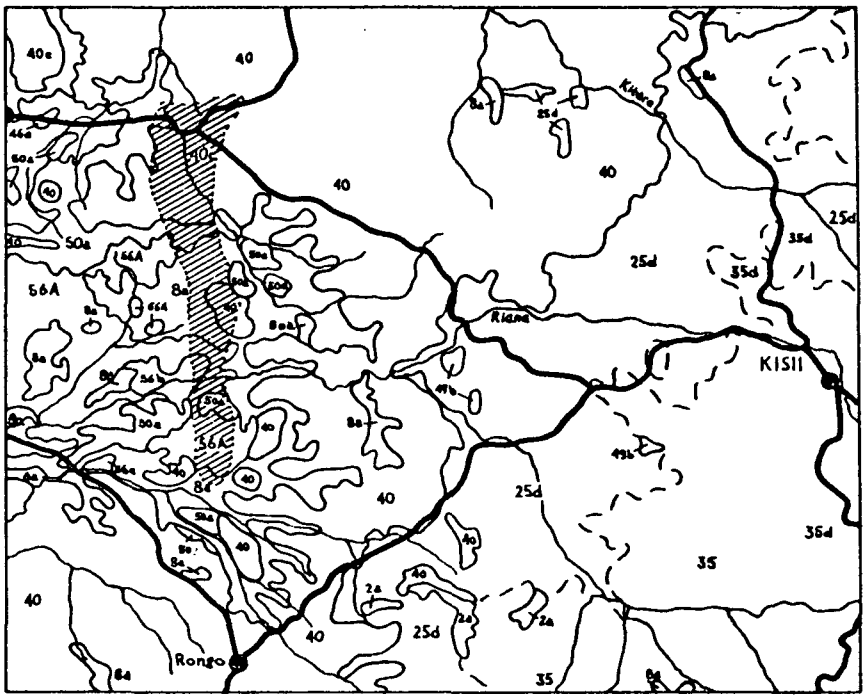
TRAINING PROJECT IN PEDOLOGY

KISII KENYA



DETAILED SOIL SURVEY OF THE RANGWE AREA

PRELIMINARY REPORT NO 17

AGRICULTURAL UNIVERSITY

WAGENINGEN - THE NETHERLANDS

DETAILED SOIL SURVEY OF THE RANGWE AREA

by
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TRAINING PROJECT IN PEDOLOGY, KISII - KENYA

Agricultural University, Wageningen, The Netherlands

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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 seventeenth one of a series to be presented to Kenya 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 postgraduate students of the Agricultural University at Wageningen, and for furnishing research opportunities to 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 by R.F. Breimer, who also wrote the report. The lay-out and editing has been carried out by Mr. H.W. Boxem.

We hope to pay back with these reports a small part of the dept 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. Introduction

1. 1 Location and extent

The Rangwe sample area is located in the South Nyanza district of Nyanza province in western Kenya. It is situated in two locations: East Nyokal (Kamagambo) location and Gem location. It covers a strip of land, 1 to 2 Km wide and almost 13 km long, along the road from Rongo to Rangwe, an area of about 1825 hacters (4510-acres). (fig. 1). The area lies between 34.35' Eastern longitude and between 0°35 20" and 0°42' 30" Southern latitude.
The altitude of the area ranges from about 1275 m (4250 ft) in the river valleys north of Rangwe, to about 1410 (4700 ft) above sea level, on top of Kuna hill.

1. 2 People of the area

The people who are living in the area nowadays, belong to the Luo tribe. Originally the Masai tribe inhabited the area until about 200 years ago. Then the Kisii tribe occupied the area for about 100 years and were displaced by the Luo tribe, around 1850.
The Luo tribe is a Nilotic tribe, originating from the Sudan, from where they moved along the Nile river and settled along the shoes of Lake Victoria. The first Luo settlers were no farmers, but they lived by fishing and cattle raising. At the beginning of this century they started growing crops like sorghum, wimbi (finger millet) and sweet potatoes. The area is not very densly populated, the population pattern is scattered, although the hills are definitely prefered for settlement, to the plains with impeded drainage. The settlements (villages) take the form of a large circular or rectangular dense hedge of Euphorbia, surrounding the huts of the father, his wives and children.

1. 3 Land Tenure

Within the survey area there are no officially registered land proprietary rights, as we find for instance in the Kisii district. The land is owned by the clans who first settled on the land.

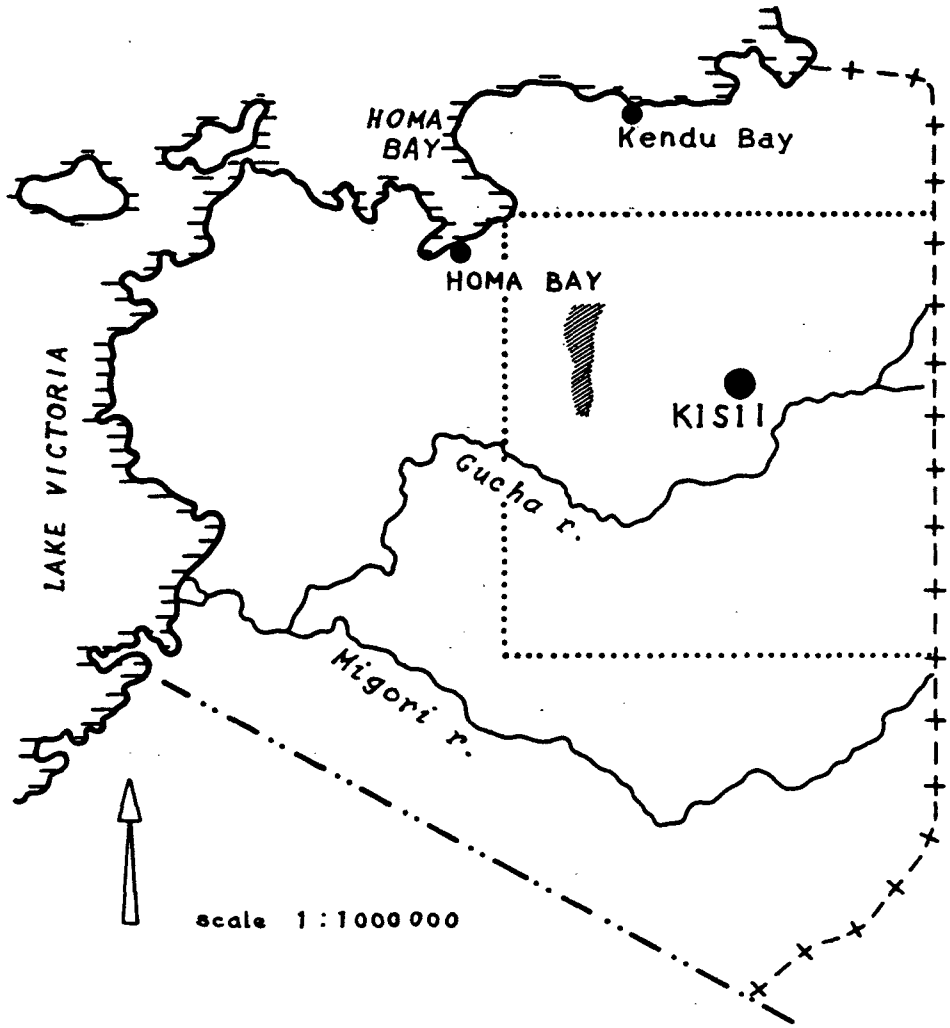


Fig. 1. Location of the survey area within the Kisii mapsheet

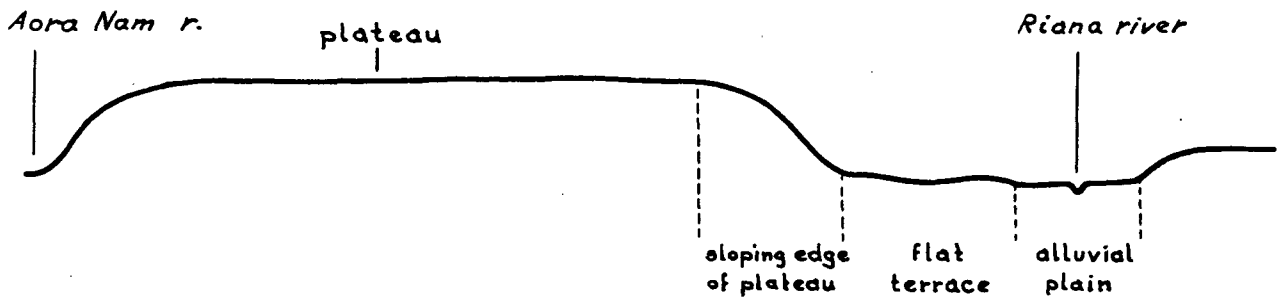


Fig.2. North - south scematic cross section through Southern 4 km of the area

The settling and consequent building of houses and the cultivation of the land was predominatly on hills and ridges. This was done for protection against the raiding Masai and to escape the poorly drained areas, which are swampy during the long rains. The elders of the clan divided the occupied land in long narrow strips, which were allocated to the different families of the clan. Afterwards the rights of cultivation and grazing became inherited.

2 Physical and Biological Enviroment

2.1 Climate

Meteorological data are available from three places around the area. The closest to the area is Asumbi mission, about 4 km South East of Rangwe Further away are Marinde, about 9 Km West of Kuna hill (in the middle of the area) and Kamagambo, about 5 km South East of the Southern boundary of the area. From the mean monthly rainfall diagrams of these meteo stations it is clear that the mean annual rainfall in the area is about 1550 mm. The rainfall distribution throughout the year shows a clear peak in April-May, with April being the wettest month with a mean rainfall of about 250 mm. A second but minor peak occurs in September-October, with about 130 mm per month. These short rains however are rather unreliable.
The driest month is January, with often less than 50 mm. Also dry, but not so pronounced, are February and July, having about 80 mm of rainfall. It should be noted that these figures are based on rather short records of data (not more than 15 years). Moreover these figures only indicate mean values and gives no information about the reliability of the rain. Marinde records for instance show a low year of 820 mm and eight out of ten years a rainfall of less than 1200 mm.
Only little is known about the evaporation in the area. To give an idea of the magnitude of the potential evapo-transpiration, the following table is given. (from V.Mourik, 1974, (9)

Table 1. Average monthly Epo (optimal potential evapo-transpiration)

	D	J	F	M	A	M	J	J	A	S	O	N
Kisii town :	113	119	108	121	105	113	108	130	123	144	137	115
Ahero :	149	168	160	174	147	146	139	137	144	159	164	148

Temperature records of Kamagambo show mean maximum temperatures of 28°C and mean minimum temperatures of 18°C. In the dry season however temperature can rise to about 35°C and in cool months temperatures can drop to about 10°C.

Geology

The first to study the geology of the survey area was Mr. A. Huddleston, who made a geological map of the Kisii district in the late 1940's. According to his map almost the whole area is made up of Nyanzian rocks, which are of pre-Cambrian age. The Nyanzian system is composed almost entirely of rhyolites, andesites and basalts, with minor local developments of tuff and agglomerate. In the survey area we find mainly rhyolites, and basalt, with only a small strip of rhyolites with intercalated tuffs and agglomerates. In the Southern part of the area we find two isolated occurrences of minor intrusives consisting of diorite porphyry, which are of post-Nyanzian age.
Apart from this geological map, I have the impresion that the Southern part of the area (south of Awundo's Village) has been considerably influenced by fine grained alluvium, deposited by the Riana river in the geological past, for instance in the Pleistocene. An indication for this idea was the occurrence of rounded pebbles in a pit on the plateau between the Aora Nam river and the Riana river
The plateau could thus be considered entirely or partly, as a terrace.
For more details see the 'Geological map of the Kisii District ' plus report by A. Huddleston (8). A copy of the relevant part of this map is given in the appendix, at the back of this report.

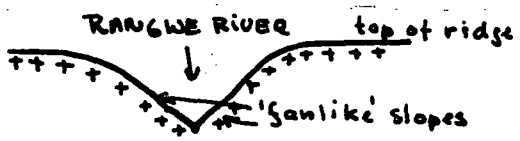
Physiography

Physiographically the area can be divided into two main landforms:
1. The hills and Ridges of Rangwe in the north,
2. The Riana river plain in the south.
The boundary is formed by the line between Awundo's Village and the place where the Rangwe river enters the survey area. In the Riana river plain, there is one element, that belongs physiographically and pedologically to the Rangwe hills. This element is Kuna hill, a kind

of inselberg' in the flat topography of the plain. These two distinguished landforms will be desribed in detail below.

Hills and ridges of Rangwe

The Rangwe landscape is dominated by ridgelike hills with rounded, slightly sloping tops and not very steep (5 - 12%), slightly convex, a bit irregular lateral or footslopes. The valleys of the streams and rivers are rather narrow and convex slopes. There is hardly any alluial plain, because the rivers have cut themselves down quite rapidly and have reached the bedrock on many places. The whole of this landscape gives the impression of an eroding landscape.
Near Rangwe we find some clear ridges, with a south-east - north-west extension. They have rather lateral slopes (10 - 25%) and a narrow top. However, the lateral slopes are not steep from top to bottom, but only the upper slopes are steep, while the lower slopes are rather flat. The transition between upper and lower slopes is often quite sharp. It is striking that on the places where the Rangwe river has cut his way through these ridges, they have formed steep "fan-like" slopes (slopes of 20-30%). These slopes are steeper than the upper lateral slopes. All of the steeper ridges, as they are desribed here, are made up of rhyolite rock, that is found very shallow under the upper lateral slopes. The top of Kuna hill also has these slopes and shallow rock. An illustration of these steep topped ridges is given below.



section along axis of ridges

transverse section through ridges

Riana river plain

This physiographic unit (with exception of Kuna hill) has a flat to undulating macrorelief. Most of the land has a slopegradient less than 5%. The southern part of the area, between the kilometer marks 99 22-23 (half-way between them), forms a part of a plateau, that extends further to the west. It has a flat topography (slopes less than 3%) with steeper sloping edges (slopes of 3 to 8%). South of the Riana river and north of this plateau we find a very flat strip of land, which perhaps is a terrace of the Riana river. Along the Riana river we

find a narrow alluvial plain (about 200 m wide), which lies lower than the adjacent land. A schematic section through the described southern part of the area is given below. The rest of the Riana river plain (north of the Riana river) has an undulating macrorelief, with gentle slopes that merge with the Rangwe hills.
In this physiographic unit most of the gentle slopes (less than 5%) are affected by seepage and become semi-swampy during the long rains In the hills of Rangwe however, the majority of the slopes are steeper and the soils are free drainimg. Only a small strip of land along the rivers has drainage problems in this landscape.

2.4 Vegetation

The most significant differences in vegetation can be distinguished between the vegetation of the Rangwe hills and that of the Riana plain. (with about the same boundary as the main physiographic units have)
-The Rangwe hills, including Kuna hill and the northern edge of the plateau in the southern part of the survey area (near the 99^{25} kilometer mark), have a Combretum woodland vegetation, a so called low tree - high grass savanna. Because of the widespread cultivation however, much of the original vegetation has been removed and a new species (e.g. Eucalyptus spp.) are introduced.
-The Riana river plain (excluding Kuna hill etc.) is an area with impeded drainage and has a grassland vegetation with grouped trees and bushes. Often these groupes of trees and bushes are located on former termite hills, where they find a better pnysical environment for their roots. The dominant grass species is pennisetum catabasis. The density of the trees-bushes clumps is variable. On the plateau in the south of the area, we find a low density of mainly bushgroups, while north of this plateau, near the Riana river a much higher density is found of mainly thorny Acacia species, together with some bush.
Besides these two main types of vegetation, there is another type, the riverine bush, which is rather dense vegetation of trees, shrubs herbs and grasses. The extension is limited to the riversides, which are quite small in this survey area, especially in the Rangwe hills.

For more details reference is made to the vegetation map of Kenya, sheet 3, 1: 250,000. The relevant part of this map has been copied and is represented in fig. 3, opposite page 7.

Legend to the vegetation map of Kenya, 1: 250.000 (partly):

Forest clearing and cultivation communities:

- From Moist Montane and Intermediate forests:
  - Undifferentiated clearings and shrub ---------- 35
  - cultivated Triumfetta - Vernonia ---------- 35[c]
  - cultivated Croton and Vernonia ---------- 35[d]
- From lower Moist Intermediate forest:
  - cultivated Albizia - Bridelia - Vernonia ---------- 25[d]

Combretum and allied broad - leaved savanna types:

- Moist Combretum and allied vegetation:
  - Undifferentiated Combretum types, including cultivated area - 40
  - Combretum with Euclea schimperi ---------- - 40[c]

Broad - leaved savanna mixtures of semi - evergreen thicket origin:

- Combretum semi - evergreen thicket mixtures ---------- - 50[a]

Intermediate semi - evergreen thicket and associated types:

- Derived clearings, cultivation communities and bushland,
  - Undifferentiated ---------- - 46
  - Albizia coriaria - Turraea type ---------- - 46[a]

Open grassland types on drained soils:

- Grasslands and scrub - grasslands of forest origin:
  - from moist montane and intermediate forests ---------- - 2[a]

Vegetation of soils with impeded drainage:

- Acacia and allied vegetation on clay plains, undifferentiated - 56
  - Acacia sieberiana vars. and A. polyacantha ---------- - 56[b]
- Open grassland areas on clay plains:
  - Hyparrhenia - pennisetum catabasis ---------- - 56[A]
- Grasslands and clump grasslands, undifferentiated
  - Vlei and drainage - line types ---------- - 8
  - Evergreen clump grassland on vlei soils ---------- - 8[a]

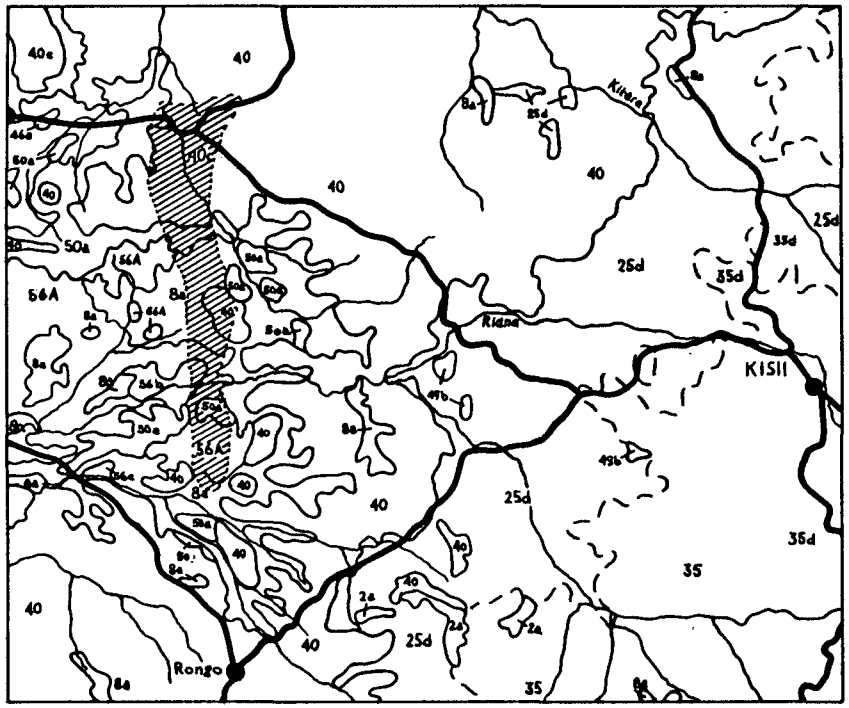


Fig. 3 Vegetation Map of kenya, sheet 3 (partly)

scale 1 : 250 000

encircled are the Rangwe sample area

for legend see page 8.

- Papyrus, swamp grass and reed swamp ---------- - 9

3 Land Use

When we look at the arable land in the survey area, it is clear that the soils of the Rangwehills are much more intensively cultivated then the dark cleyey soils of the plain. The main reason for this is the better physical characteristics of these soils (good permeability and consequently no waterlogging) and the fact that these soils are easier to till. (because of the loamy texture). In the plain most of the land is left under its natural clump grassland vegetation and is used as grasing land. All grazing in the area is communal. The agricultural system in the southern part of the area is shifting cultivation. A certain plot of land is cultivated until it becomes exhausted and is then abandoned and a new plot is cleared from its grass vegetation. In the hills near Rangwe the agriculture has a more permanent character, although not every plot is tilled each year. People use fallow periods to let the soil regain some of its natural fertility.
No manure nor fertilizers are used to improve crop yields. Most of the tillage operations is done by 'jembe'(broad bladed hoe). Only few people have an oxen plough to do the heavy ploughing work. Weed control is poor, because the time between planting and the first weeding is too long. Weeding is done by 'jembe'. An avarage crop rotation system for the Rangwe hills looks as follows:
first crops maize or finger millet
second crops: sweet potatoes and/or cassava,
followed by a few years of fallow usually.
The most important crops that are grown in the area, are listed below.

1. Maize is the principal food crop. Most of the maize is grown for home consumption, but surpluses are soild on the local markets. (at Rangwe, Oboke, Rongo etc.) sometimes it is used for brewing local beer.Maize is planted either alone or mixed with sorghum. It can also be intercropped with legumes, in many cases cowpeas.

2. Sorghum — Sorghum is the second important food crop, but it is also used for brewing beer. It is never a cash crop, but it is always consumed by the producing family. Compared with maize, sorghum has the advantage that it is less vulnerable for conditions like drought or waterlogging. On the other hand it has a longer yield potential than maize.

3. Sweet potatoes — Sweet potatoese are rather popular, but they do have an important place in the diet of the people. They are often stored as a reserve food crop, but they are seldom sold at markets. They are grown mostly on the loamy soils of the hills.

4. Finger millet — Finger millet (wimbi) is a minor cereal crop, used at home for food and beer brewing and it is never sold. In most cases some maize is interplanted with finger millet.

5. Sugar cane — Sugar cane is grown on the dark coloured, imperfectly drained soils of the area. It is used for the producion of jaggery (brown unrefined) sugar, which is sold on the markets. Much of this sugar is used for the illegal distillation of local spirits (changa). People also sell the cane in small pieces for chewing.

6. Groundnuts — Groundnuts are the most important cash crop in the area. They are grown preferabily on the reddish brown loamy soils of the hills, but also other kinds of soils are used for groundnuts. They become more and more popular to the farmers and the acreage is increasing consequently.

7. Cowpeas — Cowpeas are important legume crop. Much of it is for home consumption, but a fair part of the crop is sold to Asian traders. Many farmers use to plant cowpeas between maize, which helps to keep the weeds under control. The young green leaves are often used as a vegetable.

8. Green grams — Green grams are another legumes, however of lesser importance than cowpeas. Often green grams are grown together with maize. Most of the crop is sold to the Asian traders.

9. Cassava — Cassava is usually raised on the shallow gravelly soils of the hills, because of its ability to do well even on poor soils. Beside this it has the advantage that it is drought resistant. However the tuber has a low nutritive value. In the survey area it is not a popular crop and it is used merely as an emergency crop.

10. Vegetables — Vegetables, an important ingredient of the African menu, are usually grown on moist places, e.g in small river. The most important vegetables are cabages,onions, tomatoes and beans. Beside these kale cauliflower and carrots can be found incidentally.

11.Coffee — Coffee was found at some places in the hills of Rangwe, on rather shallow soils. Without exception the coffee trees were of very poor quality. Beside the rather unsuitable soils, coffee deseases will be responsible for the cropfailure. The altitude and particularly the rainfall of the area are marginal for coffee.

12. Fruits — On a small scale, only near villages and for home-use, fruits are grown. The most important one is bananas, but also paw-paws (Carica papaya). pumpkins , mangoes and citrus fruits can be found.

13. Sisal — Sisal has been found in the area in abandoned field mostly bearing the towering stem. No sisal is produced commercially nowadays, probably due to drop of sisal prices in the world market. It is only used in rows as fences and for the home-use production of ropes.

Besides these food and cash crops, some people grow small plots of nicotine tobacco (Nicotiana rustica) for home-use, Mostly for smoking in pipes.

4 Survey Methods

The actual soil survey is detailed one, with a rather large scale of 1: 12,500. The survey methods followed, can be described as a four step method. The first step comprises a reconnaissance of the general character of the area. The second step consists of the interpretation of aerial photgraphs and the preliminary drawing of suspected soil boundary lines. The third step is the fieldwork to check whether the preliminary boundaries are virtual soil boundaries are virtual soil boundaries or not. The fourth step is the final drawing of these boundaries on the aerial photographs. A further elucidation of these different steps is given in the following sections.

4.1. Reconnaissance

A first reconnaissance of the area was obtained by studying the topographical map of Gem (Survey of Kenya, sheet 130/1, 1:50,000), on which the whole survey area is represented. An impression of the land in the area can be obtained for instance by comparing the different densities of the 50 feet contours on the map. Also the main drainage pattern can be studied from this map. Another map important for the reconnaissance of the area, was the geological map of the Kisii district (Huddleston,1951 (8). Beside this map the Vegetation map of Kenya, sheet 3 (1: 250,000) was examined to give an impression of the local vegetation. After studying these maps, a first field trip through the area was made to get a preliminary picture of the area.

4.2. Airphoto interpretation

In order to get a first indication regarding differences in soil conditions, aerial photoes are studied steroscopically. By means of aerial photographs with a forward overlap of 60% and a mirrow stereoscope, we can obtain a three dimensional image of the area with an exaggerated relief. By carefully studying these stereo images, paying attention to differences in landscape, slopegradient, vegetation, land-use, grey-tone (often an indication for drainage conditions) etc., provisional soil boundary lines can be deduced.

In this way an airphoto interpretation map can be made, using the photographs as base maps.

4.3. Fieldwork

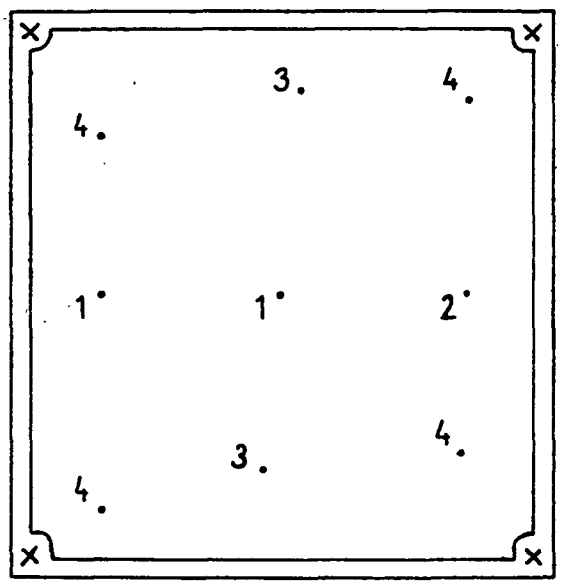
This is the most extensive and time consuming part of the soil survey. Within the units, distinguished on the interpretation map, the soil is examined at various sites to check whether the soil is enough uniform to be grouped in one soil series. The definition of a soil series is given below. (see section 5.a) The examination of the soil was done by augering with a so called 'Edelman' auger, to depth of 2.20 m maximally, if the bedrock was not found sooner. All augaring sites were numbered and their positions recorded on the airphotoes, and lateron they were all transfered to the location map of augering sites and profile pits (appendix map c). The soil material, from the augering, was tested for colour, mottling, texture, consistence, gravelliness (e.g. of concretions) and the occurence of lime.

Differences in these characteristics from top to bottom, enabled the subdivision of the soil into soil horizons. At each augering point information about the soil surface (e.g. slope, stoniness) and the environment, (e.g. vegetation, land was added to the soil profile description, on special augerhole observation forms. In this way the entire survey area was covered with augering sites, which enabled the surveyor to draw the final soil series-and soil phases boundaries. Often it appeared that the interpretation lines of the aerial photographs were not very accurate and often they had to be changed or even removed. Intensive augering was needed to find the real soil boundaries. In order to make detailed descriptions of each soil series, deep pits were dug on representative places and profile descriptions were made, mentioning soil colour, colour and density of mottling, structure, texture, pore distribution, concretions and cutans of each horizon. Not only profile descriptions were made, but also each horizon was samped for laboratory analysis, to enable a more reliable classification of the soils. These profile descriptions together with the data of the augerhole observations lists, are the basic material to distinguish and describe soil series with their range in characteristics.

This was done during the progress of the fieldwork.
After a certain part of the area was checked with augerings, the interpretation lines were adjusted and the final soil series and soil phase boundaries were drawn on to the aerial photo groups. When the entire area was covered with checked photographs, showing the soil boundaries, the following phase in soil mapping could start This is the map compilation by composing all photo images into one soil map.

4.4 Map Compilation

In order to transfer the lines on the photographs to a base map, each photograph is marked with nine points. One principal point (1), two transferred principal points (2), two wing points (3) and four transfered wingpoints (4) (see illustration).



airphoto with principal and wing points

The transferred points on a photo originate from the two adjacent in the same run (because of the 60% forward overlap of two successive photographs). These points are all transferred to a base map by means of the so called"slotted template" method. The actual transfer of the lines on the photoes is done with a Ketchmaster, with which the photo and the map can be seen simultaneously. When the apparatus has been adjusted in such a way that the points of the photo are coinciding with the corresponding points on the base map, the lines between these points can be traced on the base map. In this way photo by photo the map can be composed.

.5 Laboratory Work

To get more accurate data of soil characteristics, laboratory analysis were carried out. Especially for soil classification data

obtained from the laboratory are indispensable. However due to the limited capacities of the small laboratory in Kisii, only some rather simple analysis were done. Data were obtained on: organic matter content, texture and base saturation. They are represented together with the soil profile descriptions in the appendix. For more data reference is made to the East Konyango soil survey, for which chapter 6 gives some correlations.

5 The Soils (PART II)

5.1 Classification

The way of classification of the soils is according to the concepts of soil series, soil types and soil phases from the Soil Survey Manual, in this soil survey a soil series is not necessarily a group of soils that developed from the aame parent material. This was done for the practical reason that the differences in parent rock were not clearly reflected in soil differences. Therefore the difinintion of a soil series, as it was used in this survey can be expressed as follows:

= A soil series is a group of soils, that have the same horizon, the same horizon sequence and the same characteristics of these horizon, within the limits given in the range of characteristics.

A subdivision of the soil series is given by the soil types and the soil phases. The soil type represents the texture of the topsoil. Three classes of texture are distinguished:

A : clayey (more than 40 % clay)
B : loamy (less than 40 % clay, but finer than loamy sand)
C : sandy (less than 40 % clay, but coarser than loamy sand)

The Soil Phases are subdivisions refering to soil depth or subsoil campact clay depth (for some soil series), slope, occurence of ironstones under the profile, erosion of topsoil and for some special places an extra wet variant of the central concepth of the soil series.

The following soil depth phases are distinguished:

0 : deeper than 150 cm
1 : depth between 100 and 150 cm
2 : depth between 50 and 100 cm
3 : depth between 20 and 50 cm

4 : Shallow than 20 cm

With the term soil depth is meant the effective soil depth, which can be described as the depth of the soil that is still contributing reasonably in moisture storage, rootability, nutrient delivery etc. So a C- horizon consisting of rotten rock, where roots can only penetrates into the weathered joints, is not considered to be effective soil. For two soil series, the Akelo and the Riana-Kuna series, the soil depth phase was replaced by a depth phase of the compact subsoil clay. Both soil series has a medium textured topsoil and a very fine textured compact subsoil, with a abrupt (or at least a clear) boundary. For the agricultural potential evaluation it seems much more important how deep this water stagnating clay occurs than to know till how deep this clay continues. Therefore two clay depth phases are introduced:

c_1: clay deeper than 30 cm

c_2: clay within 30 cm depth

Note: only on a few places where ironstone or an indurated concretionary layer overlaid the compact clay, the normal depth phase was used.
Beside these depth phases, slope phases were distingushed:

A : 0 - 3%

B : 3 - 8%

C : 8 - 15%

D : 15- 30%

Slopes were measured with a simple hand slope meter, only an average of the sometimes complex slopes can be determined in this way But for the overall view of the area this is an acceptable measure. Special phase were introduced for ironstone under the profile, for erosion and for more more extreme wetness than is stated in the central concept of a soil series.

Ironstone phase: The occurrence of ironstone under the profile, especially in the Oboke series, was separated from the same profile on rotten rock, because of the impervious and root growth limiting effects of this ironrich indurated material. Often however on rotten rock a layer of loose iron - manganese concretions is found and a sharp distinction between such a soil and one on ironstone is rather difficult to establish means of a soil auger only.

Erosion phase: This phase is used to separate the plain area south (and a small piece north) of Riana river, which is moderately to severely affected by erosion. Most of the medium textured topsoil of the Riana-Kuna soils have been washed off and even the clay is being eroded at some places. The small part of this eroded unit, north of the Riana river, consists of a cow path that has been eroded down to the rocks.

Wetness phase: This phase is used for soils, that are located in a low position and that are collecting and transfering the water from adjacent higher places towards streams and rivers. Most of these soils are Akelo or Riana-Kuna soils and have in addition to the normal features more and pronounced signs of wetness: pronounced mottling and even iron-manganese concretions in topsoil and/or subsoil. The water is transported in these soils through the permeable topsoil and very soon, after even light rains these soils are in a swampy condition. And they stay like that long after surrounding soils have become practicable again.

Complexes and undifferentiated soilgroups: On some places the soil is too complex to be grouped under one soil series or soils of two series were found too close together to be mapped seperately. In the latter case a soil complex has been mapped, consisting of different percentages of two soil series. In the first mentioned case, as it was found in the flood plain of the Riana river, considerable differences in the profile characteristics on short distances were found and this made the establishment of a soil series impractical. Therefore these soils were grouped under the undifferentiated soil group of alluvial soils. Units where two or more phases of one soil series have been found, are not considered as a complex.

5.2. Description of Soil Series (including ranges of characteristics)

The legend of the soil map of the Rangwe samples area consists of ten soil series, which are subdivided in groups according to their drainage class. Only the four well drained soil series have been further subdivided after their parent material. Besides, two soil complexes have been distinguished (one on the southern plateau and one on the Kuna hill) and one undifferentiated soil group (in the Riana river flood plain).

The legend with short description of the soil series, plus their classification according to the F.A.O. system of classification, is written on the soil map of Rangwe sample area.

Furtheron in this section a detailed description will be given of the soil series, including their range in characteristics, land use and the similar soils of each series. For profile description reference is made to the appendix, at the end of this report.

1. Aora Nam Series

Surface in hectares: 168 (9.2% of the area) see profile Ra, 1, appendix.

Aora Nam series are poorly drained soils, with a very dark grey, light clay topsoil and a dark grey, heavy clay mottled subsoil with evidences of swelling and shrinking.

Classification: acc. to F,A.O. '74: gleyic phaeozems and gleyic luvisols acc. to Soil Taxonomy '73: gleyic argiaquolls and typic tropaqualfs.

The Aora Nam soils belong to two classification units because the epipedons not always fullfill the requirements for a mollic epipedon. The major part of these soils are mollisols (phaeozems).

Range in characteristics

A. Profile characteristics:

Aora Nam soils are poorly drained, with a depth ranging from 100 to more 150 cm.

- A horizon: thickness from 10 to 50 cm, very dark grey to very dark brown (10 YR 3/1. 3/2,2/2) in colour, a heavy clay loam to light clay texture (30 - 50 % clay), with a few weak fine dark brown mottles, a fine subangular blocky structure and a gradual to clear boundary towards the B2 horizon.

- B2 horizon: thickness 70 to 140 cm, dark grey colourhues yellower than 7.5 YR, values 4,5,0,1, a heavy texture (60 - 80% clay), with common weak to clear fine brown mottles and a strong coarse angular blocky structure, breaking into strong medium and fine angular blocky peds and having many intersecting slickensides.

- B3 horizon: thickness 30 - 80 cm, grey to greyish brown (hues yellower than 7.5 YR, values 5,6 chromas 1,2) in colour, with a heavy clay texture (60 - 80 % clay) and the same mottling and structure

as the B2 horizon, plus some rotten rock gravels and many intersecting slickensides.

Special features: in the B2 horizon some iron-manganese concretions may occur (less than 5%) and in the lower B2 and in the B3 horizon lime concretions can be found locally (less than 1% of exposed surface).

Erosion: Because of the gentle slopes, surface runoff is rather slow. But since the subsoil consists of heavy clay with a low permeability, the topsoil can be soon saturated with water, resulting in surface runoff. Therefore slight water erosion (sheet erosion) occurs.

B. Environment characteristics:

Physiography: An soils occur in stream and river valleys in the slightly undulating to undulating landscapes of the southern plain and as a small strip along the streams and rivers in the Rangwe hills. These strips however are not composed purely of poorly drained An soils, but also some better drained dark coloured clay loam to clay soils occur locally. But their extend was not big enough to be mapped seperately or as a complex with An soils. Slope range: 0 - 6 % in the south, 0 - 8 % in the Rangwe hills. Geology: An soils can be derived from various rocks, but generally from rhyolites, diorite porphyry and only incidentally from basalt.

Vegetation: Most An soils lie under an open grassland vegetation with grouped trees and bushes, but sometimes, at swampy places they have a rush and grass vegetation. Along the Rangwe river only the better drained soils directly bordering the river, have a riverine bush vegetation.

Land use

About 90% of the land is left under its natural vegetation and is only used for extensive grazing of cattle and goats. Only some places, where the drainage is somewhat better, small plots have been cleared for sugar cane, vegetables or for maize and sorghum. Often people have dug some superficial drainage ditches down the slope.

Similar soils

Aora Nam soils are related to Akelo and Awundo soils. The Akelo soils however are characterized by an abrupt textural change between topsoil and subsoil and moreover the dark topsoil is usually thicker.

The Awundo soils have no medium textured topsoil, but are very fine textured from top to bottom and have no mottling in the topsoil.

2. Akelo Series

surface in hectares: 280 (15.3 % of the area)
see profile Ra 5, appendix

Akelo series are poorly drained soils, with a very dark brown to very dark grey medium textured topsoil and an abrupt boundary towards the mottled dark grey, heavy clay subsoil, which has evidences of swelling and shrinking.

Classification: acc. to F.A.O. '74: gleyic phaeozems (+ gleyic luvisols)
acc. to Soil Taxonomy '73: abruptic argiaquolls (+ abruptic tropaqualfs)

Range in characteristics

A. Profile characteristics

Akelo soils are poorly drained soils, with a depth ranging from 50 to more than 150 cm, depending upon gravelly-stony layers which occur locally at shallow depth.

- A horizon: thickness from 25 to 50 cm, (very) dark brown to (very) dark grey (hues 10 YR (and 7.5 YR), values 3,4, sometimes 2, chromas 1,2), with a clay loam to silty clay loam texture (sometimes loam or silt loam) and often common fine faint brown mottles, having a very fine subangular blocky structure and an abrupt boundary towards the B2 horizon.
- B2 horizon: thickness 40 to 100 cm, can be mostly divided into two parts:

B21 horizon: very dark grey (hues 10 YR (and 7.5 YR), values 3,4,5, chromas generally 1, sometimes 2), a heavy clay texture (60 - 80 % clay) and common fine distinct brownish yellow or prominent reddish mottles, with a coarse slickensides.

B22 horizon: grey to greyish brown colours (hues 10YR (+7.5 YR), values 5,6, chromas 1,2), a heavy clay texture, with many fine distinct brownish yellow mottles and a strong fine angular blocky structure and many intersecting slickensides.

B3 horizon: thickness variable from 30 to 60 cm, same colour as B22,

mixed with light yellow, orangeish and black rotten rock colours, texture: decreasing clay content with depth and increasing gravelliness with depth; two sickensides and slightly calcareous at profile bottom.

Special features: Sometimes the lower part of the A horizon shows some signs of bleaching and is therefore somewhat lighter coloured than the upper A horizon. But a clearly lighter coloured A2 horizon can not be distinguished. Sometimes iron-manganese concretions or small gravels are found at the boundary of the A to B horizon.

Erosion: Surface runoff is slow, because of the flat to gently undulating topography. But as water can rise to the surface after rains, because of the low permeability of the B horizon, slight sheet erosion occurs.

B. Environmental characteristics:

Physiography: Akelo soils are found in two parts of the area: the southern occurrence is on the flat to gently undulating plateau, which is dissected by small river and streams. The northern occurrence is on the gently slopes between Kuna hill and the Rangwe hills. This landscape has a more undulating character. The slope range of Akelo soils on the southern plateau is less than 3%, while the northern valleyslopes range from zero to about 5%.

Geology: Akelo soils can be developed on various parent materials the southern plateau most soils lie on rhyolite and diorite porphyry rocks. The northern Akelo soils have been developed from basalt parent material.

Vegetation: Akelo soils are exclusively found under an open grassland vegetation with scattered Acacia trees and groups of bushes. Only the density of these trees and bush groups is variable. On the plateau for instance this density is low, while north of Kuna hill the trees are closer together.

Land use

Arable farming is rather difficult on Akelo soils, due to their excess of water in rainy seasons. Therefore most of the land is still under its natural vegetation and people only use it as range land for their cattle. Only some small plots on better drained places have been tilled and surgar cane, maize, sorghum, finger millet and some vegetables are grown, but not always with good results.

Similar soils

Akelo soils can be considered as intergrades between Aora Nam soils and Riana-Kuna soils, because it has the dark topsoil of Aora Nam soils and the abrupt textural change of Riana-Kuna soils. Awundo soils are also similar, but they do not have an abrupt textural change and are of clayey texture throughout the profile.

3. Riana - Kuna series

surface in hectares: 343 (18.8 % of the area)
see profile Ra 7, appendix

Riana-Kuna series are poorly drained soils, with a dark greyish brown silty topsoil, of which the lower part is grey and bleached and has an abrupt boundary with the heavy clay subsoil, which is dark grey and has yellow or red mottles and evidences of swelling and shrinking.
Classification: acc. to F.A.O. '74: solodic planosos
acc. to soil Taxonomy '73: abruptic tropaqualfs (actually they should be called tropical albaqualfs)

Range in characteristics

A. Profile characteristics:

Riana -Kuna soils are poorly drained soils, generally deeper than 150cm
- A1 horizon: thickness from 3 to 25 cm, with colours of dark grey to very dark greyish brown (hues 10 or 7,5 YR, values 3,4, chromas 1,2), having a silty clay loam to silt loam texture, with common weak mottles and a very fine subangular blocky structure.
- A2 horizon: thickness 5 to 50 cm, dark grey to light brownish grey in colour (hues 10 or 7.5 YR, values 4,5,6, chromas 1,2,) with a silt loam texture and many fine distinct brown mottles, having a very fine subangualar blocky struture and an abrupt boundary with the B2 horizon This boundary may be accomapanied by many yellow to reddish mottles and /or iron-manganese concretions.
- B2 horizon: thickness ranges from 50 to 100 cm, colours are dark grey in the upper part and grey to greyish brown downwards (hues 10 YR (or 7.5 YR), values 4, chromas 1,2, in top and value 5, chroms 1,2,3, downwards), a heavy clay texture, many prominent red, orange or yellow mottles in top and down-wards common fine distinct yellow to brown

mottles, with a moderate coarse prismatic structure, breaking into strong fine angular blocky peds and downwards many intersecting slickensides.

- B3 horizon: thickness variable from 30 to over 100 cm, colours same as B2 horizon (lower part) or some lighter and browner (e.g pale brown 10 YR 6/3), together with various rotten rock colours (ranging from whitish, yellowish to blackish), texture is heavy clay, with decreasing clay content with depth and strong very fine angular blocky structure and few slickensides are found. In the B3 horizon or in the C horizon few lime may be found.

Special features: Sometimes concretions occuring between A and B horizon are indurated and form a continuous ironstone layer, that limits augering till 30 to 50 cm depth. In these cases the normal soil depth phase is used instead of the heavy clay depth phase as use for Akelo and Riana-Kuna series. It should be noted that the A2 horizon should be distinguishable by colour in the central concept of the RK series. However, tis may be difficult in some soils mapped as RK soils. In these cases the soils are quite similar to Akelo soils and are not always well separatable from them.

Erosion: Most of the time during rainy seasons the topsoil of RK soils is saturated with water, due to the almost impervious heavy clay subsoil, and a slow surface runoff through the high grass vegetation is found. This results in a light sheet erosion, taking away the dark brown coloured A1 horizon. The thickness of this A1 horizon can be quite small therefore.

B. Environmental characteristics:

Physiography: RK soils can be found in the slightly undulating Riana river plain, which is slightly dissected by small streams and rivers. Minor parts of these soils are found in the undulating to rolling hills of Rangwe, associated with stream and river valleys, on the poorly drained sites. Slope range: in the plains, slopes have gradients usually less than 3%, while in the narrow valleys between the Rangwe hills, slopegradients can be up to 5%.

Geology: Riana-Kuna soils occur on different types of parent rock. According to the geological map of Huddleston, most of it is basalt and rhyolite, plus some diorite porphyry. But most of them might as well be developed on old fine grained sediments of the Riana river.

Vegetation: Riana-Kuna soils have been found under a grassland vegetation with scattered Acacias (often thorny Acacia species) and groups of bushes. The density of these tree and bushes can be rather high (as high as 40 %., seen on an airphoto), but everywhere the grasscover is dominant.

Land use

Almost the entire area is left under the natural vegetation and is used for extensive grazing of cattle and some goats. Only very occasionally plots have been tilled, but with poor results.

Similar soils

The most similar soils are Akelo soils, which are only darker in colour and do not have a clear A2 horizon. Aora Nam soils are also similar, having clay illuviation evidences, but less clear than AK soils. Awundo soils do not have these evidences.

4. Awundo series

surface in hectares: 23 (1,3 % of the area)
see profile Exc 13, appendix

Awundo series are poorly drained black to dark grey, heavy clay soils without an abrupt textural change from topsoil to subsoil and that have vertic properties (cracks, slickensides etc.).

Classification: acc. to F.A.O. '74: pellic and chromic vertisols
acc. to Soil Taxonomy '73: entic and typic pelluderts and aquentic chromuderts.

Range in characteristics

A. Profil characteristics

Awundo soils are poorly drained soils, with a depth generally more than 150 cm.

- A horizon: thickness of 15 to 35 cm, black to very dark grey colours (hues 10 YR (and 7.5 YR), values 2,3, chroma 1) and a clay texture, sometimes with faint dark brown mottles and a fine to medium subangular blocky structure.

B1 horizon: thickness 20 to 40 cm, dark brownish grey to brown colours (7.5 YR, values 3.4,5, chromas 1,2,) often with brown mottles, a heavy clay texture and an angular blocky structure, plus some slickensides.

- B2 horizon: thickness of 40 to 100 cm, brown to dark grey colours (10 YR, values 4,5, chromas 1,2,3,) with strong brown mottles, a heavy clay texture, an angular blocky structure and intersecting slickensides, with generally a gradual boundary towards the C horizon, but sometimes an abrupt boundary towards a R-horizon is found (boulder weathering of basalt).
- C horizon: pale brown to greyish brown colours (10 YR, values 4,5,6 chromas 2,3,) and a light clay texture.

B. Environmental characteristics

Physiography: There soils are found in the southern slopes of the Rangwe hills, as a transition between Akelo soils and Nyandara I and II soils. The slopes range from 0 to 6 %.

Geology: The parent material of Aw soils is exclusively basalt.

Vegetation: The vegetation on these soils is the same open grassland, with scattered trees and bushes as in case of the Akelo series.

Land use

The soils are rather difficult to cultivate and most of the area occupied by Awundo soils is therefore used as rangeland for cattle and goats.

Erosion

Because of the rather flat topography and the rather high clay content of the topsoil, these soils are not very susceptible to erosion. In dry seasons the soils cracks and these cracks can transport the water of rains, untill they are closed by swelling.

Similar soils

An soils are most similar, also having vertic properties (evidences of swelling and shrinking), but they have also evidences of clay illuviation. Akelo and Riana-Kuna soils are also poorly drained and of heavy clay texture, but they have pronounced clay illuviation characteristics.

5. Oboke Series

surface in hectares: 90 (4.9 % of the area)

see profile Ra 10, appendix

Oboke series are imperfectly to moderately well drained soils, with a dark brown colour and which are often gravelly and have a clay loam

to light clay texture. They are shallow and have at the profile bottom ironmanganese concretions, covering the rotten rock or they have ironstone. The occurrence of ironstone is indicated on the map with a special ironstone phase.

Classification: acc. to F.A.O. '74: haplic phaeozems

acc. to Soil Taxonomy '73: aquic, lithic and typic hapludolls.

Range in characteristics

A. Profile characteristics

Oboke soils range in drainage class from imperfectly to moderately well drained, depending upon soil depth, occurrence of impermeable ironstone and slope gradient. Most of the Oboke soils are not deeper than 50 cm, because of indurated ironstone and have low slope gradients. These soils are therefore imperfectly drained. Moderately well drained are those soils, that don't have this ironstone layer, but have gravelly rotten rock at the profile bottom, that permits a better subsoil drainage. Soil depth is more than 10 cm, but often less than 50 cm and in most cases less than 100 cm. Surface stoniness ranges from 0 - 5%, surface gravelliness from 0 up to 30 %.

- A horizon: thickness 10 to 40 cm, colour very dark brown to dark brown, (hues 7.5 or 10 YR, 2/2, 3/1, 3/2, 3/3) with a clay loam texture, often slightly gravelly to gravelly, sometimes with iron-manganese concretions, a fine subangular blocky to gradular structure and a gradual boundary towards the B horizon.
- B horizon: thickness 10 - 70 cm, colour dark brown to dark greyish brown (7.5 or 10 YR, values 3,4, chromas 2,3), a clay loam to light clay texture, gravelly from rotten rock gravels and iron-manganese concretions, in many cases (imperfectly drained soils) few to common, fine distinct yellowish brown mottles depending upon stoniness and softness of rotten rock (in case of no ironstone), mixed colours: brown, blackish yellowish from rotten rock gravels. Often iron-manganse concretions are found above the rotten rock.

Special features: Sometimes these soils are shallow over, the drainage class of the soil above it is imperfectly to poorly drained. These soils and also deeper imperfectly drained soils are sometimes artificially drained by the local people by means of shallow furrows along the slope.

Erosion: Because the ironstone layers often have a certain slope, subsoil drainage by lateral flow over the ironstone layer is sufficient to prevent surface runoff. However, the very shallow soils on ironstone will have surface runoff and consequently sheet erosion. Soils without ironstone do not have erosion because of the better subsoil drainage.

B. Environmental characteristics

Physiography: Oboke soils are found on the sloping edges of the southern plateau, where ironstone was found on many places. North of Riana river we find Oboke soils on more elevated (dome-like) places in the hydromorphic valleys and plains. Slopegradients of these soils range from 0 to 6 %.

Geology: The parent material of Oboke soils can be rhyolite, basalt or diorite porhyry.

Vegetation: Oboke soils are frequently tilled and the vegetation is mostly secondary, consisting of bushes, trees (e.g. Eucalyptus) and few grasslands.

Land use

Oboke soils a rather intensively tilled, because of their better physical properties, compared to the poorly drained soils around them. About 80% is used as arable land and 20% for extensive grazing of cattle. All kinds of subsistence crops are grown, like maize, sorghum, sweet potatoes, wimbi (finger millet), beans, vegetables etc. sugar cane is grown too.

6. Alluvial soils, undifferentiated

Surface in hectares: 16 (0.9 % of the area)

see profile Ra 15, appendix

These alluvial soils are an association of imperfectly well drained dark grey to reddish brown, mottled soils, with a sandy to clayey subsoil and a clay loam to clay topsoil. The soils close to the river bed have a permanent groundwater table, fluctuating with the river-discharge.

Classification: acc. to F.A.O. '74: eutric fluvisols

acc. to Soil Taxonomy '73: aquic eutropepts and aeric tropaquepts and some typic haplaquolls.

Range in characteristics

A. Profile characteristics

Because this unit is not a pure soil series but an association of soils, it is impossible to give the range of characteristics of only one profile. Therefore it is more sense to sketch some common alluvial profile.

Profile A (imperfectly drained):
0 - 40 cm: dark gery (± 10 YR 4/1) topsoil with aprprox. 40% clay.
40 - 100 cm: dark grey clay(+ 60 %) with big faint reddish brown mottles.
100 - 200+cm: dark grey!brownish clay loam (±30 % clay) with mottles.

Profile B (imperfectly drained):
0 - 40 cm: dark brown (7.5 YR 4/2) silty clay loam topsoil.
40 - 80 cm: brownish grey sandy loam with blackish mott .s.
80 - 200+cm: dark grey-brown, mottles with sandy texture.
Often groundwater is found

Profile C (mod. well drained):
0 - 50 cm: dark reddish brown(5 YR 3/2-3) light clay (± 40 - 50 %) topsoil.
50 - 100 cm: reddish brown (5 YR 4/3) B-horizon with a clay texture (50 - 60 %).
100 - 200+cm: dark grey (5 YR 4/1) subsoil with a silt loam to sandy loam texture downwards.

It was noted that profile A and B had a specific position compared with the riverbed. The brown sandy profile B (see also profile Ra 15, appendix) was found closest to the streambed and profile A further away of it near the boundary with the adjacent Rk soils. Profile C occured on places with better drainage within the alluvial plain of the Riana river.

B. Environmental characteristics

Physiography: The alluvial soils as described above occur in the alluvial plain along the Riana river. This plain is only about 200 m wide and it has a real flat topography, except for the riverbed which lies about 2 m lower than the plain. To the north this plain has a distinct topographical boundary: a shoulder-like difference in altitude.
To the south it has a rather gradual transition to the plain with eroding Rk soils. Perhaps this plain has belonged to the alluvial plain formerly, being a terrace now.
Geology: Recent alluvial deposts of the Riana river are the parent material for these groups of soils.

Vegetation: The vegetation on these soils has been removed to a fair extend for agricultural practices, but in general it can be called a riverine bush vegetation.

Land use

About 70 % of the soil is tilled and most of it is used for sugar cane production, because of the rather wet conditions of these soils. But also maize and sorghum and sweet potatoes are grown with fairly good results.

Similar soils

These soils are quite unique and there are no real similar soils. It should be stated however that in the An-unit along Rangwe river also few alluvial soils occur, but their extent is too limited to be mapped seperately or to necessitate the establishment of a soil complex.

7. Rabuor Series

surface in hectares: 235 (12.9 % of the area)

see profile Ra 14, appendix

Rabuor series are well drained, moderately shallow to deep reddish brown to red clay soils, with a clear clay illuviation horizon and a B3 horizon that starts within 150 cm depth.

Classification: acc. to F.A.O. '74: chromic luvisols and luvic phaeozems

acc. to Taxonomy '73: typic tropudalfs and typic argiudolls.

Range in characteristics

A. Profile characteristics

Rabuor soils are always well drained, with a depth of 40 to more than 150 cm.

- A horizon: 15 to 30 cm thick, has colours of dark brown to weak red (7.5 YR 3/2; 5 YR values 3,4, chromas 1,2,3, sometimes 2.5 YR 4/2) and a heavy clay loam to light clay texture, with a fine subangular blocky and fine granular struture.
- B1 horizon: 10 to 30 cm thick, having colours of dark reddish brown to weak red (5YR 3/2, 4/4; 2.5 YR 4/2, 4.3) and a heavy clay texture, with few to common weak to moderate clay cutans and a fine

subangular blocky structure.
- B2 horizon: 20 to 100 cm thick, with colours of reddish brown to weak red (2.5 YR 4/2, 4/3, 4/4,) a heavy clay texture, with common too many moderate clay cutans and a fine subangular to angular blocky structure,
- B3 horizon: 10 to 80 cm, colours reddish brown to weak red (2.5 YR 4/2 4/3, 4/4) plus some yellowish black rotten rock colours, a clay texture, slightly gravelly to gravelly (from rotten rock), an angular blocky structure. Special features: Soils in low positions, near streams and small rivers, may have some black mottling and/or some iron-manganese concretions in the B3 horizon.
Erosion: Rabuor soils have a low erosion hazard, because of their high permeability and the resistence of the topsoil against sealing. Only on special places, like cowpaths etc. erosion can accelerate to deep gullies. Only on the steepest slopes (over 10%), the soil can suffer of some sheeterosion after heavy rains.

B. Environmental characteristics

Physiography: Rabuor soils are found in the hills of Rangwe, on hillslopes and lateral ridgeslopes. Also on Kuna hill Rabuor soils are found, in a complex with Marando soils. The slopegradients of Rabuor soils vary from 3 to 10 %.

Geology: Rabuor soils are developed exclusively from rhyolitic rocks.
Vegetation: The vegetation on these soils is a secondary vegetation derived from a Combretum bushland vegetation. Most of the trees have been removed and other trees as for instance Eucalyptus have been planted. Most of the land however, is cleared for agriculture.

Land use

Most of the soils are used as arable land for production of maize, sorghum, beans (cowpeas, green grams,) sweet potatoes, vegetables and occassionally sugar cane and groundnuts. Only a minority of the acreage of Rabuor soils is left idle, or is only used as grazingland . Especially the deep Rabuor soils are relatively the best soils for cropland.

Similar soils

Nyandara I soils are very similar to Rabuor soils. The main difference is the parent material: Nyandara I soils are basalt-weathered soils. Minor differences are colour and texture.

8. Marando Series

surface in hectares: 475 (26.0 % of the area)
see profile Ra 11 and Ra 17 appendix

Marando soils are generally well drained, dark brown to reddish brown shallow, gravelly clay loam soils, without a clear clay illuviation horizon.

Classification: acc. to F.A.O. '74: haplic phaeozems and eutric and chromic cambisol
acc. to Soil Taxonomy '73: typic hapludolls and typic eutropepts.

Range in characteristics

A. Profile characteristics

Marando soils are usually well drained, though some of the shallower with a low slope gradient and a rather impermeable, solid rotten rock, should be called moderately well drained. However, the central concepts of Marando soils is fairly better drained than that of the Oboke soils. Soil depth (= depth of the solid rotten rock) ranges from about 30 to 130 cm. The difference between shallow and deep is mainly caused by different types and structures of rock weathering. Surface gravelliness ranges from 10 to 50 % and surface stoniness is less than 5%.

- A horizon: thickness from 10 to 40 cm, colours are dark brown to dark reddish grey (hues 7.5 and 5 YR, values 3,4 chromas usually 2, sometimes 3), with a loam to clay loam texture, slightly gravelly to gravelly and fine subangular blocky to granular structure; the boundary towards the B horizon is gradual.
- B horizon: 10 to 100 cm thick, colours are dark brown to reddish brown and weak red sometimes (hues 7.5 and 5, sometimes 2.5 YR, values 3,4, chromas 2,3, sometimes 4), which are often mixed with strong iron-manganese concretions, with a clay loam to light clay texture, gravelly to very gravelly and a fine subangular blocky structure, mostly a gradual boundary towards the soft (massive) rotten rock.

Special features: It should be noted that in the central concept of Marando soils, they do not have an argillic (clay illuviation) B horizon, but only a cambic B horizon.

It could however be that after texture analysis of many Marando soils, it would appear that a certain number of them have argillic B horizon. During the fieldwork it was not possible to distinguish these soils, having a weak argillic B horizon from those that do not have this. Therefore only the reddish brown soils with clear textural B horizons (Nyandara I and Rabuor soils) have been separated from Marando and Nyandara II soils.

Often on the rotten rhyolitic rock a layer of iron-manganese concretions is found, which is not really indurated to be called ironstone. Only on the lower edge of Kuna hill, bordering Rk and Ak soils, an ironstone layer is found under the Marando soils. The same applies to Ma soils, found on the northern plateau edge (south of the Riana river), where they border Rk, Ak soils and Oboke soils.

Erosion: The erosion hazard depends upon depth of the massive rotten rock, the slopegradient and the land use. Most sensible to watererosion are those soils, that have shallow massive rotten rock, a C class slope (8 - 15 %) and which are used as arable land. No erosion occurs on soils, having deep massive rotten rock, low slopegradient and that lie under their natural vegetation.

B. Environmental characteristics:

Physiography: Marando soils can be found on the gently to strongly sloping lateral ridgeslopes and hillslopes within the hilly landscape around Rangwe also on Kuna hill and on the northern plateau edge(± 1 km south of the Riana river) Marando soils are found. They are mostly found on the upper and lower parts of the lateral and hillslopes. Some ridges (near Rangwe) have steeper sloping tops with Orero soils and the lower (less steep) slopes under the top often have Ma soils. On Kuna hill the same sequence is found. The slopes of the Marando soils have gradients ranging from almost flat to about 15 %.

Geology: Marando soils are developed on the rhyolites and dellenites of the Nyanzian system.

Vegetation: Most of the Vegetation on Ma soils have been cleared for agriculture or is secondary, derived from Combretum woodland. There are some old Ficus trees left, but some of the trees (e.g. Eucalyptus) have been planted. The rest consists of high grasses mixed with herbs.

Land use

Most of the area with Marando soils is cultivated to be used as arable land (about 60 %.) Main crops grown on these soils are: maize sorghum sweet potatoes, groundnuts and beans. Cassava is grown on the shallower soils, while only near villages we find very small plots of domestic tobacco and trees of bananas, papaya and occassionally mango. The rest of the land is used as a natural pasture for cattle and goats grazing.

Similar soils

Marando soils are very similar to Nyandara II and soils, which are found on basaltic rocks. In general Nyandara II soils are more clayey and better drained, because of the better subsoil drainage of basaltic rotten rock. Less similar are the Orero soils, that are more shallow and do not have a B horizon.

9. Nyandara I Series

surface in hectares: 59 (3.2 % of the area)
see profile Ra 12 appendix

Nyandara I series are well drained moderately shallow to deep reddish brown to red clay soils, with a clear clay illuviation B horizon and that have B3 horizons starting within 150 cm depth.

Classification: acc. to F.A.O. '74: chromic luvisols and luvic phaeozems
acc. to Soil Taxonomy '73: typic tropudalfs and typic argiudolls.

Range in characteristics

A. Profile characteristics

Nyandara I soils are well drained; only near stream and rivers there might be some groundwater influence, giving rise to mottling and a somewhat worse drainage (moderately well drained). Soil depth can be from 40 to over 150 cm.

- A horizon: 15 - 35 cm thick, colours are dark reddish brown to weak red (hues 5 and 2.5 YR, values 3,4, chromas 2,3), a heavy clay loam to light clay texture and a fine subangular blocky and fine granular structure.

-B1 horizon: 5 to 30 cm thick, with colours of dark reddish brown to red (hues 5 and 2,5 YR 3/2, 4/2, 4/3, 4/4), a heavy clay texture, with a fine subangular blocky structure and few to common moderate clay cutans.
-B2 Horizon: to 100 cm thick, with colour varying between weak red and reddish brown (2.5 YR 4/2,4/3,4/4, sometimes 4/5), a heavy clay texture and a strong fine subangular to angular blocky structure, with abundant strong clay cutans.
-B3 horizon 10 to more than 60 cm thick, same colours as B2 plus some rotten rock colours (yellowish) and occassionally mottles (near groundwater table), a clay texture with a fine to medium angular blocky structure and possible some rotten rock gravels or stones.

Erosion: Nyandara I soils have a low erosion hazard because they are very permeable and also have a good resistence against surface sealing. The slopes on which they occur are no very steep as well.

B. Enviromental characteristics

Physiography: Nyandara I soils are found on two places in the hilly landscape of Rangwe: in the southern part near Awundo's village and along the Nyandara river. These are places where basalt is found in the hills of Rangwe.
The soils occur on tops and slopes of hills and ridges. The slopegradient therefore varies from 0 to 12%.
Geology: Nyandara I soils are formed entirely out of basaltic parent material.
Vegetation: The flora on the Nyandara I soils is the same as that on Rabuor soils, but along the Nyandara river it is more or less a riverine bush vegetation.

Land use:

Most of the Ny I soils, especially deeper ones are used for cropland. Only along the Nyandara river relatively few soil is used for cultivation, probably because of the slope. Main crops grown are maize, sorghum, sweet potatoes, beans. Besides these crops ane can find a few groundnuts, some vegetables and some fruit near villages.

Similar soils

Rabuor soils are very similar to Nyandara I soils. The differences are

just few (colour, texture), because the influence of parent material on soil formation is quite limited in the survey area. Often therefore, the pretion is not very certain. They should not be given too much value.

10. Nyandara II Series

Surface in hectares: 50 (2.8 % of the area)
see profile Ra 16, appendix

Nyandara II soils are well drained dark brown to reddish brown, shallow, often slightly gravelly clay loam to clay soils, without a clear clay illuviation B horizon.

Classification: acc. to F,A.O. '74: haplic phaeozems and eutric and chromic cambisols
acc. to Soil Taxonomy '73: typic hapludolls and typic eutropepts.

Range in characteristics

A. Profile characteristics:

Nyandara II soils are well drained soils, sometimes even somewhat excessively drained, having a depth of 30 to 100 cm. The surface gravelliness is less than 30% and the surface stoniness is not more than 2%.

- A horizon 10 to 40 cm thick and colours of dark brown to dark reddish grey (hues 7.5 and 5 YR, values 3,4, chroma 2), with a silty clay loam texture, often slightly gravelly and with a fine subangular blocky to granular structure.
- B horizon: thickness from 10 to 70 cm and colours varying between dark brown and reddish brown (hues 7.5 and 5 YR, 3,4, chromas 2,3), a (silty) clay loam to light clay texture, gravelly and/or slightly stony and a fine subangular structure. The boundary towards the C horizonis often irregular or broken, due to the tuber-like weathering of basaltic rock.

Special features: The same as was stated about a possibly present weak argillic B horizon in Marando soils, counts for the Nyandara II soils. Here could also an argillic B horizon be present, which however is not distinguishable with fieldwork methods.

Erosion: In contrast with the Marando soils with the rather massive rotten rock, Nyandara II soils have a fairly permeable rotten rock. This results in a better subsoil drainage, through which the soil will not be saturated soon. Therefore surface runoff is not likely to happen very often. So the erosion hazard of these soils, unless they are very shallow, is not high.

B. Environmetal characteristics

Physiography: Nyandara II soils are found near Awundo's village in the southern part of the hills and ridge of Rangwe, together with the Ny I soils. Another place where Ny II soils occur, are the higher parts of the slopes (northern slopes especially) of the Nyandara river valley, so on both sites they occur on hillslopes. The slopes of these soils range from 3 to 15 %.

Geology: Nyandara II soils are derived exclusively from basaltic rock.

Vegetation: The vegetation on Ny II soils is the same secondary vegetation derived from Combretum woodland as on the Marando soils. Much of the original vegetation has been removed for agricultural use of the land.

Land use:

Most of the Nyandara II soils (50 to 60 %) is used as cropland for producing crops like maize, sorghum, groundnuts, sweet potatoes, beans and sometimes cassava and some fruit trees near villages. The other part of the land is left idle or is used for cattle (and goat) grazing.

Similar soils

Marando soils are very similar to Nyandara II soils. The main differences are the parent material and the gravelliness. The same as stated under the section of Nyandara I soils, about the uncertainty of the boundary between Ra and Ny I soils, counts for the boundary between Ny II and Ma soils.

Orero Series

Surface in hectares: 86 (4.7 ? o the area)

see profile Ra 18, appendix

Orero series are excesively drained, dark brown to brown, very shallow, gravelly and stony soils.

Classification: acc. to F.A.O. '74: eutric regosols (lithic phase)
acc. to Soil Taxonomy '73: lithic ustorthents.

Range in characteristics

A. Profile characteristics

Orero soils are excessively drained soils, with a depth ranging from 5 to 30 cm, depending upon the weathering of the rocks. The surface stoniness is generally high: about 50 % of the surface is covered with gravels and stones, but stoniness can range from about 10 % to about 80% and at some places solid rotten rock is cropping out.

- A horizon: 5 to 30 thick, with a colour ranging from dark brown to brown (7.5 YR, values 3,4, chromas 2,3), texture is loam to silty clay loam, gravelly to very gravelly, slightly stony, with a very fine granular to subangular blocky structure and a clear wavy to irregular or broken boundary with the C or R horizon.

Erosion: As Orero soils occur on moderately steep and steep slopes and as the soils are shallow, surface runoff can happen and could be rather rapid. However, these soils still have their dense vegetation of bushes and low trees with grasses and herbs on the surface, so water erosion can not be severe.

B. Environmental characteristics

Physiography: Orero soils are found on strongly sloping to moderately steep ridges and hills, as they occur near Rangwe. These ridges and hills are clearly visible in the land scape because of their slopes and undisturbed vegetation. The most shallow Orero soils occur mainly on the steep lateral slopes of the ridges. The slopes range in gradient from nearly level on top of the ridges to 25% on the steep slopes.

Geology: Orero soils occur exclusively on rhyolitic rocks, especially the most acid ones (with many quartz veins and big quartz phenocrists)

Vegetation: The vegetation on Orero soils is probably still original and is composed out of many trees and bushes, with grasses and herbs beneath them. It could be called a bushland vegetation.

Land use

Only about 3 % of these soils are tilled, but with poor results, due to drought mainly. The rest of the land is left under natural vegetation and is not used or perhaps to a limited extend for grazing of goats.

Similar soils

The most similar soils are Ma and Ny II soils. They have, however, a cambic B horizon and not, as the Orero series, an AC or AR profiles Sometimes the boundaries between Orero and very gravelly Ma soils are hard to determine by means of only a soils auger. Generally a physiographical boundary is drawn in these cases.

5.3 Correlation with the East Konyango Soil Survey

In behalf of the comparability between the Rangwe soil survey and the soil survey of the East Konyango Area,, which covers most of the Rangwe sample area, a correlation table is given of the soil series distinguished in both soil surveys.

Soil series of this report:	Correspondent soil series of East Konyango
Aora Nam series	Oboke sandy loam, Nyamauro loam and for small part Nyakal sandy loam
Akelo series	Nyokal sandy loam and Nyamauro loam
Riana-Kuna series	Nyamauro loam
Awundo series	Nyamauro loam
Oboke series	Rangwe sandy loam (smaller parts not seperated, fall under Nyamauro loam and Nyokal sandy loam)
Rabuor series	Rangwe sandy loam
Marando series	Rangwe sandy loam
Nyandara I series	Rangwe sandy loam
Nyandara II series	Rangwe sandy loam
Orero series	Stony land on silicious rocks
Alluvial soils, undifferentiated	Not seperated, they fall under Nyamauro loam

It should be emphasized that the East Konyango soil survey has been made to a scale of 1.50,000 and can be less detailed of course than

the present survey, made to a scale of 1: 12,500. This fact limits the comparability of both soil maps.

6 Interpretation of the survey data

6.1 Itroduction

By no means it is the intention to make a complete land evaluation, taking into consideration the different land utilization types, the improvement capacities of the land, the land qualities before and after the improvements, the derived land suitability classes etc., as this is the work of a whole team of agricultural, economical and sociological experts. Moreover, the suitability evaluation in this report a part of a land use planning project, where it is the base for na economical land classification, but it has only the function of making the soil characteristics practical for agricultural use. It tries to translate the soil attributes, presented in the perceding chapters, into suitability classes for the production of different crops and for cattle grazing.

So the evaluation will be based mainly on the soil possibilities (including slope, surface stoniness etc.) and the crop requirements. Also some data of the present-day agricultural practices in the area, like crop rotations, use of manure or fertilizer, kind of tillage implements used etc. are given to provide a rough framework for the suitability classes.

6.2 Suitability classification system

In order to give a good picture of the feasibilities of the soils in the area, a number of crops have been selected, which are grown in the area and that can be placed in an order of decreasing demands from their physical and pedological environment. These crops are: coffee, maize, sweet potatoes and sorghum, in this order of decreasing demands. An explanation of these crops and why they were choosen for this suitability classification is given below.

Coffee (Coffee arabica) is a perennial crop, that needs a rather high, fairly well distributed rainfall (about 1500 mm is considered ideal) and a free draining, rather deep soil with a good moisture retention capacity. The altitudes where coffee can be grown range from 1200 to 2000 m above sea level

So for coffee the survey area is rather marginal, especially concerning the rainfall. But because it is a crop with high demands and because it occurs in the area, it is very useful for the suitability classification purpose.

Maize (Zea mays) is an annual cereal crop, which has specific water requirements. In the first five weeks the young maize plant is moderately drought resistant and is susceptible to unfavourable soil/air relationships (lack of oxygen). But after these five weeks the maize plant is less drought resistant and needs fairly high amounts of water for optimal growth. It needs a well drained soil and can not tolerate the slightest degree, of waterlogging. So this crop is less demanding than coffee, but still it needs quite a lot.

Sweet potatoes (Ipomea batatus) is a perennial vine, but it is mostly treated as an annual crop. It is a very drought resistence crop and it can grow in areas which have an average annual rainfall of 750 mm or more. Sweet potatoes can be grown from sea level up to 2100 m. They do not have specific soil requirements, but they need fertile soils for optimal yields. So this crop demands less than maize and can be planted on rather shallow soils, because of the drought resistence.

Sorghum (Sorghum vulgare) is an annual cereal crop, which is very drought resistant, because of its very efficient, well-branched rootsystem and because its ability to reduce transpiration by rolling its leaves. It needs a rainfall of 300 mm, during its growing period. Besides its drought resistence, sorghum withstands short periods of waterlogging, which makes it not always unsuited to the poorly drained soils of the Riana plain. So this crop has the widest range of soils where it can do well.

The suitability classes, that are distinguished for the area, range from class 1, which is well suited for all four crops to class 7, which is unsuited for all crops. To the last classes, from 5.5 to 7, an addition has been given about the suitability for use of the land as a pasture for extensive grazing of cattle and goats. The classes are given below the suitability classification table.

Suitability Classification Table

Suitability Class	coffee	maize	sw.potatoes	sorghum	graz.
1	++	++	++	++	
1.5	+	++	++	++	
2	+-	++	++	++	
2.5	-	++	++	++	
3	--	++	++	++	
3.5	--	+	++	++	
4	--	+-	++	++	
4.5	--	-	++	++	
5	--	--	+-	+-	
5.5	--	--	-	+-	+
6	--	--	--	+-	+
6.5	--	--	--	-	+
7a	--	--	--	--	+
7b	--	--	--	--	-

explanation of symbols: ++ = well suited
+ = moderately well suited
+- = moderately suited
- = rather unsuited
-- = unsuited

6.3 Framework and suitability evaluation of soil units

Before making the actual suitability evaluation, a framework, although a rough one will be sketched of the average kind of farm, that this suitability counts for. The modal farm, we aim at is atradional farm as found in the area, with an average size of about 3 hectares, with a rotation system with finger millet or maize as first crops, maize, sorghum, finger millet, beans or groundnuts as secondary crops and cassava and sweet potatoes as last crop, whereby usually a few years of fallow follow. Tilling operations are usually done by 'jembe' (broad-bladed hoe), like seedbed preparation, weeding etc. Only a minority of the people possess an oxen plough. The use of manure is negligible and commercial fertilizers are too expensive for the modal Luo farmer in the area. The kind of maize that is grown is for two-third local varieties

Note: The ironstone phase has not been taken into consideration at the suitability evaluation, because often it does not occur as a continuous indurated layer of big extend. In most cases it is just locally indurated layers, so for the utilization possibilities it is not of great importance. Besides this, the distinction between real indurated ironstone and slightly indurated layer of iron-manganese concretions was quite difficult in the field. Therefore the ironstone phase is not more than an indication that the bottom of the profile is rather indurated locally.

For the distribution of the different suitability classes over the area, one should take a look at the suitability map of the Rangwe sample area, belonging to this report.

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Appendix 1: Detailed discription of the individual Soil units.

Profile Ra 1: Aora Nam series.

Classification: Soil Taxonomy 1973: typic tropudalf.

F.A.O. 1974: gleyic luvisol.

Location: In valley of Aora Nam river, near crossing with road Rongo-Rangwe.

Coordinates: 34°35'31" E, 0°42'09" S; altitude : 1347 (4490 ft)

Described by R.F. Breimer on 25-6-1975.

Physiography: dissected plataeu, land unit: lower part of dissection slope.

Petrography: Nyanzian rhyolites (and dellenites).

Vegetation : 60% grasses, 20% trees and shrubs, 15% herbs and 5% bare ground.

Land use: extensive grazing.

Drainage class: poorly drained.

Soil fauna: high activity of ants, worms, termites etc. in upper 50-70 cm.

Root distribution: 0 - 30 cm: few fine, abundant very fine 30-120 cm:
30 -120 cm: frequent very fine, few fine
120 -170 cm: few very fine

Profile characterstics:

A1 0 - 20 cm Very dark greyish greyish brown to very dark brown (10 YR 3/2-2/2, moist); light clay; yellowish brown mottling (10 YR 5/4), common, fine faint; moderate fine and very fine subangular blocky and very fine granular; many fine and very fine, few medium biopores; hard, very friable, slightly sticky, slightly plastic; clear and wavy boundary.

B21t 20- 55 cm Dark grey (10 YR 4/1), moist); heavy clay; common, fine, distinct yellowish brown (10 YR 5/6) mottling; strong coarse angular blocky, consisting of medium and fine strong angular blocky peds; abundant, strong clay -humus cutans and many intersecting slickensides; many very fine and common fine biopores; extremely hard, friable, sticky and slightly plastic; gradual and wavy boundary.

B22t 55- 110cm Dark grey (10 YR 4/1,moist); heavy clay; few, fine faint yellowish brown (10 YR 5/6) mottling strong coarse angular blocky, consisting of fine angular blocky peds; abundant strong clay-humus cutans and intersecting slickensides (darker coloured than the matrix);
few fine and very fine biopores; same consistence as B21t; gradual and wavy boundary.

B3 110- 170+cm Grey (5 YR 5/1, moist); heavy clay; olive (5 YR 5/6) and greenish mottling, common, medium, distinct;strong very coarse angular blocky, consisting of medium and fine angulay blocky peds; abundant strong clay cutans and intesecting slickensides; few fine biopores; extr. hard, friable, sticky, slightly plastic consistence.

Note: pit depth was 170 cm; A1 horizon was at one place tonging into the B21t.

Analytic data:

depth:	sand	silt	clay	org.C	CEC	Na	K	Ca	Mg
0 - 20	14	33	53	2.4	30.1	2.2	0.3	15.4	8.3

30- 40	23	14	63	1.3	39.9	3.0	0.3	19.6	14.1
60- 70	10	30	60	0.6	53.6	2.9	0.3	29.3	21.7
90-100	6	7	87	0.3	56.8	3.2	0.3	30.5	22.6
120-130	20	4	76	0.2	54.7	6.3	0.5	28.0	21.7
160-170	18	20	62	0.1	48.2	4.2	0.4	27.6	20.8

Profile Ra 5: Akelo series.

Classification: Soil Taxonomy 1973: abruptic argiaquoll.
F.A.O. 1974: gleyic phaeozem.
Location: On plateau South of Riana river, next to the Rongo-Rangwe road
Coordinates: 34°35' 30" E, 0° 41' 13" S; altitude : 1365 m (4550 ft)
Described by R.F. Bereimer on 4-7-1975.
Physiography: dissected plateau, land unit: top of plateau.
Petrography : Nyanzian rhyolites (and dellenites).
Vegetation : 55% grasses, 20% trees and shrubs, 5% bare ground.
Land use: extensive grazing.
Drainage class: poorly drained.
Soil fauna: moderate activity of ants worms, termites etc. in upper 30 cm.
root distribution: 0 - 30 cm: abundant very fine, frequent fine, few
30 - 60 cm: abundant very fine, common fine
60 -100 cm: common very fine
over 100 cm: few very fine

Profile charactersitics:

A1 0 - 25 cm Very dark brown (10 YR 2/2, moist), dark grey (10 YR 4/1, dry); silt loam, with light brown soft bricklike pieces; moderate very fine subangular blocky; many fine, common fine and medium biopores; hard, friable, slightly sticky and slightly plastic; abrupt and wavy boundary.

B21t 25 - 60" Very dark brown (10 YR 2/2, moist), very dark greyish brown (10 YR 3/2,dry); heavy clay, with common fine distinct brownish yellow (10 YR 6/6) mottles: strong fine and very fine angular blocky peds inside weak coarse prismatic structure elements; abundant strong clay-humus cutans and abundant strong insecting slickensides; many

many very fine, few fine biopores; extr. hard, firm, sticky and plastic; clear and smooth boundary.

BC 95 -170cm Mixed colours: whitish/greenish with yellowish brown and black staining, gravelly to very gravelly clay; massive structure; few very fine biopores, very hard, firm, slightly sticky and slightly to non-plastic; few lime to be heard on applying HCl.

Note : Pit reached a depth of 170 cm and the lower part of the BC horizon could be condered as rotten rock (C horizon).

Profile Ra7: Riana - Kuna series.

Classification: Soil Taxonomy 1973: abrupt tropaqualf (actually it should be called a tropical albaqualf)
F.A.O. 1974: Solodic planosol.

Location: About one km east of the Rongo-Rangwe road, just north of the Riana river.

Coordinates: 34°35'48" E, 0°40'12" S; altitude: 1362 m (4540 ft).

Described by: R.F. Breimer on 12-7-1975.

Physiography: slight sloping plain, sloping towards, towards the Riana river.

Petrography : Nyanzian basalt (or perhaps old alluvium).

Vegetation : 60% grasses, 20% trees and shrubs, 10% bare ground.

Land use: extensive graizing.

Drainage: poorly drained.

Soil fauna: high activity of ants worms, termites etc. in upper 40 cm.

Root distribution: 0 - 40 cm: abundant very fine, frequent, few medium
40 - 75 cm: abundant very fine, common fine.
75 -150 cm: common to very few fine.

Profile characteristics:

A1 0 - 7 cm Dark grey to grey (10 YR 4-5/1, moist); silty clay loam; moderate very fine subangular blocky; many fine, common fine and few medium biopores; slightly hard, very friable, slightly sticky, slightly plastic, clear and smooth boundary.

A2 7 - 40 cm Light brownish grey (10 YR 6/2, moist); silt loam, with many fine distinct dark yellowish brown (10 YR 4/4) mottles; moderate, very fine subangular blocky:

many very fine, common fine, few medium biopores; slightly hard, very friable slightly sticky, slightly plastic, clear and smooth boundary.

B21t 40 - 75cm Dark grey (10 YR 4/1, moist); heavy clay, with many fine prominent yellowish brown (10YR 5/8) mottles, moderate coarse prismatic, consisting of strong fine angular blocky peds; abundant strong clay-humus cutans; many very fine, few fine biopores; extr. hard, friable, sticky and plastic; gradual are wavy boundary.

B22t 75 -120cm Dark grey (10 YR 4/1, moist); heavy clay, with common medium distinct yellowish brown (10 YR 5/8) mottles; strong very fine angular blocky; abundant strong strong clay-humus cutans and abundant strong intersecting slickensides; common very fine biopores extr. hard, firm, sticky and plastic; gradual and slightly wavy boundary.

B3 110-150 cm Dark grey (10 YR 4-5/1,moist); clay, slightly gravelly from rotten rock, with yellow (5 YR 7/8),yellowish brown and black staining; strong very fine angular blocky; common moderate clayskins and few moderate slickensides; few very fine biopores; extr. hard, firm, slightly sticky, plastic.

Note: the B22t was found as dry and compact clay and the transition from the A2 horizons was marked by many 10 YR 5/8 mottles.

Analtytical data:

depth	sand	silt	clay	org.C	CEC	Na	K	Ca	Mg
0 - 7	10	55	35	2.4	15.1	0.7	0.3	5.5	1.7
10 -30	10	75	15	2.4	12.3	1.4	0.2	3.9	0.5
50- 70	4	15	81	1.2	37.9	4.0	0.7	13.8	3.7
90-100	5	0	95	0.8	39.0	1.7	0.6	15.1	5.5
130-140	11	66	23	0.2	30.7	4.8	0.6	16.1	6.1

Profile Ra 10: Oboke series.

Classification: Soil Taxonomy 1973: hapludoll
F.A.O. 1974: haplic phaeozem

Location: Oboke market, just beside the Rongo - Rangwe road

Coordinates: 34°35' 16" E, 0°38' 54" S; altitude: 1350 m (45000) ft.
Described by R.F. Breimer on 11-8-1975.
Physiography: "footridge" of Kuna hill, higher as slightly sloping plains.
Petrography : Nyanzian rhyolites (and dellenites).
Vegetation: 30% grasses, 30% shrubs, trees 10%.
Land use: idle land(perhaps only for grazing of goats).
Drainage class: moderately well drained.
Soil fauna: relatively high activity of ants, termites etc. in upper 50 cm
Root distribution: 0 - 50 cm: abundant very fine, few medium and very few coarse
50 - 95 cm: frequent very fine, very few fine.

Profile characteristics:

A1 0 - 29 cm Very dark greysih brown (10 YR 3/2, moist); gravelly clay loam; moderate very fine subangular blocky and very granualar; common very fine biopores; soft, loose to very friable, slightly sticky and slightly plastic; gradual and wavy boundary.

AB 29 - 46cm Dark brown (7.5 YR 3/2),moist); very gravelly clay loam; moderate very fine subangular blocky and few fine granular; common to few fine biopores; soft, loose, slightly sticky and slightly plastic; gradual and wavy boundary.

B3 46 - 95cm Dark brown to brown (7.5 YR 4/2, moist); very gravelly clay loam (gravels small and big, light brown coloured); moderate very fine granular to subangular blocky: few very fine biopores; soft loose, slightly sticky and slightly plastic; gradual and wavy boundary.

C 95 -120cm Mixed colours: brown (10 YR 5/3) mixed with black and yellow (10 YR 7/8) rotten rock staining, very gravelly, slightly stony silt loam; massive structure,; biopores only in joints; extr. hard (rocky) consistence.

Note: Ironstone occurs very locally from 50-120 cm depth, but not at the place of description. On these places you can find ironstones and boulders, developed on top and partly mixed with rotten rock gravels.

Analytic data:

depth	sand	silt	clay	org.C	CEC	Na	K	Ca	Mg
0 - 25	40	29	31	2.4	19.3	2.6	0.5	12.9	3.1
30 - 40	32	30	38	2.3	14.9	3.2	0.3	10.0	1.0
60 - 80	41	29	30	1.5	11.1	3.8	0.3	6.8	1.4
100-110	38	58	4	0.3	14.6	2.1	0.3	12.2	1.9

Profile Ra 11: Marando series.

Classification: Soil Taxonomy 1973: typic hapludoll
F.A.O. 1974: haplic phaeozem

Location: approx. 3 km south of Rangwe, next to the road from Rongo to Rangwe.

Coordinates: 34°35'11" E, 0°37'25" S; altitude: 1365 m (4550 ft).

Described by R.F. Breimer on 15-8-1975.

Physiography: ridges dissected by rivers, land unit: hillslope.

Petrography: Nyanzian rhyolites (and dellenites).

Vegetation: trees and shrubs 30%, grasses 40%, herbs 10%, bare ground 20%.

Land use: cropland for maize, sorghum etc.

Drainage class: well drained.

Soil fauna: in upper 50 cm high activity of ants, termites, worms etc., from 50 to 70 cm moderate activity and deeper than 75 cm no activity.

Root distribution: 0 - 35 cm: abundant very fine, common fine, few medium
35 - 75 cm: common very fine, very few fine
75 -125 cm: few very fine
over 125 cm: no roots.

Profile characteristics:

A11 0 - 22 cm Dark brown (7.5 YR 3/2, moist); gravelly light clay; moderate fine and very fine subangular blocky and very fine granular; many very fine, few fine and medium biopores; hard friable, slightly sticky and slightly plastic; broken boundary.

A12 22 - 35cm Dark brown (7.5 YR 3/2 ,moist); very gravelly light clay

gravels giving yellowish orange, black staining; moderate fine and very fine subangular many very fine, few fine and medium biopores; hard, firm, sticky and plastic; gradual and wavy boundary.

AB 35 - 56cm Brown to dark brown (7.5 YR 4/3, moist); mixed with yellowish orange and black rotten colours, very gravelly light clay (small gravels); weak very fine angular to subangular blocky; many very fine, medium and coarse biopores; very hard, firm, sticky and slightly plastic; gradual and wavy boundary.

B3 56 - 75cm Mixed colours; brown to dark brown (7.5 YR 4/3) from rotten rock gravels, very gravelly (small and bigger gravels) clay loam; moderate fine and very fine subangular blocky; common fine and very fine biopores; hard, firm, and slightly plastic; gradual and wavy boundary.

C1 75 -130cm Predominantly yellowish red (5 YR 5/8), with dark brown (7.5 YR 3/2 in the joints; massive structure; pores only in the joints.

C2 130-150cm Predominantly reddish yellow (7.5 YR 6/8), massive slightly soft to hard rotten rock (more tough than C1),no pores.

Analytical data:

depth	sand	silt	clay	org.C	CEC	Na	K	Ca	Mg
0- 20	41	18	41	1.9	21.7	2.0	0.8	15.4	2.7
25-335	41	10	49	2.4	18.4	1.4	0.4	14.4	3.0
40- 50	34	14	52	1.7	15.2	2.7	0.4	12.9	2.1
60- 70	27	46	27	0.8	12.2	2.7	0.5	12.9	3.3
90-110	34	32	34	0.4	13.0	2.7	0.5	12.2	5.5
130-140	40	51	9	0.2	-	-	-	-	-

Profile Ra 12: Nyandara I series.

Classification: Soil Taxonomy 1973: typic tropudalf
F.A.O. 1974: chromic luvisol

Location: beside the road from Rangwe to Oyugis, north of the Nyandara river valley.

Coordinates: 34°35'30" E, 0°35'37" S, altitude: 1284 m (4280 ft).

Described by R.F. Breimer on 30-8-1975.
Physiography: hills, disected by rivers and small streams.
Petrography: Nyanzian basalt.
Land units: lower part of hillslope.
Vegetatioon: grasses 40%, trees 30% shrubs 20%, herbs 10%.
Land use: extensive grazing.
Drainage class: well drained.
Soil fauna: high activity of termites, ants, worms etc. throughout the whole profile.
Root distribution: 0 - 40 cm: abundant very fine, frequent fine,
40 - 85 cm: frquent very fine, common medium
85 -140 cm: common very fine, few fine, very few medium

Profile characteristics:

A1 0 - 22 cm Dark reddish brown (5 YR 3/2, moist); clay loam to light clay; moderate fine and very fine subangular blocky and fine very fine angular; many very fine, few fine, medium and coarse biopores, hard, very friable, slightly sticky and slightly plastic; clear and wavy boundary.

AB 22 - 39cm Dusky to weak red (2.5 YR 3-4/2, moist); light clay, with common fine distinct black mottles from iron-manganese cutans; moderate to strong fine and very fine blocky and moderate very fine granular; common moderate clay cutans plus few moderate to strong clay-iron, manganese cutans; many very fine, few fine, medium and coarse biopores; hard, friable slightly sticky and slightly plastic; gradual and wavy boundary.

B21t 85-120cm Weak red to reddish brown (2.5 YR 4/3, moist); clay, with the same cutans mottling as the AB horizon; moderate to strong fine and very fine subangular blocky to angular blocky; abundant strong clay cutans and common strong clay-iron-manganese cutans; many very fine, medium and coarse biopores; very hard, firm, slightly sticky and slightly plastic; gradual and wavy boundary.

B22t 85 - 120 cm Reddish brown (2.5 YR 4/4) when moist, clay, with the same cutan mottling as the B21t horizon; moderate to strong fine and very fine subangular blocky to angular; abundant strong clay cutans and common strong clay-iron-manganese cutans; many very fine, few fine and medium, very few (very) coarse biopores hard, friable, slightly sticky and slightly plastic; gradual wavy boundary.

B3 120 - 140 cm Reddish brown (2.5 YR 4/4) when moist, clay, with fine distinct black mottles (from cutans as well as from conretions of iron-manganese); structure, cutans, porosity and consistence same as B22t; slightly gravelly from iron-manganes conretions.

Note: at 140 cm depth the present groundwater table was found. It should be emphasized that this profile is a rather wet variant of the central concept of the Nyandara I series.

Analytical data;

depth	sand	silt	clay	org.C	CEC	Na	K	Ca	Mg
0 - 20	29	31	40	2.1	15.3	3.5	0.1	10.3	2.1
25 - 35	27	31	42	1.9	11.1	3.3	0.5	7.4	2.5
50 - 70	26	24	50	1.0	13.1	1.3	0.4	7.1	4.4
90 -110	21	14	65	0.7	13.1	0.5	0.4	7.1	4.7
120-140	30	19	51	0.6	11.5	0.4	0.4	11.3	5.2

Profile Ra 14: Rabuor series.

Classification: Soil Taxonomy 1973: typic argiudoll
F.A.O. 1974: luvic pha[illegible]

Location: about 200 m west of the Rongo - Rangwe road, about one km north of Awundo's Village.

Location: about 200m west of the Rongo-Rangwe road, about one km north of Awundo's Village.

Coordinates: 34°35' 04" E, 0°37'22" S; altitude: 1336 m (4545 ft).

Described by R.F. Breimer on 2-9-1975.

Physiography: ridges, dissected by rivers, land unit: hillslope.

Petrography: Nyanzian rhyolites (and dellenites).

Vegetation: 30% grasses, 30% shrubs, 20% trees and 20% herbs.
Land use: grazing, next to a large maize and beans plot.
Drainage class: moderately well drained.
Soil fauna: high activity for worms, ants, termites etc. throughout the whole profile.
Root distribution: 0 - 30 cm: abundant very fine, very frequent fine, few medium.
30 - 60 cm: frequent fine and very fine very few med.
60 - 90 cm: common very fine, very few fine.
90 -180 cm: few very fine.

Profile characteristics:

A1 0 - 15 cm Dark brown (7.5 YR 3/2, moist); clay; moderate very fine subangular blocky and very fine granular; many very fine, few fine, medium and coarse biopores; hard, very friable, slightly sticky and slightly plastic; clear and smooth boundary.

A3 15 - 26cm Dark brown (7.5 YR 3/2, moist); slightly gravelly light clay; moderate fine and very fine subangular blocky and very fine granular; many very fine few fine, medium and coarse bioprses; hard, friable, slightly sticky and slightly plastic; clear and smooth boundary.

B1 26 - 60cm Dark reddish brown (5 YR 3/2, moist); heavy clay; moderate very fine and fine subangular blocky; common moderate clay cutans; many very fine, few fine and dedium biopores, very hard, firm, sticky and slightly plastic; gradual and slightly wavy boundary.

B2t 60 - 90cm Weak red (2.5 YR 4/2); heavy clay; moderate very fine and fine subangular blocky; abundant strong clay cutans and common clay-humus cutans; many very fine and few fine biopores; very hard, firm, sticky and plastic; gradual and wavy boundary.

B31 90 -120cm Weak red to reddish brown (2.5 YR 4/3, moist); mixed with common fine distinct black-yellow mottling (from rotten rock gravels or concretions), slightly gravelley clay; moderate fine and very fine subangular blocky; common

strong clay-cutans; many very fine and fine, few fine and fine, few fine and medium biopores; very hard, firm, sticky and plastic; diffuse and wavy boundary.

B32 220-180cm Weak red to reddish brown (2.5 YR 4/3, moist); with more of the same mottling as B31, gravelly (from rotten rock) clay; strong fine and very fine angular blocky; abundant strong clay cutans; few fine and very fine and very fine biopores; very hard, firm, slightly sticky and plastic.

Note: the B31 horizon seems to have more biological activity than the B2t horizon. It should be emphasized that this profile is a rather wet variant of the central concept of the Rabuor series.

Analytical data:

depth:	sand	silt	clay	org.C	CEC	Na	K	Ca	Mg
0 - 15	20	33	47	2.4	18.5	0.4	0.7	11.3	5.2
15 - 25	21	30	49	2.3	17.3	0.3	0.4	12.5	2.4
40 - 50	19	15	66	1.1	18.7	0.4	0.4	13.2	3.6
70 - 80	20	11	69	0.8	18.9	1.3	0.4	12.5	3.3
100-110	19	0	81	0.8	18.9	1.5	0.4	11.9	3.9
140-160	15	25	60	0.4	17.4	1.1	0.6	12.5	3.6

Profile Ra 15

Representative for: Alluvial soils, undifferentiated.

Classification: Soil Taxonomy 1973: aquic eutropept

F.A.O. 1974: eutric fluvisols

Location: in the Riana river valley, about 300 m east of the Rongo Rangwe road.

Coordinates: 34°35'30" E, 0°40'23" S; altitude: 1341 m (4470 ft).

Described by R.F. Breimer on 22-9-1975.

Physiography: river plain (valley), land unit: river bank levee.

Petrography: Nyanzian basalt (probably), covered by recent alluvium.

Vegetation: probably originally bushy.

Land use: cropland for maize, sorghum and sugar cane.

Drainage class: imperfectly drained.

Soil fauna: high activity of ants, worms and other insects, especially in the upper 85 cm.

Root distribution: 0 - 35 cm: abundant very fine, common very fine,
35 - 85 cm: very frequent very fine, few fine over
over 85 cm: frequent very fine, fine

Profile characteristics:

A1 0 - 35 cm Dark reddish grey (5 YR 4/2, moist); silt loam, with blackish mottles, common, fine, faint; weak moderate and fine subangular blocky and very fine granular; many very fine, common fine and few medium biopores; slightly hard, very friable, slightly sticky and slightly plastic gradual and boundary.

IB 35 - 83 cm Reddish brown (5 YR 4/3, moist); silt loam to silt clay loam, with common fine faint blackish mottles; moderate medium and fine subangular blocky; many very fine, common fine, few medium biopores; slightly hard, very friable, slightly sticky and slightly plastic; abrupt and wavy boundary.

IIB 83-115 cm Reddish brown (5 YR 4/3, moist); silt loam to silt clay loam, with common fine faint blackish mottles; moderate medium and fine subangular blocky; many very fine, common fine, few medium biopores; slightly hard, very friable, slightly sticky and slightly plastic; abrupt and wavy boundary.

IIB 83-115 cm Reddish brown (5 YR 4/3, moist); loamy sand, with many, medium, distinct blachish mottles; weak medium and fine subangular blocky; many very fine few fine and medium biopores; loose, very friable non-sticky and non-plastic.

Note: at 115 cm depth the present groundwater table was found.

Profile Ra 16 Nyandara II series.

Classification: Soil Taxonomy 1973: typic hapludoll
F.A.O. 1974: haplic phaeozem

Location: near Awundo's Village, on the road from Rongo to Rangwe.

Coordinates: 34°35'16" E, 0°37'52" S, altitude: 1383 m.

Description by R.F. Breimer on 8-10-1975.

Physiography: round topped ridges, land unit: near top of the ridges.

Petrography: Nyanzian basalt.
Land use: cropland for maize and sorghum mainly.
Vegetation: trees and shrubs 20%, grasses 30%, arable land 50%.
Drainage: well drained.
Soil fauna: activity in upper 50 cm, down to 140 cm moderate to low activity.
Root distribution: 0 - 50 cm: abundant very fine, frequent fine, very few medium.
50 -100 cm: common very fine, very few fine

Profile characterstics:

A1 0 - 10 cm Dark brown (7.5 YR 3/2, moist); slightly gravelly silt clay loam; moderate very fine subangular blocky to very fine granular; many very fine, common fine, few medium pores; loose, very friable, slightly sticky and slightly plastic; clear and wavy boundary.

B21 45 -85 cm Dark brown (7.5 YR 3/3, moist); plus brownish-orange black rotten rock colours, gravelly and stony clay; moderate fine and very fine subangular blocky structure; few very fine and fine pores; hard, friable, slightly sticky and slightly plastic; broken boundary.

B21 10 - 45cm Dark brown (7.5 YR 3/3, moist); very gravelly silty clay; moderate very fine subangular blocky and granular; common very fine, few fine and medium biopores; hard, very friable, slightly sticky and slightly plastic; gradual and wavy boundary.

C 85-140 cm Mixed colours: yellow-orange-black + few brown soil material, mainly massive soft rotten rock, with few soil in the joints.

Analytical data:

depth	sand	silt	clay	org.C	CEC	Na	K	Ca	Mg
0- 10	14	54	32	2.2	24.0	0.3	1.3	13.2	4.2
20- 30	21	15	64	2.0	18.0	1.8	0.8	7.1	3.2
60- 70	19	3	78	1.3	16.9	0.4	0.8	8.4	2.8
90-120	9	64	27	0.5	19.6	0.4	0.6	11.6	7.0

Note: The texture figures are not very certain, because they differ enormously within short vertical distances.

Profile Ra 17 Marando series.

Classification:	Soil Taxonomy 1973: typic eutropept F.A.O 1974: Chromic cambisol	
Location:	beside Rangwe-Oyugis road, very near to the junction with the Rangwe-Asumbi road.	
Physiography:	ridges with steep slopes, less lateral sloped and small valleys in between.	
Land unit:	steep top	
Petrography:	Nyanzanian rhyolites.	
Vegetation:	Bushy woodland (maily trees and shrubs)	
Land use:	extensive grazing	
Drainage Class:	Excessively drained.	
Soil fauna:	Moderate activity, only in upper 20 cm.	
Root distrbution:	0 - 20 cm: abundant very fine, very few medium deeper than 20 cm: very few fine.	
Profile characteristics:	A1 0 - 20 cm	Dark brown (7.5 YR 3/2, moist), very gravely clay loam;moderate very fine granular structure; few very fine pores; loose; very friable, slightly sticky and slightly plastic; consistence; clear and irregular boundary.
	C over 20 cm	Whitish-Yellowish rotten rock with few brown soil in between the joints.