 3/2; diffuse smooth boundary.
- B2t1 49-75 cm : Dark reddish brown (5 YR 3/4) moist; very fine clay; moderate very fine angular blocky; friable moist, slightly sticky, slightly plastic when wet; continuous moderately thick clay cutans; common fine and many very fine pores; diffuse smooth boundary.
- B2t2 75-150 cm : Dark yellowish red (5 YR 3/6) moist; very fine clay; moderate very fine angular blocky; very friable moist; slightly sticky and slightly plastic when wet; patchy moderately thick clay cutans; few fine and many very fine pores.

Analytical data profil 3, Magombo series.

Depth (cm)	B.D. (g/cm ³)	org C (weight%)	org C (vol.%)
10-15	1.03	4.0	4.2
44-49	0.95	2.1	2.0

pF-curves



Profile no. 4 : Magombo series

Classification : Soil Taxonomy 1970: very fine clayey kaolinitic isothermic
Palehumult
FAO 1970: humic Nitosol

Location : sheet 130/2 Kisii

Coordinates : 714.2 E., 9928.4 N. photo IV-393

Elevation : 1905 m

Physiography : lower part of a linear slope

Slope gradient : 20%

Landform : hilly

Geology : Bukoban

Landuse : pasture with Eucalyptus and Cypress trees

Vegetation : 85% grasses, mainly Kikuyu grass; 15% herbs

Erosion : very slight sheet erosion

Climate : isothermic

Parent material : andesite

Drainage : well drained

Infiltration : rapid

Moistness : moist

Groundwater : -

Distribution : well distributed throughout the profile

Soil depth : much more than 2 m

H. influences : 0-30 cm friable clay and charcoal.

Soil profile:

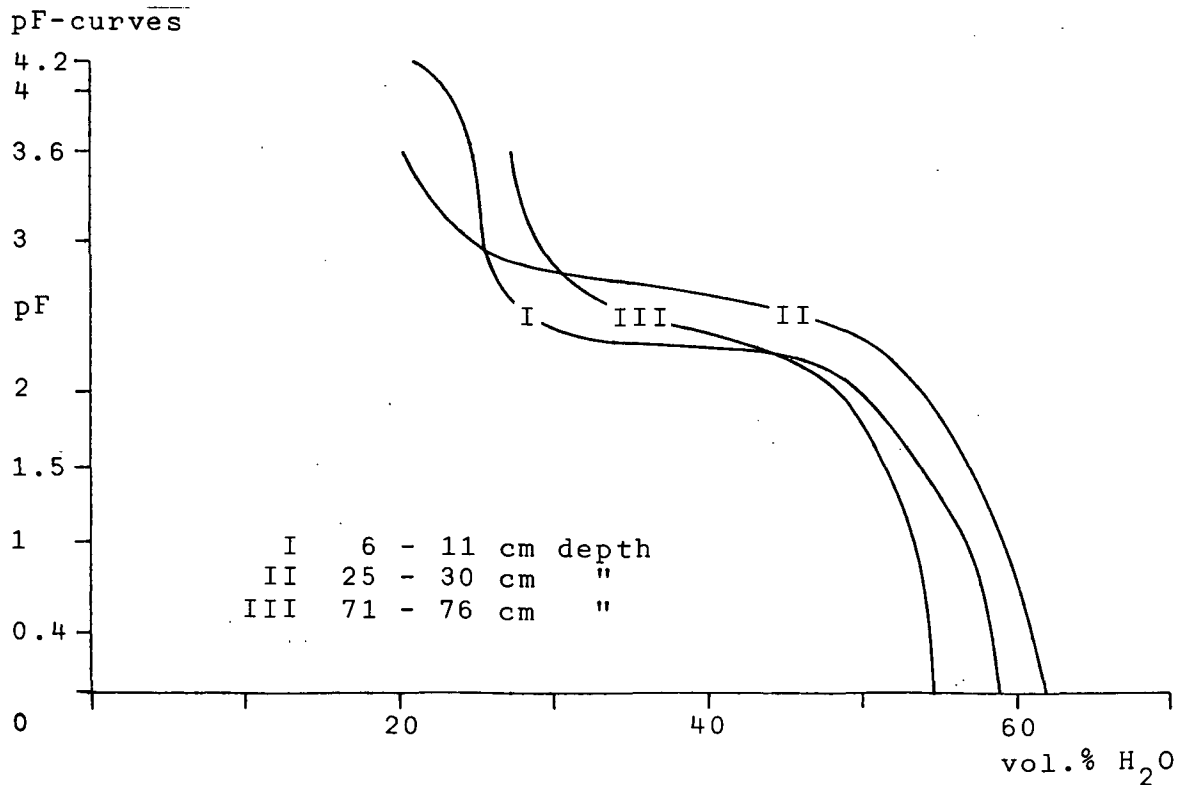
A1 0-15 cm : Dark reddish brown (5 YR 3/3) moist; very fine clay; moderate coarse subangular blocky breaking into fine angular blocky; friable moist, sticky and slightly plastic when wet; patchy thin clay-organic matter cutans; many fine medium biopores; many fine and medium roots; occasionally friable clay and charcoal; gradual smooth boundary.

B1 15-55 cm : Dark reddish brown (5 YR 3/4 moist); very fine clay; moderate very fine angular blocky; friable moist, sticky and slightly plastic when wet; broken, moderately thick clay cutans; many fine and medium biopores; common fine roots; gradual boundary.

B2t 55-150 cm : Yellowish reddish brown (5 YR 3/6); moist; very fine clay; moderate fine subangular blocky; friable moist, slightly sticky slightly plastic when wet; continuous moderately thick clay cutans; common fine and few medium biopores, few fine roots.

Analytical data profile 4, Magombo series:

Depth (cm)	B.D. (g/cm ³)
6-11	0.93
25-30	0.88
71-76	1.00



Profile no. 5 : Nyambaria series
Classification : Soil Taxonomy 1970: very fine clayey, kaolinitic, isothermic,
cumulic Palehumult
FAO 1970: humic Nitosol, deep humus phase
Location : sheet 130/2 Kisii
Coordinates : 713.5 E., 9927.6 N., photo: IV-394
Elevation : 1913 m
Physiography : nearly flat depression between hilltops
Landform : hilly
Slope : linear, 250 m, gradient: 1%
Geology : Bukoban
Landuse : pyrethrum and maize
Vegetation : 60% herbs (Mex. Marigold, div. compositae), 40% grasses
(eluesine Dough grass) trees: gum tree, Black Wattle
Climate : isothermic
Parent material : andesite
Drainage : well drained
Infiltration : rapid
Moistness : moist
Groundwater :
Distribution : well distributed throughout the profile to 2 m depth.
Soil fauna : termites, ants, beetles
Effectiveness : much more than 2 m
Human influence : plough layer.

Soil profile:

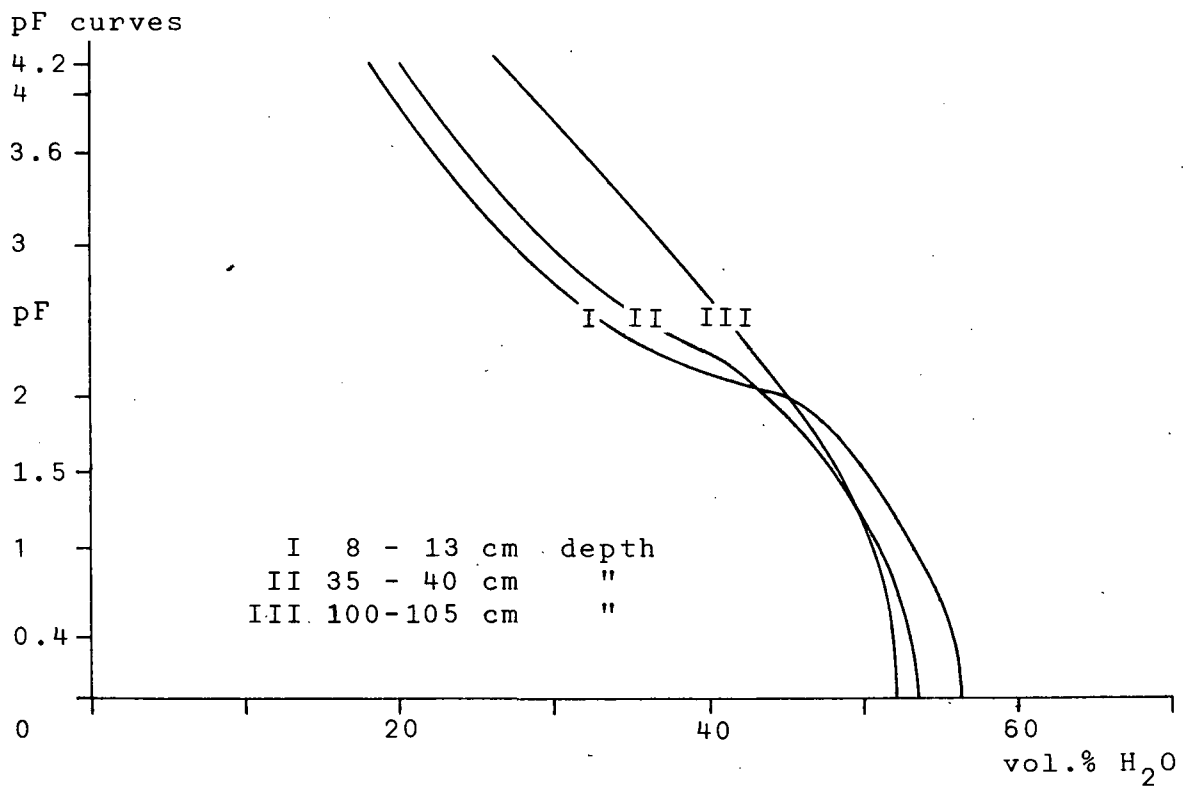
Ap 0-17 cm : Dark brown (7.5 YR 3/2) moist; very fine clay; moderate
very fine subangular blocky; very friable moist, slightly
sticky, slightly plastic when wet; many very fine, fine and
medium biopores; occasionally fried clay and charcoal;
abrupt wavy boundary.

A3 17-60 cm : Dark brown (7.5 YR 3/2) moist; very fine clay; strong very
fine subangular blocky; friable moist, slightly sticky
slightly plastic when wet; continuous thin clay-organic
matter cutans; many very fine and fine few medium biopores;
occasionally fried clay; charcoal and krotovinas with 5 cm
diameter; clear smooth boundary.

- B2,1 60-85 cm : Dark reddish brown (5 YR 3/3) moist; very fine clay; moderate very fine subangular blocky; friable moist, slightly sticky, slightly plastic when wet; continuous thin clay-organic matter cutans; many very fine, common fine and few medium biopores: occasionally krotovinas with 10 cm diameter; gradual smooth boundary.
- B2,2 85-120 cm : Dark reddish brown (5 YR 3/4) moist; very fine clay; moderate fine angular blocky; friable moist, slightly sticky, slightly plastic when wet; continuous thin clay-organic matter cutans; many very fine, common fine and few medium biopores; clear wavy boundary.
- B2,3 120-180 cm : Dark reddish brown (5 YR 3/4) moist; very fine clay; moderate fine subangular blocky; friable moist, slightly sticky, slightly plastic when wet; continuous moderately thick clay-organic matter cutans; many very fine, common fine biopores; about 50% iron-manganese nodules 5-50 mm diameter; clear wavy boundary.
- B2,4 180-210 cm : Dark brown (5 YR 3/3) moist; very fine clay; strong very fine angular blocky; very firm moist; slightly sticky, slightly plastic when wet; continuous thick clay-iron cutans; many coarse distinct yellowish mottles; many very fine few fine biopores; about 60% iron-manganese nodules 5-10 cm diameter; occasionally weathered stones; gradual wavy boundary.
- B2,5 210 + cm : Dark yellowish red (5 YR 3/5 moist); very fine clay; strong fine angular blocky; firm moist, slightly sticky, slightly plastic when wet; continuous thick clay-iron cutans; common very fine. few fine biopores; patchy coatings of iron on pores.

Analytical data profile 5, Nyambaria series

Depth (cm)	B.D. (g/cm ³)
8-13	0.78
35-40	1.00
100-105	1.12



Profile no. 6 : Kenyaware Series
Classification : Soil Taxonomy 1970: isothermic Tropofibrist
FAO 1970: eutric Histosol
Location : sheet 130/2 Kisii,
Coordinates : 714.3 E., 9928.8 N., photo IV-394
Elevation : 1857 m
Physiography : lower part of nearly flat riverplain
Landform : hilly
Slope : 2%
Described by : H. Scholten, K. van der Torren, S. ter Maat 4-9-1974
Geology : Bukoban
Vegetation : papyrus swamp
Land use : sometimes grazed by goats
Climate : isothermic
Parent material : organic matter, developed on alluvial clay
Drainage : very poorly drained
Infiltration : rapid
Moistness : wet
Groundwater : 50 cm
Distribution : well distributed from 0 to 40 cm
Soil depth : 50 cm
Human influence : beginning of drainage by means of ditches and in the
surrounding planting of Eucalyptus trees.

Soil profile:

A00 0-6 cm : Dark reddish brown (5 YR 3/3) moist; plant remains;
loose, friable, clear smooth boundary.
Q2 6-30 cm : Very dark greyish brown (10 YR 2/2) moist; peat; weak
medium subangular blocky; non sticky, slightly plastic,
friable moist; many micro to medium pores; abrupt smooth
boundary.
C1,1 30-65 cm : Very dark greyish yellow (2.5 YR 2/0) moist and multi-
coloured; peat; weak medium subangular blocky friable
moist, non sticky slightly plastic wet; few micro to
medium pores; abrupt smooth boundary.

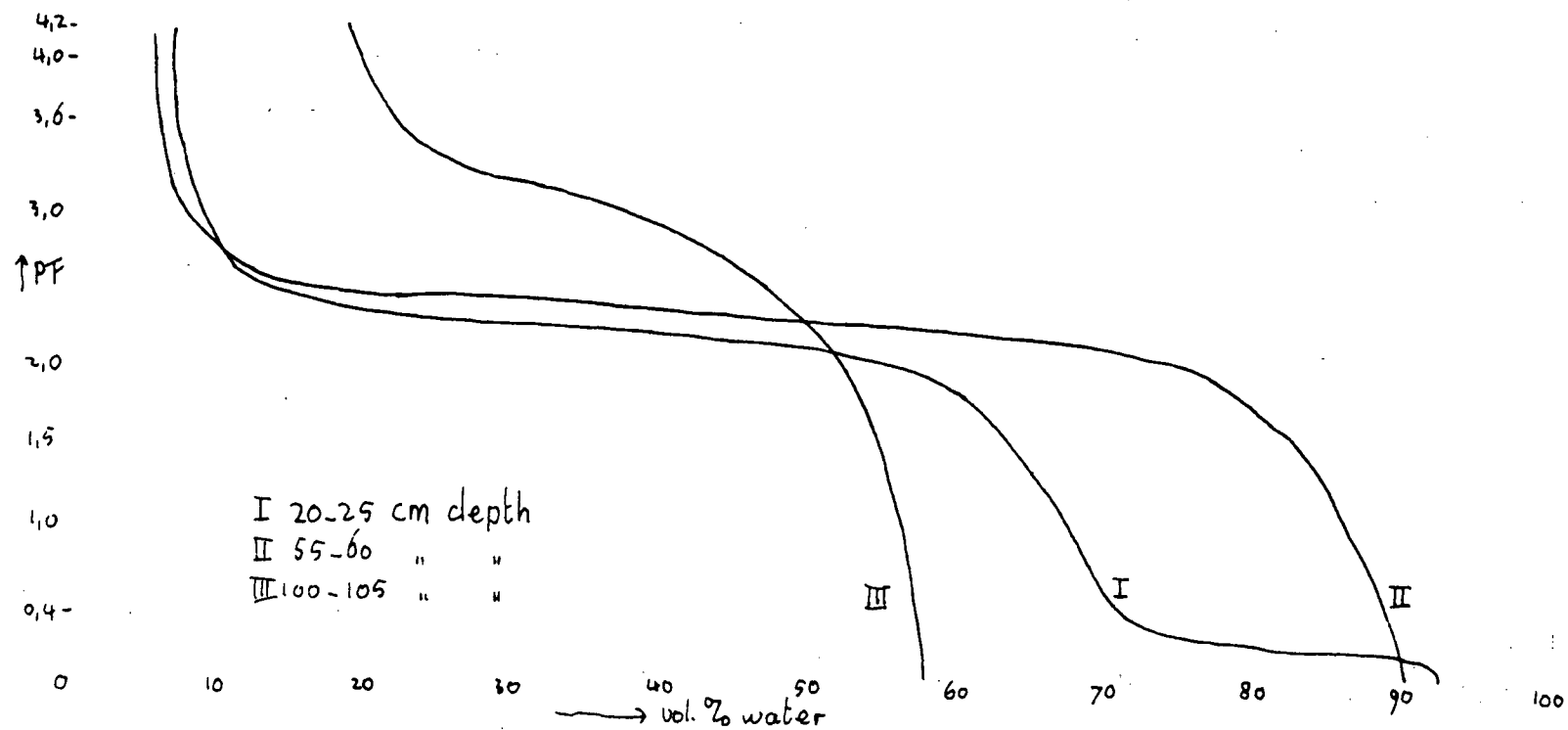
- C1,2 65-93 cm : Very dark greyish yellow (2.5 YR 2/0) moist; peat; weak medium subangular blocky; non sticky, slightly plastic; few micro to medium pores; gradual smooth boundary.
- IIC1 93-115 cm : Dark greyish (5 YR 3/1) wet with iron mottles; peaty clay; dense structure; very sticky, slightly plastic; many fine pores; many small iron-manganese concretions; gravel smooth boundary.
- IIC2 115-125 cm : Greyish yellow (5 YR 4/2) wet with iron mottles; clay; weak coarse prismatic; very sticky, slightly plastic; many fine pores; gradual smooth boundary.
- IIC3 125 + cm : Blue reduction colour wet; clay; structure not determinable; very sticky, slightly plastic.

Remarks: This series is found in lowest parts of valley bottoms, mostly in swamps. There is a peat layer which can vary in thickness from 40 cm to more than one meter. The soil is wet throughout the year unless it is drained by means of ditches.

Analytical data profile 6, Kenyaware Series:

Depth (cm)	B.D. (g/cm ³)	org C (weight %)	org C (vol.%)
20-25	0.25	19.6	4.9
55-60	0.16	19.3	3.1
100-105	1.06	1.7	1.9

pF curves



Profile no. 7 : Kenyerere series
Classification : Soil Taxonomy 1970: very fine clayey, isothermic
fluventic histic Tropaquept
FAO 1970: histic Gleysol
Location : sheet 130/2 Kisii
Coordinates : 713.4 E. 9926.65 N. photo: IV-395
Elevation : 1842 m
Described by : J.H.M. Scholten, on 16-10-1974
Physiography : nearly flat riverplain on lower part of linear slope,
30 m from stream.
Slope : 2%
Micro topography : small mounds of grasses and cyperus
Geology : Bukoban
Vegetation : bushland (marsh), 1% trees, 50% shrubs, 40% herbs,
5% sedges, 4% bare ground
Landuse : poor range, sometimes grazed by cows
Climate : isothermic
Human influence : small ditches
Parent material : alluvial clay
Drainage : very poorly drained
Moistness : wet from the surface
Groundwater : 30 cm
Surface runoff : slow
Effective s.depth : 30 cm but in the dry season probably about 1 m.

Soil profile:

O1 0-2 cm : Litter; loose; abrupt smooth boundary
A1 2-25 cm : Black (2.5 YR 2/0) wet; peaty clay; moderate fine sub-
angular blocky; slightly sticky, slightly plastic; many
very fine and fine and few medium biopores; abundant
very fine and fine, very few medium roots; clear smooth
boundary.
B1 25-60 cm : Very dark grey (7.5 YR 3/0) wet; humic clay; weak fine
angular blocky; slightly sticky, plastic; thin patchy
clay cutans; many very fine, common fine biopores;
abundant very fine and many fine roots; gradual smooth
boundary.

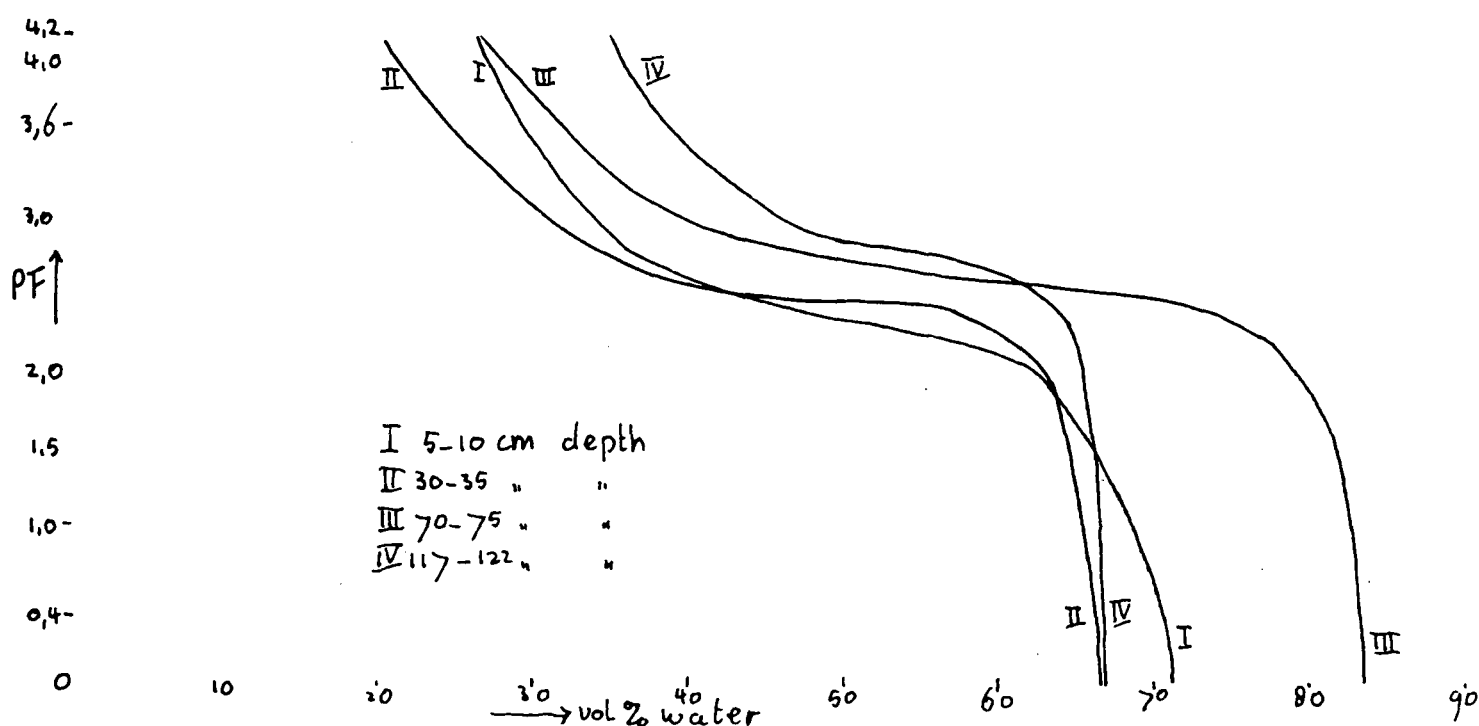
B2,1 60-100 cm : Very dark grey (5 YR 3/1) wet; clay moderate fine angular blocky; slightly sticky, plastic; many very fine and common fine biopores; abundant very fine and many fine roots; continuous thick clay cutans; few moderate slickensides; clear and smooth boundary.

IIB2,2 100-150 cm: Black (2.5 YR 2/0) wet; humic clay; strong medium subangular blocky; slightly sticky, plastic; continuous thick clay-organic matter cutans; abundant thick clay-organic matter cutans; abundant thick slickensides; many very fine, common fine biopores; abundant very fine and many fine roots.

Analytical data profile 7, Kenyerere Series:

Depth (cm)	B.D. (g/cm ³)
5-10	0.59
30-35	0.81
70-75	0.62
117-122	0.87

pF curves



Profile no. 8 : Nyamwanga series

Classification : Soil Taxonomy 1970: very fine clayey, kaolinitic, isothermic, cumulic Humitropept
FAO 1970: humic Cambisol

Location : 130/2 Kisii

Coordinates : 710.1 E., 9926.9 N. photo : II-495

Elevation : 1930 m

Described by : J.H.M. Scholten on 22-1-1975 dry season

Physiography : lower part of valley slope

Meso relief : steep, some big (very old?) pits with about 10 m diameter

Macro relief : steeply dissected

Slope : convex, 200 m length, slope gradient: 29%

Geology : Bukoban

Vegetation : 50% herbs (mex. Merigold; Blackjack), 50% grasses

Landuse : maize (fallow when surveyed)

Erosion : slight sheet erosion

Climate : isothermic

Human influence : terraces

Parent material : andesite

Drainage : well drained

Infiltration : rapid

Groundwater :

Moistness : 0-55 cm dry, 55 + moist

Soil fauna : termites, ants and beetles

Effective soil : 80 cm.

Soil Profile:

Ap 0-10 cm : Reddish brown (5 YR 4/3) dry, dark reddish brown (5 YR 3/2) moist; very fine clay; moderate very fine subangular blocky; loose dry, very friable moist and slightly sticky slightly plastic when wet; many very fine and fine, abrupt smooth boundary.

A1 10-55 cm : Reddish brown (5 YR 4/4) dry, dark reddish brown (5 YR 3/3) when moist; very fine clay; moderate medium angular blocky; hard dry, friable moist, slightly sticky and slightly plastic when wet; patchy thin clay cutans; many very fine and fine, few medium and coarse biopores; abundant very fine and fine roots; ant holes filled with Ap material; clear wavy boundary.

- B3,1 55-80 cm : Red (2.5 YR 4/6) moist; very gradual clay with multi-coloured rotten rock particles increasing downwards; moderate fine angular blocky; friable moist, slightly sticky slightly plastic when dry; patchy thin clay cutans; many very fine and fine biopores; common very fine, few fine roots; very few fine manganese nodules; gradual wavy boundary.
- B3,2 80-160 cm : Red (2.5 YR 4/6) moist; very gravelly clay with multicoloured rotten rock increasing downwards, moderate very fine sub-angular blocky; friable moist, slightly sticky slightly plastic when wet; broken moderately thick clay cutans; continuous manganese coatings; common very fine biopores; few very fine roots; many medium manganese nodules.

Profile no. 9 : Miriri series

Classification : Soil Taxonomy 1970: very fine-fine clayey skeletal,
kaolinitic, isothermic, Humitropept
FAO 1970: humic Cambisol

Location : sheet 130/2 Kisii

Coordinates : 710.4 E., 9926.7 N. photo: II-496

Elevation : 1990 m

Described by : J.H.M. Scholten, on 22-1-1975

Physiography : upper part of valley slope near hilltop.

Slope : convex, 300 m length, slope gradient: 36%

Meso relief : steep

Macro relief : steeply dissected

Geology : Bukoban

Vegetation : 10% trees (Eucalyptus), 5% shrubs, 25% herbs (ferns),
60% grasses. Plant growth at location: abundant

Landuse : pasture and timber

Rock outcrops : 0-2%

Erosion : slight sheet erosion

Climate : isothermic

Parent material : andesite

Drainage : well drained

Infiltration : rapid

Moistness : dry

Groundwater : -

Soil fauna : ants, termites, beetles

Effective soil : 90 cm

Soil profile:

A1,1 0-10 cm : Dark reddish brown (5 YR 3/3 dry, 5 YR 3/2 moist); slightly
gravelly clay; moderate very fine subangular blocky; soft
dry, friable moist, slightly sticky and slightly plastic
when wet; many very fine and fine few medium bio-
pores; many very fine and fine, common medium roots;
clear wavy boundary.

A1,2 10-40 cm : Dark reddish brown (5 YR 3/3 dry, 5 YR 3/2 moist); very
gravelly clay; moderate fine subangular blocky; soft dry,
friable moist, slightly sticky and slightly plastic when
wet;

many very fine and fine, few medium biopores; many very fine and fine, few medium roots; weathered gravel and rock; gradual wavy boundary.

B2 40-90 cm : Red (2.5 YR 5/6 dry, 2.5 YR 4/6 moist); very gravelly clay; weak very fine subangular blocky; loose dry, very friable moist, slightly sticky and slightly plastic when wet; many very fine and fine biopores; many very fine and fine roots; cambic B horizon; abrupt wavy boundary.

R 90-106 + cm : Weak red (10 YR 5/4 dry) with many fine distinct white mottles; rock; massive.

Remarks: A very fine fine clayey skeletal soil found near hilltops on steep convex slopes, and other places liable to erosion. Roots can go down as far as the depth of the massive rock; the soil will be dry readily because the amount of water stored in the soil is small.

Profile no. 10 : Loudetia series
Classification : Soil Taxonomy 1970: very fine-fine clayey skeletal,
kaolinitic, isothermic lithic Humitropept
FAO 1970: Ranker
Location : sheet 130/2 Kisii,
Coordinates : 710.1 E., 9926.9 N., photo: II-495
Elevation : 2020 m
Described by : J.H.M. Scholten, on 23-1-1975
Physiography : upper part of steep valley slope
Landform : steeply dissected
Meso relief : convex part near top of convex-linear slope
Slope : 16%
Geology : Bukoban
Vegetation : 10% trees (Black Wattle), 90% grasses (Loudetia)
Landuse : pasture and timber
Rockoutcrops : 2-10%
Erosion : slight sheet erosion
Climate : isothermic
Parent material : andesite
Drainage : well drained
Infiltration : rapid
Moistness : dry
Soil fauna : termites, beetles
Effective soil : 30 cm.

Soil profile:

A1,1 0-6 cm : Dark brown (7.5 YR 3/2 dry), dark reddish brown (5 YR 3/2) moist, slightly gravelly fine clay; moderate very fine sub-angular blocky; slightly hard dry, very friable moist, non sticky and non plastic when wet; many very fine and fine pores; many fine roots; clear smooth boundary.
A1,2 6-30 cm : Dark brown (7.5 YR 3/2) dry, dark reddish brown (5 YR 3/2) moist; very stony fine clay; moderate fine subangular blocky; hard dry, very friable moist, non sticky and non plastic when wet; many very fine and fine biopores; many very fine roots; abrupt irregular boundary.

R 30 cm + : Weak red (10 YR 5/2 dry); rock; many fine distinct white mottles; white weathered vesicles; massive structure.

Remarks: This soil is very shallow: hard rock within 50 cm from the surface, and is found on places liable to erosion: steep hilltops where the forest has been cut and along streams.

Rooting is difficult, and this soil will be dry very readily because the amount of water which can be stored is very small.

The Loudetia series is called after the Loudetia grass, frequently occurring on this soil.

Soil colour and organic carbon content

Augering nr.	depth (cm)	colour field (moist)	checked colour moist	colour dry	moisture content (weight%)	org. C (weight%)
234	0-20	5YR 3/2	5YR 3/2	7.5YR 5/4	51	2.02
	20-30	" 3/3	" "	5YR 4/3	47	2.00
	55-65	" 3/4	" 3/2.5	" "	39	1.39
	90-100	" "	" "	" 4/8	37	0.54
241	0-20	7.5YR 3/2	7.5YR 3/3	10YR 5/3	49	2.01
	40-50	" 4/4	" 4/4	" 5/4	40	1.29
	80-90	" "	" "	" 6/6	37	0.59
	90-100	" 5/6	" "	" "	39	0.56
242	0-20	5YR 3/3	5YR 3/3.5	5YR 3/4	44	1.88
	30-40	" 3/4	" 3/4	" "	45	1.23
	50-60	" 3/6	" "	" "	44	1.02
245	0-20	5YR 3/2	5YR 3/2.5	5YR 3/2	47	2.04
	30-40	" 3/3	" "	" "	49	1.99
	70-80	" 3/4	" 3/3	" 3/4	49	1.46
	80-90	" "	" "	" "	49	1.15
	100-110	" 3/6	" 3/6	" 4/4	47	0.76
275	195-205	5YR 3/4	5YR 3/4	7.5YR 4/4	39	0.21
378	0-30	5YR 3/3	5YR 3/2.5	7.5YR 4/4	20	2.02
399	0-20	5YR 3/4dry	5YR 3/3	5YR 4/4	25	2.00
	40-50	" "	" "	" "	29	1.31
401	0-20	5YR 3/2	5YR 3/2.5	5YR 3/4	39	2.02
	30-40	" 3/3	" 3/3.5	" "	35	2.00
	110-120	" 3/4	" 3/4	" "	41	0.66
405	0-20	5YR 3/3	5YR 3/2.5	5YR 3/4	42	2.01
	40-50	" "	" 3/3.5	" "	41	1.98

Determination of organic matter according to Walkley and Black;

multiplication factor used: $f = 100/80$.

soil samples: auger samples from Magombo market area (for location see Appendix).

Texture research Magombo market area Kenya: by J.H.M. Scholten.

Profile	depth (cm)	horizon	< 2 μ	2-16 μ	16-50 μ	50-74 μ	74-105 μ	105-2000 μ
1S	35-40	A1,1	50.7	30.0	13.8	0.7	1.0	3.8
	130-210	A1,3	52.1	27.2	13.9	0.7	1.1	5.0
	210-215	B2,1	29.0	22.9	17.9	0.9	2.2	27.1 ¹⁾
	215-250	B2,2	62.5	18.7	12.3	0.8	1.0	4.7
	320-325	B2,3	71.1	14.1	9.2	0.7	1.0	3.9
	450-500	B2,4	66.5	16.8	10.9	0.6	0.9	4.3
	700-710	B3,1	50.9	22.0	11.8	1.0	1.5	12.8
	750-760	B3,2	42.9	28.3	14.9	1.4	2.1	10.5
	950-1000	B3,4	29.3	30.4	19.5	1.7	2.3	16.8
	spring	B3	10.0	33.9	31.0	2.3	3.0	19.8 ²⁾
3S	40-45	A1,1	62.1	19.6	11.6	0.8	1.1	4.8
	140-145	B2,1	68.1	14.9	11.2	0.7	0.9	4.2
	340-345	B2,2	72.0	11.7	9.3	0.9	1.2	4.9
	600-610	B2,2	73.1	10.5	8.8	0.7	1.1	5.8

1) 600-2000 μ : 12.7%

2) 600-2000 μ : 8.0%

pH Research profile 1S and 3S

profile nr. 1S

horizon	depth (cm)	pH-H ₂ O	pH-KCl	pH-CaCl ₂
A1,1	0-70	6.1	5.3	5.4
A1,2	70-130	5.9	5.0	5.2
A1,3	130-210	5.7	5.0	5.0
B2,1	210-215	5.2	4.8	4.9
B2,2	215-250	5.0	4.7	4.7
B2,3	250-450	4.8	4.2	4.2
B2,4	450-500	4.6	4.2	4.2
B2,5	500-650	4.5	4.2	4.2
B3,1	700-710	4.8	3.8	3.9
B3,2	750-760	4.9	3.8	3.8
B3,3	800-950	5.1	3.7	3.9
B3,4	950-1000	5.2	4.1	4.5
B3,5	1000-1100	5.4	---	---
B3	spring	5.0	3.7	3.8

profile nr. 3S

A1,1	0-50	5.2	4.8	4.7
A1,2	50-79	5.5	4.8	4.7
B2,1	79-270	4.6	4.2	4.1
B2,2	340-345	4.5	4.0	3.9
	600-610	4.7	4.1	4.0
B2,3	740-750	5.0	4.1	4.0