Soils of the Kisii area, Kenya

W.G. Wielemaker & H.W. Boxem (Eds)

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Abstract

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The Kisii Area, named after the Kisii District, is in the south-west of Kenya; the area surveyed covers 3000 km^2 and includes parts of South Nyanza and Narok District. Land-use, vegetation, climate and ecological zones, geology, geomorphology and present status of erosion are described on the basis of thematic maps.
Soils are defined by taxonomy and physiography and depicted on a soil map of scale 1 : 100 000; factors in their formation are also discussed. For land evaluation, existing and proposed land utilization types are described in detail as a basis for selection of alternatives, for which land suitability is assessed. A detailed account is given of the rating procedures on the basis of land qualities.

Free descriptors: Land evaluation, soil suitability, land qualities, farm type, ecological zone, erosion, soil formation, geology, geomorphology, climate.

ERRATUM

Please add to "Participants in the Kisii Training Project in Pedology" at page XI:

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Appendices

Foreword

The present report is the fourth in the Kenya Soil Survey series of "Reconnaissance Soil Surveys". It is the first prepared jointly by the Kenya Soil Survey and another institution, the Training Project in Pedology of the Agricultural University, Wageningen, the Netherlands.

The Training Project in Pedology was approved by the Government of Kenya on 29 June 1973. It started in September, 1973 and operated in the Kisii area until March 1979. It then moved to the Kilifi area.

It was established jointly by the Ministry of Agriculture and the Faculty of Agriculture of the University of Nairobi. Its aim is the training of M.Sc. students of the Agricultural University, Wageningen in soil survey, land evaluation and related subjects.

Since the Kenya Soil Survey is responsible for all soil surveys in Kenya, a cooperation with the Training Project in Pedology was a logical consequence. As a result of this cooperation, the Project agreed to produce a reconnaissance soil map of Sheet 130 (Kisii) on the scale 1 : 100 000, as a contribution to the systematic reconnaissance soil mapping of the country which is a major long term activity of the Kenya Soil Survey. The accompanying report has been produced in the Netherlands, while all maps were printed in Kenya.

The Training Project in Pedology and the Kenya Soil Survey hope that this report will satisfy the need for general information on soils of the Kisii area and that it will aid agricultural development of the area.

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- Department of Civil Engineering and Irrigation: J.W. Kijne and E. Stamhuis.
- Department of Development and Economics: A. Franke and J.T. Sital.

Summary and conclusions

The Kisii sheet of the Kenya Topographic Survey (Sheet 130) covers an area of about 300 000 ha in the south-west of Kenya. The altitude ranges from 1200 m in the west to 2130 m in the east. The average annual rainfall, which is roughly correlated with altitude, ranges from 1200 mm in the north-west to slightly over 2000 mm in the Central Kisii Highlands. The wettest season is from March till June, the driest from December till March. A second dry and wet season is not pronounced.

Ecological Zone II occupies nearly the whole map, apart from a small area in the north-western corner, which belongs to Zone III (Appendix 2). Zone II is subdivided according to the agricultural suitability into a tea zone (IIa) above 1800 m altitude, a coffee zone (IIb), where maize can be grown twice a year and Zone IIc, where maize can be grown only once a year because of limited rainfall.

The well drained soils in Zone IIa and IIb (App. 1) are intensively used for permanent smallholdings, so that the original vegetation has practically disappeared. Most soils in that area are deep, permeable and highly fertile with good physical characteristics. The fertility is largely due to enrichment with volcanic ash from the Rift Valley Volcanoes. Both the thorough mixing of the ash with the original soils by termites and by intensive weathering helped to conceal that origin of part of the parent material. The well drained soils in part of Zone IIb and in Zone IIc and III are on younger erosion surfaces than the deeper soils in Zone IIa and IIb. They are only moderately deep or shallow, and less enriched by ash than in the deeper soils. Their agricultural suitability is restricted not only by fertility but also by shortage of moisture, especially in the dry season. Many of the soils in that area are used for semi-permanent cultivation or grazing.

Poorly drained soils on Plains and Bottomlands are used mostly for extensive grazing. Especially the soils with a bleached A2 horizon (Planosols) have poor physical characteristics and therefore a low agricultural suitability. Particularly the last soils are prone to gully erosion, which occurred already in the north-west. The well drained soils are not so susceptible to erosion, but continued intensive cultivation, especially of annual crops, increases the risk.

The land was evaluated and classed for several land utilization types, defined by various attributes. As types should be fitted within the physical, economic and social environment, the attributes of present land-use are described in detail according to the scheme of FAO (1975). Information on these

attributes (land, labour and farmpower, capital, technology, infrastructure and market orientation, produce and income levels) was used in defining economic constraints and relevant land utilization types.

The high birth rate is causing an increasing fragmentation of farms. More than half the farms in the densely populated Zones IIa and IIb were smaller than 2 ha, and a fifth were less than 1 ha. Lack of land and capital on the small farms causes heavy cropping for food without maintenance of fertility. Since employment outside agriculture was restricted, intensive land utilization types were defined. Unfortunately they require much capital and careful management. So they can succeed only if training and credit are available to the smaller farmer.

Possible land uses can be classed as follows:

1. Smallholder; rain-fed arable farming; low, medium and high capital input level;
2. Tree crops; low to high capital;
3. Livestock; low to high capital;
4. Fish culture;
5. Bee-keeping;
6. Extraction of natural products.

The suitability of the land for particular uses was assessed as follows. First a rating was assigned for each land quality relevant to the particular land-use. By combination of the ratings, a suitability subclass was assigned for each mapping unit, ecological zone, season and land-use. It included an indication of the most limiting land quality. If land improvement is feasible, a rating is also assigned for potential suitability. The necessary improvement measures are classed by costs or difficulty.

Farm types are distinguished and described for each ecological zone. Each should have such an assortment of produce that production capacity of the soil is maintained and that the farmer earns a reasonable income. Farm-size, produce items, types of farmpower, labour requirements, recurrent and invested capital as well as gross margins of the farm types are summarized in Table 54.

A soil engineering map, Seperate Appendix 10, was prepared by combining several soil mapping units into major soil groups which differ significantly in engineering properties. It is intended for those interested only in engineering properties of the soils.

1 The environment

1.1 SITUATION, COMMUNICATION AND POPULATION

The map is named after the Kisii District which covers the major part of the sheet; a minor part of it is situated in South Nyanza District. Both Kisii and South Nyanza District belong to Nyanza Province. A small area in the south-west belongs to Narok District, which is part of Rift Valley Province.

The area is bounded by lattitudes 0°30' and 1°00' S and longitudes 34°30' and 35°00' E (Fig. 1) and comprises about 3063 km^2. Altitude ranges from 1190 m (3900 ft) in the far north-western part of the area near Ligisa Omoya (the altitude of Lake Victoria is 1134 m (3720 ft)) to more than 2130 m (7000 ft) in the central eastern part south of Keroka (App. 1).

The area can be subdivided broadly into three equal areas by altitude:
1200 - 1520 m (4000 - 5000 ft) in the west
1520 - 1830 m (5000 - 6000 ft) in the centre
1830 - 2130 m (6000 - 7000 ft) in the east
of the surveyed area (Seperate App. 4, Map B).

The surveyed area is administered from different district headquarters (Fig. 2): Kisii Township (Kisii District), Homa Bay (South Nyanza District) and Narok Township (Narok District). The divisional headquarters for Kisii District are Nyamira, Manga, Kisii Township and Ogembo (Fig. 2). The divisional headquarters for South Nyanza District within the area mapped are Rongo and Oyugis (Fig. 2). The divisional headquarters for Narok District are in Kilgoris, which lies just off the area mapped to the south-east. The nearest big town is Kisumu which is the provincianal town for Nyanza. Kisii Town is a fast-growing centre. In most of the area surveyed, there are medium-sized villages with some shops that cater for the majority of the people who live in isolated huts on their farms.

The roads Kisumu - Kisii - Isebania and Kisii - Keroka - Sotik are tarmacked. All-weather roads have been constructed throughout the area (App. 1). Minor roads make the area reasonably accessible but in the rainy season they are only passable by vehicles with four-wheel drive. Nearly all tracks have been upgraded to minor roads. No major difficulties were encountered with access during the survey.

Figure 2 indicates population density for each location, according to the national census of 1969. The highest population density was in the central part of the Kisii District, which is under intensive cultivation. The south

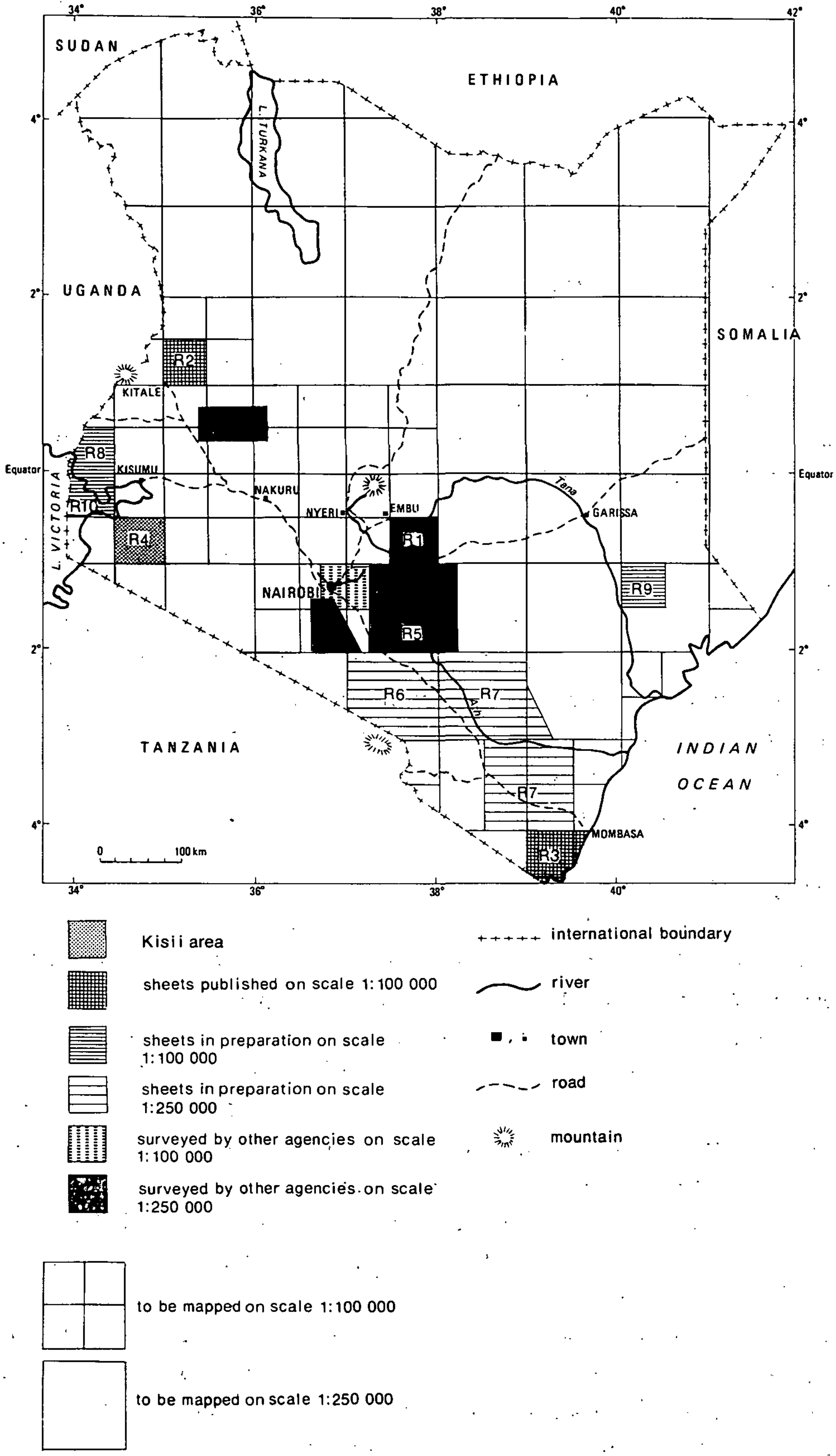


Fig. 1. Situation of published and programmed reconnaissance soil surveys. R1, R2 ... are numbers of the respective reports.

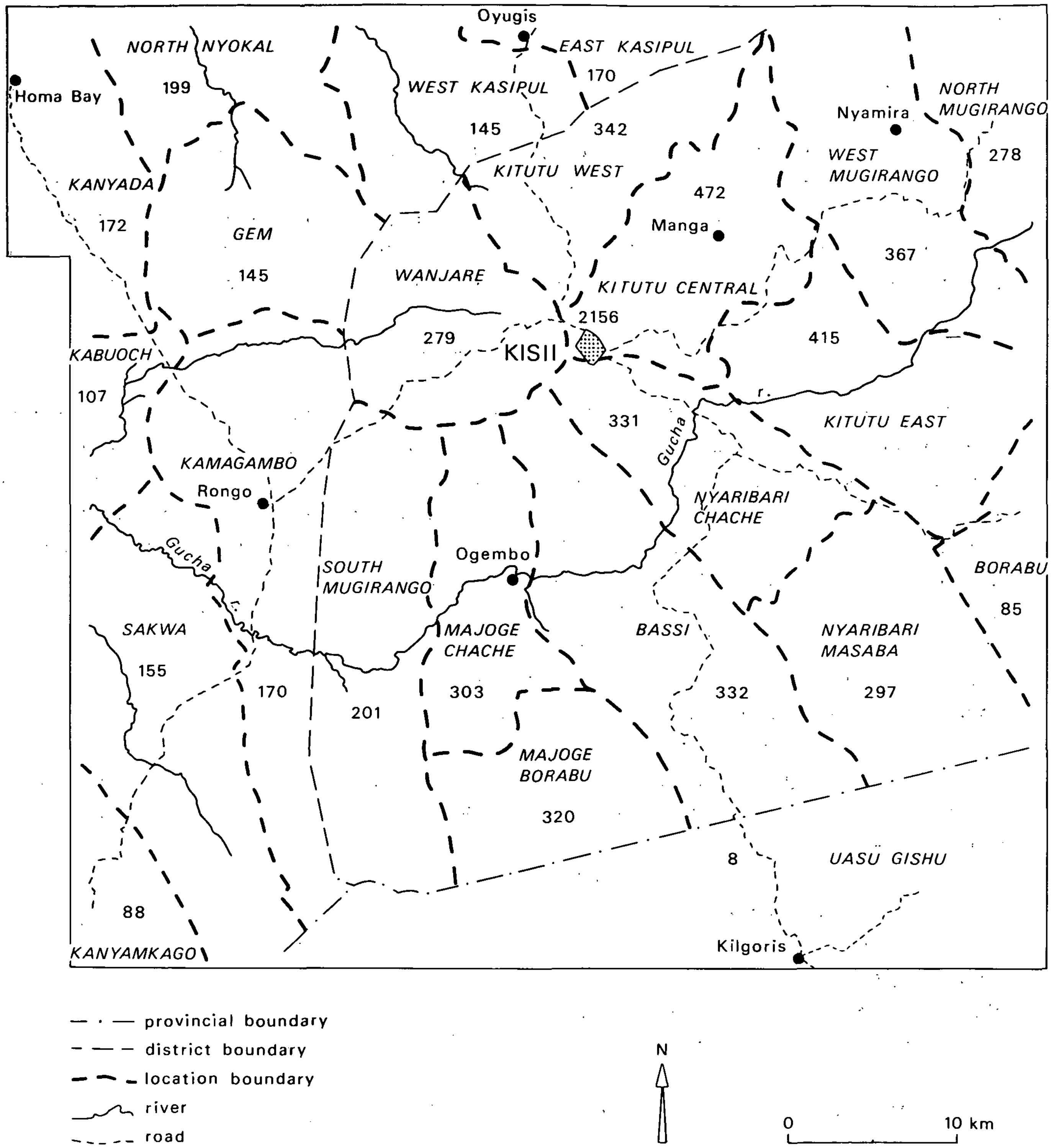


Fig. 2. Administrative boundaries in Kisii District (centre east), South Nyanza District (west) and Narok District (south) within the area mapped. Population density per square kilometer for each location according to the Kenyan population census of 1969.

is grazed by Masai cattle and has a low population density. The rate of increase in population in the Kisii District is 38 per thousand per year (Lanting, 1977).

1.2 CLIMATE

1.2.1 *Introduction*

Besides soil, the agricultural potential of an area depends closely on climate, particularly annual and seasonal balance between rainfall and evaporation. The present study of climate was largely in the survey area, the Kisii and South-Nyanza districts having already been studied (van Mourik, 1974). There were sufficient rainfall-recording stations in the survey area.

1.2.2 *Relation between altitude and climate*

Altitude affects rainfall, temperature and evaporation and consequently also vegetation (Trappnell & Griffith, 1960). Both altitude and vegetation have been used as a guide to the drawing of isohyets and iso-probability lines, discussed in following sections. The relation between altitude and mean temperature is given by EAMD (1970). Braun (1980) relates altitude and thermodynamic temperature for Kenya as follows:

mean max. temperature = 35.5 - 5.94 x (x = altitude in km)
mean min. temperature = 24.8 - 7.05 x
mean temperature = 30.2 - 6.50 x
absolute max. temperature = 42.5 - 5.51 x
absolute min. temperature = 16.3 - 6.56 x

With these equations, the range of temperatures for the Kisii area can be calculated. The altitude ranges from 1190 m (3900 ft) to 2130 m (7000 ft), which gives:

altitude	1190 m	2130 m
mean max. temperature	28.4 °C	22.8 °C
mean min. temperature	16.4 °C	9.8 °C
mean temperature	22.5 °C	16.4 °C
absolute max. temperature	35.9 °C	30.8 °C
absolute min. temperature	8.5 °C	2.3 °C

1.2.3 *Adjusted average for annual rainfall*

Of 25 rainfall stations in Figure 3, 14 had data for at least 15 years, and presumably their averages were reasonably accurate. For the other 11 stations, the annual average was adjusted by adding the annual totals available for each station (A), (EAMD, 1976 and earlier) dividing it by the total for the same years of a nearby station (B), with a longer period of records and multiplying by the long-term average for that station:

$$\bar{r}_A = \frac{\Sigma_n = i\ r_A \times \bar{r}_B}{\Sigma_n = i\ r_B}$$

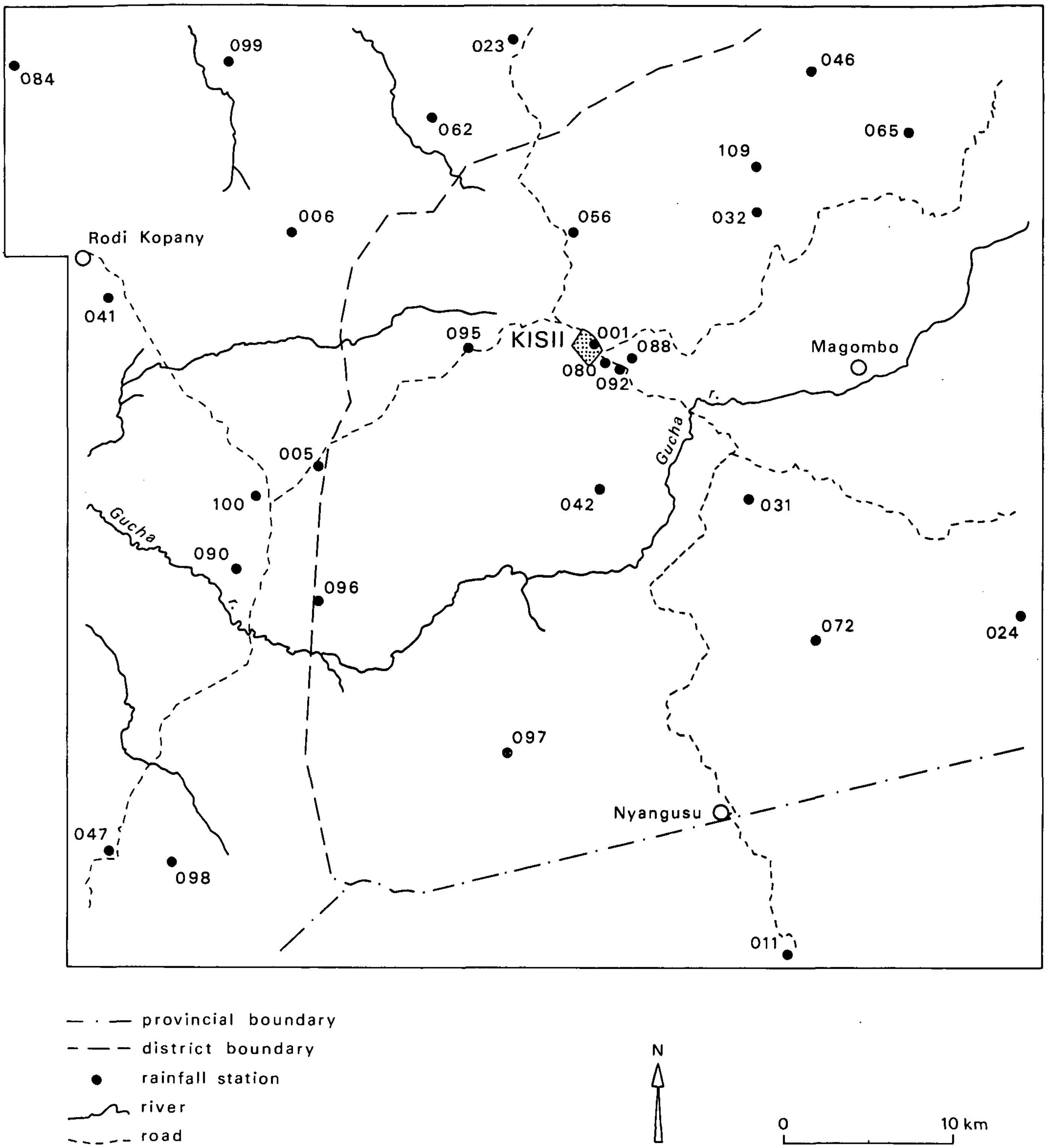


Fig. 3. Position of rainfall stations; the EAMD code number should be preceded by 90340 (Table 1).

The averages and adjusted averages of annual rainfall for stations in the Kisii area and some stations just outside that area, are given in Table 1. Striking are the differences between the normal and adjusted averages for Kisii Water Supply and Nyamarambe Chief Camp. However the data for Kisii NARS and Kisii Water Supply are, if adjusted, nearly the same. The stations are very close together.

Table 1. Annual rainfall and duration of records for 25 stations within the area mapped. The stations Singoiwek, Homa Bay and Kilgoris are just outside the area. Source and code number: East African Meteorological Department.

Station name	Number	Duration of records (years)	Average annual rainfall (mm)	Adjusted annual rain-fall (mm)
Kisii DC	9034001	66	1790	-
Kamagambo T.S.	9034005	37	1597	-
Asumbi T.T.C.	9034006	36	1598	-
Oyugis A.S.	9034023	24	1329	-
Singoiwek	9034024	36	1444	-
Nyanturubo F.C.S.	9034031	25	2099	-
Morumbo F.C.S.	9034032	34	2012	-
Marinde T.C.	9034041	26	1756	-
Nyakegogi F.C.S.	9034042	25	1706	-
Nyabomite F.C.S.	9034046	22	1865	-
Uriri C.C.	9034047	22	1379	-
Nyakoe F.C.S.	9034056	22	1756	-
Kodera F.S.	9034066	17	1630	-
Nyamira D.O.	9034065	15	1918	-
Kiamokama F.C.	9034072	13	1607	1674
Kisii C.R.F.	9034080	29	1952	-
Homa Bay	9034084	14	1163	1182
Kisii NARS	9034088	11	2450	2449
Rakwaro Sem.	9034090	4	1889	1966
Kisii W. Sup.	9034092	12	2074	2437
Wanjare C.C.	9034095	5	2021	1911
Nyamarambe C.C.	9034096	3	1980	2267
Kenyenya	9034097	5	1450	1469
Sakwa Jope	9034098	7	1633	1661
Ndiru C.C.	9034099	5	1296	1248
Rongo C.C.	9034100	9	1809	1798
Itibo Sec. S.	9034109	5	1792	1732
Kilgoris	9134011	24	1424	-

1.2.4 *Average annual rainfall and evaporation*

Maps of annual and monthly rainfall on a scale 1 : 2 000 000 are available for East Africa in 13 North and 13 South Sheets (EAC, 1971). They provide a first approximation to rainfall distribution. The data of Table 1 provide a more detailed distribution pattern. The mean annual rainfall map (Fig. 4) indicates a larger area with an annual precipitation above 2000 mm than on the EAC (1971) maps.

The sharp decrease in rainfall towards the west is striking but is well correlated with physiography (Manga, Marongo Ridge) and altitude. The rainfall stations however, are not regularly distributed over the area mapped, so that data are easily misinterpreted. In general the pattern follows the main altitude lines. The average annual rainfall varies from less than 1200 mm in the north-west near Ligisa Omoya to more than 2000 mm in the central Kisii Highlands. A sharp increase in altitude results in extra rainfall as the prevailing direction of rainstorms is from south-east to north-

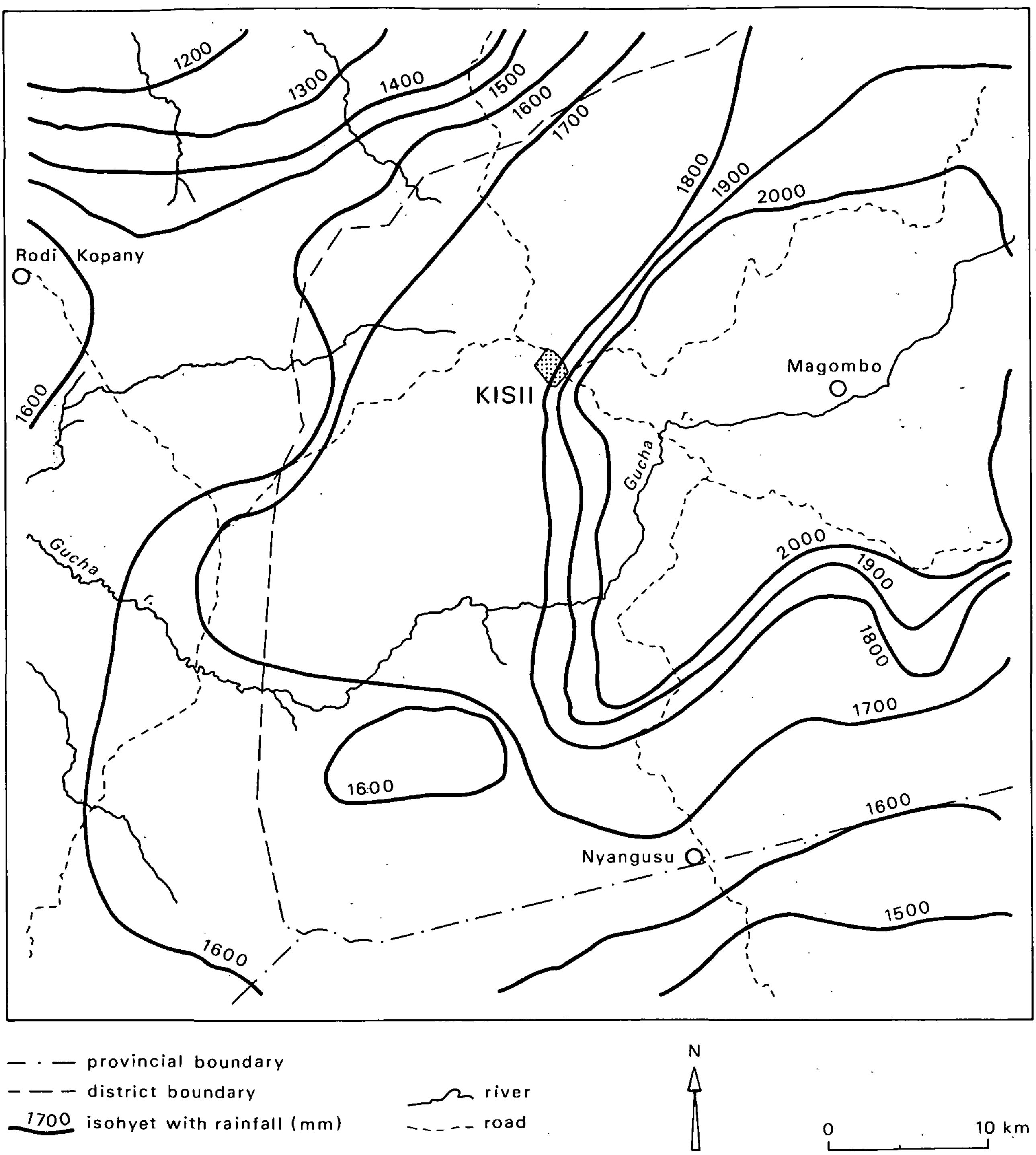


Fig. 4. Map of average annual rainfall.

west. Although rainfall maps reflect differences in altitude, they do not account for differences in rainfall due to local differences in topography, for instance between the west and east sides of hills.

The map of the average annual potential evaporation (Fig. 5) is an adaptation of the 1 : 3 000 000 map by Woodhead (1968). The iso-evaporation lines of Figure 5 follow the altitude more closely than the isohyets (Fig. 4). The evaporation varies from less than 1800 mm (but higher than 1600 mm) in the central part of the Kisii Highlands to more than 2100 mm in the utmost north-west of the mapped area near Ligisa Omoya. The trend in evapora-

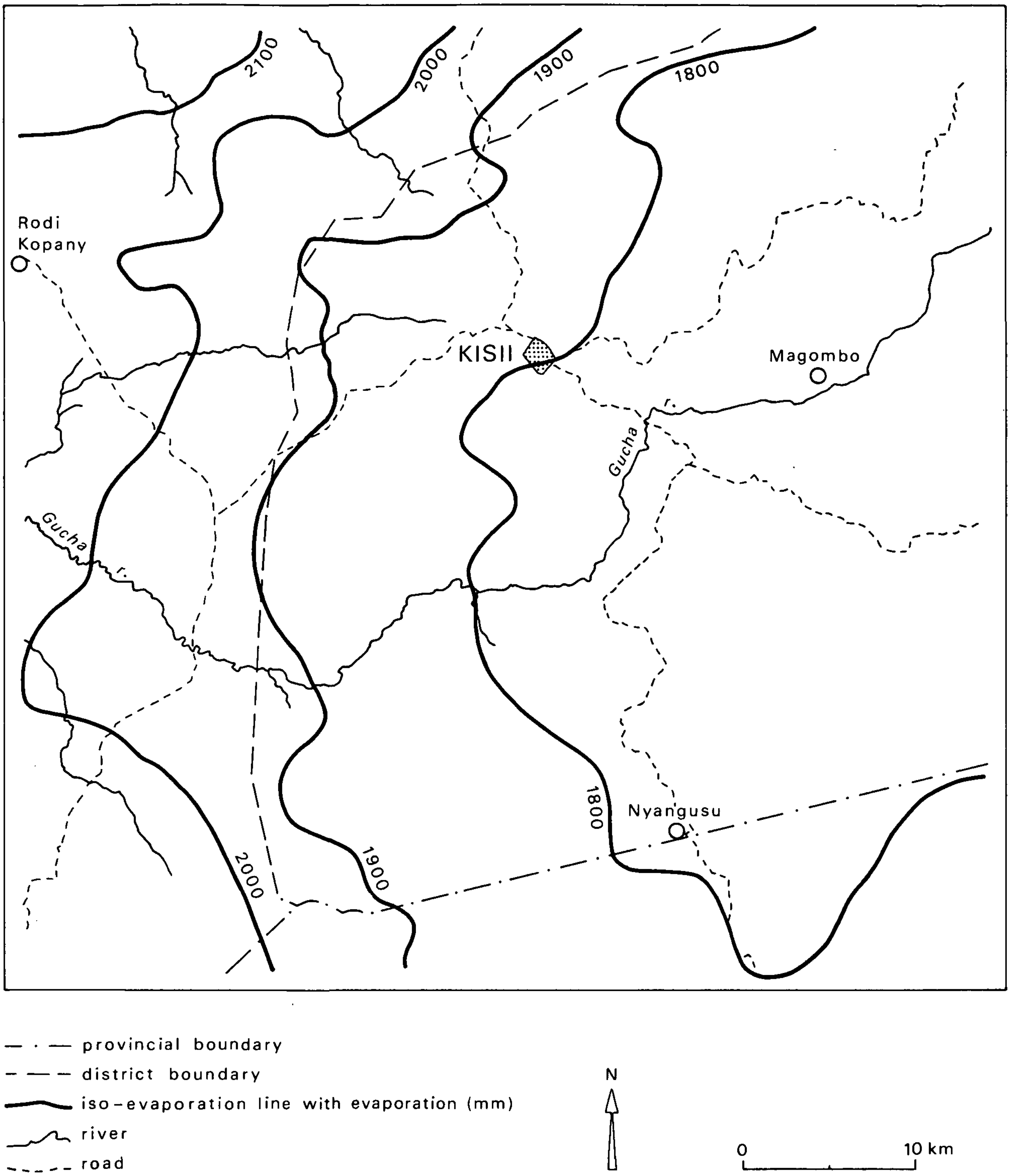


Fig. 5. Map of average annual potential evaporation.

tion is opposite to that in precipitation; areas with a low rainfall have a high evaporation. The ratio of rainfall to evaporation varies considerably.

1.2.5 *Average seasonal rainfall and evaporation*

Unlike most parts of Kenya, there are no pronounced wet and dry seasons in most of the area, but the distribution of rainfall within a year fluctuates considerably from long-term averages. Heavy rain may fall in an expected dry season. The seasons of the year are, however, more clearly marked in the drier area than in the wetter mapped area.

The seasonal fluctuation in evaporation is not great (App. 9.1.4).

Four seasons are distinguished as a general pattern:

- March - May: Major rainy season, precipitation is about 36% of the annual total.
- June - August: Intermediate season, precipitaion about 21% of the annual total.
- September - November: Minor rainy season, precipitation about 27% of the annual total.
- December - February: Dry season, precipitation about 15% of the annual total.

There are three major discrepancies in this general pattern where the four seasons cannot be distinguished.

- In the higher parts (Kisii Highlands) with a total annual rainfall of over 2000 mm, the intermediate season has the same or even a higher (Morumba) precipitation than the following rainy season. This resembles a monomodal system with an extended rainy season of nine months and a dry season of three months, which still has a precipitation of more than 500 mm.
- July is the driest month of the year in the south and south-east, and January or February are the driest in the remainder. For Kilgoris and Uriri, the driest season is not December - January, but June - August.
- The north-western drier part has a much more pronounced rainy season (41%) than the general pattern (36%). The 'intermediate' season is as dry as the 'dry' season.

If a month with an average rainfall of less than 100 mm is taken as dry, 100 mm to 150 mm as a moist month and more than 150 mm as a wet month, then there are 2-8 wet months and 1-6 dry months (Table 2). January, February and June are the driest months except for Kilgoris and Singoiwek in the south-east. Noteworthy is the station of Uriri which has two pronounced dry periods in December - March and June - September.

1.2.6 *The reliability of monthly and annual rainfall*

Figure 6 shows that annual rainfall fluctuates considerably. Optimum growth of crops requires continuous moisture throughout the growing season. It is therefore worthwhile to consider the reliability of rainfall not only for the year but also for each month. The monthly rainfall reached or exceeded in 3 out of 4 years is given in Table 3 for 11 stations with a recording period of more than 20 years.

Crops can presumably be grown if the seasonal rainfall is at least two-

Table 2. The distribution of wet (++), moist (+) and dry (-) months of stations with a recording period longer than 5 years. Wet = more than 150 mm; dry = less than 100 mm. Source rainfall records from EAMD to 1977.

	J	F	M	A	M	J	J	A	S	O	N	D	Dry	Moist	Wet
Kisii	-	-	++	++	++	++	+	++	++	+	+	+	2	4	6
Kamagambo	-	-	+	++	++	+	-	+	+	+	++	+	3	6	3
Asumbi	-	-	+	++	++	+	-	+	+	+	+	-	4	6	2
Oyugis	-	-	+	++	++	+	+	+	+	-	+	-	4	6	2
Nyanturubo	-	-	++	++	++	++	+	++	++	++	++	+	2	1	8
Morumba	-	-	++	++	++	++	+	++	++	++	++	+	2	1	8
Marinde	-	-	++	++	++	+	-	+	++	++	++	+	3	3	6
Nyakegoli	-	-	++	++	++	++	-	+	++	+	++	+	3	3	6
Nyabomite	-	-	++	++	++	++	+	++	++	++	++	+	2	2	8
Uriri	-	-	+	++	++	-	-	-	+	+	+	-	6	4	2
Nyakoe	-	-	++	++	++	+	-	+	++	+	++	+	3	4	5
Kodera	-	-	+	++	++	+	-	+	+	+	+	+	3	7	2
Kisii CRF	-	+	++	++	++	++	+	++	++	+	++	+	1	4	7
Wanjare	-	-	++	++	++	++	++	++	++	+	+	-	3	2	7
Kilgoris	-	+	++	++	++	+	-	-	+	-	+	+	4	5	3
Homa Bay	-	-	+	+	++	-	-	-	-	-	-	-	9	2	1

thirds of potential evaporation (if effectiveness of rainfall be ignored). This fraction of potential evaporation is called potential evapotranspiration, with which the monthly rainfall reliability is compared for stations representative of Ecological Zones IIa, IIb and IIc (Section 1.6 and App. 2) in Figure 7. There Zone III is not represented since Homa Bay has records for less than 20 years. However Appendix 9.1.4 gives data for the average monthly and annual rainfall and potential evaporation for stations representative of all the ecological zones. Chapter 4 and Appendix 9.1 give a detailed appraisal of the availability of water for crops.

Table 3. Average monthly and annual rainfall (mm), reached or exceeded in three out of four years in the Kisii and South Nyanza Districts.

Station	J	F	M	A	M	J	J	A	S	O	N	D	Year
Kisii	30	25	120	245	170	85	50	105	115	75	45	50	1525
Asumbi	20	20	95	200	185	85	60	100	105	90	55	50	1425
Oyugis	10	20	70	175	165	70	80	100	70	65	50	20	1125
Nyanturubo	35	25	115	130	175	130	55	115	120	95	70	70	1500
Morumba	40	30	150	240	210	130	90	110	135	125	85	70	1800
Marinde	10	20	110	200	145	50	30	75	100	95	85	40	850
Nyakegogi	20	10	105	180	105	80	45	75	90	80	110	65	825
Nyabomite	20	10	100	140	145	80	65	105	130	160	60	35	1400
Uriri	20	15	70	165	120	60	10	55	80	80	75	55	1100
CRF	30	55	130	240	205	110	70	135	145	120	80	65	1800
Kilgoris	55	65	130	145	100	60	35	80	60	40	105	95	1300

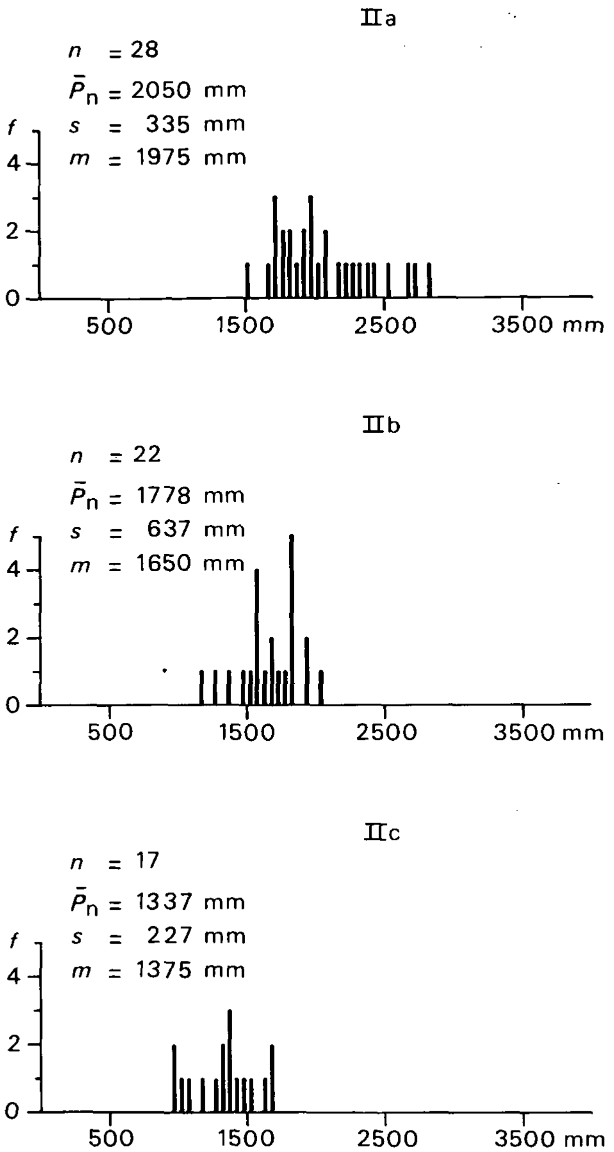


Fig. 6. Frequency of occurrence of different annual rainfalls for stations representative of Ecological Zones IIa (Morumba 9034032), IIb (Kisii 9034001) and IIc (Oyugis 9034023).

1.3 GEOLOGY, GEOMORPHOLOGY AND HYDROLOGY

1.3.1 *Geology*

The geology of the area was surveyed in 1947-1949 and the map and report were published by Huddleston (1951). To clarify the relationship between geology and soil formation, a simplified geological map has been prepared from Huddlestons' publication (App. 4, Map A).

- Precambrian rocks occupy the major part of the area mapped. They are composed of an older Nyanzian system, below an altitude of about 1500 m in the west and a younger or Bukoban system, occurring above an altitude of 1500 m in the east. Intrusives are especially important in the Nyanzian system. Conglomerates occur both in the Bukoban and Nyanzian rock system and are

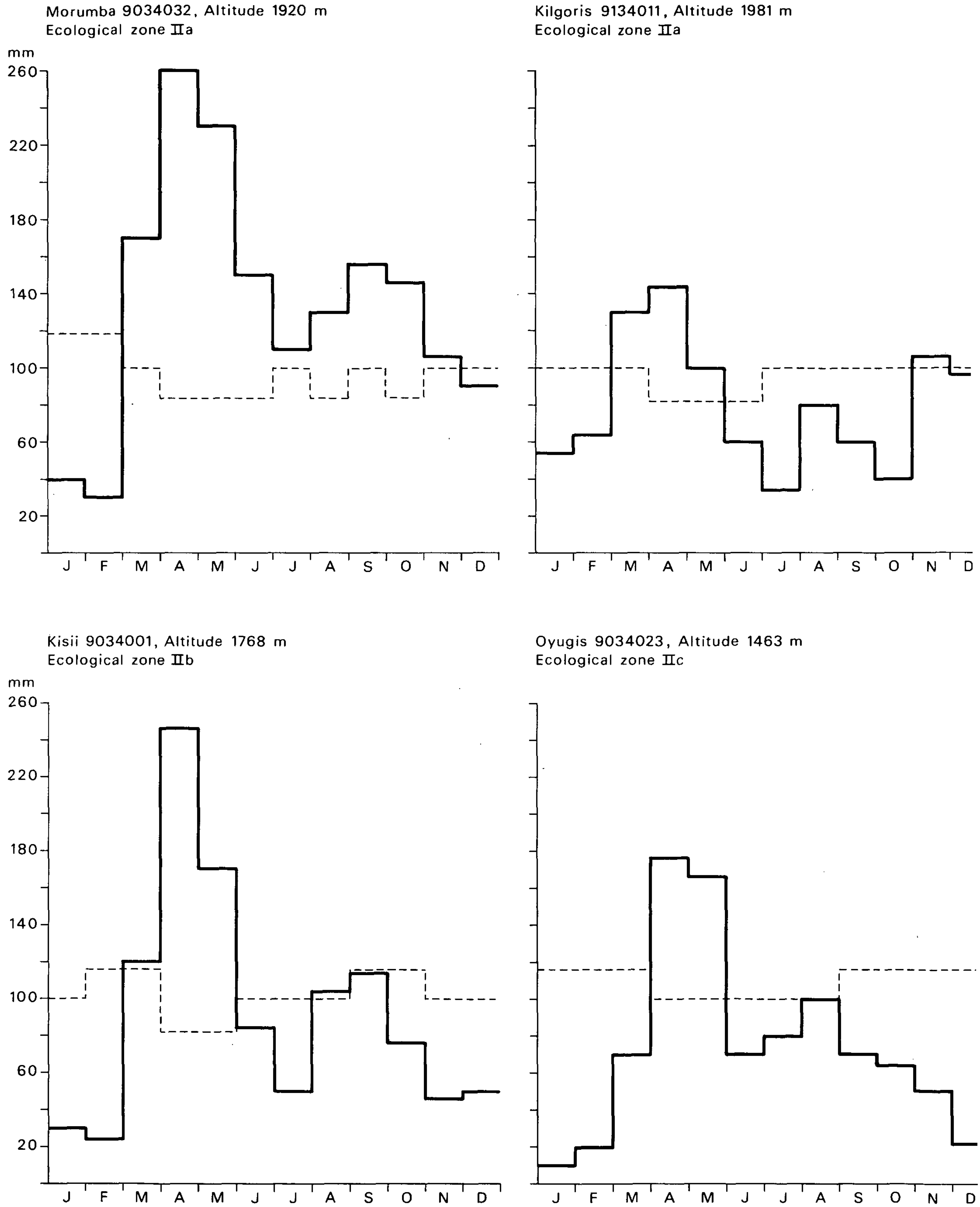


Fig. 7. Average monthly rainfall (solid line), reached or exceeded in three out of four years and the average monthly potential evapotranspiration ($E_T = {}^2/_3\ E_o$) (broken line), for stations representative for ecological zones IIa, IIb and IIc (Section 1.6).

probably late Precambrian.

- Tertiary rocks occupy a small area near Rodi Kopany (McCall, 1958).
- Quaternary rocks occur especially in the south-east.

The Nyanzian system consists of folded lavas: basalts, andesites, diorites, rhyolites and rhyolitic tuffs. Rhyolitic rocks are by far the most widespread. The Bukoban system consists mainly of lava: basalts, felsites, andesites, rhyolites and rhyolitic tuffs. Soapstone occurs locally between the basalts and the quartzites of this system. The Bukoban system is slightly folded. Its synclines and anticlines, but especially the presence of resistant quartzites, govern the present geomorphological structure of the Kisii Highlands. The intrusives are the granites of Kitere, Wanjare and Oyugis. Field work showed Wanjare granites in fact, to be quartz diorites associated with granites (App. 4, Map A). Intrusives of dolerites are of minor importance in the area. Conglomerates belonging to the Kavirondian system were probably deposited during periods of erosion. They often occur as resistant lenses in valleys associated with cataracts and valley narrowing.

The Tertiary rocks are alkali basalts. The Quaternary rocks are volcanic ash deposits originating from the rift valley volcanoes and blanketing the older rocks. In the west of the area mapped, ash deposits are found only in flat-bottomed valleys in layers 4 m thick. The small scale of mapping does not indicate them (App. 4, Map A).

1.3.2 *Geomorphology*

The area has been divided into the following major physiographic units (App. 4 Map C):

- hills and minor scarps,
- footslopes,
- uplands and plateau remnants,
- plains,
- bottomlands.

Hills and minor scarps. Hills occur in the west and are mostly remnants of older erosion surfaces. Slopes range from 6 to over 30%. Scarps are found along the quartzite ridges, and in the area south of Igare and north of Tonga (Fig. 8). The scarps are well formed; the dip slope on the other side follows the slope of the rock layering.

Footslopes are found at the foot of hills and scarps. Their slopes are 8-25%. Debris from scarps and hills may have accumulated and been carried downslope (Fig. 8).

Uplands and plateau remnants. The uplands are divided in four levels. The criteria for subdivision are based on altitude and geomorphology. The uplands

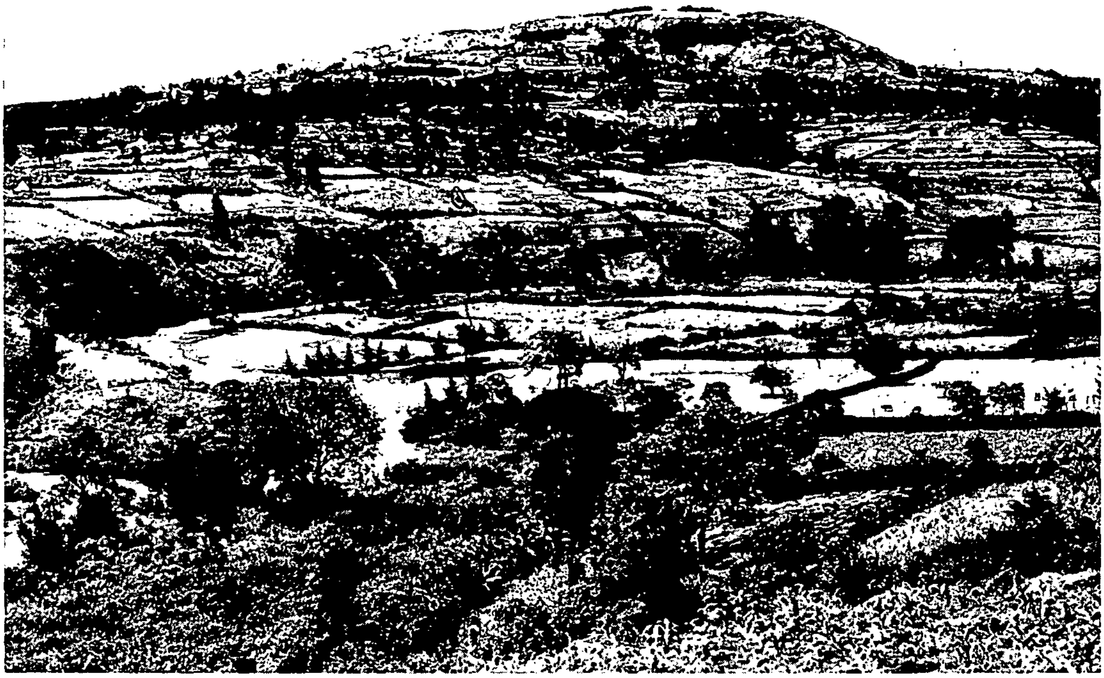


Fig. 8. View from the Marongo ridge to Sameta Hill across the valley of the Gucha River. Geomorphological features are from background to foreground: plateau remnant on top of the hill; quartzite scarp; footslope and flat-topped ridges of the Kisii Upland.

are dissected erosion surfaces, but each upland level does not necessarily correlate with a different erosion surface.

The summits of the highest upland level (Keroka Uplands) are still clearly recognizable on Figure 9. They correspond with the Kisii Surface in the study of Wielemaker & van Dijk (1981). According to Shackleton (1946), it is probably of Cretaceous age. King (1972) correlates it with the Buganda Surface and places it at the end of the Mesozoic era. The surface has tilted since Tertiary times, when the Great Rift Valley started to form. It attains its highest altitude near Keroka (2150 m) and an altitude of 1800 m at its western most occurrence on the Marongo Range (the area bordered by scarps west of Ogembo). The erosion surface is strongly dissected and slopes of over 20% are quite common.

The Magombo Uplands occur in the east. Characteristic for the landscape are the flat-topped ridges alternating with bottomlands (Fig. 9). The topography is undulating to rolling. Its altitude is 1700-1950 m. Wielemaker & van Dijk (1981) call it the Magombo Surface, and suggest that it formed in the early Tertiary just before the formation of the Rift Valley.

The Kisii Uplands resemble the Magombo Uplands south and east of Ogembo, where the ridges are associated with bottomlands. The same type of landscape occurs north of Kisii but at a lower level; it is probably younger. The rest of the Kisii Uplands are more dissected with rolling topography and V-shaped valleys. The altitude is 1450-1800 m.

Fig. 9. View from Nyambaria across the Magombo Uplands. In the background are the Keroka Uplands.

The Rongo Uplands lie west of the Marongo Range. The landscape consists of parallel flat-topped ridges. The flat-topped parts often carry a 1 m thick ironstone cap. A veneer of riverine deposits, mainly rounded quartzitic stones, are embedded in the ironstone or occur as a stone layer above the weathered rock. In the study of Wielemaker & van Dijk (1981) one part of the uplands is correlated with an early Pleistocene or Rongo Surface and another part with a Mid-Pleistocene or Magena Surface. The altitude is 1580-1250 m.

Plains are all imperfectly to poorly drained. The plains occupied by units PXa and PGa (App. 1) are somewhat dissected. The undissected parts are remnants of the youngest erosion surface in the area. This surface, equivalent to the Magena Surface, probably matured during the Mid-Pleistocene. Many rounded resistant stones are found at a depth of 50-100 cm just above the rotten rock. The maximum altitude is slightly more than 1500 m. The plain in the south-east is older and hardly dissected. It occurs at an altitude of slightly less than 1800 m.

Bottomlands. Many poorly drained flat-bottomed valleys occur along the tributaries of the Gucha River and along the upstream part of the Gucha River itself in the east. The incision of streams proceeds irregularly because of very resistant conglomerate and quartzite lenses in the rocks. Near these lenses the valleys narrow, giving cataracts and rapids. The flat-bottomed

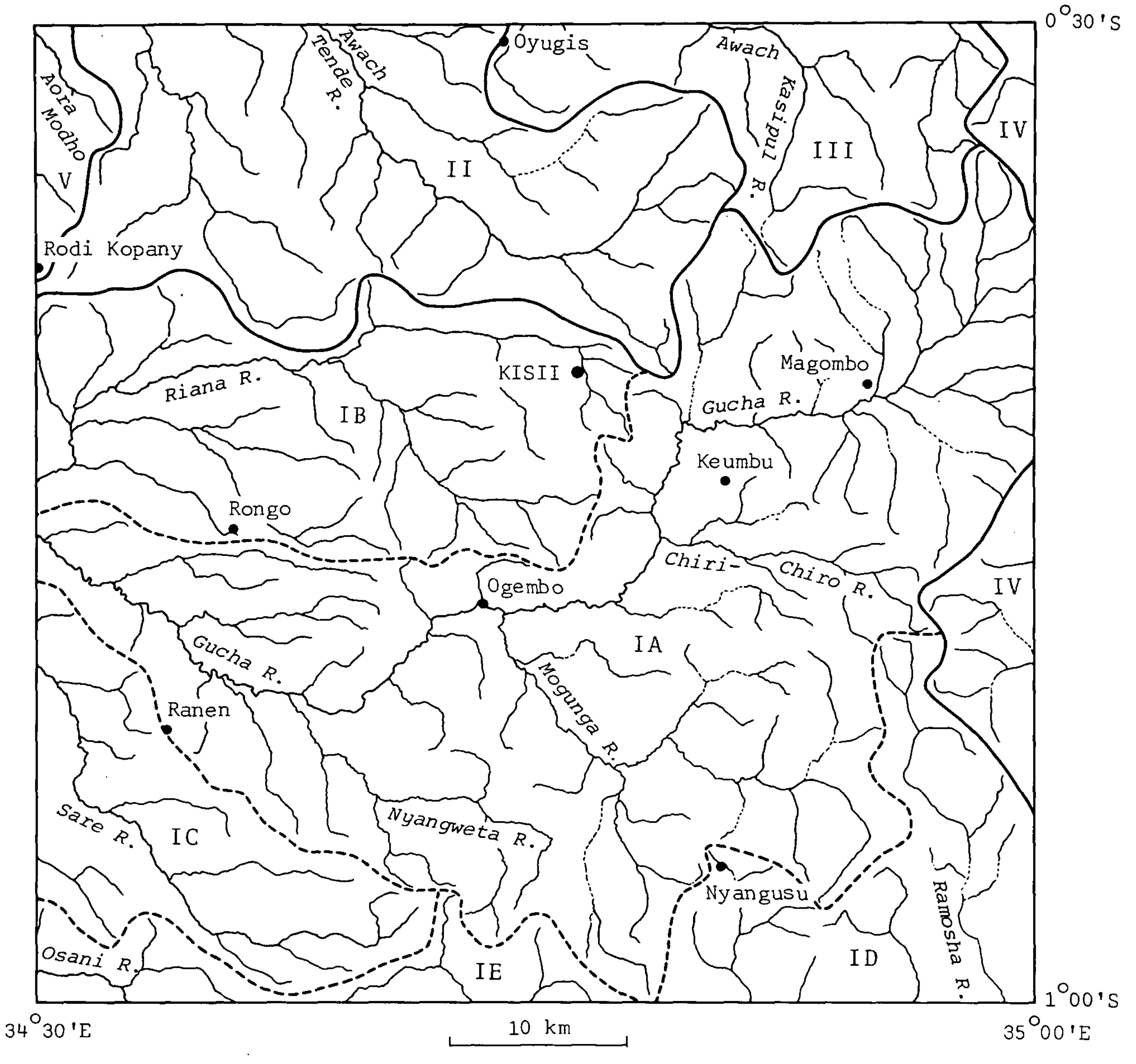


Fig. 10. Drainage basins of the following rivers: I Gucha, II Awach Tende, III Awach Kasipul, IV Sondu, V Aoro Modho and Agulo. I is subdivided into: IA Gucha, IB Riana, IC Sare, ID Migori and IE Osani.

valleys south of Ogembo still exist, because the Gucha River starts incising strongly further west of Ogembo. Extensive bottomlands occur also in the west, especially along the Riana River and its tributaries. All bottomlands are filled with fine clayey deposits 4-6 m thick. Layers of volcanic ash are common and transitions from pure volcanic ash to clay are found everywhere. The clays and ashes are partly eroded. The eroded parts are filled with peat and peaty clays (App. 1, unit BXo).

1.3.3 *Hydrology*

The whole area drains into Lake Victoria. The major all-year rivers draining the area are in order of importance (Fig. 10): Gucha, Awach Tende, Awach

Table 4. Mean monthly discharge and low-flow discharge (95% flow duration) for the rivers Gucha, Riana, Awach and Migori. Data from WHO 1973.

River	Gauge	Area of catchment (km^2)	Discharge (m^3/s) monthly mean J	F	M	A	M	J	J	A	S	O	N	D	annual mean	Low-flow discharge (m^3/s) (P=0.95)
Gucha	Gucha	1110	7.9	14.5	22.4	30.6	36.7	18.0	9.5	7.4	10.4	7.7	10.4	21.7	16.1	2.7
Gucha	Keumbu	342	4.0	3.4	4.0	10.9	15.6	5.9	4.7	4.6	6.5	4.5	3.7	6.8	6.5	0.96
Riana	Magena	264	2.1	3.6	3.9	9.1	13.2	5.8	2.5	1.6	2.6	4.1	6.9	9.2	5.3	0.68
Awach	near Kendu Bay	508	2.8	2.7	5.5	8.8	20.7	14.3	4.8	4.9	5.5	3.9	6.7	6.6	6.3	0.95
Migori	Migori	3050	7.6	13.0	17.4	31.8	27.7	13.2	4.3	1.9	5.4	4.0	6.0	13.1	13.0	0.89

Table 5. Volume rate and quality of potable water from boreholes at Kisii town (C3125 and C3126) and Asumbi (C3499).

Borehole	Water level (m)	Total depth (m)	Volume rate (cm^3/s)	Year drilled	Quality
C 3125	4.3	121.9	63.1	1961	slightly polluted, contains carbon dioxide
C 3126	7.6	121.9	2734	1961	contains carbon dioxide
C 3499	11.3	91.7	681.4	1953	hard, slightly alkaline

Kasipul, Sondu River, Aoro Modho (with Agulo) River. The Gucha River has several large tributaries: The Riana, the Sare, the Migori and the Osani rivers. For discharge characteristics of the rivers Gucha, Riana, Awach and Migori see Table 4. The river gauges of the Awach and the Migori rivers are off the area mapped.

Numerous springs and small streams occur in the eastern part of the mapsheet, of which some have water the whole year round. A few small dams occur in the western part of the mapsheet. Enough water is stored to provide water for cattle during the whole year. The available borehole data are presented in Table 5.

1.4 EROSION

1.4.1 *Introduction*

The erosion hazard after clearing the vegetation is estimated in Appendix 4, Map G. It depends on the interaction of the following factors (Hudson, 1971; Morgan, 1979):

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

- crop management,
- conservation practices.

It results mainly in two types of erosion: splash and gully erosion. Transport of particles over short distances by impact is called splash erosion; on slopes without run-off, it is the only form. Where run-off occurs, rills and gullies can be formed.

To assess the hazard of either type of erosion, especially the erodibility of the soil and the slope are rated (App. 12). This is done in relation to the other factors, which were taken as constant for the area mapped. All factors are described separately in the succeeding section; the present status of erosion is discussed in the last section.

1.4.2 *Factors controlling erosion*

1.4.2.1 Erosivity

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

In the survey area, the number of rainstorms of a high intensity correlated with rainfall (areic volume), which corresponds with the relatively dry and wet seasons (Table 6). The Spearman correlation coefficient between rainfall and the number of "erosive" rainstorms is 0.7. The monthly rainfall distribution (Section 1.2) shows a gradual increase in rainfall from the drier to the wetter seasons. So the number of showers of high intensity also increase from the drier to the wetter seasons. The majority of erosive rainstorms fall, when the soil has a vegetative cover, which reduces the erosion hazard.

1.4.2.2 Erodibility

The erodibility of the soil is determined by susceptibility of the soil

Table 6. Estimated maximum areic volume rate of rainfall (intensity μm/s) recorded over 10-15 min. for different seasons and different frequencies of recurrence. Only peaks of more than 5.6 μm/s were recorded. Casella rain recorder, Kisii Town, April 1974-July 1977.

Frequency	Dec.-Feb.	March-June	July	Aug.-Nov.
10	-	-	-	-
20	-	9.7	6.4	7.5
100	7.8	28.1	16.9	21.1
1000	19.2	90.6	-	64.7
	Time during which measurements were taken (d)			
	159	315	76	302

to rainfall erosivity. Factors in this susceptibility are permeability of topsoil and subsoil, cohesion of the surface as determined by texture, content of organic matter and form, grade and size of the structure.

The least erodible soils in the region (Hennemann & Kauffman, 1975) were the deep permeable red soils in Ecological Zones IIa and IIb (App. 2) with infiltration rates of more than 70 µm/s (Section 3.6). These high infiltration rates are maintained by the great activity, especially of termites (Section 3.4.2).

Content of organic matter had a clear positive effect on structural stability, and grass roots had a strong cohesive effect on soil aggregates. The most erodible well drained soils were red soils on granite and quartzite and soils with a very high mass ratio of silt to clay (over 0.5) in the eastern part of the Kisii District (App. 1, unit U1Ph). Structure decay in the topsoil was also noteworthy in red soils of Ecological Zones IIc and III (App. 1 and 2). The drier and hotter climate of these zones limits biological activity. Restoration of topsoil structure and maintainance of a good pore system by soil animals is less than in the red soils of Zones IIa and IIb. Infiltration rates were 28-70 µm/s. Both the rather low infiltration rates and the weak topsoil structures in these red soils increase the run-off hazard at high rainfall intensities, so that rills and small gullies are formed at certain places.

Low and very low infiltration rates (less than 7 µm/s) occur on dense clay soils, classified as Planosols and Vertisols (App. 4D). By their very low infiltration rates and very compact dense subsoils, Planosols are very prone to run-off. Even after dry periods, most of the water will run-off. Run-off may already start at low rainfall intensities and if the soil is not protected by vegetation, rill and gully erosion will occur, even on gently sloping land (Fig. 11).

In contrast, Vertisols shrink and form cracks when dry, so they absorb large amounts of water till the soil is saturated.

In summary, the erodibility is *low* for soils with a high biological activity, a fine moderately to strongly structured humic topsoil and a low substance ratio of SiO_2 to R_2O_3 (less than 1) in Ecological Zones IIa and IIb. These soils were classified as dystro*-mollic* and mollic* Nitosols and luvic Phaeozems (App. 4, Map D).

Soil erodibility is *moderate* for soils similar to the ones above but without a humic topsoil or with an acid humic topsoil or with a mass ratio of silt to clay above 0.5. It is also *moderate* for heavy cracking clay soils and the reddish soils with slight drainage problems: humic Acrisols, humic Nitosols, chromic Luvisols, luvic Phaeozems with a high mass ratio of silt to clay, Vertisols, Verto*-luvic Phaeozems, gleyic Phaeozems and gleyic Luvisols. It is moderate for soils of the types mentioned under low erodibility but in Ecological Zones IIc and III (App. 2; App. 4, Map D).

It is *high* for soils with a leached topsoil and a heavy compact subsoil

Fig. 11. Gully erosion in unit BGa. The compact clayey B horizon stands out and forms a sharp line, where it borders the sandy A2 horizon.

or soils with a high mass ratio of silt to clay in the topsoil and a dense subsoil: Planosols and gleyic Luvisols with a high mass ratio of silt to clay.

It is *very high* for dense clay soils with a substance fraction of exchangeable sodium of more than 0.15. These soils are classified as Solonetz.

Whether gullies will be formed, depends on the run-off hazard, which is estimated as follows. It is *negligible* for all soils with a low erodibility in Ecological Zones IIa and IIb. It is *low* for the soils similar to the above but with a weaker topsoil structure (sealing sensitive soils). It is *moderate* for permeable soils without a humic surface and for reddish soils with drainage problems and for all soils with a low or negligible run-off hazard but in Ecological Zones IIc and III. It is *high* for permeable shallow soils and for soils with dense clay at a depth between 50 and 100 cm and for cracking heavy-clay soils. It is *very high* for shallow soils with bedrock underneath and for soils with dense compact clay within 50 cm of the surface.

1.4.2.3 The slope and its length

There is a strong interaction between erosivity of rainfall, erodibility and slope. Erosion increases progressively with slope and length of a slope determines velocity of the running water. Running water is, however, often slowed down by obstacles like hedges.

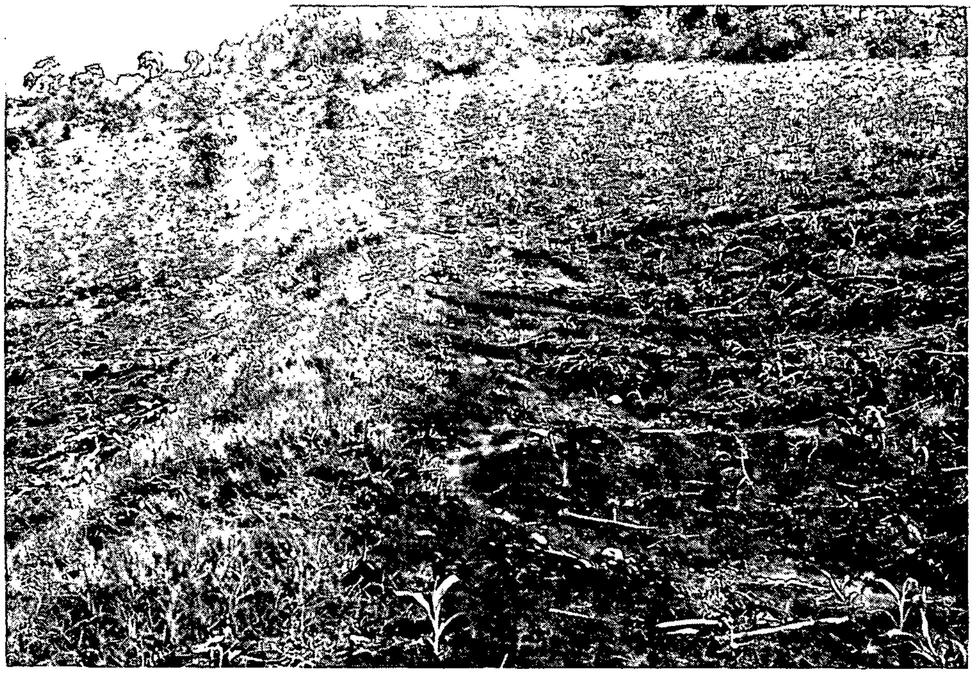


Fig. 12. Terraces developed from trash-lines. Accumulation of topsoil at lower end of terrace as a result of splash and sometimes gully erosion.

1.4.2.4 crop management and conservation practices

Erosion on the deep red soils is not a serious problem. The increasing population has caused farms to be split into smaller units and cultivation to become more intensive. On the smaller holdings, the proportion of land under food crops is larger than on the larger holdings, where grass and cash crops like tea, coffee and sugar-cane have a larger share. Cultivation of food crops leaves the soil bare and susceptible to erosion for more of the year than does cultivation of such cash crops or a grass cover. Grass, moreover, restores soil structure, which may gradually deteriorate under continuous cultivation. The circumstances probably contribute to an increase in the rill and splash erosion, as suggested by evidence of Hennemann & Kauffman (1975). They found very thick dark topsoils at the lower end of fields protected by trash-lines (Fig. 12) and rather shallow ones at the top of these fields.

Tillage with a hoe or simple plough leaves a rather rough surface, which is less susceptible to erosion than a finely tilled topsoil. Since the loss of the thick fertile topsoil would be disastrous, terraces must be constructed and maintained. They do exist in Kisii District and developed from trash-lines of maize stalks. This method is effective and simple, but should be applied more widely. Recently a start was made with the construction of cut-off drains along some very steep slopes south of Igare (east of Ogembo, App. 1).

Herbicides and fungicides harmful for termites would be catastrophic for red soils. The destruction of termites would decrease permeability and increase erosion. In the drier areas of the north-west, more grazing occurs especially on the heavy-textured soils but overgrazing in the pronounced dry season causes gully erosion, especially on the slopes of soil unit BGa and BXal. Large areas are already severely gullied and denuded of soil (Fig. 11).

1.4.3 *Present status of erosion*

Severe splash and rill erosion are common on steep slopes, scarps, hills, ridges and steep-sided valleys with shallow soils. These areas should be kept under a permanent vegetation of either trees or grass.

The well drained deeper soils on rolling to hilly terrain are not so susceptible to erosion, except under poor management (Section 1.4.4). Compact imperfectly drained heavy clay soils are susceptible to run-off and gully erosion, even on gentle slopes, especially with overgrazing (Section 1.4.2). Run-off and gully erosion are not marked in de area with well drained red soils.

Roads and footpaths, especially if running downhill are sometimes deeply gullied and are a hazard to adjoining cultivated land.

1.5 VEGETATION

1.5.1 *Introduction*

The simplified vegetation map (App. 4, Map F) is directly derived from the 1 : 250 000 vegetation map by Trapnell et al. (1970, Sheet 3) and the legend is an adaption of the original. More than 75% of the surveyed area has been at least half-cleared (land-use map App. 4E). Former vegetation has influenced soil formation of cleared land. Most of the cultivated land has been cleared recently (15-20 years ago). So the map represents climax vegetation for cultivated areas, as extrapolated from uncultivated areas. The legend of Map 4F lists the dominant species of each vegetation unit.

1.5.2 *Description of the vegetation units*

(1) Montane *Acacia* vegetation of probable forest origin. Major parts consist of undifferentiated secondary and valley types and of Intermediate Diospyros forest. A substantial part has been cleared and cultivated but *Acacia abyssinica* remains in the fields. These areas were cleared about 1965-1970.

(2) Forest clearings and cultivation communities from moist montane intermediate forest consisting of undifferentiated clearings and shrubs, cultivated *Croton* and *Vernonia-Clerodendron* and cultivated *Triumfetta-Vernonia*. The valleys in the north-west of the unit are substantially lower in altit-

ude and carry cultivated *Albizia-Bridelia-Vernonia*. Near Tombe, they are choked up with papyrus, swamp-grasses and reeds. Somewhat higher valleybottoms carry evergreen clump grasslands.

(3) Forest clearings and cultivation communities from *Diospyros-Olea* intermediate forest consisting of *Dombeya* and allied clump vegetation, evergreen clump grassland and undifferentiated clearings and shrub. Some very small patches are still under forest, designated as an intermediate *Diospyros-Olea* forest, which is mainly semidecideous.

(4) *Combretum* and allied broad-leaved savanna, a complex consisting mainly of undifferentiated *Combretum* types including cultivated areas and *Combretum* with *Euclea schimperi*. South of Awendo, a *Parinari-Combretum* mixture occurs in the complex. In the north, the *Combretum* semi-evergreen thicket mixtures are included in the unit and in the north-west some derived clearings, cultivation communities and undifferentiated bushland from the intermediate semi-evergreen thicket and associated types.

(5) Evergreen clump grasslands consisting of the following grasses *Pennisetum catabasis*, *Pennisetum clandestinum* and *Pennisetum hohenackeri*, which mostly cover more than 70% of the surface. Also some *Hyparrhenia rufa* is found. Other common species are *Desmodium histum* and *Kyllinga erecta*. This unit occurs only in the utmost western part, west of Rongo and west of Awendo/Sare and is confined to the soils with impeded drainage.

(6) Open grasslands consisting of *Hyparrhenia rufa* and *Pennisetum catabasis* (over 60%). These grasses occur only on the heavy vertisols around Rodi Kopani. The unit includes small areas of *Acacia seyal* and *Balanites*.

(7) Undifferentiated grasslands on well drained soils. These grasslands are derived from forest, mainly from moist montane and intermediate forest. The common grasses found in this unit are *Loudetia kagerensis*, *Brachiaria soluta* and *Eragrostis atrovireus*. Forest remnants and patches are confined to termite hills because of grass burning. The unit occurs solely in the south in the Narok District where Masai cattle graze.

(8) Upland evergreen and semideciduous bushland is mainly dense evergreen woodland. There is a minor inclusion of open evergreen and semideciduous bushland of the central region consisting of an evergreen bush-clump vegetation. More than 60% of the grasses are *Pennisetum* species. This unit is found in the south-east along the Ramasha Migori river.

(9) Complex A. Undifferentiated grasslands on poorly and imperfectly drained clay soils. In this complex, much *Pennisetum clandestinum* (20%) may generally be found. Also *Kyllinga* spp. are more prominent than in the units of which

this is a complex (20%).

(10) Complex of clearings from *Diospyros-Olea* and grasslands on poorly drained soils. In general the clearings show a higher covering of *Hyparrhenia spp.* (20%) and *Eragrostis atrovirens* (20%). *Loudetia kagerensis* is the most common gràss on the somewhat better drained soils which are generally shallow.

1.6 ECOLOGICAL ZONATION

The boundary between Ecological Zones II and III (App. 2) is based on the ratio of annual rainfall to potential evaporation (r/E_0). The ratio of 0.64 is close to the boundary value of 0.67 taken for the Kapenguria area (Gelens et al., 1976). Zone II, being the area with the greatest agricultural potential has been subdivided according to agricultural possibilities. As diagnostic criterion between Zones IIa and IIb was taken as altitude 1800 m. The altitude limit corresponds to a mean temperature of 18°C. In Zone IIa above this altitude, tea and pyrethrum are the main cash crops and one crop of maize is grown per year. In Zone IIb below this altitude, coffee and sugarcane and maize can be grown twice a year. Additional cash-crops are tobacco and bananas.

The diagnostic boundary between Zones IIb and IIc was r/E_0 72, which separates the zone where a second maize crop per year is risky (IIc) from the zone where it is usually safe (IIb). Zone III is the warmer drier area near the lake, where cotton can be grown. Usually a second crop of maize is not possible.

1.7 PRESENT LAND-USE

1.7.1 *Land-use units*

The map of present land-use (separate Appendix 4, Map E) was based on interpretation of aerial photographs and field observations. Photo-interpretation was based on aerial photographs of 1967, scale 1 : 50 000 and of 1978, scale 1 : 75 000 of the entire Kisii District and part of South Nyanza District. A preliminary legend was made and checked by observation in the field. General descriptions were preferably made from hilltops in order to estimate the proportion of land cultivated and the cropping pattern. The basic criteria for the map legend were the area fraction cleared for cultivation and the type of grazing area. The major part of the area is under permanent cultivation (80%).

The cultivation classes were as follows:

- Class A, Permanent cultivation: three quarters to entirely cleared and cultivated; grazing area all consists of improved grassland (Fig. 9).
- Class B, Permanent cultivation: half to three quarters cleared and cultiv-

Fig. 13. Area with semi-permanent cultivation. Most of the area is extensively grazed. In the cultivated area, cotton is the major cash crop.

ated; three quarters of grazing area is improved grasslands and a quarter of extensive rangeland (or natural grazing land).

- Class C, Permanent cultivation: quarter to half cleared and cultivated; half grazing area consists of improved grasslands and half of extensive rangeland.
- Class D, Semi-permanent cultivation: none to a quarter cleared and cultivated; quarter of grazing area consists of improved grasslands and three quarters of extensive rangeland (Fig. 13).
- Class E, Scattered cultivation: none to a tenth cleared and cultivated; grazing area all consists of extensive rangeland. Improved grasslands was taken as all grazing area with signs of partial clearing; these areas have been cultivated occasionally. Frequently burned rangeland was not included in the improved grassland.

Total areas of each class were measured by planimeter. In each class, the area fraction under each crop was estimated by field survey. Fractions under cash crops were used for division of the classes. The remainder of the cultivated land was mainly used for maize *(Zea mays)*, mostly intercropped with beans *(Phaesolus vulgaris)*.

Class A has the following divisions by cash crop:

1. maize 40%, major cash crop tea 80%, other cash crop pyrethrum 20%;
2. maize 40%, major cash crop tea 50%, other cash crop pyrethrum 50%;
3. maize 50%, major cash crop pyrethrum 70%, other cash crop tea 30%;

4. maize 50%, major cash crops tea 40% and coffee 40%, other cash crops pyrethrum 10% and sugar-cane 10%;
5. maize 50%, major cash crop coffee 70%, other cash crops bananas 20%, various other crops 10%.
It covers nearly all the Kisii District. The distribution of the subclasses is related to altitude. The land is mostly prepared either with an ox plough or a hoe according to farm size. Other cultivation is by hand.

Class B had the following divisions by cash crops:
1. maize 80%, major cash crop coffee 60%;
2. maize 70%, major cash crop sugar-cane 60%;
3. maize 70%, major cash crop tobacco 60%.
It covers the remainder of the Kisii District and a strip in South Nyanza bordering the Kisii District. Tobacco was recently introduced into the area and the amount of sugar-cane is steadily increasing because of a newly developed sugar-cane centre in Awendo (Sony Sugar Co.).

Class C had the following divisions:
1. maize 60%, major cash crop sugar-cane 80%;
2. maize 60%, major cash crop cotton 40%;
3. maize 70%, various cash crops including sugar-cane, bananas and cotton.
Scattered sugar-cane occurs north of Rongo and South of Rodi Kopani. Elsewhere those areas seem too dry; the crop grows on moderately drained soils on the slopes of the ridge landscape. Cane is used mainly for chewing and for local sugar mills and is therefore included in the cash crop. Cotton grows around Ligisa Omoya, which is the driest part. Production tends to be rather low.

Class D had the following divisions:
1. maize 60%, major cash crop cotton 60% (Fig. 13);
2. maize 90%, various cash crops including sugar-cane and bananas.
Less than a quarter is cultivated, largely under maize (60%), so the area for cash crops is not extensive. The major one is cotton but production seems low.

Class E was not divided, since no cash crops occur. Such scattered cultivation as there is, is nearly always maize.

1.7.2 *Crops*

The major grain crop was maize *(Zea mays)* grown during both the major and the minor wet seasons. In the higher altitudes (> 1800 m), there was no second crop because growth took more than six months. In the lowest part of the area, there was no second crop because rains in the minor wet season were unreliable. Most of the planted maize was an improved hybrid. In the drier area, some sorghum is found *(Sorghum vulgare)* and in the centre of the Kisii District a diminishing area of finger millet *(Eleusine corocana)*. Other staple crops in order of decreasing area were sweet potatoes *(Ipomoea* *batatas)*, cassava *(Manihot esculenta)*, beans *(Phaseolus vulgaris)*, pigeon peas *(Cajanus Cajan)*, cowpeas *(Vigna unguiculata* and green grams *(Vigna aureus)*.

Cash crops are mentioned below in order of declining area. In area, pyrethrum *(Chrysanthemum cinerariaefolium)* was the major cash crop. It covered more than 120 km^2 and formerly even reached 210 km^2 (1972). The total area was declining but the crop remained important, the Kisii District producing about 40% of world production.

Although considered a coffee-growing area, tea *(Camellia sinensis)* had overtaken coffee in area. Already four tea factories operated, at Kebirigo, Kiamokama Nyankoba and Nyamache. The total area was estimated at about 90 km^2. Coffee *(Coffea arabica)* was the third cash crop with a total of about 80 km^2. About 60 coffee factories operated in the area.

Bananas (*Musa* spp.) were grown in most of the area, occasionally in monoculture. It was rather difficult to estimate the area (about 30 km^2). A considerable amount of the crop was exported to the larger cities.

Cotton *(Gossypium hirsutum)* was a common cash crop in the drier north-west but only a few successful fields were seen during the field check.

Sugar-cane *(Saccharum officinarum)* was a common cash crop in Unit B but occurred also to a lesser extent in a large area around Rongo and Rodi Kopani. A recent development was a sugar refinery in Awendo, which has encouraged the area of cane tremendously.

Tobacco *(Nicotiana tobacum)* was also introduced recently, especially in the south-west. The farmers responded positively to the introduction of that crop.

Other cash crops were passion fruit *(Passiflora edulis)*, groundnuts *(Arachis hypogaea)*, potatoes *(Solanum tuberosum)*, tomatoes *(Solanum lycopersicum)*, onions *(Allium cepa)*, cabbages *(Brassica oleracea)*, sunflower *(Helianthus annuus)*, papaya *(Carica papaya)* and egg plant (Solanum melongena).

In the drier areas, sisal *(Agave sisalana)* was grown, mostly in rows for demarcation purposes. A few leaves were harvested for local production of fibre.

1.7.3 *Grazing area and rangeland*

The south-west belonging to the Narok District was used only for grazing (Fig. 14). All other cleared but not actually cultivated parts were grazed too (Table 7).

At least 38% of the area was used for grazing, of which half has been improved; the other half was extensive grazing or ranging. The improved grassland was grazed mostly by cattle, to a lesser extent by sheep and goats. Browsing was relatively unimportant, about 10% of the cattle being kept for dairy purposes. Most cattle are kept for traction (e.g. ox-ploughing) and for meat. In the extensive grazing area, one finds large herds of Masai cat-

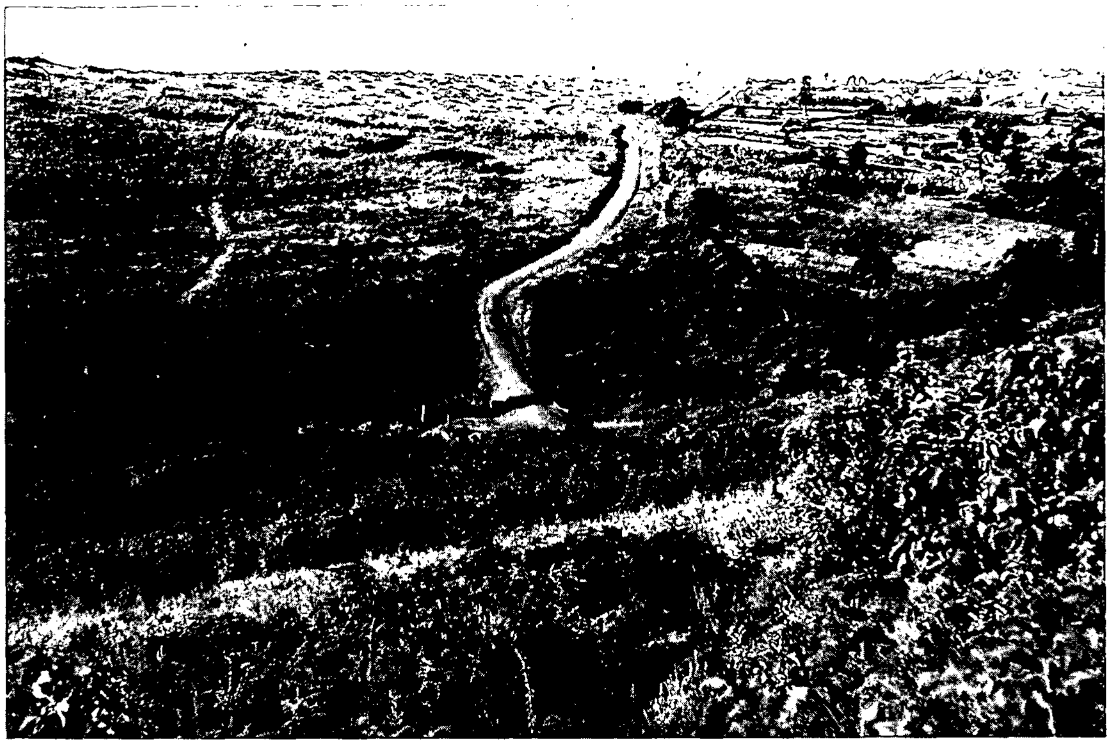


Fig. 14. The intensively cultivated Kisii District borders on the extensively grazed Narok District in the south.

tle. In the west, cattle graze with sheep and goats. No severe overgrazing occurs except in the driest north-west around the village of Ligisa Omoya.

1.7.4 *Silviculture*

Two sites with exotic gymnosperms *(Pinus patula)* were the young plantations of Nyamweta Forest (2 km^2) and Kodera Forest (8 km^2). Charcoal burning was practised in most of the area and in the densely populated Kisii District

Table 7. Area fraction and area of grazing land and of improved grassland in each land-use class.

Class	Area (km^2)	Area grazed (km^2)	Area fraction grazed	Area of improved grassland (km^2)
A	1 600	217	0.14	217
B	600	217	0.36	163
C	400	279	0.70	140
D	100	93	0.93	23
E	400	372	0.93	-
Total	3 100	1178		543

nearly exterminated indigenous trees, which had to a small extent, been replaced by blue gums (*Eucalyptus* spp.), cypress (*Cupressus* spp.) and black wattle (*Acacia mearnsii*), mainly planted in rows as demarcation of plot boundaries.

Ornamental trees such as yacaranda (*Yacaranda minosifolia*) and the nandi flame (*Spathodea nilotica*), grow in the bigger villages. Striking is the very small number of fruit trees; only guave (*Psidium guajava*) and a few avocados (*Persea americana*) occur.

2 Methods

2.1 SOIL SURVEY AND SOIL CHARACTERISATION

2.1.1 *Office methods*

The initial step in the reconnaissance soil survey was to collect and study available aerial photographs, topographical and geological maps and information about the area. A preliminary survey of a larger area for physiography, climate and land-use, covered both Kisii and South Nyanza District and was published as a preliminary report (Wielemaker, 1974).

The survey area had been covered by four topographic maps on the scale 1 : 50 000, published by Survey of Kenya, comprising sheet numbers 130/1 (1963), 130/2 (1962), 130/3 (1962) and 130/4 (1962). All aerial photographs were acquired from the Survey of Kenya. The entire area is covered by aerial photographs on the scale 1 : 50 000 (1967). Most prints are of reasonable quality.

2.1.2 *Field methods*

With results of the preliminary survey, six sample areas were selected and detailed soil surveys began in October 1973. The Marongo area was surveyed in detail first (Boerma et al., 1974), then the Irigonga area (van Mourik, 1974), next the Magombo area (Scholten et al., 1975), the Nyansiongo area (Guiking, 1976), the Rangwe area (Breimer, 1976) and the Ranen area (van Keulen & van Reuler, 1977). Each detailed survey was followed by a reconnaissance survey of the area surrounding it, so that the general soil pattern of the detailed survey could be extrapolated to a larger area. The separate reconnaissance maps were then compiled into the actual Kisii mapsheet on scale 1 : 100 000.

The detailed maps were based on large-scale aerial photographs 1 : 12 500. These photographs and stereoscopic interpretation provided a basis for an adjusted base map, also on the scale 1 : 12 500. The photogrammetric slotted template method was used for adjusting the main and wing points and a vertical sketch master was used to copy the necessary data onto the base map. The positions of these detailed surveys are indicated in Separate Appendix 4, Map H.

For compilation of the soil map of the most western part, the East Konyango semi-detailed soil survey was used, (Miller, 1961).

Table 8. Distribution of records from the detailed and the reconnaissance soil surveys.

Sample area		Augerings		Soil pits		Selected profiles
No	name	detailed	reconnaissance	detailed	reconnaissance	
I	Marongo	2000	50	50	10	18
II	Irigonga	600	30	12	4	7
III	Magombo	800	30	14	6	4
IV	Nyansiongo	600	50	15	10	6
V	Ranen	2000	30	25	10	8
VI	Rangwe	1800	80	15	10	133

Routine soil augerings were made with an Edelman soil auger (mostly clay type) in general to a depth of 2.00 m (soil depth permitting) at sites chosen from aerial photographs and pinpointed on the field maps. Properties of land and soil were recorded on standard forms obtained from the Kenya Soil Survey. Their method of description is based on that of FAO (1967).

All completed forms went into the Kenya Soil Survey Archives (Table 8).

There were 72 soil pits for other research (e.g. moisture and fertility), of which 10 are described in Appendix 5. About 7800 augerings were made and about 200 profile pits were described, of which 72 were selected as representative. Only 43 of these representative profiles were analysed (completely or partially). Their position is given in Separate Appendix 4, Map H. The position of augerings and profile pits in the various sample areas are given in the Reports mentioned.

In all soil units, representative sites were selected where profile pits were dug. The pits were usually 1.50-2.00 m deep, but in some units with very deep soils, pits to a depth of 7-10 m were dug. Each soil horizon was sampled for physical and chemical analysis. From some profiles, undisturbed ring-samples were collected for estimaton of bulk density and moisture tension. A few horizons were sampled for thin-section analysis.

Infiltration was measured with an adaptation of the system developed by Mussgrove (Hennemann & Kauffman, 1975). Various soils were deep-augered with a powered auger to a depth of 10 m if bed rock permitted. Samples of rotten rock were taken for "total" analysis. Some fifteen soil peels were made from selected profiles for further studies and for demonstration.

2.1.3 *Laboratory methods*

Most measurements were done at laboratories of the Agricultural University in Wageningen, the Netherlands (AU) or at the field laboratory of the training project in pedology at Kisii (TPIP). Later in the survey, some samples were analysed at the (Kenyan) National Agricultural Laboratories (NAL) and at the Soils and Crops Laboratory at Oosterbeek, the Netherlands (SCL). Sometimes different methods were used as described below. All soil samples entering a laboratory were ground with pestle and mortar. Only soil material passing through a 2-mm sieve was used further. Mass fraction of gravel was calculated from the residue with respect to the whole soil.

Texture

NAL. Treat mechanically to remove cementing agents; shake overnight with sodium hexametaphosphate and sodium carbonate in an end-over-end shaker. Measure silt and clay (<0.05 mm) with a hydrometer after 40 s and clay (<0.002 mm) after 6.4 h. The difference represents sand (0.05-2 mm) (Day, 1956).

TPIP, AU and SCL. Destroy organic matter with hydrogen peroxide (volume fraction 0.3); remove carbonates and iron coatings with HCL (concent. 2 mol/l). Dilute the sample and siphon three times (TPIP) or filter the soil suspension by suction and wash four times (AU). Sieve wet with a 0.05-mm sieve to separate sand. Collect the rest in a sedimentation cylinder and disperse with sodium pyrophosphate (concent. 120 mmol/l) or (SCL) sodium carbonate and pyrophosphate. After shaking, pipette off <0.05 mm (silt) and <0.002 mm (clay). After drying sieve the sand into fractions of 2.0-1.0, 1.0-0.50, 0.05-0.25, 0.25-0.10 and 0.10-0.05 mm.

Remarks. At AU, the HCl solution was replaced by a buffered solution of acetate and acetic acid (pH 5.0). An extra amount of this solution was added for removal of carbonates if present.

pH and electrical conductivity

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

AU. Shake soil intermittently for 2 d with distilled water, potassium chloride (concent. 1 mol/l) or $CaCl_2$ (10 mmol/l) in a volume ratio (1:2.5) and measure pH of supernatant with a combined glass calomel electrode.

Mass fraction of carbon

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

TPIP. Walkley and Black with a correction factor of 1.43.

AU. Method of Schollenbergen (in Begheijn and van Schuylenborgh, 1971) with spectrometer, filter of wavelength 594 nm. The correction factor was 1.15. After 1977, the Kurmies (1949) titration was used with a potentiometric end-point.

SCL. Loss of weight after heating at 600°C for 2 h.

Mass fraction of nitrogen

(NAL/AU). Semi micro-Kjeldahl for A horizon only (Black, 1965, p. 1374-1375).

Substance content of exchangeable cations

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

Cation-exchange capacity

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

Exchangeable acidity

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

Mass fraction of available nutrients

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

Bulk density (volumic mass)

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

Moisture tension

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

Clay mineralogy

AU. Separate the fraction <0.002 mm and dry about 15 mg on a porous ceramic plate at reduced pressure to orient the clay. Saturate with different ions (Mg^{2+}, K^+) for X-ray diffraction.

Elemental analysis

AU. for X-ray fluorescence spectrometry, bombard the sample melted in dilithiumtetraborate and mounted on a glass disc with X-rays and estimate

Si, Al, Ca, Mg, Mn and P with the Kα line, Ti with the Kβ line and Ba at the Lβ line. In wet analysis for Fe^{2+}, Fe^{3+}, Na and Mg, remove silicon by volatilization as silicon fluoride and bind liberated water with concentrated sulphuric acid.

Sand minerology

NAL. Sand (particle size 50-250 μm) obtained by the method of AU or TPIP was gently boiled with water or, in the presence of iron, with HCl solution to remove coatings from sand grains. The sand grains as such or, after separation with bromoform, the light and heavy minerals were mounted with Canada balsam on microscopic slides and examined under a polarizing microscope.

2.1.4 *Cartographic methods*

For the survey area, a base map on the scale 1 : 100 000 was not available. So four adjoining sheets (130/1-4) of the Survey of Kenya (1962/1963) on the scale 1 : 50 000 were assembled to cover the area. Each sheet was simplified and three negatives were prepared for each sheet: a negative with topographical details; one with contour lines; and one with drainage aspects. After duffing out unwanted details, each sheet was reduced to the final scale of 1 : 100 000 and the four sheets were joined together as a positive film. New elements not featured on the original sheets were added, for instance new main roads. This additional information was collected during fieldwork and from the recent aerial photographs taken in 1978, scale 1 : 75 000.

The coloured soil map (Separate Appendix 1) was prepared with a sequence of seven plates: a black plate for all topographic details, soil boundaries, symbols and legend; a solid blue plate for rivers and other drainage aspects; a brown plate for contour lines; a black plate to provide symbols or screens for hills, minor scarps and depth classes; and three plates in the primary colours yellow, red and blue for the soil units.

The black-and-white soil map (Separate Appendix 2) required four plates: three were the first three plates for the coloured map; the fourth was a black plate with ecological zones.

The cartographic work was done in the studios of the training project at Kisii, of the Kenya Soil Survey in Nairobi and at the Agricultural University, Department of Soil Science and Geology in Wageningen. The colour separation was done at the Netherlands Soil Survey Institute (Stiboka) in Wageningen. After preparation of all plates, a proof print of the coloured soil map on "Kromecote" was produced with a "Cromalin" proofing machine. The maps were offset-printed by Printpak Ltd in Nairobi.

2.2 SOIL FERTILITY

Soil fertility was studied in field and greenhouse trials and by chemical analysis of soils and leaves. The methods were described by Guiking (1977) and Oenema (1980), and will be discussed in detail by van der Eijk (in preparation). So only an outline is given below.

2.2.1 *Field trials*

Most field trials were set up to find the response of maize to P fertilizers triple superphosphate ($Ca(H_2PO_4)_2 \cdot H_2O$) on different soils. In one trial, rock phosphate was tested too (Guiking, 1977).

Fertilizer was either placed, or broadcast and incorporated by rotary cultivation. Rates of P_2O_5 were 12.5, 25, 50, 75, 100 and 300 kg/ha with placement and 75, 150, 300, 600, 1200, 2400 and 4800 kg/ha with broadcasting. The highest rates equalled those needed to obtain mass concentration of P in the soil solution of 0.2 mg/l in laboratory studies on sorption. This concentration was then taken as the requirement for maximum growth of maize (Fox et al., 1974).

Calcium ammonium nitrate was applied as a standard dressing of N (60 kg/ha), and in some trials the effects of K, Mg and trace nutrients were studied. In other trials, dung, garbage from a town market, sewage sludge and other materials were applied, alone or in combination with triple superphosphate (van der Eijk, in preparation; Oenema 1980).

2.2.2 *Greenhouse trials*

Composite topsoil (0-20 cm) samples (50-100 kg) were used in greenhouse trials in Wageningen. The results were described in internal reports and an interim summary of results was given by Janssen et al. (1979). Besides phosphorous fixation and its alleviation, one trial studied the availability of K and another the availability of Zn.

2.2.3 *Sampling and analysis of leaves*

Maize leaves were sampled on farmers' fields and on trial fields. In field trials, grains, axes and stems were also sampled too for estimation of removed nutrients. Often intermediate harvests were made to study the time course of nutrient uptake. Leaves of coffee and tea were sampled on farmers' fields at sites representative of the most important soil units.

Leaves were sampled as follows:

- for maize: youngest fully grown leaf, i.e. about the third youngest leaf of plants with 8-12 leaves; at each site, gather 10-30 leaves into one composite sample.
- for coffee: the fourth pair of leaves at mid-height of the tree at the four points of the compass; 8 leaves per tree and 5-10 trees per site.
- for tea: the first leaf below the fish leaf, about 30 leaves per site.

Wash the sampled leaves free of dust, dry at 70°C and grind the samples. Digest with a mixture of H_2SO_4, H_2O_2 and salicylic acid and estimate N, P, K and sometimes also Mg and Ca. Estimate N by absorption spectrometry with indophenol blue (Novozamsky et al., 1974), and P with ammonium molybdate blue. Estimate K by emission spectrometry and Ca and Mg by atomic absorption spectrometry. All methods were described by van Schouwenburg & Walinga (1978).

2.2.4 *Sampling and analysis of soils*

Composite samples of 1 kg of topsoil (0-20 cm) were taken at about one site in five, whence leaf samples had been taken. All trial fields were sampled before and often several times during the trial, mainly to follow the change in content of available P. From about 15 trial fields, subsoil (50-70 cm samples were collected as well. Samples were air-dried and sent to Wageningen. After separation through a 2-mm sieve, pH-H_2O and pH-KCl, cation-exchange capacity, contents of exchangeable cations (K, Na, Ca and Mg) and organic C were measured (Section 2.1.3). As correction factor for the Kurmies method, the generally accepted value 1.03 was used. By comparison of the two methods, 1.26 was found as correction factor for the Walkley-Black method.

Phosphorus

Phosphorus-Olsen. Adjust aqueous $NaHCO_3$ (concentr. 0.5 mol/l) with NaOH to pH 8.5. Phosphorus-Bray I. With NH_4F (concentr. 30 mmol/l) and HCl (25 mmol/l). Phosphorus-water. Soil-water in vol. ratio of 1-60. Phosphorus-total. Digest with Fleischmann's acid.

Organic nitrogen

Digest with H_2SO_4 and salicylic acid and estimate N colorimetrically with the indophenol blue method as for leaf analysis (Houba et al., 1979).

3 The soils

3.1 PREVIOUS WORK

Jones & Scott (see soil map, scale 1 : 3 000 000 in the atlas of Kenya, published by Survey of Kenya, 1970) distinguished the following soils within the survey area:

- strong brown loams (ando-like soils) in the south-east with 5-8% organic carbon in the dark-brown topsoil over a strong-brown subsoil derived from volcanic ash (App. 1, unit U1Ph).
- dark-red friable clays with very humic often deep topsoil (latosolic soils) (App. 1, red soils of units U1, U2 and U3),
- red friable clays with a medium humic topsoil and red to strong-brown friable clays with laterite horizon (App. 1, U4 and FY),
- shallow and stony soils with rock outcrops (App. 1, shallow soils of units U4 and H),
- black clays (App. 1, unit PPa).

The FAO (1974) "Soil Map of the World" shows the following soil units:

- Humic Nitosols for the red or reddish soils (U1, U2 and U3),
- Orthic and Rhodic Ferralsols for the red and reddish soils (U4),
- Pellic Vertisols (PBd and PPa).

Scott & Webster (1971) included some soil information in description of land systems and land facets.

Wielemaker (1974) made a reconnaissance survey of the physiography of Kisii and South Nyanza Districts and part of Trans-Mara Division in Narok District.

Miller (1961) provided a semi-detailed soil survey of the East Konyango area on a scale of 1 : 20 000, including a suitability appraisal of the soils for the growth of sugar-cane. Only the eastern part of the East Konyango area falls within the Kisii area (App. 4, Map H).

The soils of the East Konyango area were correlated with the soils of the Kisii area. Some soil profile descriptions from that report were included in this report as representative. App. 4, Map H, also shows the situation of sample areas surveyed in detail for the reconnaissance survey. The correlation of soil units between the detailed soil surveys and the reconnaissance survey is given in Bound Appendix 11.

3.2 *General properties of the soils*

The soils in undulating to rolling and hilly well drained areas fell into two main groups (App. 1):

- very deep red to reddish-brown very permeable soils (U1, U2 and U3),
- moderately deep reddish and reddish-brown permeable soils (U4).

The former had a fine clayey texture, mainly of kaolinitic mineralogy except in the eastern part of Kisii, where soils were medium-textured, rich in silt and kaolinitic and illitic. Base saturation and pH varied with parent rock, relief and volcanic ash enrichment.

Soils on basalt had subsoils with base saturations of around 0.5, on granite 0.3 and on quartzite 0.05. More basic subsoils had a pH of 5 and more acid ones about 4-4.5.

Base saturation of topsoils was 0.7-1 in upland soils in the east, where soils were strongly influenced by volcanic ash (units U1Ph and U2Ihn). On footslopes in the same area, it was lower: about 0.5 for unit FPg and less for unit FQh. In contrast the composition of the parent rock correlated well with base saturation of topsoils in the west: on basalt, base saturation was more than 0.8 and on granite 0.15-0.3 and on quartzite less than 0.05. All soils were underlain by thick weathered rotten rock. All topsoils were dark and rich in organic matter.

The latter group occurred mainly in the west. They were shallower and had a thinner layer of weathered rock. The influence of the parent rock was therefore more felt, although the clay mineralogy and physical characteristics were about the same. Mass fraction of clay was about 0.25-0.6 (soils on granite). Base saturation was low for soils on granite (0.43 in the topsoil and 0.27 in the subsoil), but high for soils on rhyolite, andesite and diorite (>0.8 in the topsoil and 0.5-0.8 in the subsoil). The reddish well drained soils had good physical properties but were sometimes chemically poor. Most of them fixed phosphorous. The pH-H_2O was usually 5 or less.

The soils of rather flat plains and bottomlands are imperfectly to poorly drained. The plains carry heavy-textured dense soils with silty top layers except if the parent material is basic, and imperfectly or poorly drained cracking clay soils occur. The bottomlands are practically all filled with quaternary volcanic ash deposits, in which dense clay soils with bleached silty top layers have developed. Some have a slightly to strongly alkaline subsoil (units BXal and BXg). Some have no bleached top layer, but are cracking clay soils (units BBd and BBh). Both plains and bottomlands have subsoils chiefly of poorly crystallized montmorillonitic clay mineralogy. These soils pose physical problems for agriculture.

3.3 DESCRIPTIONS OF THE SOIL MAPPING UNITS

3.3.1 *Systematics and nomenclature*

The broadest category of the legend of the soil map (App. 1) is based on geomorphology: hills, uplands and plateau remnants, plains and bottomlands. These land types were subclassed by the parent material on which the soils are developed, such as basalts, and pyroclastic materials (volcanic ash). Abrupt textural changes, humic topsoils, stoniness, rockiness, salinity or sodicity were mentioned only in mapping unit descriptions where they occurred.

Each soil description is followed by the name of the FAO nomenclature (Chapter 3.4). Each mapping unit is identified in Appendix 1 by a symbol consisting of:

- a soil mapping symbol, including a letter for land type, one for parent material and two for profile characteristics such as drainage, depth, colour, consistence and texture,
- a depth class symbol, if the unit was (partly) less than 80 cm deep, (listed in App. 1),
- a slope class symbol (listed in App. 1)

The following letters were used in soil mapping symbols:

Physiography

H hills and minor scarps
F footslopes
U uplands and plateau remnants
P plains
B bottomlands
V minor valleys

Geology

B basalt
Y rhyolites
P pyroclastic deposits (volcanic ash)
I intermediate igneous rocks
X various parent materials
G granites
Q quartzites

Soils

g gleyic
h humic
b brown
d dark
a abrupt
o organic
p moderately deep (50-80 cm)
P shallow (0-50 cm)
M shallow over petroplinthite
C complex of soils
n nitic
t rocky
1,2 general subdivisions

Most of the terms used in the legend of the soil map and in the following description of individual soil mapping units are based on FAO (1967). All colours were described by the Munsell scheme (Munsell Colour Co., 1959); colours mentioned in the mapping unit description are for moist soil conditions, unless otherwise stated. For information contents of weatherable minerals are given in Appendixes 5 and 7.

3.3.2 *Soils of the Hills and minor scarps*

Unit HBhP

Total area: 3470 ha.
Parent material: porphyritic and non-porphyritic basalts.
Macro relief: usually hilly, (slope class E), but gentle slopes of 2-5% (slope class B) occur near and on hilltops.
Surface stoniness/rockiness: rock outcrops occur occasionally.
Vegetation/landuse: many trees including Eucalyptus spp., pine, cypress and wattle; some grazing and coffee occurs; annual crops like maize, beans and onions are on the increase.
Soils, general: permeable, somewhat excessively drained and moderately deep; a stone layer occurs at shallow depth and demarcates the layer with significant biological activity above from the layer with little biological activity. The last horizon has both characteristics of strongly weathered rock (C horizon) and a fully developed B horizon. The horizon sequence is usually ABCR.
colour: A horizon, dark-reddish-brown (5YR 3/3-3/2); B horizon, yellowish-red (5YR 4/6-4/8) to reddish-yellow (5YR 6/8).
texture: clayey throughout (mass fraction 0.6-0.7), but gravelly near the surface, especially in the stone layer, with mass fraction of gravel and stones up to 0.8; mass ratio of silt to clay 0.5.
structure: moderate to strong very fine subangular blocky above the stone layer; moderate to strong fine angular blocking grading to massive below the stone layer.
consistence: friable when moist.
chemical properties: mass fraction of organic C in the A horizon 15-25 g/kg; pH-H_2O about 5.0; base saturation is less than 0.5 in the top 50 cm and increases with depth; cation-exchange capacity of topsoil is 210 mmol/kg soil, of subsoil 140 mmol/kg and of the clay in subsoil 170 mmol/kg.
Soil classification, FAO/Unesco: humic Cambisols, paralithic phase (definition according to Soil Taxonomy, 1975).
Soil Taxonomy: typic Eutropepts.
For a representative profile, see App. 6, Profile 1 and App. 11 (Mugirango and the Ogembo series of the Marongo detailed survey). For comparison with other soils see Appendix 5.

Unit HXP (Fig. 8)

Total area: 9560 ha.
Parent material: quartzite, granite, rhyolite, andesite, diorite and conglomerate.
Macro and meso relief: steep on scarps and hilly on the hills, slope classes F and E.
Surface stoniness/rockiness: rock outcrops are especially common on the scarps.
Vegetation/land use: a part of the map unit is planted with cypress, pine, wattle and Eucalyptus spp. The rest of the unit is used for extensive grazing and charcoal production.
Soils, general: soils are very shallow and excessively drained with only an acid-humic horizon over consolidated slightly weathered rock. The horizon sequence is AR or R only. The A horixon has the following characteristics
colour: dark brown (7.5YR 3/2) to dark-reddish-brown (5YR 3/3).
texture: clay loam to clay, often gravelly.
structure: strong to weak very fine granular and subangular blocky.
consistence: soft when dry; very friable when moist.
chemical properties: mass fraction of organic C in the A horizon 24 g/kg;

the pH-H_2O is 4.8; the base saturation is 0.1 to 0.2 and the CEC of the soil is 150 mmol/kg.
Soil classification, FAO/Unesco: Lithosols and Rankers.
soil taxonomy: lithic Troporthents.
For a representative profile see App. 6, profiles 2 and 3 and App. 11 (Gesusu and Marongo series of the Marongo detailed survey, the Kebuye and Matiti series of the Irigonga detailed survey and the Oreru series of the Ranen detailed Survey.
For comparison with other soils see Appendix 5.

3.3.3 *Soils of the Footslopes*

Unit FBh

Total area: 2020 ha.
Parent material: basalt, with minor admixtures of quartzite.
Meso relief: undulating to hilly, slope classes CD and DE.
Vegetation/land use: permanent cultivation of annual crops, cultivation of perannial crops like coffee and bananas; little grazing.
Soils, general: soils are well drained, deep to very deep with clear horizon boundaries, and ABCR horizon sequence and a humic topsoil. Clay cutans are present in the B horizon. The biological activity is very high throughout.
colour: A horizon, dark-reddish-brown (5YR 3/2); B horizon, dark-red (2.5YR 3/6).
texture: clayey throughout, but with a clear increase in the B horizon; the clay ratio between the B and the A horizon is 0.2.
structure: moderate to strong very fine subangular blocky in the A horizon, grading into very fine angular blocky in the B horizon.
consistence: friable when moist; slightly sticky and slightly plastic when wet.
chemical properties: mass fraction of organic C is 17 g/kg; the pH-H_2O about 5.5; base saturation is slightly more than 0.5; the CEC of the clay is 210 mmol/kg.
Soil classification, FAO/Unesco: luvic Phaeozems and mollic* Nitosols
soil taxonomy: oxic Argiudols and typic Paleudolls.
For a representative profile, see App. 6 profile 4. For comparison with other soils see Appendix 5.

Unit FBht

Total area: 5820 ha.
Parent material: like unit FBh, but with inclusions of quartzite
Meso relief: rolling to hilly, slope class DE. Convex outcrops within a rather linear overall slope.
Vegetation/land use: like unit FBh, but with more trees.
Soils: like unit FBh, but with inclusions of soils of unit HBhP or sometimes HXP.
Soil classification: the deeper soils are, FAO/Unesco: mollic* Nitosols with haplic Phaeozems and soil taxonomy: typic Paleudoll and oxic Argiudoll.
The shallow soils are, FAO/Unesco: haplic Phaeozems and some humic Cambisols and Soil Taxonomy: Oxic Hapludoll and some lithic Humitropepts.
For a representative profile, see App. 6, profile 5 and App. 11 (Gucha series of the Marongo detailed survey). For comparison with other soils see Appendix 5.

Unit FYh

Total area: 5820 ha.
Parent material: rhyolites, some being meta-rhyolites.

Meso relief: gently undulating, slope class BC and CD.
Vegetation/land use: permanent cultivation of annual crops; cultivaton of annual crops as sugar cane and coffee. Grazing is not common.
Soils, general: deep to very deep, well drained, very permeable with clear and gradual horizon boundaries, an AB(C)R horizon sequence and a humic topsoil. Clay cutans are present in the B horizon. The biological activity is very high throughout.
colour: A horizon, dark-reddish grey to reddish-brown (5YR 3-4/2.5); B horizon, reddish-brown (2.5YR 4/4).
texture: clay loam in the A horizon and clay in the B horizon; the mass ratio of silt to clay in the B horizon is 0.5; the mass ratio of the clay of B and A horizon is 1.8.
structure: very fine granular to subangular blocky in the A horizon grading into fine angular to subangular blocky in the B horizon.
consistence: friable to very friable, when moist and slightly sticky, slightly plastic, when wet.
chemical properties: mass fraction of organic C is 20 g/kg; pH-H_2O just above 5; base saturation ranges from 0.6-0.75; the CEC-$clay^2$ is 160 mmol/kg.
Soil classification, FAO/Unesco: luvic Phaeozems and mollic* Nitosols
soil taxonomy: oxic Argiudolls and typic Paleudolls.
For a representative profile, see App. 6, profile 6 and App. 11 (Ranen series of the Ranen detailed Survey and the Nyokal and Nduru series of the Marongo detailed Survey). For comparison with other soils see Appendix 5.

Unit FPg

Total area: 1550 ha.
Parent material: quaternary deposits of volcanic ash with some admixture of quartzite.
Meso relief: undulating to rolling, slope class CD. A uniform, linear to slightly concave slope underneath a quartzite ridge.
Vegetation/land use: extensive grazing.
Soils, general: a dense, mottled dark-red clay is overlain by 50-80 cm mottled reddish-brown clay loam. The transition to the dense clay is abrupt and wavy and albic (leached) soil material is found on transition. An interrupted layer of volcanic ash is found in the top of the dense clay. The dense clay is very slowly permeable for water and air. The soils are deep (somewhat) imperfectly drained and very susceptible to gully erosion and landsliding. Clay cutans occur above the dense clay and also in the dense clay. Biological activity is almost restricted to the top 50-80 cm of the soil.
colour: A horizon, dark-reddish-brown (5YR 3/2) and B horizon, reddish-brown to dark-red (2.5YR 4/4 to 2.5YR 3/6).
texture: clay, except in the horizon with albic material which has a loam to clay-loam texture. The mass ratio of clay between B and A2 horizon is 1.8 and of silt to clay 0.7 (B horizon).
structure: moderate fine subangular blocky in the first 50-80 cm and strong angular blocky below.
consistence: slightly hard when dry, friable when moist. In the dense clay below 50-80 cm: hard when dry, and firm, when moist.
chemical properties: mass fraction of organic C in the A horizon 18 g/kg; pH-H_2O just above 5; base saturation is over 0.50 throughout; the CEC-$clay^2$ is 180 mmol/kg.
Clay minerals: predominantly kaolinite and halloysite; little illite.
Soil classification, FAO/Unesco: gleyic Luvisols.
soil taxonomy: aquic thapto albic tropaqualfic Tropudalfs.
For a representative profile, see App. 6, profile 7. For comparison with other soils see Appendix 5.

Unit FQh

Total area: 2790 ha.
Parent material: quartzites and quaternary ash.
Meso relief: rolling to hilly, slope classes CD and DE. The map unit consists of uniform linear to slightly concave slopes at the foot of quartzite ridges.
Vegetation/land use: extensive grazing, occasionally maize cultivation
Soils, general: permeable, well drained, deep with clear to gradual boundaries, an AB(C)R horizon sequence and an acid humic topsoil. The biological activity is high throughout.
colour: A horizon, dark-reddish-brown (5YR 2/2) and B horizon, reddish-brown (5YR 4/4).
texture: clay throughout but with a clear clay increase towards and in the B horizon. The clay ratio between B and A horizon is 1.4; the silt/clay ratio in the B horizon is 0.43.
structure: very fine strong subangular blocky, grading into angular blocky in the B horizon.
consistence: friable when moist; slightly sticky, slightly plastic when wet.
chemical properties: mass fraction of organic C in the A horizon 29 g/kg; pH-H_2O just below 5; base saturation is around 0.40; CEC-clay is 200 mmol/kg.
Clay minerals: mainly kaolinites.
Soil classification, FAO/Unesco: humic Acrisols.
soil taxonomy: oxic Tropudalfs.
For a representative profile, see App. 6, profile 8. For comparison with other soils see Appendix 5.

3.3.4 *Soils of the Uplands and Plateau remnants*

3.3.4.1 Soils of the Keroka Upland

Unit U1Ph

Total area: 11260 ha.
Parent material: mainly quaternary volcanic ash deposits.
Macro relief: the major part of the area has a hilly topography, due to strong dissection of the original erosion surface, of which now only isolated undulating remnants are left, slope classes BE and DE.
Vegetation/land use: permanent cultivation of annual crops like maize and beans etc. and perannial crops like tea and pyrethrum.
Soils, general: deep to very deep, well drained, very permeable with an ABC horizon sequence and gradual transitions between the horizons. The humic A horizon is thick and dark. The bulk density is rather low (0.9-1.0). Clay cutans occur in the B horizon. The biological activity is high throughout.
colour: A horizon, dark-reddish-brown (5YR 3/2-3/3) and B horizon, dark-reddish-brown (5YR 3/4-2.5YR 3/4). Deeper than 80 cm the soil is mottled and contains manganese concretions.
texture: silty clay loam grading into clay loam below 80 cm depth. Mass ratio of silt to clay is 1.6 and the mass ratio of clay between the B and A horizon is 1.3.
structure: moderate very fine granular structure in the A horizon grading into very fine subangular blocky in the B horizon.
consistence: friable to very friable when moist; slightly sticky and slightly plastic when wet.
chemical properties: mass fraction of organic C in the A horizon 24 g/kg; pH-H_2O of 6 or slightly below 6; base saturation is 0.50 to 1.00 and CEC-clay is 210 mmol/kg.

Clay minerals: mainly kaolinitic-halloysitic with traces of illite.
Soil classification, FAO/Unesco: luvic Phaeozems.
soil taxonomy: oxic Argiudolls
Remark: the soils have a high silt content, a low bulk density, a high base saturation and a high organic matter content, all characteristics which are indicative for "andic" properties. According to the classification system these properties are not sufficient to fulfill the requirements for an "ANDOSOL".
For a representative profile, see App. 6, profile 9 and App. 11, (Ichuni, Narangai and Nyanturago series of the Nyansiongo detailed survey). For comparison with other soils see Appendix 5.

Unit U1XhP

Total area: 12050 ha.
Parent material: andesites; rhyolitic tuffs with inclusions of conglomerates.
Macro and meso relief: undulating narrow ridge tops in a strongly dissected landscape and the upper part of steep slopes. Undulating to hilly and steep, slope classes BC, CD, DE, EF.
Vegetation/land use: extensive grazing; planted trees and natural bushes are used for charcoal production.
Soils, general: somewhat excessively drained, mainly shallow with an acid humic topsoil over weathered and consolidated rock. The horizon sequence is A(B)CR, ACR or AR. The A horizon has the following characteristics:
colour: dark-reddish-brown (5YR 3/3).
texture: gravelly clay loam.
structure: moderate very fine subangular blocky.
consistence: friable-very friable; slightly sticky and slightly plastic.
chemical properties: mass fraction of organic C in the A horizon 25 g/kg; pH-H_2O is around 4.5; the base saturation is 0.1-0.2 and the CEC is 180 mmol/kg.
Soil classification, FAO/Unesco: Rankers and Lithosols.
soil taxonomy: lithic oxic Humitropept.
For a representative profile, see App. 6, profile 10 and App. 11, (Miriri and Loudetia series of the Magombo detailed survey and the Kapsagut and Nyamasibi series of the Nyansiongo detailed survey). For comparison with other soils see Appendix 5.

Unit U1Xh

Total area: 31170 ha.
Parent material: andesites, rhyolites and some inclusions of felsites and especially on the gently sloping parts a substantial admixture with volcanic ash.
Macro and meso relief: the rather flat ridge tops are gently undulating; the rest of the unit consists of long slopes with slope percentages ranging from 20 to sometimes almost 30%. Undualating and hilly, slope classes CD, DE or E.
Vegetation/land use: permanent cultivation of principally maize, beans, tea and pyrethrum.
Soils, general: well drained, deep to very deep, very permeable with gradual horizon boundaries and an ABC(R) horizon sequence. Soils have humic topsoils, except on steep slopes, where the topsoils are acid humic. The B horizon has clay-cutans.
colour: A horizon, dark-reddish-brown (5YR 3/3-3/2) and B horizon, dark-reddish-brown (5YR 3/3-3/4 to reddish-brown and red (5YR 3/4-3/4 to 2.5YR 4/6).
texture: clay throughout. The clay ratio between B and A horizon is 1.2. Mass ratio of silt to clay in the B horizon 0.3-0.4.
structure: moderate to strong very fine subangular blocky, grading into angular blocky in the B horizon.

consistence: slightly hard when dry; friable when moist; slightly sticky and slightly plastic when wet.
chemical properties: mass fraction of organic C in the A horizon 30-50 g/kg; The majority of the soils in this unit have a pH-H_2O of 5-6 in the top soil; at a depth of more than 100 cm the pH is usually lower than 5, but not less than 4. In accordance base saturation in the top-soils is between 0.5 and 1.0 and in the lower subsoil less than 0.5. The very steep parts have a pH of less than 5 and base saturation is less than 0.5 throughout. The CEC-clay is 180 mmol/kg.

Clay minerals: mainly kaolinite with traces of illite.

Soil classification, FAO/Unesco: luvic Phaeozems, dystro*-mollic* Nitosols and humic Acrisols.
soil taxonomy: oxic Argiudoll, typic Paleudoll, orthoxic Palehumult and a humoxic Tropohumult.

For a representative profile, see App. 6, profiles 11 and 16 (undulating parts) and 12 (steep parts) and App. 11 (Nyamwanga series of the Magombo detailed survey and the Gesima series of the Nyansiongo detailed survey). For comparison with other soils see Appendix 5.

Unit U1Bh

Total area: 450 ha.

Parent material: basalts

Meso relief: gently undulating to undulating remnants of the highest erosion surface; slope class BC.

Vegetation/land use: permanent cultivation of annual crops; cultivation of perannial crops like coffee and bananas; little grazing.

Soils, general: well drained deep to very deep with gradual horizon boundaries, an ABCR horizon sequence and a humic topsoil. Clay cutans are present in the B horizon. The biological activity is very high throughout.
colour: A horizon, dark-reddish-brown (5YR 3/3) and B horizon, dark-red (2.5YR 3/6)
texture: clayey throughout. Mass ratio of clay between the B and A horizon is 1.4. Mass ratio of silt to clay of the B horizon is 0.2.
structure: strong very fine subangular blocky in the A horizon, grading into angular blocky in the B horizon.
consistence: friable to very friable, when moist; slightly sticky and slightly plastic, when wet.
chemical properties: mass fraction of organic C in the A horizon 2 g/kg; pH-H_2O is 5.0 to 5.5; the base saturation is slightly more than 0.50 and the CEC-clay is 110 mmol/kg.

Soil classification, FAO/Unesco: luvic Phaeozems and mollic* Nitosols
soil taxonomy: oxic Argiudolls and typic Paleudolls.
Soils are very similar to those of unit U3Bh and FBh, but differ in geomorphological position.

For a representative profile, see App. 6, profile 13. For comparison with other soils see Appendix 5.

Unit U1Ihn

Total area: 790 ha.

Parent material: felsites with volcanic ash admixture.

Relief: undulating to rolling remnants of the highest erosion surface; slope classes BC and CD.

Vegetation/land use: permanent cultivation of maize, beans, bananas, coffee and tea; some grazing.

Soils, general: well drained, very deep, very permeable with gradual horizon boundaries and an ABC(R) horizon sequence. Clay cutans are present in the B horizon.
colour: A horizon, dark-brown to dark-reddish-brown (7.5YR 3/2-5YR 3/2) and B horizon, dark-reddish-brown to dark red (2.5YR 3/4-3/6)

texture: clay throughout; the mass ratio of clay between the B and A horizon is 1.3. The mass ratio of silt to clay of the B horizon is 0.17.
structure: moderate very fine angular to subangular blocky in the B horizon.
consistence: friable when moist; slightly sticky, slightly plastic when wet.
chemical properties: mass fraction of organic C in the A horizon 20-40 g/kg; The soils have a pH-H_2O of 5.5 to 6.5 till about a depth of 100 cm, decreasing to 5 below that depth. The base saturation drops from about 1.00 in the topsoil to 0.35 at a depth of more than one meter. The CEC-clay is 110 mmol/kg.

Clay minerals: predominantly kaolinites, traces of a 14 A^o mineral.
Soil classification, FAO/Unesco: dystro-mollic* and mollic* Nitosols.
soil taxonomy: orthoxic Palehumult and typic Paleudoll.
Remark: the soils have a high silt content, a low bulk density, a high base saturation and a high organic matter content till a depth of 50-100 cm, all charecteristics indicative for "andic" properties. These properties are however not sufficient to fulfill the requirements for "Andosol".
For a representative profile, see App. 6, profile 14 and App. 11 (Nyakembene and Skuli series of the Marongo detailed survey). For comparison with other soils see Appendix 5.

Unit U1Qh

Total area: 790 ha.
Parent material: quartzites, with admixtures of siltstone.
Meso relief: undulating to rolling remnants of the highest erosion surface; slope classes BC and CD.
Vegetation/land use: extensive grazing; exploitation of bushes for charcoal; trees; cultivation of tea, coffee and some annual crops.
Soils, general: well drained, deep to very deep, permeable with gradual horizon boundaries and an AB(C)R horizon sequence.
colour: A horizon, dark-reddish-brown (5YR 3/3) and B horizon, reddish-brown to dark-reddish-brown (5YR 4/6-2.5YR 3/6)
texture: clay throughout with a mass fraction of 0.6-0.75. The mass ratio of clay between B and A horizon is 1 and the mass ratio of silt to clay in the B horizon is 0.3.
structure: moderate to weak very fine and fine subangular blocky.
consistence: friable when moist; slightly sticky and slightly plastic when wet.
chemical properties: mass fraction of organic C in the A horizon 20-40 g/kg. The pH-H_2O is around 5.0, the base saturation is less than 0.05 throughout and the CEC-clay is 126 mmol/kg.

Clay minerals: mainly kaolinites, but poorly crystallized.
Soil classification, FAO/Unesco: humic Ferralsols.
soil taxonomy: typic Haplohumox.
For a representative profile, see App. 6, profile 15 and App. 11 (Nyangori, Kiabigori and Itumbe series of the Marongo detailed survey). For comparison with other soils see Appendix 5.

3.3.4.2 Soils of the Magombo Upland

Unit U2Ihn

Total area: 41720 ha.
Parent material: andesites, with inclusions of conglomerate and a substantial enrichment with quarternary volcanic ash.
Macro and meso relief: broad rather flat topped ridges; undulating to rolling, slope class CD.
Vegetation/land use: permanent cultivation of mainly maize, beans, tea and pyrethrum; some grazing.

Soils, general: well drained, very deep, very permeable with gradual horizon boundaries, an ABCR horizon sequence and a humic topsoil. Clay cutans are present in the B horizon. The C and R horizons are found at great depth. Biological activity is very high throughout.

colour: A horizon, dark-reddish-brown (5YR 3/2-7.5YR 3/2) varying in depth from 30 cm to 100 cm. B horizon, dark-reddish-brown to yellowish-red (5YR 3.5/4 to 5YR 4/6).

texture: clay throughout, with a mass fraction increasing from about 0.6 in the A horizon to over 0.7 in the B horizon. Mass ratio of silt to clay in the B horizon is 4-6 g/kg.

structure: moderate fine subangular blocky in the A horizon grading into moderate fine angular blocky in the B horizon.

consistence: very friable to friable when moist; slightly sticky, slightly plastic when wet.

chemical properties: mass fraction of organic C in the A horizon 20-40 g/kg. The pH-H_2O drops from about 5.5 in the topsoil to 4.5 in the B horizon; in accordance the base saturation drops from about 0.6 in the A horizon to as low as 0.25 in the B horizon. The CEC-clay is 180 mmol/kg.

Clay minerals: predominantly kaolinites.

Soil classification, FAO/Unesco: dystro*-mollic* Nitosols.

soil taxonomy: orthoxic Palehumult and typic Paleudoll.

Remark: according to the degree of ash-enrichment, soils in flat positions may have a base saturation of more than 0.5 till a depth of more than 125 cm, in which case they meet the requirement for a mollic* Nitosol.

For a representative profile, see App. 6, profile 16 and App. 11 (Nyambaria and Magombo series of the Magombo detailed survey). For comparison with other soils see Appendix 5.

3.3.4.3 Soils of the Kisii Upland

Unit U3Bhn

Total area: 31970 ha.

Parent material: basalts.

Macro and meso relief: dissected uplands, with straight to slightly convex lateral valley slopes and some rather flat topped ridges. Undulating to rolling, slope classes BC, CD.

Vegetation/land use: permanent cultivation of annual crops as maize, beans, onions etc. and perannial crops as coffee and bananas; some grazing.

Soils, general: well drained, very deep, very permeable with gradual horizon boundaries, an ABCR horizon sequence and a humic topsoil. Clay cutans are present in the B horizon.

colour: A horizon, dark-reddish-brown to dark-brown (5YR 3/2-3/3 and 7.5YR 3/2). B horizon, dark-red (2.5YR 3/6) to dark-reddish-brown (2.5YR 3/4).

texture: clay throughout; the mass ratio of clay between the B and A horizon is 1.3. The mass ratio of silt to clay in the B horizon is 0.3.

structure: moderate fine subangular blocky in the A horizon grading into strong very fine angular blocky in the B horizon.

consistence: friable when moist; slightly sticky and slightly plastic when wet.

chemical properties: mass fraction of organic C in the A horizon 2-4.5 g/kg. The pH-H_2O varies between 5.0 and 6.0. The base saturation is usually above 0.50 throughout, but occasionally the base saturation in the B horizon is somewhat below 0.50. The CEC-clay is 160 mmol/kg.

Clay minerals: predominantly kaolinite.

Soil classification, FAO/Unesco: mollic* Nitosols occasionally dystro*mollic* Nitosols.

soil taxonomy: typic Paleudoll and occasionally orthoxic Palehumult.

For a representative profile, see App. 6, profile 17 (mollic* Nitosols) and 18 (dystro*mollic* Nitosol) and App. 11 (Nyaborumbasi and Changà series of the

Marongo detailed survey). For comparison with other soils see Appendix 5.

Unit U3Bh

Total area: 15600 ha.
Parent material: basalts.
Meso relief: convex, sometimes dissected valley slopes of incising rivers. Rolling to hilly, slope classes CD and DE.
Vegetation/land use: as for unit U3Bhn.
Soils, general: the soils range in depth from moderately deep to very deep; they are well drained, very permeable with gradual and clear horizon boundaries, an ABCR horixon sequence and a humic or acid humic topsoil. The B horizon has clay cutans. The biological activity is high to very high.
colour: A horizon, dark-reddish-brown to dark-brown (5YR 3/2-3/3 and 7.5YR 3/2). B horizon, dark-red (2.5YR 3/6) to dark-brown (7.5YR 3/2) in the least deep soils.
texture: like U3Bhn, except for the least deep soils, which have a clay loam texture and a higher mass ratio of silt to clay up to 1.2.
chemical properties: mass fraction of organic C 30-35 g/kg. pH-H_2O, base saturation and CEC-clay of the deeper soils as in unit U3Bhn, the less deep soils have a CEC-clay of 240 mmol/kg.
Weatherable primary minerals: see U3Bhn for the deeper soils.
Clay minerals: see U3Bhn for the deeper soils.
Soil classification, FAO/Unesco: luvic Phaeozems, mollic* Nitosols.
soil taxonomy: typic or orthoxic Argiudoll and a typic Paleudoll. Inclusions of rather shallow soils like profile 19 are haplic Phaeozems (FAO/Unesco) and typic Hapludoll (soil taxonomy).
Profiles 17 and 18 of Appendix 6 are representative for the deepest soils; they are called Ikoba and Muma series in the Marongo detailed survey (App. 11). The Machogo series are representative for the moderately deep to deep soils (App. 11), while the least deep and least common soils within the association are represented by profile 19 of Appendix 6, which is called Mugirango series in the Marongo detailed Survey (App. 11).

Unit U3Ihn

Total area: 4000 ha.
Parent material: quartz-diorite.
Macro and meso relief: rather broad flat topped ridges with slightly convex linear lateral slopes. Undulating to rolling, slope classes BC and CD.
Vegetation/land use: permanent cultivation of annual crops as maize and beans; cultivation of perennial crops as bananas and coffee; some grazing.
Soils, general: well drained, very deep, permeable to very permeable, with gradual and clear horizon boundaries an ABCR horizon sequence and a humic or acid humic topsois. The B horizon has clay cutans. The biological activity is high to very high.
colour: A horizon, dark-reddish-brown (5YR 3/3-3/2). B horizon, reddish-brown to red (2.5YR 4/5).
texture: clay throughout; increasing from 0.5 in the A horizon to 0.6-0.7 in the B horizon. The mass ratio of silt to clay in the B horizon is about 0.2.
structure: weak to moderate subangular blocky in the A horizon, grading into moderate angular and subangular blocky in the B horizon.
consistence: friable when moist; slightly sticky and slightly plastic when wet.
chemical properties: organic C in the A horizon 20-30 g/kg. The soils on the rather flat ridgetop have a pH-H_2O of 4.5-5.5 throughout and a base saturation of 0.25-0.35. The soils on the slopes have a pH-H_2O of 5-5.5 and a base saturation of 0.60 to 0.90. The CEC-clay is 65 mmol/kg for the soils on the ridge tops and 140 for the soils on the slopes.
Soil classification, FAO/Unesco: mollic* Nitosols on the slopes and humic Nitosols

on the broad ridge tops. If the narrower Nitosol concept of the Kenya Soil Survey would be applied the classification of the humic Nitosols would read: Ferral* humic Acrisols.

soil taxonomy: typic Paleudoll and orthoxic Palehumult.

For a representative profile, see App. 6, profile 20 (humic Nitosols) and 21 (mollic* Nitosols) and App. 11 (Nyasoka and Kaganga series of the Irigonga detailed survey). For comparison with other soils see Appendix 5.

Unit U3Ghn

Total area: 1400 ha.

Parent material: Wanjare and Kitere granites.

Macro and meso relief: rather broad flat topped ridges with slightly convex linear lateral slopes. Undulating to rolling, slope classes BC and CD.

Vegetation/land use: see U3Ihn.

Soils, general: well drained, very deep, permeable, with gradual to clear horizon boundaries, an ABCR horizon sequence and an acid humic topsoil. In the C horizon many soft iron concretions occur. The biological activity is high throughout.

colour: A horizon, dark-reddish-brown (5YR 3/3-3/4). B horizon, yellowish-red to red (5YR 4/6-2.5YR 4/5).

texture: A horizon, clay loam to clay. B horizon, clay. The mass ratio of clay between B and A horizon is 1.2. the mass ratio of silt to clay in the B horizon is 0.3.

structure: weak subangular blocky in the A horizon and weak to moderate subangular blocky in the B horizon.

consistence: friable when moist; slightly sticky and slightly plastic when wet.

chemical properties: mass fraction of organic C in the A horizon 15-20 g/kg. The pH-H_2O is 4.5-5.0, the base saturation is 0.1-0.35 and the CEC-clay is 100 mmol/kg.

Clay minerals: predominantly kaolinite.

Soil classification, FAO/Unesco: humic Nitosols. If the narrower Nitosol-concept of the Kenya Soil Survey would be applied, the classification would read: Ferral*-humic Acrisols.

soil taxonomy: orthoxic Palehumult.

For a representative profile, see App. 6, profile 22 and App. 11 (Nyasoka series of the Marongo detailed survey). For comparison with other soils see Appendix 5.

Unit U3Gh

Total area: 2270 ha.

Parent material: Wanjare granites.

Macro relief: rather strongly dissected area with actively incising rivers. Rolling, slope class CD.

Vegetation/land use: see U3Ihn.

Soils, general: well drained in places somewhat excessively drained, deep to very deep, permeable to very permeable with gradual and clear horizon boundaries, an ABCR horizon sequence and an acid humic topsoil. The B horizon has clay cutans. The biological activity is high throughout.

colour: A horizon, dark-reddish-brown (5YR 3/2-5YR 3/3)). B horizon, yellowish-red to red (5YR 5/8-2.5YR 5/8).

texture: clay loam in the A horizon and clay in the B horizon. The mass ratio of clay between B and A horizon is 1.3. The mass ratio of silt to clay in the B horizon is 0.2. The inclusions with gravelly soil have a sandy loam A horizon and a clay loam B horizon.

structure: weak to moderate fine subangular blocky in the A horizon and moderate fine angular to subangular blocky in the B horizon.

consistence: friable to very friable when moist; slightly sticky and slightly plastic when wet.

chemical properties: mass fraction of organic C is 17 g/kg. The base saturation is 0.18+ in the A horizon and 0.18+ in the B horizon. The CEC-

clay is 110 mmol/kg.
Clay minerals: predominantly kaolinite.
Soil classification, FAO/Unesco: Ferral*-humic Acrisols.
soil taxonomy: orthoxic Tropohumult.
For a representative profile, see App. 6, profile 23, for the fine textured soils see the Matongo series and for the medium textured soils the Nyamatutu, Riana and Iruma series of the Irigonga detailed survey. (App. 11). For comparison with other soils see Appendix 5.

3.3.4.4 Soils of the Rongo Upland

Unit U4Bh

Total area: 800 ha.
Parent material: melanephelinites (basalts).
Meso relief: usually higher gently undulating and undulating parts of plain, slope classes AB and BC.
Vegetation/land use: extensive grazing; cultivation of maize, sorghum, beans and sugar-cane.
Soils, general: moderately well drained, moderately deep and permeable with clear horizon boundaries, an ABCR horizon sequence and a humic topsoil.
colour: A horizon, very dark-grey (10YR 3/1). B horizon, dark-gray (10YR 4/1).
texture: A horizon, clay loam; B horizon, clay. The mass ratio of clay between B and A horizon is 1.4. The mass ratio of silt to clay in the B horizon is 0.3.
structure: the A horizon has a fine granular structure and the B horizon has a strong medium to fine angular blocky structure.
consistence: hard in the A horizon and very hard in the B horizon when dry; friable in the A horizon and firm in the B horizon when moist; slightly sticky and slightly plastic in the A horizon when wet, sticky and plastic in the B horizon when wet.
chemical properties: mass fraction of organic C is 2.3. The pH-H_2O is 6 to 6.5 throughout, the base saturation is about 1.00 and the CEC-clay is 600-700 mmol/kg.
Soil classification, the B horizon has vertic properties and shows a clay increase with respect to the A horizon, for which reasons it qualifies as an argillic horizon
FAO/Unesco: verto*-luvic Phaeozems.
soil taxonomy: vertic Argiudolls.
For a representative profile, see App. 6, profile 24 and App. 11 (the Bhanji series of the East Konyango soil survey). For comparison with other soils see Appendix 5.

Unit U4YhP

Total area: 4250 ha.
Parent material: mainly rhyolites and some andesites conglomerates and diorites.
Meso relief: narrow ridges and eroded plateau remnants; undulating to rolling, slope class: BC and CD.
Vegetation/land use: extensive grazing, bushland for charcoal production; occasional crops like cassava, groundnuts and maize.
Soils, general: somewhat excessively drained, shallow, moderately permeable, with clear horizon boundaries, an A(B)R or AR horizon sequence and a humic topsoil. The biological activity is moderate.
The A horizon has the following characteristics
colour: dark-brown to brown (7.5YR 3/2-7.5YR 4/2).
texture: loam to clay loam; silt to clay ratio 1-1.8.
structure: moderate fine and very fine subangular blocky.
consistence: hard when dry; friable when moist; slightly sticky and

slightly plastic when wet.
chemical properties: mass fraction of organic C in the A horizon is 23 g/kg. The pH-H_2O is around 5.5. The base saturation ranges from 0.50 to almost 1.00.
Soil classification, FAO/Unesco: haplic Phaeozems.
soil taxonomy: typic Hapludoll.
For a representative profile, see App. 6, profile 25 and App. 11 (the Kananga series of the Marongo detailed survey and the Uriri and Kokuro series of the Ranen detailed survey and the Rangwe series of the East Konyango area). For comparison with other soils see Appendix 5.

Unit U4Yhp

Total area: 9890 ha.
Parent material: mainly rhyolites with inclusions of andesites.
Macro and meso relief: ridges with slightly convex lateral slopes; undulating to rolling, slope classes BC and CD.
Vegetation/land use: permanent cultivation of mainly sugar-cane and maize; some tobacco and some grazing.
Soils, general: well drained, moderately deep to deep, very permeable with clear and gradual horizon boundaries, an AB(C)R horizon sequence and a humic topsoil. The B horizon has clay cutans. The biological activity is very high throughout.
colour: A horizon, dark-reddish-brown (5YR 3/2) and B horizon, dark-red (2.5YR 3/2).
texture: clay throughout. The mass ratio of clay between B and A horizon is 1.2. The mass ratio of silt to clay in the B horizon is 0.5.
structure: moderate very fine subangular blocky in the A horizon grading into moderate and strong fine angular and subangular blocky in the B horizon.
consistence: friable when moist; slightly sticky and slightly plastic when wet.
chemical properties: mass fraction of organic C in the A horizon is 23 g/kg. The pH-H_2O ranges from 5 to 6, the base saturation ranges from 0.6 to 0.9. The CEC-clay is 180 mmol/kg.
Clay minerals: in view of the rather low CEC-clay, a predominance of kaolinite minerals is expected.
Soil classification, FAO/Unesco: luvic Phaeozems and some chromic luvisols if the topsoil does not meet the requirements of a mollic A.
soil taxonomy: oxic Argiudoll.
For a representative profile, see App. 6, profile 26 and App. 11 (the Nyarega and Kitere series of the Marongo detailed survey). For comparison with other soils see Appendix 5.

Unit U4Ybp

Total area: 1170 ha.
Parent material: mainly rhyolites with admixtures of resistent alluvial gravel of the Magena erosion surface (Wielemaker and Van Dijk, 1981).
Meso relief: gently undulating broad ridge tops, slope class BC.
Vegetation/land use: cassava, groundnuts, sorghum, maize and natural pasture.
Soils, general: well drained, moderately deep, permeable with gradual and clear horizon boundaries, and an ABCR horizon sequence with in places a humic A horizon. The C horizon is still important especially for deeper rooting crops and trees. The biological activity is moderate to high.
colour: A horizon, dark-brown (7.5YR 3/2-3/4) and B horizon, brown to dark-brown (7.5YR 4/3) and reddish-brown (5YR 4/3).
texture: gravelly clay loam to clay. The mass ratio of clay between the B and the A horizon is 1.3. The mass ratio of silt to clay in the B horizon is 0.25.
structure: A horizon, moderate fine and very fine subangular blocky. B

horizon, weak to moderate fine to very fine angular to subangular blocky.
consistence: friable to firm when moist; slightly sticky and slightly plastic when wet.
chemical properties: mass fraction of organic C in the A horizon is around 25 g/kg. The pH-H_2O ranges from 5 to 6, the base saturation from 0.6 to 1.0 and the CEC-clay is 200 mmol/kg. In a similar profile a mass fraction of more than 0.01 oriented clay was found, so that in this profile the clay increase is enough to qualify as an argillic horizon.

Soil classification, FAO/Unesco: orthic Luvisols and luvic Phaeozems (in case the A horizon qualifies as mollic A)
soil taxonomy: mollic Hapludalf and an oxic Argiudoll.

Profile 27 (App. 6) and the Nyandara II series of the Rangwe detailed survey (App. 11) are representative for luvic Phaeozems, while the Rangwe series of the East konyango soil survey (App. 11) are representative for orthic Luvisols. Profile Exc. 15 (sample no.'s 77/335, 336) is also representative for orthic Luvisols. For comparison with other soils see Appendix 5.

Unit U4Yg

Total area: 750 ha.
Parent material: mainly rhyolites with inclusions of andesites.
Meso relief: the slightly concave, lateral slopes of ridges and plains in transition to valley bottoms. Undulating, slope class BC.
Vegetation/land use: grazing; cultivation of sugar-cane and maize a.o.
Soils, general: moderately well drained, deep, permeable, with clear horizon boundaries, an ABCR horizon sequence and a humic topsoil. The soils have mottles increasing with depth and concretions in the lower part. The biological activity is high.
colour: A horizon, dark-reddish-grey to dark-reddish-brown (5YR 4/2-3/2) and B horizon, dark-grey to dark-reddish-grey (5YR 3.5/1-4/2).
texture: A horizon, sandy clay loam to clay loam; B horizon, sandy clay loam to clay, the mass ratio of clay between the B and A horizon is 1.2 and the mass ratio of silt to clay in the B horizon is 0.7.
structure: A horizon, moderate fine and very fine subangular blocky; B horizon, moderate fine and medium subangular blocky.
consistence: hard, when dry; friable when moist; slightly sticky and slightly plastic when wet.
chemical properties: mass fraction of organic C is 14 g/kg. The pH-H_2O is above 5. The base saturation ranges from 0.8 in the A horizon to 1.0 in the B horizon.

Soil classification, FAO/Unesco: gleyic Phaeozems.
soil taxonomy: aquic Hapludoll.

For a representative profile, see App. 6, profile 28 and App. 11 (the Manyata series of the Ranen detailed survey). For comparison with other soils see Appendix 5.

Associations:

The units U4YhP, U4Yhp, U4Ybp, U4Yg all occur in a regularly associated pattern. Where possible, units are separately mapped. In some instances separate mapping was not possible due to the intricate soil pattern. Two or more soils were mapped as one map-unit and called soil association. For the characteristics of the members of a soil association one is referred to the respective unit description. The soil associations are:

Unit U4YhP - U4Yhp

Total area: 4410 ha.
Relief: the Gucha river and its tributaries deeply incised the Rongo erosion surface. Unit U4YhP occupies the steeper convex valley slopes (slope class E, hilly), while unit U4Yhp occupies the rather uniform gentler valley slopes (slope class D, rolling). The relief elsewhere is similar

to that of the map units already described.

Unit U4Yhp - U4Ybp

Total area: 15830 ha.
Relief: gently undulating to undulating, slope classes AB and BC.
Unit U4Ybp occupies especially the gently undulating rather wide ridge tops, while unit U4Yhp occupies both the slopes and the gently undulating parts of the ridges.

Unit U4Yhp - U4Yg

Total area: 5750 ha.
Relief: gently undulating, slope class B.
Unit U4Yg occupies the lower lateral slopes of the ridges, transitional to the Bottomlands. Unit U4Yhp occupies the well drained higher parts of the same ridges.

Unit U4YC

Total area: 6650 ha.
The member units of this soil association are: U4Yhp, U4Ybp and U4Yg.
Relief: undulating to rolling, slope classes BC and CD.
Unit U4Ybp occupies especially the gently undulating rather wide ridge tops, while unit U4Yhp occupies both the upper slopes and the gently undulating parts of the ridges. Unit U4Yg occupies the lower lateral slopes of the ridges, transitional to the Bottomlands.

Unit U4Gh

Total area: 11660 ha.
Parent material: Wanjare and Kitere granites.
Macro and meso relief: ridges, with slightly convex lateral slopes, or only the lateral slopes of ridges. Undulating to rolling, slope classes BC, CD.
Vegetation/land use: bushes for charcoal production; semipermanent cultivation of maize, groundnuts, cassava, sugar-cane, some grazing.
Soils, general: well drained, predominantly deep, permeable, with an ABCR horizon sequence, clear horizon boundaries and an acid humic topsoil. The B horizon has clay cutans. Biological activity is moderate to high.
colour: A horizon, dark-reddish-brown (5YR 3/2) and B horizon, yellowish-red (5YR 5/6).
texture: A horizon, loamy sand to sandy loam; B horizon, sandy clay loam. The mass ratio of clay between B and A horizon is 1.4, the mass ratio of silt to clay in the B horizon is 0.7.
structure: weak to moderate fine subangular blocky in the A horizon, grading into fine angular blocky in the B horizon.
consistence: slightly hard to hard when dry; very friable to friable when moist; slightly sticky and slightly plastic when wet.
chemical properties: mass fraction of organic C is around 19 g/kg. The pH-H_2O is 4.5 to 5, the base saturation ranges from 0.4 to 0.2 and the CEC-clay is 150 mmol/kg.
Clay minerals: in view of the rather low CEC-clay (150 mmol/kg soil) a predominance of kaolinitic clay minerals is expected.
Soil classification, FAO/Unesco: humic Acrisols.
soil taxonomy: orthoxic or typic Tropudult.
For a representative profile, see App. 6, profile 29 and App. 11 (the Paulo

and Ndiwa series of the Marongo detailed survey). For comparison with other soils see Appendix 5.

Unit U4GhM

Total area: 2890 ha.
Parent material: granite with admixtures of alluvial gravel of the Rongo erosion surface.
Meso relief: the flat to slightly undulating remnants of the former erosion surface, slope class AB.
Vegetation/land use: extensive grazing; bushland used for charcoal production. Occasional crops.
Soils, general: shallow, moderately well drained, moderately permeable with clear to abrupt horizon boundaries, an A(B)R or AR horizon sequence and commonly with a humic topsoil. The biological activity is limited. The R horizon is not very penetrable for roots, since a rather indurated vesicular ironstone layer is found on top of it.
colour: A horizon, brown to dark-brown (7.5YR 3/2-7.5YR 4/4); B horizon, (if present) reddish-brown (5YR 4/4).
texture: clay loam to sandy clay loam. Mass ratio of silt to clay 0.4.
structure: weak to moderate very fine subangular blocky.
consistence: very friable when moist; slightly sticky and slightly plastic when wet.
chemical properties: mass fraction of organic C in the A horizon is around 15 g/kg. The pH-H_2O is 4.5 to 5.0. The base saturation is around 0.3 and the CEC-clay is less than 240 mmol/kg.
Soil classification, FAO/Unesco: ferralo* humic and ferralic Cambisols "petroferric phase".
soil taxonomy: oxic Humitropepts and oxic Dystropepts.
Profile 30 (App. 6) and the Magina series of the East Konyango soil survey (App. 11) are representative for the ferralo*-humic Cambisols. For ferralic Cambisols see the Rongo and Riosiri series of the Marongo detailed survey (App. 11). For comparison with other soils see Appendix 5.

Unit U4GM

Total area: 790 ha.
Parent material: granite with some admixtures of resistant alluvial gravel of the former erosion surface.
Meso relief: the soils cover the summits of the intergully divides and the upper part of the lateral slopes. Gently undulating, slope class AB.
Surface stoniness/rockiness: many granite boulders occur on the surface
Vegetation/land use: semi permanent cultivation of annual crops like groundnuts, maize and sorghum. Permanent cultivation of cassava as perennial crop.
Soils, general: moderately wel drained and even somewhat excessively drained, mainly shallow with clear and abrupt horizon boundaries, an ACR horizon sequence and sometimes an acid humic topsoil. The biological activity is limited. Soils are susceptible to sealing.
colour: dark-brown (7.5YR 3/2-4/2)
texture: sandy loam to loamy sand, often gravelly. The mass ratio of silt to clay is 0.4 to 0.5.
structure: weak subangular blocky.
consistence: hard when dry; very friable when moist; non sticky and non plastic when wet.
chemical properties: mass fraction of organic C in the A horizon is 16 g/kg or less. The pH-H_2O is about 5.5 and the base saturation ranges from 0.4 to 0.9. On transition to the rock mostly a hard layer of iron concretions is found. Because of the low CEC, the weak structure grade and the hard consistency, when dry no mollic A horizon is recognized.
Soil classification, FAO/Unesco: ferralo humic Cambisols and ferralic Arenosols.

soil taxonomy: oxic Humitropept and typic Ustipsamment.

For a representative profile of the deeper soils in this unit see App. 6, profile 31. For comparison with other soils see Appendix 5.

3.3.5 Soils of the Plains

Unit PBd

Total area: 2880 ha.

Parent material: melanephelinites (alkali basalts) and volcanic ash of Tertiary age.

Macro relief: flat to gently undulating plain, slope class AB.

Micro relief: termite mounds about 1.5 m high and 2-5 m wide.

Vegetation/land use: semi permanent cultivation of maize, sugar-cane, beans etc. Extensive grazing. Some superficial drainage is practiced.

Soils, general: imperfectly to poorly drained, deep with slowly permeable subsoils, rather abrupt horizon boundaries and an ABCR horizon sequence. The B2 horizon is an intimate mixture of A and B horizon characteristics due to the churning characteristics of this soil e.g. strong cracking when dry, and intersecting slickensides. The biological activity is almost confined to the A horizon, apart from termite mounds, where material of the A, B and C horizon is thoroughly mixed.

colour: A horizon, very dark-brown (10YR 2/2); B2 horizon, dark grey to grey (10YR 4.0/1); B horizon grey (10YR 5/1).

texture: ranging from a mass fraction of 0.3-0.4 clay in the A horizon to about 0.5-0.6 in the B2 and B3 horizon. The mass ratio of silt to clay in the B2 horizon is around 1.

structure: A horizon, strong very fine granular to subangular blocky. B2 and B3 horizon, strong prismatic and coarse to medium angular blocky.

consistence: very hard and hard when dry; very friable when moist in the A horizon, firm in the B2 and B3 horizon; sticky and very plastic when wet.

chemical properties: mass fraction of organic C in the A horizon is 26 g/kg. The pH-H_2O varies between 5 and 6. The base saturation ranges from 0.8 -1.0 and the CEC-clay is 800 mmol/kg.

Clay minerals: predominantly montmorillonites with small amounts of kaolinites/halloysites.

Soil classification, FAO/Unesco: pellic Vertisols

soil taxonomy: typic Pelludert

Remark: the soils intergrade slightly between Vertisols and Planosols, as shown by the lower mass fraction of clay in the A12 than in the B horizon and by the rather abrupt transition of the A12(A2) to the AB horizon.

For a representative profile, see App. 6, profile 32 and App. 11 (the Rodi series of the East Konyango soil survey). For comparison with other soils see Appendix 5.

Unit PXhM

Total area: 1450 ha.

Parent material: various rocks (The main rocks are rhyolites, then granites, followed by andesites and basalts).

Meso relief: the (gently) undulating, somewhat better drained transitions from plains to bottomland, slope class, AB and BC.

Vegetation/land use: semi permanent cultivation of maize, sugar-cane, cassava, beans etc.; some grazing.

Soils, general: moderately well drained to imperfectly drained mainly shallow, moderately permeable, with gradual and clear horizon boundaries, an ABCR horizon sequence and a humic topsoil.
Ironstone, containing alluvial gravel and stones, occurs locally and overlies the weathering rock at depths of 50-80 cm. At places, the same

layer is decomposed to form a layer with many concretions.
colour: A horizon, very-dark-greyish-brown (10YR 3/2) and B horizon, dark-brown sometimes mottled (7.5YR 3/2-4/2).
texture: clay loam, often gravelly; the mass ratio of silt to clay of the B horizon is 1.
structure: moderate very fine subangular blocky.
consistence: very friable and friable when moist; slightly sticky and slightly plastic when wet.
chemical properties: mass fraction of organic C in the A horizon is around 30 g/kg. The pH-H_2O ranges from 5 to 6 and the base saturation from 0.7-1.0.

Clay minerals: amorphous with some halloysites and some montmorillonites.
Soil classification, FAO/Unesco: haplic Phaeozems wth inclusions of gleyic Phaeozems: locally a petroferric phase occurs.
soil taxonomy: typic and aquic Hapludolls.

The soils resemble the Akijo, Kibubu ad Nyangu series of the East Konyango soil survey (App. 11). Profile 33 of App. 6 is representative, apart from consistence and structure. For comparison with other soils see Appendix 5.

Unit PXa

Total area: 1580 ha.
Parent material: the main rocks are rhyolites followed by andesites. The surface shows clear alluvial influences, like layers of rounded stones and gravel, resistent to weathering. Volcanic ash has been mixed through the A and B horizons.
Meso relief: flat to very gently undulating plain, slope class AB.
Micro relief: termite mounds of 1.5 m high and 2-6 meter wide.
Vegetation/land use: mainly extensive grazing.
Soils, general: imperfectly to poorly drained, deep with an A1 and A2 (bleached) horizon, abruptly overlying a dense clay B horizon at a depth of 30-60 cm, which is very slowly permeable. The B horizon has clay cutans. The C horizon is deeply weathered. The biological activity is mainly confined to the top 40-60 cm, apart from the termite mounds where material from A, B and C horizons is thoroughly mixed.
colour: A horizon, very-dark-grey to dark grey (10YR 3/1-10YR 4/1). A2 horizon, dark-greyish-brown to grey (10YR 4/2-10YR 5/1)); B horizon, black to greyish-brown (N2/0-10YR 5/2). The top of the B has distinct red mottles.
texture: A horizon, loam to silt loam. B horizon, the mass ratio of clay between B and A horizon is 2.5. The mass ratio of silt to clay in the B horizon is 0.21 and in the A horizon around 2. In the B horizon rounded stones and gravel resistant to weathering, occur in varying amounts.
structure: A horizon, moderate to weak very fine subangular blocky. B horizon, coarse prismatic to columnar and coarse angular blocky. Intersecting slickensides occur in the lower part of the B horizon.
consistence: A horizon, slightly hard when dry; friable when moist; slightly sticky and slightly plastic when wet. B horixon, very hard when dry; firm when moist; sticky and slightly plastic when wet.
chemical properties: mass fraction of organic C in the A horizon is 20-40 g/kg. The pH-H_2O ranges from about 5.0 in the A horizon to 5.5-6 in the B horizon. The base saturation is around 0.5 in the A and A2 horizons and 0.6-0.8 in the B horizon. The CEC-clay is 600 mmol/kg in the B horizon.

Soil classification, FAO/Unesco: eutric Planosols.
soil taxonomy: abruptic Tropaqualfs.

For a representative profile, see App. 6, profile 34 and App. 11 (the Nyokal series of the East Konyango Soil survey). For comparison with other soils see Appendix 5.

Unit PXhM-PXa

Total area: 2270 ha.
Relief: gently undulating to undulating; slope classes AB and BC. Unit PXhM usually occupies the more sloping positions; it also occurs on very gently undulating parts of the dissected Plains, where it is difficult to predict its occurrence on the basis of physiography.

Unit PPa

Total area: 2890 ha.
Parent material: Quaternary volcanic ash deposits.
Macro relief: flat, with locally deeply incised rivers, slope class AB.
Micro relief: huge termite mounds occur at regular distances.
Vegetation/land use: extensive grazing. Low trees and bushes grow on the termite mounds.
Soils, general: imperfectly to poorly drained, deep with an A1 and A2 (leached) horizon abruptly overlying a dense clay B horizon at a depth of 20-40 cm, which is very slowly permeable. The B horizon has clay cutans. The C horizon consists of compact somewhat weathered slightly calcareous volcanic ash. The biological activity is low and mainly restricted to the topsoil and the large termite mounds.
colour: A horizon, black (5YR 2.5/1); A2 horizon, dark-brown to dark-greyish-brown (7.5YR-10YR 4/2) and dry (7.5YR 7/2); B horizon, black (10YR 2.5/1).
texture: clay loam in the A horizon and clay in the B horizon. The mass ratio of clay between the B and A horizons is 1.8. The mass ratio of silt to clay in the A horizon is 0.8, in the B horizon 0.4.
structure: A horizon, strong fine subangular blocky. B horizon, strong coarse prismatic in the upper part and fine angular blocky in the lower part, where also intersecting slickensides occur.
consistence: A horizon, slightly hard when dry; slightly sticky and slightly plastic when wet. B horizon, very hard when dry; very firm when moist; sticky and plastic when wet.
chemical properties: mass fraction of organic C in the A horizon is around 20 g/kg. The base saturation ranges from 0.6 in the A horizon to 0.7-1.0 in the B horizon. The CEC-clay is 750 mmol/kg. The soil below 80 cm depth is calcareous.
Clay minerals: because of the high CEC-clay (750 mmol/kg), claymineralogy will be montmorillonitic.
Soil classification, FAO/Unesco: eutric Planosols.
soil taxonomy: abruptic Tropaqualf.
For a representative profile, see App. 6, profile 35 and App. 11 (the Nyansiongo, Manga and Isoge series of the Nyansiongo detailed survey). For comparison with other soils see Appendix 5.

Unit PGa

Total area: 1060 ha.
Parent material: granite with admixtures of alluvial stones and gravel of quartzitic composition. Volcanic ash has been mixed with the A and B horizons.
Relief: as unit PXa.
Vegetation/land use: as unit PXa.
Soils, general: as unit PXa.
colour: A horizon, very-dark-grey to very-dark-greyish brown (10YR 3/1-2). B horizon, very-dark-brown (10YR 2/2).
texture: A horizon, loam to sandy loam. B horizon, the mass ratio of clay between B and A horizon is 3. The mass ratio of silt to clay in the B horizon is 0.2 and in the A horizon it varies from 0.5-1.2.
structure: A horizon, weak to moderate fine subangular blocky. B horizon,

coarse and medium angular blocky and some slickensides which are not intersecting.

consistence: as in unit PXa.

chemical properties: mass fraction of organic C in the A horizon is about 30 g/kg. The pH-H_2O ranges from 4.6 in the A horizon to 5.5 in the B horizon. The base saturation is 0.28 in the A and 0.7 in the B horizon. The CEC-clay is 700 mmol/kg.

Clay minerals: kaolinites and some montmorillonites.

Soil classification: as unit PXa.

For a representative profile, see App. 6, profile 36 and App. 11 (the Misathe series of the East Konyango soil survey). For comparison with other soils see Appendix 5.

3.3.6 *Soils of the Bottom lands*

Unit BBh

Total area: 570 ha.

Parent material: fine textured alluvial deposits with volcanic ash admixture.

Meso relief: flat to very gently undulating plain between hills, slope class AB.

Vegetation/land use: semi permanent cultivation of cotton, maize, sorghum etc.; some extensive grazing.

Soils, general: moderately well drained, deep, slowly permeable with gradual and clear horizon boundaries, cracking when dry, but without intersecting slickensides. The biological activity is low.

colour: black to very-dark-grey (5YR 2/1-5YR 3/1).

texture: clay throughout; a mass fraction of clay ranging from 0.55-0.7. The mass ratio of clay between B and A horizon is 1.3. The mass ratio of silt to clay is 0.4-0.6.

structure: strong fine and medium angular blocky.

consistence: A horizon, hard when dry; friable when moist; sticky and plastic when wet. B horizon, very hard when dry; friable to firm when moist and when wet as in A horizon.

chemical properties: mass fraction of organic C in the A horizon is around 1.5 g/kg. The pH-H_2O ranges from 6-7 and the base saturation is 1.0 throughout. The soil is calcareous from a depth of about 80 cm. The soil has not enough vertic characteristics to qualify as Vertisol.

Soil classification, FAO/Unesco: vertic Phaeozems.

soil taxonomy: vertic udic Argiustols.

For a representative profile, see App. 6, profile 37. For comparison with other soils see Appendix 5.

Unit BBd

Total area: 560 ha.

Parent material: alluvial material derived from basalts with volcanic ash admixture.

Meso relief: nearly flat valley bottoms, slope class AB.

Micro relief: termite mounds occur at regular distances.

Vegetation/land use: extensive grazing; occasionally sugar-cane and maize.

Soils, general: imperfectly to poorly drained, deep, very slowly permeable, cracking, with clear and gradual horizon boundaries. The biological activity is low, except in the termite mounds.

colour: dark-grey in the topsoil (10YR 4/1) to dark-grey and very-dark-greyish-brown (10YR 4/1-3/2) in the subsoil. Yellowish-red mottles are common in the subsoil.

texture: clay throughout; the B horizon has a mass ratio of silt to clay of 0.4.

structure: A horizon, moderate fine to very fine subangular blocky. B

horizon, moderate coarse prismatic and in the subsoil strong medium angular blocky; the clay is dispersible and mobile, which is probably the reason for the weakly developed slickensides.
consistence: hard and very hard when dry; firm when moist; sticky and plastic when wet.
chemical properties: mass fraction of organic C in the A horizon ranges from 18-25 g/kg. The pH-H_2O ranges from 6 in the topsoil to 7 or 8 in the subsoil. The base saturation ranges from 0.75-1.0 The CEC-clay is 570 mmol/kg.

Clay minerals: the vertic characteristics indicate a predominantly montmorillonitic clay mineralogy.

Soil classification, FAO/Unesco: pellic Vertisols, sodic phase. Unfortunately the sodic phase is not mentioned in the legend in Appendix 1.
soil taxonomy: entic Pelludert.

For a representative profile, see App. 6, profile 38 and App. 11 (the Aora nam series of the Ranen detailed survey and the Oboke and Kibigori series of the East Konyango soil survey). For comparison with other soils see Appendix 5.

Unit BXa1

Total area: 19020 ha.

Parent material: Quaternary volcanic ash deposits with little alluvial admixture.

Meso relief: flat to gently undulating valley bottoms, slope class AB.

Micro relief: termite mounds of 1-2 metres high and 6 metre wide occur at regular distances of about 50 metres.

Vegetation/land use: extensive grazing. Termite mounds are covered with Acacia and Euphorbia spp.

Soils, general: poorly drained, deep, with an A1 and A2 horizon abruptly overlying a dense, very slowly permeable B horizon at a depth of 20-50 cm. The B horizon is underlain by alternating compact volcanic ash layers and heavy clay formed from volcanic ash. The top of the columns is coated with white A2 material, while the ped surfaces and the root channels in the B horizon are coated with thick clay flows. Biological activity is low and mainly restricted to the topsoil and the termite mounds.
colour: A1 horizon, black to dark-grey (10YR 2.5/1-10YR 4/1). A2 horizon, grey (10YR 5/1). B horizon, grey to dark-greyish-brown (10YR 5/1-10YR 4/2). The A2 horizon may have prominent reddish-brown mottles.
texture: A horizon, loam to silty clay loam. B horizon, clay. The mass ratio of clay between B and A horizons is 2.5. The mass ratio of silt to clay in the A horizon is about 1.6 and in the B horizon 0.4-0.6.
structure: A horizon, moderate to strong fine subangular blocky. A2 horizon, massive to weak subangular blocky. B horizon, strong coarse columnar in the upper part and strong medium angular blocky in the lower part, slickensides sometimes occur in the lower part.
consistence: A horizon, slightly hard when dry; friable when moist; slightly sticky and slightly plastic when wet. B horizon, very hard when dry; firm when moist; very sticky and very plastic when wet.
chemical properties: mass fraction of organic C in the A horizon ranges from 1.4-3.3 g/kg. The pH-H_2O ranges from around 5-5.5. The base saturation in the A and A2 horizon ranges from 0.3-0.4, in the B horizon from 0.5-1.0. The CEC-clay is 600 mmol/kg. The substance fraction of exchangeable sodium in the B horizon is slightly over 0.06.

Clay minerals: mainly montmorillonite, little kaolinite.

Soil classification, FAO/Unesco: solodic Planosols.
soil taxonomy: abruptic Tropaqualf.

Inclusions: soils of unit BBd.

For a representative profile, see App. 6, profile 39 and App. 11 (the Nyamauro series of the East Konyango soil survey and the Riana Kuna and Sare series of the Rangwe and Ranen detailed surveys). For comparison with other soils see Appendix 5.

Fig. 15. Dystric Planosol of map unit BXa2. Abrupt transition from bleached silty A2 horizon to darker clayey B horizon.

Unit BXa2 (Fig. 15)

Total area: 12630 ha
Parent material: Quaternary volcanic ash deposits with little alluvial admixture.
Meso relief: flat to gently undulating valley bottom, slope class AB.
Micro relief: numerous small ant hills (20-30 cm high, 40 cm wide) and some 50 cm high and 2-3 metre wide termite mounds occur.
Vegetation/land use: grazing.
Soils, general: imperfectly to poorly drained, deep with an A1 and A2 horizon abruptly overlying a dense, very slowly permeable B horizon at a depth of 30-75 cm. On top of the B horizon a concretionary layer occurs. The biological activity in the A horizon is moderate, and mainly restricted to ants and termite mounds.
colour: A horizon, very-dark-grey to greyish-brown (10YR 3/1-7.5YR 3/1). A2 horizon, grey to dark-greyish-brown (10YR 5/1-7.5YR 4/1). B horizon, dark-greyish-brown to dark-grey (7.5YR 4/1-10YR 4/1). Distinct yellowish-brown iron-mottles occur in the upper part of the B horizon.

texture: A horizon, silt loam to silty clay loam. B horizon, mass fraction of clay (0.6-0.8). The mass ratio of clay between the B and A horizon is 2.7. The mass ratio of silt to clay in the B horizon is 0.19.

structure: A horizon, moderate fine to very fine (sub) angular blocky. B horizon, moderate prismatic in the top part and moderate medium angular blocky below. Slickensides occur at a depth of more than 80 cm.

consistence: A horizon, friable when moist; slightly sticky and slightly plastic when wet. B horizon, firm when moist, sticky and plastic when wet.

chemical properties: mass fraction of organic C in the A horizon is 30-40 g/kg. The pH-H_2O ranges from 4.5 in the A horizon to 5.5 in the B horizon. The base saturation ranges from about 0.28 in the A horizon to 0.6-0.7 in the lower part of the B horizon. The CEC-clay is 520 mmol/kg.

Clay minerals: mainly montmorillonite, some kaolinite.

Soil classification, FAO/Unesco: eutric Planosols and dystric Planosols. Unfortunately the dystric Planosols are not mentioned in the legend of Appendix 1.

soil taxonomy: aeric abruptic Tropaqualfs.

For a representative profile, see App. 6, profile 40 and App. 11 (the Nyachogochogo series of the Magombo detailed survey). For comparison with other soils see Appendix 5.

Remark: in some places the base saturation in the B horizon may be lower than 0.5 as e.g. profile no. 40 which meets the requirement of a dystric Planosol. Other, but similar profiles have base saturation figures of more than 0.5.

Unit BXg

Total area: 690 ha.

Parent material: Quaternary volcanic ash deposits with little alluvial admixture.

Meso relief: flat valley bottom, slope class A.

Micro relief: termite mounds as in unit BXa1.

Vegetation/land use: mainly grazing with some small patches of maize and sugar cane.

Soils, general: imperfectly to poorly drained, deep, dense soils with a thin A horizon and an abrupt transition to the underlying B horizon, which is capped with a thin layer of leached silty material. The upper part of the B horizon shows thick continuous clay flows on the ped surfaces. The biological activity is low.

colour: A horizon, very-dark-brown to very-dark-greyish-brown (10YR 2.5/2). B horizon, dark-grey to greyish-brown (10YR 4/1-5/2).

texture: ranging from clay loam in the A horizon to clay in the B horizon. The mass ratio of clay between B and A horizon is 1.2. The mass ratio of silt to clay in the B horizon is 0.7.

structure: strong very fine subangular blocky in the A horizon. B horizon, strong coarse prismatic to columnar in the upper part and strong medium angular blocky in the lower part.

consistence: hard to very hard when dry; firm when moist; very sticky and very plastic when wet.

chemical properties: mass fraction of organic C in the A horizon is about 20 g/kg. The pH-H_2O ranges from about 5-5.5 in the topsoil to 8-8.5 in the B horizon. The base saturation ranges from about 0.5 in the A horizon to 1.0 in the B horizon. The substance fraction of exchangeable sodium in the B horizon ranges from 0.2-0.4. Lime concretions are found at a depth of 100-180 cm. The CEC-clay is 900 mmol/kg.

Clay minerals: mainly montmorillonite, little kaolinite.

Soil classification, FAO/Unesco: gleyic Solonetz.

soil taxonomy: typic Natraqualf.

For a representative profile, see App. 6, profile 41 and App. 11 (the Marinde series of the East Konyango soil survey). For comparison with other soils see Appendix 5.

Unit BXo

Total area: 2450 ha.
Parent material: organic remains (peat) mixed with some silty alluvial material. Humus rich silty alluvial material is found from a depth of about 1.5 metres till 4.00 metres, being the bottom of the valley.
Meso relief: flat lowest part of the valleys, slope class A.
Vegetation/land use: in natural conditions, sedges, ferns and grass. When cultivated and drained, wattle trees, eucalyptus, patches with maize and beans.
Soils, general: dark-reddish-brown (5YR 3/3) to very-dark-grayish-brown (10YR 2/2) rather decomposed peat underlain by less decomposed rather fibrous reddish and black peat to a depth of 100-150 cm. Deeper black to dark-olive clay and still deeper, whitish silty alluvial material is found. The soils sometimes have a black humus rich clayey topsoil.
chemical properties: mass fraction of organic C ranges from more than 300 g/kg for the peat soils to more than 100 g/kg for the humus-rich clay soils. The pH-H_2O ranges from 4 in the peat soils to 5 in the humus-rich clay soils.
Clay minerals: montmorillonite and kaolinite.
Soil classification, FAO/Unesco: dystric Histosols with inclusions of mollic Gleysols.
soil taxonomy: typic Tropohemist with inclusions of aëric Tropaquoll.
For a representative profile, see App. 6, profile 42 and App. 11 (for mollic Gleysols see Kenyerere series of the Magombo detailed survey). For comparison with other soils see Appendix 5.

Unit BGa

Total area: 1770 ha.
Parent material: granite with some alluvial admixtures.
Meso relief: gently sloping valley sides and valley bottoms, slope class AB.
Micro relief: termite mounds.
Vegetation/land use: extensive grazing.
Soils, general: imperfectly to poorly drained, deep, with an A1 and A2 horizon abruptly overlying a dense, compact, very slowly permeable B horizon at a depth of 10 to 30 cm. The B horizon has a coarse columnar breaking into angular blocky structure and is susceptible to erosion. The biological activity is low.
colour: A horizon, very-dark-greyish-brown (10YR 3/2) and B horizon, very-dark-grey (10YR 3/1).
texture: A horizon, sandy loam; B horizon, clay. The mass ratio of clay between B and A horizon is 3.6 and the mass ratio of silt to clay in the B horizon is 0.12.
structure: A horizon, weak medium subangular blocky. B horizon, moderate coarse prismatic to columnar.
consistence: A horizon, slightly hard when dry; friable when moist; non-sticky and slightly plastic when wet. B horizon, very hard when dry; very firm when moist; sticky and plastic when wet.
chemical properties: mass fraction of organic C in the A horizon is 11 g/kg. The pH-H_2O is about 7 and the base saturation is 0.7-1.0. The CEC-clay is 460 mmol/kg.
Soil classification, FAO/Unesco: eutric Planosols.
soil taxonomy: abruptic Tropaqualf.
For a representative profile, see App. 6, profile 43. For comparison with other soils see Appendix 5.

3.3.7 *Soils of Minor valleys*

Unit VXP

Total area: 3580 ha.
Meso relief: convex lateral slopes of incising rivers. Undulating to rolling, slope classes CD and D.
Remarks: soils are comparable with those of unit U1XhP and to a minor extent, those of unit HXP.

3.4 SOIL CLASSIFICATION, CORRELATION AND GENESIS ASPECTS

3.4.1 *Introduction*

The soils in the survey area were classified by the FAO/UNESCO (1976) legend for the soil map of the world. Such a classification serves several purposes. The names represent major chemical and sometimes physical characteristics, which are therefore directly understood. To a certain extent, the names indicate the range in characteristics within the mapping unit. Names are associated with similar soils elsewhere, so that information on management and performance can be exchanged.

The FAO classification is based only on measurable and observable characteristics, which however largely result from soil formation. As background to classification, the soil-forming factors will be discussed in Section 3.4.2: climate, geomorphology, age, parent material, soil fauna and vegetation, drainage and man. The main classification units of the soil map are described in Section 3.4.3. Where necessary new categories have been introduced, which are also defined there. Appendix 5 provides detailed evidence.

3.4.2 *Soil genesis*

Soil characteristics result from the combined action of soil-forming factors. An understanding of the influence of these factors is a great aid when mapping and classifying soils. How some of these factors relate to mapping units, soil characteristics and classification names is shown in Appendix 3 and Table 9.

3.4.2.1 Geomorphology and age

Slope and geomorphological situation are strongly correlated with soil depth, as they influence rates of erosion and sedimentation. Where slopes are more gentle, as on the rather flat remnants of former erosion surfaces, soil depth and stage of soil development should be correlated with the age of the surface. Wielemaker & van Dijk (1981) found a good correlation between age of the surface and soil depth, attributable to degree of weathering of

Table 9. Relation between drainage class, soil depth, geomorphological position, type of parent material, soil names and map units. The symbol X refers to a wide range of rocks; in the surveyed area, it refers to soils developed on granite and quartzite.

Drainage class	Type of parent material, soil names and mapping units			Depth and geomorphology
	basic (B)	intermediate (P,X,I,Y)	acidic (G,Q)	
(somewhat) excessively drained	humic Cambisols (HBhP)	Lithosols (HXP, U1XhP) Rankers (HXP, U1XhP) haplic Phaeoxems (VXP, U4YhP)	haplic Phaeozems (HXP, VXP)*	shallow on hills, scarps, valley slopes and narrow ridge-tops
well drained to moderately drained	verto*-luvic Phaeozems (U4Bh) luvic Phaeozems (FBh, U3Bh, FBht, U1Bh) mollic*-Nitosols (U3Bhn, FBh, U3Bh, U1Bh)	humic Nitosols (U3Ihn) dystro*-mollic* Nitosols (U1Ihn, U2Ihn, U1Xh) orthic Luvisols (U4Ybp) mollic* Nitosols (FYh) luvic Phaeozems (U1Ph, U1Xh, U4Ybp, U4Yhp, FYh) gleyic Luvisols (FPg, U4Yg)	ferral*-humic Acrisols (U3Gh) humic Acrisols (U4Gh, FQh) Ferralsol (U1Qh) humic Nitosols (U3Ghn)	moderately deep to very deep on footslopes and in uplands
moderately drained to imperfectly drained		haplic Phaeozems (PXhM)	humic and ferralic Cambisols (U4GhM) ferralo* humic Cambisols (U4GM) ferralic Arenosols (U4GM)	shallow on plains and flat ridge tops
imperfectly drained to poorly drained	pellic Vertisols (PBd)	eutric Planosols (PXa, PPa)	eutric Planosols (PGa)	deep on plains
	vertic* Phaeozems (BBh) pellic Vertisols (BBh)	eutric Planosols (BXa2) solodic Planosols (BXa1) gleyic Solonetz (BXg)	eutric Planosols (BGa)	very deep on bottomlands

the parent rock and to amount of ash deposited. Stage of soil development did not correlate with age of the surface because of rejuvenation of the soils by ash deposition.

The excessively drained shallow soils occur on hill tops, scarps (units HBhP, HXP), upper slopes and narrow ridges (units U1XhP and U4YhP) and on steep valley slopes (unit VXP). The moderately drained shallow soils occur on rather gently undulating land associated with Plains (unit PXhM) and flat ridge tops (unit U4GhM and U4GM), where an ironstone layer or concretions occur at shallow depth.
The shallow soils undergo constant rejuvenation by erosion.

The well drained soils occur on footslopes (slope class CD) and in a rolling to sometimes even hilly upland with gently undulating ridge tops. These soils are the most developed in the area. The deeper ones occur on older surfaces (U1 and U3 and on footslopes), and the moderately deep upland soils occur on the younger surfaces (U4). The imperfectly and poorly drained soils occur on flat to gently undulating Plains and Bottomlands. In Bottomlands, sedimentation is the major process and soils are deeper.

3.4.2.2 Climate and vegetation

Climate and vegetation are related factors, especially under natural conditions. A change in climate means a change in vegetation. Both factors have altered considerably during the past 15 000 years (review by Lind & Morrison, 1974). Much drier periods occurred 14 500-12 000 years ago, when Lake Victoria was without an outlet (Kendall, 1969); much wetter periods occurred afterwards. These changes affected soil formation and erosion considerably.

Deep and very deep soils are much more common in the east, while shallow soils occur on very steep slopes, compared to more gentle slopes in the west. Perhaps soil forms more rapidly in the east with a moister climate and a better cover of vegetation. Such an obvious conclusion is, however, not justified since the climatic effect is probably overruled by two other factors. The youngest erosion surfaces with younger and shallower soils (units U4Yhp, U4Ybp, U4Yg and U4Gh) are in the west. Volcanic ash deposits are much more widespread and thicker in the east (units U1Ph, U2Ihn) than in the west (Section 3.4.3).

3.4.2.3 Drainage

Geomorphology depth and drainage conditions are correlated (Table 10).

Excessively drained soils are permeable, but lose part of the rainwater as run-off because of limited moisture-storage capacity, impermeable subsoil and sloping topography. Leaching is limited.

Well drained soils are permeable and have a good moisture-storage capacity. Most of the rainwater is stored and excess feeds groundwater. Run-off is

Table 10. Relation between total chemical composition of basic (basalt), intermediate (felsite, andesite, volcanic ash, quartz diorite) and acidic rocks (rhyolite, granite and quartzite) and the chemical and mineral soil characteristics of some map units on these rock types. The numbers 1 and 2 refer to the two soil types occurring within map unit U3Ihn; . data lacking; -, value exactly zero; 0,≦0,5; 0.0≦0.05.

Mass fraction of	Basalt	Felsite (andesite)		Volcanic ash	Quartz diorite		Rhyolite		Granite		Quartzite
SiO_2	0.56	0.67		0.61	0.52		0.62		0.77		0.93
Al_2O_3	0.15	0.13		0.14	0.17		0.13		0.12		0.02
Fe_2O_3	0.13	0.07		0.10	0.07		0.10		0.25		0.03
MnO	0.002	0.001		0.007	0.0		0.002		0.0		0.0
Mgo	0.06	0.006		0.006	0.05		0.03		0.001		0.0
CaO	0.06	0.02		0.009	0.13		0.07		0.01		0.0
Na_2O	.	0.02		0.02	0.04		.		0.05		0.0
K_2O	0.02	0.06		0.02	0.004		0.03		0.03		-
TiO_2	0.01	0.005		0.007	0.006		0.01		0.002		0.0
P_2O_5	0.001	0.001		0.001	0.002		0.0		0.0		0.0
Map unit	U3Bhn	U1Ihn,	U2Ihn	U1Ph	U3Ihn (1)	(2)	U4Yhp,	FYh	U3Ghn,	U3Gh	U1Qh
Top soil											
-base saturation	0.8	1.0	0.65	0.85	0.7	0.32	0.84	0.64	0.14	0.25	0.01
Sub soil[1]											
- base saturation	0.75	0.33	0.30	0.83	0.75	0.20	0.68	0.73	0.33	0.16	0.0
- cation-exchange capacity-clay (mmol/kg)	160	110	180	210	140	65	180	160	100	110	126
- mass fraction clay	0.80	0.83	0.68	0.32	0.63	0.63	0.61	0.59	0.43	0.48	0.68
- SiO_2/Al_2O_3 substance ratio	2.1	2.1	2.3	3.2	4.0	2.4	2.3	.	1.3	2.0	1.3
- SiO_2/R_2O_3 substance ratio	1.6	1.5	1.7	2.2	3.0	1.9	1.7	.	1.1	1.6	0.8

1. Central part of the B2 horizon.

limited, but leaching is marked in these soils.

Moderately drained shallow soils occur on gentle slopes with slow run-off; they stay wet longer than excessively drained shallow soils. Leaching is limited.

Imperfectly drained soils are slowly to very slowly permeable, and run-off is slow because of the flat and gently undulating terrain. They are wet for a considerable time. Leaching is limited. Peat developed in the lower parts of the flat bottomed valleys above an altitude of 1700 m.

3.4.2.4 Parent material

Parent material will be discussed according to differences in soil depth and drainage, which are the main differentiating criteria (Table 10).

Excessively drained shallow soils have topsoils with base saturation of less than 0.5, except unit U4Yhp, which occurs on a gently sloping topography in the drier zones. Moderately well drained shallow soils on intermediate parent materials have humic topsoils (unit PXhM), acid parent rock carry soils with an acid humic topsoil or a ferralic B horizon (unit U4GhM and U4GM).

For well drained deep soils, rock composition and soil characteristics were only slightly correlated (see Table 11).

The characteristics of units U3Bhn, U3Ihn (profile description 21 of App. 6), U3Ghn, U3Gh and U1Qh depend on the parent rock. Base saturation of topsoil ranges from o.8 in basalt soils to almost zero in quartzite soils and of subsoil from almost 0 to 0.75. The cation-exchange capacity of the clay fraction ranges from about 120 mmol/kg in the quartzite soils to 160 mmol/kg in basalt soils. The clay mineralogy is accordingly kaolinitic.

The relation was less clear in the units U1Ihn, U2Ihn, U1Ph, U3Ihn(1), FYh and U4Yhp. Topsoils of units U1Ihn and U2Ihn are unusually rich relative to their subsoils. Soil units U3Ihn(1), U1Ph, FYh and U4Yhp were much richer than expected from rock composition. However, unit U1Ph and the topsoil of U2Ihn developed in young volcanic ash. In mineral studies, volcanic glass particles were also detected in unit U3Ihn(1). Glass particles were intimately mixed with the existing soil materials. Volcanic ash did not explain all the erratic relations in Table 10 (Section 3.4.3).

For imperfectly drained soils, basic parent materials are covered by Vertisols, and intermediate and acid materials by Planosols and Solonetz. The Bottomland soils developed mainly in volcanic ash, and Plain soils to some degree. In the Plain soils, the volcanic ash was intimately mixed with materials derived from the rock. The Planosols over granite (units BGa and PGa) were therefore more sandy than the Planosols over intermediate rock (Section 3.4.3, unit PXa). Most units had a montmorillonitic clay, except unit PGa, which was rich in kaolinite.

3.4.2.5 Soil fauna

The well drained reddish soils were extremely permeable and had low bulk densities of 0.9-1.2 Mg/m^3. The intricate pores were maintained by soil animals, especially termites and ants. The fungus chambers of termites were found in almost every pit and many termites were encountered alive to a depth of 3-4 m. They were even active to a depth of over 7 m in the rotten rock of Profile 21 (App. 6). Their enormous activity churns soil materials and promotes weathering of rotten rock.

The commonly encountered stone lines can also be ascribed to their activity. Because of the size of their mandibles, they can move no particles larger than 2 mm. Therefore the larger particles tend to sink relatively in the soil to a level, where biological activity is sharply less, usually where weathered rock starts. Termites are probably also the main cause of soil creep.

In the imperfectly drained soils, animal life was more restricted. At regular intervals, termites (*Macrotermes* spp.) built mounds 1-2 m high and, where they built, the soil was rather well mixed. Ants make hills about 50 cm high and 1 m in diameter and excavate soil from a layer above the dense clay. The ants and termites improve aëration and drainage of such soils.

3.4.2.6 Man

During the past 50 years, most of the original vegetation in the Kisii Highlands has disappeared. The population grew so rapidly, that all land was needed for agricultural production. Only some poorly drained areas retained their original vegetation but, even there, soils are now being drained and cultivated. In the west, the original vegetation still exists where agricultural potential of the land is limited. The small trees and bushes are cut regularly to provide wood for fuel and charcoal. Destruction of the original forest changed soil climate. Soils are more exposed to direct sun, which raises soil tempeatures (Fig. 16).

The higher soil temperatures and the lower production of organic matter in agricultural crops both decrease content of organic matter in the soil. In soils from Kisii District, van Wissen (1974) found that organic carbon disappeared at a rate of 20 $t.ha^{-1}yr^{-1}$ in the upper 37.5 cm of the soil after two years of cultivation. Afterwards the decrease was less dramatic, 1.3 $t.ha^{-1}yr^{-1}$ between the 2nd and 18th year and 0.9 $t.ha^{-1}yr^{-1}$ between the 18th and 30th year. Under agriculture, the soil is less protected against the impact of rain and erodes more. Soils would become impoverished by man, unless proper agricultural methods be adopted.

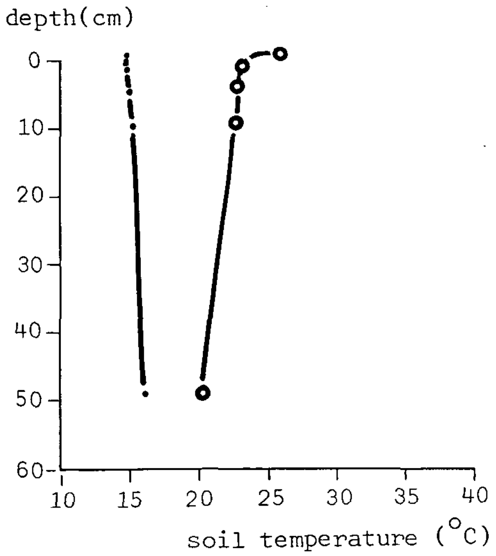


Fig. 16. Relation between average daily temperature and soil depth under tea (·) and without vegetation (o) at an altitude of 1800 m (Oenema, 1978).

3.4.3 Volcanic ash

Distribution. Since Tertiary times, volcanic ash has influenced the area. The more recent volcanic ash is especially noticeable in the east (Fig. 17), where it covers the whole landscape (units U1Ph and PPa) except the steepest slopes (unit U1XhP). The more westerly unit U2Ihn has young volcanic ash in

Fig. 17. Volcanic ash in a valley bottom in East Kisii. The compact ash-layer sticks out.

the topsoil and associated Bottomlands are filled with 4-6 m of ash or clay derived from ash (unit BXa2). In the west, at first volcanic ash seemed to be confined to the Bottomlands only, where it occurred in layers 4 m thich (units BXa1 and BXg). A study of the mineral composition of some soils in the west (units PGa, PXa and U3Ihn), however, revealed that volcanic glass particles were quite common, but intimately mixed with materials derived from parent rock (Section 3.4.2.5). The amount of ash would be difficult to measure. It depends largely on topography, exposure, vegetation, run-off and direction and distance from the source volcano. It may therefore vary from mapping unit to unit, and even within a mapping unit.

Age and origin. The decrease in ash from east to west suggests a source east of Kisii, most probably one or more of the volcanoes in the Rift Valley. Carbon-14 dating of an ash layer 3 m deep in a valley bottom in East Kisii, gave an age of 50 000 years. Thus, the ash above that layer is younger than 50 000 years (Wielemaker & van Dijk, 1981).

Influence on soil characteristics. Because of recent ash deposits, ash-derived and ash-influenced soils are still rich in easily weatherable minerals (mainly volcanic glass). If only the topsoil is enriched, chemical and mineral characteristics of topsoil should differ from that of subsoil. Characteristic are the very deep soils of unit U2Ihn (Fig. 18 and 19 and Profile 11

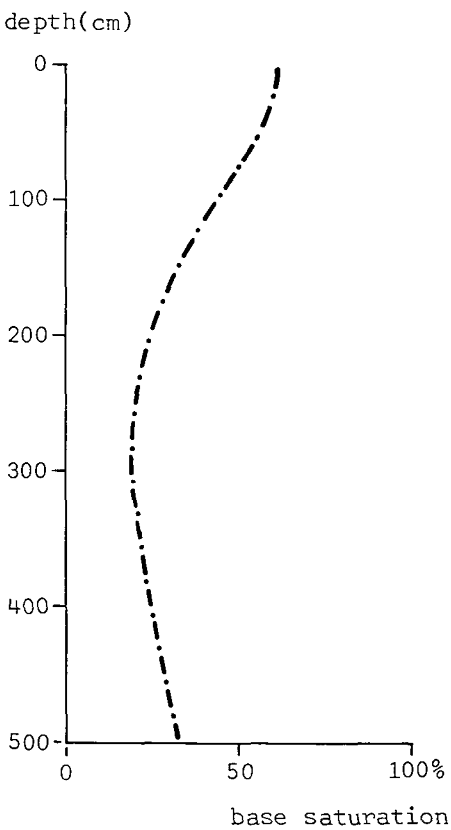


Fig. 18. Relation between base saturation and depth in soil (unit U2Ihn).

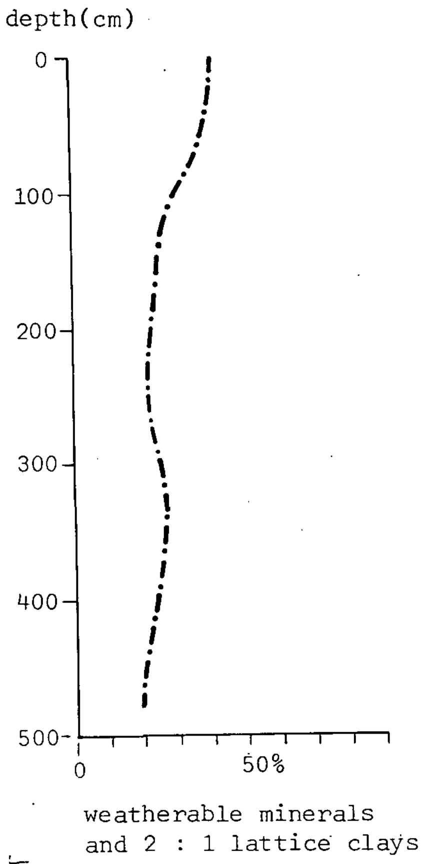


Fig. 19. Relation of mass fraction of normative weatherable minerals and 2:1 lattice clays with depth in soil (unit U2Ihn).

of unit U1Xh, App. 6).

Base saturation was high in topsoil and low in subsoil. The content of normative weatherable minerals and 2:1 lattice clays was also higher in topsoil than in subsoil. In some well drained soils with ash (e.g. unit U3Ihn) the topsoil and subsoil hardly differed because of the local and introduced parent materials were thoroughly mixed.

The younger ash soils and soil materials were characterized by poorly crystallized clays. Well drained soils contained poorly ordered kaolinitic clay, transitional to halloysite. The cation-exchange capacity of the clay was accordingly higher (160-240 mmol/kg) than in soils with well crystallized kaolinite (60-120 mmol/kg). In the youngest ash-derived soils (U1Ph), illite clay mineral occurred too. The imperfectly drained mineral soils were characterized by poorly ordered (2:1) clay minerals, readily dispersible on wetting and readily eluting downwards to cover ped surfaces with a thick skin. This characteristic was most striking in the Planosols and Solonetz soils, but also occurred in the Vertisols.

3.4.4 *Major classification units*

Definitions and descriptions of major units can be found in FAO/UNESCO (1974). This section discusses the units as they occur in the area mapped

(App. 4, Map D). New categories were introduced and defined (Siderius & van der Pouw, 1980), but only certain of them were established in time to be included in the map legend. The influence of ash on soil characteristics (Section 3.4.3) is not expressed in the soil names but is mentioned in the descriptions of map units (Section 3.3).

The following new classes of soil were defined to take account of volcanic ash (Siderius & van der Pouw, 1980), not expressed in the present name.

Unit	present name	proposed name
U1Ph	luvic Phaeozems	Ando*-luvic Phaeozems
U1Xh	luvic Phaeozems and	Ando*-haplic Phaeozems
	dystro*-mollic* Nitosols	Ando*-mollic* Nitosols
U1Ihn	dystro*-mollic* Nitosols	Ando*-mollic* Nitosols

The names and the roots marked with an asterisk are tentative, awaiting international agreement.

(a) Arenosols. Only the ferralic subgroup, whose clay fraction has a cation-exchange capacity less than 240 mmol/kg, occurred in the area (unit U4GM). The soils were sandy with a low content of weatherable minerals and little organic matter. Moisture storage capacity and chemical fertility were low.

(b) Ferralsols. Only the humic subgroup occurred (unit U1Qh). Humic Ferralsols were well drained clay soils with good physical characteristics and very low contents of weatherable minerals and nutrients. The clay was kaolinitic. Because of the high content of iron oxide, they fix phosphate.

(c) Nitosols. These soils were widespread with the following subgroups:

- mollic* Nitosols: with a humic topsoil and a eutric subsoil;
- dystro*-mollic* Nitosols: with a humic topsoil but a dystric* subsoil;
- humic Nitosols: with an acid humic topsoil and a dystric* subsoil.

They were well drained clays with good physical characteristics and humic or acid humic topsoils. The subgroups with an asterisk were established to account for differences in topsoil and subsoil fertility. The chemical fertility was high, especially of the mollic* subunits. Because of the high content of iron oxide, they fix phosphate (van der Eijk, in preparation).

(d) Acrisols. The humic and ferral*-humic subgroups occurred. Both had an acid humic topsoil. The ferral*-humic subgroup is an intergrade between Ferralsols and Acrisols, distinguished by the low cation-exchange capacity of its clay fraction (100 mmol/kg) and the low base saturation in the B horizon (0.6). They were well drained and loamy to clayey with clay cutans in the B horizon and good physical characteristics. The moisture-storage capacity was moderate. Chemical fertility was low. Because of the high content of

iron oxide, they fix phosphate (van der Eijk, in preparation).

(e) Luvisols. The orthic and gleyic subgroups occurred. Orthic Luvisols were well drained, moderately deep, gravelly clayey and good in physical characteristics. Chemical fertility was rather high. The gleyic subgroup was moderately well drained, rather deep and had a dense clayey subsoil, which was physically unfavourable for agriculture. Chemical fertility was high.

(f) Planosols. The eutric and solodic subgroups occurred. They were imperfectly to poorly drained, having a poorly permeable dense clayey subsoil. The lower part of the B horizon had slickensides. The clay was readily dispersible on wetting and flowed easily, covering ped surfaces. This characteristic was not related to the content of exchangeable sodium, but probably to the type of clay mineral (Section 3.4.3.1). Subsoil of the solodic subunit had a substance fraction of 0.06 exchangeable sodium. Soils had poor physical characteristics, but the subsoil had a high chemical fertility.

(g) Solonetz. Only the gleyic subgroup occurred. It was poorly drained with a substance fraction of exchangeable sodium in the subsoil greater than 0.15. The upper part of the B horizon was capped with a thin layer of white silty leached material. They are dense clays with poor physical characteristics but a high chemical fertility.

(h) Vertisols. Only the pellic subgroup occurred within the mapsheet. These imperfectly drained soils were clearly differentiated in texture between topsoil and subsoil by an unstable type of clay also encountered in Planosols. The topsoil had rather good physical characteristics; the subsoil was rather impermeable dense clay with slickensides. Chemical fertility was high.

(i) Cambisols. Humic and ferralic subgroups occurred. They were rather shallow. The humic subgroup had an acid humic topsoil with a weakly developed B horizon over ironstone or rotten rock. In unit HBhP, the rotten rock was completely weathered and penetrable to roots, but still looked more like rock than soil. The ferralic subgroup had a weakly developed A horizon over a cambic B horizon, whose clay fraction had a cation-exchange capacity less than 240 mmol/kg. Both subgroups were somewhat excessively drained, except the ones over petroplinthite, which were moderately drained. Moisture storage was limited and the subsoil was slowly permeable, so that the soils wer prone to run-off and erosion, especially on steeper slopes. Chemical fertility was moderate for the humic subunit and low for the ferralic one.

(j) Phaeozems. Haplic, luvic, verto*-luvic, vertic and gleyic subgroups occurred.

- Haplic Phaeozems resembled humic Cambisols, but had a mollic A horizon and were therefore chemically more fertile.

- Luvic Phaeozems resembled mollic* Nitosols, but were shallower.
- Gleyic Phaeozems were like the luvic ones, but had impeded drainage as indicated by mottles in the subsoil.
- Verto*-luvic Phaeozems were too shallow to class as Vertisols. This intergrade was defined because of cracks and the clayey texture. Physical characteristics were good. Chemical fertility was high.
- Vertic* Phaeozems were moderately deep, cracked and were clayey, but had very weakly developed slickensides. This subgroup was defined to take account of these vertic properties. Physical characteristics were moderate. Chemical fertility was high.

(k) Rankers. These soils had an acid humic topsoil directly over rock or slightly weathered rock. They occurred in areas of strong relief, where cultivation was risky.

(l) Lithosols. These soils had less than 10 cm of soil over rock or slightly weathered rock. They occurred in areas of strong relief, where no cultivation should be practised.

3.5 SOIL FERTILITY

Fertility of the soils in the Kisii area was evaluated by field and greenhouse trials and by analysis of soils and plants (Section 2.2). How the data were used to assess fertility is briefly explained in Sections 3.5.1-5.

3.5.1 *Relations between chemical properties of soil (0-20 cm), and land use*

Soils used for perennials or for grazing proved to differ in some characteristics from soils under annual crops (Table 11). On soils with pH-KCl less than 4.0 or a content of exchangeable K less than 4 mmol/kg, annuals were hardly ever grown. These soils were often shallow, another objection to annual crops.

If the soils had both pH-KCl less than 4.0 and less exchangeable K than 4 mmol/ kg, they were considered acid. Such soils were used for grazing. However the low pH of some soils under coffee or tea probably resulted from cropping practices, because similar soils under annual crops in adjacent fields had higher pH.

The soil fertility rating outlined below was primarily for soils under maize. In the section "Nutrient availability", however, it is tried to extend its use to other crops (Section 4.3).

Table 11. Relations of land-use to pH-KCl, content of organic carbon and of exchangeable potassium in topsoil (0-20 cm). Content of organic N can be obtained by dividing organic C by 10.

pH-KCl	Organic C (g/kg)	Exchangeable K (mmol/kg)	Land-use
<4.0	<18		grazing
	18-40	>4	grazing
		≥4	coffee, tea
	>40	<4	grazing
		≥4	tea
4.0-4.2	<18	<4	grazing
		≥4	coffee
	18-40	<4	grazing
		≥4	coffee, tea, maize
	>40	≥4	tea
>4.2	<18	<4	grazing
		≥4	coffee, maize
	18-40	<4	coffee
		≥4	coffee, maize
	>40	≥4	coffee, tea, maize

3.5.2 *Principles of the Kisii fertility rating*

The evaluation of fertility by what will henceforth be called the Kisii system is based on uptake of N, P and K by a maize crop during one growing season of a field trial. As maize takes up large amounts of nutrients, values were considered as potential removal and we tried to relate them to chemical properties of soil and leaf.

For each of the nutrients N, P and K, three classes of potential removal or availability were distinguished. They were related to yields reached without application of that nutrient (Table 12). For these yields, other cropping factors such as time of planting, weeding and pest control should be optimum, and other nutrients should not limit yield. The upper limit of the lowest class (yield 2500 kg/ha) was still rather high as compared to yields elsewhere in Kenya under similar climatic conditions and management. So the Kisii soils must be chemically rich by comparison.

Table 12. Classes of nutrient availability, corresponding yields of grain of hybrid maize, and uptake of N, P and K. For explanation see text.

Availability class	Yield (kg/ha)	Uptake (kg/ha)		
		N	P	K
1	> 5000	> 120	> 16	> 110
2	2500-5000	70-120	8-16	60-110
3	< 2500	< 10	< 8	< 60

Table 13. Ranking of contents of organic C in topsoil (0-20 cm) by N availability in relation to other soil properties. Content of organic N can be obtained by dividing organic C by 10.

Org. C (g/kg)	Availability class	Other conditions
< 19	3	
19-27	3	if pH-KCl < 4.3, P-Olsen < 4.0 mg/kg and exchangeable K < 10 mmol/kg
	2	in all other samples
28-39	2	if pH-KCl < 4.6, P-Olsen < 4.0 mg/kg and exchangeable K < 15 mmol/kg
	2	if pH-KCl 4.6-5.0, P-Olsen < 4.0 mg/kg and exchangeable K < 10 mmol/kg
	1	in all other samples
> 39	1	

3.5.3 *Relations of chemical properties to availability class*

Of the 10-20 soil properties investigated, four proved most clearly related to nutrient availability: pH-KCl, organic carbon, and P-Olsen and exchangeable K. The relationships, however, were rather complicated. Commonly a certain soil property had upper or lower limits for which availability was certainly low or high, respectively, but between those limits other soil properties had to be taken into account as well (Tables 13, 14 and 15).

Table 13 gives the values of organic C or organic N (content of organic N can be obtained by dividing organic C by 10) corresponding with the ranking of N availability. With the range 19-39 g/kg for constant of organic C, N availability depended on pH-KCl, P-Olsen and exchangeable K. Low pH and low available P would depress N mineralization and crops would not fully exploit the N, if yields were limited by P and K. For organic C below 19 or above 39, N availability would be low and high, respectively, whatever the other properties.

In soils with a content of P-Olsen less than 6 mg/kg, P availability was primarily related to pH (Janssen et al., 1979). Content of P-Olsen was slight-

Table 14. Ranking of mass fraction of P-Olsen in topsoil (0-20 cm) by P availability, in relation to pH-KCl and content of organic C.

P-Olsen	Availability class	Other conditions
< 4.0	3	if pH-KCl < 4.3
	3	if pH-KCl 4.3-4.5 and organic C < 28 g/kg
	2	in all other samples
4.0-5.9	2	if pH-KCl < 4.6
	1	in all other samples
> 5.9	1	

Table 15. Ranking of substance content of exchangeable K in topsoil (0-20 cm) by K availability, in relation to other soil properties.

Exchangeable K (mmol/kg)	Availability class	Other conditions
< 4	3	
4-9	2	
10-14	2	if pH-KCl < 4.6
	2	if pH-KCl 4.6-5.0, organic C < 28 g/kg and P-Olsen < 4.0 mg/kg
	1	in all other samples
> 14	1	

ly correlated to pH-KCl. For example, if pH-KCl was less than 4.3, P-Olsen was never more than 6 mg/kg on soils used for annual crops and if pH-KCl was more than 5.0, P-Olsen was never less than 4 mg/kg. For soils with pH-KCl 4.2-4.6 and P-Olsen less than 4 mg/kg, P availability was influenced to a certain extent by organic C, probably because it is related to organic P (Table 14).

Table 15 shows that K availability was high in soils with exchangeable K 9-15 mmol/kg as long as N and P were not too low for growth. In soils under annual crops, exchangeable K was never less than 4 mmol/kg, so that K availability was always moderate to good.

The rankings for availability of N, P and K were combined into a fertility ranking. Of the 18 possible combinations (3 for N, 3 for P and 2 for K) with soils under annual crops, only eight existed. Except in soil units FPg, BXo and BGa (Section 3.5.7) they were ranked into four fertility classes (Table 16). The main criterion in the ranking was availability of P, which is the first yield-limiting nutrient in Kisii soils.

Table 16. Fertility rankings by availability of N, P and K, with indicative corresponding grain yields and uptakes of N, P and K by unmanured maize.

Fertility ranking	Availability ranking			Yield (kg/ha)	Uptake (kg/ha)		
	N	P	K		N	P	K
A1	1	1	1	> 5000	> 120	> 16	> 110
A2	2	1	1	4500	95	> 16	110
B1	1	2	1	3750	> 120	14	> 110
B2	2	2	1	3250	85	12	> 110
C1	2	2	2	2750	75	10	90
C2	3	2	2	2250	55	8	70
D1	2	3	2	1500	70	6	70
D2	3	3	2	< 1000	50	4	60

Table 17. Diagnostic criteria for fertility of Kisii soils under annual crops (0-20 cm). Content of organic N can be obtained by dividing organic C by 10.

pH-KCl	Org. C (g/kg)	P-Olsen (mg/kg)	Exchangeable K (mmol/kg)	Availability class			Fertility class
				N	P	K	
< 4.0	< 40						E
4.0-4.2	< 19	< 4.0	4-9	3	3	2	D2
	19-27	< 4.0	4-9	3	3	2	D2
			10-14	2	3	2	D1
		4.0-5.9	4-14	2	2	2	C1
			> 14	2	2	1	B2
4.3-4.5	< 19	< 4.0	4-9	3	3	2	D2
		4.0-5.9	4-9	3	2	2	C2
	19-27	< 4.0	4-14	2	3	2	D1
		4.0-5.9	4-14	2	2	2	C1
			> 14	2	2	1	B2
		> 5.9	> 14	2	1	1	A2
	28-39	< 4.0	4-14	2	2	2	C1
	> 27	< 6.0	> 14	1	2	1	B1
		> 5.9	> 9	1	1	1	A1
4.6-5.0	< 19	< 4.0	4-14	3	2	2	C2
	19-27	< 4.0	4-14	2	2	2	C1
			> 14	2	2	1	B2
		> 3.9	> 9	2	1	1	A2
	28-39	< 4.0	4-9	2	2	2	C1
	> 27	< 4.0	> 9	1	2	1	B1
		> 3.9	> 9	1	1	1	A1
> 5.0	19-27	> 3.9	> 9	2	1	1	A2
	> 27	> 3.9	> 9	1	1	1	A1

Soils with pH-KCl less than 4.0 were too acid for maize and were classed E.

Combination of Tables 13-16 gave Table 17, presenting diagnostic criteria for fertility on the basis of combinations of pH-KCl, organic C, P-Olsen and exchangeable K. There are 240 possible combinations of possible availability classes (4 for organic C, 3 for P-Olsen, 4 for exchangeable K and 5 for pH-KCl). However, since many combinations did not exist and several combinations were rated equally, only 24 groups were needed.

3.5.4 *Relations between content of nutrients in maize leaf and nutrient availability of soil*

Interpretation of plant composition is hazardous, being influenced by many factors like drought, age of the plant and of the particular leaf and competition from weeds.

The cropping history needs to be known, though seldom adequately possible for commercial crops. Farmers differ much in their care for crop and land.

A second problem is that a certain nutrient acts in concert with other nutrients, so that critical levels are difficult to establish. For maize,

Table 18. Relations content N, P and K in dry matter of maize leaves and availability class of N, P and K in topsoil.

Nutrient	Mass fraction (g/kg)	Availability class
N	< 26	3
	26-33	3, 2 or 1
	> 33	2 or 1
P	< 14	3
	14-17	3 or 2
	18-29	2 or 1
	> 29	1
K	19-28	2
	29-39	2 or 1
	> 39	1

some contents of N, P and K in leaves were certainly low, and of P and K were certainly high (Table 18) but values within those limits corresponded to a wide range of availability in soil. Leaf composition could be used to support other data on soil fertility, but should not be used as sole criterion.

3.5.5 *Additional topsoil properties and subsoil characteristics*

Besides pH-KCl, organic C, P-Olsen and exchangeable K, other characteristics were measured and used for additional distinction of topsoil fertility, if necessary. The most important ones were: total P cation-exchange capacity, nutritive base saturation, being exchangeable (Ca + Mg + K) x CEC (Tables 19-22).

Table 19 shows that the additional properties are rather well related to the ranking for P and to a lesser degree, to the ranking for N. The relationships are indicated in Table 20.

Table 19. Fertility subclass averages of diagnostic and additional properties of soil (0-20 cm). Number of samples in parenthesis. CEC, cation-exchange capacity; NBS, nutritive base saturation defined as substance fraction of exchangeable ionic equivalent of Ca, Mg and K in CEC.

Sub class	Ranking			Diagnostic properties				Additional properties		
	N	P	K	pH-KCl	org. C (g/kg)	P-Olsen (mg/kg)	exch. K (mmol/kg)	CEC (mmol/kg)	NBS	total P (mg/kg)
A1	1	1	1	5.1 (10)	38 (10)	37 (9)	20 (9)	285 (9)	0.85 (9)	1845 (8)
A2	2	1	1	5.1 (5)	25 (4)	9.3 (4)	15 (4)	197 (3)	0.73 (3)	1164 (3)
B1	1	2	1	4.6 (7)	40 (7)	3.1 (6)	16 (5)	239 (5)	0.61 (5)	977 (3)
B2	2	2	1	4.5 (2)	26 (2)	5.7 (1)	23 (2)	174 (2)	0.67 (2)	873 (1)
C1	2	2	2	4.7 (16)	24 (16)	2.8 (12)	9 (15)	170 (15)	0.69 (15)	767 (12)
C2	3	2	2	4.7 (2)	16 (2)	.	7 (2)	147 (2)	0.54 (2)	
D1	2	3	2	4.4 (3)	26 (3)	2.2 (3)	9 (3)	145 (3)	0.60 (3)	727 (3)
D2	3	3	2	4.1 (4)	21 (4)	1.8 (4)	5 (3)	118 (3)	0.40 (3)	526 (3)

Table 20. Approximate cation-exchange capacity (CEC) for ranking of N availability, and approximate nutritive base saturation (NBS: see caption of Table 19) and content of total P for ranking of P availability.

N availability ranking	CEC (mmol/kg)	P availability ranking	NBS	Mass fraction of total P (mg/kg)
1	> 200	1	> 0.70	> 1000
2	150-200	2	0.50-0.70	750-1000
3	< 150	3	< 0.50	< 750

The rating of soil fertility was primarily based on topsoil properties, following the scheme of Table 17. This procedure was adequate if soils had developed from underlying rock and characteristics of topsoils and subsoils were interrelated. In Kisii, however, that was not always so, since many soils, and especially topsoils, contain some volcanic ash. In the field trials, subsoil characteristics had a considerable influence on maize growth. So, for the ranking of soil fertility, one could not rely only on topsoil properties. Where properties of the subsoils clearly contradicted the topsoil ranking, they were taken into account.

3.5.6 *Relations between soil mapping units and fertility*

Soil classification takes account of the whole profile, often with emphasis on subsoil characteristics, whereas topsoil properties predominate in assessment of fertility. So mapping units do not automatically correspond to fertility classes. Fertility assessments have only short-term validity, as cultivation practices may alter the fertility. Fertility of soil mapping units requires more information than only diagnostic criteria for topsoil properties. Such information was obtained by analysis of leaf and profile samples, profile descriptions, field observations and especially field trials with fertilizers. Final decisions were made in close consultation with the soil surveyors, especially for the soil mapping units of which no suitable chemical data were available.

Chemical data on topsoil were available from 24 mapping units, with 1-8 samples per unit (Table 21). To indicate the variation within one soil mapping unit, Table 22 gives the lowest and highest values for the units where three or more samples were analysed. Samples from fields with annual crops were distinguished from samples form grazing land.

The variation within one mapping unit was too large to allow ranking of averages of the diagnostic properties. The results of ranking of individual samples are shown in Table 23. Most mapping units included more than one fertility subclass. So the final ranking was not valid for each part of any unit. In Section 3.5.7 and in Table 24, only one ranking was assigned if at least 70% of the area fell into that fertility class. Otherwise two fertility

Table 21. Diagnostic and additional properties of soils averaged for each mapping unit (0-20 cm). NBS: see caption of Table 19. * see Table 22.

Mapping unit	Number of samples	Diagnostic properties				Additional properties		
		pH-KCl	org. C (g/kg)	P-Olsen (mg/kg)	exch. K (mmol/kg)	CEC (mmol/kg)	NBS	total P (mg/kg)
Under annual crops								
HBhP	2	4.8	26	10	10	195	0.53	1744
HXP	3	4.9	22	3.6	11	170	0.72	728
FYh	1	4.6	17	.	6	174	0.47	.
U1Ph	8	5.0	38	18	16	221	0.79	1343
U1XhP	1	4.7	38	4.8	14	204	0.50	873
U1Ihn	2	5.3	40	5.2	20	280	0.98	1391
U2Ihn	4	4.5	41	3.1	19	238	0.56	957
U3Bhn	6	4.6	31	3.7	18	219	0.68	950
U3Bh	4	4.6	26	3.0	13	197	0.65	873
U3Ihn	5	4.5	23	2.0	8	141	0.58	717
U3Ghn	3	4.4	21	*	7	134	0.56	711
U3Gh	1	4.8	14	.	8	120	0.61	.
U4Yhp	2	4.6	25	2.8	11	163	0.70	774
U4Ybp	1	4.9	19	3.4	10	174	0.92	622
U4Yhp-U4Ybp	1	5.0	22	3.9	14	177	0.90	593
U4Gh	2	4.1	21	3.0	8	114	0.50	539
U4GhM	1	3.9	12	4.0	7	71	0.44	437
PBd	2	5.3	30	104	24	359	0.90	3056
PXhM	1	4.8	25	5.0	11	193	0.71	873
BXa2	1	3.8	24	3.0	8	174	0.36	873
Under Grazing								
U1Qh	1	3.9	30	.	.	118	.	.
BBh	1	.	19	.	7	360	.	.
BXa1	3	.	24	.	5	219	0.70	.
BXo	2	3.7	101	8.5	7	316	0.36	1528

Table 22. Lowest (L) and highest (H) values of diagnostic and additional soil properties (0-20 cm), for soil mapping units in which three or more samples were analysed. NBS: see caption of Table 19.* Only two samples analysed. + Only one sample analysed.

Mapping unit	Number of samples	L or H	Diagnostic properties			Additional properties			
			pH-KCl	org. C (g/kg)	P-Olsen (mg/kg)	exch. K (mmol/kg)	CEC (mmol/kg)	NBS	total P (mg/kg)
Under annual crops									
HXP	3	L	4.8	22	1.3	6	157	0.58	437
		H	5.2	23	8.3	19	173	0.80	873
U1Ph	8	L	4.7	27	2.8	7	160	0.50	770
		H	5.4	73	60	22	353	0.97	2081
U2Ihn	4	L	4.4	37	2.0	17*	228*	0.55*	879*
		H	4.7	44	4.0	21*	247*	0.56*	1035*
U3Bhn	6	L	4.3	23	2.0	11	157	0.54	629
		H	5.0	40	6.1	28	294	0.82	1310
U3Bh	4	L	4.1	19	2.0*	10	144	0.58	.+
		H	4.8	38	3.9*	17	257	0.71	.+
U3Ihn	5	L	4.1	20	1.6	4	114	0.41	490
		H	4.8	26	2.6	10	161	0.77	873
U3Ghn	3	L	4.0	19	1.6*	4	118	0.29	549*
		H	4.7	22	18 *	9	158	0.74	873*
Grazing land									
BXa1	3	L	.	23	.	3	138	0.43	.
		H	.	25	.	8	301	0.87	.

Table 23. Number of samples of each soil mapping unit with different fertility rankings, based on the analytical results of topsoil (0-20 cm) under annual crops.

	Subclass									Total number
	A1	A2	B1	B2	C1	C2	D1	D2	E	
NPK ranking	111	211	121	221	222	322	232	332		
Mapping unit										
HBhP	-	1	-	-	1	-	-	-	-	2
HXP	-	1	-	-	2	-	-	-	-	3
FYh	-	-	-	-	-	1	-	-	-	1
U1Ph	4	2	-	-	2	-	-	-	-	8
U1XhP	1	-	-	-	-	-	-	-	-	1
U1Ihn	2	-	-	-	-	-	-	-	-	2
U2Ihn	-	-	4	-	-	-	-	-	-	4
U3Bhn	1	-	2	1	2	-	-	-	-	6
U3Bh	-	-	1	1	1	-	-	1	-	4
U3Ihn	-	-	-	-	2	-	2	1	-	5
U3Ghn	-	-	-	-	2	-	-	1	-	3
U3Gh	-	-	-	-	-	1	-	-	-	1
U4Yhp	-	-	-	-	1	-	1	-	-	2
U4Ybp	-	-	-	-	1	-	-	-	-	1
U4Yhp-U4Ybp	-	-	-	-	1	-	-	-	-	1
U4Gh	-	-	-	-	1	-	-	1	-	2
U4GhM	-	-	-	-	-	-	-	-	1	1
PBd	2	-	-	-	-	-	-	-	-	2
PXhM	-	1	-	-	-	-	-	-	-	1
BXa2	-	-	-	-	-	-	-	-	1	1
Total number	10	5	7	2	16	2	3	4	2	51

classes are mentioned together with the corresponding area fractions.

Much of the area had soils of Classes A and B, which could be considered chemically rich. The poorer soils of Classes C and D occurred mainly in the west.

Sometimes characteristics of the subsoils predominated and caused deviation from the ranking of the topsoil.

Fertility is understood in the restricted sense of the capacity of the soil to supply plants with nutrients. Some soils with very poor crop growth, for instance because of bad drainage, could still be ranked as Class A. The chemical richness of the soil would show up after the adverse physical conditions were eliminated.

3.5.7 *Fertility rating of soil mapping units*

HBhP, Class B. Fertility was not the major constraint for these shallow soils. At some places, they were enriched with volcanic ash; elsewhere they were rather poor. The majority was Class B.

HXP, Class C (0.4) and D (0.6). These soils were too shallow and too steep

Table 24. Soil mapping units grouped according to soil fertility classes A-E.

A	B	C	D	E
U1Ph	HBhP	HXP (0.4)	HXP (0.6)	U1Qh
U1XhP	FBh	FYh	FQh	U4GhM (0.5)
U1Bh	FBht	FPg	U3Ihn (0.6)	U4GM (0.5)
U1Ihn	U1Xh	U3Ihn (0.4)	U3Gh (0.6)	PXa
U4Bh	U2Ihn	U3Ghn (0.4)	U4Gh	PXhM-PXa (0.4)
PBd	U3Bhn	U3Gh (0.4)	U4GhM (0.5)	PGa
PXhM	U3Bh	U4YhP	U4GM (0.5)	BXa1
PXhM-PXa (0.6)	VXP	U4Yhp		BXa2
BBh		U4Ybp		
BBd		U4Yg		
BXg		U4YhP-U4Yhp		
BXo		U4Yhp-U4Ybp		
		U4Yhp-U4Yg		
		U4YC		
		PPa		
		BGa		
Approximate area (km^2)				
360	1350	670	260	410
Area fraction				
0.12	0.44	0.22	0.09	0.13

for arable crops. Fertility depended on the parent material. On the less steep parts, N, as indicated by organic C, was in moderate supply; P and K were moderate or sometimes high.

FBh, Class B. No suitable data on topsoils were available. Fertility was probably the same as of other soils on basalt, with less available P than N and K.

FBht, Class B. No data were available from fields under annual crops. Since this unit had more quartzite admixtures and since the soils were less deep, the fertility of FBht was expected to be somewhat less than of FBh.

FYh, Class C. Analytical data suggested moderate availability of P and K; N was moderate to low.

FPg, Class C. With volcanic ash mixed in the profile, P might be high, but the overall fertility was low, as N and K were low. Average rating was probably 222.

FQh, Class D. Although there might be some enrichment in P by volcanic ash, the low pH suggest that it was not readily available; N and K were low to moderate.

U1Ph, Class A. These volcanic ash soils were very rich in K; N and P were moderate or more often high. This unit was considered the most productive of the Kisii area.

U1XhP, Class A. As these soils are shallow, they were not suitable for arable crops. Where maize grew, leaf analysis showed high N and K and at least moderate P; soil analysis indicated high levels of all three nutrients. The high fertility was due to admixture of volcanic ash.

U1Xh, Class B. Many of these soils were used for tea and pyrethrum. No samples were collected from maize fields. Analysis of tea leaves and soil from the comparable units U1XhP and U1Ihn indicate that available N and K would be abundant. Where admixture with volcanic ash was substantial, the soils were rich in P too. Elsewhere P was at least moderate. However, on steep slopes where part of the topsoil had been lost, fertility was less.

U1Bh, Class A. Chemical data on topsoil was not available. Because of admixture of volcanic ash, this unit was considered more fertile than U3Bhn and U3Bh.

U1Ihn, Class A. Rich in exchangeable K and often in organic C and in P.

U1Qh, Class E. There were no data from fields under annual crops. Soil samples from under grass, coffee and tea indicated moderate to high levels of organic C and of P-Olsen. However pH-KCl ranged from 3.5-3.9.

U2Ihn, Class B. Although P-Olsen, pH and base saturation were lower than in U1Ihn, yield of maize grain from these soils was more than 4 t/ha (0.4 kg/m^2) without P fertilizers. Total P was around 1000 mg/kg in topsoils and more than 600 mg/kg in subsoils, accounting for the rather good P supply to crops.

U3Bhn, Class B. According to the results of both soil and plant analysis, about half of the sampled sites belonged to Class B and the other half to Class A and C. For available N, P and K, the grading was moderate to high. Variation was probably due to admixture of volcanic ash. Class B was on average the most appropriate evaluation.

U3Bh, Class B. The averages of nearly all diagnostic and additional fertility properties were somewhat lower than those of unit U3Bhn (Table 21); P was moderate and N and K varied considerably. On average, soils met criteria for Class B.

U3Ihn, Class C (0.4) and D (0.6). The nutrients N and P were moderate or low; K was moderate. The subsoils were often chemically poor. Only soils on slopes were good enough to qualify for Class C (App. 6, Profile 21), soils on the flat ridge tops being assigned to Class D. Variation in fertility was due to volcanic ash.

U3Ghn, Class C (0.4) and D (0.6). The nutrient K was moderate, but N and P were moderate and low. Where volcanic ash had some influence, soils were rich in P and K. However the poor condition of the subsoils made the soils less fertile than indicated by the topsoil.

U3Gh, Class C (0.4 and D (0.6). This unit had about the same qualities as U3Ghn, but organic C was still lower.

U4Bh, Class A. Chemical data on Profile 24 (App. 6) indicated high N, P and K, as in the adjoining and comparable unit PBd. The high pH might create deficiencies of trace nutrients like Zn and Cu.

U4YhP, Class C. This soil was often too shallow for annual crops. Profile 25 (App. 6) had moderate supply of N, P and K.

U4Yhp, Class C. On average, chemical properties fitted the average for Fertility Class C2 (Tables 19 and 21). Leaf analysis and response to P fertilizers showed that P availability was sometimes below par.

U4Ybp, Class C. Organic C was somewhat lower, and pH-KCl and, as a result, available P was somewhat higher than of unit U4Yhp (Table 21).

U4Yg, Class C. According to data on Profile 28 (App. 6), available N was of Grade 3, subclass C2. Where organic C was higher, ranking was C1.

U4YhP-U4Yhp, Class C.

U4Yhp-U4Ybp, Class C.

U4Yhp-U4Yg, Class C.

U4YC, Class C. Soil fertility of these associations was the same as of the member units.

U4Gh, Class D. These soils were low in organic C and pH, and moderate to low in K. Subsoils are chemically poor and often compact. Without fertilizers, yield of maize grain hardly reached 1 t/ha, even under otherwise optimum management of field trials.

U4GhM, class D (0.5) and E (0.5). This unit was very poor in N and P and poor to moderate in K. The soil was seldom used for annual crops. Where pH-KCl was below 4.0, it fell into Class E.

U4GM, Class D (0.5) and E (0.5). No topsoil data were available, but at best fertility probably equalled that of unit U4GhM.

PBd, Class A. Soils were rich in N, P and K. Total P was very high, but greenhouse and laboratory trials showed that P was less available in these Tertiary volcanic ashes than in Quaternary volcanic ash. Nevertheless, available P was high. Trace nutrients like Zn and Cu might be deficient because of the high pH.

PXhM, Class A. Less rich than unit PBd, but the contribution of volcanic ash was large enough to class it as rich in P and K; N was moderate.

PXa, Class E. The analytical data of Profile 34 (App. 6) indicate low pH, N, P and K. The soil was only used for grazing.

PXhM-PXa, Class A (0.6) and E (0.4). The fertility of the association was the same as that of its composing parts.

PPa, Class C. Although the soil had developed in rich volcanic ash, the few data (App. 6, Profile 35) suggest moderate rather than high nutrient status, perhaps because of leaching of the topsoil.

PGa, Class E. The properties of these soils are essentially the same as of PXa: low pH, P and K (App. 6, Profile 36).

BBh, Class A. This unit was similar to PBd.

BBd, Class A. Rich in P and K, and moderate in N.

BXal, Class E. This soil was not used for annual crops. Although the subsoils were chemically rich, the low pH and the low levels of organic C, P and K in topsoils made the soil less fertile.

BXa2, Class E. The low pH of the topsoil made this unit unsuitable for annual crops. Where maize was grown, leaves were low in N and P, and moderate in K.

BXg, Class A. These soils were chemically rich. Nevertheless the productivity of these soils was low, because of high exchangeable Na (Section 4.3.2).

BXo, Class A. Soil samples were from grazing land. Content of organic C was at least 90 g/kg and of P-Olsen at least 7 mg/kg. Although pH-KCl was less than 4, the soils were Grade 1 for N and P, and Grade 2 for K. The rating 112 of these peaty soils was not foreseen in Table 16 but fertility could be ranked as Class A, despite the low grading for K.

BGa, Class C. The data of Profile 43 (App. 6) was rated 312 or 313, a combination not foreseen in Table 16. For P, the soil could be ranked Class A, but with such a low N and K it was ranked as Class C.

VXP, Class B. No chemical data were available. The unit was similar to U1XhP and HXP, and its fertility was ranked as Class B.

3.6 PHYSICAL PROPERTIES OF SOIL

3.6.1 *Infiltration and percolation*

Rates of intake and percolation. Run-off is restricted to shallow well drained soils and imperfectly drained soils (Sections 1.4 and 4.3). In the well drained soils, infiltration is so rapid that surface flow does not occur, except if raindrops cause sealing or decay of structure. Measurement of the intake rate gives a good estimate of the capacity of a soil to absorb rainwater. The 'final' intake rates were estimated by the double-ring method (Fig. 20) after a certain time (Table 25). The intake rates in the deep well drained soils did not become constant, even after a considerable time.

The intake rates were measured in two ways in order to estimate any effect of sealing or decay of structure.

- Method 1. Water was introduced into the ring from a nozzle and a constant head was maintained with a floater (Fig. 20). The amount of water used was regularly measured.
- Method 2. Water was poured into the ring and the amount of water added was measured every 15 min.

The first method practically avoided sealing whereas pouring in the second method could disturb the topsoil.

All the deeper well drained soils had a rapid to very rapid infiltration . Cultivation enhanced infiltration in unit U3Bhn (Table 25). The rates for the shallow soil (HXP) on quartzite and for the imperfectly drained dense clay soil (BGa) were moderately slow.

The subsoils of Planosols, common on Plains and Bottomlands, had similar rates. These dense clays often had a perched watertable.

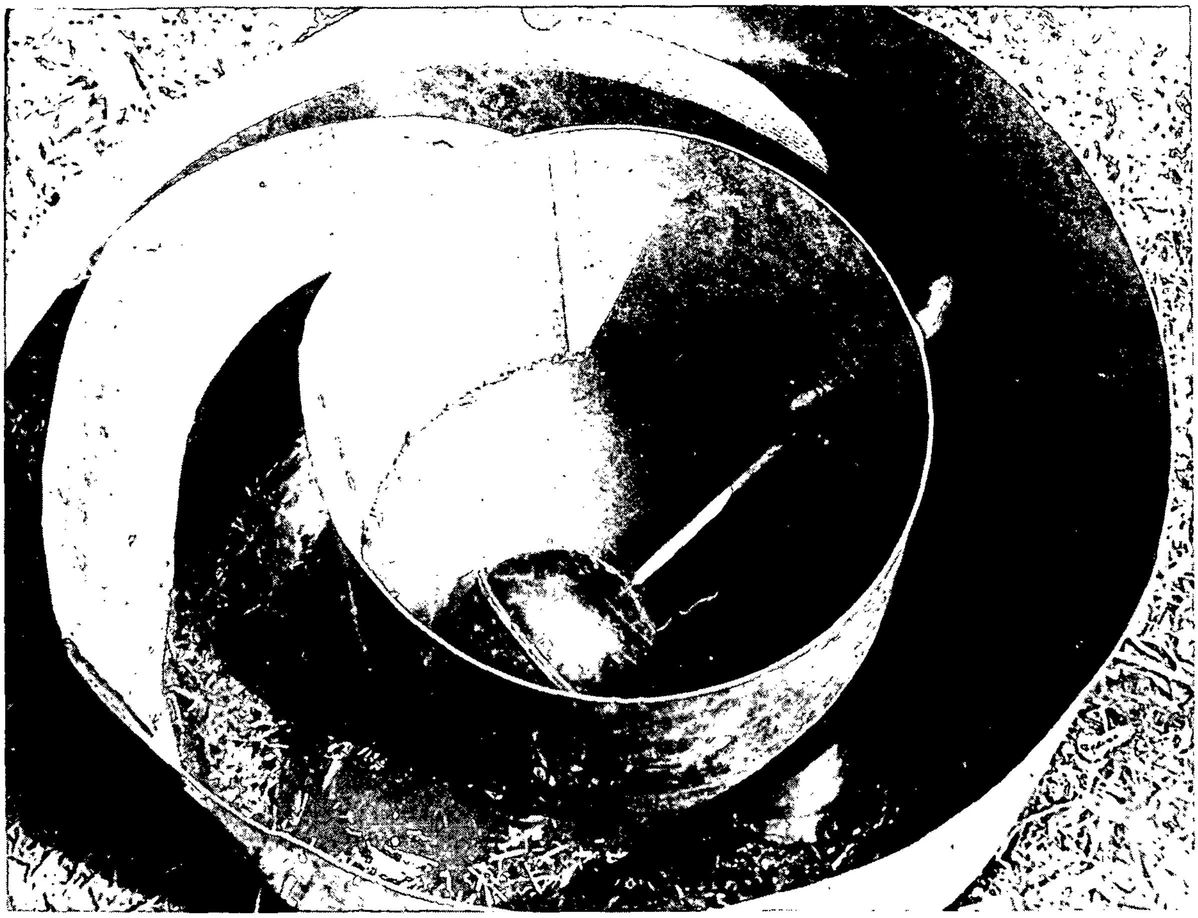


Fig. 20. Double ring infiltrometer with floater. The floater consisting of a plastic ball is connected with a nozzle.

Table 25. Final infiltration rate (areic volume rate) in some mapping units by the double-ring method. 1. with a floater; 2. without a floater.

Mapping unit (with time under cultivation, years)	Classification (FAO)	Vegetation/land-use	Measuring time (min)	Final intake rate (µm/s) method	
				1	2
U3Bhn (0)	mollic Nitosol	natural pasture	120	50	.
U3Bhn (10)	mollic Nitosol	maize	135	184	116
U3Bhn (30)	mollic Nitosol	finger millet, maize	135	104	31
HXP	Lithosol	natural pasture	45	5	.
FQh	humic Acrisol	maize	105	53	104
FQh	humic Acrisol	maize	135	136	126
U3Ihn	humic Nitosol	maize, beans	225	142	.
U4Yg	gleyic Phaeozem	sorghum, groundnuts, cotton	180	39	14
U3GhM	ferralic Cambisol	maize	150	131	78
BGa	eutric Planosol	natural pasture	120	0.6	12

Fig. 21. Permeability measurements in a valley bottom in east Kisii.

Permeability and drainage of valley bottom soils. Especially units BXa1 and BXa2 suffer from waterlogging. Seepage water from the surrounding permeable hill soils adds water to the perched watertable and aggravates the drainage problem. At many places at the foot of the slopes, there are springs fed by groundwater from the hill soils. A study of the feasibility of drainage should therefore include the study of seepage of water from the hill soils and also the study of the permeability of topsoil and subsoil of the poorly drained valley bottom soils (Fig 21).

A few measurements were made with a ring infiltrometer to assess the permeability of the soils. To 100-ml rings filled with undisturbed soil, a 'constant head' was applied. Flow was regularly measured till it became constant. Table 26 shows the permeability of topsoil and subsoil of the Planosol (BXa2) and of the peaty soil (BXo). Especially the deeper subsoil of unit BXa2 was slowly permeable. Unit BXo was rapidly permeable, but after artificial drainage soils could shrink.

3.6.2 *Bulk density and porosity*

Bulk density is the mass of bulk soil divided by its volume (volumic mass of bulk soil). Porosity is the volume fraction of gas and liquid in soil, in other words the volume fraction not occupied by solid phase. Bulk density was usually measured with cores of volume 100 cm^3. The bulk density of clods

Table 26. Permeability of valley bottom soils estimated with a constant head of water on core samples of 100 cm³ of soil.

Mapping unit	BXa2		Mapping unit BXo (peaty clay)	
depth (cm)	horizon	permeability (μm/s)	depth (cm)	permeability (μm/s)
33	A2	64	40	112
50	A2	137	80	39
70	B2t	0.69	120	53
90	B2t	0.35		
500	B2t	0.007		

was slighly higher, probably because the pore space of clods does not include the space occupied by cracks between clods.

Bulk density was usually measured in profiles where percolation was also measured. The average bulk density of the B horizon was very low, 1.23 Mg/m³ (Table 27). The lower values were in Nitosols and Ferralsols: assuming a particle density of 2.6 Mg/m³, their porosity was on average 0.65, which was much higher than the B horizon of the Acrisols and Planosols, which had an average porosity of 0.49 (Section 3.4.2).

3.6.3 *Moisture retention and available moisture*

Water retention of 16 soils at a range of moisture tensions is given in Appendix 6. Appendix 9.1.2 summarizes available moisture (difference in water retention between pF 2.0 and 3.7) for each mapping unit and rooting depth class, corrected for rootability and rooting intensity. Table 28 summarizes the data.

The literature is not consistent in use of pF 2.0 or 2.3 as lower limit in estimating available moisture. The upper limit of 3.7 corresponded better

Table 27. Bulk density in Mg/m³ and its standard deviation for the major classification units. n, number of estimates; m, mean; s, standard deviation.

Unit	n	Bulk density ± standard deviation(Mg/m³)			
		A horizon		B horizon	
		m	s	m	s
Ferralsols	3	0.94	0.08	1.15	0.12
Acrisols	5	1.21	0.29	1.33	0.17
Nitosols	12	0.99	0.10	1.17	0.05
Phaeozems	12	1.15	0.14	1.22	0.12
Planosols	6	1.04	0.08	1.32	0.13

Table 28. Readily available moisture (pF 2.0 to 3.7) for different depths in 10 groups of mapping units.

Number of group	Classification	Depth range (cm)				
		areic volume of readily available moisture (mm)				
		0-50	0-80	0-120	0-180	0-300
1	mollic* Nitosols and Histosols	100	160	230	310	466
2	Phaeozems and mollic* Nitosols	105	155	215	295	.
3	Phaeozems and Luvisols	100	155	207	.	.
4	humic Nitosols	60	95	143	203	323
5	Acrisols	80	110	150	210	.
6	Vertisols	125	225	281	.	.
7	Phaeozems	100	138	198	.	.
8	Cambisols and Arenosols	40	60	.	.	.
9	Planosols	104	158	.	.	.
10	Planosols, Solonetz, Lithosols and Rankers	97	156	.	.	.

with studies on crops than pF 4.2, which is sometimes used. Actual consumption by crops was measured with a neutron probe. Use by sugar-cane was summarized by Kluyfhout (1978).

The studies were complicated by the interruption of the relatively dry season, by wet spells. The upper limit of moisture extraction could hardly be measured, except in a very dry season.

4 Land evaluation

4.1 INTRODUCTION

Land must be evaluated as an indication of expected performance, when used for specified purposes. Land use planners need guidance in taking decisions on land use so that the resources of the environment are put to the most benefical use with due regard for conservation of those resources for the future (FAO, 1976; Beek, 1978).

Therefore land evaluation involves a study of present agricultural practices, the benefits derived from it, the beneficial or retrograde effects on the environment, and the factors limiting profitability, physical and socio-economic (Section 4.2). This knowledge enables us to indicate ways of improvement within the physical and socio-economic setting. Those types of land utilization can be indicated that remain profitable for the area in the long term and the conditions can be stated under which these types can be introduced (Section 4.4).

Profitability to the farmer is to a large extent determined by yields, price and marketing outlets of the products, and is unpredictable for the long term. Suitability should therefore be primarily based on physical qualities which will be discussed in Section 4.3.1.

4.2 ATTRIBUTES OF LAND UTILIZATION TYPES

To characterize a land utilization type certain attributes need to be described as accurately as possible.

Land. The size, distribution and lay-out of land, and the system of land tenure.

Labour and farm operations. What is the productivity of labour? How are tasks assigned to family members (for instance by sex and age)? What is the share of the family in the labour requirement of the farm? What power sources are used: human labour, draught animals or machinery using fuel.

Capital. What are the invested capital and the recurrent capital for a given area or per holding?

Technical knowledge and its application. How sophisticated and knowledgable is the farmer and how far does the farmer use available information in management of his holding?

Infra structure and services. What agricultural advisory services are available? Processing factories for farm products, roads and markets.

Produce and profitability. Knowing the suitability of a soil for a certain use, one can predict yields, defined as the amount of produce per unit area, for a certain technology level.

4.2.1 *Present systems of tenure, size of holdings , availability of land and layout of fields*

Land is a wider concept than soil. It embraces climate, relief, hydrology and vegetation and past and present human activity like clearance, drainage and exposure to soil erosion. Agricultural production is not only determined by physical factors, but by such socio-economic factors as land tenure, size of farms, availability of land, farm lay-out, parcellation, fragmentation, land prices and land rent.

All land in Kisii District and in South Nyanza District is registered, especially in the south of the survey area. In the north-west of the survey area, land registration is in progress. In unregistered areas, cattle can graze anywhere except on land under crops.

Table 29 shows the size of holdings in Kisii District. According to the Kenyan Central Bureau of Statistics (CBS, 1977), the average size of holdings in Nyanza Province is 1.93 ha. In the Koluoch Subdivision of South Nyanza District, the proportion of holdings in various size classes were as follows: <0.5 ha 0.39%; 0.5-1 ha 8.5%; 1-1.5 ha 13.3%; 1.5-2 ha 14%; 2-4 ha 33.3%; 4-6 ha 13.7%; 6-10 ha 11.7%; >10 ha 5.1%. (J.W.F. Cools, Undergraduate thesis)

In Kisii District, Lanting (1977) found that the proportion of farmers in possession of extra plots decreases with increasing population density, from 52% in a zone with population density more than 330 km^{-2} to 15% in the areas with more than 450 km^{-2}. A similar trend was not found in South Nyanza District, so that many farmers there probably still have more land than they can or need to cultivate. The price of land in Kisii District was rising steadily from 2500-5000 Kenyan shillings per hectare in 1975 to about 7500 Kenyan shillings per hectare in 1978. In Kanyada and North Nyokal, prices in 1978 were around 1700-2300 Kenyan shillings per hectare. The land rent

Table 29. Proportion of holdings in different size classes as a funtion of the area's population density. Kisii District (data from Lanting 1977).

Population density (km^{-2})	Size of holding (ha)			
	< 0.2	1.2-2.4	2.4-4.8	> 4.8
	proportion of holdings in size class (%)			
50-350	6	37	30	27
350-400	6	42	40	12
> 450	21	51	15	13

Fig. 22. Farms in Kisii District occupy a strip of land from the top of the hill to the valley bottom.

in Kisii District was around 500 Kenyan shillings per year in 1978.

A farm in Kisii usually occupies a strip of land from the top of the hill to the valley bottom (Fig. 22). The farmhouse was situated in the upper part.

Holdings become fragmented at an alarming rate, because of the high birth rate and the lack of work outside agriculture (Lanting 1977). This will result in a dramatic increase in the number of very small farms (Tables 29 and 30).

4.2.2 *Labour and farm operations*

The labour requirement of various agricultural activities is given in

Table 30. Present and future farm size (ha), calculated according to present number of children in Kisii District per population density zone.

Present	Future in areas with a population density of	
	350-450 km^{-2}	> 450 km^{-2}
0-1.2	0.85	0.8
1.2-2.4	1.4	1.5
2.4-4.8	3.9	2.7
>4.8	3.1	2.9

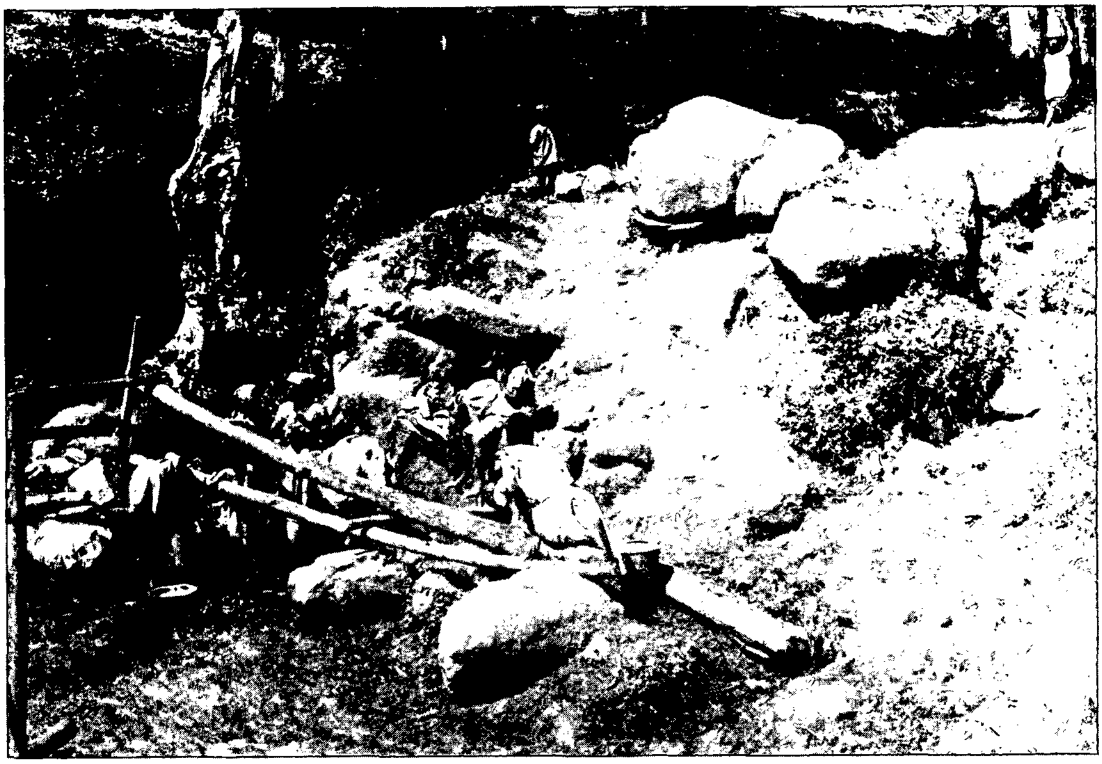


Fig. 23. Kisii women fetching water and washing clothes at a spring.

Appendix 13. Those of some crop-independant activities are as follows:

- clearing bushed land with a hachette 100-200 h/ha,
- preparation of pasture land with a hoe 500 h/ha, and with an ox plough 35 h/ha,
- preparation of arable land with a hoe 250-400, with an ox plough 20-25 and with a tractor plough 1 h/ha.

Sowing and planting is done by hand or while ploughing. Fertilizer may be applied during sowing or planting and requires 10 h/ha. Crops are weeded with a hoe or a fork. Labour requirement is 400 h/ha for heavy weeds and 150 h/ha for light weeds. Most harvesting operations are by hand. Many products are sold on a local market, which is held once or twice a week. Products not sold there, are usually taken to a centre (e.g. tea, pyrethrum and coffee) or are collected from the farm (sugar-cane and tobacco).

Tasks were assigned within the family by sex and age (S.C.W. Kamil, undergraduate thesis; Müller, 1978). Time spent on farmwork daily varies considerably, but the following data from South Nyanza are indicative. Men spend 3-4 h in the fields and afterwards herd cows and do other things including social activities. Women spend 2 h in the fields, 1½ h at markets, 5½-6 h working in the home (Fig. 23) and 1-1½ h on other activities. Children help during holidays and after school.

The area a family actually cultivated with or without hired labour and the area of the holding was related to the number of wives (Fig. 24). The

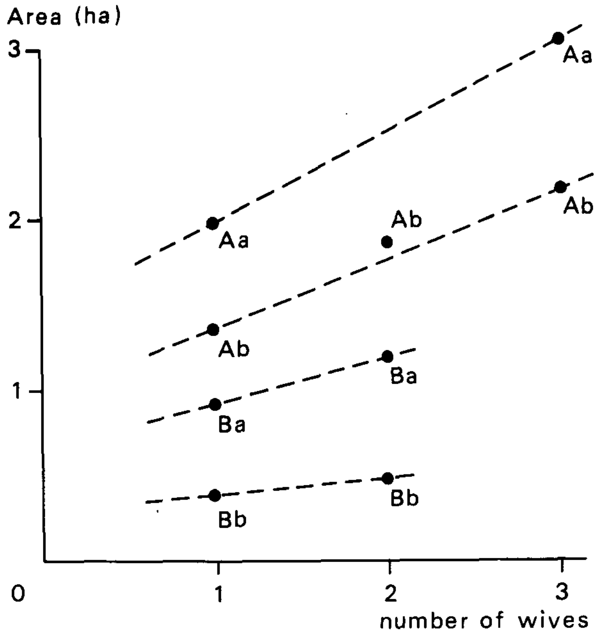


Fig. 24. Relation between cultivated area and number of wives in Koluoch, South Nyanza District A, With ox-plough; B, Without ox-plough; a, With hired labour; b, Without hired labour. Data of J.W.F. Cools.

number of dependents on the farm and the number of wives are related, so that the smallest farms also support the smallest number of people. It varies between an average of 8 persons on the smallest farms to 18 on the largest farms.

Hired labour was required especially on larger farms (Table 31). The size of holding for which hired labour was needed, depended on the cropping pattern. In a densely populated area (450 km^{-2}) where labour-intensive crops such as tea and pyrethum were grown, smaller farms hired labour too. Price and presence of hired labour were correlated with farm size: A higher proportion of small farms in a certain area meant a larger and cheaper supply of labour (Lanting, 1977).

The ox-plough (Victory type) is the common type of plough, especially on

Table 31. Proportion of farmers in holdings of various sizes having a plough and hiring labour for zones of different population density in Kisii District.

Farm size (ha)	Population density zone			
	350-400 km^{-2}		450 km^{-2}	
	plough	labour	plough	labour
0-1.2	-	-	-	10
1.2-2.4	25	40	12.5	25
2.4-4.8	79	79	28.6	75
<4.8	80	80	50	100

Fig. 25. Ox-ploughing in South Nyanza District.

the bigger farms (more than 2 ha). Two to four oxen are used to pull it (Fig. 25). A span of local oxen usually worked from about 07.00 till 09.00 o'clock (A. Adema, undergraduate thesis). The maximum ploughing day was about 4 h. Ox-ploughing as usually practised had several shortcomings: the oxen are insufficiently trained and the plough is often poorly maintained. Oxen could be better trained as in India, where they are led by a rope connected to a ring through the nose. In Kanyada and North Nyokal, farmers paid cash for the ploughing of their fields or sometimes divided the ploughed land with the plougher, who could use his half for one season. Oxen were also used to pull a sledge or an ox-cart, and sometimes to turn a sugar-cane press. Donkeys are also used to carry freight but less often than the ox-sledge.

Individual farmers rarely used wheel tractors, but sugar-mills, the British American Tobacco and Sony Sugar Co. did. Farmers increasingly used these companies to prepare land. The hilly Kisii District with its small farms is not very suitable for 4-wheel tractors; 2-wheel tractors could have a future.

4.2.3 *Present input of capital*

Four items were distinguished in capital inputs.

1. Permanent structures, usually called invested capital, with low depreciation.
2. Tools that need regular replacement and maintenance, for which deprecia-

Table 32. Capital-input and technology level based on studies in several areas. Ksh, Kenyan shillings.

Low	Low to medium	Medium
1. Huts with thatched or occasionally corrugated-iron roofs	same	corrugated-iron roofs are common
2-8 granaries	same barn for tobacco	smaller number milkingshed; watertanks and wells, occasionally wires and poles for passion-fr.
Fences occasional	Fences common	Fences common
2. 3-20 hoes, ox-plough common; hachette; recurrent costs 75-100 Ksh/a.ha	same 75-100 Ksh/a.ha	same but also spraying equipment (occ.) 100-150 Ksh/a.ha
3. Local cattle, sheep, goats, chicken, oxen and donkeys	same, occasionally improved cattle	same, but usually improved and graded cattle
4. Local seeds, manure, some cashcrops like cotton and sugar-cane.	local and hybrid maize; cashcrops like coffee, tobacco and sugar-cane; fertilizer and pesticides only for tobacco (on credit); occasional dipping of cattle.	cashcrops common, including pyrethrum, tea and passion fruit; spraying and dipping of cattle.

tion and maintenance are significant costs.
3. Living and productive capital: domestic animals; animals used for traction and transport; perennial cashcrops.
4. The yearly capital inputs are called recurrent capital.
Sample areas (Table 32) ranged in input level from low to medium. Change from a low to a medium input level usually coincides with the adoption of new management techniques, which required a higher capital input level.

A higher level required more investment capital and was usually related to farm size because a bigger farm size meant more available capital for investment, unless money became available from an off-farm job. Many of the farmers with bigger holdings also owned shops and maize mills. Agencies giving loans to farmers considered bigger farms more credit-worthy since their capacity to repay was higher. Off-farm capital and investment opportunities thus became progressively more available as farm size increased. On very small farms in Kisii District, even crop residues and cowdung were used as fuel for cooking. Those farmers had no capital to buy fuel or fertilizers and were exhausting the fertility of their soils, because the organic matter was used for cooking.

4.2.4 *Present technical knowledge and its application*

The degree to which the farmer adopted new more-capital-requiring techniques is linked with the ecological zones and the agricultural potential of the area. Studies of sample areas (Müller, 1978) showed that where cash crops were successful, other innovations were more readily accepted, perhaps explaining why the technology level is so clearly linked with the ecological zones (Section 1.6).

The following parameters, which give an impression of the technology and its application, will be discussed for the above mentioned ecological zones.

1. Cropping pattern and proportion cash crops per farm. Zone IIc, III and part of IIb: cotton and sugar-cane 1-10%, groundnuts 1-2%, foodcrops 20-45% and pasture 39-67%. Part of zone IIb: bananas, coffee, sugar-cane and groundnuts (tobacco) 8-15%, foodcrops 30-45% and pasture 35-55%. Zone IIa: tea, pyrethrum and bananas 13%, foodcrops 33%, ley 37% and pasture 6%. Cashcrops were cultivated in all zones, but the type and area fraction differs. Resown grassland (ley) was found only only in zone IIa.
2. Insecticides and fertilizers were mainly applied to cash crops, for which credit and advice were available. Technology correlated with the type of crop and varied considerably on the same farm. In South Nyanza (Zone III, II and part of IIb), fertilizers, pesticides and a rotation were hardly applied. Tobacco, a relatively new crop, was an exception. Dung was applied if available.
3. Livestock traditionally has various functions (Müller, 1978):

- Social, as a dowry or for slaughter on the occasion of visitors, celebrations or funerals.
- Savings and revenues from off-farm jobs and crop sales are invested in livestock. School fees, purchases and dowries can be paid by sale of animals.
- Cattle supply milk (Fig. 26), serve for draught or transport, and provide manure. Their value increases by growth, like interest at the bank.

The social function and investment were primary but nowadays the utility function is coming increasingly to the fore. So, not merely the number of livestock units counts, but rather the quality and the production capacity. Especially where land is scarce and has many promising alternative uses, production capacity of the livestock becomes important, as in the east of Kisii District. There the number of grade cows was noteworthy and especially on the bigger farms, wells were being installed and spraying equipment was used. Cows on smaller farms were taken to cattle dips. Where the land had been registered (Kisii District and the east of South Nyanza District), the number of cattle was related to farm size. Very few cattle were kept on farms of less than 1.5 ha. In the rest of South Nyanza, grazing land was not scarce, not registered and communal apart from the homestead and cropped land. The cattle were of the local type and dipping was not regularly practiced. The social function and investment remained primary.

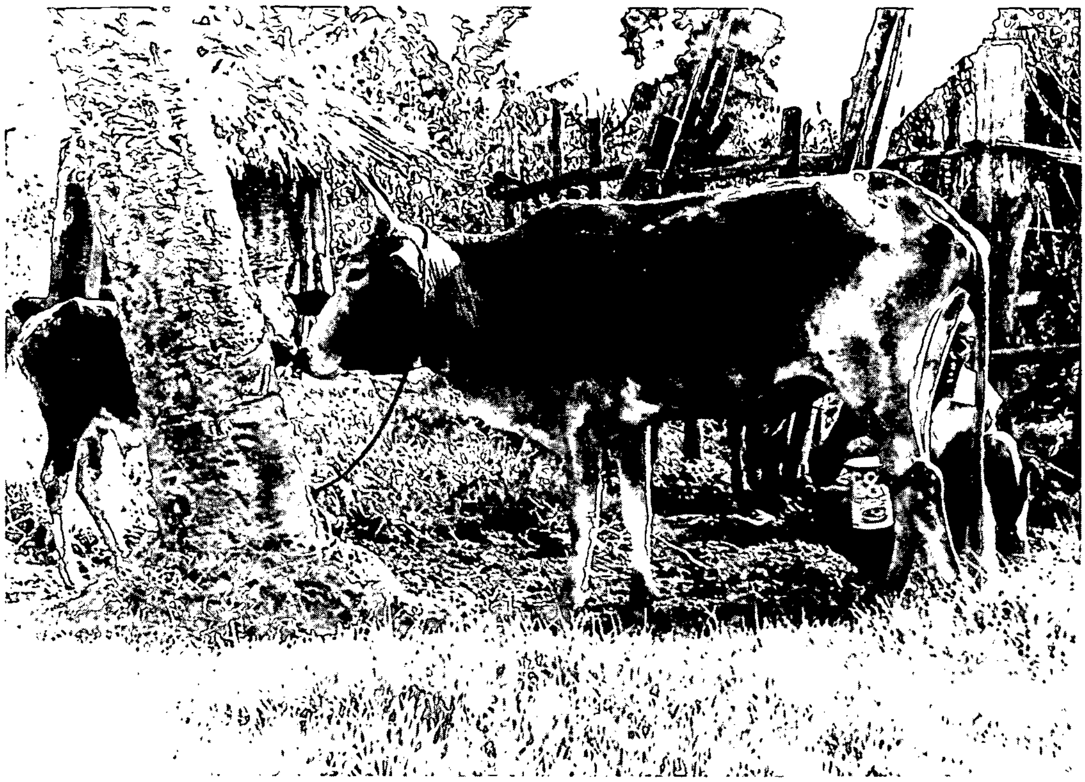


Fig. 26. Milking of zebu cows at a homestead near the north-west border of Kisii District.

4. Availability of credit and training was somewhat correlated to farm size. Farmers with more than 2.4 ha received more credit and training than farmers with less (Lanting, 1977). Some crop concerns (British American Tobacco, BAT, Kenya Tea Development Authority, KTDA, coffee societies and Sony Sugar Co.) did provide services and credit to farmers independently of farm size. Credit consisted of fertilizers, planting material and pesticides. Their costs were deducted from the payment the farmer received on delivery.
5. Use of tools, draught animals and machinery power. Ox-ploughing was somewhat more common in South Nyanza District, where soils were heavier than in Kisii District. The range of tools and instruments was small. Machine-operated tools, small two-wheel tractors or other fuel-operated machines for soil preparation were absent, surprisingly in view of the rather high opportunity costs of labour, especially in Zone IIa. The increasing fragmentation of the farms, however, and the lack of work outside agriculture will not encourage mechanization.
6. Drainage. Soil Units BXa2, BXo and PBd had haphazard drainage ditches, usually shallow and made by individual farmers. Units BXa2 and BXo could still be improved further by drainage for a valley as a whole.
7. Terracing. In Kisii District, erosion was controlled by trashlines, which developed over the years into effective terraces. On steep slopes, especially with shallow soils, well organized bench terraces and cut-off drains are needed. Terracing needs much more emphasis in South Nyanza. Units BGa and

BXa1 were locally severely eroded by overgrazing. Land was not registered there and no measures had been taken to check gully erosion.
8. Fertility maintenance and improvement. Under prevailing intensive agriculture animal husbandry was decreasing. As a result, input of organic matter and content of organic matter in soils was declining (van Wissen, 1974). Economically, animal husbandry may not compete with cash crops for a certain piece of land. Its role in long-term maintenance of fertility is, however, of great importance, not only by production of manure but also by rotation of crops with grass. The manure production of a farm can also alter with the system of animal husbandry (Section 4.4). Farmers were not familiar with the use or production of compost. Town refuse was not used, although field trials with maize (Oenema, 1980) showed that it was beneficial to the crop. It was, however, somewhat inferior to cowdung, probably because of its lower content of P. Green manures were not grown. Their introduction in the rotation system could help to raise fertility.
9. Rotation of annual crops should be alternated with grass, which benefits soil structure and microbial life. A sown grass (like Rhodes) would be more productive and could be easier uprooted and ploughed in than those presently used.

4.2.5 *Infrastructure and services*

The extension service was run mainly by the Ministry of Agriculture. Cash crops like tea, pyrethrum and recently, sugar-cane received more emphasis than other crops. Marketing and processing was in the hands of semi-government agencies. Coffee was processed and marketed by numerous societies. Cotton was marketed by cotton societies. Other crops could be sold to the National Cereals and Produce Board, a marketing agency of the Government, or on the local market. Tobacco was marketed by the British American Tobacco Company (BAT). The veterinary services were well organized in Kisii District, but milk marketing needed more emphasis (Kenya Ministry of Agriculture, 1975; Hubert, 1973).

The National Agricultural Research Station at Kisii conducted research in animal husbandry, principal food crops like maize and beans, horticultural crops and fruits. The work of the coffee substation of the Coffee Research Foundation (CRF) at Kisii included cultivation, manuring, pruning and spacing trials, pest and disease control, and plant breeding. The National Sugar Research Station (NSRS) substation at Opapo mainly conducted varietal and fertilizer trials on farmers fields. The British American Tobacco (BAT) leaf centre at Oyani conducted fertilizer trials and varietal research.

The Farmer Training Centre at Kisii gave courses to farmers and extension staff, on crop husbandry, animal husbandry, farm management and economics, and home economics.

The Agricultural Finance Corporation supplied loans to farmers, which

Table 33. Household consumption in Kenya shillings (1975) for the ecological zones IIa, IIb and III. Data from CBS (1977).

	IIa Tea, west of Rift	IIb Coffee west of Rift	III Cotton west of Rift
Home-produced food	1205	1466	744
Purchased food	791	1237	1015
Non-food purchase	498	501	325
Miscellaneous	227	250	129
Total cash	1516	1988	1470
Total consumption	2721	3454	2215

were administered by the Ministry of Agriculture's Farm Management Division. Farmers producing tea, pyrethrum, tobacco and sugar received credit for recurrent production costs, which were deducted on delivery.

Tea, sugar and milk were processed in Kisii and South Nyanza Districts and pyrethrum, cotton, passion fruit and horticultural products elsewhere. Roads were satisfactory in all the tea growing zones (KTDA). The Sony Sugar Co. had a system of feeder roads for its out-growers. Elsewhere the state of roads left much to be desired. The Kenya Farmers Association (KFA) supplied farm implements, fertilizers, seeds, insecticides and pesticides, and had shops in Kisii and Homa Bay.

4.2.6 *Production rates and incomes*

To assess farm incomes, one must know the consumptive needs of a rural family in terms of food and money (Table 33). School fees were not included. A secondary boarding school costs about 2000 Kenya shillings per year. The total cash need for subsistence of a family ranges from 2500-3000 shillings per year. If at least one child were to attend secondary school, the cash requirement per holding would be at least 5000 shillings and the total consumption would amount to 7500-8000 shillings. If inflation be taken as 15% per year, prices would in 1982 be 2.66 times as high as in 1975.

4.3 IDENTIFICATION OF POSSIBLE LAND UTILIZATION TYPES

Land utilization type is defined as "a kind of land use described or defined in a degree of detail greater than that of a major kind of land use", which is defined, by examples, as rainfed agriculture, irrigated agriculture, grassland, forestry or recreation. As discussed here, it means a single use of the land. Compound land utilization types (in the sense of Beek, 1978, in contrast to FAO, 1976) such as mixed cropping of maize and beans, coffee and bananas, pyrethrum and onions, were not considered for lack of data. Attributes of the land utilization types are described here as accurately as possible. Production level was estimated, in line with the rating of land qualities and resulting suitability classes. In this way, the types can supply information needed for farm planning and farming systems.

Farming systems as such were not the aim of the land evaluation, since they depend on too many socio-economic variables, which may change rapidly. Decisions should be left to the farming community, which has the sole responsibility for how land should be managed and farmed. Nevertheless the combination of production items and the rotation chosen by the farmer will be important for future fertility. For instance, a farmer with only annual crops, which have heavy nutrient demands could only maintain production capacity, at high cost because of a decline in organic matter and in soil structure. In contrast, a farmer with perennial crops like tea or with annual crops rotated with grass for grazing will spend less on maintaining fertility. In that way, a farmer is restricted in his combinations of crops. Or, more generally expressed, he is restricted in his combinations of land utilization types (Section 4.5).

The land utilization types discussed in Section 4.4 can be grouped under the following major kinds of land use:

- smallholder, rainfed arable farming, low, medium and high capital input;
- trees, low to high capital input;
- livestock, low to high capital input;
- fish culture;
- bee keeping;
- extraction of natural products.

4.3.1 *Structure of the suitability classification*

Two kinds of interpretative classification were used. The current suitability classification appraised suitability for a specific use in the present condition or with "modest improvement". The potential suitability classification appraised suitability for a specific use, granted that major improvements would be made where necessary. The difference between the two classifications indicates to the user whether and how land improvement or land conservation measures have been taken into account in assessing the suitability. "Major improvement" was taken as a substantial capital investment (as opposed to recurrent costs) in land improvement that would effect a major and reasonably permanent change in the characteristics of that land. For most uses, current suitability classification was considered relevant. For some mapping units, drainage of waterlogged land could effect a major improvement for certain uses.

Two orders of land suitability were used (FAO, 1976).

- Order 1, Suitable land: land on which sustained use (continuing use without deterioration) for the defined purpose in the defined manner should yield benefits that justify required recurrent inputs without unacceptable risk to land resources on the site or in adjacent areas.

- Order 2, Unsuitable land: land whose characteristics appear to preclude its sustained use for the defined purpose or which would create production, upkeep or conservation problems requiring a level of recurrent inputs now unacceptable.

In Order 1, three classes were distinguished: Class 1.1, highly suitable; Class 1.2, moderately suitable; Class 1.3, marginally suitable. Each area of land was assessed for current and potential suitability for particular land utilization types. The assessment for potential suitability assumed that major improvements had been made according to the following ranking:

- A (low): low technical input; may require some technical advisory services to the land owner; low cost could be borne by land-owner.
- B (moderate): moderate technical input; requires considerable advice to the land-owner; moderate cost.
- C (high): high technical input; specialists needed for planning and execution; special equipment needed; high cost.
- D (very high): high technical input as for C; very high cost.

The evaluation data for the Kisii area are presented in Appendix 8. Given the number of land utilization types for which an evaluation was made, the cost of map production prohibited the "ideal" situation of having a colour-printed suitability map for each land utilization type. This problem was solved by presenting, in addition to the coloured soil map, a black-and-white soil map (Seperate App. 2), on which the ecological information was superimposed as an overprint, together with a key for land evaluation (App. 8). The key should enable the user to colour the map by hand according to the suitability for a particular land utilization type he is interested in. Uncoloured copies of the map are available on request from the Kenya Soil Survey, National Agricultural Laboratories, Nairobi.

In Appendix 8, the top row shows the respective land utilization types for which an evaluation was made. Each evaluation as such has been considered independantly and without reference to the desirability of their relevant use of the land.

The first column gives the soil units which occur under various slope classes and different ecological zones (see Section 1.4). In parallel horizontal columns the suitability class and subclass of each "mapping unit" (being a combination of soil, slope class and ecological zone) for each land utilization type are shown. The subclasses are indicated by letter suffixes. Each letter stands for a landquality of which the most deficient ones are indicated. For some mapping units both current and potential suitability are given. Also indicated is the level of input required. If the suitability subclass of an annual crop differs according to season, the suitability subclass of the less suitable season is indicated with asterisk(s) explained in Appendix 8.

4.3.2 *Diagnostic procedures and criteria*

Land qualities determine the physical suitability of land. They are defined as a complex attribute of land that acts in a distinct manner in its influence on the suitability of land for a specific kind of use (FAO, 1976). Land qualities are not independent characteristics, but can be evaluated only in relation to a certain use of the land. A land quality rating is based on relevant land characteristics, which are each rated for the particular land-use. To simplify procedure, each characteristic determining land quality is rated independently. Then the characteristic is rated for a particular land utilization type. The criteria for rating are discussed in Section 4.3.2.1 and Appendix 9.

Each land utilization type requires an evaluation for a certain set of relevant land qualities, which leads to the determination of a suitability class and subclass. The relevant land utilization types are discussed in Section 4.4 and their suitability is listed in Appendix 8.

4.3.2.1 Land characteristics for land qualities

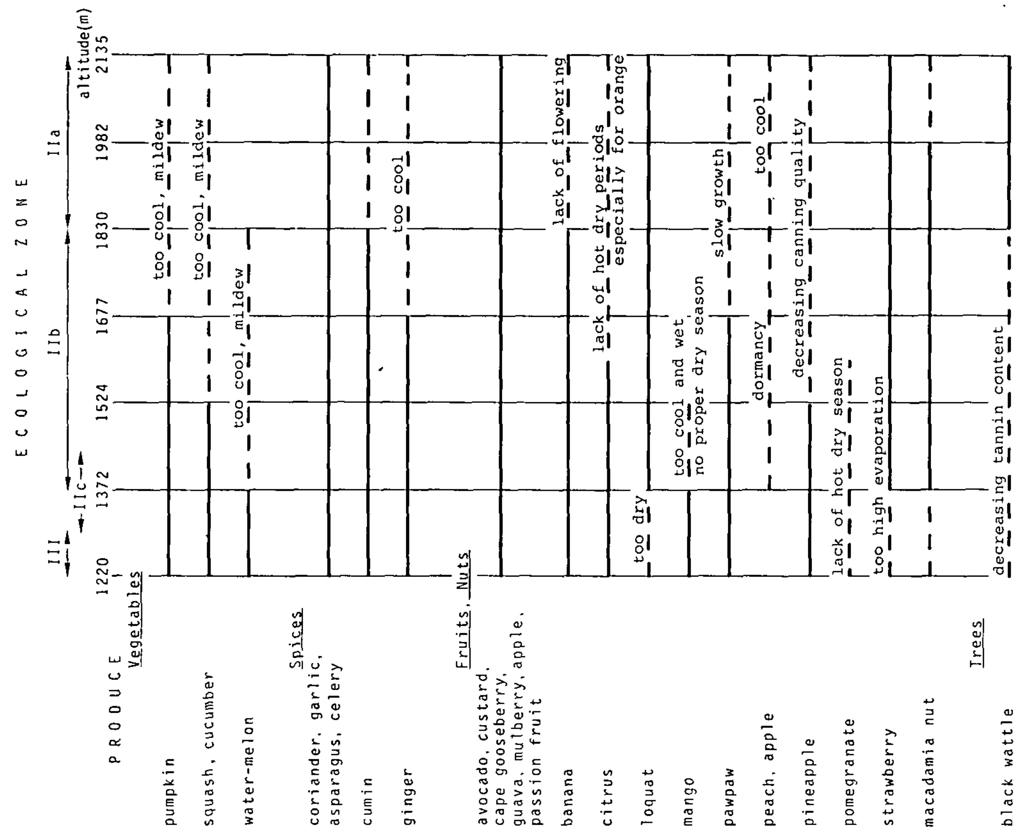
The following land qualities are relevant for the Kisii area:

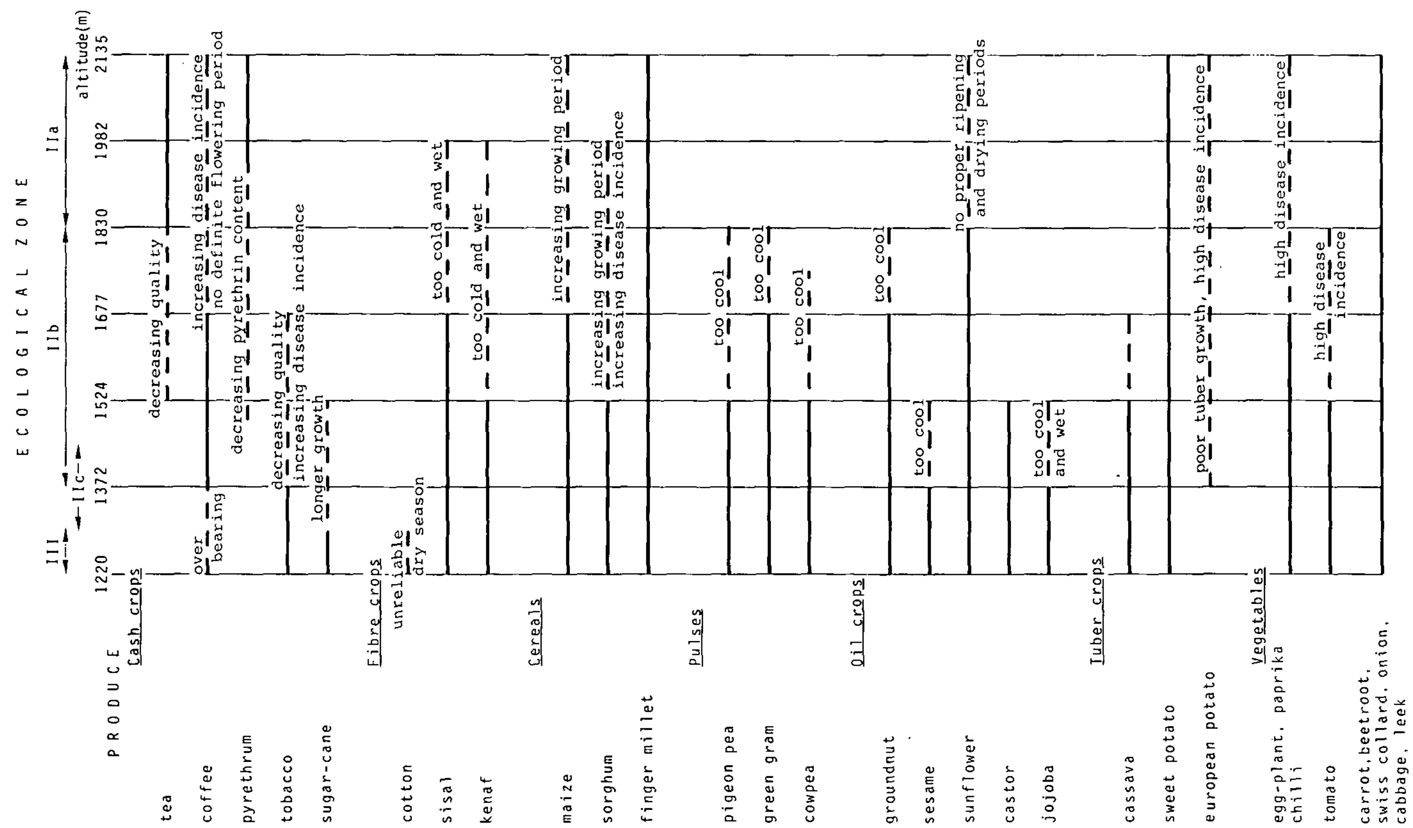
- temperature regime,
- climatic hazards affecting plant growth (e.g. hail),
- pests and diseases related to the land,
- availability of water,
- availability of oxygen,
- availability of nutrients,
- difficulty for agricultural implements,
- workability of the land,
- conditions for germination (tilth),
- erosion hazard,
- resistance to tuber development,
- rootability and uprootability,
- alkalinity,
- flooding hazard,
- overgrazing.

The first three land qualities are determined only by climate. They were directly rated for growth of crops, including some not cultivated in the district (Table 34). The criteria for rating of land characteristics for the other landqualities are degree of risk, difficulty, or availability in five grades as follows:

1. very high availability / very low risk
2. high availability / low risk
3. moderate availability / moderate risk

Table 34. Suitability of the climate for crops, except for the land-quality of wateravailability





4. low availability / high risk
5. very low availability / very high risk.

The establishment of criteria for rating requires a thorough and systematic comparison with the local situation in the field and situations elsewhere. This allows for the necessary corrections, so that the results are in agreement with the real situation. The advantage of such a rating procedure is that a proper suitability appraisal can be made even for soils from which data on crop performance are scarce.

4.3.2.2 Availability of water

For this discussion, a distinction is necessary between 'moisture capacity' defined as the difference in amount of water in a soil between pF 2.0 and 3.7, and 'plant-available moisture', which also depends on rooting volume and rainfall. Moisture capacity, as defined here, is often called 'readily available moisture'. To assess the 'actual available moisture capacity' relevant for the crop, moisture capacity is corrected for rooting depth and rootability (App. 9.1.1) of the soil and rooting intensity of the crop. Without profile hindrances, the crop was assumed capable of extracting all the 'readily available moisture' within its rooting depth. The rootability factor is a reduction factor for moisture extraction, introduced to account for hindrances to root development. It ranges from 1, for no hindrance, to 0 for complete hindrance. Rooting intensity is the ability of the crop to overcome hindrances to root development.

The rootability factor of crops with a strong rooting intensity (marked with an asterisk in App. 9.1.3) is a quarter more up to a maximum of 1 than the rootability factor of crops without a strong rooting intensity.

The 'actual available moisture capacity' and the effective rainfall (App. 9.1.2 and 9.1.4) determine the amount of water available for the crop (App. 9.1.5). The rating depended on the amount of available water and water requirement of the crop (App. 9.1.3). The crop's water requirement depends on actual consumption (App. 9.1.4) and on tolerance to drought (App. 9.1.3), which differ between crops and between growth stages. The rating applies to two seasons except for vegetables for which three seasons were rated. Since no data on effective rainfall were available, average rainfall was taken. As they were uncorrected for efficiency of use and probability, they could be too optimistic for what is available. Thus water requirement of the crops used in rating of water availability (App. 9.1.5) was increased by a factor.

In summary the following steps are required for the rating of water availability:

- calculation of 'actual available moisture capacity'. With the crop rooting depth and crop rooting type of Appendix 9.1.1 and Appendix 9.1.3 the 'actual available moisture capacity' is found in Appendix 9.1.2.
- With the 'actual available moisture capacity' (App. 9.1.2), the rainfall

and crop evaporation (App. 9.1.4), monthly figures for actual evaporation were calculated. Those figures should be compared with the criteria for rating (App. 9.1.5) to arrive at a crop water availability rating: ++ good, + moderate, - marginal. The ratings for a mapping unit, ecological zone, crop-water requirement type and growing season are presented in Appendix 9.1.6.

4.3.2.3 Availability of oxygen in the rooting zone

This land quality is determined by the frequency, duration and degree of waterlogging of the soil, evapotranspiration and by the tolerance of the crop to waterlogged conditions.

To account for differences in rainfall and evaporation two growing seasons and two areas were distinguished based on Ecological Zones IIa and IIb, and IIc and III.

To account for soil characteristics, drainage class was used, modified by depth of any semi-impermeable layer.

To account for differences in crop tolerance to waterlogging, three classes were recognized.

- Very tolerant: rice (not relevant)
- Moderately tolerant: sugar-cane, sorghum, grass species
- Not tolerant: other crops.

The rating criteria are presented in Appendix 9.3 and the rating of each mapping unit in Appendix 9.6.

4.3.2.4 Nutrient availability

To assess nutrient availability in soils for different crops, one must know:

- the potential nutrient supply by the soils,
- the nutrient requirements of the crops.

The potential nutrient supply was assumed to equal the amount of nutrients absorbed by maize during one cropping season (Section 3.5.2). So other crops could not absorb more nutrients during a half-year season than does maize. Table 16 in Section 3.5.3 gives the estimated N, K and P supplies for eight soil fertility subclasses.

The nutrient requirements of crops depend on the yield that can be obtained. To judge whether sufficient nutrients are available for a certain crop, one must know what yield is to be expected. For that purpose, 'normative (good) yields' were defined for the major crops in the Kisii area. Appendix 9.2.1, left half, gives these normative yields and the corresponding estimated uptake of N, P and K. The data were collected and adapted from the literature (Acland, 1971; de Geus, 1973; Fried & Broeshart, 1967, p. 119-132; Jacob & von Uexküll, 1963; Mengel & Kirkby, 1978, p. 259-266; Purseglove, 1968, 1972; Sanchez, 1976, p. 198-205. If no published data were available, estimates were made by comparison with probably equally demanding crops. The normative yields are the same as the 'high' yields mentioned in Appendix 14 for high input of capital. The nutrient uptakes refer to one cropping season for annual crops and one year for biennnial or perennial crops.

For comparison of nutrient supply and nutrient requirement, an equal time should be considered: 6 months. Thus, requirements of crops growing longer or shorter than 6 months, were converted to 'half-year requirements' by dividing by a factor (CF, see App. 9.2.1) for relative duration of cropping season. Legumes were taken as self-supporting for half of their nitrogen needs (App. 9.2.1, right half). This procedure is rather crude, but seemed the best possible at the moment.

For ease and simplicity, crops were divided into five groups according to their nutrient requirement (App. 9.2.2. Since phosphorus is commonly the first limiting nutrient in Kisii soils, P requirement should be taken as the principal criterion. The N and K requirements followed almost the same ranking as P requirements. Exceptions were banana and pineapple (Group V), which demand large amounts of K.

The next step in the evaluation procedure was to match nutrient requirements and nutrient supplies. Appendix 9.2.3 gives the results for the soil fertility classes and Appendix 9.2.4 for the individual soil mapping units. Nutrient availability was ranked into four classes by the ratio of potential nutrient supply to nutrient requirement for normative yields as follows: 1 : >0.8, 2 : 0.55-0.8, 3 : 0.3-0.55, 4 : <0.3. This ratio can also be interpreted as the ratio of yield without fertilizers but with all other growth factors optimum to normative yield. On Class A soils, normative yields were obtained, even for the most exacting crops, without application of fertilizers (App. 9.2.3). On Class D soils, fertilizers were needed, even for the least demanding crops, to obtain normative yields.

If other growth factors are more strongly yield-limiting than nutrient availability, Appendix 9.2.1 and 9.2.3 can be applied after some calculations, which are best clarified by an example.

If the target yield rate of sugar from cane was 5000 kg/ha/annum, the normative yield rate of sugar is 12 000 kg/ha.a (App. 9.2.1). Therefore the target yield is about 40% of the normative yield. Sugar-cane belongs to Group III crops (App. 9.2.2) and yields of Group III crops are higher than 55% of normative yield for Fertility Classes A, B and C (App. 9.2.3). So only on soils of Fertility Class D is availability of nutrients too low for the target yield rate.

4.3.2.5 Difficulty for agricultural implements

The rating was based mainly on steepness of slope. Slope E (>16%) is unsuitable for the use of 4-wheel tractors. Slope D is moderately suitable only if regular cultivation is necessary. The last condition is included, because regular cultivation with machines, may cause compaction of the soil and a decrease in permeability, which aggravates the risk of erosion.

4.3.2.6 Workability of the land

The ratio between rainfall and potential evaporation, and the difference in amount of water between the lower tillage limit and upper tillage limit determine the period in which the soil is workable.

The tillage limits are lowest and highest pF at which the soil is workable. The difference in volume fraction of water held between pF 2.0 (field capacity) and the upper limit determines the waiting time before the soil can be tilled. The tractive force needed to cut the soil is a second factor to be considered for rating. A third factor is the type of implement used. Tractive force is overriding for workability with the hoe, but less significant for animal or engine-powered traction. The criteria for rating are presented in Appendix 9.4 and the rating for each mapping unit in Appendix 9.6.

4.3.2.7 Conditions for germination or tilth

Tilth is the suitability of a tilled topsoil for germination, emergence and initial root development. The rating depends on moisture conditions of the topsoil after tillage and on susceptibility of the soil to surface sealing.

Moisture conditions in the topsoil depend on the volume fraction of available water remaining at the upper tillage limit. If no available water remains for germination, the farmer must wait for rain. Some soils just do not hold enough available water for germination (sandy soils). The moisture conditions are further determined by climate, which is more critical in the drier ecological zones (IIc, III) than in the wetter zones (IIa, IIb).

The crumbiness of the topsoil after tillage was correlated with the grade and type of structure. The finer the structure the better. The susceptibility of the soil to surface sealing was correlated with the soil type. Slight surface sealing occurred in reddish soils developed from granites and quartzites and in the soils with a mass ratio of silt to clay more than 0.5 (Kauffman, 1975). Criteria for rating are related to soil type and ecological zones and are presented in Appendix 9.5 and the rating of each mapping unit is presented in Appendix 9.6.

Tilth is a relevant land quality for annual crops, which require shallow sowing; moderately relevant for crops which are sown deeper, and irrelevant for perennial crops.

4.3.2.8 Resistance to soil erosion

The rating of soil erosion (Section 1.4; App. 4, Map G) for the various land utilization types reflects the protection a crop affords to the soil. It depends on degree and period of coverage by the crops, grouped as follows:

- Crops affording full protection (except when planted): tea and grass spp.
- Crops affording moderate protection: coffee and tree crops, shrubs, sugarcane, bananas, groundnuts and sweet potato
- Crops affording little protection: vegetables, pyrethrum, pineapple and most annual crops.

The rating for each mapping unit is presented in Appendix 9.6.

4.3.2.9 Suitability for tuber development and (up)rootability

These two land qualities are relevant for crops with tubers or seeds in the soil. On very shallow soils, tuber development is limited and on heavy clays the uprooting is difficult. Rootability is especially relevant for trees. As these qualities were usually overruled by others, they were not rated.

4.3.2.10 Alkalinity

This land quality was relevant only for unit BXg, which is moderately alkaline. The rating presented under the respective land utilization types was based on the tolerance of the relevant crops to alkalinity.

4.3.2.11 Flooding

Unit BXo was subject to flooding, unless drained.

4.3.2.12 Overgrazing

This land quality was rated for traditional farming and range only. The criteria for rating were based on present status and area fraction of overgrazed land, as estimated by visual observation (Appendix 9.6).

4.4 RESULTS OF THE LAND EVALUATION

4.4.1 *Introduction*

To assess the suitability of a mapping unit for a certain use or land utilization type, a more integrated approach is necessary than in Section 4.3. It requires the evaluation of all relevant land qualities in a certain mapping unit for each type. The most deficient land quality actually determines the suitability class. When more than one land quality is deficient, the suitability class may be downgraded. More specific rules cannot be given, because the suitability rating was largely a matter of comparison and weighting of the importance of various land qualities. The result of the rating procedure is presented in Appendix 8. Only a selection of land utilization types were rated, although the individual land qualities were rated for a more extensive range of land-uses.

A reader interested in the suitability of a mapping unit or ecological zone for a land-use not mentioned in Appendix 8 should consider the relevant land qualities. A study of the land quality allows selection of a crop or land use with requirements matching the one of interest, so that the rating of a comparable type in Appendix 8 should provide all the information needed.

Three levels of capital input were distinguished, which corresponded to increasing management requirements.

(L) Low capital input; low management requirements. Local varieties are used; no hybrids. Livestock are of local types and grass is not improved. Fertilizers, pesticides and insecticides are not applied; manure may be applied, if available. Ground is tilled with a hoe or ox-plough and no measures are taken to check erosion. Yield depends primarily on fertility and environmental conditions. The farmer is self-supporting for seeds, planting material and livestock; only some tools are bought.

(M) Medium capital input; medium management requirements. Improved varieties are used but management leaves to be desired; e.g. insufficient fertilizer, and inadequate disease control and pruning. Good plant material is often not replaced in time, leading to a declining productivity. Ground is usually tilled with an ox-plough and weeded with a hoe. Some measures are taken to check erosion. The recurrent costs are higher than for low capital input, capital being needed to buy fertilizers, hybrid seeds, planting material and insecticides. For some land utilization types, the fixed costs are high too, for instance a milking shed and perennial planting material (tea and coffee).

(H) High capital input; high management requirements. Improved varieties are used: use of fertilizers and control of disease are adequate. Management is as recommended by research stations or such that yields are maximum for the prevailing conditions; ground is tilled with an ox-plough or tractor plough, and weeded with a hoe. For livestock, the system approaches zero grazing. Grade cows are used and receive appropriate care. Pasture is improved. Measures are taken to check erosion. Items of cost are essentially the same as for medium capital input, but larger.

Appendix 13 summarizes the labour requirement for the relevant land utilization types under existing and possible capital input. With the yields for each type (App. 14), productivity of labour (yield divided by labour requirement) can be calculated.

Appendix 14 lists relevant land utilization types, range in production for different capital inputs and for three suitability classes. The highest possible yield can be reached only if capital input is high and if environ-

Table 35. Number of hectares tea per suitability class, per ecological zone and per capital input level.

Capital input level - ecological zone	Suitability class			
	1.1	1.2	1.3	2
High-IIa	96180	1550	14860	15080

mental conditions are suitable.

4.4.2 *Relevant land utilization types and their suitability*

Areas of suitable and unsuitable land are given only for ecological zones with a suitable climate for the land utilization types as described below. All the types apply to smallholders using rainfed arable farming.

(1) *Tea* (high input) starts to produce in the third year after planting and is in full production after the ninth year. Highest yields occur in Kisii District sometimes without fertilizer, but fertilizer is necessary for sustained production (Table 35).

Fig. 27. Pyrethrum is a small perennial flowering herb whose flower heads are used for manufacture of pyrethrins.

Table 36. Number of hectares pyrethrum per suitability class, per ecological zone and per capital input level.

Capital input level - ecological zone	Suitability class			
	1.1	1.2	1.3	2
Medium-IIa	51330	4894	29856	41590
High-IIa	59824	29856	12410	29180

(2) *Pyrethrum* (medium and high input) is a small perennial flowering herb 50-80 cm high (Fig. 27). Flower heads are regularly picked and dried in the sun. Dried flowers contain pyrethrin at a mass fraction of 8-20 g/kg. Plants produce in the year of planting and are fully productive in the second year. The dried flowers are processed in a factory at Nakuru. The products are insecticides and *pyrethrum marc*, which is a high quality cattle food. Advanced technology requires the introduction of clones with a higher pyrethrin content. Weeding needs to be done frequently (every 2-4 weeks). The practice of intercropping depresses yield (Table 36).

(3) *Coffee (Coffea arabica):* (low to medium and high input) produces in the third year after planting and is in full production after 5 years. Lack of proper disease control seriously depresses quality and production. Spraying by society employees is at present inadequate; it might be better to let farmers organize the spraying themselves (Table 37).

(4) *Sugar-cane* (low and high input) is largely grown by smallholders in a traditional way. The cane is processed in sugar-mills or on the farm if the farmer owns a crusher (Fig. 28). The product is called jaggery sugar, which is sold in lumps of about 1 kg. Only recently the Sony Sugar Co. introduced modern sugar-cane production on their central estate and among their outgrowers. In order to join the outgrowers scheme, not more than three farmers should have a suitable block of 6 ha available for sugar-cane production. Moreover the distance to the factory should not exceed 32 km. For outgrowers,

Table 37. Number of hectares coffee per suitability class, per ecological zone and per capital input level.

Capital input level - ecological zone	Suitability class			
	1.1	1.2	1.3	2
Low to medium-IIb	101430	0	5290	38010
High-IIb	101430	3470	1820	38010

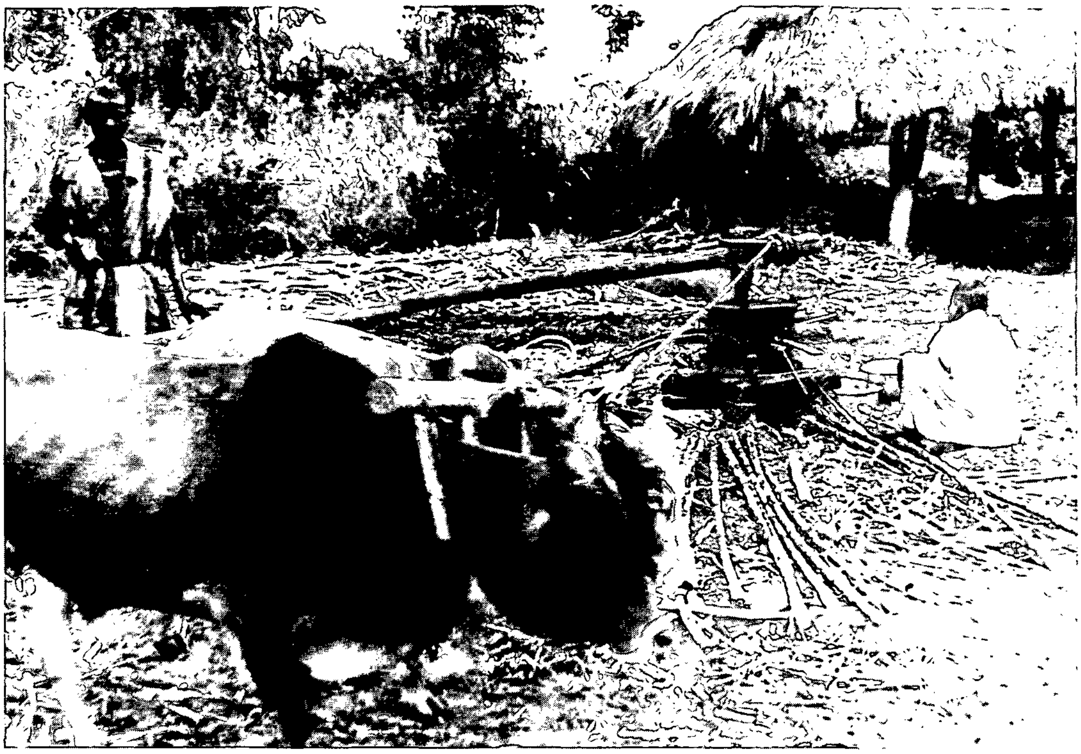


Fig. 28. Crushing of sugar-cane on a farm.

the standards of management are prescribed and controlled by the company, which also supplies credit, extension and operational services (Table 38).

(5) *Tobacco* (high input) is mainly the flue-cured type. The tobacco is planted from February till March and harvested from June till August. It is not grown in the second season to avoid a build-up of fungus (Table 39).

(6) *Cotton* (low and high input) is not commonly grown with advanced technology because of the high disease incidence, which renders management difficult. Cotton cake is a useful cattle feed (Table 40).

(7) *Sunflower* (high input) is cultivated for its oil, which ranges in mass fraction from 0.25-0.50 in seed, with the variety. The dried heads are a use-

Table 38. Number of hectares sugar-cane per suitability class, per ecological zone and per capital input level.

Capital input level - ecological zone		Suitability class			
		1.1	1.2	1.3	2
Low-IIb and High-IIb	current	0	49500	23440	72790
	potential	1690	53670	17580	72790

Table 39. Number of hectares tobacco per suitability class, per ecological zone, per season and per capital input level.

Capital input level - ecological zone		Suitability class, season							
		1.1		1.2		1.3		2	
		first	second	first	second	first	second	first	second
High-IIb	current	34710	34710	64560	51780	4850	41340	41610	17900
	potential	37850	36400	84860	73530	3160	17900	19860	17900
High-IIc	current	8270	0	5150	2850	480	5950	5440	12590
	potential	10360	0	7240	2850	4150	5950	0	12590
High-III	current	0	0	2610	0	590	0	2320	5520
	potential	570	0	2040	0	2910	0	0	5520

ful cattlefeed. It is a drought-resistant crop; some varieties have a growing season of only 3 months. The crop is rather new in the area. Birds are the main pest but can be kept off with wire netting and early harvesting. The oil is extracted in a factory at Nakuru (Table 41).

(8) *Castor (Ricinus communis)* grows wild throughout the area. It produces a valuable oil, whose mass fraction in seeds is 0.35-0.55. The plant is very drought-resistant. Although a promising crop for Ecological Zones IIc and III, its suitability for particular mapping units is irrelevant, because there is no extracting mill in Kenya.

(9) *Jojoba (Simmondsia chinensis)* is a perennial shrub 4 m high, originating

Table 40. Number of hectares cotton per suitability class, per ecological zone and per capital input level.

Capital input level - ecological zone		Suitability class			
		1.1	1.2	1.3	2
Low-IIc	current	0	8270	4860	8300
	potential	0	10360	3830	7240
Low-III	current	0	1250	570	4990
	potential	0	1820	1700	3290
High-IIc	current	0	10650	5340	5440
	potential	0	12740	7400	1290
High-III	current	0	1840	570	3110
	potential	0	4110	620	790

Table 41. Number of hectares sunflower per suitability class, per ecological zone, per season and per capital input level.

Capital input level - ecological zone		Suitability class, season 1.1 first	1.1 second	1.2 first	1.2 second	1.3 first	1.3 second	2 first	2 second
High-IIb	current	91380	91380	7050	12150	4580	20470	36900	15910
	potential	97410	117710	27350	9010	0	0	15150	13190
High-IIc	current	11040	11040	4950	4950	0	0	5450	5450
	potential	13130	13130	3920	3920	3090	3090	1290	1290
High-III	current	2040	1250	1660	1660	0	0	2320	3110
	potential	2610	1820	2290	2290	620	620	0	790

from the deserts of Arizona and Mexico. It is extremely drought-tolerant and thrives with as little as 400 mm of rainfall per year. The seeds contain valuable sperm oil, mass fraction 0.5. At a crop density of 0.2 m^{-2}, annual yield of seed from wild plants is about 0.3 kg/m^2 (3t/ha). Plants start to produce after 3 years, are fully productive after 5 years and remain productive for over 20 years. An extracting plant and market facilities were not available. If such facilities became available, Jojoba would be a promising crop for Ecological Zone III mapping units U4GM, U4Ybp, U4YhP and U4Bh.

(10) *Groundnuts* (low and medium input) are grown in pure stand or intercropped with maize and sorghum. Dung is sometimes applied, fertilizer seldom; but both measures would help to increase yield. Shelling by hand can be replaced by shelling with a sheller, which would decrease the labour cost considerably (Table 42).

(11) *Maize* (low and medium to high input) is the main staple food of the population; it is grown throughout the area. The growing season is 4 months in Zone III, 5 months in Zone IIc, 5-6 months in Zone IIb and 7 months in Zone IIa. Hybrid seed is commonly used, but use of fertilizer is not sufficient for top yields (Table 43), and plant spacing is too wide. *Striga hermonthica* is a serious root parasite (below an altitude of 1600 metres). (Table 44).

(12) *Sorghum* (low and medium input) has about the same requirement as maize, but more resistant to drought and waterlogging. Hybrids are not used, but with hybrids yields of 3000-5000 kg/ha (300-500 g/m^2) can be reached, whereas present yield is between 500 and 1700 kg/ha. *Striga hermonthica*, a root parasite, causes serious yield reductions in the zones considered (Table 45).

Table 42. Number of hectares groundnuts per suitability class, per ecological zone, per season and per capital input level.

Capital input level - ecological zone		Suitability class, season 1.1 first	1.1 second	1.2 first	1.2 second	1.3 first	1.3 second	2 first	2 second
Low-IIb	current	31600	31600	64400	65850	1690	3650	45500	42090
	potential	33050	33050	68810	68810	0	1960	41330	39370
Low-IIc	current	0	0	11040	10360	2090	3830	8300	7240
	potential	0	0	13130	10360	1060	3830	7240	7240
Low-III	current	0	0	1250	0	2490	0	2910	5520
	potential	0	0	1820	0	2490	0	1210	5520
Medium-IIb	current	49000	31600	52430	71280	1690	23950	41610	17900
	potential	50450	33050	74420	90240	0	3440	19860	17900
Medium-IIc	current	11040	0	4950	13610	0	0	5440	7820
	potential	13130	0	3920	13610	0	4150	1290	6760
Medium-III	current	0	0	2610	0	590	0	2320	5520
	potential	570	0	2040	0	2910	0	0	5520

(13) *Finger millet (Eleusine corocana)* (low input) is grown throughout the area, but especially in Kisii District. The crop is sown around February, is labour-demanding because of the fine seedbed needed and laborious weeding and thinning. Yields are 600-1600 kg/ha (60-160 g/m²), although yields of 4500 kg/ha can be obtained in trials. The seeds of finger millet can be stored for up to 10 years without insect attack; it is therefore popular for famine relief. The crop is similar to maize in suitability.

(14) *Sisal* (low and high input) is especially suitable for the driest Ecolog-

Table 43. Yield (kg/ha) of a first season maize crop on different soils and with phosphate fertilizer placed near the seed (1) or mixed with the topsoil (2). Optimum yield is yield under good management and optimum conditions. Crop density 5 555 km^{-2}. Rate of N on all plots 60 kg N/ha. Data from van der Eijk (in preparation).

Mapping unit	Fertilizer rate (kg/ha) 0	50 (1)	100 (1)	150 (1)	150 (2)	Optimum
U3Ihn, Ghn	600	2200	2900	1300	5500	6000
U3Ghn	1300	2200	3700	3000	3700	5000
U4Yhp, FYh	4500	6000	7000	7200	8700	10000
U3Bhn	4500	5700	7200	7800	8500	10000
U1Ihn	7500	8500	8700	8500	8800	10500
U1Ph	9200	9300	9500	9300	9500	10-11000

Table 44. Number of hectares maize per suitability class, per ecological zone, per season and per capital input level.

Capital input level - ecological zone		Suitability class, season 1.1 first	1.1 second	1.2 first	1.2 second	1.3 first	1.3 second	2 first	2 second
Low-IIa	current	54480	53720	0	760	12604	12604	60586	60586
	potential	54480	53720	2450	3210	25234	25234	45506	45586
Low-IIb	current	59080	59030	29450	26690	17590	0	39610	60010
	potential	59080	59030	38200	26710	29010	16000	19440	41290
Low-IIc	current	0	0	8270	0	4860	0	8300	21430
	potential	0	0	10360	0	3830	0	7240	21430
Low-III	current	0	0	1250	0	570	0	3700	5520
	potential	0	0	1820	0	1700	0	2000	5520
Medium to high-IIa	current	54480	53720	12604	13364	31406	31406	29180	29180
	potential	54480	53720	15054	15814	44036	44036	14100	14100
Medium to high-IIb	current	26830	26780	56830	54040	4580	1580	38720	58430
	potential	28280	31360	61410	50360	20300	20300	16970	39710
Medium to high-IIc	current	760	0	11440	0	3790	0	5440	21430
	potential	2850	0	9350	0	7940	0	1290	21430
Medium to high-III	current	0	0	1820	0	590	0	3110	5520
	potential	570	0	1250	0	2320	0	790	5520

Table 45. Number of hectares sorghum per suitability class, per ecological zone, per season and per capital input level.

Capital input level - ecological zone		Suitability class, season 1.1 first	1.1 second	1.2 first	1.2 second	1.3 first	1.3 second	2 first	2 second
Low-IIc	current	0	0	13130	10360	1060	2900	7240	8170
	potential	0	0	14190	10360	0	2900	7240	8170
Low-III	current	0	0	1820	0	1700	0	2000	5520
	potential	0	0	3520	0	0	0	2000	5520
Medium to high-IIc	current	10360	9600	5150	760	1540	3380	4380	7690
	potential	10360	9600	6210	1820	3570	5410	1290	4600
Medium to high-III	current	1820	0	0	0	2910	0	790	5520
	potential	1820	0	1700	0	1210	0	790	5520

Fig. 29. Decortication of sisal strips.

ical Zones (IIc and III). The water requirements are low so that it tolerates considerable drought. The crop can stand waterlogging, if not too serious, so that all soils in these zones are suitable. At present the plant is grown in hedgerows. Leaves are cut into longitudinal strips and decorticated by pulling them through two pieces of a panga blade, set into a stake (Fig 29). The ropes are used locally or sold at the local market, while the flowering stalks are used as building material. A more advanced plantation-like cultivation, of sisal would require a factory.

(15) *Cassava* (low and high input) is a perennial drought-resistant tuber crop. The leaves can be eaten as a vegetable. It is planted at the start of the rainy season and first harvested after 1 or 2 years. As tubers can stay in the soil much longer, harvesting can be done whenever time is available. Practically all the cassava is infected with cassava mosaic virus. A high-capital input would be justified only if mosaic-free cuttings were used. Cassava is sold on the local market. It could become a cashcrop if a processing factory for the preparation of tapioca were established (Table 46).

(16) *Sweet potato (Ipomoea batatas)* (low input) is a drought resistant tuber widely grown in the whole area. It is used for home consumption and the vines are often given to cattle. Only local varieties are used, farmyard manure is hardly applied.

Table 46. Number of hectares <u>cassava</u> per suitability class, per ecological zone and per capital input level.

Capital input level - ecological zone		Suitability class 1.1	1.2	1.3	2
Low-IIb	current	33010	65530	1690	45500
	potential	37180	67220	0	41330
Low-IIc	current	0	13130	0	8300
	potential	2090	11040	1060	7240
Low-III	current	0	1250	1360	2910
	potential	0	1820	2490	1210
High-IIb	current	33010	69420	1690	41610
	potential	34460	91410	2890	16970
High-IIc	current	8270	5340	2380	5440
	potential	10360	4310	5470	1290
High-III	current	0	1250	1950	2320
	potential	0	3520	2000	0

(17) *European potato (Solanum tuberosum)* (low and high input) is grown for home consumption or as a commercial crop. A high-capital input hardly exists through lack of good-quality blight-resistant seed potatoes, lack of rotation and lack of knowledge of spraying against diseases. Potatoes should be marketed through collection points, as proposed in the horticultural development study of the Ministry of Agriculture (1978) (Table 47).

(18) *Beans, peas and grams* (low and medium to high input) are an important source of proteins. Dried beans are extensively cultivated. French beans (Table 48) are not eaten by the population but are occasionally grown for the market. Cowpeas, green grams and particularly pigeon peas are rather drought-resistant. The pigeon pea is a perennial crop, which can last for

Table 47. Number of hectares <u>European potatoes</u> per suitability class, per ecological zone and per capital input level.

Capital input level - ecological zone		Suitability class 1.1	1.2	1.3	2
Low-IIa	current	0	54480	12604	60586
	potential	0	56930	12604	58136
High-IIa	current	0	67084	31406	29180
	potential	0	69534	31406	26730

Table 48. Number of hectares French beans per suitability class, per ecological zone and per capital input level.

Capital input level - ecological zone		Suitability class			
		1.1	1.2	1.3	2
Low-IIa	current	54480	0	12604	60586
	potential	56930	0	12604	58136
Medium to high-IIa	current	54480	12604	31406	29180
	potential	56930	12604	31406	26730

two to three years. Disease control is not practised, and new and higher-yielding varieties are not commonly used.
Soya beans are not used for home consumption. Only if a processing factory were built would this type become more important.

(19) *Vegetable crops*. Many horticultural crops are grown, often at a small scale The most widespread are cabbage, leaf cabbage, potatoes, tomatoes (Table 49), pumpkins, onions and peppers (A). Near Kisii Town, the following vegetables are cultivated: cauliflower, lettuce, French beans, cucumber, squash, beetroot, radish, celery, leek, chard, egg-plant(B). Table 34 also shows scope for cumin, coriander, ginger, garlic and asparagus. There is a rather large demand for Type A vegetables; they are sold in open-air markets and in the town markets of Kisii and Homa Bay. The demand for Type B vegetables is small. Collection and transport to places with larger demand (e.g. Kisumu) is the main problem; but knowledge and the means of controlling diseases is a factor seriously inhibiting production of the Type B vegetables. Besides, the indigenous population uses a variety of vegetables, growing wild or as a garden crop, these are (Kokwaro, 1972)

Local name	Latin name
A chak	*Sonchus schavein furthii*
A lot-bo	*Phaseolus multiflorus*
Apoth	*Corchorus olitorius*
Atipa	*Asystasia schimperi*
Awayo	*Oxalis corniculata, Oxygonum sinnalum*
Bwambwe	*Cyphostema orondo*
Kandhira	*Brassica oleracea*
Mit oo	*Crotelaria brevidens*
Nyayado	*Cassia floribunda*
Odicla	*Commelena africana*
Okuru	*Alternanthera pungens*

Table 49. Number of hectares <u>tomatoes</u> per suitability class, per ecological zone, per season and per capital input level.

Capital input level - ecological zone		Suitability class, season 1.1 first	1.1 second	1.2 first	1.2 second	1.3 first	1.3 second	2 first	2 second
Low-IIa	current	0	0	54480	54480	42460	42460	30730	30730
	potential	0	0	56930	56930	42460	42460	28280	28280
Low-IIb	current	34760	0[a]	66780	82590[a]	0	21990[a]	44190	41150[a]
	potential	34760	1450	72810	85720	0	20300	38160	38260
Low-IIc	current	0	0[a]	11040	0[a]	2090	0[a]	8300	21430[a]
	potential	0	0	13130	0	1060	0	7240	21430
Low-III	current	0	0[b]	2040	870[b]	570	0[b]	2910	4650[b]
	potential	0	0	2610	870	1700	0	1210	4650
High-IIa	current	0	0	96940	96940	1550	1550	29180	29180
	potential	0	0	99390	99390	1550	1550	26730	26730
High-IIb	current	47270	0[a]	47270	84280[a]	1690	4300[a]	41610	57150[a]
	potential	47270	3140	73600	104330	0	0	16970	38260
High-IIc	current	11040	0[a]	4950	1840[a]	1060	0[a]	4380	19590[a]
	potential	13130	0	3920	1840	3060	0	1290	19590
High-III	current	2040	870[b]	1160	0[b]	1700	0[b]	0	4650[b]
	potential	2610	870	2290	0	620	0	0	4650

a. first season: 8 months, second season (drier): 4 months.
b. first season: 4 months, second season (drier): 8 months.

Omboga *Amaranthus* sp.

Osuga *Solanum nigrum*

Remark: leaves of cassava, cowpeas and beans are eaten as well.

(20) *Fruit* (low and high input) is not produced on a commercial scale, apart from passion fruit, bananas (Table 50) and pineapple. However, tomatoes, strawberries, citrus, avocado, mango, papaya (Table 51), guava (Table 52), loquat and annona are also grown. The varieties of bananas grown in East Africa are adapted to the drier and cooler conditions prevailing in the Highlands. The two types are the plantain for cooking and the ripening banana. A banana plantation is productive in the second year and remains productive for more than 20 years. Bananas are mulched with the chopped up leaves and remnants of harvested plants. Fertilizers and varietal improvement could increase productivity. Table 34 lists some other fruits, which could be cultivated. Production and income from some fruits could be increased if a processing factory were established; for others, marketing needs to be organized.

Table 50. Number of hectares <u>bananas</u> per suitability class, per ecological zone and per capital input level.

Capital input level - ecological zone		Suitability class 1.1	1.2	1.3	2
Low to medium -IIa	current	0	98490	14100	15080
	potential	0	100940	14100	12630
Low to medium -IIb	current	46380	42320	50	56980
	potential				
High-IIa	current	0	96940	15650	15080
	potential	0	99390	15650	12630
High-IIb	current	46380	42320	50	56980
	potential				

High-input culture hardly exists, except for passion fruit. For it, new varieties should be distributed; knowledge about pruning, fertilizers and spraying needs to be strengthened.

(21) *Livestock*.(Sections 4.2, especially 4.2.4; Müller, 1978) with

A low input is still important in South Nyanza and will remain so for some time.

A medium to high input is applied in the eastern part of Kisii District. The management is not yet optimum, so that mortality is still rather high.

High input is recommended to increase cattle productivity with a system approaching grazing. Under such management, cows are kept indoors and fed on fodder crops and concentrates. The system is labour-intensive, but requir-

Table 51. Number of hectares <u>papaya</u> per suitability class, per ecological zone and per capital input level.

Capital input level - ecological zone		Suitability class 1.1	1.2	1.3	2
Medium-IIa	current	0	97730	760	29180
	potential	0	100180	760	26730
Medium-IIb	current	54050	0	50	91630
	potential				
High-IIa	current	0	97730	760	29180
	potential	0	100180	760	26730
High-IIb	current	54050	0	50	91630
	potential				

Table 52. Number of hectares guava per suitability class, per ecological zone and per capital input level.

Capital input level - ecological zone		Suitability class			
		1.1	1.2	1.3	2
Medium-IIc	current	11520	4470	0	5440
	potential	13610	6530	0	1290
Medium-III	current	1250	1160	790	2320
	potential	1820	2910	790	0
High-IIc	current	13900	0	0	5440
	potential	15990	4150	0	1290
High-III	current	1250	1160	790	2320
	potential	1820	2910	790	0

es less land than a grazing system and produces more manure. Land demarcation is a prerequisite for this system. Besides cattle, poultry are kept in traditional fashion. Modern poultry keeping methods are being introduced. This is a promising system for small farms; management requirements are, however, high in order to control diseases and to feed the hens properly. Rabbits, ducks and pigs are not important but may become so for small farms. Marketing of the products is still a constraint to production. For an appraisal of the suitability of the soils for cattle production, the composition and quality of grassland is important (Plaizier, 1980) as indicated below.

On well drained red soils, *Pennisetum clandestinum* (Kikuyu grass) is the most common species of these soils. It is a strong grass with a good herbage yield and is well palatable. Farmers favour this grass and propagate it vegetatively. It occurs naturally in the Highlands. Rotation grasses recommended for high input are *Chloris gayana* (Rhodes grass) and *Setaria sphacelata*. The species are sown. Their herbage yield is high and their palatability is good.

Fallow lands are usually invaded by *Pennisetum scrobiculatum*. It covers 70% of the surface within the first year of fallowing. Its nutritional value and yield is rather low. The production of fallow land would be much higher if species like *Chloris gayana* and *Setaria sphacelata* were sown; these species have a much higher nutritional value and can be destroyed easily by ploughing.

Shallow soils are characterized by the following species: *Loudetia kagerensis*, *Themeda triandra*, *Setaria sphacelata*, *Brachiaria soluta*, *Exotheca abyssinica*. The first is edible, but less valuable than the other species, but if the grazing pressure increases, its coverage also increases. Shallow soils usually carry permanent pastures.

Imperfectly to poorly drained bottomlands and plains carry permanent pasture, as on the shallow soils, but distinguished by the grasses *Pennisetum hohenackeri*, *Dichantium insculptum*, *Eragrostis exaspera* and *Hyparrhenia rufa*, the sedge *Fimbristylis* spp. and the herb *Justicia anseliana*. Herbage yield is low and proportion of nutritive grasses is small. Drainage improves floristic composition of this type of grassland, as a drainage trial near Magombo showed. There 85% of the original vegetation of sedges and low-quality grasses was replaced after three years by *Setaria atrata*, which did not occur originally (Table 53).

(22) *Fish ponds* (Maar et al., 1966) are rare within the area. There exists, however, an outlet for fish, especially in South Nyanza. The turn-over from

Table 53. Number of hectares for dairy grazing per suitability class, per ecological zone and per capital input level.

Capital input level - ecological zone		Suitability class			
		1.1	1.2	1.3	2
Low-IIa	current	112590	12630	0	2450
	potential	127670	0	0	0
Low-IIb	current	107720	38010	0	0
	potential	134740	10990	0	0
Low-IIc	current	8270	7720	5440	0
	potential	10360	9780	1290	0
Low-III	current	570	1840	3110	0
	potential	570	4160	790	0
Medium-IIa	current	79440	33150	12630	2450
	potential	81890	45780	0	0
Medium-IIb	current	107720	16850	21160	0
	potential	134050	11680	0	0
Medium-IIc	current	8270	7720	5440	0
	potential	10360	9780	1290	0
Medium-III	current	570	1840	3110	0
	potential	570	4160	790	0
High-IIa	current	72230	7210	33150	15080
	potential	72230	22290	33150	0
High-IIb	current	50	110810	34180	690
	potential	3190	130860	11680	0
High-IIc	current	760	9600	5630	5440
	potential	2850	7510	9780	1290
High-III	current	0	1820	590	3110
	potential	0	1820	2910	790

food and waste material to animal protein is very high. The number of fishponds should be increased and training and extension facilities in this field stepped up to exploit them. A site for a fishpond should meet the following requirements: a continuous water supply and rather flat impermeable soils. These requirements are met in mapping units BXa2 and sometimes also BXa1. Existing streams can be rechannelled along the contours of the valley. The water supply and drainage system would need a plan for the whole valley and so cooperation between farmers. Ducks could also be kept.

(23) *Beekeeping* could become an important cash earner, when done according to the instructions of the beekeeping section of the National Agricultural Laboratories (Mann, 1973). Under traditional beekeeping, bees are removed by fire, which means death for many bees; honey and wax are not properly separated and therefore of poor quality. By recommended beekeeping methods, honey and wax are separated and of good quality; the bees are not killed but calmed by smoke. Capital and labour requirement are low.

(24) *Natural product extraction.*

People catch and eat flying termites. They put a basket across the opening of the nest, and when the termites start flying, trap them in the basket. The termites fly under certain weather conditions.

Charcoal production is an important source of income on shallow and poorly drained soils.

Stone carving is a home industry, especially near Tabaka, where soapstone is found. The industry is an important cash earner.

4.5 PROPOSED FARM TYPES

By definition, the proposed farm types meet the following requirements.

1. They should make optimum use of existing land, maintaining the production capacity of the soil.
2. Livestock should always be part of the farm type in order to:
   - earn cash,
   - convert waste materials,
   - produce manure,
   - benefit structure of soils (by growing grass),
   - provide protein for local consumption and
   - to utilize land not suitable for other purposes than grazing.
3. They should supply an adequate income to the farmer and his family. A cash earner is part of each farm type, providing a cash income to the farmer and his family and allowing investment and improvement on the farm.
4. Farm income should be independent of farm size class and land suitability, for instance by more intensive use of land.
5. Family labour is used rationally.

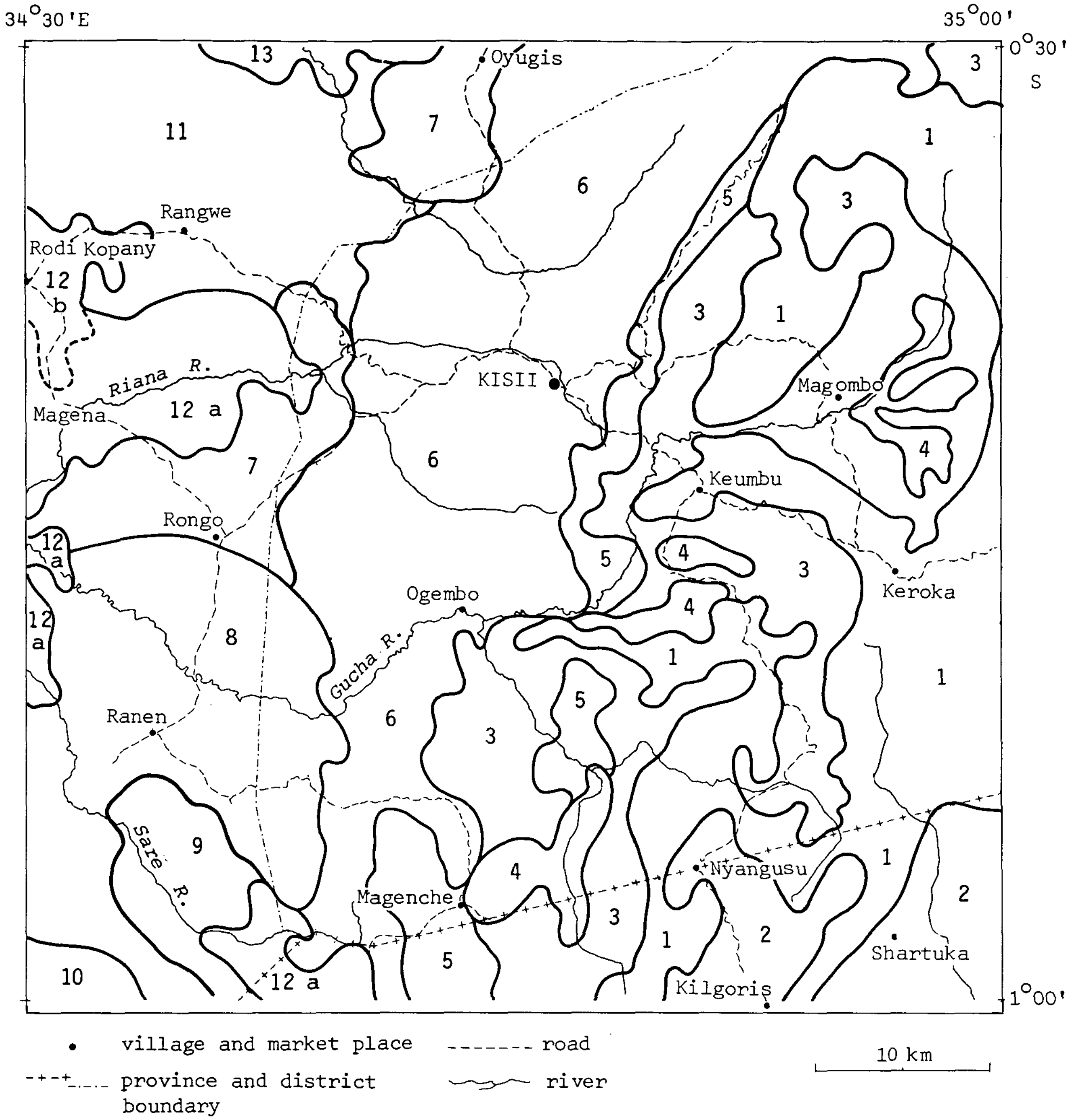


Fig. 30. Situation of the proposed farm types. 1, DzTPyFo, DzHFo; 2, Ge; 3, DzHFo, DgTFo, (FPHFo); 4, DgTFo, FPHFo; 5, DgTFo; 6, DzCBaFo, DgCBaFo, PHFo; 7, DgTo(Pi)Fo, DzTo(Pi)Fo, DzCBaFo, DgCBaFo; 8, DzSlFo, DzTo(Pi)Fo, DgTo(Pi)Fo; 9, DgSlFo, DgTo(Pi)Fo; 10, DzTo(Pi)Fo, DgTo(Pi)Fo; 11, GFrFo, FrBeSuL;
12, (a)GS2Fo, (b)GFo; 13, GCoSuFo, GFrFo. Abbreviations stand for produce items, explained in Table 54.

Some of the farm types (Table 54; Fig. 30) do not yet exist. Their development will require a different approach by extension, training and credit services. These services should to a large degree, be directed to the smaller farmer, who hitherto hardly had access to them. There is no other way to avoid the ever-increasing disparity of income and lack of opportunity for the small farmer. The lack of income for the small farmer will not only impoverish the farmer and his family, but also the soil on which he lives (Section 4.2.3).

The data in Table 54 are based on Appendixes 13 and 14. The proposed farm types are the result of our studies in the area, discussions with staff of the Ministry of Agriculture, the National Sugar Research Station, the Nyanza Agricultural Research Station, the British American Tobacco Company and the Sony Sugar Co., and reports and books mentioned earlier in this chapter in Appendixes 13 and 14.

The costs mentioned in Table 54 are for 1978. The cost-benefit calculations correspond to highly suitable soils. The basic suitability and corresponding physical production (Section 4.3.4, App. 8) remain valid as a base for future cost-benefit calculations.

Table 54. Summary of proposed farmtypes for smallholder mixed farming and their key attributes. Rotation intensity is the coëfficient, indicating which part of the year the soil can be used for the defined produce items.

Proposed farm-type and ecological zone	Produce	Surface (ha) of the farm and rotation intensity (R)	Farm-size (ha) and land tenure	Farm power	Labour intensity (hour per holding)	Recurrent capital per holding (Ksh)	Gross margin (farm income + hired labour) Ksh. per holding	Conditions
medium to high capital input DgTFo - IIa	Dg:dairy (grazing) 1.milk 2.beef T: tea Fo:1.maize, fingermillet, beans 2.sweet potato, beans, cabbage	1.4 - 2.0; 1 0.5 - 1.0; 1 0.6 - 1.0; 1	2.5-4	manual ploughing with oxen	2600-4550	3660-5600	10500-18000	Disease control in cattle and proper milk marketing
high capital input DzTPyFo - IIa	Dz: dairy (zero-semizero grazing): milk, beef T,Py: tea, pyrethrum Fo:foodcrops as for DgTFo and Be (beekeeping)	0.5 - 1.8; 1 0.2 - 0.5; 1 0.3 - 1.0; 1	1-2.5	manual ploughing with oxen or hoe	3460-3720	3260-4720	9000-14500	Disease control in cattle and proper milk marketing; training
high capital input DzHFo - IIa and part of IIb	Dz: see DzTPyFo H: horticultural crops like onions, European potato, herbs and fruits (Table 34) Fo: see DgTFo Be: beekeeping	0.5 - 1.0; 1 0.2 - 0.8; 1 0.3 - 0.7; 1	1-2.5	manual occasional ploughing with oxen	3740-4200	3640-5980	11000-23500	Disease control in cattle and proper milk marketing; training in production techniques; collection and marketing of products
high capital input FPHFo - IIa, IIb	F: fishculture P: ducks and or poultry for meat and eggs H: horticultural crops: (see Table 34) Fo: food crops: see DgTFo, but 1 or 2 maize crops per year Fodder crops: leguminous crops	0.05- 0.1; 1 0.25- 0.5; 1 0.2 -0.34; 1	0.5-1	manual	2300-3700	15500-16300	13500-19000	Training, credit and assistance in fishpond and poultry development; collection and marketing of products

Table 54. Continued

Proposed farm-type and eco-logical zone	Produce	Surface (ha) of the farm and rota-tion in-tensity (R)	Farm-size (ha) and land tenure	Farm power	Labour in-tensity (hour per holding)	Recurrent capital per hold-ing (Ksh)	Gross mar-gin (farm income + hired labour) Ksh. per holding	Conditions
medium to high capital input DgCBaFo - IIb	Dg: see DgTFo CBa: coffee a/o bananas Fo: maize (2 seasons), beans, groundnuts, sw. potato, cabbage	1.4 - 2.0; 1 0.5; 1 0.6 - 1.0; 1	2.5-4	manual ploughing with oxen	2800-3720	3900-5500	13000-16500	Disease control in cattle. Farmer, who sprays coffee him-self. Milk market-ing
high capital input DzCBaFo - IIb	Like DgCBaFo, but with zero grazing or semizero grazing	0.5 - 1.0; 1 0.2 - 0.5; 1 0.3 - 1.0; 1	1-2.5	manual occasional ploughing with oxen	4055-13542	5030-13352	8000-16000	Disease control in cattle. Farmer, who sprays coffee him-self.Milk marketing
high capital input DzSFo - IIb	Dz: zero grazing S: sugar-cane (outgr. scheme) Fo: see DgCBaFo	0.5; 1 2.0; 1 0.5; 1	3	manual and tractor	3980	21525	26000	Proper milkmar-keting
medium to high input DgSFo - IIb	Dg: dairy (grazing) S: sugar-cane Fo: maize (2nd season)	1.5 - 2.5; 1 2; 1 0.5; 1	2.5-4	manual and tractor	1980	21500-23300	26000-29000	Disease control in cattle and proper milk marketing
medium to high capital input DgTo(Pi)Fo - IIb	Dg: grazing type: 1. milk 2. beef To: tobacco + sunflower or pineapple Fo: see DgCBaFo	1.5 - 3.0; 1 0.5; 1 0.5 - 1.0; 1	2.5-4	manual ploughing with oxen or tractor	2950	4650-8150	10000-16000	Disease control in cattle and proper milk marketing
high capital input DzTo(Pi)Fo - IIb	Dz: zero grazing: 1.milk 2.beef To and Fo: see DgToFo	0.5 - 1.0; 1 0.5; 1 0.5 - 1.0; 1	1.5-2.5	as above	4000-4600	4575-5650	10000-12000	Disease control in cattle and proper milk marketing

Table 54. Continued

Proposed farm-type and ecological zone	Produce	Surface (ha) of the farm and rotation intensity (R)	Farm-size (ha) and land tenure	Farm power	Labour intensity (hour per holding)	Recurrent capital per holding (Ksh)	Gross margin (farm income + hired labour) Ksh. per holding	Conditions
high capital input PHFo - IIb	P: poultry: eggs, meat H: horticultural crops a/o fruits see Table 34 Be: beekeeping Fo: food crops, see DgCBaFo	0.05; 1 0.25- 0.5; 1 0.2 -0.45; 1	0.5-1	manual	1850-2300	15000-16000	9000-14500	Credit, training and assistance for poultry development. Collection and marketing of products
low to medium capital input GFo - IIb, IIc	G: grazing: 1. beef 2. milk Fo: 1st season: maize, sorghum, groundnuts, beans 2nd season: sunflower, sweet potato perennial: cassava, pigeon peas, cowpeas	3-5; 1	4-6 land registration necessary	manual, ploughing with oxen	2400-3200	1020-1700	8000-10500	Land registration, upgrading with Sahiwals and tick-control
medium capital input GFrFo - IIc, III, lower part IIb	G: grazing Fr: fruits a/o hort. crop see Table 34 Bee keeping GFo: Foodcrops and oil crops	1.8 - 3.8; 1 H: 0.6; 0.6 Fr:0.6; 1 0.6; 0.8	3-5 land registration necessary	manual ploughing mostly done by oxen	2240-4640	1112-1962	11500	Disease control in cattle and proper milk marketing. Fruit collection and processing
low to medium capital input GSFo - IIb (IIc)	G: grazing: meat, milk S: sugar-cane for jaggery (own jaggery) Fo: food crops: maize (1 or 2 times/year) beans, cabbage, cowpeas, pigeon peas	1.5 - 3.5; 1 1; 1 0.5; 0.8	3-5 land registration necessary	manual ploughing with oxen	1600-2400	310-390	5500-8500	Land registration, upgrading with Sahiwals; tick control, land drainage and conservation

Table 54. Continued

Proposed farm-type and ecological zone	Produce	Surface (ha) of the farm and rotation intensity (R)	Farm-size (ha) and land tenure	Farm power	Labour intensity (hour per holding)	Recurrent capital per holding (Ksh)	Gross margin (farm income + hired labour) Ksh per holding	Conditions
low to medium capital input GCoSuFo - IIc and III	G: grazing Co, Su: cotton a/o oil crops, sunflower, groundnuts Fo: food crops: sorghum, beans, pigeon peas, cassava	1.8 - 3.8; 1 0.6; 0.7 0.6; 0.8	3-5 land registration necessary	see above	1860-2680	372-454	6500-9000	Land registration, upgrading with Sahiwals; tick control, land drainage and conservation
medium capital input FrBeSuL - IIc and III	Fr: trees and shrubs, see Table 34 Be: beekeeping Su: food and oil crops 1st season: maize, groundnuts, cowpeas, cabbage 2nd season: sunflower, whole year: cassava, pigeon peas L: small livestock	0.5 - 1.0; 1 0.5 - 1.0; 1 0.5 - 1.0;1	1.5-3 land registration necessary	manual occasional plouging with oxen	1420-2810	800-1540	7500-13500	Land registration, upgrading with Sahiwals; tick control, land drainage and conservation. Fruit collection and processing
low capital input Ge	Extensive grazing beef and milk		communal land					

LABORATORY DATA OF PROFILE DESCRIPTION No: 1

FIELD OBSERVATION No: 130/2 - C5   MAPPING UNIT: HBhP   SOIL CLASSIFICATION: Humic CAMBISOL

Laboratory no. ..77/	507	508	509	510		
Horizon	A1	B1	B2	B3		
Depth (cm)	0-15	15-45	45-90	90-120		
pH-H_2O(1:5 v/v)	5.1	5.0	4.9	4.8		
pH-KCl ..	4.4	4.2	4.0	4.1		
EC(mmho/cm) ..	0.11	0.07	0.03	0.02		
$CaCO_3$ (%)						
$CaSO_4$ (%)						
C (%)	2.4	1.6	0.4	0.4		
N (%)	0.33					
C/N	7					
CEC (me/100g), pH 8.2						
CEC .. .. pH 7.0	21.3	13.3	14.0	14.2		
Exch.Ca (me/100g)	3.5	2.4	6.3	6.5		
.. Mg ..	2.9	2.1	0.1	0.8		
.. K ..	0.8	0.4	0.5	0.4		
.. Na ..	0.1	0.1	0.1	0.1		
Sum of cations	7.3	5.0	7.0	7.8		
Base sat. %, pH 8.2						
.. .. %, pH 7.0	34	38	50	55		
ESP at pH 8.2						
Saturation extract:						
Moisture %						
pH-paste						
ECe (mmho/cm)						
Na (me/l)						
K ..						
Ca ..						
Mg ..						
Sum of cations(me/l)						
CO_3 (me/l)						
HCO_3 ..						
Cl ..						
SO_4 ..						
Sum of anions(me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3(mol/mol)						
SiO_2/R_2O_3 ..						
Fe_2O_3(mmol%)						
X-ray report:						

Depth (cm)	0-15	15-45	45-90	90-120		
Gravel %		58.0				
Texture, limited pretreatment:						
Sand % 2.0 – 0.05 mm						
Silt % 0.05–0.002mm						
Clay % 0.002–0 mm						
Texture class						
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 – 1.0mm	2.9	7.6	0.6	1.0		
.. .. 1.0 – 0.50mm	0.2	3.5	1.4	0.8		
.. .. 0.50 – 0.25mm	1.6	1.9	0.8	0.4		
.. .. 0.25 – 0.10mm	2.1	1.8	0.8	0.5		
.. .. 0.10 – 0.05mm	0.6	1.6	1.2	0.6		
Total sand %	7.4	16.4	4.8	3.3		
Silt %	26.8	26.4	31.5	35.3		
Clay %	65.8	57.1	63.7	61.4		
Texture class	C	C	C	C		
Bulk density	0.89	0.91	1.12			
Moisture % w/v at:						
pF 0	62.4	60.1	59.8			
pF 2.0	48.6	41.1	42.3			
pF 2.3	47.1	40.0	41.5			
pF 2.7	43.7	38.0	39.7			
pF 3.0	31.6	28.6	34.2			
pF 3.6	26.5	27.9	31.5			
pF 4.2	22.6	21.3	31.0			
Fertility aspects: (0–15 cm)	Laboratory no. /					
Ca (me/100g)	5.6	Available		Total		
Mg ..	3.0					
K ..	0.94					
P (ppm)	4					
Mn (me/100g)	0.64					
Exch. acidity (me/100g)						
pH-H_2O (1: v/v)						
C%						
N%						
Silt/clay ratio			0.5			
CEC (me/100g clay)			17.2			

Kenya Soil Survey
Drawing No. 79050

Appendix 6

DETAILED DESCRIPTION OF REPRESENTATIVE SOIL PROFILES, AND ANALYTICAL DATA

Unit HBhP, Profile 1

Soil classification: humic Cambisol; ST: typic Eutropept
Ecological zone: IIb
Observation: 130/2-5, Kisii District, E 695.3, N 9924.5, 2100 m, 13-1-1977
Geological formation: bukoban
Local petrography: basalt
Physiography: rounded rather flat hill top
Surrounding landform: hilly
Relief - meso: convex linear slope
Vegetation: no natural vegetation
Land use: cultivated (onions, maize, coffee)
Erosion: nil
Surface stoniness: nil
Soil fauna: some termite activity
Slope gradient: 6%
Drainage class: well drained

A1 0-15 cm dark reddish brown (5YR 3/3, moist); slightly gravelly clay; strong very fine subangular blocky; friable, slightly sticky and slightly plastic; many fine roots; clear and wavy transition to:

B1 15-45 cm dark reddish brown (5YR 3/3 and 3/4, moist) clay with 80% weathering stones and quartz gravel; strong very fine subangular blocky; thin few clay cutans; friable, slightly sticky, and slightly plastic, common very fine roots; clear and wavy transition to:

B2 45-90 cm yellowish red (5YR 4/6, moist) clay with 10% reddish yellow rotten rock and quartz gravel; moderate very fine angular blocky; thin moderate common clay cutans; friable, slightly sticky and slightly plastic; common very fine roots; gradual and wavy transition to:

B3 90-120 cm yellowish red (5YR 4/6, moist) clay with 60% reddish yellow, fine rotten rock; moderate very fine angular blocky; pressure cutans; very friable, slightly sticky and slightly plastic; common very fine and few fine pores; few very fine roots.

LABORATORY DATA OF PROFILE DESCRIPTION No: 2

FIELDOBSERVATION No: 130/2 - Ex3 MAPPING UNIT: HXP

Laboratory no. ..77./	537					
Horizon	A1					
Depth (cm)	0-10					
$pH-H_2O$(1: 5 v/v)	4.8					
pH-KCl ..	4.1					
EC(mmho/cm) ..	0.10					
$CaCO_3$(%)						
$CaSO_4$(%)						
C (%)	2.3					
N (%)	0.25					
C/N	9					
CEC (me/100g), pH 8.2						
CEC .. .. pH 7.0	15.4					
Exch.Ca (me/100g)	0.2					
.. Mg ..	1.1					
.. K ..	0.3					
.. Na ..	0.1					
Sum of cations	1.7					
Base sat. %, pH 8.2						
.. .. %, pH 7.0	11					
ESP at pH 8.2						
Saturation extract:						
Moisture %						
pH-paste						
ECe (mmho/cm)						
Na(me/l)						
K ..						
Ca ..						
Mg ..						
Sum of cations(me/l)						
CO_3(me/l)						
HCO_3 ..						
Cl ..						
SO_4 ..						
Sum of anions(me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3(mol/mol)						
SiO_2/R_2O_3 ..						
Fe_2O_3(mmol%)						
X-ray report:						

SOIL CLASSIFICATION: LITHOSOL

Depth (cm)	0-10					
Gravel %	18.4					
Texture, limited pretreatment:						
Sand % 2.0 – 0.05 mm	43					
Silt % 0.05–0.002mm	12					
Clay % 0.002–0 mm	45					
Texture class	C					
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 – 1.0mm	2.2					
.. .. 1.0 – 0.50mm	2.4					
.. .. 0.50 – 0.25 mm	11.3					
.. .. 0.25 – 0.10mm	14.4					
.. .. 0.10 – 0.05mm	2.2					
Total sand %	32.5					
Silt %	10.8					
Clay %	56.7					
Texture class	C					
Bulk density						
Moisture % w/v at:						
pF 0						
pF 2.0						
pF 2.3						
pF 2.7						
pF 3.0						
pF 3.7						
pF 4.2						

Fertility aspects: (0–10cm)	Laboratory no. /	
	Available	Total
Ca (me/100g)	14.4	
Mg ..	7.0	
K ..	3.60	
P (ppm)	274???	
Mn (me/100g)	0.8	
Exch. acidity (me/100g)		
$pH-H_2O$ (1: v/v)		
C%		
N%		
Silt/clay ratio	0.3	

Kenya Soil Survey
Drawing No. 79050

Unit HXP, Profile 2

Soil classification: lithosol; ST: Lithic Troporthent
Ecological zone: IIa
Observation: 130/2-Ex 3, Kisii District, E 704.2, N 9932.8, 1905 m, 1-12-1975
Geological formation: quartzite from the Bukoban system
Local petrography: top of the Manga Ridge
Surrounding landform: gently undulating
Relief - meso: convex hilltop
Vegetation: 20% trees (black wattle) 20% shrubs, 60% grasses and herbs
Land use: fallow, timber for building purposes
Erosion: moderate sheet and rill erosion
Surface stoniness/rockiness: at the edge of the ridge extremely rocky; near the observation less rocky
Soil fauna: ants
Slope gradient: 3%
Drainage class: somewhat excessively drained
Remark: the government has made a start with reforestation

A1	0-10 cm	dark reddish brown (5YR 3/3, moist), dark brown (7.5YR 4/4, dry) slightly gravelly to gravelly clay; weak very fine to medium granular; soft, very friable, slightly sticky and slightly plastic; abrupt and broken transition to:
A+R	10+ cm	quartzite rock, within the joints material of A horizon

LABORATORY DATA OF PROFILE DESCRIPTION No: 3

FIELD OBSERVATION No: 130/1 - WAN1 MAPPING UNIT: HXP

Laboratory no. .76../	76
Horizon	A1
Depth (cm)	0-35
pH-H_2O(1: v/v)	4.0
pH-KCl ..	3.6
EC(mmho/cm) ..	
$CaCO_3$(%)	
$CaSO_4$(%)	
C (%)	24.1
N (%)	0.25
C/N	9.6
CEC (me/100g), pH 8.2	
CEC .. .. pH 7.0	18.7
Exch.Ca (me/100g)	0.7
.. Mg ..	0.4
.. K ..	0.5
.. Na ..	N.d
Sum of cations	
Base sat. %, pH 8.2	
.. .. %, pH 7.0	9+
ESP at pH 8.2	
Saturation extract:	
Moisture %	
pH-paste	
ECe (mmho/cm)	
Na (me/l)	
K ..	
Ca ..	
Mg ..	
Sum of cations(me/l)	
CO_3(me/l)	
HCO_3 ..	
Cl ..	
SO_4 ..	
Sum of anions(me/l)	
Adj. SAR	
Clay mineralogy:	
SiO_2/Al_2O_3(mol/mol)	9.1
SiO_2/R_2O_3 ..	7.5
Fe_2O_3(mmol%)	4.2
X-ray report:	
The sample has a high peak surface in	
Kaolinite (7A) in the clay fraction.	

SOIL CLASSIFICATION: Ranker

Depth (cm)	0-35
Gravel %	20.2
Texture, limited pretreatment:	
Sand % 2.0 – 0.05 mm	
Silt % 0.05–0.002mm	
Clay % 0.002–0 mm	
Texture class	
Dispersed clay %	
Flocculation index	
Texture USDA:	
Sand % 2.0 – 1.0mm	19.6
.. .. 1.0 – 0.50mm	10.5
.. .. 0.50 – 0.25mm	7.3
.. .. 0.25 – 0.10mm	7.7
.. .. 0.10 – 0.05mm	4.6
Total sand %	49.7
Silt %	19.2
Clay %	31.3
Texture class	SCL
Bulk density	0.97
Moisture % w/v at:	
pF 0	61.2
pF 2.0	35.2
pF 2.3	30.9
pF 2.8	25.3
pF 3.0	17.7
pF 3.6	16.7
pF 4.2	11.0

Fertility aspects: (0-35 cm)	Available	Total
	Laboratory no. /	
Ca (me/100g)	0.4	
Mg ..	1.5	
K ..	0.64	
P (ppm)	4	
Mn (me/100g)	1.07	
Exch. acidity (me/100g)		
pH-H_2O (1: v/v)		
C%		
N%		
"Free" F2O3	2.0	
"Free" AL2O3	2.8	

Kenya Soil Survey
Drawing No. 79050

Unit HXP, Profile 3

Soil classification: Ranker; ST: lithic Humitropept
Ecological zone: IIb
Observation: 130/1-WAN 1, Kisii District, E.689.9, N 9930.1, 1647 m, 19-12-1975
Geological formation: Precambrium/post kavirondian system
Local petrography: Wanjare granite
Physiography: hill top
Surrounding landform: rolling to hilly
Relief - meso: eroded top with termite mounds (30 cm)
Vegetation: dense bushland; 30% shrubs, 20% herbs, 30% grasses
Land use: extensive grazing
Erosion: slight sheet and gully erosion
Surface stoniness/rockiness: extremely rocky, few stones
Soil fauna: termites and ants
Slope gradient: 2%
Drainage class: somewhat excessively drained

A11	0-5/14 cm	dark brown (7.5YR 3/2, dry), dark reddish brown (5YR 3/2 moist) slightly gravelly sandy clay loam; strong very fine granular; due to termite activity abundant pores in all size classes up to 10 mm; soft, friable, slightly sticky and slightly plastic; clear and broken transition to:
A12	5/14-20/35 cm	dark brown (7.5YR 3/2 dry), dark reddish brown (5YR 3/2, moist) slightly gravelly sandy clay loam; strong very fine granular; many fine and fine biopores; soft, friable slightly sticky and slightly plastic; abrupt and broken transition to:
R	20/35+ cm	rock (granite)

LABORATORY DATA OF PROFILE DESCRIPTION No: 4

FIELD OBSERVATION No: 130/2 - C7 MAPPING UNIT: FBh

Laboratory no. ..77/	515	516	517	518		
Horizon	A	B2.1	B2.2	B2.3		
Depth (cm)	0-45	45-90	90-135	135-150		
pH-H_2O(1:5 v/v)	5.4	5.6	5.5	5.7		
pH-KCl ..	4.6	4.6	4.8	4.9		
EC(mmho/cm) ..	0.10	0.68	0.08	0.08		
$CaCO_3$(%)						
$CaSO_4$(%)						
C (%)	1.7	0.87	0.49	0.32		
N (%)	0.10					
C/N	17					
CEC (me/100g), pH 8.2						
CEC .. .. pH 7.0	22.8	24.1	17.9	17.3		
Exch.Ca (me/100g)	7.8	6.8	5.0	5.2		
.. Mg ..	3.5	3.6	3.4	5.8		
.. K ..	0.7	0.3	0.5	0.6		
.. Na ..	0.2	0.1	[illegible]	0.1		
Sum of cations	12.2	10.8	9.0	11.7		
Base sat. %, pH 8.2						
.. .. %, pH 7.0	54	45	50	68		
ESP at pH 8.2						
Saturation extract:						
Moisture %						
pH-paste						
ECe (mmho/cm)						
Na(me/l)						
K ..						
Ca ..						
Mg ..						
Sum of cations(me/l)						
CO_3(me/l)						
HCO_3 ..						
Cl ..						
SO_4 ..						
Sum of anions(me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3(mol/mol)						
SiO_2/R_2O_3 ..						
Fe_2O_3(mmol%)						
X-ray report:						

SOIL CLASSIFICATION: Luvic PHAEOZEM

Depth (cm)	0-45	45-90	90-135	135-150		
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 – 0.05 mm						
Silt % 0.05–0.002mm						
Clay % 0.002–0 mm						
Texture class						
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 – 1.0mm	2.2	1.3	1.2	0.5		
.. .. 1.0 – 0.50mm	2.1	1.5	1.4	1.2		
.. .. 0.50 – 0.25 mm	2.1	1.0	2.2	1.4		
.. .. 0.25 – 0.10mm	2.6	1.6	2.8	1.5		
.. .. 0.10 – 0.05mm	2.0	0.7	1.1	1.1		
Total sand %	11.0	6.1	8.7	5.7		
Silt %	32.0	18.9	29.1	36.4		
Clay %	57.1	75.1	62.4	58.0		
Texture class	C	C	C	C		
Bulk density						
Moisture % w/v at:						
pF 0						
pF 2.0						
pF 2.3						
pF 2.7						
pF 3.0						
pF 3.7						
pF 4.2						

Fertility aspects: (0–45 cm)	Laboratory no. /	
Ca (me/100g)	6.4 Available	Total
Mg ..	3.0	
K ..	1.14	
P (ppm)	4	
Mn (me/100g)	1.46	
Exch. acidity (me/100g)		
pH-H_2O (1: v/v)		
C%		
N%		

Kenya Soil Survey
Drawing No. 79050

Unit FBh, Profile 4

Soil classification: luvic Phaeozem; ST: oxic Argiudoll
Ecological zone: IIb
Observation: 10312-C7, South Nyanza District, E 698.2, N 9941.8, 1525 m, 18-1-1977
Geological formation: bukoban system
Local petrography: basalt
Physiography: footslope
Surrounding landform: rolling
Relief - meso: straight uniform slope
Vegetation: no natural vegetation (all cleared)
Land use: cultivated (coffee)
Erosion: nil
Surface stoniness: nil
Soil fauna: termites and moles
Slope gradient: 10%
Drainage class: well drained

A1	0-45 cm	dark reddish brown (5YR 3/2, moist) clay with few angular gravel; strong very fine subangular blocky; very friable, slightly sticky and slightly plastic; few medium and many fine pores; common medium roots; clear and wavy transition to:
B21t	45-90 cm	dark red (2.5YR 3/6, moist) clay with few angular gravel; strong very fine angular blocky; thin few clay cutans; friable, slightly sticky and slightly plastic; few fine and many very fine pores; few fine and very fine roots; gradual and smooth transition to:
B22t	90-135 cm	dark red (2.5YR 3/6, moist) clay with few angular gravel; strong very fine angular blocky; moderate abundant clay cutans and moderate common manganese cutans; friable, slightly sticky and slightly plastic; many fine pores, few fine and very fine roots; clear and smooth transition to:
B23	135-185 cm	red (2.5YR 4/6, moist) clay with 10% weathering gravel on transition from B22 to B23; moderate very fine angular blocky; thin clay cutans; very friable, slightly sticky and slightly plastic; common very fine pores; few fine and very fine roots

LABORATORY DATA OF PROFILE DESCRIPTION No:5

FIELD OBSERVATION No:130/2 - C8 MAPPING UNIT: FBht

Laboratory no. ..77./	519	520	521	522		
Horizon	A1	B2.1	B2.2	B3		
Depth (cm) of sampling	0-15	15-60	60-110	110-160		
pH-H_2O(1:5 v/v)	5.2	5.0	4.9	4.8		
pH-KCl ..	4.5	4.1	3.9	3.8		
EC(mmho/cm) ..	0.17	0.07	0.05	0.04		
$CaCO_3$(%)						
$CaSO_4$(%)						
C (%)	2.3	0.90	0.41	0.73		
N (%)	0.28					
C/N	8					
CEC (me/100g), pH 8.2						
CEC .. .. pH 7.0	21.3	16.6	12.3	12.7		
Exch.Ca (me/100g)	8.0	2.7	3.0	3.1		
.. Mg ..	4.5	3.4	3.3	3.2		
.. K ..	0.9	0.3	0.2	0.2		
.. Na ..	0.1	0.1	0.1	0.2		
Sum of cations	13.5	6.5	6.6	6.7		
Base sat. %, pH 8.2						
.. .. %, pH 7.0	63	39	52	53		
ESP at pH 8.2						
Saturation extract:						
Moisture %						
pH-paste						
ECe (mmho/cm)						
Na(me/l)						
K ..						
Ca ..						
Mg ..						
Sum of cations(me/l)						
CO_3(me/l)						
HCO_3 ..						
Cl ..						
SO_4 ..						
Sum of anions(me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3(mol/mol)						
SiO_2/R_2O_3 ..						
Fe_2O_3(mmol%)						
X-ray report:						

SOIL CLASSIFICATION: Luvic PHAEOZEM

Depth (cm)	0-15	15-60	60-110	110-160		
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 – 0.05 mm	19	13	11	27		
Silt % 0.05–0.002mm	26	14	20	18		
Clay % 0.002–0 mm	55	73	69	55		
Texture class	c	c	c	c		
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 – 1.0mm	1.0	1.7	1.9	3.8		
.. .. 1.0 – 0.50mm	1.6	1.6	1.9	9.2		
.. .. 0.50 – 0.25mm	2.1	2.4	1.4	4.9		
.. .. 0.25 – 0.10mm	2.4	1.6	0.7	2.5		
.. .. 0.10 – 0.05mm	1.6	0.9	0.6	0.8		
Total sand %	8.7	8.2	6.5	21.2		
Silt %	22.8	24.9	31.0	39.0		
Clay %	68.6	66.9	62.5	39.9		
Texture class	c	c	c	c		
Bulk density						
Moisture % w/v at:						
pF 0						
pF 2.0						
pF 2.3						
pF 2.7						
pF 3.0						
pF 3.7						
pF 4.2						
Fertility aspects: (0–15cm)	Laboratory no. /					
Ca (me/100g)	6.4 Available			Total		
Mg ..	4.0					
K ..	0.40					
P (ppm)	4					
Mn (me/100g)	1.16					
Exch. acidity (me/100g)						
pH-H_2O (1: v/v)						
C%						
N%						

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Unit FYh, Profile 6

Soil classification: luvic Phaeozem; ST. oxic Argiudoll
Ecological zone: IIb
Observation: 130/3-Ran2, South Nyanza district, E 673.7, N 9905.0, 1503 m, 11-9-1975
Geological formation: Nyanzian system
Local petrography: rhyolite
Physiography: footslope
Surrounding landform: undulating - gently undulating
Relief - meso: upper part of linear convex slope
Vegetation: no natural vegetation
Land use: annuals: maize, beans, groundnuts; perannials: coffee, sugar-cane
Erosion: nil
Surface stoniness: nil
Soil fauna: ants, worms, termites
Slope gradient: 10%
Drainage class: well drained

A1 0-18 cm dark reddish grey to reddish brown (5YR 4/2.5, moist) sandy clay-loam; moderate to weak medium compound angular blocky consisting of very fine granular and fine subangular blocky; very friable, slightly sticky and slightly plastic; clear and smooth transition to:

A3/(B1) 18-36 cm reddish brown (5YR 4/4 to 2.5YR 4/4, moist) clay loam; weak fine subangular blocky; few very weak clay cutans many very fine, common medium and few coarse biopores; very friable, slightly sticky and slightly plastic; clear and smooth transition to:

B21t 36-120 cm reddish brown (2.5YR 4/4, moist) clay; moderate to weak, fine to medium, subangular to angular blocky; abundant strong clay cutans; many very fine to fine, common medium and few coarse biopores; very friable, slightly sticky and slightly plastic; clear and smooth transition to:

B22 120-210 cm as above, but with a clay loam texture and few clay cutans

LABORATORY DATA OF PROFILE DESCRIPTION No: 6

FIELD OBSERVATION No: 130/3 - Ran2 MAPPING UNIT: FYh

Laboratory no. ...77/	323	324	325	326	327	
Horizon	A1	B1	B2	B2	B2	
Depth (cm)	0-18	18-36	36-80	80-120	120-180	
pH-H_2O(1: 5 v/v)	5.3	5.4	5.5	5.0	5.2	
pH-KCl ..	4.6	4.4	4.7	4.6	4.2	
EC(mmho/cm) ..						
$CaCO_3$(%)						
$CaSO_4$(%)						
C (%)	2.0	1.6	1.1	0.9	0.5	
N (%)	0.18					
C/N	11					
CEC (me/100g), pH 8.2	17.50	16.95	13.69	13.69	12.7	
CEC .. .. pH 7.0	12.0	11.8	12.0	9.5	8.9	
Exch.Ca (me/100g)	5.1	5.7	5.7	4.0	2.1	
.. Mg ..	2.1	2.2	2.8	2.6	1.6	
.. K ..	0.5	0.3	0.3	0.3	0.4	
.. Na ..	n.d.	n.d.	n.d.	n.d.	n.d.	
Sum of cations	7.7+	8.2+	8.8+	6.9+	4.1+	
Base sat. %, pH 8.2						
.. .. %, pH 7.0	64+	69+	73+	73+	46+	
ESP at pH 8.2						
Saturation extract:						
Moisture %						
pH-paste						
ECe (mmho/cm)						
Na (me/l)						
K ..						
Ca ..						
Mg ..						
Sum of cations(me/l)						
CO_3(me/l)						
HCO_3 ..						
Cl ..						
SO_4 ..						
Sum of anions(me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3(mol/mol)						
SiO_2/R_2O_3 ..						
Fe_2O_3(mmol%)						
X-ray report:						

SOIL CLASSIFICATION: Mollic* Nitosol

Depth (cm)	0-18	18-36	36-80	80-120	120-180	
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 – 0.05 mm						
Silt % 0.05–0.002mm						
Clay % 0.002–0 mm						
Texture class						
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 – 1.0mm	2.1	2.6	1.6	0.9	2.5	
.. .. 1.0 – 0.50mm	5.7	3.7	0.1	0.7	4.6	
.. .. 0.50 – 0.25 mm	13.8	5.3	5.2	3.3	5.9	
.. .. 0.25 – 0.10mm	17.3	6.5	7.4	4.4	13.0	
.. .. 0.10 – 0.05mm	10.0	3.8	5.5	3.6	7.0	
Total sand %	48.9	21.9	19.8	12.9	33.0	
Silt %	18.1	47.0	28.2	27.9	36.0	
Clay %	33.1	31.3	51.9	59.3	31.0	
Texture class	SCL	CL	C	C	CL	
Bulk density	1.02		1.04	1.16	1.01	
Moisture % w/v at:						
pF 0						
pF 2.0	47.7		46.5	50.0	52.4	
pF 2.3	46.3		45.7	48.6	51.0	
pF 2.5	45.0		44.2	46.7	48.5	
pF 3.0	31.6		30.2	26.0	26.5	
pF 3.6	23.7		22.9	27.9	23.8	
pF 4.2	17.5		16.9	21.7	23.0	
Fertility aspects: (0– 18cm)	Laboratory no. /					
Ca (me/100g)	6.4 Available			Total		
Mg ..	3.6					
K ..	1.26					
P (ppm)	8					
Mn (me/100g)	1.86					
Exch. acidity (me/100g)						
pH-H_2O (1: v/v)						
C%						
N%						

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Unit FBht, Profile 5

Soil classification: luvic Phaeozem; ST: oxic Argiudoll
Ecological zone: IIb
Observation: 130/2-C8, Kisii District, E 704.0, N 9934.1, 1800 m, 17-1-1977
Geological formation: bukoban system
Local petrography: basalts with some quartzite
Physiography: footslope
Surrounding landform: hilly
Relief - meso: convex outcrops on linear slope
Vegetation: no natural vegetation
Land use: coffee and some gum trees (Eucalyptus)
Erosion: nil
Surface stoniness: nil
Soil fauna: ants and termites
Slope gradient: 20%
Drainage class: well drained

A1	0-15 cm	dark reddish brown (5YR 3/2, moist and 5YR 4/2, dry) clay; strong very fine subangular blocky; friable, slightly sticky and slightly plastic; many very fine and few medium pores; clear and smooth transition to:
B21t	15-110 cm	dark red (2.5YR 3/6, moist and dry) clay; strong very fine angular blocky; moderate common clay cutans; friable, slightly sticky and slightly plastic; common very fine and few fine pores; clear and smooth transition to:
B22t	60-110 cm	(2.5YR 4/6, moist and dry) clay with 15% rotten rock and quartz gravel; strong very fine angular blocky; moderate common clay cutans; friable, slightly sticky and slightly plastic; few very fine pores; gradual and smooth transition to:
B3	110-160+ cm	reddish brown (2.5YR 4/4, moist) clay with 30% light red, rotton rock; moderate very fine angular blocky, friable, slightly sticky and slightly plastic; few fine pores

LABORATORY DATA OF PROFILE DESCRIPTION No: 7

FIELD OBSERVATION No: 130/4 - Ex10 MAPPING UNIT: FPg

Laboratory no. 76./	143	144	146	147		
Horizon	AI	B2t	A2	IIB2tg		
Depth (cm)	0-16	16-76	76-104	104+		
$pH-H_2O$(1:5 v/v)	5.1	-	-	-		
pH-KCl ..	-		-	-		
EC(mmho/cm) ..						
$CaCO_3$(%)						
$CaSO_4$(%)						
C (%)	1.8	1.5	0.36	0.45		
N (%)	0.19					
C/N	9					
CEC (me/100g), pH 8.2						
CEC .. .. pH 7.0	14.8	12.7	12.8	16.1		
Exch.Ca (me/100g)	5.9	4.5	6.8	10.0		
.. Mg ..	2.0	1.7	2.2	3.0		
.. K ..	0.5	0.5	1.1	1.8		
.. Na ..	N.d.	N.d.	N.d.	N.d.		
Sum of cations						
Base sat. %, pH 8.2						
.. .. %, pH 7.0	57+	53+	79+	92+		
ESP at pH 8.2						
Saturation extract:						
Moisture %						
pH-paste						
ECe (mmho/cm)						
Na(me/l)						
K ..						
Ca ..						
Mg ..						
Sum of cations(me/l)						
CO_3(me/l)						
HCO_3 ..						
Cl ..						
SO_4 ..						
Sum of anions(me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3(mol/mol)	3.2	2.8	3.7	2.7		
SiO_2/R_2O_3 ..	2.3	2.1	2.8	2.1		
Fe_2O_3(mmol%)	14.3	13.0	11.5	12.9		
X-ray report:						

SOIL CLASSIFICATION: Gleyic Luvisol

Depth (cm)	0-16	16-76	76-104	104+		
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 – 0.05 mm						
Silt % 0.05–0.002mm						
Clay % 0.002–0 mm						
Texture class						
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 – 1.0mm	1.0	0.1	1.2	1.2		
.. .. 1.0 – 0.50mm	2.7	1.8	3.2	1.9		
.. .. 0.50 – 0.25mm	5.0	5.8	4.7	4.1		
.. .. 0.25 – 0.10mm	5.1	6.3	10.7	6.1		
.. .. 0.10 – 0.05mm	7.5	3.1	5.0	7.1		
Total sand %	21.3	17.1	24.8	20.4		
Silt %	37.2	32.9	48.0	28.9		
Clay %	41.5	50.0	27.3	50.8		
Texture class	C	C	CL	C		
Bulk density						
Moisture % w/v at:						
pF 0						
pF 2.0						
pF 2.3						
pF 2.7						
pF 3.0						
pF 3.7						
pF 4.2						

Fertility aspects: (0–16 cm)	Laboratory no. /	
	Available	Total
Ca (me/100g)	14.0	
Mg ..	6.2	
K ..	1.08	
P (ppm)	19	
Mn (me/100g)	0.44	
Exch. acidity (me/100g)		
$pH-H_2O$ (1: v/v)		
C%		
N%		

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<u>Unit FPg, Profile 7</u>

Soil classification: gleyic Luvisol; ST. aquic thapto albic tropaqualfic Tropudalf
Ecological zone: II a
Observation: 130/4-Ex 10, Narok District, E 15.0, N 9891.8, 1815 m, 16-7-1975
Geological formation: bukoban system and quaternary volcanic ash deposits
Local petrography: quartzite with volcanic ash
Physiography: footslope of ridge
Surrounding landform: undulating to rolling
Relief - meso: linear to slightly concave slope
Vegetation: 5% shrubs, 95% grasses
Land use: extensive grazing
Erosion: "Landslides"
Surface stoniness: class 2, tillage impractical
Soil fauna: termites, ants
Slope gradient: 6%
Drainage class: imperfectly drained

A1	0-16 cm	dark reddish brown (5YR 3/2, moist) clay; strong fine and subangular blocky; few very fine biopores; slightly hard, slightly sticky and slightly plastic; clear and smoooth transition to:
B2t	16-76 cm	reddish brown (2.5YR 4/4, moist); common medium, distinct, black mottles; clay; moderate, fine subangular blocky; patchy thin clay cutans, common fine and many very fine biopores; friable, slightly sticky and slightly plastic; gradual and smooth transition to:
B2t + A2	76-104 cm	reddish brown (2.5-5YR 4/4, moist), pink (5YR 7/4 dry); common, medium, distinct black mottles; loam to clayloam; moderate fine angular blocky; few medium, common fine, many very fine biopores; slightly hard, friable, slightly sticky and slightly plastic; abrupt and wavy transition to:
IIB2t	104-164 cm	dark red (5YR 3/6, moist); many medium distinct black mottles; clay; moderate to strong fine angular blocky; continuous thick clay-humus-manganese cutans; common very fine, few fine biopores; hard, firm, sticky and plastic

LABORATORY DATA OF PROFILE DESCRIPTION No: 8

FIELD OBSERVATION No: 130/4-C3 MAPPING UNIT: FQh

Laboratory no. ..77/	502	503	504			
Horizon	A1	B1	B2t			
Depth (cm)	0-25	25-50	50-100			
pH-H_2O(1: 5 v/v)	4.7	4.8	5.2			
pH-KCl ..	4.3	4.2	4.3			
EC(mmho/cm) ..	0.25	0.10	0.07			
$CaCO_3$(%)						
$CaSO_4$(%)						
C (%)	2.9	1.8	1.1			
N (%)	0.29					
C/N	10					
CEC (me/100g), pH 8.2						
CEC .. .. pH 7.0	21.3	17.2	17.6			
Exch.Ca (me/100g)	4.7	3.2	4.5			
.. Mg ..	3.3	2.8	3.3			
.. K ..	0.6	0.4	0.3			
.. Na ..	0.1	0.1	0.2			
Sum of cations	8.7	6.5	8.3			
Base sat. %, pH 8.2						
.. .. %, pH 7.0	41	38	47			
ESP at pH 8.2						
Saturation extract:						
Moisture %						
pH-paste						
ECe (mmho/cm)						
Na (me/l)						
K ..						
Ca ..						
Mg ..						
Sum of cations(me/l)						
CO_3(me/l)						
HCO_3 ..						
Cl ..						
SO_4 ..						
Sum of anions(me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3(mol/mol)						
SiO_2/R_2O_3 ..						
Fe_2O_3(mmol%)						
X-ray report:						

SOIL CLASSIFICATION: Humic Acrisol

Depth (cm)	0-25	25-50	50-100			
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 – 0.05 mm						
Silt % 0.05–0.002mm						
Clay % 0.002–0 mm						
Texture class						
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 – 1.0mm	2.6	1.7	1.0			
.. .. 1.0 – 0.50mm	3.1	2.2	1.7			
.. .. 0.50 – 0.25mm	5.9	7.1	3.7			
.. .. 0.25 – 0.10mm	6.1	8.1	4.3			
.. .. 0.10 – 0.05mm	2.1	2.4	2.1			
Total sand %	19.8	21.5	12.8			
Silt %	36.9	24.6	26.5			
Clay %	43.4	54.0	60.6			
Texture class	C	C	C			
Bulk density						
Moisture % w/v at:						
pF 0						
pF 2.0						
pF 2.3						
pF 2.7						
pF 3.0						
pF 3.7						
pF 4.2						

Fertility aspects: (0– cm)	Laboratory no. /	
	Available	Total
Ca (me/100g)	3.2	
Mg ..	2.6	
K ..	0.46	
P (ppm)	4	
Mn (me/100g)	0.89	
Exch. acidity (me/100g)		
pH-H_2O (1: v/v)		
C%		
N%		
Silt clay ratio	0.4	
CEC (me/100g clay)	20	

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Unit FQh, Profile 8

Soil classification: humic Acrisol; ST: oxic Tropudalf
Ecological zone: II a
Observation: 130/4-C3, Narok district, E 713.5, N 9890.7, 1861 m, 6-1-1977
Geological formation: bukoban system overlain with quaternary volcanic ash
Local petrography: quartzite and volcanic ash
Physiography: footslope
Surrounding landform: rolling to hilly
Relief - meso: uniform lateral slope about 100 m long
Vegetation: clustered shrubs in grassland
Land use: extensive grazing
Erosion: nil
Surface stoniness: nil
Soil fauna: termites
Slope gradient: 10%
Drainage class: well drained

A1 0-25 cm dark reddish brown (5YR 2/2, moist) clay; strong very fine subangular blocky; friable, slightly sticky and slightly plastic; many very fine pores; many fine roots; clear and smooth transition to:

B1 25-50 cm dark reddish brown (5YR 3/3, moist) clay; friable, slightly sticky and slightly plastic; strong very fine subangular blocky, common very fine pores; common fine roots; clear and smooth transition to:

B2t 50-100 cm reddish brown (5YR 4/4, moist) clay; moderate very fine angular blocky; common thin clay and manganese cutans, slightly sticky and slightly plastic; common very fine pores; very fine roots; abrupt and wavy transition

LABORATORY DATA OF PROFILE DESCRIPTION No: 9

FIELD OBSERVATION No: 130/4 Nyan 8 MAPPING UNIT: U1Ph

Laboratory no. ..76 /	148	149	150	151	152	153
Horizon	A1	B1	B2	B3	C1	
Depth (cm) of sampling	0-23	23-55	55-81	81-125	125-160	160-230
pH-H_2O(1:5 v/v)						
pH-KCl ..						
EC(mmho/cm) ..						
$CaCO_3$(%)						
$CaSO_4$(%)						
C (%)	2.4	1.8	0.9	0.3	0.1	
N (%)						
C/N						
CEC (me/100g), pH 8.2	20.1	15.2	10.3	11.4	9.5	
CEC .. .. pH 7.0	14.3	11.5	9.8	8.8	9.0	10.4
Exch.Ca (me/100g)	6.2	5.8	4.8	3.2	2.5	2.3
.. Mg ..	1.2	1.7	1.9	2.7	3.0	0.7
.. K ..	1.2	0.6	0.6	0.7	0.9	1.1
.. Na ..	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Sum of cations	8.6+	8.1+	7.3+	6.6+	6.4	4.1+
Base sat. %, pH 8.2						
.. .. %, pH 7.0	60+	70+	74+	75+	71+	39+
ESP at pH 8.2						
Saturation extract:						
Moisture %						
pH-paste						
ECe (mmho/cm)						
Na (me/l)						
K ..						
Ca ..						
Mg ..						
Sum of cations(me/l)						
CO_3(me/l)						
HCO_3 ..						
Cl ..						
SO_4 ..						
Sum of anions(me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3(mol/mol)	3.3	3.1	2.9	2.9	2.8	3.2
SiO_2/R_2O_3 ..	2.2	2.1	2.0	2.1	2.1	2.3
Fe_2O_3(mmol%)	15.5	15.8	16.1	15.4	14.5	14.1
X-ray report:						

)* Determined in Serengeti research station

SOIL CLASSIFICATION: Luvic PHAEOZEM

Depth (cm)	0-23	23-55	55-81	81-125	125-160	
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 – 0.05 mm						
Silt % 0.05–0.002mm						
Clay % 0.002–0 mm						
Texture class						
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 – 1.0mm	0.8	0.8	0.7	2.3	8.6	
.. .. 1.0 – 0.50mm	2.5	2.9	2.6	5.9	9.0	
.. .. 0.50 – 0.25mm	3.9	5.4	4.0	5.5	6.7	
.. .. 0.25 – 0.10mm	6.3	6.5	5.8	7.1	9.3	
.. .. 0.10 – 0.05mm	3.3	5.5	4.3	5.0	7.9	
Total sand %	16.8	21.1	17.4	25.8	41.5	
Silt %	52.0	51.0	54.3	42.9	22.5	
Clay %	31.3	27.9	28.2	31.3	36.0	
Texture class	SiCL	SiL	SiCL	CL	CL	
Bulk density	0.98	1.13	1.12	1.10		
Moisture % w/v at:						
pF 0	58.3	52.0	49.0	51.3	51.9	
pF 2.0	41.4	41.2	37.2	36.6	37.7	
pF 2.3	39.9	40.7	36.3	35.7	36.9	
pF 2.8	35.3	37.0	32.7	32.5	33.9	
pF 3.0	27.4	25.8	25.2	27.0	26.0	
pF 3.6	17.7	21.0	19.4	20.4	21.3	
pF 4.2	15.7	18.6	18.2	17.4	20.1	

Fertility aspects: (0–23 cm)	Laboratory no. /	
Ca (me/100g)	Available	Total
Mg ..		
K ..		
P (ppm)		
Mn (me/100g)		
Exch. acidity (me/100g)		
pH-H_2O (1: v/v)		
C%		
N%		

CEC(me/100g clay)	63.9	54.3	36.6	36.5	26.4
Ech AC	0.7	0.6	0.6	0.4	0.5
Ech H	<0.1	< 0.1	-	-	< 0.1

Kenya Soil Survey
Drawing No. 79050

Unit U1Ph, Profile 9

Soil classification: luvic Phaeozem; ST: oxic Argiudoll
Ecological zone: II a
Observation: 130/4-Nyan.8, Kisii District, E 721.2, N 9913.6, 2021 m, 22-7-1975
Geological formation: bukoban system overlain with quaternary volcanic ash
Local petrography: rhyolite with volcanic ash
Physiography: Keroka upland (Tinderet Range)
Surrounding landform: rolling
Relief - meso: lateral slope
Vegetation: no natural vegetation
Land use: grazing
Erosion: slight
Surface stoniness: nil
Soil fauna: ants and other insects
Slope gradient: 12%
Drainage class: moderately well drained

A1 0-23 cm — dark reddish brown (5YR 3/2-3/3, moist) silty clay loam; moderate, very fine granular to crumb structure; very friable, slightly sticky and slightly plastic; many very fine biopores; abrupt and smooth transition to:

A3 23-55 cm — dark reddish brown (5YR 3/2-3/4, moist) silty clay loam; weak, very fine subangular blocky; very friable, slightly sticky and slightly plastic to plastic; few Fe-Mn concretions, ca 3 mm; common, very fine biopores; clear and smooth transition to:

B2 55-81 cm — dark reddish brown (2.5YR 3/4, moist) silty clay loam; moderate very fine subangular blocky; very friable, slightly sticky, slightly plastic; few Fe-Mn concretions (2%) 5 mm diameter; common very fine biopores clear and smooth transition to:

B3 81-96/135 cm — dark reddish brown (2.5YR 3/4, moist) clay loam; moderate strong, very fine subangular blocky, friable, sticky and plastic; continuous, moderately thick clay cutans; Fe-Mn concretions, ca 40% common, very fine biopores; abrupt and wavy irregular transition to:

C1 96/135-375 cm — mottled clay loam; 80% Fe-Mn concretions, few quartz pebbles; abrupt and wavy transition to:

C2 375+ cm — reddish yellow (7.5YR 6/6) material; soft

LABORATORY DATA OF PROFILE DESCRIPTION No: 10

FIELDOBSERVATION No: 130/4 - C1 MAPPING UNIT: U1XhP SOIL CLASSIFICATION: RANKER

Laboratory no. . 77. /	496	497	498			
Horizon	A1	B1	B+C			
Depth (cm)	0-15	15-40	40-60			
pH-H_2O(1: 5 v/v)	4.5	4.3	4.4			
pH-KCl ..	4.1	4.0	4.0			
EC(mmho/cm) ..	0.08	0.03	0.02			
$CaCO_3$(%)						
$CaSO_4$(%)						
C (%)	2.6	2.1	1.5			
N (%)	0.35					
C/N	7					
CEC (me/100g), pH 8.2						
CEC .. .. pH 7.0	10.9	11.7	6.0			
Exch.Ca (me/100g)	0.5	0.2	0.			
.. Mg ..	0.2	0.1	0.1			
.. K ..	0.2	0.2	0.1			
.. Na ..	0.1	0.1	0.0			
Sum of cations	1.0	0.6	0.7			
Base sat. %, pH 8.2						
.. .. %, pH 7.0	9	5	9			
ESP at pH 8.2						
Saturation extract:						
Moisture %						
pH-paste						
ECe (mmho/cm)						
Na(me/l)						
K ..						
Ca ..		.				
Mg ..						
Sum of cations(me/l)						
CO_3(me/l)						
HCO_3 ..						
Cl ..						
SO_4 ..						
Sum of anions(me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3(mol/mol)						
SiO_2/R_2O_3 ..						
Fe_2O_3(mmol%)						
X-ray report:						

Depth (cm)	0-15	15-40	40-60			
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 – 0.05 mm	51	39	39			
Silt % 0.05–0.002mm	12	16	18			
Clay % 0.002–0 mm	37	45	43			
Texture class	S C	C	C			
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 – 1.0mm	33.5	28.0	15.0			
.. .. 1.0 – 0.50mm	7.5	8.3	10.4			
.. .. 0.50 – 0.25mm	6.7	7.1	7.5			
.. .. 0.25 – 0.10mm	4.6	4.6	6.0			
.. .. 0.10 – 0.05mm	2.0	2.3	3.9			
Total sand %	54.3	50.3	42.8			
Silt %	11.8	16.9	17.0			
Clay %	34.0	32.8	39.9			
Texture class	SCL	SCL	CL			
Bulk density						
Moisture % w/v at:						
pF 0						
pF 2.0						
pF 2.3						
pF 2.7						
pF 3.0						
pF 3.7						
pF 4.2						

Fertility aspects: (0– 15cm)	Laboratory no. /	
	Available	Total
Ca (me/100g)	0.2	
Mg ..	0.2	
K ..	0.26	
P (ppm)	4	
Mn (me/100g)	0.26	
Exch. acidity (me/100g)		
pH-H_2O (1: v/v)		
C%		
N%		
Silt/clay ratio	0.5	

Kenya Soil Survey
Drawing No. 79050

Unit U1XhP, Profile 10

Soil classification: Ranker; ST: lithic oxic Humitropept
Ecological zone: II a
Observation: 130/4-C1, Kisii District, E 718.8, N 9909.3, 2089 m, 6-1-1977
Geological formation: bukoban system
Local petrography: rhyolites and rhyolitic tuffs
Physiography: undulating narrow ridge-tops
Surrounding landform: undulating to hilly
Relief - meso: convex upper part of linear slope
Vegetation: bushed grassland with some black wattle
Land use: extensive grazing
Erosion: nil
Surface stoniness: no stones
Soil fauna: termites
Slope gradient: 25%
Drainage class: somewhat excessively drained

A1	0-15 cm	dark reddish brown (5YR 3/3, moist) very gravelly sandy clay loam; moderate very fine subangular blocky; very friable, slightly sticky and slightly plastic; many very fine roots; clear and smooth transition to:
B1	15-40 cm	dark reddish brown (5YR 3/4, moist) very gravelly sandy clay loam; moderate very fine subangular blocky; very friable, slightly sticky and slightly plastic; common fine roots; diffuse and smooth transition to:
B+C	40-60 cm	dark reddish brown (2.5YR 3.5/4, moist) very gravelly clay loam in between 60% rotten rock; moderate, very fine subangular blocky; very friable, slightly sticky and slightly plastic; common fine roots diffuse and smooth transition to:
C	60+ cm	rotten rock with some B material in cracks

LABORATORY DATA OF PROFILE DESCRIPTION No: 11

FIELDOBSERVATION No: 130/3 - 201 MAPPING UNIT: U1Xh SOIL CLASSIFICATION: Luvic haplic PHAEOZEM

Laboratory no. . 74 /	194	195	196	197	198	199
Horizon	Ap	A1.2	B2t	B3	B3	R
Depth (cm)	0-18	18-35	35-47	47-100	100-140	140-190
pH-H_2O(1: 5 v/v)	5.6	5.8	5.7	5.9	5.6	5.2
pH-KCl ..	4.6	4.5	4.3	4.3	4.5	4.5
EC(mmho/cm) ..						
$CaCO_3$ (%)						
$CaSO_4$ (%)						
C (%) *)	5.0	3.8	2.5	0.5	0.2	
N (%)	0.49	0.26	0.17	0.04	0.03	
C/N	10	15	15	12	7	
CEC (me/100g), pH 8.2						
CEC .. .. pH 7.0	26.3	27.9	17.7	8.0	6.6	2.6
Exch.Ca (me/100g)	12.1	11.0	5.8	0.8	0.6	0.3
.. Mg ..	3.3	3.1	2.0	0.3	0.2	0.1
.. K ..	1.2	0.5	0.4	0.1	0.1	0.1
.. Na ..	tr	tr	tr	tr	tr	tr
Sum of cations	16.6	14.6	8.2	1.2	0.9	0.8
Base sat. %, pH 8.2						
.. .. %, pH 7.0	63	59	46	15	14	31
ESP at pH 8.2						
Saturation extract:						
Moisture %						
pH-paste						
ECe (mmho/cm)						
Na (me/l)						
K ..						
Ca ..						
Mg ..						
Sum of cations(me/l)						
CO_3 (me/l)						
HCO_3 ..						
Cl ..						
SO_4 ..						
Sum of anions(me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3(mol/mol)	[illegible]	[illegible]	[illegible]	2.0	2.0	[illegible]
SiO_2/R_2O_3 ..	1.6	1.5	1.5	1.5	1.5	1.7
Fe_2O_3(mmol%)	108	111	111	107	106	58
X-ray report:						

*) Method Schollenberger

Depth (cm)	0-18	18-35	35-47	47-100	100-140	140-190
Gravel %	11.9	8.7	4.2	39.0	51.1	59.3
Texture, limited pretreatment:						
Sand % 2.0 – 0.05 mm						
Silt % 0.05–0.002mm						
Clay % 0.002–0 mm						
Texture class						
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 – 1.0mm						
.. .. 1.0 – 0.50mm						
.. .. 0.50 – 0.25mm						
.. .. 0.25 – 0.10mm						
.. .. 0.10 – 0.05mm						
Total sand %	11.7	11.0	8.7	35.9	28.4	32.1
Silt %	23.6	20.5	21.0	27.6	30.6	42.2
Clay %	64.7	68.5	70.3	36.5	41.0	25.7
Texture class	C	C	C	CL	C	L
Bulk density		0.86				
Moisture % w/v at:						
pF 0		69.3				
pF 2.0		40.6				
pF 2.3		28.0				
pF 2.7		26.3				
pF 3.0		24.0				
pF 3.7		21.0				
pF 4.2		20.1				
Fertility aspects: (0–18cm)	Laboratory no. /					
Ca (me/100g)	Available			Total		
Mg ..						
K ..						
P (ppm)						
Mn (me/100g)						
Exch. acidity (me/100g)	4.6	5.6	13.7	33.7	36.4	38.5
pH-H_2O (1: v/v)						
C%						
N%						
[illegible] (me/100g clay)	40.6	36.4	27.9	21.[illegible]	16.1	10.2
P205 ppm	85	50	25	5		
"Free" FE203	7.7	5.8	6.0	8.6	6.9	5.7
"Free" AL203	12.3	11.3	11.7	16.4	7.4	5.1

Kenya Soil Survey
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Unit U1Xh, Profile 11

Soil classification: luvic to haplic Phaeozem; ST: oxic Argiudoll to typic-Humitropept
Ecological zone: II a
Observation: 130/3-201, Kisii District, E 686.3, N 9911.5, 1860 m, 15-2-1974
Geological formation: bukoban system
Local petrography: non porphyritic, vesicle rich felsite
Physiography: summit of small hill
Surrounding landform: rolling plateau
Relief - meso: single slope, very gently sloping
Vegetation: no natural vegetation
Land use: cultivated (maize)
Erosion: nil
Surface stoniness: interferes with tillage (class I)
Soil fauna: some termites and ants
Slope gradient: 3%
Drainage class: well drained

Ap 0-18 cm dark brown to dark reddish brown (7.5YR 3/3, dry) clay; moderate very fine and fine continuous, random, inped, tubular biopores; slightly hard, non-sticky and slightly plastic common very fine and fine roots, few medium roots; very fine rounded and weathering gravel of felsite and quartz; clear and wavy transition to:

B1t 18-35 cm dark brown to dark reddish brown (7.5YR 3/3, dry) clay; weak very fine subangular blocky; common very fine continuous, random, inped, tubular biopores; slightly sticky and slightly plastic; very few fine distinct clear yellow and light red mottles; common very fine and fine, few medium roots; thin and continuous cutans; very few rounded and weathering gravel of felsite and quartz; clear and smooth transition to:

B2t 35-47 cm dark reddish brown (5YR 3/3-3/4, dry) clay; moderate fine subangular to angular blocky; common very fine and fine continuous, random, inped, tubular biopores; slightly hard to hard, slightly sticky and slightly plastic; few fine and medium distinct clear yellow, light red to red and white mottles, common very fine and fine few medium and large roots; thin and continuous clay cutans; few rounded and angular gravel of felsite and quartz; clear and smooth transition to:

B3 47-140 cm reddish brown (5YR 4/4, moist) clay loam; moderate fine subangular to angular blocky; common very fine and few fine, discontinuous, random, inped, tubular biopores; friable, slightly sticky and slightly plastic; many medium and coarse prominent, clear yellow, red and purple weathering mottles; common very fine and fine roots; thin and continuous cutans; strongly weathered rotten rock; very many rounded, weathered gravel and stones of felsite; clear and broken transition to:

R 140-190 cm partly rotten rock and more solid rock of felsite with fresh yellow, red, purple and white weathering colours.

LABORATORY DATA OF PROFILE DESCRIPTION No: 12

FIELD OBSERVATION No: 130/2 - Sch8 MAPPING UNIT: UIXh

Laboratory no. 77 /	467	468	469	470		
Horizon	Ap	B1	B2	B3		
Depth (cm)	0-10	10-55	55-80	80-160		
pH-H_2O(1:5 v/v)	4.7	4.5	4.5	4.6		
pH-KCl ..	4.0	3.9	3.9	4.0		
EC(mmho/cm) ..						
$CaCO_3$(%)						
$CaSO_4$(%)						
C (%)	4.0	3.3	2.5	1.1		
N (%)	0.38					
C/N	10					
CEC (me/100g), pH 8.2						
CEC .. .. pH 7.0	21.6	16.2	14.2	11.1		
Exch.Ca (me/100g)	3.8	1.5	1.7	2.1		
.. Mg ..	1.2	0.5	0.7	0.6		
.. K ..	Nd	Nd	Nd	Nd		
.. Na ..	1.0	0.5	0.3	0.3		
Sum of cations						
Base sat. %, pH 8.2						
.. .. %, pH 7.0	28+	15+	19+	27+		
ESP at pH 8.2						
Saturation extract:						
Moisture %						
pH-paste						
ECe (mmho/cm)						
Na(me/l)						
K ..						
Ca ..						
Mg ..						
Sum of cations(me/l)						
CO_3(me/l)						
HCO_3 ..						
Cl ..						
SO_4 ..						
Sum of anions(me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3(mol/mol)						
SiO_2/R_2O_3 ..						
Fe_2O_3(mmol%)						
X-ray report:						

SOIL CLASSIFICATION: Humic ACRISOL

Depth (cm)	0-10	10-55	55-80	80-160		
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 - 0.05 mm						
Silt % 0.05-0.002mm						
Clay % 0.002-0 mm						
Texture class						
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 - 1.0mm	4.9	4.8	5.0	9.6		
.. .. 1.0 - 0.50mm	6.3	6.5	6.4	9.7		
.. .. 0.50 - 0.25mm	6.4	6.4	6.3	7.7		
.. .. 0.25 - 0.10mm	6.5	6.8	6.6	7.9		
.. .. 0.10 - 0.05mm	5.6	5.8	5.8	7.0		
Total sand %	29.7	30.3	30.1	41.9		
Silt %	30.7	24.2	19.4	16.0		
Clay %	39.7	45.6	50.3	42.1		
Texture class	CL	C	C	C		
Bulk density	0.9	1.03	1.28			
Moisture % w/v at:						
pF 0						
pF 2.0	60.9	48.8	48.7			
pF 2.3						
pF 2.7						
pF 3.0	30.0	39.9				
pF 3.7						
pF 4.2						

Fertility aspects: (0-10 cm)	Laboratory no. 77 / 381	
	Available	Total
Ca (me/100g)	0.2	
Mg ..	Trace	
K ..	0.17	
P (ppm)	6	
Mn (me/100g)	0.42	
Exch. acidity (me/100g)		
pH-H_2O (1: v/v)		
C%		
N%		

Kenya Soil Survey
Drawing No. 79050

Unit UIXh, Profile 12

Soil classification: humic Acrisol ST: humoxic Tropohumult
Ecological zone: II a
Observation: 130/2-Sch VIII, Kisii District, E 710.3, N 9926, 1930 m, 22-1-1975
Geological formation: bukoban system
Local petrography: andesites
Physiography: lower part of convex valley slope
Surrounding landform: steeply dissected; hilly
Relief - meso: linear slope
Vegetation: 50% grasses, 50% herbs (mexican merigold, black jack)
Land use: cultivated (maize, fallow when surveyed)
Erosion: slight sheet erosion
Surface stoniness: nil
Soil fauna: ants and termites
Slope gradient: 29%
Drainage class: well drained

Ap	0-10 cm	reddish brown (5YR 4/3 dry) dark reddish brown (5YR 3/2 moist) clay loam to clay; moderate very fine subangular blocky; loose, very friable, slightly sticky and slightly plastic; many very fine, many fine and few medium pores, abrupt and smooth transition to:
B1t	10-55 cm	reddish brown (5YR 4/4, dry), dark reddish brown (5YR 3/3, moist) clay; moderate medium angular blocky; patchy, thin clay cutans; hard, friable, slightly sticky and slightly plastic; many fine and very fine, few medium and coarse pores; occasionally krotovinas (20 cm diameter) clear wavy transition to:
B2t	55-80 cm	red (2.5YR 4/6) very gravelly clay with many pieces of multicoloured rotten rock; moderate fine angular blocky; patchy thin clay cutans; friable, slightly sticky and slightly plastic; many very fine and fine pores; very few black manganese concretions gradual and wavy transition to:
B3t	80-160 cm	red (2.5YR 4/6) very gravelly clay; multicoloured rotten rock; moderate very fine subangular blocky; friable, slightly sticky and slightly plastic; broken, moderate thick clay cutans; common very fine pores; many coarse broken thick manganese coatings; common very fine pores; many coarse black manganese concretions.

LABORATORY DATA OF PROFILE DESCRIPTION No: 13

FIELD OBSERVATION No: 130/2 - C6 MAPPING UNIT: U1Bh

Laboratory no. ...77/	511	512	513	514		
Horizon	A1	B1	B21	B2.2		
Depth (cm)	0-40	40-90	90-130	130-180		
pH-H_2O(1: 5 v/v)	5.1	5.3	5.4	5.4		
pH-KCl ..	4.5	4.7	5.0	5.2		
EC(mmho/cm) ..	0.12	0.09	0.07	0.05		
$CaCO_3$ (%)						
$CaSO_4$ (%)						
C (%)	[illegible]	0.96	0.77	0.23		
N (%)	0.21					
C/N	10					
CEC (me/100g), pH 8.2						
CEC .. .. pH 7.0	22.4	16.2	13.2	10.2		
Exch.Ca (me/100g)	8.0	4.1	3.0	2.3		
.. Mg ..	3.2	2.2	2.8	2.7		
.. K ..	0.6	1.1	0.8	0.3		
.. Na ..	0.1	0.1	0.1	0.6		
Sum of cations	11.9	7.5	6.7	5.9		
Base sat. %, pH 8.2						
.. .. %, pH 7.0	53	46	51	58		
ESP at pH 8.2						
Saturation extract:						
Moisture %						
pH-paste						
ECe (mmho/cm)						
Na (me/l)						
K ..						
Ca ..						
Mg ..						
Sum of cations(me/l)						
CO_3 (me/l)						
HCO_3 ..						
Cl ..						
SO_4 ..						
Sum of anions(me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3(mol/mol)						
SiO_2/R_2O_3 ..						
Fe_2O_3(mmol%)						
X-ray report:						

SOIL CLASSIFICATION: Mollic NITOSOL

Depth (cm)	0-40	40-90	90-130	130-180		
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 - 0.05 mm						
Silt % 0.05-0.002mm						
Clay % 0.002-0 mm						
Texture class						
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 - 1.0mm	0.4	0.7	0.7	1.5		
.. .. 1.0 - 0.50mm	0.5	0.6	0.8	0.8		
.. .. 0.50 - 0.25mm	0.5	0.4	0.7	0.5		
.. .. 0.25 - 0.10mm	1.0	0.7	0.8	0.5		
.. .. 0.10 - 0.05mm	1.0	0.7	1.2	0.7		
Total sand %	3.4	3.1	4.2	4.0		
Silt %	40.9	16.7	15.6	25.4		
Clay %	55.6	80.2	80.2	70.6		
Texture class	C	C	C	C		
Bulk density						
Moisture % w/v at:						
pF 0						
pF 2.0						
pF 2.3						
pF 2.7						
pF 3.0						
pF 3.7						
pF 4.2						

Fertility aspects: (0-40cm)	Laboratory no. 77/390	
Ca (me/100g)	12.4 Available	Total
Mg ..	3.4	
K ..	1.47	
P (ppm)	16	
Mn (me/100g)	0.84	
Exch. acidity (me/100g)		
pH-H_2O (1: v/v)		
C%		
N%		
Silt/clayratio	0.2	
CEC(me/100g clay)	11	

Kenya Soil Survey
Drawing No. 79050

Unit U1Bh, Profile 13

Soil classification: mollic Nitosol ST: typic Paleudoll
Ecological zone: II a
Observation: 130/2-C6, Kisii District, E 695.5, N 9924.7, 1839 m, 13-1-1977
Geological formation: bukoban system
Local petrography: basalt
Physiography: plateau remnant
Surrounding landform: hilly
Relief - meso: slight convex slope
Vegetation: no natural vegetation
Land use: cultivated (bananas)
Erosion: nil
Surface stoniness: nil
Soil fauna: some termites
Slope gradient: 0%
Drainage class: well drained

A 0-14 cm dark reddish brown (5YR 3/3, moist) clay; strong very fine subangular blocky; very friable, slightly sticky and slightly plastic; common very fine, few fine pores; gradual smooth transition to:

B1t 40-90 cm dark reddish brown (2.5YR 3/4, moist) clay; strong very fine angular blocky, thin common clay cutans; very friable, slightly sticky and slightly plastic; common very fine pores; gradual and smooth transition to:

B21t 90-130 cm dark red (2.5YR 3/3, moist) clay; strong very fine angular blocky; moderate common clay cutans; very friable, slightly sticky and slightly plastic; few very fine pores; abrupt and smooth transition to:

B22t 130-180 cm dark red (2.5YR 3/6, moist) clay with 10% rotten rock and quartz gravel on transition form B21 to B22; moderate very fine angular blocky; thin common clay cutans; very friable, slightly sticky and slightly plastic; few very fine pores.

LABORATORY DATA OF PROFILE DESCRIPTION No: 14

FIELD OBSERVATION No: 130/3 - 203 MAPPING UNIT: U1Ihn

Laboratory no. 14../	00/201	202/203	205	208	209	211
Horizon	Ap	A1.2	A3	B1	B2.2t	B2.3t
Depth (cm)	0-20	20-55	55-77	77-130	130-155	180-250
pH-H_2O(1: 5 v/v)	6.6	6.7	6.7	6.8	6.6	6.5
pH-KCl ..	5.8	5.7	5.6	5.6	5.1	4.9
EC(mmho/cm) ..						
$CaCO_3$(%)	0.13	0.08	N.d	N.d.	N.d	N.d
$CaSO_4$(%)						
C (%)	3.5	2.4	1.6	0.6	0.3	N.d
N (%)	0.41	0.30	0.19	0.11	0.06	-
C/N	9	8	8	6	5	-
CEC (me/100g), pH 8.2						
CEC .. .. pH 7.0	25.7	23.6	18.3	14.7	12.8	12.7
Exch.Ca (me/100g)	18.8	15.7	10.2	6.6	2.8	2.9
.. Mg ..	5.2	5.7	3.8	1.8	1.8	1.2
.. K ..	0.3	0.6	2.1	1.7	0.8	tr
.. Na ..	tr	tr	tr	tr	tr	tr
Sum of cations	24.3	20.8	16.1	10.1	5.4	4.1
Base sat. %, pH 8.2						
.. .. %, pH 7.0	95	88	88	69	42	32
ESP at pH 8.2						
Saturation extract:						
Moisture %						
pH-paste						
ECe (mmho/cm)						
Na(me/l)						
K ..						
Ca ..						
Mg ..						
Sum of cations(me/l)						
CO_3(me/l)						
HCO_3 ..						
Cl ..						
SO_4 ..						
Sum of anions(me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3(mol/mol)	2.3	2.2	2.1	2.1	2.1	2.1
SiO_2/R_2O_3 ..	1.6	1.6	1.5	1.5	1.5	1.6
Fe_2O_3(mmol%)	108	109	111	106	104	102
X-ray report:						

SOIL CLASSIFICATION: Dystro* Mollic* NITOSOL

Depth (cm)	0-20	20-55	55-77	77-130	130-155	180-250
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 – 0.05 mm						
Silt % 0.05–0.002mm						
Clay % 0.002–0 mm						
Texture class						
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 – 1.0mm						
.. .. 1.0 – 0.50mm						
.. .. 0.50 – 0.25mm						
.. .. 0.25 – 0.10mm						
.. .. 0.10 – 0.05mm						
Total sand %	7.8	5.6	4.6	3.6	3.0	2.8
Silt %	29.3	25.5	16.9	14.0	14.4	13.6
Clay %	63.0	69.1	78.5	82.2	82.6	83.5
Texture class	C	C	C	C	C	C
Bulk density	0.87	0.86	0.94	1.09	1.16	
Moisture % w/v at:			85-90			
pF 0	63.9	65.4	60.4	61.9	62.8	
pF 2.0	35.2	40.8	46.3	52.3	52.5	
pF 2.5	31.0	31.0	37.0	42.3	46.5	
pF 2.7	N.d	N.d	N.d	N.d	N.d	
pF 3.0	27.7	23.6	30.8	33.9	37.5	
pF 3.6	24.2	21.5	29.0	31.9	33.6	
pF 4.2	22.8	20.4	28.5	30.5	32.8	
Fertility aspects: (0– cm)		Laboratory no. 77 / 392				
Ca (me/100g)	24.0	Available			Total	
Mg ..	5.8					
K ..	2.5					
P (ppm)	30					
Mn (me/100g)	1.1					
Exch. acidity (me/100g)	0.9	1.3	N.d	2.4	7.7	
pH-H_2O (1: v/v)						
C%						
N%						
Silt/clay ratio	0.5	0.7	0.2	0.2	0.2	0.2
P205 ppm	84	17	-	-	-	-
"Free" Fe203	4.4	4.9	5.2	6.3	6.7	6.7

Kenya Soil Survey
Drawing No. 79050

Unit U1Ihn, Profile 14

Soil classification: mollic* or dystro*-mollic* Nitosol; ST: orthoxic Palehumult or typic Paleudoll
Ecological zone: II a
Observation: 1303/-203, Kisii District, E 686.3, N 9911.7, 1841 m, 16-2-1977
Geological formation: bukoban system, (precambriam), upper Kisii series
Local petrography: non-porphyritic vesicle rich felsite
Physiography: uniform lower slope
Surrounding landform: rolling plateau
Relief - meso: single slope
Vegetation: no natural vegetation
Land use: cultivated (bananas, maize)
Erosion: nil
Surface stoniness: no stones
Soil fauna: termites
Slope gradient: 7%
Drainage class: well drained

Ap	0-20 cm	dark brown (7.5YR 3/2, moist) clay; moderate very fine subangular blocky to crumby structure; common very fine and fine, few medium, *random, inped, continuous, tubular biopores;* very friable, slightly sticky and plastic; thin and patchy cutans; few fresh and partly weathered quartzite gravel; frequent very fine and few medium roots; common rodent burrows (diameter 10 cm); clear and wavy transition to:
A3	20-55 cm	dark reddish brown (5YR 3/2, moist) clay moderate very fine subangular blocky; common very fine, and few medium, random, inped, continuous, tubular biopores; friable, slightly sticky and plastic; few to common medium and coarse, distinct clear dark reddish brown to dark red (2.5YR 3/5) mottles; thin and continuous cutans; common very fine and fine, frequent medium roots; common krotovinas; clear and wavy transition to:
B1t	55-77 cm	dark reddish brown (5YR 3/2-3/3, moist) clay; fine subangular to angular blocky; common very fine and fine random, continuous, inped, tubular biopores; friable slightly sticky and slightly plastic; few fine, distinct clear, dark reddish brown to dark red (2.5YR 3/4) mottles; moderate thick and continuous cutans; few fine and very fine, common medium roots; large krotovinas filled with dark brown (7.5YR 3/2) topsoil; rodent burrows (diameter 3-6 cm) common; gradual and wavy transition to:
B21t	77-130 cm	dark reddish brown (2.5YR 3/4, moist) clay; moderate fine angular blocky; few very fine and fine, continuous, random, inped, tubular biopores; friable to firm, non to slightly sticky and slightly plastic; no mottles; thick and continuous cutans; few medium and fine roots; termite nests common; inside old coarse root channels filled with dark brown (7.5YR 3/2) topsoil; gradual and smooth transition to:
B22	130-155 cm	dark reddish brown (2.5YR 3/4, moist) clay; strong fine angular blocky; few very fine and fine biopores; friable, non-sticky and slightly plastic; thick continuous cutans; *few fine roots; gradual and smooth transition to:*
B23t	155-200+ cm	dark reddish brown to dark red (2.5YR 3/5, moist) clay; moderate strong angular blocky; few very fine and fine biopores; friable, non sticky and non to slightly plastic; thick and continuous cutans
Remark:		profile was augered to 500 cm and no recognizable changes in soil properties were recorded.

LABORATORY DATA OF PROFILE DESCRIPTION No: 15

FIELD OBSERVATION No: 130/3-210 MAPPING UNIT: UIQh

Laboratory no. ...74/	.222	.223	.225	227	229	232
Horizon	A1	A1.2	B1	B2.1	B2.2t	B3.1t
Depth (cm)	0-12	12-31	31-48	48-95	95-155	155-180
pH-H_2O(1: 5 v/v)	4.6	4.8	5.0	5.0	5.3	4.9
pH-KCl ..	3.9	4.0	4.1	4.3	4.3	4.2
EC(mmho/cm) ..						
$CaCO_3$ (%)						
$CaSO_4$ (%)						
C (%)	3.5	2.2	1.6	0.7	0.3	0.3
N (%)	0.36	0.15	0.12	0.10	0.07	0.08
C/N	10	15	13	7	4	4
CEC (me/100g), pH 8.2						
CEC .. .. pH 7.0	N.d	11.8	10.0	8.7	2.2	1.8
Exch.Ca (me/100g)	N.d	0.2	tr	tr	0.1	tr
.. Mg ..	N.d	0.1	tr	tr	tr	tr
.. K ..	N.d	0.1	tr	tr	tr	tr
.. Na ..	N.d	-	-	-	-	-
Sum of cations	N.d	0.4	0.1	0.1	0.2	0.1
Base sat. %, pH 8.2	N.d	-	-	-	-	-
.. .. %, pH 7.0	N.d	3	1	1	9	6
ESP at pH 8.2						
Saturation extract:						
Moisture %						
pH-paste						
ECe (mmho/cm)						
Na(me/l)						
K ..						
Ca ..						
Mg ..						
Sum of cations(me/l)						
CO_3(me/l)						
HCO_3 ..						
Cl ..						
SO_4 ..						
Sum of anions(me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3(mol/mol)	2.2	2.2	2.2	2.2	2.2	2.3
SiO_2/R_2O_3 ..	1.6	1.6	1.6	1.6	1.6	1.6
Fe_2O_3(mmol%)	103	103	101	98	99	98
X-ray report:	This profile contains mainly Kaolinite (with a poor crystallinity): the quartz percentage is low.					

SOIL CLASSIFICATION: humic FERRALSOL

Depth (cm)	0-12	12-31	31-48	48-95	95-155	155-180
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 – 0.05 mm						
Silt % 0.05–0.002mm						
Clay % 0.002–0 mm						
Texture class						
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 – 1.0mm						
.. .. 1.0 – 0.50mm						
.. .. 0.50 – 0.25mm						
.. .. 0.25 – 0.10mm						
.. .. 0.10 – 0.05mm						
Total sand %	9.7	8.7	8.1	7.8	7.7	11.5
Silt %	19.3	19.9	17.8	18.2	18.0	18.7
Clay %	71.0	71.3	74.1	74.0	74.3	69.8
Texture class	C	C	C	C	C	C
Bulk density	0.94	-	1.13	1.18	1.15	1.27
Moisture % w/v at:						
pF 0	N.d	64.2	57.2	55.6	51.5	49.4
pF 2.0	N.d	43.7	45.9	47.0	41.9	38.0
pF 2.3	N.d	32.5	36.5	41.5	38.3	35.5
pF 2.7	N.d	N.d	N.d	N.d	N.d	N.d
pF 3.0	N.d	23.7	27.3	37.3	37.7	32.9
pF 3.7	N.d	22.2	27.1	28.2	33.1	29.5
pF 4.2	N.d	21.2	25.0	26.7	27.5	28.5
Fertility aspects: (0–55 cm)	Laboratory no. 77/393					
Ca (me/100g)	0.2 Available			Total		
Mg ..	0.1					
K ..	0.3					
P (ppm)	6					
Mn (me/100g)	1.1					
Exch. acidity (me/100g)	N.d	55.9	49.0	39.1	27.3	24.7
pH-H_2O (1: v/v)						
C%						
N%						
Silt clay ratio					0.26	
P_2O_5 ppm	51	47	8	6	tr	
"Free" Fe_2O_3	3.2	3.6	3.9	7.2	5.1	5.0
CEC(me/100g clay)					12.6	

Kenya Soil Survey
Drawing No. 79050

Unit UIQh, Profile 15

Soil classification: humic Ferralsol; ST: typic Haplohumox
Ecological zone: II a
Observation: 130/3-210, Kisii District, E 6886.3, N 9912.6, 1833 m, 26-2-1974
Geological formation: Middle Kisii series, bukoban system
Local petrography: quartzites and siltstone
Physiography: concave slope near summit of plateau-remnant
Surrounding landform: undulating to rolling
Relief - meso: concave single slope
Vegetation: 80% grasses, 20% shrubs
Land use: extensive grazing
Erosion: nil
Surface stoniness: no stones
Soil fauna: termites
Slope gradient: 3%
Drainage class: well drained

A11 0-12 cm dark reddish brown (5YR 3/4, dry) clay; moderate very fine and fine subangular blocky; common, very fine continuous random, inped, tubular biopores; very hard, non-sticky and slightly plastic; common fine roots; few coarse, black sand grains; clear and smooth transition to:

A12 12-31 cm dark reddish brown (2.5YR 3/4, moist) clay; moderate very fine and fine subangular blocky; common very fine, fine and medium, random biopores; friable, non-sticky and slightly plastic; few coarse, black sand grains; abundant very fine and fine roots; clear and smooth transition to:

B1 31-48 cm dark reddish brown (2.5YR 3/5, moist) clay; moderate, very fine to fine subangular to angular blocky; few very fine and medium, random, biopores; friable, non- to slightly sticky, slightly plastic; common very fine roots; gradual and smooth transition to:

B21 48-95 cm dark reddish brown (2.5YR 3/6, moist) clay; moderate fine angular blocky; few very fine and fine biopores; friable to firm, slightly sticky and slightly plastic; thin patchy cutans; few very fine roots gradual and smooth transition to:

B22 89-155 cm dark reddish brown (2.5YR 3/6, moist) clay; moderate fine subangular to angular blocky; common very fine and fine, random, tubular biopores; friable to firm, slightly sticky and slightly plastic; thin patchy cutans; at 130-140 cm depth few large, angular and slightly weathered quartzite gravels; clear and wavy transition to:

B31 155-180 cm dark reddish brown (2.5YR 3/6, moist) clay; moderate fine subangular blocky; few very fine and fine biopores; friable to very friable, slightly sticky and slightly plastic; few fine distinct iron and manganese, black to dark blue concretions; thin continuous cutans; few small gravels and quartzite stones, angular when fresh to rounded when slightly weathered; boundary abrupt and irregular.

LABORATORY DATA OF PROFILE DESCRIPTION No: 16

FIELD OBSERVATION No: 130/2 - 3S   MAPPING UNIT: U2Ihn

Laboratory no. 75.../	366	367	368	369	370	371
Horizon	A11	A12	B21t	B22t	B22t	B23t
Depth (cm)	0-50	50-79	79-270	270-350	350-610	740-750
pH-H_2O(1:5 v/v)	5.2	5.5	5.4	4.5	4.7	5.0
pH-KCl ..	4.8	4.8	4.2	4.0	4.1	4.1
EC(mmho/cm) ..						
$CaCO_3$(%)						
$CaSO_4$(%)						
C (%)	2.4	1.7	0.4	N.d	N.d	N.d
N (%)						
C/N						
CEC (me/100g). pH 8.2						
CEC .. .. pH 7.0	20.3	18.7	13.6	14.0	15.0	14.4
Exch.Ca (me/100g)	8.6	6.7	1.1	1.6	3.9	4.7
.. Mg ..	3.0	3.5	2.0	0.6	1.1	1.7
.. K ..	0.4	0.5	0.7	0.7	0.8	0.8
.. Na ..	N.d	N.d	N.d	N.d	N.d	N.d
Sum of cations	12.0+	10.7+	3.8+	2.9+	5.8	
Base sat. %, pH 8.2						
.. .. %, pH 7.0	59+	57+	30+	25+	39+	50+
ESP at pH 8.2						
Saturation extract:						
Moisture %						
pH-paste						
ECe (mmho/cm)						
Na(me/l)						
K ..						
Ca ..						
Mg ..						
Sum of cations(me/l)						
CO_3(me/l)						
HCO_3 ..						
Cl ..						
SO_4 ..						
Sum of anions(me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3(mol/mol)	2.4	N.d	2.2	2.3	2.4	N.d
SiO_2/R_2O_3 ..	1.7	N.d	1.7	1.7	1.7	N.d
Fe_2O_3(mmol%)	17.2	N.d	14.9	15.2	15.7	N.d
X-ray report:	Predominantly Kaolinitic, few quartz and feldspars.					

SOIL CLASSIFICATION: Dystro* mollic* and mollic[x] Nitosols

Depth (cm)	0-50	50-79	79-270	270-350	350-610	740-750
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 – 0.05 mm						
Silt % 0.05–0.002mm						
Clay % 0.002–0 mm						
Texture class						
Dispersed clay %						
Flocculation index						
Texture USDA:		@)				@)
Sand % 2.0 – 1.0mm						
.. .. 1.0 – 0.50mm						
.. .. 0.50 – 0.25mm						
.. .. 0.25 – 0.10mm						
.. .. 0.10 – 0.05mm						
Total sand %	6.7	7.9	5.8	7.0	10.5	13.0
Silt %	31.2	28.4	26.1	21.0	20.0	17.3
Clay %	62.1	64.7	68.1	72.0	69.7	69.7
Texture class	C	C	C	C	C	C
Bulk density	1.09		1.10	1.19	1.22	1.22
Moisture % w/v at:	40-45		140-145	340-345	600-610	740-745
pF 0	60.1		52.3	50.7	55.1	60.2
pF 2.0	48.5		45.6	46.2	52.9	58.8
pF 2.3	45.6		44.3	45.0	52.0	57.8
pF 2.7	44.6		43.7	44.2	51.2	56.7
pF 3.0	28.9		32.4	38.8	34.1	46.8
pF 3.7	26.4		30.8	35.4	33.2	32.8
pF 4.2	22.5		25.5	31.1	29.9	28.8

Fertility aspects: (0– cm)	Laboratory no. 77 / 383	
	Available	Total
Ca (me/100g)	2.8	
Mg ..	2.6	
K ..	0.8	
P (ppm)	5	
Mn (me/100g)	1.1	
Exch. acidity (me/100g)		
pH-H_2O (1: v/v)		
C%		
N%		

	0-50	50-79	79-270	270-350	350-610	740-750
"Free" Fe2O3	10.23		11.8	12.6	-	13.8
"Free" Al2O3	5.0		6.0	4.4	-	5.0

@) Method Oosterbeek.

Kenya Soil Survey
Drawing No. 79050

Unit U2Ihn, Profile 16

Soil classification: dystro*-mollic* Nitosol; ST: orthoxic Palehumult
Ecological zone: II a
Observation: 130/2-3s, Kisii District, E 714.9, N 9926.3, 1880 m, 22-3-1975
Geological formation: bukoban system
Local petrography: andesite
Physiography: saddle between hill-tops
Surrounding landform: hilly
Relief - meso: uniform slope of 500 m
Vegetation: 80% grasses, few bushes
Land use: grazing
Erosion: nil
Surface stoniness: nil
Soil fauna: termites and ants
Slope gradient: 5%
Drainage class: well drained

A11	0-50 cm	dark reddish brown (5YR 3/2, moist) clay; moderate fine subangular blocky; very friable, slightly sticky and slightly plastic; many fine and very fine, common medium and few coarse pores; clear and smooth transition to:
A12	50-79 cm	dark reddish brown (2.5YR 3/3, moist) clay; moderate fine subangular blocky; friable, slightly sticky, slightly plastic; many fine and very fine, common medium pores; gradual and smooth transition to:
B21	79-270 cm	dark reddish brown (5YR 3.5/4 moist) clay; moderate fine angular- subangular blocky; friable, slightly sticky and slightly plastic; moderate thick broken clay-cutans; many fine and very fine pores, few medium pores; from 205-210 cm very many, small soft manganese concretions; clear and smooth transition to:
B22t	270-700 cm	yellowish red (5YR 4/6, moist) clay; moderate medium angular blocky; firm, slightly sticky and slightly plastic; common fine and very fine pores thick broken clay cutans; black continuous coatings from iron and manganese; gradual and smooth transition to:
B23t	700-750+ cm	yellowish red (5YR 4/6, moist) very fine clay; moderate medium-coarse prismatic; firm, slightly sticky and slightly plastic; patchy thick clay cutans, continuous thick cutans of iron and manganese; common fine and very fine pores.

LABORATORY DATA OF PROFILE DESCRIPTION No: 17

FIELD OBSERVATION No: 130/2 - NARS1 MAPPING UNIT: U3Bhn

Laboratory no. ...../						
Horizon	Ap	AB	B2.1	B2.2	B3	
Depth (cm)	0-30	30-60	60-90	90-120	160-200	
$pH-H_2O$ (1: 5 v/v)	5.2	5.7	6.0	6.1	6.0	
pH-KCl ..	4.4	4.9	5.0	5.1	5.3	
EC (mmho/cm) ..	0.21	0.24	0.21	0.14	0.10	
$CaCO_3$ (%)						
$CaSO_4$ (%)						
C (%)	2.5	2.	1.4	1.0	0.72	
N (%)	0.30					
C/N	8					
CEC (me/100g), pH 8.2						
CEC .. .. pH 7.0	14.0	14.0	15.5	16.0	16.5	
Exch. Ca (me/100g)	8.0	8.0	8.9	7.5	8.2	
.. Mg ..	3.6	4.3	4.0	4.0	4.6	
.. K ..	1.22	1.42	1.00	0.90	0.96	
.. Na ..	0.1	0.16	tr	tr	tr	
Sum of cations	12.9	13.9	13.9	12.4	13.8	
Base sat. %, pH 8.2						
.. .. %, pH 7.0	92	99	96	93	85	
ESP at pH 8.2						
Saturation extract:						
Moisture %						
pH-paste						
ECe (mmho/cm)						
Na (me/l)						
K ..						
Ca ..						
Mg ..						
Sum of cations (me/l)						
CO_3 (me/l)						
HCO_3 ..						
Cl ..						
SO_4 ..						
Sum of anions (me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3 (mol/mol)						
SiO_2/R_2O_3 ..						
Fe_2O_3 (mmol%)						
X-ray report:						

SOIL CLASSIFICATION: Mollic* NITOSOL

Depth (cm)	0-30	30-60	60-90	90-120	160-200	
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 – 0.05 mm	24	16	8	10	8	
Silt % 0.05–0.002mm	16	24	24	16	12	
Clay % 0.002–0 mm	60	60	68	74	80	
Texture class	C	C	C	C	C	
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 – 1.0mm						
.. .. 1.0 – 0.50mm						
.. .. 0.50 – 0.25mm						
.. .. 0.25 – 0.10mm						
.. .. 0.10 – 0.05mm						
Total sand %						
Silt %						
Clay %						
Texture class						
Bulk density	1.07	1.15	1.25	1.30	1.31	
Moisture % w/v at:						
pF 0	57.0	52.9	53.1	53.6	N.d	
pF 2.0	48.3	46.1	47.0	46.7	N.d	
pF 2.3	47.8	45.4	46.4	45.4	N.d	
pF 2.7	46.5	44.5	46.0	45.8	N.d	
pF 3.0	32.5	42.0	42.6	43.2	N.d	
pF 3.7	29.9	33.8	37.6	38.3	N.d	
pF 4.2	27.8	33.3	36.6	36.2	N.d	
Fertility aspects: (0–30cm)	Laboratory no. /					
	Available				Total	
Ca (me/100g)	5.5	6.6	4.1	2.2	2.9	
Mg ..	2.6	3.5	3.6	3.3	3.3	
K ..	0.64	0.66	0.75	0.75	0.20	
P (ppm)	4	4	5	6	6	
Mn (me/100g)	0.85	0.78	0.72	0.50	0.40	
Exch. acidity (me/100g)	0.2					
$pH-H_2O$ (1: v/v)						
C%						
N%						

Kenya Soil Survey
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Unit U3Bhn, Profile 17

Soil classification: mollic* Nitosol; ST: typic Paleudoll
Ecological zone: II b
Observation: 130/2-NARS I, Kisii District, E 698.2, N 9925.50, 1885 m, 1-8-1975
Geological formation: bukoban system
Local petrography: basalt (some quartzites)
Physiography: middle part of terraced hill slope
Surrounding landform: rolling upland
Relief - meso: nil
Vegetation: no natural vegetation (weeds, herbs)
Land use: cultivated, hybrid maize
Erosion: nil
Surface stoniness: nil
Soil fauna: burrows, many worm holes, high termite and ant activity
Slope gradient: 8%
Drainage class: well drained

Ap	0-30 cm	dark reddish brown (5YR 3/4) clay; moderate fine and very fine subangular blocky; breaking into fine crumb; friable moist, slightly sticky and slightly plastic wet, micro and common very fine pores; gradual and smooth transition to:
B1	30-60 cm	dark reddish brown (2.5YR 3/4) clay; moderate fine subangular blocky, breaking into fine crumb; very friable moist, sticky and plastic wet; many fine pores and few coarse; gradual and smooth transition to:
B21t	60-90 cm	dark reddish brown (2.5YR 3/4) clay; moderate fine and medium angular blocky; friable moist, sticky and plastic wet; common continuous clay cutans; many fine pores; gradual and smooth transition to:
B22t	90-120 cm	dark reddish brown (2.5YR 3/4) clay; structure and consistence as in B21; many continuous clay cutans; common fine pores; gradual and smooth transition to:
B23t	120-160 cm	dark red (2.5YR 3/6) clay; moderate fine angular blocky; very friable, slightly sticky and slightly plastic; many fine pores, many continuous clay cutans; abrupt and wavy transition to:
B3	160-220 cm	coarse angular quartz fragments and rotten rock in a red (2.5YR 4/6) clay matrix; structure, consistence and pores as in B23; abundant strong clay cutans.

LABORATORY DATA OF PROFILE DESCRIPTION No: 18

FIELD OBSERVATION No: 130/3 - 5 MAPPING UNIT: U3Bhn SOIL CLASSIFICATION: Dystro* mollic* NITOSOL

Laboratory no. 1974/	264	265	266	267	268	
Horizon	A1	A3	B1	B2t	B2t	
Depth (cm)	0-20	20-60	60-85	85-150	150 +	
pH-H_2O(1: 5 v/v)						
pH-KCl ..	4.6	4.4	4.6	4.4	4.3	
EC(mmho/cm) ..						
$CaCO_3$ (%)						
$CaSO_4$(%)						
C (%)						
N (%)						
C/N						
CEC (me/100g), pH 8.2						
CEC .. .. pH 7.0	23.3	21.8	17.0	11.4	11.6	
Exch.Ca (me/100g)	8.1	6.9	4.5	1.2	1.9	
.. Mg ..	2.4	2.9	2.9	1.4	0.9	
.. K ..	2.4	0.3	0.2	0.3	0.7	
.. Na ..	N.d	N.d	N.d	N.d	N.d	
Sum of cations	12.9	10.1	7.6	2.9	3.5	
Base sat. %, pH 8.2						
.. .. %, pH 7.0	55+	46+	45+	25+	30+	
ESP at pH 8.2						
Saturation extract:						
Moisture %						
pH-paste						
ECe (mmho/cm)						
Na (me/l)						
K ..						
Ca ..						
Mg ..						
Sum of cations(me/l)						
CO_3(me/l)						
HCO_3 ..						
Cl ..						
SO_4 ..						
Sum of anions(me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3(mol/mol)	2.2	2.1	2.1	2.1	2.2	
SiO_2/R_2O_3 ..	1.6	1.6	1.5	1.6	1.7	
Fe_2O_3(mmol%)	106	99	108	96	94	
X-ray report:						

Depth (cm)	0-20	20-60	60-85	85-150	150 +	
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 – 0.05 mm						
Silt % 0.05–0.002mm						
Clay % 0.002–0 mm						
Texture class						
Dispersed clay %						
Flocculation Index						
Texture USDA:						
Sand % 2.0 – 1.0mm						
.. .. 1.0 – 0.50mm						
.. .. 0.50 – 0.25mm						
.. .. 0.25 – 0.10mm						
.. .. 0.10 – 0.05mm						
Total sand %	3.3	2.6	3.1	2.5	1.8	
Silt %	23.7	17.5	20.2	17.6	16.1	
Clay %	73.0	79.9	76.7	79.9	81.1	
Texture class	C	C	C	C	C	
Bulk density	0.88	0.90	1.04	1.14		
Moisture % w/v at:						
pF 0						
pF 2.0						
pF 2.3						
pF 2.7						
pF 3.0						
pF 3.7						
pF 4.2						

Fertility aspects: (0– cm)	Laboratory no. /	
Ca (me/100g)	Available	Total
Mg ..		
K ..		
P (ppm)		
Mn (me/100g)		
Exch. acidity (me/100g)		
pH-H_2O (1: v/v)		
C%		
N%		

CEC me/100g clay	36.9	37.3	22.2	14.3	14.1

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Unit U3Bhn, Profile 18

Soil classification: dystro*-mollic* Nitosol: ST; orthoxic Palehumult
Ecological zone: II b
Observation: 130/35, Kisii District, E 689.1, N 9913.8, 1586 m, 8-12-1973
Geological formation: bukoban system
Local petrography: non porphyritic basalts
Physiography: sloping near top of low hill
Surrounding landform: hilly
Relief - meso: uniform slope
Vegetation: no natural vegetation
Land use: cultivated (coffee)
Erosion: few rills
Surface stoniness: nil
Soil fauna: some termite activity
Slope gradient: 12%
Drainage class: well drained

A1 0-20 cm dark brown (7.5YR 3/2, moist) clay; moderate fine subangular blocky; common very fine and few fine and medium pores; slightly sticky and slightly plastic; gradual and smooth transition to:

A3 20-60 cm dark reddish brown (5YR 3/3, moist) clay; moderate fine subangular blocky; common very fine and few fine and medium biopores; slightly sticky and slightly plastic; gradual and smooth transition to:

B1t 60-85 cm dark reddish brown (5YR 3/3, moist) clay; strong fine angular blocky; common very fine, few fine and medium biopores; friable, slightly sticky and slightly plastic; broken clay cutans; gradual transition to:

B2t 85-150 cm dark red (2.5YR 3/6, moist) clay; strong very fine angular blocky; few fine biopores; firm; *slightly sticky and slightly plastic*; continuous clay cutans.

LABORATORY DATA OF PROFILE DESCRIPTION No: 19

FIELD OBSERVATION No: 130/3 - 55 MAPPING UNIT: U3Bh

Laboratory no. ..74./	289	290	291			
Horizon	A1	B1	C			
Depth (cm)	0-22	22-50	50 +			
pH-H_2O(1: 5 v/v)						
pH-KCl ..	4.[illegible]	4.4	4.1			
EC(mmho/cm) ..						
$CaCO_3$ (%)						
$CaSO_4$ (%)						
C (%)	3.7	2.3	1.7			
N (%)						
C/N						
CEC (me/100g), pH 8.2						
CEC .. .. pH 7.0	25.7	18.4	16.0			
Exch.Ca (me/100g)	10.6	6.0	3.9			
.. Mg ..	3.2	2.2	2.6			
.. K ..	N.d	N.d	N.d			
.. Na ..	1.0	0.2	0.2			
Sum of cations	14.8+	8.4+	6.7			
Base sat. %, pH 8.2						
.. .. %, pH 7.0	58+	46-	42.			
ESP at pH 8.2						
Saturation extract:						
Moisture %						
pH-paste						
ECe (mmho/cm)						
Na (me/l)						
K ..						
Ca ..						
Mg ..						
Sum of cations(me/l)						
CO_3 (me/l)						
HCO_3 ..						
Cl ..						
SO_4 ..						
Sum of anions(me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3(mol/mol)	2.7	2.5	2.4			
SiO_2/R_2O_3 ..	1.8	1.7	1.6			
Fe_2O_3(mmol%)	116	114	118			
X-ray report:						

SOIL CLASSIFICATION: Haplic Phaeozem

Depth (cm)	0-22	22-50	50 +			
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 – 0.05 mm						
Silt % 0.05–0.002mm						
Clay % 0.002–0 mm						
Texture class						
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 – 1.0mm						
.. .. 1.0 – 0.50mm						
.. .. 0.50 – 0.25mm						
.. .. 0.25 – 0.10mm						
.. .. 0.10 – 0.05mm						
Total sand %	20.9	31.2	19.6			
Silt %	39.2	37.4	45.5			
Clay %	39.9	31.4	34.9			
Texture class	CL	CL	SiCL			
Bulk density						
Moisture % w/v at:						
pF 0						
pF 2.0						
pF 2.3						
pF 2.7						
pF 3.0						
pF 3.7						
pF 4.2						

Fertility aspects: (0– cm)	Laboratory no. /	
	Available	Total
Ca (me/100g)		
Mg ..		
K ..		
P (ppm)		
Mn (me/100g)		
Exch. acidity (me/100g)		
pH-H_2O (1: v/v)		
C%		
N%		
Silt/clay ratio	1.2	
CEC(me/100g clay)	23.8	

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Unit U3Bh, Profile 19

Soil classification: haplic Phaeozem; ST: typic Hapludoll
Ecological zone: II b
Observation: 130/3-55, Kisii District, E 691.6, N 9912.7, 1589 m, 30-11-1973
Geological formation: bukoban system (Precambrium)
Local petrography: non porphyritic basalt
Physiography: convex slope near summit of small hill
Surrounding landform: gently undulating
Relief - meso: normal very gently sloping
Vegetation: no natural vegetation
Land use: cultivated (sweet potatoes)
Erosion: nil
Surface stoniness: 5% stones and boulders
Soil fauna: termites occur
Slope gradient: 4%
Drainage class: well drained

A1 0-22 cm dark brown (7.5YR 3/2, moist) clay loam; moderate very fine subangular blocky; common very fine and few fine continuous inped and exped, random biopores; friable, slightly sticky and slightly plastic; common fine and medium distinct yellowish brown (10YR 5/8) and red (2.5YR 4/8) mottles; no cutans; few rounded, weathered stones and boulders; clear and wavy transition to:

B 22-50 cm dark brown (7.5YR 3/2, moist) clay loam; moderate very fine angular blocky; very fine continuous random, inped, tubular biopores; friable, slightly sticky and slightly plastic; many coarse prominent clear yellowish brown (10YR 5/8) and red (2.5YR 4/8) mottles; thin and broken clay cutans; very many weathered basalt knobs (boulders and stones) clear and broken transition to:

B3+C 50+ cm red (2.5YR 4/8, moist) silty clay loam; no biopores; very friable, slightly sticky and slightly plastic; many coarse and prominent clear yellowish brown (10YR 5/8) and dark brown (5YR 3/3) mottles; in volume 70-90% consist of rotten rock and loose weathered material with strong colouring.

LABORATORY DATA OF PROFILE DESCRIPTION No: 20

FIELD OBSERVATION No: 130/1 - WAN 9 MAPPING UNIT: U3Ihn

Laboratory no. ..77./	58	59	60	61	62	63
Horizon	A1.1	A1.2	B1	B2.1	B2.2	B2.3
Depth (cm)	0-16	16-38	38-80	80-130	130-210	210-280
$pH-H_2O$(1:5 v/v)	5.1	5.0	4.9	5.1	5.0	5.1
pH-KCl ..	4.1	4.2	4.2	4.6	4.3	4.2
EC(mmho/cm) ..						
$CaCO_3$ (%)						
$CaSO_4$ (%)						
C (%)	2.5+	1.8	1.8	0.7	0.5	-
N (%)	0.21					
C/N	12					
CEC (me/100g), pH 8.2						
CEC .. .. pH 7.0	13.0	11.6	9.6	6.3	6.1	5.9
Exch.Ca (me/100g)	2.7	2.4	1.8	2.2	0.8	0.6
.. Mg ..	1.2	0.9	0.5	0.5	0.2	0.2
.. K ..	0.3	0.2	0.2	0.2	0.2	0.2
.. Na ..	N.d	N.d	N.d	N.d	N.d	N.d
Sum of cations	4.2+	3.5+	2.5+	2.9+	1.2+	1.0+
Base sat. %, pH 8.2						
.. .. %, pH 7.0	32+	30+	26+	46+	19+	17 +
ESP at pH 8.2						
Saturation extract:						
Moisture %						
pH-paste						
ECe (mmho/cm)						
Na (me/l)						
K ..						
Ca ..						
Mg ..						
Sum of cations(me/l)						
CO_3 (me/l)						
HCO_3 ..						
Cl ..						
SO_4 ..						
Sum of anions(me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3(mol/mol)	2.4	2.1	2.0	2.4	2.3	2.4
SiO_2/R_2O_3 ..	1.8	1.6	1.5	1.9	1.9	1.9
Fe_2O_3(mmol%)	94	111	109	87	83	86
X-ray report:						

SOIL CLASSIFICATION: Humic Nitosol

Depth (cm)	0-16	16-38	38-80	80-130		
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 – 0.05 mm						
Silt % 0.05–0.002mm						
Clay % 0.002–0 mm						
Texture class						
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 – 1.0mm						
.. .. 1.0 – 0.50mm						
.. .. 0.50 – 0.25mm						
.. .. 0.25 – 0.10mm						
.. .. 0.10 – 0.05mm						
Total sand %	27.6	28.5	28.3	27.1		
Silt %	21.0	12.6	11.7	11.6		
Clay %	51.4	58.9	60.0	61.3		
Texture class	C	C	C	C		
Bulk density	1.19		1.15	1.17		
Moisture % w/v at:						
pF 0	58.9		59.1	52.3		
pF 2.0	41.4		42.9	36.3		
pF 2.3	37.7		40.9	34.6		
pF 2.7	36.6		38.3	33.2		
pF 3.0	35.4		33.2	31.1		
pF 3.7	N.d		30.4	N.d		
pF 4.2	21.0		N.d	N.d		

Fertility aspects: (0– 16cm) Laboratory no. 77 / 397

	Available	Total
Ca (me/100g)	0.4	
Mg ..	1.1	
K ..	0.17	
P (ppm)	4	
Mn (me/100g)	1.78	
Exch. acidity (me/100g)	0.9	
$pH-H_2O$ (1: v/v)		
C%		
N%		

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Unit U3Ihn, Profile 20

Soil classification: humic Nitosol; ST: orthoxic Palehumult
Ecological zone: II b
Observation: 130/1-WAN 9, Kisii District, E 687.4, N 9931.0, 1571 m, 2-3-1976
Geological formation: Post Kavirondian intrusive in Nyanzian system
Local petrography: quartz-diorite
Physiography: flat-topped ridges
Surrounding landform: undulating to rolling
Relief - meso: nil
Vegetation: 60% grass, 40% herbs
Land use: grazing
Erosion: nil
Surface stoniness: nil
Soil fauna: termite activity to 2.17 m
Slope gradient: 0%
Drainage class: well drained

A11	0-16 cm	dark reddish brown (5YR 3/3) when moist, clay; weak fine angular to subangular blocky; friable, slightly sticky and slightly plastic; few very fine pores; clear and smooth transition to:
A12	16-38 cm	dark reddish brown (2.5YR 3/4) when moist, clay; moderate fine subangular blocky; friable, slightly sticky and slightly plastic; few medium and fine, many very fine pores; common termite chambers 5-20 cm in diameter; gradual and smooth transition to:
B21t	80-130 cm	red (2.5YR 4/5) when moist, clay; moderate very fine angular to subangular blocky; friable, slightly sticky and slightly plastic; moderately thick, common clay cutans; many fine and very fine, few medium pores; small termite holes of 2 cm diameter; gradual and smooth transition to:
B22t	130-210 cm	red (2.3YR 4/6) when moist, clay with some quartz gravel; moderate fine and very fine angular blocky; slightly sticky and slightly plastic; moderately thick common clay cutans; many fine and very fine pores small termite holes of less than 2 cm diameter; one piece of rotten rock with diameter of 5 cm; gradual and smooth transition to:
B23	210-280 cm	like B22, but with 5% rounded soft manganese concretions of 5 cm diameter, clear and smooth transition to:
B24	280-310 cm	like B22, but with 10% soft rounded manganese concretions of 5-10 cm diameter, abrupt and wavy transition to:
B3	310-330 cm	dark red (2.5YR 3/6) when moist, clay with 5% small quartz gravel; moderate very fine angular blocky; firm, slightly sticky and slightly plastic; moderate thick, common, clay and manganese cutans; few fine pores; 75% rounded and angular manganese concretions of 3-8 cm diameter; clear broken and wavy transition to:
	330+ cm	mixtures of rotten rock, quartz diorite stones and gravelly soil.
Remark:		at 310-330 cm allochthonic stone fragments were found.

LABORATORY DATA OF PROFILE DESCRIPTION No: 21 (part 1)

FIELD OBSERVATION No: 130/1 -WAN 3 MAPPING UNIT: U3 Ihn

Laboratory no. . .74 /	87	89	91	92	96	99
Horizon	A1	A3	B1	B2.1	B2.2	B2.2
Depth (cm)	0-25	25-55	55-85	85-100	145-160	190-205
$pH-H_2O$(1: v/v)	6.0	5.2	5.2	5.3	5.2	5.5
pH-KCl ..	5.2	4.3	4.5	4.[illegible]	4.7	5.1
EC(mmho/cm) ..						
$CaCO_3$(%)						
$CaSO_4$(%)						
C (%)	2.2	1.8	1.4	1.8	0.8	0.5
N (%)						
C/N						
CEC (me/100g), pH 8.2						
CEC .. .. pH 7.0	17.5	13.3	14.4	12.0	[illegible].7	9.1
Exch.Ca (me/100g)	13.6	6.3	6.0	6.2	3.6	4.0
.. Mg ..	2.8	1.5	1.4	1.4	1.7	1.9
.. K ..	1.0	0.4	0.4	0.3	0.5	0.8
.. Na ..	N.d	N.d	N.d	N.d	N.d	N.d
Sum of cations						
Base sat. %, pH 8.2						
.. .. %, pH 7.0	99.4	61.6	62.9	65.8	66.7	73.6
ESP at pH 8.2						
Saturation extract:						
Moisture %						
pH-paste						
ECe (mmho/cm)						
Na(me/l)						
K ..						
Ca ..						
Mg ..						
Sum of cations(me/l)						
CO_3(me/l)						
HCO_3 ..						
Cl ..						
SO_4 ..						
Sum of anions(me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3(mol/mol)	2.2	2.1	2.1	N.d	4.0	4.0
SiO_2/R_2O_3 ..	1.6	1.6	1.6	N.d	3.0	3.0
Fe_2O_3(mmol%)	96	93	90	90	71	73
X-ray report:						
	Throughout the profile there is a high peak surface is Kaolinite (7A) in the clay fraction					

SOIL CLASSIFICATION: mollic[x] NITOSOL

Depth (cm)	0-25	25-55	55-85	75-100	145-160	190-205
Gravel %	1.3	4.0	2.3	5.3	2.2	0.8
Texture, limited pretreatment:						
Sand % 2.0 – 0.05 mm						
Silt % 0.05–0.002mm						
Clay % 0.002–0 mm						
Texture class						
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 – 1.0mm	12.1	9.9	6.5	5.2	7.5	6.9
.. .. 1.0 – 0.50mm	13.7	12.2	9.4	[illegible].2	10.2	7.6
.. .. 0.50 – 0.25mm	10.2	7.9	6.9	6.3	6.5	4.8
.. .. 0.25 – 0.10mm	3.5	5.5	5.1	4.9	5.2	3.5
.. .. 0.10 – 0.05mm	2.8	1.9	2.3	2.6	3.1	1.8
Total sand %	42.2	37.1	30.2	27.2	32.5	24.6
Silt %	7.4	5.8	8.8	9.8	6.2	8.6
Clay %	50.3	57.1	61.0	63.1	61.2	66.8
Texture class	C	C	C	C	C	C
Bulk density	1.17	1.21	1.24	1.17		1.24
Moisture % w/v at:				125-130		174-180
pF 0	57.6	52.2	49.9	53.3		50.1
pF 2.0	34.3	37.2	35.5	42.6		40.4
pF 2.3	33.1	36.1	34.0	40.9		38.8
pF 2.8	31.3	34.2	31.9	39.9		36.9
pF 3.0	25.1	29.1	31.5	35.7		33.0
pF 3.6	23.2	25.8	30.1	30.5		31.7
pF 4.2	18.0	22.0	27.6	25.2		26.4
Fertility aspects: (0– cm)	Laboratory no. /					
Ca (me/100g)	Available			Total		
Mg ..						
K ..						
P (ppm)						
Mn (me/100g)						
Exch. acidity (me/100g)						
$pH-H_2O$ (1: v/v)						
C%						
N%						
CEC clay	33.4	21.6	20.0	19.0	14.2	13.6
"Free"Fe2O3 %	5.4	6.8	7.2	6.4	7.4	7.2
"Free" AL2O3 %	2.8	3.2	3.[illegible]	3.[illegible]	3.5	3.2

Kenya Soil Survey
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Unit U3Ihn, Profile 21

Soil classification: mollic[x] Nitosol; ST: typic Paleudoll
Ecological zone: II b
Observation: 130/1-WAN3, Kisii District, E 689.5, N 9930.1, 1567 m, 30-12-1975
Geological formation: Post kavirondian intrusive in Nyanzian system
Local petrography: quartz diorite
Physiography: upper part of a footslope
Surrounding landform: undulating - rolling
Relief - meso: terraces, developed from thrash-lines
Vegetation: no natural vegetation
Land use: cultivated area (maize)
Erosion: few rills
Surface stoniness: nil
Soil fauna: termite activity
Slope gradient: 8%
Drainage class: well drained

A1 0-30 cm reddish brown (5YR 4/2, dry) dark reddish gray (5YR 3/2, moist) clay; moderate medium compound subangular blocky, many very fine, fine and few medium biopores; hard, very friable, slightly sticky and slightly plastic; clear and smooth transition to:

A3 30-55 cm reddish brown (2.5YR 4/3-5YR 4/3, when dry), dark reddish brown (5YR 3/2, moist) clay to sandy clay; moderate very fine and fine angular blocky many very fine, fine and common medium biopores; slightly hard, very friable, slightly sticky and slightly plastic; gradual clear and smooth transition to:

B1t 55-85 cm reddish brown (5YR 4/4, dry) reddish brown (5YR 4/3, moist) clay; moderate fine subangular blocky; weak to common clay and organic matter cutans; many fine, common medium and a few coarse biopores; hard, friable, slightly sticky and slightly plastic; gradual and wavy transition to:

B21t 85-110 cm reddish brown (2.5YR 4/4-5YR 4/4, dry), weak red to reddish brown (2.5YR 4/3, moist) clay; moderate fine and medium subangular blocky; moderate common clay/organic matter cutans; many very fine and fine, common medium, few coarse and very coarse biopores; hard, friable, slightly sticky and slightly plastic; gradual and wavy transition to:

B22t 110-235 cm reddish brown to red (2.5YR 4/5, dry), reddish brown (2.5YR 4/4, moist) clay; moderate fine and medium subangular blocky; moderate common to abundant clay/organic matter cutans; many very fine, common medium and few coarse biopores; very hard, friable, slightly sticky and slightly plastic, gradual and wavy transition to:

B23t 235-290 cm red (2.5YR 4/6, dry), reddish brown to red (2.5YR 4/5, moist) clay; moderate medium subangular blocky; moderate common clay/organic matter cutans; many very fine, common fine and few medium, coarse and very coarse biopores; hard, very friable, slightly sticky and slightly plastic; clear and wavy transition to:

B24t 290-245 cm red (2.5YR 3/6, dry), reddish brown (2.5YR 4/4, moist) clay; weak medium and fine subangular blocky; moderate common clay/organic matter cutans; 15% 3-4 mm diameter iron-manganese concretions; many very fine, common fine and few common coarse- very coarse biopores; hard, friable; slightly sticky and slightly plastic; abrupt and wavy transition to:

B31 345-485 cm yellowish red to red (5YR 5/6-2.5YR 5/6, dry), dark red (2.5YR 3/6, moist), common prominent 3-6 mm diameter manganese mottles; very gravelly clay, no macro structure; common fine and medium biopores, very hard, firm non-sticky and non-plastic; clear and wavy transition to:

B32 485-550 cm yellowish red to red (5YR 5/6-2.5YR 5/6, dry), dark red (2.5YR 3/6, moist); abundant 5-10 mm diameter manganese mottles; very gravelly clay; no macro structure; common fine and medium biopores; very hard, very firm, non-sticky and non-plastic; gradual and wavy transition to:

LABORATORY DATA OF PROFILE DESCRIPTION No: 21 (part 2)

FIELD OBSERVATION No: 130/1 - WAN3 MAPPING UNIT: U3. Ihn SOIL CLASSIFICATION: mollic[x] NITOSOL

Laboratory no. . .76 /	102	103	105/107	109	111	115
Horizon	B2.3	B2.3	B2.4	B3.1	B3.2	C
Depth (cm)	240-255	255-270	285-330	338-410	485-550	730-740
pH-H_2O(1: 5 v/v)	5.1	5.2	4.8	4.8	4.8	4.8
pH-KCl ..	4.4	4.5	4.0	3.8	3.8	3.8
EC(mmho/cm) ..						
$CaCO_3$ (%)						
$CaSO_4$ (%)						
C (%)	0.3	0.2	0.2	0.1	tr*)	tr*
N (%)						
C/N						
CEC (me/100g), pH 8.2						
CEC .. .. pH 7.0	8.5	8.0	8.2	7.9	4.7	5.9
Exch.Ca (me/100g)	2.0	5.0	2.0	1.7	1.9	2.2
.. Mg ..	0.6	1.4	0.7	0.7	0.7	0.6
.. K ..	1.3	1.8	1.3	0.7	0.4	0.3
.. Na ..	N.d	N.d	N.d	N.d	N.d	N.d
Sum of cations						
Base sat. %, pH 8.2						
.. .. %, pH 7.0	45.9	102.5	49.1	38.0	70. 0	52.5
ESP at pH 8.2						
Saturation extract:						
Moisture %						
pH-paste						
ECe (mmho/cm)						
Na(me/l)						
K ..						
Ca ..						
Mg ..						
Sum of cations(me/l)						
CO_3 (me/l)						
HCO_3 ..						
Cl ..						
SO_4 ..						
Sum of anions(me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3(mol/mol)	2.1	2.1	2.2	2.2	2.2	2.2
SiO_2/R_2O_3 ..	1.5	1.6	1.7	1.6	1.7	1.7
Fe_2O_3(mmol%)	70	74	71	63	71	63
X-ray report:						
*) Trace	Throughout the profile there is a high peak					
	surface in Kaolinite (7A) in the clay					
	fraction.					

Depth (cm)	240-255	255-270	285-330	385-450	485-550	635-650
Gravel %	7.1	2.1	3.7	22.7	12.2	7.4
Texture, limited pretreatment:						
Sand % 2.0 – 0.05 mm						
Silt % 0.05–0.002mm						
Clay % 0.002–0 mm						
Texture class						
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 – 1.0mm	9.0	7.7	11.1	27.3	14.7	11.6
.. .. 1.0 – 0.50mm	5.9	6.0	6.8	6.4	10.1	12.3
.. .. 0.50 – 0.25mm	4.2	4.6	5.4	2.9	5.3	6.2
.. .. 0.25 – 0.10mm	4.2	4.7	5.3	2.2	4.2	3.9
.. .. 0.10 – 0.05mm	3.3	5.9	3.7	1.4	1.9	1.7
Total sand %	28.3	28.9	32.3	40.2	36.2	35.7
Silt %	9.0	7.9	5.8	7.9	25.0	27.8
Clay %	62.6	63.1	61.9	52.1	38.9	36.5
Texture class	C	C	C	C	CL	CL
Bulk density						
Moisture % w/v at:						
pF 0						
pF 2.0						
pF 2.3						
pF 2.7						
pF 3.0						
pF 3.7						
pF 4.2						
Fertility aspects: (0– cm)	Laboratory no. /					
Ca (me/100g)	Available			Total		
Mg ..						
K ..						
P (ppm)						
Mn (me/100g)						
Exch. acidity (me/100g)						
pH-H_2O (1: v/v)						
C%						
N%						
						730-740
CEC(me/100g clay)	13.6	12.7	13.6	15.2	12.2	16.3
"Free" Fe2O3 %	7.2	7.7	7.7	7.4	8.3	7.7
"Free" AL2O3 %	3.3	3.2	2.5	2.0	2.3	1.8

Kenya Soil Survey
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C 550-750 cm multicoloured, varying from red (2.5YR 5/8, dry) to dark red (2.5YR 3/6 moist), red (10YR 5/8, dry) to dark red (2.5YR 3/6 moist), red (10YR 5/8, dry) to red (10YR 5/6 moist), with many white and yellow rotten rock spots; abundant 5-10 mm diameter manganese mottles; very gravelly clay; no macro-structure; common fine and medium biopores (see remark), very hard, very firm non-sticky and non-plastic.

Remark: many agrotubules diameter 5 mm filled with clay reddish brown (2.5YR 4/4) when moist, they occur from about 5.50 m to the bottom of the pit (7.50 m).

LABORATORY DATA OF PROFILE DESCRIPTION No: 22

FIELD OBSERVATION No: 130/3-13 MAPPING UNIT: U3Ghn SOIL CLASSIFICATION: Humic NITOSOL

Laboratory no. . . 74/	274	275	276	277		
Horizon	A1	B1	B2	B3		
Depth (cm)	0-30	30-80	80-150	150		
$pH-H_2O$ (1: 5 v/v)						
pH-KCl ..	4.1	4.4	4.4	4.2		
EC(mmho/cm) ..						
$CaCO_3$ (%)						
$CaSO_4$ (%)						
C (%)	1.9	1.4	1.3	1.1		
N (%)						
C/N						
CEC (me/100g), pH 8.2						
CEC .. .. pH 7.0	7.1	6.5	6.6	6.2		
Exch.Ca (me/100g)	0.6	1.6	1.5	0.7		
.. Mg ..	0.3	0.4	0.7	0.2		
.. K ..	0.1	0.1	0.03	0.1		
.. Na ..	N.d	N.d	N.d	N.d		
Sum of cations						
Base sat. %, pH 8.2						
.. .. %, pH 7.0	14+	32+	33+	16+		
ESP at pH 8.2						
Saturation extract:						
Moisture %						
pH-paste						
ECe (mmho/cm)						
Na(me/l)						
K ..						
Ca ..						
Mg ..						
Sum of cations(me/l)						
CO_3 (me/l)						
HCO_3 ..						
Cl ..						
SO_4 ..						
Sum of anions(me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3 (mol/mol)	2.2	2.1	1.3	2.2		
SiO_2/R_2O_3 ..	1.8	1.7	1.1	1.7		
Fe_2O_3 (mmol%)	77	80	80	82		
X-ray report:						

Depth (cm)	0-30	30-80	80-150	150 +		
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 – 0.05 mm						
Silt % 0.05–0.002mm						
Clay % 0.002–0 mm						
Texture class						
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 – 1.0mm						
.. .. 1.0 – 0.50mm						
.. .. 0.50 – 0.25mm						
.. .. 0.25 – 0.10mm						
.. .. 0.10 – 0.05mm						
Total sand %	50.4	46.8	43.5	48.3		
Silt %	14.7	13.9	13.1	17.1		
Clay %	34.9	39.3	43.4	34.6		
Texture class	SCL	SC	C	SCL		
Bulk density	1.47		1.51			
Moisture % w/v at:						
pF 0						
pF 2.0	22.3		22.1			
pF 2.3	20.0		19.0			
pF 2.7	18.5		18.0			
pF 3.0	11.7		15.0			
pF 3.7	10.4		13.3			
pF 4.2	8.4		9.4			

Fertility aspects: (0– cm)	Laboratory no. /	
	Available	Total
Ca (me/100g)		
Mg ..		
K ..		
P (ppm)		
Mn (me/100g)		
Exch. acidity (me/100g)		
$pH-H_2O$ (1: v/v)		
C%		
N%		
CEC (me/100g clay)	10	

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Unit U3Ghn, Profile 22

Soil classification: humic Nitosol, ST: orthoxic Palehumult
Ecological zone: II a
Observation: 130/3-13, Kisii District, E 680.5, N 9915.0, 1510 m, 4-1-1974
Geological formation: intrusive in Nyanzanian system
Local petrography: granite
Surrounding landform: hills
Relief - meso: nearly level
Vegetation: 90% grasses, few bushes
Land use: grazing
Erosion: nil
Surface stoniness: nil
Soil fauna: few termites
Slope gradient: 2%
Drainage class: well drained

A1 0-30 cm dark reddish brown (5YR 3/4, dry) sandy clay loam; weak very fine subangular blocky; very many very fine pores; slightly hard, slightly sticky and slightly plastic; common distinct coarse channels filled with humic material; very few quartz gravel to a depth of 30 cm; gradual and smooth transition to:

B1 30-80 cm dark reddish brown (5YR 3.5/4, moist) sandy clay; weak very fine subangular blocky; many very fine and common fine biopores; very friable, non-sticky to slightly sticky and slightly plastic; common distinct coarse channels filled with humic material; few krotovinas (5 cm diameter); diffuse and smooth transition to:

B2t 80-150 cm yellowish red (5YR 4/6, moist) clay; weak very fine subangular blocky, thin common clay cutans; many very fine common fine biopores; friable, non-sticky to slightly sticky and slightly plastic; common distinct coarse channels filled with humic materials; clear to gradual and wavy transition to:

B3 150+ cm yellowish red (5YR 4/6, moist) sandy clay loam; stongly weathered granite; many very fine and few fine biopores; friable, non-sticky and plastic; common medium sferical soft knobby black concretions.

LABORATORY DATA OF PROFILE DESCRIPTION No: 23

FIELD OBSERVATION No: 130/3-11 MAPPING UNIT: U3Gh

Laboratory no. ...75/	205	206	207	208		
Horizon	A1	B1	B2t	C		
Depth (cm)	0-25	25-50	50-90	90 +		
pH-H_2O(1: 5 v/v)						
pH-KCl ..	4.2	4.3	4.4	4.4		
EC(mmho/cm) ..						
$CaCO_3$ (%)						
$CaSO_4$(%)						
C (%)	1.70	1.2	0.7	0.3		
N (%)						
C/N						
CEC (me/100g), pH 8.2						
CEC .. .. pH 7.0	10.0	9.5	7.6			
Exch.Ca (me/100g)	1.2	1.2	1.0			
.. Mg ..	0.5	0.5	0.3			
.. K ..	0.1	0.1	0.1			
.. Na ..						
Sum of cations						
Base sat. %, pH 8.2						
.. .. %, pH 7.0	18.+	19.+	18.+			
ESP at pH 8.2						
Saturation extract:						
Moisture %						
pH-paste						
ECe (mmho/cm)						
Na(me/l)						
K ..						
Ca ..						
Mg ..						
Sum of cations(me/l)						
CO_3(me/l)						
HCO_3 ..						
Cl ..						
SO_4 ..						
Sum of anions(me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3(mol/mol)						
SiO_2/R_2O_3 ..						
Fe_2O_3(mmol%)						
X-ray report:						

SOIL CLASSIFICATION: FERRAL* humic Acrisol

Depth (cm)	0-25	25-50	50-90	90 +		
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 – 0.05 mm						
Silt % 0.05–0.002mm						
Clay % 0.002–0 mm						
Texture class						
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 – 1.0mm						
.. .. 1.0 – 0.50mm						
.. .. 0.50 – 0.25mm						
.. .. 0.25 – 0.10mm						
.. .. 0.10 – 0.05mm						
Total sand %	43.9	39.4	39.8	56.8		
Silt %	21.4	11.2	10.3	10.1		
Clay %	34.7	49.3	48.7	33.0		
Texture class	CL	C	C	SCL		
Bulk density	1.27	1.23	1.19			
Moisture % w/v at:						
pF 0						
pF 2.0	41.0	43.6	40.5			
pF 2.3	38.8	40.4	37.3			
pF 2.8	38.1	39.5	36.4			
pF 3.0	34.7	38.7	34.5			
pF 3.6	29.4	31.6	32.3			
pF 4.2	26.0	28.2	27.2			

Fertility aspects: (0–25cm)	Laboratory no. /	
Ca (me/100g)	Available	Total
Mg ..		
K ..		
P (ppm)		
Mn (me/100g)		
Exch. acidity (me/100g)		
pH-H_2O (1: v/v)		
C%		
N%		

	0-25	25-50	50-90	90 +
"Free" Fe_2O_3			6.3	8.4
CEC (me/100g clay)				

Kenya Soil Survey
Drawing No. 79050

Unit U3Gh, Profile 23

Soil classification: Ferral* humic Acrisol; ST: orthoxic Tropohumult
Ecological zone: II b
Observation: 130/3-11, Kisii District, E 680.5, N 9915.0, 1510 m; 04-01-1974
Geological formation: intrusive in Nyanzian system (Precambium)
Local petrography: granite
Physiography: convex slope
Surrounding landform: rolling
Relief - meso: nearly level
Vegetation: 80% grasses and herbs, few bushes
Land use: extensive grazing
Erosion: nil
Surface stoniness: nil
Soil fauna: few termites
Slope gradient: 3%
Drainage class: moderately well drained

A1 0-25 cm dark reddish brown (5YR 3/3, dry) clay loam; weak very fine subangular blocky; many very fine and common biopores; slightly sticky and slightly plastic; clear and smooth transition to:

B2t 25-50 cm dark reddish brown (5YR 3/4) to yellowish red (5YR 4/8, dry) clay; weak very fine subangular blocky; many very fine and common fine biopores, slightly hard, sticky and plastic; broken clay cutans; clear and smooth transition to:

C 90+ cm dark red (2.5YR 3/6, moist) sandy clay loam; partly cemented and oxidised plinthite gravel; moderate very fine and fine biopores; very friable, non-sticky and non-plastic; common medium prominent angular black concretions; very many (70-80%) colourless and angular quartz gravel; few rounded quartz and granite stones.

LABORATORY DATA OF PROFILE DESCRIPTION No: 24

FIELD OBSERVATION No: 130/1-SH1   MAPPING UNIT: U4Bh

Laboratory no. . .77 /	328	329		330		
Horizon	A1	B2	B3	C		
Depth (cm)	0-4	4-25	25-50	50-70		
pH-H_2O(1:5 v/v)	6.3	5.9		6.3		
pH-KCl ..	5.1	4.8		5.0		
EC(mmho/cm) ..						
$CaCO_3$ (%)						
$CaSO_4$ (%)						
C (%)	2.[illegible]	1.7	0.[illegible]9	0.35		
N (%)	0.20					
C/N	10					
CEC (me/100g), pH 8.2						
CEC .. .. pH 7.0	35.7	34.3		40.4		
Exch.Ca (me/100g)	24.5	25.0		30.0		
.. Mg ..	9.3	10.5		11.4		
.. K ..	1.7	1.1		1.6		
.. Na ..	N.d	N.d		N.d		
Sum of cations	35.5	36.6		43.0		
Base sat. %, pH 8.2						
.. .. %, pH 7.0	99+	100+		100+		
ESP at pH 8.2						
Saturation extract:						
Moisture %						
pH-paste						
ECe (mmho/cm)						
Na(me/l)						
K ..						
Ca ..						
Mg ..						
Sum of cations(me/l)						
CO_3 (me/l)						
HCO_3 ..						
Cl ..						
SO_4 ..						
Sum of anions(me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3(mol/mol)						
SiO_2/R_2O_3 ..						
Fe_2O_3(mmol%)						
X-ray report:						

SOIL CLASSIFICATION: "Verto" luvic PHAEOZEM

Depth (cm)	0-4	4-52	25-50	50-70		
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 – 0.05 mm						
Silt % 0.05–0.002mm						
Clay % 0.002–0 mm						
Texture class						
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 – 1.0mm	6.9	11.6	12.0	7.1		
.. .. 1.0 – 0.50mm	9.9	9.4	6.5	[illegible].6		
.. .. 0.50 – 0.25mm	7.8	8.2	5.4	5.9		
.. .. 0.25 – 0.10mm	7.0	8.9	4.7	5.4		
.. .. 0.10 – 0.05mm	1.2	6.6	4.3	4.8		
Total sand %	32.8	44.7	32.9	29.8		
Silt %	32.8	12.7	8.5	16.7		
Clay %	34.4	42.6	58.6	53.4		
Texture class	CL	C	C	C		
Bulk density		1.3				
Moisture % w/v at:						
pF 0						
pF 2.0						
pF 2.3						
pF 2.7						
pF 3.0						
pF 3.7						
pF 4.2						

Fertility aspects: (0–25cm)	Laboratory no. 77 / 69	
Ca (me/100g)	2.0 Available	Total
Mg ..	2.4	
K ..	0.72	
P (ppm)	6	
Mn (me/100g)	0.96	
Exch.acidity (me/100g)		
pH-H_2O (1: v/v)		
C%		
N%		
Silt clay ratio	0.2	
CEC (me/100g clay)	67	

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Unit U4YhP, Profile 25

Soil classification: haplic Phaeozem; ST: typic Hapludoll
Ecological zone: II b
Observation: 130/3-65, Kisii District, E 683.2, N 9907.1, 1476 m, 4-1-1974
Geological formation: Nyanzian system (Precambrium)
Local petrography: rhyolites and rhyolitic tuffs
Physiography: summit of minor ridge from Marongo ridge
Surrounding landform: hilly area
Relief - meso: normal
Vegetation: 70% grasses and herbs, 30% bushland
Land use: poor range (extensive grazing)
Erosion: nil
Surface stoniness: class 2 (tillage impracticle)
Soil fauna: few termites
Slope gradient: 8%
Drainage class: somewhat excessively drained

A1 0-17 cm reddish brown (5YR 5/2, dry) dark brown to brown (7.5YR 4/2, moist) clay loam; moderate fine and very fine angular to subangular blocky; common fine and very fine continuous random, inped, tubular biopores; hard, slightly sticky and slightly plastic; some weathering colours (see B3 horizon); common krotovinas; very many gravel, angular and weathered, some quartz gravel; clear and broken transition to:

B+C 17-110 cm weathering colours: strong brown (7.5YR 5/8), reddish yellow (7.5YR 8/6) yellow (10YR 8/6), red (2.5YR 5/6) moist; loam; massive and weak very fine subangular to angular blocky; common fine and very fine continuous random, inped tubular biopores; hard, slightly sticky and slightly plastic common krotovinas; colour of soil material reddish brown (5YR 4/4) and dark brown (7.5YR 4/4); termite holes; very many gravel and stones, weathered; clear and broken transition to:

R 110+ cm weathering colours; very few fine continuous biopores following the joints; between the many joints roots; vertical parallel joints crossing other joints under an angle of 75° In the joints weathered material.

Remark: Depth of the pit 130 cm in jointed and partly weathered rock. Weathered rock is sandy and contains much iron (black and red colours). Fragmental angular rock-fragments up to 2.5 cm across are abundant. They weather into creamy white rocks.

LABORATORY DATA OF PROFILE DESCRIPTION No:25

FIELD OBSERVATION No: 130/3-65 MAPPING UNIT: U4YhP

Laboratory no. ..75./	209	210	211	212		
Horizon	A1	B+C	R	Rock (in between)		
Depth (cm)	0-17	17-110	110+	110+		
pH-H_2O(1: 5 v/v)	5.0					
pH-KCl ..	4.8	4.7	5.1	6.2		
EC(mmho/cm) ..						
$CaCO_3$ (%)				0.2		
$CaSO_4$(%)						
C (%)	2.3	0.47	0.5?	0.15		
N (%)	0.17					
C/N	13					
CEC (me/100g), pH 8.2						
CEC .. .. pH 7.0	18.0	18.4	12.4			
Exch. Ca (me/100g)	8.6	8.4	8.0			
.. Mg ..	4.6	6.9	2.1			
.. K ..	0.9	0.4	0.3			
.. Na ..	Nd	N.d	N.d			
Sum of cations						
Base sat. %, pH 8.2						
.. .. %, pH 7.0	80+	85+	84+			
ESP at pH 8.2						
Saturation extract:						
Moisture %						
pH-paste						
ECe (mmho/cm)						
Na (me/l)						
K ..						
Ca ..						
Mg ..						
Sum of cations(me/l)						
CO_3(me/l)						
HCO_3 ..						
Cl ..						
SO_4 ..						
Sum of anions(me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3(mol/mol)						
SiO_2/R_2O_3 ..						
Fe_2O_3(mmol%)						
X-ray report:						

SOIL CLASSIFICATION: Haplic PHAEOZEM

Depth (cm)	0-17	17-110	110+	110+		
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 – 0.05 mm						
Silt % 0.05–0.002mm						
Clay % 0.002–0 mm						
Texture class						
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 – 1.0mm						
.. .. 1.0 – 0.50mm						
.. .. 0.50 – 0.25mm						
.. .. 0.25 – 0.10mm						
.. .. 0.10 – 0.05mm						
Total sand %	28.9	38.9	30.3	79.7		
Silt %	35.5	38.9	23.7	14.3		
Clay %	35.6	21.0	45.8	6.0		
Texture class	CL	L	C	LS		
Bulk density						
Moisture % w/v at:						
pF 0						
pF 2.0						
pF 2.3						
pF 2.7						
pF 3.0						
pF 3.7						
pF 4.2						

Fertility aspects: (0– 12cm)	Laboratory no. 77 / 405	
Ca (me/100g)	1.6 Available	Total
Mg ..	1.9	
K ..	0.32	
P (ppm)	5	
Mn (me/100g)	1.68	
Exch. acidity (me/100g)		
pH-H_2O (1: v/v)		
C%		
N%		
Silt/clay ratio	1.8	

Kenya Soil Survey
Drawing No. 79050

Unit U4Bh, Profile 24

Soil classification: verti[x]-luvic Phaeozem; ST: vertic Argiudoll
Ecological zone: II c
Observation: 130/1-SN, south Nyanza District, E 669.8, N 9936.9, 1338 m; 28-11-1975
Geological formation: Tertiary volcanics
Local petrography: basalts (or nephelinites)
Physiography: dissected small plateau
Surrounding landform: slightly sloping edge of plateau
Relief - meso: undulating
Vegetation: semi-evergreen thicket
Land use: extensive grazing
Erosion: moderate rill and gully erosion
Surface stoniness: few stones
Soil fauna: moderate activity of ants, termites etc.
Slope gradient: 3%
Drainage class: moderately well drained

A1	0-4 cm	very dark grey (10YR 3/1, moist) dark grey (10YR 4/1, dry) clay loam; strong very fine granular structure; few fine pores, hard, friable, slightly sticky, and slightly plastic; clear and smooth transition to:
B2	4-25 cm	dark grey (10YR 4/1, moist and dry) clay (with vertic properties); strong medium angular blocky, breaking into fine and very fine angular peds; many clear pressure cutans; many very fine, few fine and medium biopores; very hard, firm, sticky and plastic; clear and wavy transition to:
B3	25-50 cm	dark greyish brown (10YR 4/3, moist and dry) gravelly clay (vertic properties); strong fine angular blocky structure; many clear pressure cutans; common very fine pores; very hard, firm, sticky and plastic, irregular boundary:
C	50-170+ cm	yellowish black rotten rock.

LABORATORY DATA OF PROFILE DESCRIPTION No: 26

FIELD OBSERVATION No: 130/24 **MAPPING UNIT:** U4Yhp **SOIL CLASSIFICATION:** Luvic PHAEOZEM

Laboratory no. . .74./	284	285	286	287	288	
Horizon	A	B1	B2	B3.1	B3.1	
Depth (cm)	0-25	25-36	36-93	93-100	100-130	
pH-H_2O(1: 5 v/v)	6.0					
pH-KCl ..	5.2	5.1	5.0	5.1	5.1	
EC(mmho/cm) ..						
$CaCO_3$ (%)						
$CaSO_4$(%)						
C (%)	2.3	2.2	1.5	0.61		
N (%)	0.24					
C/N	10					
CEC (me/100g), pH 8.2						
CEC .. .. pH 7.0	19.9	15.2	14.4	12.1	9.4	
Exch.Ca (me/100g)	12.2	7.9	6.2	5.2	3.5	
.. Mg ..	3.0	2.6	2.8	2.8	2.9	
.. K ..	1.5	1.2	0.8	0.5	0.5	
.. Na ..	N.d	N.d	N.d	N.d	N.d	
Sum of cations						
Base sat. %, pH 8.2						
.. .. %, pH 7.0	84 +	77+	68+	79+	73+	
ESP at pH 8.2						
Saturation extract:						
Moisture %						
pH-paste						
ECe (mmho/cm)						
Na (me/l)						
K ..						
Ca ..						
Mg ..						
Sum of cations(me/l)						
CO_3(me/l)						
HCO_3 ..						
Cl ..						
SO_4 ..						
Sum of anions(me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3(mol/mol)	2.4	2.4	2.3	2.3	2.7	
SiO_2/R_2O_3 ..	2.0	1.7	1.7	1.7	1.6	
Fe_2O_3(mmol%)	79	108	107	106	117	
X-ray report:						

Depth (cm)	0-25	25-36	36-93	93-100	100-130	
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 – 0.05 mm	10.3	9.2	7.2	30.0	13.7	
Silt % 0.05–0.002mm	39.1	38.8	31.7	30.1	53.3	
Clay % 0.002–0 mm	50.6	52.0	61.[illegible]	39.9	33.0	
Texture class						
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 – 1.0mm	0.7	0.3	0.6	0.5		
.. .. 1.0 – 0.50mm	2.1	1.6	1.6	1.2		
.. .. 0.50 – 0.25mm	3.0	3.0	2.8	2.2		
.. .. 0.25 – 0.10mm	3.2	3.5	3.3	2.7		
.. .. 0.10 – 0.05mm	2.0	2.3	2.0	6.5		
Total sand %	11.0	10.7	10.3	13.1		
Silt %	39.6	43.5	38.2	41.0		
Clay %	49.4	45.8	51.6	46.0		
Texture class	C	SiC	C	SiC		
Bulk density	1.13	1.18	1.14			
Moisture % w/v at:						
pF 0						
pF 2.0						
pF 2.3						
pF 2.7						
pF 3.0						
pF 3.7						
pF 4.2						

Fertility aspects: (0–25 cm)	Laboratory no. 77 / 404	
Ca (me/100g)	13.6 Available	Total
Mg ..	3.0	
K ..	1.01	
P (ppm)	8	
Mn (me/100g)	1.60	
Exch. acidity (me/100g)		
pH-H_2O (1: v/v)		
C%		
N%		
CEC (me/100g clay)	18	

Kenya Soil Survey
Drawing No. 79050

Unit U4Yhp, Profile 26

Soil classification: luvic Phaeozem; ST: oxic Argiudoll
Ecological zone: II b
Observation: 130/3-24, South Nyanza District, E 677.0, N 9909.4, 1482 m, 2-2-1974
Geological formation: Nyanzian rock system
Local petrography: rhyolite
Physiography: summit of convex hill
Surrounding landform: hilly
Relief - meso: gently sloping
Vegetation: 80% grass, 20% herbs, few scrubs
Land use: grazing
Erosion: nil
Surface stoniness: nil
Soil fauna: termites
Slope gradient: 7%
Drainage class: well drained

A	0-25 cm	dark reddish brown (5YR 3/2, moist) clay; weak fine to very fine subangular blocky; many fine and very fine continuous biopores; very hard, slightly sticky and slightly plastic; many small and few large krotovinas; clear and smooth transition to:
B1t	25-36 cm	dark reddish brown (2.5YR 3/4, moist) silty clay; weak fine subangular blocky; common fine and many very fine biopores; friable, slightly sticky and slightly plastic; moderately thick broken clay cutans; many small krotovinas; gradual and smooth transition to:
B2t	36-93 cm	dark red (2.5YR 3/6, moist) clay; moderate fine to very fine angular blocky; common fine and many very fine, continuous biopores; friable, slightly sticky and slightly plastic, very few small soft sferical manganese concretions; moderately thick broken clay cutans; many small krotovinas; abrupt and smooth transition to:
B31	93-100 cm	dark red (2.5YR 3/6, moist) silty clay; strong fine and very fine angular blocky; common fine and many very fine continuous biopores; many very soft sferical black manganese concretions; no clay cutans; clear and smooth transition to:
B32	100-130 cm	brownish yellow (10YR 6/6) rotten rock, moist; dominant angular, strongly weathered gravels of rhyolite.

Remark on substrate: depth of pit 130 cm.

LABORATORY DATA OF PROFILE DESCRIPTION No: 27

FIELD OBSERVATION No: 130/1- Ra 11 MAPPING UNIT: II 4Ybp

Laboratory no. ...75/	38	39	40	41	42	
Horizon	A1.1	A1.2	AB	B3	C 1	C2
Depth (cm)	0-20	25-35	40-50	60-70	90-100	100-140
pH-H_2O(1: 5 v/v)	5.6					
pH-KCl ..						
EC(mmho/cm) ..						
$CaCO_3$(%)						
$CaSO_4$(%)						
C (%)	2.1	2.4	1.7	0.8	0.3	0.2
N (%)	0.22					
C/N	10					
CEC (me/100g), pH 8.2	21.7	18.5	15.2	12.2	13.0	
CEC .. .. pH 7.0						
Exch.Ca (me/100g)	15.43	14.66	12.66	12.86	12.21	
.. Mg ..	2.69	3.04	2.14	3.26	5.16	
.. K ..	0.77	0.43	0.43	0.53	0.49	
.. Na .. *	1.9	1.38	1.69	2.66	2.71	
Sum of cations	20.87	19.51	17.12	19.31	20.57	
Base sat. %, pH 8.2	96+	100+	100+	100+	100+	
.. .. %, pH 7.0	96.3			>100		
ESP at pH 8.2						
Saturation extract:						
Moisture %						
pH-paste						
ECe (mmho/cm)						
Na(me/l)						
K ..						
Ca ..						
Mg ..						
Sum of cations(me/l)						
CO_3(me/l)						
HCO_3 ..						
Cl ..						
SO_4 ..						
Sum of anions(me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3(mol/mol)						
SiO_2/R_2O_3 ..						
Fe_2O_3(mmol%)						
X-ray report:						

* Data for exchangeable Na determined in Serengeti are unreliable

SOIL CLASSIFICATION: Luvic PHAEOZEM

Depth (cm)	0-20	25-35	40-50	60-70	90-100	100-140
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 – 0.05 mm						
Silt % 0.05–0.002mm						
Clay % 0.002–0 mm						
Texture class						
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 – 1.0mm	10.3	5.3	7.5	4.2	2.4	3.1
.. .. 1.0 – 0.50mm	8.5	9.6	8.9	5.8	7.6	9.7
.. .. 0.50 – 0.25mm	8.1	12.1	6.9	7.1	10.0	11.3
.. .. 0.25 – 0.10mm	8.1	9.6	6.8	7.0	9.6	10.3
.. .. 0.10 – 0.05mm	5.2	4.5	4.1	2.9	4.4	5.0
Total sand %	40.2	41.1	34.2	27.0	34.0	39.4
Silt %	18.3	10.2	13.5	45.6	32	51.6
Clay %	41.5	49.0	52.4	27.4	34	8.9
Texture class	C	C	C	L	C	SiL
Bulk density						
Moisture % w/v at:						
pF 0						
pF 2.0						
pF 2.3						
pF 2.7						
pF 3.0						
pF 3.7						
pF 4.2						

Fertility aspects: (0–20cm)	Laboratory no. 77 / 398	
	Available	Total
Ca (me/100g)	12.8	
Mg ..	5.5	
K ..	0.74	
P (ppm)	5	
Mn (me/100g)	1.28	
Exch. acidity (me/100g)		
pH-H_2O (1: v/v)		
C%		
N%		

Kenya Soil Survey
Drawing No. 79050

Unit U4Ybp, Profile 27

Soil classification: luvic Phaeozem; ST: oxic Argiudoll
Ecological zone: II b
Observation: 130/1-Ra 11, South Nyanza District, E 676.5, N 99312, 1365 m; 15-8-1975
Geological formation: Nyanzian rock system
Local petrography: rhyolites and dellinites
Physiography: dissected ridges
Surrounding landform: hill slopes
Relief - meso: undulating and rolling
Vegetation: 30% trees and scrubs, 40% grasses, 10% herbs, 20% bare
Land use: cultivated land (maize, sorghum)
Erosion: slight erosion on bare ground
Surface stoniness: 20% gravel
Soil fauna: high activity of termites, worms and ants
Slope gradient: 8%
Drainage class: well drained

A11	0-22 cm	dark brown (7.5YR 3/2, moist) gravelly 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; clear and broken transition to:
A12	22-35 cm	dark brown (7.5YR 3/2, moist) very gravelly clay with gravel giving yellowish orange, black staining; moderate fine and very fine subangular blocky and very fine granular; many very fine, few fine and medium biopores; hard, firm, sticky, slightly plastic; gradual and wavy transition to:
B21	35-56 cm	brown to dark brown (7.5YR 4/3, moist) mixed with yellowish orange and black rotten rock colours, very gravelly light clay to gravel; (small gravel); weak very fine angular to subangular blocky; many very fine, medium and coarse biopores; very hard, firm, sticky and slightly plastic; gradual and wavy transition to:
B22	56-75 cm	mixed brown to dark brown (7.5YR 4/3) soil with yellowish red (5YR 5/8) and black colours from weathering gravel; very gravelly (small and big gravel) loam; moderate fine and very fine subangular blocky; common fine and very fine biopores; hard, firm, sticky, slightly plastic; gradual and wavy transition to:
C1	75-130 cm	predominantly yellowish red (5YR 5/8), with dark brown (7.5YR 3/2) in the joints; massive structure; pores only in the joints.
C2	130-150 cm	predominantly reddish yellow (7.5YR 6/8) massive slightly soft to hard rotten rock (more tough than C1), no pores.

LABORATORY DATA OF PROFILE DESCRIPTION No: 28

FIELD OBSERVATION No: 130/1-Ex. 17 MAPPING UNIT: U4Yg

Laboratory no. ..77/	337	338					
Horizon	A	B2	B2ir				
Depth (cm)	0-30	30-70	70-110				
pH-H_2O(1: 5 v/v)	5.5	5.8					
pH-KCl ..	4.6	5.0					
EC(mmho/cm) ..							
$CaCO_3$(%)	1.14						
$CaSO_4$(%)							
C (%)	1.1	1.5	0.95				
N (%)	0.10						
C/N	11						
CEC (me/100g). pH 8.2							
CEC .. .. pH 7.0	8.9	13.9					
Exch.Ca (me/100g)	5.0	10.2					
.. Mg ..	1.9	4.2					
.. K ..	0.5	0.1					
.. Na ..	N.d	N.d					
Sum of cations							
Base sat. %, pH 8.2							
.. .. %, pH 7.0	90 †	100 +					
ESP at pH 8.2							
Saturation extract:							
Moisture %							
pH-paste							
ECe (mmho/cm)							
Na(me/l)							
K ..							
Ca ..							
Mg ..							
Sum of cations(me/l)							
CO_3(me/l)							
HCO_3 ..							
Cl ..							
SO_4 ..							
Sum of anions(me/l)							
Adj. SAR							
Clay mineralogy:							
SiO_2/Al_2O_3(mol/mol)							
SiO_2/R_2O_3 ..							
Fe_2O_3(mmol%)							
X-ray report:							

SOIL CLASSIFICATION: Gleyic PHAEOZEM

Depth (cm)	0-30	30-70	70-100			
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 – 0.05 mm						
Silt % 0.05–0.002mm						
Clay % 0.002–0 mm						
Texture class						
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 – 1.0mm	27.0	4.7	27.4			
.. .. 1.0 – 0.50mm	22.2	7.6	10.2			
.. .. 0.50 – 0.25mm	9.6	9.6	6.4			
.. .. 0.25 – 0.10mm	6.3	18.1	6.0			
.. .. 0.10 – 0.05mm	2.4	14.1	1.7			
Total sand %	67.5	54.1	51.7			
Silt %	8.6	24.7	13.8			
Clay %	24.0	21.3	34.4			
Texture class	SCL	SCL	SCL			
Bulk density	1.33	1.39				
Moisture % w/v at:						
pF 0	49.2	48.3				
pF 2.0	37.9	39.6				
pF 2.3	32.5	33.9				
pF 2.7	31.6	33.3				
pF 3.0	27.9	28.3				
pF 3.7	24.3	26.7				
pF 4.2	23.5	24.8				

Fertility aspects: (0– cm)	Laboratory no. 77 /372	
Ca (me/100g)	3.6 Available	Total
Mg ..	2.6	
K ..	0.92	
P (ppm)	8	
Mn (me/100g)	1.00	
Exch. acidity (me/100g)		
pH-H_2O (1: v/v)		
C%		
N%		
Silt/clay ratio	0.7	
CEC (me/100g clay)	39	

Kenya Soil Survey
Drawing No. 79050

Unit U4Yg, Profile 28

Soil classification: gleyic Phaeozem; ST: aquic Hapludoll
Ecological zone: II c
Observation: 130/1-Ex. 17, South Nyanza District, E 690.6, N 9940.8, 1410 m, 25-8-1975
Geological formation: Nyanzian system
Local petrography: rhyolites
Physiography: valley slopes
Surrounding landform: hills and broad valleys
Relief - meso: linear slope with erosion gullies
Vegetation: mainly grasses with scattered trees and scrubs
Land use: cultivated land (cassave)
Erosion: slight sheet erosion, due to surface sealing
Surface stoniness: very few
Soil fauna: high activity of ants, termites and worms
Slope gradient: 5%
Drainage class: moderately well drained

A	0-25 cm	dark reddish grey to dark reddish brown (5YR 4-3/2, moist), dark reddish grey (5YR 4/2, dry) sandy clay loam; moderate fine and very fine subangular blocky and very fine crumb; many very fine, common fine, few medium and coarse biopores; hard, very friable, slightly sticky and slightly plastic; clear and smooth transition to:
B2	25-70 cm	dark grey to very dark grey (5YR 4-3/1, moist) dark grey (5YR 4/1, dry); common, faint, medium reddish brown (5YR 4/3) mottles; sandy clay loam; moderate, fine and medium subangular blocky; many very fine, common fine, few medium and coarse biopores; hard, friable, slightly sticky and slightly plastic; clear and wavy transition to:
Bir	70-110 cm	accumulation of Fe-Mn concretions, at places indurated and ironstone; yellowish-black; gravelly to stony.

LABORATORY DATA OF PROFILE DESCRIPTION No: 29

FIELD OBSERVATION No: 130/1 - EX 21 MAPPING UNIT: U4Gh

Laboratory no. ..77./	532		533	534	535	
Horizon	A1	A3	B2t	B3	C	
Depth (cm)	0-26	26-44	44-76	76-130	> 130	
$pH-H_2O$(1: 5 v/v)	4.7		5.0	4.1	4.4	
pH-KCl ..	4.0		3.9	3.8	40	
EC(mmho/cm) ..						
$CaCO_3$(%)						
$CaSO_4$(%)						
C (%)	0.98		0.35	0.55	0.29	
N (%)	0.10					
C/N	10					
CEC (me/100g), pH 8.2						
CEC .. .. pH 7.0	6.2		5.7	7.7	5.9	
Exch.Ca (me/100g)	1.1		0.3	0.6	0.5	
.. Mg ..	1.1		1.4	0.8	0.6	
.. K ..	0.2		0.1	0.5	0.2	
.. Na ..	0.3		0.1	0.1	0.3	
Sum of cations	2.7		1.9	2.0	1.6	
Base sat. %, pH 8.2						
.. .. %, pH 7.0	45		33	26	27	
ESP at pH 8.2						
Saturation extract:						
Moisture %						
pH-paste						
ECe (mmho/cm)						
Na(me/l)						
K ..						
Ca ..						
Mg ..						
Sum of cations(me/l)						
CO_3(me/l)						
HCO_3 ..						
Cl ..						
SO_4 ..						
Sum of anions(me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3(mol/mol)						
SiO_2/R_2O_3 ..						
Fe_2O_3(mmol%)						
X-ray report:						

SOIL CLASSIFICATION: Humic ACRISOL

Depth (cm)	0-26	44-76	76-130	>130		
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 – 0.05 mm	75	55	57	55		
Silt % 0.05–0.002mm	8	18	8	12		
Clay % 0.002–0 mm	19	27	35	33		
Texture class						
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 – 1.0mm	22.8	28.7	29.8	16.3		
.. .. 1.0 – 0.50mm	19.9	13.8	18.3	16.2		
.. .. 0.50 – 0.25 mm	18.8	9.3	8.9	7.9		
.. .. 0.25 – 0.10mm	19.6	6.3	7.1	9.0		
.. .. 0.10 – 0.05mm	3.9	2.9	0.7	16.1		
Total sand %	85.0	61.0	64.8	65.5		
Silt %	5.3	16.3	8.9	12.6		
Clay %	9.9	22.7	26.2	21.8		
Texture class	LS	SCL	SCL	SCL		
Bulk density		1.30				
Moisture % w/v at:						
pF 0						
pF 2.0						
pF 2.3						
pF 2.7						
pF 3.0						
pF 3.7						
pF 4.2						

Fertility aspects: (0–26cm)	Laboratory no. 77 / 380	
Ca (me/100g)	2.8 Available	Total
Mg ..	1.5	
K ..	0.33	
P (ppm)	8	
Mn (me/100g)	0.50	
Exch. acidity (me/100g)		
$pH-H_2O$ (1: v/v)		
C%		
N%		
Silt clay ratio	0.34	
CEC (me/100g clay)	15	

Kenya Soil Survey
Drawing No. 79050

Unit U4Gh, Profile 29

Soil classification: humic Acrisol; ST: orthoxic Tropudult
Ecological zone: II b
Observation: 130/1-Ex 21, South Nyanza District, E 680.4, N 9936.1; 27-8-1975
Geological formation: Post-Kavirondian intrusives
Local petrography: Wanjare granites
Physiography: lateral slope of ridges
Relief - meso: slightly convex slope
Vegetation: 40% grasses and herbs, 60% trees and scrubs
Land use: extensive grazing
Erosion: nil
Surface stoniness: less than 5% stones
Soil fauna: high activity of termites and ants
Slope gradient: 5%
Drainage class: well drained

A1 0-26 cm — dark reddish brown (5YR 3/2, moist), dark reddish grey (5YR 4/2, dry) gravelly loamy sand; moderate, fine subangular blocky; many, very fine, common fine, few medium biopores; slightly hard, very friable, slightly sticky and slightly plastic; gradual and smooth transition to:

B1 26-44 cm — dark reddish brown (5YR 3/4, moist); reddish brown (5YR 4/3 dry) gravelly sandy clay loam; weak subangular blocky; many very fine, common fine, few medium biopores; slightly hard, very friable, slightly sticky and slightly plastic; clear and smooth transition to:

B2t 44-76 cm — yellowish red (5YR 5/6, moist) in the matrix, with dark reddish brown (5YR 3/4) coloured clayskins and in addition black-yellowish colours from rotten rock-fragments; very gravelly sandy clay loam; moderate fine angular blocky; many moderate clay cutans; many very fine, few fine and medium biopores; hard, friable, slightly sticky and slightly plastic; clear and smooth transition to:

C 130 cm — mainly black-yellow colours of rotten rock and some yellowish red (5YR 5/6) colours of soil material.

Remarks: B2t contains more quartz gravel and less weathering rock gravel.

LABORATORY DATA OF PROFILE DESCRIPTION No: 30

FIELD OBSERVATION No: 130/3 -217   MAPPING UNIT: U4GhM   SOIL CLASSIFICATION: Ferralo^x humic CAMBISOL

Laboratory no. ...75/	248					
Horizon	A1					
Depth (cm)	0-33					
pH-H_2O(1: 5 v/v)						
pH-KCl ..	4.1					
EC(mmho/cm) ..						
$CaCO_3$ (%)						
$CaSO_4$ (%)						
C (%)	1.5					
N (%)						
C/N						
CEC (me/100g), pH 8.2						
CEC .. .. pH 7.0	9.7					
Exch.Ca (me/100g)	2.0					
.. Mg ..	0.6					
.. K ..	0.1					
.. Na ..	n.d					
Sum of cations	2.7+					
Base sat. %, pH 8.2						
.. .. %, pH 7.0	29					
ESP at pH 8.2						
Saturation extract:						
Moisture %						
pH-paste						
ECe (mmho/cm)						
Na (me/l)						
K ..						
Ca ..						
Mg ..						
Sum of cations(me/l)						
CO_3 (me/l)						
HCO_3 ..						
Cl ..						
SO_4 ..						
Sum of anions(me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3(mol/mol)						
SiO_2/R_2O_3 ..						
Fe_2O_3(mmol%)						
X-ray report:						

Depth (cm)	0-33					
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 – 0.05 mm	58					
Silt % 0.05–0.002mm	12.3					
Clay % 0.002–0 mm	27.2					
Texture class	SCL					
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 – 1.0mm						
.. .. 1.0 – 0.50mm						
.. .. 0.50 – 0.25mm						
.. .. 0.25 – 0.10mm						
.. .. 0.10 – 0.05mm						
Total sand %						
Silt %						
Clay %						
Texture class						
Bulk density						
Moisture % w/v at:						
pF 0						
pF 2.0						
pF 2.3						
pF 2.7						
pF 3.0						
pF 3.7						
pF 4.2						

Fertility aspects: (0– cm)	Laboratory no. 77 / 399	
	Available	Total
Ca (me/100g)	0.6	
Mg ..	1.3	
K ..	0.4	
P (ppm)	4	
Mn (me/100g)	0.96	
Exch. acidity (me/100g)		
pH-H_2O (1: v/v)		
C%	1.74	
N%	0.19	

Kenya Soil Survey
Drawing No. 79050

Unit U4GhM, Profile 30

Soil classification: ferralic humic Cambisol; ST: oxic Dystropept
Ecological zone: II b
Observation: 130/-217, South Nyanza District, E 677.2, N 9912.6, 1448 m, 21-7-1975
Geological formation: Post Kavirondian intrusives
Local petrography: Kitere granite
Physiography: level, uniform gently sloping
Surrounding landform: slightly undulating
Relief - meso: nil
Vegetation: no natural vegetation
Land use: cultivated land
Erosion: few rills
Surface stoniness: nil
Soil fauna: termites
Slope gradient: 5%
Drainage class: well to moderately well drained

A1 0-33 cm — dark brown (7.5YR 3/2, moist) sandy clay loam; weak to moderate; very fine and fine subangular blocky; very friable, slightly sticky and slightly plastic; few to no coarse, many fine, and many very fine, inped, random, tubular, continuous biopores; few krotovinas; very few gravel; abrupt and smooth transition to:

B31 33-50 cm — reddish brown (5YR 4/4) to yellowish red (5YR 4/6 moist); sandy clay loam; many fine and many very fine, inped, and exped, random, tubular, continuous biopores; this horizon is an indurated ironstone layer with very many quartzite gravel; black Mn-concretions; quartzite gravel and stones with weathering colours of reddish yellow, (7.5YR 6/8,), dark red, (10YR 3/6) and red (10YR 4/6); gradual and smooth transition to:

B32+ 50-70 cm — red (2.5YR 4/6, moist); rest of description as above except less stones in the indurated ironstone layer.

Cir 70-100 cm — indurated ironstone and at some places rotten rock with iron-manganese concretions.

Remark: gravel in this profile mainly consists of iron-manganese concretions.

LABORATORY DATA OF PROFILE DESCRIPTION No: 31

FIELD OBSERVATION No: 130/1 - EX 19 MAPPING UNIT: U4GH

Laboratory no. 77 /	538	539				
Horizon	A	AC				
Depth (cm)	0-35	35-70				
$pH-H_2O$ (1: 5 v/v)	5.6	5.4				
pH-KCl ..	4.9	4.3				
EC (mmho/cm) ..						
$CaCO_3$ (%)						
$CaSO_4$ (%)						
C (%)	1.1	0.7				
N (%)	0.10					
C/N	11					
CEC (me/100g), pH 8.2						
CEC .. .. pH 7.0	8.8	8.4				
Exch. Ca (me/100g)	1.8	3.2				
.. Mg ..	1.3	1.2				
.. K ..	0.3	0.2				
.. Na ..	0.1	0.1				
Sum of cations	3.5	4.7				
Base sat. %, pH 8.2						
.. .. %, pH 7.0	40	56				
ESP at pH 8.2						
Saturation extract:						
Moisture %						
pH-paste						
ECe (mmho/cm)						
Na (me/l)						
K ..						
Ca ..						
Mg ..						
Sum of cations (me/l)						
CO_3 (me/l)						
HCO_3 ..						
Cl ..						
SO_4 ..						
Sum of anions (me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3 (mol/mol)						
SiO_2/R_2O_3 ..						
Fe_2O_3 (mmol%)						
X-ray report:						

SOIL CLASSIFICATION: Ferralo[x] humic Cambisol

Depth (cm)	0-35	35-70				
Gravel %		64.2				
Texture, limited pretreatment:						
Sand % 2.0 - 0.05 mm	75	75				
Silt % 0.05-0.002 mm	6	6				
Clay % 0.002-0 mm	19	19				
Texture class	SL	SL				
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 - 1.0 mm	11.2	5.0				
.. .. 1.0 - 0.50 mm	14.2	13.2				
.. .. 0.50 - 0.25 mm	26.6	25.9				
.. .. 0.25 - 0.10 mm	17.9	26.8				
.. .. 0.10 - 0.05 mm	4.0	7.5				
Total sand %	73.9	78.4				
Silt %	9.5	6.5				
Clay %	16.5	15.2				
Texture class	SL	SL				
Bulk density						
Moisture % w/v at:						
pF 0						
pF 2.0						
pF 2.3						
pF 2.7						
pF 3.0						
pF 3.7						
pF 4.2						

Fertility aspects: (0-25cm)	Laboratory no. 77 / 378	
Ca (me/100g)	2.8 Available	Total
Mg ..	1.2	
K ..	0.36	
P (ppm)	3	
Mn (me/100g)	0.76	
Exch. acidity (me/100g)		
$pH-H_2O$ (1: v/v)		
C%		
N%		

Kenya Soil Survey
Drawing No. 79050

Unit U4GH, Profile 31

Soil classification: ferralo[x] humic Cambisol; ST: oxic Humitropept
Ecological zone: III
Observation: 130/1-Ex 19, South Nyanza District, E 680.4, N 9944.2, 1266 m, 27-8-1975
Geological formation: Post Nyanzian Intrusive
Local petrography: Oyugis granite
Physiography: top of the flat ridge
Surrounding landform: undulating ridges
Relief - meso: nearly level
Vegetation: mainly poor grasses (no complete soil cover) few trees and shrubs
Land use: extensive grazing some cultivated areas (cassava, maize and sweet potatoes
Erosion: moderate sheet erosion (surface sealing)
Surface stoniness: 20% big boulders
Soil fauna: moderate activity of insects in upper 40 cm
Slope gradient: 2%
Drainage class: moderately well drained

A1 0-35 cm dark brown (7.5YR 3/2, moist), brown (7.5YR 5/2, dry) sandy loam; weak medium and fine subangular blocky; many very fine, common fine, few medium and coarse biopores; hard, very friable, non-sticky and non-plastic; clear and wavy transition to:

AC 35-70 cm dark brown (7.5YR 3/2, moist), brown (7.5YR 5/2, dry) very gravelly sandy loam; weak, fine subangular blocky; common very fine, few fine and medium biopores; hard, very friable, non-sticky and non-plastic, gradual and irregular transition to a hard layer of iron concretions, which are found on transition to the slightly weathered granite rock.

LABORATORY DATA OF PROFILE DESCRIPTION No: 32

FIELD OBSERVATION No: 130/1 EX 14 MAPPING UNIT: PBd

Laboratory no. . . 77/	331	332	333	334		
Horizon	A11	A12	B2	B		
Depth (cm)	0-30	30-44	44-80	80-110		
pH-H_2O(1: 5 v/v)	5.8	5.9	6.8	7.5		
pH-KCl ..	4.8	4.7	5.6	6.3		
EC(mmho/cm) ..						
$CaCO_3$ (%)						
$CaSO_4$(%)						
C (%)	2.4	1.5	0.74	0.84		
N (%)	0.21					
C/N	11					
CEC (me/100g). pH 8.2						
CEC .. .. pH 7.0	30.7	29.3	45.0	44.3		
Exch.Ca (me/100g)	16.5	15.5	31.5	33.2		
.. Mg ..	8.5	8.5	16.3	16.7		
.. K ..	0.7	0.5	1.1	1.0		
.. Na ..	N.d	N.d	N.d	N.d		
Sum of cations						
Base sat. %, pH 8.2						
.. .. %, pH 7.0	84+	84+	100+	110+		
ESP at pH 8.2						
Saturation extract:						
Moisture %						
pH-paste						
ECe (mmho/cm)						
Na(me/l)						
K ..						
Ca ..						
Mg ..						
Sum of cations(me/l)						
CO_3(me/l)						
HCO_3 ..						
Cl ..						
SO_4 ..						
Sum of anions(me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3(mol/mol)						
SiO_2/R_2O_3 ..						
Fe_2O_3(mmol%)						
X-ray report:						

SOIL CLASSIFICATION: Pellic VERTISOL

Depth (cm)	0-30	30-44	44-80	80-110		
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 – 0.05 mm						
Silt % 0.05–0.002mm						
Clay % 0.002–0 mm						
Texture class						
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 – 1.0mm	9.3	17.1		13.8		
.. .. 1.0 – 0.50mm	13.5	14.8		10.8		
.. .. 0.50 – 0.25mm	5.1	6.9		6.6		
.. .. 0.25 – 0.10mm	5.7	1.8		4.5		
.. .. 0.10 – 0.05mm	2.8	0.6		2.0		
Total sand %	36.4	41.2		37.7		
Silt %	24.5	30.2		9.1		
Clay %	39.2	28.4		53.3		
Texture class	CL	L		C		
Bulk density	1.23	1.23		1.27		
Moisture % w/v at:						
pF 0	45.3	43.7	45.0			
pF 2.0	43.5	42.5	43.7			
pF 2.3	43.1	42.2	42.8			
pF 2.7	42.6	41.7	42.7			
pF 3.0	39.6	36.0	36.9			
pF 3.7	32.3	33.3	33.4			
pF 4.2	28.0	25.7	26.2			

Fertility aspects: (0– cm)	Laboratory no. 77 / 374	
Ca (me/100g)	17.2 Available	Total
Mg ..	8.4	
K ..	1.20	
P (ppm)	20	
Mn (me/100g)	0.76	
Exch. acidity (me/100g)		
pH-H_2O (1: v/v)		
C%		
N%		
Silt/clay Ratio	C. 2	
CEC (me/100g clay)	80	

Kenya Soil Survey
Drawing No. 79050

Unit PBd, Profile 32

Soil classification: pellic vertisol; ST: typic Pelludert
Ecological zone: II b
Observation: 130/1-Ex 14, South Nyanza District, E 668.6, N 9927.6, 1334 m, 28-9-1975
Geological formation: Tertiary volcanics
Local petrography: melanephelinites (alkali basalts)
Physiography: top of flat ridges
Surrounding landform: slightly dissected gently undulating to flat
Relief - meso: many termite mounds
Vegetation: mainly grasses
Land use: extensive grazing, sugar-cane and maize
Erosion: nil
Surface stoniness: nil
Soil fauna: termites
Slope gradient: 2%
Drainage class: imperfectly drained

A11	0-30 cm	very dark brown (10YR 2/2, moist) clay-loam; strong very fine granular to subangular blocky; many very fine, few fine, few medium biopores; hard, very friable, slightly sticky and slightly plastic; abrupt and smooth transition to:
A12	30-44 cm	very dark grey (10YR 3/1, moist) loam; strong medium prismatic; common very fine, few fine biopores; extremely hard, firm, sticky and very plastic; clear and smooth transition to:
B2	44-80 cm	dark grey to grey (10YR 4.5/1, moist) clay; strong very coarse angular blocky; breaking into moderate medium angular blocky; few very fine biopores; extremely hard, firm, sticky and very plastic; intersecting slickensides; clear and wavy transition to:
B3	80-100 cm	grey (10YR 5/1, moist), mixed with brown and yellow rotten rock colours; gravelly clay; strong fine angular blocky; few very fine biopores; extremely hard, firm, sticky and very plastic.

LABORATORY DATA OF PROFILE DESCRIPTION No: 33

FIELD OBSERVATION No: 130/1 - Ra 10 MAPPING UNIT: PXhM

Laboratory no. .. 75 /	34	35	36	37		
Horizon	A1	AB	B3	C		
Depth (cm)	0.29	29.46	46-95	95-120		
pH-H_2O(1:5 v/v)						
pH-KCl ..						
EC(mmho/cm) ..						
$CaCO_3$ (%)						
$CaSO_4$(%)						
C (%)	3.0	2.3	1.7	1.1		
N (%)	0.27					
C/N	11					
CEC (me/100g). pH 8.2	19.29	14.94	11.14	14.60		
CEC .. .. pH 7.0						
Exch.Ca (me/100g)	12.86	9.96	6.75	12.21		
.. Mg ..	3.07	0.97	1.37	1.85		
.. K ..	0.46	0.27	0.27	0.27		
.. Na ..	2.55	3.20	3.75	2.09		
Sum of cations	18.9	14.4	12.1	16.4		
Base sat. %, pH 8.2	98	96	100+	100+		
.. .. %, pH 7.0	90		100			
ESP at pH 8.2						
Saturation extract:						
Moisture %						
pH-paste						
ECe (mmho/cm)						
Na (me/l)						
K ..						
Ca ..						
Mg ..						
Sum of cations(me/l)						
CO_3 (me/l)						
HCO_3 ..						
Cl ..						
SO_4 ..						
Sum of anions(me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3(mol/mol)						
SiO_2/R_2O_3 ..						
Fe_2O_3(mmol%)						
X-ray report:						

SOIL CLASSIFICATION: Haplic PHAEOZEM

Depth (cm)	0-29	29-46	46-95	95-120		
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 – 0.05 mm						
Silt % 0.05–0.002mm						
Clay % 0.002–0 mm						
Texture class						
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 – 1.0mm	7.2	7.4	16.6	9.1		
.. .. 1.0 – 0.50mm	4.7	4.6	8.2	9.5		
.. .. 0.50 – 0.25mm	6.7	5.3	4.7	6.7		
.. .. 0.25 – 0.10mm	13.7	7.6	5.5	6.8		
.. .. 0.10 – 0.05mm	8.2	7.1	6.7	6.1		
Total sand %	40.5	32.0	41.7	38.4		
Silt %	29.2	30.3	28.5	57.9		
Clay %	30.5	37.6	29.8	3.7		
Texture class	CL	CL	CL	SiL		
Bulk density						
Moisture % w/v at:						
pF 0						
pF 2.0						
pF 2.3						
pF 2.7						
pF 3.0						
pF 3.7						
pF 4.2						

Fertility aspects: (0– cm)	Laboratory no. 77 / 395	
Ca (me/100g)	11.4 Available	Total
Mg ..	2.7	
K ..	1.00	
P (ppm)	10	
Mn (me/100g)	1.54	
Exch. acidity (me/100g)		
pH-H_2O (1: v/v)		
C%		
N%		
Silt/clay ratio	0.96	

Kenya Soil Survey
Drawing No. 79050

Unit PXhM, Profile 33

Soil classification: haplic Phaeozem, ST: typic Hapludoll
Ecological zone: II b
Observation: 130/1-Ra 10, South Nyanza District, E 676.7, N 9928.1, 1350 m, 11-8-1975
Geological formation: Nyanzian rock system
Local petrography: rhyolites and dellinites
Physiography: ridge of Huma hill
Surrounding landform: higher on slightly sloping plains
Relief - meso: gently undulating
Vegetation: 30% grasses, 30% herbs, 30% scrubs, 10% trees
Land use: extensive grazing
Erosion: slight sheet erosion
Surface stoniness: 50% gravel
Soil fauna: ants and termites (high activity)
Slope gradient: 1-2%
Drainage class: moderately well drained

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

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

B3 46-95 cm dark brown to brown (7.5YR 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, slightly plastic; gradual and wavy transition to:

C 95-120 cm mixed colours (10YR 5/3) mixed with black and yellow (10YR 7/8) colours of weathering gravel, slightly stony; massive structure; biopores only in joints; extremely hard (rocky) consistence.

Remark: Ironstone containing alluvial gravel and stones occurs locally and overlies the weathering rock at depths of 50-80 cm.

LABORATORY DATA OF PROFILE DESCRIPTION No: 34.

FIELD OBSERVATION No: 130/1 -34   MAPPING UNIT: PXa

Laboratory no. 1958/	5077	5078	5080	5081	5082	
Horizon	A1	A21/A22	B2t	B3	C1	
Depth (cm)	0-15	15-70	70-100	100-125	125-175	
pH-H_2O(1:5 v/v)	4.6	4.9	5.4	5.2	5.2	
pH-KCl ..	3.[illegible]	3.8	3.7	3.6	3.5	
EC(mmho/cm) ..						
$CaCO_3$(%)						
$CaSO_4$(%)						
C (%)	1.9	1.1	1.1	0.5	0.1	
N (%)	0.17					
C/N	11					
CEC (me/100g), pH 8.2						
CEC .. .. pH 7.0	10.8	6.7	24.9	29.5	29.0	
Exch.Ca (me/100g)	2.1	1.1	11.2	15.8	19.8	
.. Mg ..	0.4	0.1	0.6	1.1	0.2	
.. K ..	0.4	0.2	0.4	0.4	0.3	
.. Na ..	0.3	0.3	1.4	1.7	1.7	
Sum of cations	3.2	1.6	13.6	19.0	22.0	
Base sat. %, pH 8.2						
.. .. %, pH 7.0	30	24	55	64	76	
ESP at pH 8.2						
Saturation extract:						
Moisture %						
pH-paste						
ECe (mmho/cm)						
Na(me/l)						
K ..						
Ca ..						
Mg ..						
Sum of cations(me/l)						
CO_3(me/l)						
HCO_3 ..						
Cl ..						
SO_4 ..						
Sum of anions(me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3(mol/mol)						
SiO_2/R_2O_3 ..						
Fe_2O_3(mmol%)						
X-ray report:						

SOIL CLASSIFICATION: Eutric PLANOSOL

Depth (cm)	0-15	15-70	70-90	90-125	125-175	
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 – 0.05 mm						
Silt % 0.05–0.002mm						
Clay % 0.002–0 mm						
Texture class						
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 – 1.0mm						
.. .. 1.0 – 0.50mm						
.. .. 0.50 – 0.25mm						
.. .. 0.25 – 0.10mm						
.. .. 0.10 – 0.05mm						
Total sand %	38.3	52.4	15.3	18.1	44.0	
Silt %	38.2	27.3	12.0	22.6	14.0	
Clay %	23.5	20.3	72.7	59.3	42.0	
Texture class	L	SCL	C	C	C	
Bulk density	0.96	1.16	1.15			
Moisture % w/v at:						
pF 0						
pF 2.0	52.3	45.5	53.9			
pF 2.3						
pF 2.7						
pF 3.0						
pF 3.7						
pF 4.2	20.2	26.8	42.1			

Fertility aspects: (0– cm)	Laboratory no. 77 /400	
	Available	Total
Ca (me/100g)	1.4	
Mg ..	2.2	
K ..	0.17	
P (ppm)	6	
Mn (me/100g)	0.48	
Exch. acidity (me/100g)		
pH-H_2O (1: v/v)		
C%		
N%		

Kenya Soil Survey
Drawing No. 79050

Unit PXa, Profile 34

Soil classification: eutric Planosol; ST: abruptic Tropaqualf
Ecological zone: II c
Observation: 130/1-34; South Nyanza District, E 676.2, N 9924.3, 1373 m, 15-3-1977
Geological formation: Nyanzian rock system
Local petrography: rhyolite
Physiography: plains
Surrounding landform: nearly level to gently undulating
Relief - meso: some termite mounds (overgrown)
Vegetation: tall grass savannah type
Land use: extensive grazing
Erosion: moderate gully erosion
Surface stoniness: nil
Soil fauna: medium termite activity
Slope gradient: 1-2%
Drainage class: poorly drained

A1	0-15 cm	very dark grey to grey (10YR 3.5/1, moist) dark grey to grey (10YR 4.5/1, dry) loam; moderate, fine angular blocky; slightly hard, friable, non-sticky and non-plastic; abundant fine and medium roots; clear and wavy transition to:
A21	15-60 cm	very dark grey (10YR 3/1.5, moist) grey (10YR 5/1, dry) sandy clay loam; weak to moderate fine granular; slightly hard to soft, friable non-sticky and non-plastic; abundant, fine and medium roots; clear and wavy transition to:
A22	60-70 cm	very dark grey (10YR 3/1, moist) gravelly sandy clay loam; weak medium granular; loose, very friable, non-sticky and non plastic; many fine and medium roots; abrupt and broken transition to:
B2t	70-100 cm	black (N 2/0, moist) clay; moderate coarse compound columnar breaking into strong, coarse angular blocky; very hard, firm, very sticky and very plastic; many fine roots; many fine, prominent yellowish-red (5YR 4/6) moist mottles; 15% fine weathering rhyolite gravel; 5-10% black fine manganese "shot"; thick black clay flows on ped faces; abrupt and broken transition to:
B3t	100-125 cm	multi coloured viz, 40% black (N 2/0, moist, 30% yellowish red (5YR 4/6, moist), 30% greyish brown (10YR 5/2, moist) clay; strong medium subangular blocky; hard, firm, sticky and plastic; few fine roots; thick clay flows on rootprints and slickenside faces; 50% well weathered rhyolite gravel; gradual and wavy transition to:
C1	125-175 cm	multicoloured (see above); loamy sand; compound moderate fine granular to subangular blocky; slightly hard, loose to friable, non-sticky and non-plastic; very few fine roots; gradual and smooth transition to:
C2	175-265 cm	light olive brown (2.5YR 5/4, moist) loamy sand; weak fine granular; soft, loose, non-sticky and non-plastic; no roots; much mica; 40% weathering rhyolite gravel.

LABORATORY DATA OF PROFILE DESCRIPTION No: 35

FIELD OBSERVATION No: 130/1 - Ex9 MAPPING UNIT: PPa

Laboratory no. 1977/	138	139	140	141	142	
Horizon	A1	A2	B2.1t	B2.2t	B2.3ca	
Depth (cm)	0-7	7-23	23-34	34-86	86-160	
pH-H_2O(1:5 v/v)	5.1					
pH-KCl ..						
EC(mmho/cm) ..						
$CaCO_3$ (%)						
$CaSO_4$(%)						
C (%)	1.9			1.0	0.32	
N (%)	0.22					
C/N	9					
CEC (me/100g), pH 8.2						
CEC .. .. pH 7.0	26.9	17.8	32.9	42.6	35.4	
Exch.Ca (me/100g)	15.6	9.9	24.0	38.9	32.1	
.. Mg ..	2.4	1.0	1.8	3.0	2.6	
.. K ..	1.1	0.6	1.7	2.3	2.4	
.. Na ..	N.d	N.d	N.d	N.d	N.d	
Sum of cations						
Base sat. %, pH 8.2						
.. .. %, pH 7.0	71+	65+	84+	100+		
ESP at pH 8.2						
Saturation extract:						
Moisture %						
pH-paste						
ECe (mmho/cm)						
Na(me/l)						
K ..						
Ca ..						
Mg ..						
Sum of cations(me/l)						
CO_3(me/l)						
HCO_3 ..						
Cl ..						
SO_4 ..						
Sum of anions(me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3(mol/mol)	3.7	3.0	4.2	4.7	4.9	
SiO_2/R_2O_3 ..	3.2	3.2	3.2	3.5	3.6	
Fe_2O_3(mmol%)	49	52	66	66	66	
X-ray report:						

SOIL CLASSIFICATION: Eutric PLANOSOL

Depth (cm)	7-23	23-34	34-86	86-160		
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 – 0.05 mm						
Silt % 0.05–0.002mm						
Clay % 0.002–0 mm						
Texture class						
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 – 1.0mm	6.2	6.6	5.2	4.9		
.. .. 1.0 – 0.50mm	7.0	7.3	5.0	5.4		
.. .. 0.50 – 0.25mm	6.5	6.0	4.7	5.5		
.. .. 0.25 – 0.10mm	7.6	5.8	4.9	6.3		
.. .. 0.10 – 0.05mm	6.7	5.7	4.7	4.3		
Total sand %	34.0	31.4	24.5	26.4		
Silt %	36.6	29.6	21.8	26.1		
Clay %	29.4	38.9	53.7	47.5		
Texture class	CL	CL	C	C		
Bulk density			1.40			
Moisture % w/v at:						
pF 0						
pF 2.0						
pF 2.3						
pF 2.7						
pF 3.0						
pF 3.7						
pF 4.2						

Fertility aspects: 0-23 (0– cm)	Laboratory no. 77 / 368	
	Available	Total
Ca (me/100g)	5.2	
Mg ..	1.1	
K ..	0.50	
P (ppm)	5	
Mn (me/100g)	0.57	
Exch. acidity (me/100g)		
pH-H_2O (1: v/v)		
C%		
N%		
Silt/clay ratio	0.4	
CEC(me/100g clay)	75	

Kenya Soil Survey
Drawing No. 79050

Unit PPa, Profile 35

Soil classification: eutric Planosol; ST: abruptic Tropaqualf
Ecological zone: II b
Observation: 130/4-Ex 9, Narok District, E 718.5, N 9893.5, 1740 m, 25-8-1975
Geological formation: windblown quaternary volcanic ash
Local petrography: quaternary volcanic ash
Physiography: plain
Surrounding landform: flat to very gently undulating
Relief - meso: common large termite mounds
Vegetation: 20% shrubs, 80% grasses
Land use: extensive grazing
Erosion: nil
Surface stoniness: nil
Soil fauna: termites (mounds)
Slope gradient: 1-2%
Drainage class: poorly drained

A1	0-7 cm	black (5YR 2.5/1, moist) loam; strong, fine, subangular blocky; few to common very fine biopores; slightly hard, slightly sticky and slightly plastic; clear and smooth transition to:
A2	7-23 cm	dark brown to dark greyish brown (7.5-10YR 4/2, moist) pinkish grey (7.5YR 7/2, dry) clay-loam; few, very fine distinct reddish yellow (7.5YR 6/8) mottles; loam; strong, medium prismatic; few to common, very fine biopores; hard, slightly sticky and slightly plastic; abrupt and wavy transition to:
B21t	23-34 cm	black (10YR 2.5/1, moist) clay loam; strong, coarse prismatic; cutans of clay and organic matter, thick and continuous; few, very fine biopores; very hard, very firm sticky and plastic; gradual and smooth transition to:
B22t	34-86 cm	black (10YR 2.5/1, moist) clay; strong, fine angular blocky; slickensides in lower part of the horizon; few very fine biopores; very hard, very firm, sticky and plastic; few lime concretions; clear and smooth transition to:
B23ca	86-160 cm	dark brown (10YR 4/3-3/3, moist), common, fine, distinct reddish yellow (7.5YR 6/8) mottles; clay; moderate, fine angular blocky; common, very fine biopores; hard, firm, sticky and plastic; few small iron-manganese concretions; lime concretions; clear and smooth transition to:
B31ca	160-175 cm	dark brown (10YR 4/3-3/3, moist); many, distinct, reddish yellow (7.5YR 6/8) mottles; clay; strong fine angular blocky; few, very fine biopores; very hard, firm sticky and plastic; common, small iron manganese concretions; few lime-concretions; gradual and wavy transition to:
B32g	175-225 cm	very mottled, yellowish and black material (ash); silt; compact; few biopores; very hard; many iron-manganese concretions; positive reaction on HCl.

LABORATORY DATA OF PROFILE DESCRIPTION No: 36

FIELD OBSERVATION No: 130/1 - 36 MAPPING UNIT PGa

Laboratory no. 1977/	431	430	429	428	427	426
Horizon	A1	A21	A22	B2t	B3	C11
Depth (cm)	0-15	15-40	40-45	45-85	85-120	120-170
pH-H_2O(1: 5 v/v)	4.6	4.9	5.4	5.5	5.2	5.2
pH-KCl ..	3.7	3.8	3.9	3.7	3.6	3.5
EC(mmho/cm) ..						
$CaCO_3$(%)						
$CaSO_4$(%)						
C (%)	2.9	1.1	0.8	1.1	0.5	0.1
N (%)						
C/N						
CEC (me/100g), pH 8.2						
CEC .. .. pH 7.0	10.8	6.7	8.1	24.1	29.5	29.0
Exch.Ca (me/100g)	2.1	1.1	1.8	11.2	15.8	19.8
.. Mg ..	0.4	0.1	0.1	0.6	1.1	0.2
.. K ..	0.4	0.2	0.1	0.4	0.4	0.3
.. Na ..	0.3	0.3	0.3	1.4	1.7	1.7
Sum of cations	3.2	1.7	2.3	13.6	19.0	22.0
Base sat. %, pH 8.2						
.. .. %, pH 7.0	30	25	28	56	64	76
ESP at pH 8.2						
Saturation extract:						
Moisture %						
pH-paste						
ECe (mmho/cm)						
Na(me/l)						
K ..						
Ca ..						
Mg ..						
Sum of cations(me/l)						
CO_3(me/l)						
HCO_3 ..						
Cl ..						
SO_4 ..						
Sum of anions(me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3(mol/mol)	4.0	3.7	3.0	2.9	3.7	3.8
SiO_2/R_2O_3 ..	3.1	2.9	2.3	2.3	2.9	3.0
Fe_2O_3(mmol%)	63	63	71	70	58	61
X-ray report:						

SOIL CLASSIFICATION: Eutric PLANOSOL

Depth (cm)	0-15	15-40	40-45	45-85	45-120	120-170
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 – 0.05 mm						
Silt % 0.05–0.002mm						
Clay % 0.002–0 mm						
Texture class						
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 – 1.0mm						
.. .. 1.0 – 0.50mm						
.. .. 0.50 – 0.25mm						
.. .. 0.25 – 0.10mm						
.. .. 0.10 – 0.05mm						
Total sand %	38.3	52.4	80.6	15.3	18.1	44.0
Silt %	38.2	27.3	6.5	12.0	22.6	14.0
Clay %	23.5	20.3	12.9	72.7	59.3	42.0
Texture class	L	SCL	SL	C	C	C
Bulk density						
Moisture % w/v at:						
pF 0						
pF 2.0						
pF 2.3						
pF 2.7						
pF 3.0						
pF 3.7						
pF 4.2						

Fertility aspects: (0– cm)	Laboratory no. 77 / 384	
	Available	Total
Ca (me/100g)	0.4	
Mg ..	tr	
K ..	0.2	
P (ppm)	4	
Mn (me/100g)	0.12	
Exch. acidity (me/100g)		
pH-H_2O (1: v/v)		
C%		
N%		

Kenya Soil Survey
Drawing No. 79050

Unit PGa, Profile 36

Soil classification: eutric Planosol; ST: abruptic Tropoqualf
Ecological zone: II c
Observation: 130/1-3, South Nyanza District, E 671.8, N 9923.2, 1345 m, 5-1-1977
Geological formation: Kavirondian system
Local petrography: granite
Physiography: upper river terrace
Surrounding landform: gently undulating
Relief - meso: flat
Vegetation: 90% grasses and herbs, 10% shrubs
Land use: extensive grazing
Surface stoniness: nil
Soil fauna: some termite (mounds)
Slope gradient: 1%
Drainage class: poorly drained

A1 0-15 cm very dark greyish brown to dark greyish brown (10YR 3.5/2, moist), dark grey (10YR 4/1, dry) loam; common fine, faint dark yellowish brown mottles; weak to moderate very fine subangular blocky; very friable, slightly sticky and slightly plastic; few very fine and fine pores; frequent very fine, few fine roots; clear and smooth transition to:

A21 15-40 cm very dark greyish to dark greyish brown (10YR 3.5/2, moist); grey (10YR 5/1, dry) sandy clay loam; common fine faint dark yellowish brown (10YR 3/4) mottles; weak very fine subangular blocky; very friable, slightly sticky and slightly plastic; few very fine and fine pores; common very fine and very few fine roots; abrupt and wavy transition to:

A22 40-45 cm dark brown (10YR 3/3 moist) coarse sandy loam; few fine faint dark yellowish brown (10YR 4/4) mottles; weak very fine subangular blocky to granular; very friable, slightly sticky and slightly plastic; few very fine pores; common very fine roots; abrupt and broken transition to:

B2t 45-85 cm very dark brown (10YR 2/2, moist) clay; many, medium prominent red (2.5YR 5/8) mottles; strong fine angular blocky; firm, sticky and slightly plastic; thick abundant clay skins; few very fine pores; common fine roots; clear and wavy transition to:

B3 84-120 cm dark grey (10YR 4/1, moist) locally very gravelly and slightly stony clay; common fine distinct yellowish brown (10YR 5/8) mottles; weak coarse angular blocky; firm, sticky and slightly plastic; weak few not intersecting slickensides; no pores; much rounded gravel of different origin and few rounded stones mostly quartzites and quartz; clear and smooth transition to:

C11 120-170 cm mixed colour, from grey (10YR 5/1) to light olive grey (5YR 6/2, moist) very gravelly clay; few medium, faint yellowish brown (10YR 5/8) mottles; structureless; much angular small quartz gravel; diffuse transition to:

R 170-200+ cm rotten rock of granite.

LABORATORY DATA OF PROFILE DESCRIPTION No: 37

FIELD OBSERVATION No: 130/1 - C9 MAPPING UNIT: BBh

Laboratory no. ...77/	523	524	525			
Horizon	A1	B2.1	B2.2			
Depth (cm)	0-20	20-90	90-140			
pH-H_2O(1: 5 v/v)	6.4	7.0	6.1			
pH-KCl ..	5.0	6.0	4.8			
EC(mmho/cm) ..	0.35	0.65	0.14			
$CaCO_3$ (%)						
$CaSO_4$ (%)						
C (%)	1.5	1.6	0.6			
N (%)	0.15					
C/N	10					
CEC (me/100g), pH 8.2						
CEC .. .. pH 7.0	36.0	38.0	12.3			
Exch.Ca (me/100g)	23.0	22.3	40.0			
.. Mg ..	24.0	23.0	12.0			
.. K ..	0.7	0.7	0.6			
.. Na ..	2.1	1.8	2.6			
Sum of cations	49.8	47.8	55.2			
Base sat. %, pH 8.2						
.. .. %, pH 7.0	100+	100+	100+			
ESP at pH 8.2						
Saturation extract:						
Moisture %						
pH-paste						
ECe (mmho/cm)						
Na(me/l)						
K ..						
Ca ..						
Mg ..						
Sum of cations(me/l)						
CO_3 (me/l)						
HCO_3 ..						
Cl ..						
SO_4 ..						
Sum of anions(me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3(mol/mol)						
SiO_2/R_2O_3 ..						
Fe_2O_3(mmol%)						
X-ray report:						

SOIL CLASSIFICATION: Vertic PHAEOZEM

Depth (cm)	0-20	20-90	90+			
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 – 0.05 mm						
Silt % 0.05–0.002mm						
Clay % 0.002–0 mm						
Texture class						
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 – 1.0mm	8.2	0.8	0.3			
.. .. 1.0 – 0.50mm	3.4	1.5	0.5			
.. .. 0.50 – 0.25mm	2.4	1.2	0.7			
.. .. 0.25 – 0.10mm	2.6	1.0	0.8			
.. .. 0.10 – 0.05mm	1.2	0.2	0.9			
Total sand %	17.8	4.7	3.2			
Silt %	31.8	24.7	37.7			
Clay %	50.4	70.6	59.1			
Texture class	C	C	C			
Bulk density						
Moisture % w/v at:						
pF 0						
pF 2.0						
pF 2.3						
pF 2.7						
pF 3.0						
pF 3.7						
pF 4.2						

Fertility aspects: (0– cm)	Laboratory no. /	
	Available	Total
Ca (me/100g)		
Mg ..		
K ..		
P (ppm)		
Mn (me/100g)		
Exch. acidity (me/100g)		
pH-H_2O (1: v/v)		
C%		
N%		
Silt/clay ratio	0.37	
CEC(me/100g clay)	54	

Kenya Soil Survey
Drawing No. 79050

Unit BBh, Profile 37

Soil classification: vertic Phaeozem; ST: vertic udic Argiustoll
Ecological zone: III
Observation: 130/1-C9, South Nyanza District, E 677.5, N 9943.9, 1220 m, 18-1-1977
Geological formation: Pleistocene lacustrine deposits
Local petrography: volcanic ash deposits
Physiography: plain between major hills
Surrounding landform: very gently undulating
Relief - meso: flat
Vegetation: 80% grasses (the rest is cultivated)
Land use: grazing and cultivation of cotton, maize sorghum and wimbi
Erosion: nil
Surface stoniness: nil
Soil fauna: termites
Slope gradient: 0%
Drainage class: imperfectly drained

A1	0-20 cm	black (5YR 2/1, moist) clay; strong fine angular blocky; hard, friable, sticky and plastic; no pores; many roots; gradual and smooth transition to:
B21	20-90 cm	dark grey (5YR 3/1, moist) compact clay; strong medium angular blocky, breaking into fine angular blocky; very hard, friable-firm, sticky and plastic; no pores; few fine roots; clear and smooth transition to:
B22	90-140+ cm	very dark grey (10YR 3/1, moist) with white mottles of lime; clay; moderate fine angular blocky; common fine pores; very friable, slightly sticky and plastic.

LABORATORY DATA OF PROFILE DESCRIPTION No: 38

FIELD OBSERVATION No: 130/1 - 39 MAPPING UNIT: BBd

Laboratory no. ...77/	450	451	452	453	454	455
Horizon	Ap	B2t1	B2t2	C(+B)	IB_2tc_x	IIICCa
Depth (cm)	0-18	18-60	60-123	123-150	150-340	340-360+
pH-H_2O(1:5 v/v)	5.4	5.8	5.6	6.9	8.0	7.7
pH-KCl ..	4.3	4.2	4.1	5.0	6.6	6.2
EC(mmho/cm) ..						
$CaCO_3$(%)						
$CaSO_4$(%)						
C (%)	1.8	1.1	0.3	0	0	0
N (%)						
C/N						
CEC (me/100g), pH 8.2						
CEC .. .. pH 7.0	17.4	27.0	42.7	45.4	37.8	40.1
Exch.Ca (me/100g)	5.8	13.8	26.7	31.0	33.2	31.5
.. Mg ..	1.9	3.3	4.8	4.3	3.8	4.1
.. K ..	0.5	0.5	1.0	2.3	1.4	1.3
.. Na ..	6.3	2.1	4.9	4.3	3.1	3.1
Sum of cations	14.5	19.7	37.4	41.9	41.5	40.0
Base sat. %, pH 8.2						
.. .. %, pH 7.0	83	73	88	92	100+	100
ESP at pH 8.2						
Saturation extract:						
Moisture %						
pH-paste						
ECe (mmho/cm)						
Na(me/l)						
K ..						
Ca ..						
Mg ..						
Sum of cations(me/l)						
CO_3(me/l)						
HCO_3 ..						
Cl ..						
SO_4 ..						
Sum of anions(me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3(mol/mol)	4.7	4.1	4.4	4.8	4.3	4.8
SiO_2/R_2O_3 ..	3.4	3.0	3.2	3.6	3.2	3.3
Fe_2O_3(mmol%)	66	70	68	62	64	78
X-ray report:						

SOIL CLASSIFICATION: Pellic VERTISOL

Depth (cm)	0-18	18-60	60-123	123-150	150-340	340-360
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 – 0.05 mm						
Silt % 0.05–0.002mm						
Clay % 0.002–0 mm						
Texture class						
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 – 1.0mm						
.. .. 1.0 – 0.50mm						
.. .. 0.50 – 0.25mm						
.. .. 0.25 – 0.10mm						
.. .. 0.10 – 0.05mm						
Total sand %	17.8	24.9	5.2	23.9	10.9	24.1
Silt %	36.7	32.9	28.2	54.5	32.3	23.7
Clay %	45.5	42.2	66.6	21.6	56.8	52.2
Texture class	C	C	C	SiCL		
Bulk density						
Moisture % w/v at:						
pF 0						
pF 2.0						
pF 2.3						
pF 2.7						
pF 3.0						
pF 3.7						
pF 4.2						

Fertility aspects: (0– cm)	Laboratory no. Available	Total
Ca (me/100g)		
Mg ..		
K ..		
P (ppm)		
Mn (me/100g)		
Exch. acidity (me/100g)		
pH-H_2O (1: v/v)		
C%		
N%		

Kenya Soil Survey
Drawing No. 79050

Unit BBd, Profile 38

Soil classification: Pellic Vertisol; ST: entic Pelludert
Ecological zone: II c
Observation: 130/1-12, South Nyanza District, E 649.7, N 9907.7, 1370 m, 21-1-1977
Geological formation: quaternary deposits
Local petrography: volcanic ash and alluvium
Physiography: valley bottom
Surrounding landform: gently undulating
Relief - meso: some termite mounds
Vegetation: 90% grasses and herbs, 10% trees and shrubs
Land use: extensive grazing
Erosion: nil
Surface stoniness: nil
Soil fauna: medium termite activity
Slope gradient: 1%
Drainage class: poorly drained

Ap	0-18 cm	dark grey (10YR 4/1, moist) grey to light grey (10YR 6/1, dry) few, fine, distinct, yellowish brown (10YR 5/8) mottles clay; weak fine angular blocky; hard, very friable, slightly sticky and slightly plastic; many very fine and few common fine pores; very frequent, very fine and few fine roots; abrupt and wavy transition to:
B2t1	18-60 cm	very dark greyish brown (10YR 3/2, moist) clay with locally very thin layers of fine sand; strong very fine and fine angular blocky; very hard, firm, slightly sticky and slightly plastic; few thin clay skins; few very fine pores; few very fine roots; gradual and smooth transition to:
B2t2	60-123 cm	dark brown (10YR 3/2, moist) clay with locally some sand; strong, very fine and fine angular blocky; very hard, firm, slightly sticky and slightly plastic; common thin clay and pressure cutans; common very fine pores; clear and smooth transition to:
C(+B)	123-150 cm	light grey (5YR 7/2, moist); and white (2.5Y 8/2, dry), volcanic ash; broken layer with abundant strong manganese skins around pieces of ash; locally between ash pieces dark brown (10YR 3/3) clay, with fine angular blocky structure; abrupt and smooth transition to:
IIB2t	150-340 cm	greyish brown (2.5Y 5/2, moist) clay; strong coarse angular blocky breaking into strong very fine angular locky; very hard, friable, slightly sticky and slightly plastic; abundant thin, not intersecting slickensides and abundant thick manganese skins; few very fine and medium pores; some irregular shaped, white, weathered stones (artefacts?) on transition with underlying horizon; few small and large, hard irregular white calcium carbonate nodules; abrupt and smooth transition to:
IIIC	340-360 cm	light olive brown (2.5Y 5/4, moist); very gravelly clay; structureless, massive; few very fine pores; much rounded gravel mainly of laterite.

LABORATORY DATA OF PROFILE DESCRIPTION No: 39

FIELD OBSERVATION No: 130/1 -39 MAPPING UNIT: BXa1 SOIL CLASSIFICATION: Solodic PLANOSOL

Laboratory no. ..... /	80046	80047	80048	80049	80050	80051
Horizon						
Depth (cm)	10-20	20-30	30-40	45-55	70-80	130-140
pH-H_2O(1: 5 v/v)	5.5	5.6	5.6	5.6	5.4	5.6
pH-KCl ..	3.7	3.6	3.5	3.5	3.4	3.5
EC(mmho/cm) ..						
$CaCO_3$ (%)						
$CaSO_4$ (%)						
C (%)	1.4	1.1	1.0	0.9	0.6	0.2
N (%)	0.13	0.13	0.12	0.13	0.08	0.06
C/N	10.8	8.5	8.3	6.9	7.8	3.3
CEC (me/100g), pH 8.2						
CEC .. .. pH 7.0	13.2	16.1	29.8	34.5	28.6	24.0
Exch.Ca (me/100g)	4.3	5.4	10.4	13.7	15.4	13.0
.. Mg ..	0.7	0.8	1.6	2.1	2.7	2.6
.. K ..	0.3	0.4	0.6	0.7	0.7	0.7
.. Na ..	0.2	0.4	1.1	1.7	2.0	1.6
Sum of cations	5.5	7.0	13.7	18.2	20.8	17.9
Base sat. %, pH 8.2						
.. .. %, pH 7.0	41.7	43.5	46.0	52.8	72.7	74.6
ESP at pH 8.2						
Saturation extract:						
Moisture %						
pH-paste						
ECe (mmho/cm)						
Na (me/l)						
K ..						
Ca ..						
Mg ..						
Sum of cations(me/l)						
CO_3 (me/l)						
HCO_3 ..						
Cl ..						
SO_4 ..						
Sum of anions(me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3(mol/mol)	4.1	3.7	3.2	3.2	3.6	4.1
SiO_2/R_2O_3 ..	3.2	2.9	2.5	2.5	2.7	3.1
Fe_2O_3(mmol%)	61	66	66	63	68	69
X-ray report:						

Depth (cm)	10-20	20-30	30-40	45-55	70-80	130-140
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 – 0.05 mm	36	20	16	16	12	
Silt % 0.05–0.002mm	36	40	40	20	12	
Clay % 0.002–0 mm	28	40	44	64	76	
Texture class						
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 – 1.0mm	0.4	8.9	0.4	0.3	0.2	0.9
.. .. 1.0 – 0.50mm	2.1	2.2	1.4	0.8	0.7	5.1
.. .. 0.50 – 0.25mm	3.9	3.6	1.8	1.4	0.9	4.6
.. .. 0.25 – 0.10mm	5.3	5.2	2.2	1.5	1.7	5.1
.. .. 0.10 – 0.05mm	2.5	4.6	1.7	1.2	0.6	3.2
Total sand %	14.3	24.5	7.5	5.2	4.2	18.9
Silt %	48.0	49.5	33.9	34.0	28.9	36.2
Clay %	37.7	26.1	58.7	60.7	66.9	44.9
Texture class	SiCL	SiL	C	C	C	C
Bulk density		1.20	1.16	1.31		
Moisture % w/v at:						
pF 0						
pF 2.0						
pF 2.3						
pF 2.7						
pF 3.0						
pF 3.7						
pF 4.2						
Fertility aspects: (0– cm)	Laboratory no. 77/402					
Ca (me/100g)	7.6 Available			Total		
Mg ..	2.9					
K ..	0.44					
P (ppm)	10					
Mn (me/100g)	0.87					
Exch.acidity (me/100g)	11.8	13.4	19.3	20.7	14.2	10.2
pH-H_2O (1: v/v)						
C%						
N%						

Kenya Soil Survey
Drawing No. 79050

Unit BXa1, Profile 39

Soil classification: solodic Planosol; ST: abruptic Tropaqualf
Ecological zone: II b
Observation: 130/1-39, South Nyanza District, E 668.1, N 9919.8, 1360 m, 17-9-1978
Geological formation: quaternary deposits over Nyanzian rocks
Local petrography: volcanic ash with alluvium over granites
Physiography: flat to gently undulating valley bottom
Surrounding landform: undulating
Relief - meso: flat
Relief - micro: termite mounds, 1.5 m high and 2-6 m wide
Vegetation: 90% grasses and herbs; 10% shrubs and trees
Land use: extensive grazing
Erosion: only along the river
Surface stoniness: no stones
Soil fauna: termites
Slope gradient: 3%
Drainage class: poorly drained

A1 *0-15 cm* *brown (10YR 5/3) and grey (10YR 4/1) moist*, common fine distinct yellowish red (5YR 5/8) mottles, silty clay loam, weak very fine to fine subangular blocky, friable slightly sticky and slightly plastic, Fe-concretions, clear and smooth transition to:

A2 15-37 cm grey (10YR 5/1) moist, common fine faint yellowish red (5YR 5/6) mottles, silt loam; moderate very fine angular blocky; friable, slightly sticky and slightly plastic; Fe-concretions; abrupt and smooth transition to:

B21t 37-50 cm grey (5YR 5/1) moist, common fine faint (when dry prominent) strong brown (7.5YR 5/8) mottled clay; weak very fine to fine angular blocky; firm, slightly sticky, slightly plastic; clear and smooth transition to:

B23t 113+ cm brown (10YR 5/3) moist, common fine distinct reddish yellow (7.5YR 6/8) mottled clay; weak medium prismatic breaking into weak very fine angular blocky; few Mn cutans; friable, slightly sticky, slightly plastic.

LABORATORY DATA OF PROFILE DESCRIPTION No: 40

FIELD OBSERVATION No: 130/2 - Dr I MAPPING UNIT: BXa2

Laboratory no. ISM /	80052	80053	80054	80055	80056	80057
Horizon	A1	A2.1	A2.2	A2.3	B2.1	B2.4
Depth (cm)	10-20	20-30	30-40	45-55	70-80	130-140
pH-H_2O(1: 5 v/v)	4.6	4.8	5.1	5.7	5.2	5.0
pH-KCl ..	3.6	3.5	3.7	4.6	3.8	3.4
EC(mmho/cm) ..						
$CaCO_3$ (%)						
$CaSO_4$ (%)						
C (%)	12.3	2.7	0.8	0.5	1.0	0.3
N (%)	0.92	0.26	0.08	0.05	0.1	0.08
C/N	13.4	10	10	10	10	3.8
CEC (me/100g), pH 8.2						
CEC .. .. pH 7.0	42.1	16.6	7.5	9.8	24.1	30.3
Exch.Ca (me/100g)	3.9	1.9	1.0	1.4	5.1	9.1
.. Mg ..	1.3	0.5	0.2	0.4	1.4	2.8
.. K ..	1.0	0.2	0.2	0.2	0.4	0.7
.. Na ..	0.1	0.0	0.0	0.0	0.1	0.1
Sum of cations	6.3	2.6	1.4	2.0	7.0	12.7
Base sat. %, pH 8.2						
.. .. %, pH 7.0	15.0	15.7	18.7	20.4	29.0	41.9
ESP at pH 8.2						
Saturation extract:						
Moisture %						
pH-paste						
ECe (mmho/cm)						
Na(me/l)						
K ..						
Ca ..						
Mg ..						
Sum of cations(me/l)						
CO_3(me/l)						
HCO_3 ..						
Cl ..						
SO_4 ..						
Sum of anions(me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3(mol/mol)	3.7	3.8	5.2	4.2	3.2	3.3
SiO_2/R_2O_3 ..	3.1	3.1	3.6	2.7	1.4	2.5
Fe_2O_3(mmol%)	47	54	60	107	242	76
X-ray report:						

SOIL CLASSIFICATION: Dystric PLANOSOL

Depth (cm)		25-45	50-65	66-74	75-85	95-105
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 – 0.05 mm						
Silt % 0.05–0.002mm						
Clay % 0.002–0 mm						
Texture class						
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 – 1.0mm		0.1	0.2	6.7	6.1	0.1
.. .. 1.0 – 0.50mm		0.4	0.1	4.2	4.4	0.1
.. .. 0.50 – 0.25mm		0.4	0.2	0.6	1.5	0.2
.. .. 0.25 – 0.10mm		0.3	0.2	0.4	0.4	0.1
.. .. 0.10 – 0.05mm		2.2	2.7	1.6	11.3	0.6
Total sand %		3.4	3.5	13.5	23.7	2.1
Silt %		54.4	71.6	59.3	8.4	36.9
Clay %		42.2	24.9	27.2	67.9	61.0
Texture class		SiC	SiL	SiCL	C	C
Bulk density	-	-	1.04	1.09	-	1.27/1.24
Moisture % w/v at:						
pF 0						
pF 2.0						
pF 2.3						
pF 2.7						
pF 3.0						
pF 3.7						
pF 4.2						

Fertility aspects: (0– cm)	Laboratory no. 77 / 377	
	Available	Total
Ca (me/100g)	1.6	
Mg ..	1.4	
K ..	0.98	
P (ppm)	8	
Mn (me/100g)	0.25	
Exch. acidity (me/100g)		
pH-H_2O (1: v/v)		
C%	3.62	
N%		

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Unit BXa2, Profile 40

Soil classification: dystric Planosol; ST: aeric abruptic Tropaqualf
Ecological zone: II a
Observation: 130/2-Dr I, Kisii District, E 712.6, N 9927.2, 1905 m; 2-8-1976
Geological formation: quaternary valley fills
Local petrography: volcanic ash with alluvial admixtures
Physiography: flat bottomed valley
Surrounding landform: rolling
Relief - meso: small mounds from termites and ants
Vegetation: grasses (95%), herbs (1%), shrubs (2%), trees (1%)
Land use: extensive grazing
Erosion: nil
Surface stoniness: nil
Soil fauna: ants and termites
Slope gradient: 1%
Drainage class: imperfectly to poorly drained

A1	0-27 cm	very dark brown (7.5YR 2/1, moist); common fine grey mottles; silty clay, moderate fine to weak very fine subangular blocky; very friable when moist, slightly sticky and slightly plastic, few medium, very few fine, common very fine pores; many white points; gradual and wavy transition to:
A21	27-46 cm	very dark greyish brown (7.5YR 3/1, moist); many fine prominent yellowish brown iron mottles; silty clay; weak to moderate fine to medium angular blocky structure; tendency to very coarse prisms; slightly sticky and slightly plastic; few medium and fine, common very fine pores; many white points; gradual and smooth transition to:
A22	46-66 cm	dark greyish brown (7.5YR 4/1, moist); common medium prominent yellowish brown iron mottles; silt loam; massive porous prisms, weak tendency to very coarse longitudinal prisms; firm when moist, non sticky and slightly plastic; few medium fine and very fine pores; many white points; wavy and abrupt transition to:
B21ir	66-74 cm	dark greyish brown (7.5YR 4/1, moist); many medium distinct iron mottles on peds; very gravelly silty clay loam; moderate angular blocky; non sticky and slightly plastic; few medium, fine and very fine pores; many white points many Fe- and Mn- concretions; wavy and abrupt transition to:
B22t	74-85 cm	dark greyisch brown (7.5YR 4/1, moist); common fine distinct red rootrust mottles; many medium distinct red and yellow pedrust mottles; clay; moderate fine angular blocky; sticky and slightly plastic; few fine, common very fine pores; a clear an smooth transition to:
B23t	85-105 cm	dark grey (10YR 4/1, moist); few fine distinct reddish brown rootrust mottles, common medium distinct yellowish coatings on peds; clay; moderate coarse prismatic to moderate medium angular blocky; sticky and plastic, few fine and very fine pores; a gradual and smooth transition to:
B24	105+ cm	dark grey (10YR 4/1, moist); few fine distinct reddish brown rootrust mottles, common medium distinct yellowish coatings on peds, common fine faint dark grey coatings on peds; clay; weak fine angular blocky; sticky and plastic; few fine and very fine pores; locally silty and ash-like material.

LABORATORY DATA OF PROFILE DESCRIPTION No: 41

FIELD OBSERVATION No: 130/1 - 41 MAPPING UNIT: BXg SOIL CLASSIFICATION: Gleyic SOLONETZ

Laboratory no. 1958 /	3794	3795	3796	3797	3798	
Horizon	A1	B2.1	B2.2	C1	C2	
Depth (cm)	0-7	7-30	30-60	60-115	115-170	
pH-H_2O(1: 5 v/v)	5.2	6.0	7.4	7.8	8.4	
pH-KCl ..						
EC(mmho/cm) ..						
$CaCO_3$ (%)						
$CaSO_4$ (%)						
C (%)	2.1	0.9	0.65	0.25	0.22	
N (%)	0.50	0.09	0.07	0.03	0.02	
C/N	4.2	10	10	8	11	
CEC (me/100g), pH 8.2						
CEC .. .. pH 7.0	42.0	34.4	41.6	48.0	48.8	
Exch.Ca (me/100g)	19.2	10.8	9.4	6.3	10.0	
.. Mg ..	6.8	5.1	5.9	7.1	5.1	
.. K ..	0.8	0.5	0.4	0.4	0.4	
.. Na ..	0.9	6.1	8.2	20.5	30.5	
Sum of cations	27.7	22.5	23.9	34.3	46.0	
Base sat. %, pH 8.2						
.. .. %, pH 7.0	66	65	57	71	94	
ESP at pH 7						
Saturation extract:						
Moisture %						
pH-paste						
ECe (mmho/cm)						
Na (me/l)						
K ..						
Ca ..						
Mg ..						
Sum of cations (me/l)						
CO_3 (me/l)						
HCO_3 ..						
Cl ..						
SO_4 ..						
Sum of anions (me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3 (mol/mol)						
SiO_2/R_2O_3 ..						
Fe_2O_3 (mmol%)						
X-ray report:						

Depth (cm)	0-7	7-30	30-60	60-115	115-170	
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 – 0.05 mm						
Silt % 0.05–0.002mm						
Clay % 0.002–0 mm						
Texture class						
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 – 1.0mm						
.. .. 1.0 – 0.50mm						
.. .. 0.50 – 0.25mm						
.. .. 0.25 – 0.10mm						
.. .. 0.10 – 0.05mm						
Total sand %	32	26	26	24	26	
Silt %	30	32	30	22	18	
Clay %	38	42	44	54	66	
Texture class	CL	C	C	C	C	
Bulk density						
Moisture % w/v at:						
pF 0						
pF 2.0						
pF 2.3						
pF 2.7						
pF 3.0						
pF 3.7						
pF 4.2						
Fertility aspects: (0– cm)	Laboratory no. /					
Ca (me/100g)	19.2	10.8 (Available)	9.4	6.3	10.0 (Total)	
Mg ..	6.8	5.1	5.9	7.1	5.1	
K ..						
P (ppm)	10	28	38	85	138	
Mn (me/100g)						
Exch. acidity (me/100g)						
pH-H_2O (1: v/v)						
C%						
N%						

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Unit BXg, Profile 41

Soil classification: gleyic Solonetz, ST: typic Natraqualf
Ecological zone: II c
Observation: 130/1-41, South Nyanza District, E 667.1, N 9928.4, 1340 m, 17-3-1969
Geological formation: quaternary
Local petrography: alluvium
Physiography: level stream terraces
Surrounding landform: gently undulating
Relief - meso: level
Vegetation: 90% grasses (Pennisetum catabasis) 10% trees (accacia sp.)
Land use: extensive grazing
Erosion: nil
Surface stoniness: nil
Soil fauna: medium termite activity
Slope gradient: 2%
Drainage class: imperfectly drained

A1 0-8 cm very dark brown to very dark greyish-brown (10YR 2.5/2, moist) clay loam, strong, fine subangular blocky; abundant fine and medium roots, hard, firm, sticky and plastic; few yellowish red brown concretions; abrupt and smooth transition to:

B21t 3-30 cm very dark brown (10YR 2/2, moist) clay; strong coarse prisms coated with a very thin sprinkling of grey (10YR 6/1, dry) silt loam or loam on prism tops and along cracks between prisms; very hard, very firm, very sticky and very plastic; plentiful fine and medium roots, some through prisms; thick continuous clay flows on all ped faces; clear and wavy transition to:

B22t 30-60 cm dark grey (10YR 4/1, moist) clay; strong medium subangular blocky; hard, firm, sticky and plastic; plentiful fine and medium roots, somewhat flattened between peds; thick discontinous clay flows on some peds; gradual transition to:

C1 60-115 cm grey to greyish brown (10YR-75YR 5/6, moist) clay; structure and consistance as above; plentiful fine roots; distinct common, fine strong brown (7.5YR 5/6, moist) mottles and 10% fine brown hard 'shot'; gradual and wavy transition to:

C2 115-170 cm greyish brown (10YR 5/2, moist) clay; strong medium subangular blocky; hard, firm, sticky and plastic; few fine roots; faint yellowish brown (10YR 5/4) mottles, about 5% concretions as above.

LABORATORY DATA OF PROFILE DESCRIPTION No: 42

FIELD OBSERVATION No: 130/2 **MAPPING UNIT:** BXo **SOIL CLASSIFICATION:** Dystric HISTOSOL

Laboratory no. ...../						
Horizon	O_2	C11	IIC1			
Depth (cm)	20-25	55-60	100-105			
pH-H_2O(1: 5 v/v)						
pH-KCl ..						
EC(mmho/cm) ..						
$CaCO_3$(%)						
$CaSO_4$(%)						
C (%)	19.6	19.3	1.7			
N (%)						
C/N						
CEC (me/100g), pH 8.2						
CEC .. .. pH 7.0						
Exch.Ca (me/100g)						
.. Mg ..						
.. K ..						
.. Na ..						
Sum of cations						
Base sat. %, pH 8.2						
.. .. %, pH 7.0						
ESP at pH 8.2						
Saturation extract:						
Moisture %						
pH-paste						
ECe (mmho/cm)						
Na(me/l)						
K ..						
Ca ..						
Mg ..						
Sum of cations(me/l)						
CO_3(me/l)						
HCO_3 ..						
Cl ..						
SO_4 ..						
Sum of anions(me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3(mol/mol)						
SiO_2/R_2O_3 ..						
Fe_2O_3(mmol%)						
X-ray report:						

Depth (cm)	20-25	55-60	100-105			
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 – 0.05 mm						
Silt % 0.05–0.002mm						
Clay % 0.002–0 mm						
Texture class						
Dispersed clay %						
Flocculation index						
Texture USDA:						
Sand % 2.0 – 1.0mm						
.. .. 1.0 – 0.50mm						
.. .. 0.50 – 0.25mm						
.. .. 0.25 – 0.10mm						
.. .. 0.10 – 0.05mm						
Total sand %						
Silt %						
Clay %						
Texture class						
Bulk density	0.25	0.16	1.06			
Moisture % w/v at:						
pF 0						
pF 2.0						
pF 2.3						
pF 2.6						
pF 3.0						
pF 3.7						
pF 4.2						

Fertility aspects: (0– cm)	Laboratory no. 77 / 376	
	Available	Total
Ca (me/100g)	1.2	
Mg ..	1.0	
K ..	0.68	
P (ppm)	10	
Mn (me/100g)	1.16	
Exch. acidity (me/100g)		
pH-H_2O (1: v/v)		
C%		
N%		

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Unit BXo, Profile 42

Soil classification: dystric Histosol; ST: typic Tropohemist
Ecological zone: II a
Observation: 130/2, Kisii District, E 714.3, N 9928.8, 2031 m, 4-9-1974
Geological formation: quaternary system
Local petrography: organic matter and alluvial deposits with volcanic ash
Physiography: flat bottomed valley
Surrounding landform: rolling to hilly
Relief - meso: level
Vegetation: papyrus and sedges, locally ferns
Land use: extensive grazing
Erosion: nil
Surface stoniness: nil
Soil fauna: some ants
Slope gradient: 0%
Drainage class: very poorly drained
Flooding: usually ponded

O1	0-6 cm	dark reddish brown (5YR 3/3, moist) plant remains; loose, friable; clear and smooth transition to:
O2	6-30 cm	very dark greyish brown (10YR 2/2) moist peat; weak medium subangular blocky; friable, non-sticky, slightly plastic; many micro to medium pores; abrupt and smooth transition to:
C11	30-65 cm	very dark greyish yellow (2.5YR 2/0) moist and multicoloured peat; weak medium subangular blocky; friable, non sticky, slightly plastic; few micro to medium pores; abrupt and smooth transition to:
C12	65-93 cm	very dark greyish yellow (2.5YR 2/0, moist) peat; weak medium subangular blocky; non sticky, slightly plastic; few micro to medium pores; gradual and smooth transition to:
IIC1	93-115 cm	dark greyish (5YR 3/1) wet with iron mottles; peaty clay; dense structure; very sticky, slightly plastic; many fine pores; many small iron manganese concretions; gradual and smooth transition to:
IIC2	115-125 cm	greyish yellow (5YR 4/2, moist) with iron mottles; clay; weak coarse prismatic; very sticky, slightly plastic; many fine pores; gradual and smooth transition to:
IIC3	125+ cm	blue reduction colours; clay; structure not determinable; very sticky, slightly plastic.

Remark: the soil is found in the lowest parts of valley bottoms, mostly in swamps. There is a peat layer which can vary in thickness from 40 cm to more than 1 m. The soil is wet throughout the year unless it is drained by means of ditches.

LABORATORY DATA OF PROFILE DESCRIPTION No: 43

FIELD OBSERVATION No: 130/1 - Ex20 MAPPING UNIT: BGa

Laboratory no. . . 77/	528	529	530	531		
Horizon	A1	A2.1	A2.2	B2		
Depth (cm)	0-16	16-30	30-80	80-130		
pH-H_2O(1:5 v/v)	7.4	7.3	7.0	5.0		
pH-KCl ..	5.9	5.7	5.3	4.2		
EC(mmho/cm) ..	0.29	0.70	0.50	0.04		
$CaCO_3$(%)						
$CaSO_4$(%)						
C (%)	1.8	0.55	0.64	0.12		
N (%)	0.13					
C/N	8					
CEC (me/100g), pH 8.2						
CEC .. .. pH 7.0	8.7	15.5	30.4	23.6		
Exch.Ca (me/100g)	4.5	6.4	23.0	14.8		
.. Mg ..	1.3	2.4	3.4	3.1		
.. K ..	0.6	0.7	1.2	0.9		
.. Na ..	0.1	1.7	1.6	1.1		
Sum of cations	6.2	13.2	29.2	19.9		
Base sat. %, pH 8.2						
.. .. %, pH 7.0	71	85	96	84		
ESP at pH 8.2						
Saturation extract:						
Moisture %						
pH-paste						
ECe (mmho/cm)						
Na(me/l)						
K ..						
Ca ..						
Mg ..						
Sum of cations(me/l)						
CO_3(me/l)						
HCO_3 ..						
Cl ..						
SO_4 ..						
Sum of anions(me/l)						
Adj. SAR						
Clay mineralogy:						
SiO_2/Al_2O_3(mol/mol)						
SiO_2/R_2O_3 ..						
Fe_2O_3(mmol%)						
X-ray report:						

SOIL CLASSIFICATION: Eutric PLANOSOL

Depth (cm)	0-16	16-30	30-80	80-130		
Gravel %						
Texture, limited pretreatment:						
Sand % 2.0 - 0.05 mm						
Silt % 0.05-0.002mm						
Clay % 0.002-0 mm						
Texture class						
Dispersed clay %						
Flocculation index		- -				
Texture USDA:						
Sand % 2.0 - 1.0mm	5.0	20.9	4.8	7.3		
.. .. 1.0 - 0.50mm	[illegible]	1[illegible].3	[illegible]	[illegible]		
.. .. 0.50 - 0.25mm	26.6	17.2	10.2	11.8		
.. .. 0.25 - 0.10mm	27.7	13.9	6.9	10.5		
.. .. 0.10 - 0.05mm	0.6	3.5	2.2	4.5		
Total sand %	72.7	73.8	32.3	42.8		
Silt %	10.2	7.8	7.3	13.1		
Clay %	17.1	18.2	60.4	44.1		
Texture class	SL	SL	C	C		
Bulk density	1.16	1.12	1.49	1.20		
Moisture % w/v at:						
pF 0						
pF 2.0	-	-	42.6	43.4		
pF 2.3	-	-	40.4	41.5		
pF 2.[illegible]	-	-	40.3	40.7		
pF 3.0			31.[illegible]	[illegible]		
pF 3.6	-	-	31.3	32.3		
pF 4.2	-	-	22.6	25.3		
Fertility aspects: (0-1[illegible] cm)			Laboratory no. 77/ 37[illegible]			
Ca (me/100g)	4.2	Available		Total		
Mg ..	1.2					
K ..	0.30					
P (ppm)	8					
Mn (me/100g)	0.26					
Exch. acidity (me/100g)						
pH-H_2O (1: v/v)						
C%						
N%						
Silt/clay ratio,	0.6	0.2	0.1	0.2		

Kenya Soil Survey
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Unit BGa, Profile 43

Soil classification: eutric Planosol; ST: abruptic Tropaqualf (sodic phase)
Ecological zone: III
Observation: 130/1-Ex20, South Nyanza District, E 680.7, N 9944.1, 1251 m, 17-7-1975
Geological formation: Oyugis granite (Post Nyanzian intrusive)
Local petrography: granites
Physiography: lateral slope of ridge
Surrounding landform: undulating ridges
Relief - *meso:* convex slope with erosion gullies
Vegetation: 30% shrubs, 5% trees, 50% grasses and herbs, 15% bare
Land use: extensive grazing
Erosion: slight gully erosion
Surface stoniness: interferes with tillage (5%)
Soil fauna: moderate activity of insects in upper 30 cm
Slope gradient: 5%
Drainage class: imperfectly drained

A1	0-16 cm	very dark reddish brown (10YR 3/2, moist), grey to greyish brown (10YR 5/1.5, dry) sandy loam; weak medium subangular blocky; common very fine and fine, few medium biopores; slightly hard when dry, friable when moist, non sticky, slightly plastic when wet; clear and wavy transition to:
A2	16-30 cm	dark greyish brown (10YR 4/2, moist) light brownish grey (10YR 5/1.5, dry) sandy loam; weak medium subangular blocky; many very fine, common fine and few medium biopores; slightly hard, friable; non-sticky, non plastic, abrupt and wavy transition to:
B21t	30-56 cm	same colours as A2 and in addition dark greyish brown colours of cutans; clay; moderate coarse prismatic, breaking into fine angular blocky peds; common, cutans of humus (?); common very fine, few fine and medium biopores; very hard, very firm, slightly sticky and slightly plastic; clear and wavy transition to:
B22t	56-80 cm	very dark grey (10YR 3/1, moist and wet) clay with common medium prominent reddish mottles; moderate coarse prismatic to columnar, breaking into strong fine angular blocky peds; many moderate pressure cutans, common very fine and few fine biopores; very hard, very firm, sticky and plastic; gradual and wavy transition to:
B23	80-130 cm	grey and dark grey (10YR 4/1 and 5/1) slightly gravelly clay; strong medium to fine angular blocky; some pressure cutans and slickensides; few very fine and fine biopores; very hard, very firm, sticky and plastic.
R	130+ cm	not described.

Appendix 7. Mineral percentages of the light (s.g.<2.9) fine sand fraction (50-250 μm).

Soil mapping unit	Depth (cm)	Quartz	Phytolite	Volcanic glass	Feldspar	Opaque
U1Ph	0-20	34	8	1	57	25
	60-80	81	10	2	7	37
U1Qh	0-20	100	0	0	0	75
	60-80	100	0	0	0	75
U2Ihn	0-20	56	31	7	6	78
	60-80	57	25	6	12	52
U3Bhn	0-20	86	13	1	-	94
	60-80	96	2	2	-	49
U3Ihn	0-20	96	3	1	-	41
	60-80	83	15	2	-	24
U3Ghn	0-20	99	0	1	-	5
	60-80	99	tr	tr	-	2
U4Yhp	0-20	98	0	-	2	29
	60-80	97	2	1	-	12
U4Ybp	0-20	98	0	-	2	29
	60-80	97	2	1	-	12
U3Gh	0-20	99	0	1	-	5
	60-80	99	tr	tr	-	2
U4Gh	0-20	98	1	1	-	9
	60-80	93	3	4	-	38
U4GhM	0-20	100	0	tr	-	8
PBd	0-20	89	4	5	2	66
PGa	0-20	97	3	0	0	2
	60-80	100	0	0	0	100
BXa1	0-20	75	8	5	12	18
BXa2	0-20	85	5	4	6	53
	70-90	51	35	6	8	38
BXg	0-20	100	0	0	0	15
	60-80	98	0	0	2	52
BXo	0-20	40	40	20	0	74
	100-120	88	5	6	1	86

Appendix 9. Rating of landqualities of the mapping units.

9.1. Water availability.

Appendix 9.1.1. Rootability factor per soil layer for the calculation of Actual Available Moisture Capacity for ten groups of mapping units (cf. Appendix 9.1.2).

Number corresponding with group of mapping units (cf. App. 9.1.2).	Rootability factor per soil layer			
1	0-180 (1/1),	180-300 (3/4)		
2	0-120 (1/1),	120-180 (3/4),	180-300 (1/2)	
3	0-80 (1/1),	80-120 (3/4),	120-180 (1/2)	
4	0-50 (1/1),	50-180 (3/4),	180-300 (1/2)	
5	0-50 (1/1),	50-120 (3/4),	120-180 (1/2)	>180 (0)
6	0-50 (1/1),	50-80 (1/4),	80-120 (1/4)	
7	0-50 (1/1),	50-80 (1/2),	80-120 (1/4)	
8	0-50 (1/1),	50-80 (1/2),	80-120 (1/4)	
9	0-50 (1/1),	50-80 (1/4),	80-120 (0)	
10	0-25 (1/1),	25-50 (1/2),	50-80 (1/4)	

Appendix 9.1.2. Actual available moisture capacity per mapping unit, rooting depth class (1-5) and rooting intensity type (1*-5*) (cf. App. 9.1.3).

Mapping unit	Group no (App. 9.1.1)	1	1*	2	2*	3	3*	4	4*	5	5*
HBhP	7	100	100	119	128	134	158				
HXP	10	75	86	88	112						
FBh	2	105	105	155	155	215	215	275	295		
FBht	3	100	100	155	155	194	207				
FYh	2	105	105	155	155	215	215	275	295		
FPg	9	104	104	117	129						
FQh	5	80	80	103	110	133	150	163	195		
U1Ph	2	105	105	155	155	215	215	275	295		
U1XhP	10	75	86	88	112						
U1Xh	2	105	105	155	155	215	215	275	295		
U1Bh	2	105	105	155	155	215	215	275	295		
U1Ihn	1	100	100	160	160	230	230	310	310	427	466
U1Qh	5	80	80	103	110	133	150	163	195		
U2Ihn	1	100	100	160	160	230	230	310	310	427	466
U3Bhn	1	100	100	160	160	230	230	310	310	427	466
U3Bh	2	105	105	155	155	215	215	275	295		
U3Ihn	4	60	60	86	95	122	143	167	203	227	293
U3Ghn	4	60	60	86	95	122	143	167	203	227	293
U3Gh	5	80	80	103	110	133	150				
U4Bh	7	100	100	119	128	134	158				
U4YhP	10	75	86	88	112						
U4Yhp	3	100	100	155	155	194	207				
U4Ybp	3	100	100	155	155	194	207				
U4Yg	7	100	100	119	128	134	158				
U4Gh	5	80	80	103	110	133	150				
U4GhM	10	75	86	88	112						
U4GM	8	40	40	50	55						
PBd	6	125	125	150	163	164	190				
PXhM	7	100	100	119	128	134	158				
PXa	9	104	104	117	129						
PPa	10	75	86	88	112	101	136				
PGa	9	104	104	117	129						
BBh	6	125	125	150	163	164	190				
BBd	6	125	125	150	163	164	190				
BXa1	9	104	104	117	129						
BXa2	9	104	104	117	129						
BXg	10	75	86	88	112						
BXo	1	100	100	160	160	230	230	310	310		
BGa	10	75	86	88	112						
VXP	10	75	86	88	112						

Appendix 9.1.3. Crop-water requirement types for rating of water availability.

A1V1:	cabbage, asparagus, cucumber, lettuce, carrots, melons, swiss collard, tomatoes, squash, leaks, egg-plant, french beans, ginger
A2V1:	European potatoes, groundnuts, beans (dried), green grams
A2M2	maize, finger millet, pumpkin, cowpeas
A2To2:	tobacco, chillies
A2M4*:	sorghum
A3Co4*:	cotton
A3Su4*:	sunflower
B1V1:	strawberries, pyrethrum
B1S2:	bananas
B1S3*:	sugar-cane
B1C4:	citrus
B1T4:	passion fruit, macadamia nut, papaya, cape gooseberry
B1C5*:	coffee
B1T5:	tea, loquat, apples, pears
B2V1:	sweet potatoes, pineapple
B2S4*:	castor, pigeon peas, grasses
B2C5*:	avocado, guava, anona
B3S2:	cassava
B3C5*:	mango, jojoba, sisal

Explanation of the symbols:
First letter; A = annual crop, B = perannial crop
Second letter; Crop-evaporation type (cf. App. 9.1.4); V = vegetables, M = maize, To = tobacco, Su = sunflower, Co = cotton, T = tea, C = coffee, S = sugar-cane
First number; 1 = not tolerant, 2 = tolerant in certain stages, 3 = tolerant
Second number: rooting depth class in cm (cf. App. 9.1.2); 1 = 0-50, 2 = 0-80, 3 = 0-120, 4 = 0-180, 5 = 0-300
Asterisk*: strong rooting intensity (cf. App. 9.1.2)

Appendix 9.1.4. Monthly surplusses or deficiencies (av. R-Ep) in optimal evapotranspiration (Ep) for different crops, for one or two stations per ecological zone, Av.R = average rainfall, Eo = optimal evapotranspiration, Ep = crop factor (not given) x Eo.

	Month												Year
	J	F	M	A	M	J	J	A	S	O	N	D	
Morumba, nr 9034 032 (1941-1972). Ecological-zone IIa (cf. App. 2)													
Av.R	82	96	169	307	225	180	127	190	191	161	167	132	2027
Eo	175	175	150	125	125	125	150	125	150	125	150	150	1725
Tea													
Ep	140	140	120	100	100	100	120	100	120	120	100	120	
Av.R-Ep	-58	-44	49	207	125	80	7	90	71	41	67	12	
Coffee													
Ep	90	90	105	100	100	90	105	75	75	65	105	90	
Av.R-Ep	-8	6	64	207	125	90	22	115	116	96	62	42	
Sugar-cane													
Ep	160	160	135	115	115	115	135	115	135	115	135	135	
Av.R-Ep	-78	-64	64	192	100	65	-8	75	56	46	-32	-3	
Vegetables													
Ep	125	125	105	90	90	90	105	90	105	90	105	105	
Av.R-Ep	-43	-29	64	217	135	90	22	100	86	71	62	27	
Maize													
Ep		80	75	90	120	125	115	60					
Av.R-Ep		16	94	217	105	55	12	130					
Ep	85						70	60	105	120	150	115	
Av.R-Ep	-3						57	130	86	41	17	17	
Tobacco													
Ep			60	75	100	100			60	75	120	120	
Av.R-Ep			247	150	80	27			131	86	47	12	
Sunflower													
Ep	140	105	60	75	100	110	120	75	60	75	120	135	
Av.R-Ep	-58	-9	109	232	125	70	-7	125	131	86	47	-3	

Appendix 9.1.4 continued.

	Month												Year
	J	F	M	A	M	J	J	A	S	O	N	D	
Kilgoris, nr: 9134-011 (1956-1977). Ecological-zone IIa													
Av.R	95	103	153	184	152	103	53	97	121	75	129	144	1409
Eo	150	150	150	125	125	125	150	150	150	150	150	150	1725
Tea													
Ep	120	120	120	100	100	100	120	120	120	120	120	120	
Av.R-Ep	-25	-17	23	84	52	3	-67	-23	1	-45	9	24	
Coffee													
Ep	75	75	105	100	100	90	90	90	75	75	105	90	
Av.R-Ep	20	28	48	84	52	13	-37	7	46	0	24	54	
Sugar-cane													
Ep	135	135	135	115	115	115	135	135	135	135	135	135	
Av.R-Ep	-40	-32	18	69	37	12	-82	-38	14	-60	-6	9	
Vegetables													
Ep	105	105	105	90	90	90	105	105	105	105	105	105	
Av.R-Ep	-10	-2	48	94	62	13	-52	-8	16	-30	24	39	
Maize													
Ep		68	75	90	120	125	115	70					
Av.R-Ep		33	78	94	32	-22	-62	27					
Ep	70						70	75	105	141	150	115	
Av.R-Ep	25						-17	22	16	-66	-21	29	
Tobacco													
Ep			60	75	100	100			60	90	120	120	
Av.R-Ep			93	109	52	3			61	-15	9	24	
Sunflower													
Ep	120	90	60	75	100	115	120	90	60	90	120	135	
Av.R-Ep	-25	13	93	109	52	-12	-67	7	61	-15	9	9	

Appendix 9.1.4 continued.

	Month												Year
	J	F	M	A	M	J	J	A	S	O	N	D	
Kisii, nr.: 9034-001 (1939-1972). Ecological-zone IIb													
Av.R	65	99	179	259	212	143	105	146	155	143	156	108	1770
Eo	150	175	175	125	125	150	150	150	175	175	150	150	1850
Tea													
Ep	120	140	140	100	100	120	120	120	140	140	120	120	
Av.R-Ep	-55	-41	39	159	112	23	-15	26	15	3	36	-12	
Coffee													
Ep	75	90	90	100	100	105	105	90	90	90	105	90	
Av.R-Ep	75	85	89	159	112	38	0	56	65	53	51	18	
Sugar-cane													
Ep	135	160	60	115	115	135	135	135	160	160	135	135	
Av.R-Ep	-70	-61	19	144	97	8	-30	11	-5	-17	21	-27	
Vegetables													
Ep	105	125	125	90	90	105	105	105	125	125	105	105	
Av.R-Ep	-40	-26	54	169	122	38	0	41	30	18	51	3	
Maize													
Ep	105	90	115	100	120	150	105	75	115	140	145	150	
Av.R-Ep	-40	9	64	159	92	-7	0	71	40	3	11	-42	
Tobacco													
Ep			70	75	100	120			70	105	120	120	
Av.R-Ep			109	184	112	23			85	38	36	-12	
Sunflower													
Ep	120	105	70	75	100	135	120	90	70	105	120	135	
Av.R-Ep	-55	-6	109	179	112	-8	-15	56	85	38	36	-27	

Appendix 9.1.4 continued.

	Month												Year
	J	F	M	A	M	J	J	A	S	O	N	D	
Kamagambo, nr: 9034-005 (1939-1969). Ecological-zone IIb													
Av.R	50	66	136	236	194	112	79	119	127	96	140	107	1462
Eo	175	175	150	150	125	125	150	150	175	175	150	150	1850
Tea													
Ep	140	140	120	120	100	100	120	120	140	140	120	120	
Av.R-Ep	-90	-74	16	116	94	12	-41	-1	-13	-44	20	13	
Coffee													
Ep	90	90	105	120	100	90	105	90	90	90	105	90	
Av.R-Ep	-40	-24	31	116	94	22	-26	29	37	6	35	17	
Sugar-cane													
Ep	160	160	135	135	115	115	135	135	160	160	135	135	
Av.R-Ep	-110	-94	1	101	79	-3	-56	-16	-33	-64	-5	-28	
Vegetables													
Ep	125	125	105	105	90	90	105	105	125	125	105	105	
Av.R-Ep	-79	-59	31	131	104	22	-26	14	2	-29	35	2	
Maize													
Ep	125	90	100	120	120	125	105	75	115	140	145	150	
Av.R-Ep	-75	-24	36	116	74	-13	-26	44	12	-44	-5	-43	
Tobacco													
Ep			60	90	100	100			70	105	120	120	
Av.R-Ep			76	146	94	12			57	-9	20	-13	
Sunflower													
Ep	140	105	60	90	100	115	120	90	70	105	120	135	
Av.R-Ep	-90	-39	76	146	94	-3	-41	29	57	9	20	28	

Appendix 9.1.4 continued.

	Month												Year
	J	F	M	A	M	J	J	A	S	O	N	D	
Oyugis, nr: 9034-023 (1939-1972). Ecological-zone IIc													
Av.R	28	49	110	190	213	100	99	127	109	104	109	73	1311
Eo	175	175	175	150	150	150	150	150	175	175	150	175	1950
Tea													
Ep	140	140	140	120	120	120	120	120	140	140	120	140	
Av.R-Ep	-112	-91	-30	70	93	-20	-21	7	-31	-36	11	-67	
Coffee													
Ep	90	90	125	120	120	105	105	90	90	90	105	105	
Av.R-Ep	-62	-41	-15	70	93	-5	-6	37	19	14	4	32	
Sugar-cane													
Ep	160	160	160	135	135	135	135	135	160	160	135	160	
Av.R-Ep	-132	-111	-50	55	78	-35	-36	-8	-51	-54	-26	-87	
Vegetables													
Ep (peak use)	125	125	125	105	105	105	105	105	125	125	105	125	
Av.R-Ep	-97	-76	-15	85	108	-5	-6	22	-16	-21	4	-52	
Maize													
Ep			105	120	143	150	105						
Av.R-Ep			15	70	70	-50	-6						
Tobacco													
Ep			70	90	120	120			70	105	120	140	
Av.R-Ep			40	100	97	20			39	1	-11	-67	
Sunflower													
Ep	140	105	70	90	120	135	120	90	70	105	120	160	
Av.R-Ep	-112	-56	40	100	93	-35	-21	37	39	-1	-11	-87	

Appendix 9.1.4 continued.

	Month												Year
	J	F	M	A	M	J	J	A	S	O	N	D	
Homa Bay, nr. 9034-087 (1963-1977). Ecological-zone III													
Av.R	57	68	112	211	162	95	59	81	76	67	84	91	1163
Eo	180	180	180	180	155	155	155	155	180	155	155	180	2010
Tea													
Ep	145	145	145	145	125	125	125	125	145	125	125	145	
Av.R-Ep	-88	-72	-33	66	37	-30	-66	-44	-79	-58	-41	-54	
Coffee													
Ep	90	90	125	145	120	110	110	95	90	80	110	130	
Av.R-Ep	-33	-22	-13	66	42	-15	-51	-14	-24	-13	-26	-39	
Sugar-cane													
Ep	160	160	160	160	140	140	140	140	160	140	140	160	
Av.R-Ep	-103	-92	-48	51	22	-45	-81	-59	-94	-73	-56	-69	
Vegetables													
Ep	125	125	125	125	110	110	110	110	125	110	110	125	
Av.R-Ep	-68	-57	-13	86	52	-15	-51	-29	-49	-43	-26	-34	
Maize													
Ep			110	125	150	155	110						
Av.R-Ep			2	86	12	-60	-51						
Tobacco													
Ep			70	110	125	125			70	95	125	145	
Av.R-Ep			52	101	37	-30			6	-28	-41	-54	
Sunflower													
Ep	145	110	70	110	125	140	125	95	70	95	125	160	
Av.R-Ep	-88	-42	42	101	37	-45	-66	-14	6	-28	-41	-67	
Cotton													
Ep					60	60	95	130	125				
Av.R-Ep					102	35	-36	-49	-49				

Appendix 9.1.5. Criteria for rating of the water availability of the crop water requirement types (see App. 9.1.3).

++ = good water availability
+ = moderate water availability
- = marginal water availability
Ea = monthly actual evaporation (under optimal conditions equal to Ep)
Ep = monthly potential evaporation
St = readily available moisture (RAM) which is left when Ea = Ep

$$m = \frac{Ea + St}{Ep}$$

$\bar{m}$ = average of m values of several months.

A1V1 rated for three seasons

	Ecological zones IIa, IIb				IIc, III			
1st season	M	A	M	J	A	M	J	J
2nd season	J	A	S	O	A	S	O	N
3rd season	N	D	J	F	D	J	F	M

++ if $\bar{m}$ > 120, every m > 100
+ if $\bar{m}$ > 120, lowest m between 70 and 100 or 110 < $\bar{m}$ < 120, every m > 100
- if not meeting the requirements for ++ and + above

A2V1 rated for two seasons, to be compared with A1V1
A2V1 rated for two seasons, according to water availability for A1V1 in 1st and 2nd season or in 2nd and 3rd season

++ if both seasons are rated as ++ or if one of the seasons is rated as + and the other as ++
+ if one of the seasons is rated as ++ and the other as +
- if one of the seasons is rated as + and the other as -

A2M2 rated for three crop stages which are different for the three ecological zones

	IIa	IIb	IIc/III
Initial stage (I)	3 months	3 months	2 months
Full vegetative growth stage (F)	2 months	2 months	2 months
Ripening stage (R)	2 months	1 month	1 month

++ if I : $\bar{m}$ > 120, every m > 100,
F : $\bar{m}$ > 120, every m > 110 and
R : $\bar{m}$ > 100, every m > 90
+ if I : $\bar{m}$ > 100, every m > 90,
F : $\bar{m}$ > 110, every m > 100 and
R : $\bar{m}$ > 90, every m > 60
- if not meeting the requirements for ++ and + above

A2To2 can be compared with the Initial and Full vegetative growth stages of A2M2
++ if I : $\bar{m}$ > 100, every m > 90 and
F : $\bar{m}$ > 110, every m > 100
+ if I : $\bar{m}$ > 90, every m > 80
- if not meeting the requirements for ++ and + above

A3Co4*
++ if $\bar{m}$ > 110, every m > 100
+ if $\bar{m}$ > 110 (4 months), m > 70 (5th month)
- if not meeting the requirements for ++ and + above

Appendix 9.1.5 continued.

A3Su4*
++ if $\bar{m}$ > 120 (4 months) every m > 100
+ if $\bar{m}$ > 110 (3 months), every m > 100, m > 80 (4th month)
- if not meeting the requirements for ++ and + above

B1V1 can be compared with A1V1

	1st season	2nd season	3rd season (A1V1-type)
++ if	++	++	++/+
+ if	++	++	-
- if	++	+	-
	++/+	-	-

B1S
++ if $\bar{m}$ > 120 (9 months) every m > 100 and
$\bar{m}$ > 50 (3 months)
+ if $\bar{m}$ > 120 (9 months), every m > 75 and
m > 50 (3 months)
- if not meeting the requirements for ++ and + above

B1C rated for three seasons
M A M J $\bar{m}$ > 120, not more than one m between 110 and 120
++ if J A S O N $\bar{m}$ > 130, not more than one m between 110 and 120
DJF $\bar{m}$ > 120, not more than one m between 100 and 120
M A M J $\bar{m}$ > 110, not more than one m between 100 and 110
+ if J A S O N $\bar{m}$ > 120, not more than one m between 110 and 120
DJF $\bar{m}$ > 120, not more than one m between 90 and 110

B1T
++ if $\bar{m}$ > 120 (9 months)
$\bar{m}$ > 110 (2 months) and
$\bar{m}$ > 100 (1 month)
+ if $\bar{m}$ > 120 (8 months),
$\bar{m}$ > 100 (4 months)
$\bar{m}$ > 90 (2 months) and
m > 80 (1 month)

B2V1 can be compared with A1V1
1st season 2nd season 3rd season (A1V1-type)
++ if ++/+ ++/+ ++/+/- and if $\bar{m}$ of the 3rd season
of A1V1 is not less than 30
+ if not meeting the requirements for ++ above
- not relevant

B2S4*
++ if $\bar{m}$ > 100 (9 months), every m > 60 and
$\bar{m}$ > 30 (3 months)
+ if $\bar{m}$ > 80 (9 months), every m > 50 and
$\bar{m}$ > 30 (3 months)
+ if $\bar{m}$ > 110 (4 months) and
$\bar{m}$ > 50 (5 months) and $\bar{m}$ > 40 (3 months)
- if not meeting the requirements for ++ and + above

B2C5* rated for three seasons
M A M J $\bar{m}$ > 110, not more than one m ≦ 80
++ if J A S O N $\bar{m}$ > 100, not more than one m ≦ 70
DJF $\bar{m}$ > 65, not more than one m ≦ 50
M A M J $\bar{m}$ > 100, not more than one m ≦ 60
+ if J A S O N $\bar{m}$ > 90, not more than one m ≦ 50
DJF $\bar{m}$ > 55, not more than one m ≦ 30
- if not meeting the requirements for ++ and + above

B3S2
++ if $\bar{m}$ > 100 (9 months), not more than one m ≦ 50,
$\bar{m}$ > 50 (3 months), not more than one m ≦ 25
$\bar{m}$ > 80 (9 months), not more than one m ≦ 40
$\bar{m}$ > 30 (3 months), not more than one m ≦ 10

B3C5*
The water availability is not limiting for the growth of these crop types.

Appendix 9.1.6. Rating of water availability (++, good; +, moderate; -, marginal) per mapping unit, per ecological zone, per crop-water requirement type[5] and per season (1, 2 and 3).

Ecological zone and mapping unit	Crop-water requirement type																									
	A1V1			A2V1		A2M2		A2To2		A2M4*[2]		A3Co4*	A3Su4*		B1V1	B1S2	B1S3*	B1C4	B1T4	B1C5*	B1T5	B2V1	B2S4*	B2C5*	B3S2	B3C5*
	1	2	3	1	2	1	2	1	2	1	2		1	2												
IIa																										
FPg	++	+	++	++	++	++	++						++	++	++	++		++	++	++	++	++	++	++		++
FQh	++	++	++	++	++	++	++						++	++	++	++		++	++	++	++	++	++	++		++
U1XhP	++	+[1]	++	++	++	++	+						++	++	++	++		++	-[4]	++	-[4]	++	++	++		++
U1Bh	++	++	++	++	++	++	++						++	++	++	++		++	++	++	++	++	++	++		++
U1Ph	++	++	++	++	++	++	++						++	++	++	++		++	++	++	++	++	++	++		++
U1Xh	++	++	++	++	++	++	++						++	++	++	++		++	++	++	++	++	++	++		++
U1Ihn	++	++	++	++	++	++	++						++	++	++	++		++	++	++	++	++	++	++		++
U1Qh	++	++	++	++	++	++	+						++	++	++	++		++	++[4]	++	++[4]	++	++	++		++
U2Ihn	++	++	++	++	++	++	++						++	++	++	++		++	++	++	++	++	++	++		++
U3Bhn	++	++	++	++	++	++	++						++	++	++	++		++	++	++	++	++	++	++		++
BXa2	++	++	++	++	++	++	++						++	++	++	++		++	++	++	++	++	++	++		++
BXo	++	++	++	++	++	++	++						++	++	++	++		++	++	++	++	++	++	++		++
IIb																										
HBhP	++	++	+	++	++	++	+	++	++	++	++		++	++	++	++		++	++	++	++	++	++	++	++	++
HXp, VXP	++	++	-	++	+	++	-	++	+	++	++		++	++	+	++(-)[3]		++	++(-)[3]	++	++(-)[3]	++	++	++	++	++
FBh	++	++	+	++	++	++	++	++	++	++	++		++	++	++	++		++	++	++	++	++	++	++	++	++
FBht	++	++	+	++	++	++	++	++	++	++	++		++	++	++	++		++	++	++	++	++	++	++	++	++
FYh	++	++	+	++	++	++	++	++	++	++	++		++	++	++	++	++	++	++	++	++	++	++	++	++	++
U3Bhn	++	++	+	++	++	++	++	++	++	++	++		++	++	++	++	++	++	++	++	++	++	++	++	++	++
U3Bh	++	++	+	++	++	++	++	++	++	++	++		++	++	++	++	++	++	++	++	++	++	++	++	++	++
U3Ihn	++	++	-	++	+	++	-	++	+	++	++		++	++	+	++	+	++	++	++	++	++	++	++	++	++
U3Ghn	++	++	-	++	+	++	-	++	+	++	++		++	++	+	++	+	++	++	++	++	++	++	++	++	++
U3Gh	++	++	-	++	+	++	-	++	+	++	++		++	++	+	++	+	++	++	++	++	++	++	++	++	++
U4Bh	++	++	+	++	++	++	+	++	++	++	++		++	++	++	-[3]	+	++	-[3]	++	+[3]	++	++	++	++	++
U4YhP	++	++	-	++	+	++	-	++	+	++	++		++	++	+	-	++	++	-	++	-	++	++	++	++	++
U4Yhp	++	++	+	++	++	++	++	++	++	++	++		++	++	++	+	++	++	-	++	-	++	++	++	++	++
U4Ybp	++	++	+	++	++	++	++	++	++	++	++		++	++	++	-	++	++	-	++	-	++	++	++	++	++
U4Yg	++	++	+	++	++	++	+	++	++	++	++		++	++	++	-	++	++	-	++	-	++	++	++	++	++
U4Gh	++	++	-	++	+	++	-	++	+	++	++		++	++	+	-	+	++	-	++	-	++	++	++	++	++
U4GhM	++	++	-	++	+	++	-	++	+	++	++		++	++	+	-	-	++	-	++	-	++	++	++	++	++
PBd	++	++	+	++	++	++	++	++	++	++	++		++	++	++	+	++	++	-	++	-	++	++	++	++	++
PXhM	++	++	+	++	++	++	-	++	++	++	++		++	++	++	-	+	++	-	++	-	++	++	++	++	++
PXa, PGa	++	++	+	++	++	++	+	++	++	++	++		++	++	++	-	-	++	-[4]	++	-[4]	++	++	++	++	++
PPa	++	+	++	++	++	++	+	++	+	++	++		++	++	++	+	n.r.	++	+	++	+	++	++	++	++	++
BBd	++	++	+	++	++	++	++	++	++	++	++		++	++	++	+	++	++	-	++	-	++	++	++	++	++
BXa1(BXa2)	++	++	+	++	++	++	+	++	++	++	++		++	++	++	-	-	++	-	++	-	++	++	++	++	++
BXg	++	++	-	++	+	++	-	++	+	++	++		++	++	+	-	-	++	-	++	-	++	++	++	++	++
IIc																										
U4Bh	++	++	-	++	+	++	-	++	+	++	+	++	++	++	+	-	-	++	-	++	++	++	++	++	++	++
U4YhP	++	++	-	++	+	++	-	++	-	++	+	++	++	++	+	-	-	-	-	-	+	++	+	++	+	++
U4Ybp	++	++	-	++	+	++	-	++	++	++	++	++	++	++	+	-	-	++	-	++	++	++	++	++	++	++
U4Yg	++	++	-	++	+	++	-	++	+	++	++	++	++	++	+	-	-	++	-	++	++	++	++	++	++	++
U4Gh	++	++	-	++	+	++	-	++	-	++	+	++	++	++	+	-	-	+	-	+	+	++	+	++	+	++
U4GhM	++	+	-	++	+	+	-	++	-	+	-	+	++	++	-	-	-	-	-	-	-	++	+	++	+	++
PBd	++	++	-	++	+	++	-	++	++	++	++	++	++	++	+	-	-	++	-	++	++	++	++	++	++	++
PGa	++	++	-	++	+	++	-	++	-	++	+	++	++	++	+	-	-	+	-	+	+	++	+	++	+	++
BBh, BBd	++	++	-	++	+	++	-	++	++	++	++	++	++	++	+	-	-	++	-	++	++	++	++	++	++	++
BXa1	++	++	-	++	+	++	-	++	-	++	+	++	++	++	+	-	-	+	-	+	+	++	+	++	+	++
BGa	++	++	-	++	+	++	-	++	-	++	+	++	++	++	+	-	-	+	-	+	+	++	+	++	+	++
III																										
U4YhP	++	-	-	+	-	+	-	++	-	+	-	++	++	++	-	-	-	-	-	-	-	+	+	++	+	++
U4Ybp	++	-	-	+	-	++	-	++	-	++	-	++	++	++	-	-	-	-	-	-	-	+	+	++	+	++
U4Yg	++	-	-	+	-	+	-	++	-	++	-	++	++	++	-	-	-	-	-	-	-	+	+	++	+	++
U4GM	++	-	-	+	-	-	-	+	-	-	-	-	++	-	-	-	-	-	-	-	-	+	-	-	-(+)	++
BBh	++	-	-	+	-	++	-	++	-	++	-	++	++	++	-	-	-	-	-	-	-	+	+	++	+	++
BXa1	++	-	-	+	-	+	-	++	-	+	-	++	++	++	-	-	-	-	-	-	-	+	+	++	+	++
BGa	++	-	-	+	-	+	-	++	-	+	-	++	++	++	-	-	-	-	-	-	-	+	+	++	+	++

1. U1XhP is + in the 2nd season in the driest south-eastern part of this zone, and + in the 3rd season in the rest of this zone.
2. Waterstorage in the second season is assumed to be complete below 80 cm depth, because a shallow rooting crop has been grown in the first season (thus not sorghum, which roots deeper).
3. Mapping units in this zone are below this mark rated according to the meteorological data of Kamagambo.
4. Mapping units are rated according to meteorological data of Kilgoris.
5. Cf. App. 9.1.3.

Appendix 9.2. Nutrient availability

Appendix 9.2.1. Normative (good) yields (in kg marketable product per ha) and estimated nutrient requirements (in kg N, P and K per ha) per year or per growing season (A), and per half year (B). See for explanation of conversion factor (CF) Section 4.3.2.4. Crops are arranged in the order of P requirement in a half year period.

Crop	Normative good yield	A			CF	B		
		N	P	K		N	P	K
tea	5000 a	70	5	35	0.5	35	3	20
papaya	15000	40	7	40	0.5	20	4	20
coffee	7500 b	50	7	65	0.5	25	4	35
pigeon pea	1100 c	35	5	30	1.0	20 k	5	30
pyrethrum	750 d	40	5	40	1.0	40	5	40
egg-plant	15000	40	5	50	1.0	40	5	50
banana	30000	80	10	200	0.5	40	5	100
castor	1500 c	50	6	50	1.0	50	6	50
sisal	20000 e	100	12	125	0.5	50	6	65
leeks	7500	25	7	25	1.0	25	7	25
tomato	20000	55	7	65	1.0	55	7	65
citrus	30000	150	15	130	0.5	75	8	65
pineapple	40000	150	15	275	0.5	75	8	140
green gram	500 c	35	5	30	2.0	35 k	10	60
onions	15000	55	10	35	1.0	55	10	35
sunflower	1500 c	70	10	70	1.0	70	10	70
swiss collard	20000	75	10	75	1.0	75	10	75
finger millet	1500	30	7	25	1.5	45	11	40
cucumber, squash and pumpkin	10000	20	6	30	2.0	40	12	60
european potato	20000	80	15	120	1.0	80	15	120
sweet potato	17500	90	15	140	1.0	90	15	140
sorghum	4500	120	15	110	1.0	120	15	110
cowpea	750 c	50	8	50	2.0	50 k	16	100
cassava	30000	90	20	175	0.8	70	16	140
sugar-cane	12000 f	110	25	225	0.7	80	18	160
cotton	1200 c	110	18	100	1.0	110	18	100
groundnuts	1200 c	80	10	70	2.0	80 k	20	140
tobacco	2000 g	120	22	160	1.0	120	22	160
carrots	30000	150	18	200	1.2	180	22	240
grasses	20000 h	300	45	300	0.5	150	23	150
maize	6000	150	25	140	1.0	150	25	140
french beans	4000 j	100	14	70	2.0	100 k	28	140
cabbage	40000	180	30	150	1.0	180	30	150

a. green tea
b. berries
c. seeds
d. dried flowers
e. leaves
f. sugar per year
g. cured leaf
h. dry matter
j. pulses
k. amount absorbed from soil (see Section 4.3.2.4)

Appendix 9.2.2. Grouping of crops according to their nutrient requirements in a half year period. Requirements in kg N, kg P, and kg K per ha per half year. Summarized from Appendix 9.2.1

Group	Requirements		Crops
I	N	20-75	tea, papaya, coffee, pigeon pea, pyrethrum, egg-plant,
	P	3-8	castor, sisal, leeks, tomato, citrus
	K	20-65	
II	N	35-75	green gram, onions, sunflower, swiss collard, finger
	P	9-13	millet, cucumber, squash, pumpkin
	K	35-75	
III	N	50-110	european potatoes, sweet potatoes, sorghum, cowpea,
	P	14-20	cassava, sugar-cane, cotton, groundnuts
	K	100-160	
IV	N	100-180	carrots, grasses, maize, french beans, cabbage
	P	21-30	
	K	140-240	
V	N	40-75	banana, pineapple
	P	5-8	
	K	100-140	

Appendix 9.2.3. Nutrient availability marks for different crop groups and soil fertility classes. Without fertilizer application maximum yield is 1: more than 80%, 2: 55-80%, 3: 30-55% and 4 less than 30% of the normative good yield.

Soil fertility class	Crop group				
	I	II	III	IV	V
A	1	1	1	1	1
B	1	1	1	2	1
C	1	2	2	3	2
D	2	3	3	4	2/3

Appendix 9.2.4. Nutrient availability marks for the groups per soil mapping unit. Marks: 1: more than 80%, 2: 55-80%, 3: 30-55%, 4: less than 30% of normative good yields can maximally be obtained when no fertilizers are applied. For crop groups see Appendix 9.2.2.

Soil mapping unit	Crop group				
	I	II	III	IV	V
HBhP	1	1	1	2	1
HXP 40%	1	2	2	3	2
60%	2	3	3	4	2
FBh	1	1	1	2	1
FBht	1	1	1	2	1
FYh	1	2	2	3	2
FPg	1	2	2	3	2
FQh	2	3	3	4	3
U1Ph	1	1	1	1	1
U1XhP	1	1	1	1	1
U1Xh	1	1	1	2	1
U1Bh	1	1	1	1	1
U1Ihn	1	1	1	1	1
U1Qh	4	4	4	4	4
U2Ihn	1	1	1	2	1
U3Bhn	1	1	1	2	1
U3Bh	1	1	1	2	1
U3Ihn 40%	1	2	2	3	2
60%	2	3	3	4	2/3
U3Ghn 40%	1	2	2	3	2
60%	2	3	3	4	2/3
U3Gh 40%	1	2	2	3	2
60%	2	3	3	4	2/3
U4Bh	1	1	1	1	1
U4YhP	1	2	2	3	2
U4Yhp	1	2	2	3	2
U4Ybp	1	2	2	3	2
U4Yg	1	2	2	3	2
U4YhP-U4YbP	1	2	2	3	2
U4Yhp-U4Ybp	1	2	2	3	2
U4Yhp-U4Yg	1	2	2	3	2
U4YC	1	2	2	3	2
U4Gh	2	3	3	4	2/3
U4GhM 50%	2	3	3	4	2/3
60%	4	4	4	4	4
U4GM 50%	2	3	3	4	2/3
60%	4	4	4	4	4
PBd	1	1	1	1	1
PXhM	1	1	1	1	1
PXa	4	4	4	4	4
PXhM-PXa 60%	1	1	1	1	1
40%	4	4	4	4	4
PPa	1	2	2	3	2
PGa	4	4	4	4	4
BBh	1	1	1	1	1
BBd	1	1	1	1	1
BXa1	4	4	4	4	4
BXa2	4	4	4	4	4
BXg	1	1	1	1	1
BXo	1	1	2	3	2
BGa	1	2	2/3	3	2/3
VXP	1	1	1	2	1

Appendix 9.3. Rating criteria for oxygen availability with (A, B) and without (-) improvements. Rating for moderately tolerant crops between brackets.

Soil criteria	Improvements	Rating			
		IIa	IIb	IIc	III
		season		season	
		1st	2nd	1st	2nd
Well drained to somewhat excessively drained	-	++	++	++	++
Moderately well drained	-	+(++)	++	++	++
Imperfectly to poorly drained Vertisols	-	-(+)	+(++)	+	+(++)
	A	+(++)	++	+(++)	++
Imperfectly to poorly drained Planosols and shallow soils over ironstone	-	-(+)	+	-(+)	+
	B	+(++)	+(++)	+(++)	+(++)
Poorly drained Solonetz	-	-(+)	-(+)		
	B	+	+(++)		
Very poorly drained peaty soils	-	-	-(+)		
	B	++	++		

Appendix 9.4. Rating of workability of the land.

Soil criteria	Ecological zone	
	IIa, IIb	IIc, III
Easy to work, somewhat imperfectly to somewhat excessively drained soils having less than 50% clay in the topsoil	1	1
Easy apart from work with the hoe, somewhat imperfectly to somewhat excessively drained soils, having more than 50% clay in the topsoil	2	2
Somewhat difficult for all implements due to impeded drainage, Planosols	3	2
Difficult, especially for the hoe, Vertisols	4	3
Very difficult, especially for the hoe, Solonetz	5	

Appendix 9.5. Rating of the tilth.

Soil criteria	Ecological zone	
	IIa, IIb	IIc, III
Nitosols, Luvisols, Acrisols, Phaeozems not developed from granite and quartzite	1	2
Nitosols, Acrisols, Luvisols, Phaeozems, developed from granite and quartzite, Cambisols (not sandy)	2	2
Vertisols, Verto* and Vertic* Phaeozems	4	3
Soils with sandy topsoil (Cambisols, Arenosols)	3	4
Planosols	4	4
Solonetz	5	

Appendix 9.6. Rating[1] of the landqualities, availability of oxygen (actual and potential), workability, tilth, presence of overgrazing, use of agricultural implements and resistance to soil erosion, per ecological zone, per season and per mapping unit (see Section 4.3.3).

Ecological zone and mapping unit	Availability of oxygen								Workability[4]				Tilth		Presence of overgrazing	Use of agricultural[5] implements		Resistance to soil[6] erosion		
	actual				potential				annuals		requiring perennials		requiring annuals	less requiring annuals		regular	not regular	protection of soil by crop		
	N.T.[2]		M.T.[3]		N.T.[2]		M.T.[3]		hoe	oxen	hoe	oxen						little	moderate	full
	season																			
	1	2	1	2	1	2	1	2												
IIa																				
FPg	-	+	+	+	+	+	++	++	++	++	++	++	++	++	+	+(CD)	++	-	+	++
FQh	++	++	++	++					++	++	++	++	+	++	++	+(CD)-(DE)	-(DE)	+(CD)-(DE)	+(DE)	++
U1XhP	++	++	++	++					++	++	++	++	++	++	++	-(F)	-(F)	+(BC)-(F)	-(F)	++
U1Bh	++	++	++	++					+	++	++	++	++	++	++	++	++	++	++	++
U1Ph	++	++	++	++					++	++	++	++	++	++	++	-(DE)	-(DE)	+(BC)-DE)	+(DE)	++
U1Xh	++	++	++	++					+	++	++	++	++	++	++	+(CD)-(E)	++(CD)-(E)	-(E)	+(E)	++
U1Ihn	++	++	++	++					+	++	++	++	++	++	++	+(CD)	++	++	++	++
U1Qh	++	++	++	++					++	++	++	++	+	++	++	+(CD)	++	+(CD)	++	++
U2Ihn	++	++	++	++					+	++	++	++	++	++	++	+(CD)	++	++	++	++
U3Bhn	++	++	++	++					+	++	++	++	++	++	++	+(CD)	++	++	++	++
BXa2	-	+	+	+	+	+	++	++	+	+	+	++	-	+	++	++	++	+	++	++
BXo	-	-	-	+	++	++	++	++	++	++	++	++	++	++	++	++	++	++	++	++
IIb																				
HBhP	++	++	++	++					++	++	++	++	++	++	++	-	-	-	-	++
HXP, VXP	++	++	++	++					.	.	.	.	.	.	+	-	-	-	-	++
FBh	++	++	++	++					+	++	++	++	++	++	++	+(CD)-(DE)	-(DE)	+(DE)	++	++
FBht	++	++	++	++					+	++	++	++	++	++	++	-(DE)	-DE)	+(DE)	++	++
FYh	++	++	++	++					+	++	++	++	++	++	++	+(CD)	++	++	++	++
U3Bhn	++	++	++	++					+	++	++	++	++	++	++	+(CD)	++	++	++	++
U3Bh	++	++	++	++					+	++	++	++	++	++	++	+(CD)-(DE)	+(DE)	+(DE)	++	++
U3Ihn	++	++	++	++					++	++	++	++	+	++	++	+(CD)	++	+(CD)	++	++
U3Ghn	++	++	++	++					++	++	++	++	+	++	++	+(CD)	++	+(CD)	++	++
U3Gh	++	++	++	++					++	++	++	++	+	++	++	+(CD)	++	+(CD)	++	++
U4Bh	++	++	++	++					+	++	++	++	++	++	++	++	++	+(BC)	++	++
U4YhP	++	++	++	++					++	++	++	++	++	++	++	+(CD)	++	+(BC)-(CD)	++(BC)+(CD)	++
U4Yhp	++	++	++	++					+	++	++	++	++	++	++	+(CD)	++	++	++	++
U4Ybp	++	++	++	++					++	++	++	++	++	++	++	++	++	+(BC)	++	++
U4Yg	+	++	++	++					+	++	++	++	++	++	++	++	++	+(BC)	++	++
U4Gh	++	++	++	++					++	++	++	++	+	++	++	+(CD)	++	+(CD)	++	++
U4GhM	-	+	+	+	+	+	++	++	++	++	++	++	+	++	+	++	++	++	++	++
PBd	-	+	+	++	+	++	++	++	-	+	+	++	-	+	++	++	++	++	++	++
PXhM	-	+	+	+	+	+	++	++	+	++	++	++	+	++	++	++	++	++	++	++
PXa, PGa	-	+	+	+	+	+	++	++	+	+	+	++	-	+	++	++	++	++	++	++
PPa	-	+	+	+	+	+	++	++	+	+	+	++	-	+	++	++	++	+	++	++
BBd	-	+	+	++	+	++	++	++	-	+	+	++	-	+	++	++	++	++	++	++
BXa1,(BXa2)	-	+	+	+	+	+	++	++	+	+	+	++	-	+	++	++	++	+	++	++
BXg	-	-	+	+	+	+	+	++	-	-	+	+	-	-	++	++	++	+	++	++
IIc, III																				
HXP, VXP	++	++	++	++					.	.	.		.	.	+	-	-	-	-	++
U4Bh	++	++	++	++					+	++	++	++	++	++	+(+)	++	++	+	++	++
U4YhP	++	++	++	++					++	++	++	++	++	++	+(+)	+(CD)	++	-	+(BC)-CD)	++
U4Ybp	++	++	++	++					++	++	++	++	++	++	++	++	++	+(BC)	++	++
U4Yg	++	++	++	++					+	++	++	++	++	++	++	++	++	+(BC)	++	++
J4Gh	++	++	++	++					++	++	++	++	+	++	++	+(CD)	++	+(BC)-(CD)	+(CD)	++
U4GhM	-	+	+	+	+	+	++	++	++	++	++	++	++	++	+	++	++	++	++	++
U4GM	++	++	++	++					++	++	++	++	-	+	+	++	++	+	++	++
PBd	+	+	+	++	+	++	++	++	+	+	+	++	+	++	++	++	++	+	++	++
PGa	-	+	+	+	+	+	++	++	+	++	+	++	-	+	++ +(BC)	++	++	+(AB)-(BC)	+(BC)	++
BBh, BBd	+	+	+	++	+	++	++	++	+	+	+	++	+	++	++	++	++	+	++	++
BXa1	-	+	+	+	+	+	++	++	+	++	+	++	-	+	++	++	++	+(AB)	++	++
BGa	-	+	+	+	+	+	++	++	+	++	+	++	-	+	+	++	++	+	++	++

1. ++ good availability, + moderate availability, - marginal availability
2. N.T. = not tolerant crops.
3. M.T. = moderately tolerant crops.
4. Cultivation with hoe or oxen for annuals or for perennials, requiring regular operations.
5. Use of machines (mainly 4 wheel traction) for a) crops requiring regular cultivation and b) crops not requiring regular cultivation. Slope classes, if limiting, are indicated.
6. Slope classes, if limiting, are indicated.

Appendix 11. Correlation of the mapping units with soils of the detailed surveys.

MARONGO-DETAILED SURVEY
(Boerma et al., 1974)

Soils on basalts

Mugirango series - HBhP
Ogembo series - HBhP
Gucha series - FBht
Machogo series - U3Bh
Nyaborumbasi series - U3Bhn
Changá a series - U3Bhn
Ikoba series - U3Bhn + U3Bh
Muma series - U3Bhn + U3Bh

Soils on felsites

Gesusu series - HXP
Nyakembene series - U1Ihn
Skuli series - U1Ihn

Soils on rhyolites

Kananga series - U4Yhp
Nyerega series - U4Yhp
Kitere series - U4Yhp
Nyokal series - FYh
Nduru series - FYh

Soils on granites

Shallow over laterite - U4GhM
Rongo series - U4GhM
Riosiri series - U4GhM
Paulo series - U4Gh
Ndiwa series - U4Gh
Nyasoka series - U3Ghn

Soils on quartzites

Marongo series - HXP
Nyangori series - U1Qh
Kiabigori series - U1Qh
Itumbe series - U1Qh

Poorly drained soils

Rakwaro series - PXa
Maraba series - PXa
Olando series - BXa1

IRIGONGA-DETAILED SURVEY
(van Mourik, 1974)

Kebuye series - HXP
Matiti series - HXP
Nyasoka series - U3Ihn
Raganga series - U3Ihn
Matongo series - U3Gh
Nyamatutu series - U3Gh
Riana series - U3Gh
Iruma series - U3Gh

MAGOMBO-DETAILED SURVEY
(Scholten et al., 1975)

Shallow and very shallow soils

Mirir series - U1XhP
Loudetia series - U1XhP

Soils on andesites and rhyolites

Nyamwanga series - U1Xh

Soils on andesites (rhyolites)

Nyambaria series - U2Ihn
Magombo series - U2Ihn

Soils of the valley-bottoms

Nyachogochogo series - BXa2
Gekano series - BXa2
Kenyamware series - BXo
Kenyerere series - BXo

NYANSIONGO-DETAILED SURVEY
(Guiking, 1976)

Singoiwek series - U1XhP, HXP
Kapsagut series - U1XhP + U1Ph
Nyamasibi series - U1XhP + U1Ph
Gesima series - U1Xh
Ichuni series - U1Ph
Narang'ai series - U1Ph
Nyanturago Series - U1Ph
Nyansiongo series PPa
Mango series - PPa
Isoge series - PPa
Kesaili series - BXo

Appendix 11 continued.

RANEN-DETAILED SURVEY
(van Keulen & van Reuler, 1976)

Oreru series - HXP
Ranen series - FYh
Uriri series - U4YhP
Kokuro series - U4YhP
Marando series - U4Ybp
Manyata series - U4Yg
Awundo series - PBd
Oboke series - PXhM
Aora nam series - BBd
Riana Kuna series - BXal
Sare series - BXal

RANGWE-DETAILED SURVEY
(Breimer, 1976)

Nyandara series I - U4YhP
Nyandara series II - U4Ybp

SOILS OF THE EAST KONYANGO AREA
(Miller, 1961)

Rangwe series - U4YhP
U4Ybp
U4Yhp
Bhanji series - u4Bh
Magina series - U4GhM
Kibugo series - PBd
Rodi series - PBd
Obiero series - PBd
Akijo series - PXhM
Kibubu series - PXhM
Nyangu series - PXhM
Nyokal series - PXa
Ongeng series - PXhM - PXa
Misathe series - PGa
Oboke series - BBd
Kibigori series - BBd
Marinde series - BXg

Appendix 12. Rating of the soil erosion hazard.

Soil erodibility

Rating 1 for soils with a high biological activity; a fine moderate to strong structure, a humic topsoil, a SiO_2/R_2O_3 molar ratio of less than 1.

Rating 1.5 for soils as with rating of 1, but with a weaker structure or an acid humic toplayer or with silt/clay ratio above o.5 and also for heavy cracking clay soils with a fine topsoil structure and for soils with slight drainage problems.

Rating 2 for soils with a leached topsoil and a heavy dense subsoil.

Rating 3 for dense clay soils with an exchangeable sodium percentage of more than 15.

Run-off hazard

Rating 0 for the soils with a soil erodibility rating of 1

Rating 0.5 for soils as above but with a soil erodibility rating of 1.5.

Raging 1 for soils with not too severe drainage problems.

Rating 2 for permeable shallow soils and for soils with dense clay between 50 and 100 cm depth and for Vertisols.

Rating 3 for shallow soils with hard rock underneath, for soils wit dense compact clay within 50 cm depth and also for soils with an ESP of > 15.

To the rating for soil erodibility and run-off should be added slope class and its rating value: A, 1; B, 2; C, 3.5; D, 6; E, 10; F, 15; AB, 1.5; BC, 3; CD, 5; DE, 8.

To the rating for soil erodibility and run-off is added 1.5 if occurring in ecological zone IIc and III. Gully erosion hazard is only considered for soils with run-off hazard of 2 or more, except when shallow.

Soil erosion hazard

Class	Rating
1	0-5 inclusive slight to moderate splash and slight rill erosion
2	6-12 inclusive moderate splash and rill erosion
2a	6-12 inclusive moderate rill and slight to moderate gully erosion
3	12-20 inclusive strong splash and rill erosion
3a	12-20 inclusive strong rill and moderate gully erosion
4	20 inclusive severe splash and rill erosion
4a	20 severe rill and gully erosion
2 + 3	moderate to strong splash and rill erosion.

Appendix 13. Monthly and seasonal labour demand in hrs/ha for the land utilization types and farm types, discussed in Sections 4.4 and 4.5.

Land utilization type: crop	capital input		J	F	M	A	M	J	J	A	S	O	N	D	Year	Unproductive period	
Tea	H	Plucking	205	135	185	202	192	209	174	203	203	236	196	215	2357	Digging and planting	680
		Delivery	23	19	21	22	22	23	21	22	22	23	22	22	262		
		Fertilizer				5				5					10	Weeding	3860
		Total	228	154	206	229	214	232	195	236	225	259	218	237	2629	Plucking	450
			Year of pruning (every 4th year)												Total	4990	
		Total	228	171	473	5	33	92	37	80	113	135	135	135	1639		
Pyrethrum	M/H	L + W	57	57	57	114	114	114	57	57	114	114	114	114	1083	Planting every 3rd year (hoe)	490
			Planting in every third year												163		
		Picking	136	117	78	58	78	136	117	117	136	156	176	195	1500	Weeding once	114
		Drying	1	1	1	1	1	1	1	1	1	1	1	1	12		
		Delivery	5	5	4	4	5	5	5	5	5	5	5	5	58		
		Total	in maturity year											2816			
Coffee	M/H	Picking	4		7	5	11	9	5	68	360	336	68	875	1750	Planting and land preparation	2250
		Delivery								4	16	16	4	40	80		
			W + F + Pruning												610		
		Spraying	if not done by society												70		
		Total													2510		
Sugar-cane average/yr for 1 plantcrop + 2 ratoons	L	Bush clearing	L-oxen, Pl. W.H. Transport												435		
			same, but also jaggery preparation												516		
	H	Farmer:	Pl + W + F												290	Partly mechanized farming	
		Company:	Bush clearing, P-tractor, Ridging and H														
Tobacco	H	Ridging, Planting, F.W. + ridging, suckering, topping, Cu, Gr, Spr. + M. 160 80 32 264 168 400 240 40													2040/6 months		
Cotton	L		L-pl(2x)	S		W	Plu,De										
			45 → ← 70 → ← 600 → ← 250-700 →									970			140/9 months		
	H					Spr ← 40 →											
						W											
			45 → ← 70 → ← 600 → ← 350-700 →												1105-1455/9 months		
Sunflower	H		L-h	S	W	W	W	H	Thr (with sheller)						1150-1250/4 months		
			500	140	200	200	100	6-20									
			L-h	S	W	W	W	H	Thr (with sheller								
			45	140	200	200	100	6-20							700/4 months		
Groundnuts	M		← L-h →		S	W →				← H	Sh-h						
			500		140	200				600	30-70				1500/5-6 months		
			← L-pl→		S	W →				← H	Sh-sh						
			45		140	200				600	5-12				1030/5-6 months		

Maize (Sorghum)	L		L-h	S;F		W	W	W	← H →						
			350	140		200	200	150	60						1100/5-7 months
	M/H		L-pl	S		W;Spr	W	W	← H →						
			45	145		210	200	150	60						800/5-7 months
Sisal	M/H		Pl + F + I + H + W												14400
Cassava	L		Weeding and harvesting 306-650 hrs/year												650
European potatoes	L		L-h	Pl		W	W	H							
			500-650	140		300	200	50-160							1300-1450/5 months
	H		L-pl	Pl		W;Spr	W	H							
			45	140		240	100	160-400							700-920/5 months
Beans, peas, grams	L		L-h	S		W	W	H							
			350	140		200	150	240							1080/4 months
	H		L-pl	S		W	W	H							
			45	140		200	150	240							775
Vegetables	H		400	400	400	400	400	400	400	400	400	400	400	400	4800/year
			650	650	650	650	650	650	650	650	650	650	650	650	7200
Bananas			100	100	100	100	100	100	100	100	100	100	100	100	1200 Planting: 750 h/ha
Pineapple	L		Weeding, mulching, harvesting, selling transport												
			475	475	475	475	475	475	475	475	475	475	475	475	5700 Bushel. + Pl + W
	H		Large scale - mechanized production												970 for 6 year cycle: 1030
Grazing/dairy	L	cows, grazing	512/LU, herding, watering, milking, selling, buying												512/ha · 1 LU/ha stocking rate
	M	grazing -semi-zero grazing	385/LU, spraying + dipping, A.I., milking, feeding, watering, selling,buying												770/ha 2 LU/ha
	H	zero-grazing	1200/LU + fodder production (zero-grazing)												5000/ha 4 LU/ha
	H	Poultry	425 h/yr/200 hens												425/200 hens
Fish-culture	M/H		30 h/pond/month												360 h/pond/year
Beekeeping	M/H		16 h/hive/year												

Legend: Cu = curing; De = delivery; F = fertilisation; Gr = grading; H = harvesting; L = land preparation; L-h = land preparation with hoe; L-pl = land preparation with plough; LU = livestock unit; M = marketing; Pl = planting; Plu = plucking; S = sowing; Spr = spraying; Su = suckering; T = topping; Thr = threshing; W = weeding.

Sources: Etherington (1973), Maar et al., (1966), Mann (1973), Ministry of Agriculture (1978) Farm Management Div., Extension reports of the Naivasha animal husbandry research station, BAT, SONY-Sugar Co, Fieldwork by students and staff of the Agricultural University of Wageningen, the Netherlands.

Appendix 14. Yield levels, recurrent and invested capital (1978 prices) for the land utilization types and farm types, discussed in Sections 4.4 and 4.5.

Land utilization type		Yield levels[1]/ha/year or season				Price (Ksh.)	Recurrent capital in Ksh.			Items[2]
crop	capital input level	low	medium	high			low	medium	high	
Tea	H	3000	4000	5000	kg green leaves	2.25/kg	480	600	720	F,To
Pyrethrum	M	200	350	500	kg dried flowers	50/kg (1-1.2% pyrethrins)	75	75	75	B,Tr
	H	250	500	750	kg dried flowers		175	175	175	F,B,Tr
Coffee	L,M	1500	3000	4500	kg cherries	3.50/kg	50	50	50	To
	H	2500	5000	7500	kg cherries		860	860	860	F,I,To
Sugar-cane	L	1600	2500	3400	kg sugar	50/ton cane	100	100	100	To
	H	4000	8000	12000	kg sugar	133/ton cane	3000	5000	7000	F,S,Op
Tobacco	H	400	800	1200	kg dried leaves	8-12/kg	2658	3918	5144	F,Pl,I
Cotton	L	100	200	400	kg seed	1.7-3.45/kg	30	30	30	To
	H	400	800	1200	kg seed	1.7-3.45/kg	450	450	450	To,I
Sunflower	H	500	1000	1500	kg seed	1.8/kg	450	600	750	To,F,S,Tr
Groundnuts	L	200	500	800	kg seed	3.4(shelled)/kg	50	50	50	To
	M	400	800	1200	kg seed	3.4(shelled)/kg	800	860	920	S,F,Tr,To
Maize	L	1000	2000	3500	kg seed	0.88/kg	50	60	70	S,Tr
	M,H	2000	4000	6000	kg seed	0.88/kg	1350	1350	1350	F,S,I,To,Tr
Sorghum	L	500	1250	2000	kg seed	0.63/kg	50	60	70	S,Tr
	H	1500	3000	4500	kg seed	0.63/kg	1350	1350	1350	F,S,I,To,Tr
Sisal	M,H	6000	13000	20000	kg fibre	700-1000/ton rope	.	.	.	
Cassava	L	2000	6000	10000	kg tubers	0.2-0.4/kg	50	50	50	To
	H	6000	15000	30000	kg tubers		.	.	.	
Sweet potato	L	2500	5000	10000	kg tubers		.	.	.	
European potato	L	2000	5000	8000	kg tubers	1.50/kg	1300	1300	1300	S,Tr
	H	8000	14000	20000	kg tubers	1.50/kg	4200	4200	4200	S,I,F,Tr
Beans	L	600	1200	1800	kg beans	2.50/kg	100	150	200	S,To,Tr
	M,H	1000	2500	4000	kg beans		500	575	650	S,F,I,Tr
Onions	L	2500	5000	7500	kg onions	1-2/kg	100	200	300	S,Tr,To
	H	5000	10000	15000	kg onions		1000	1500	2000	S,F,Tr
Tomato	L	4000	7000	10000	kg tomatoes	2.00/kg	100	200	300	S,Tr,To
	H	7000	14000	20000	kg tomatoes		3000	4000	5000	S,F,I,To,Tr
Banana	L,M	2500	5000	10000	kg	6/bunch	15	15	15	To
	H	5000	15000	30000			250	500	750	F
Pawpaw	L,M	2500	5000	10000	kg fruit	1/kg				
	H	5000	10000	15000			1000	1000	1000	F,I,Tr
Grazing/dairy	L	100	200	400	kg milk	1/liter milk		100/LU		To
	M	500	1000	2000	kg milk			900/LU		I,Fo,To
	H	1000	2500	4000	kg milk			1090/LU		I,Fo,To
Fish-culture	H		800		kg fish/pond	8/kg		300		Fo,Tr
Beekeeping	H	40 kg honey and 4 kg wax/hive				10/kg honey; 25/kg wax				Tr

1. Source: Extension reports of the Naivasha animal research station, Horticultural development Plan, ministry of Agriculture Nairobi, ministry of Agriculture (1975), Etherington (1973), Acland (1971), ministry of Agriculture (1978), Müller (1978), Mann (1973), Maar et al. (1966), discussions with staff of BAT, SONY-Sugar Co, Pyrethrum Board, NARS-Kisii, the National Sugar Research Station, Fieldwork by TPIP.
2. B = baskets, trays; F = fertilizer; Fo = food; I = insecticides and/or pesticides; Op = operations by company; Pl = plants; S = seed; To = tools; Tr = transport.

References

Acland, J.D., 1971. East African crops. Longman, London. 252 pp.

Beek, K.J., 1978. Land evaluation for agricultural development. International Institute for Land Reclamation and Improvement (ILRI), Wageningen, the Netherlands. 333 pp.

Begheijn, L.Th. & J. van Schuylenborgh, 1971. Methods for the analysis of soils. Department of Soil Science and Geology, Agricultural University, Wageningen, the Netherlands, Internal Report. 156 pp.

Black, C.A., 1965. Methods of soil analysis. Agronomy No 9, American Society of Agronomy Inc., Madison, Wisconsin, U.S.A. 2 vol. 1572 pp.

Boerma, P.N., G.R. Hennemann, J.H. Kauffman & H.E. Verwey, 1974. Detailed soil survey of the Marongo area. Preliminary Report 3. Department of Soil Science and Geology, Agricultural University, Wageningen, the Netherlands. 116 pp.

Braun, H.M.H., 1980. Agroclimatic zones of Kenya. Paper presented at the Fourth Annual General Meeting of the Soil Science Society of East Africa, Arusha, October 1980. Kenya Soil Survey, Nairobi. 12 pp.

Breimer, R.F., 1976. Detailed soil survey of the Rangwe area. Preliminary Report 17. Department of Soil Science and Geology, Agricultural University, Wageningen, the Netherlands. 41 pp.

CBS, 1977. Integrated rural survey. Central Bureau of Statistics, Nairobi, Kenya.

Day, P.R., 1956. Report of the Committee on physical analysis 1954-1955. Soil Science Society American Proceedings 20: 167-169.

EAC, 1971. Mean annual rainfall map of East Africa (based on all available data until 1966), scale 1:2 000 000 East African Community, Nairobi.

EAMD, 1970. Temperature data for stations in East Africa, Part 1 Kenya. East African Meteorological Department, Nairobi.

EAMD, 1976, 1977. Monthly and yearly rainfall data from the East African Meteorological Department, Nairobi.

Eijk, D. van der, (in preparation). Relations between phosphorus fixation and fertilizer management in some soils in south-west Kenya. Agricultural Research Reports, Pudoc, Wageningen, the Netherlands.

Etherington, D.M., 1973. An econometric analysis of smallholder tea production in Kenya, East African Literature Bureau, Nairobi. 151 pp.

FAO, 1967. Guidelines for soil profile descriptions. Food & Agricultural Organization, Rome. 53 pp.

FAO-Unesco, 1974. FAO-Unesco Soil map of the world. 1:5 000 000. Vol. 1. Legend. Unesco, Paris. 59 pp.

FAO, 1976. A framework for land evaluation. Food & Agricultural Organization, Rome. Soils Bulletin 32.

Fox, R.L., R.K. Hashimoto, J.R. Thompson & R.S. de la Péna, 1974. Comparative external phosphorus requirements of plants growing in tropical soils. 10th International Soil Sci. Congr. Moscow. Vol. 4. 232-239.

Fried, M. & H. Broeshart, 1967. The soil-plant system. Academic Press, New York. 358 pp.

Gelens, H.F., H.C.K. Kinyanjui & R.F. van de Weg (Ed.), 1976. Soils of the Kapenguria area. Reconnaissance Soil Survey Report no R2, Kenya Soil Survey. Government Printer, Narirobi.

Geus, J. de, 1973. Fertilizer guide for the tropics and subtropics. Centre d'étude de l'azote, Zurich. 774 pp.

Guiking, F.C.T., 1977. Split application of phosphate to hybrid maize and grass in some soils in Kisii district (S.W. Kenya). Internal report. Department of Soil Science and Plant Nutrition, Wageningen. 94 pp.

Guiking, I.M., 1976. Detailed soil survey of the Nyansiongo area. Preliminary Report 18. Department of Soil Science and Geology, Agricultural University, Wageningen, the Netherlands. 50 pp.

Hennemann, G.R. & J.H. Kauffman, 1975. Erosion in the western part of the Kisii District. Preliminary Report 8. Department of Soil Science and Geology, Agricultural University, Wageningen, the Netherlands. 115 pp.

Houba, V.J.G., J.Ch. van Schouwenburg & I. Walinga, 1979. Methods of analysis of soils. M. Sc. course in Soil Science and Water Management. Department of Soil Science, Agricultural University, Wageningen, the Netherlands.

Hubert, K., 1973. Draftplan for Kisii District. Office of the District Commissioner, Kisii, Kenya.

Huddleston, M.J., 1951. Geology of the Kisii District. Rep. Geol. Survey. Kenya 18.

Hudson, N., 1971. Soil Conservation. Batsford, London.

Jacob, A. & H. von Uexküll, 1963. Fertilizer use: Nutrition and manuring of tropical crops. 3rd ed. Verlagsgesellschaft für Ackerbau, Hannover. 617 pp.

Janssen, B.H., F.C.T. Guiking & D. van der Eijk, 1979. Soil fertility aspects of the Kisii soils. Preliminary Report 6. Department of Soil Science and Plant Nutrition, Agricultural University, Wageningen, the Netherlands. 46 pp.

Kauffman, J.H., 1975. Tillage properties of the Kapenguria soils and some other soils in Kenya as examined with the microtillage test. M. Sc. thesis, Wageningen. Department of Soil Science and Plant Nutrition, Agricultural University, Wageningen, the Netherlands and Kenya Soil Survey, Nairobi, Kenya. 62 pp.

Kendall, R.L., 1969. An ecological history of the Lake Victoria Basin. Ecol. Monogr. 39: 121-176.

Keulen, J. van & H. van Reuler, 1976. A detailed soil survey of the Ranen (sample) area. Preliminary Report 16. Department of Soil Science and Geology, Agricultural University, Wageningen, the Netherlands. 78 pp.

King, B.C., M.J. Le Bas & D.S. Sutherland, 1972. The history of the alkaline volcanoes and intrusive complexes of eastern Uganda and western Kenya. J. Geol. Soc. 128: 173-205.

Kluyfhout, H., 1978. Water availability for sugar-cane in South Nyanza. Preliminary Report 29. Department of Soil Science and Geology, Agricultural University, Wageningen, the Netherlands. 55 pp.

Kurmies, R., 1949. Humusbestimmung nach der Bichromat-verfahren ohne Kalium jodid. Zeitschrift für Pflanzenernährung, Düngung und Bodenkunde 44: 121-125.

Lanting, H., 1977. Land utilization types in the Kisii District. Preliminary Report 15. Department of Soil Science and Geology, Agricultural University, Wageningen, the Netherlands. 85 pp.

Lind, E.N. & M.E.S. Morrison, 1974. East African vegetation. Longman, London. 257 pp.

Maar, A., M.A.E. Mortimer & I. van der Lingen, 1966. Fish culture in Central East Africa. FAO, Rome. 158 pp.

Mann, I., 1973. Bees are wealth, a handy guide to beekeeping in East Africa. East African Literature Bureau, Kampala, Nairobi, Dar Es Salaam. 115 pp.

McCall, G.J.H., 1958. Geology of the Gwasi area. Rep. Geol. Surv. Kenya 45.

Mehlich, A., A. Pinkerton, W. Robertson & R. Kempton, 1962. Mass analysis methods for soil fertility evaluation. Internal Report. Ministry of Agriculture, Nairobi, Kenya.

Mengel, K. & E.A. Kirkby, 1979. Principles of plant nutrition. 2nd Ed. International Potash Institute. Worblaufen-Bern. 593 pp.

Miller, F.T., 1961. Soil Survey of the East Konyango area. Department of Agriculture, Kenya Soil Survey, Nairobi, Kenya. 151 pp. 2 maps.

Ministry of Agriculture, 1975. Agriculture in Kisii District, Ministry of Agriculture, Kisii, Kenya.

Ministry of Agriculture, 1978. Farm management division guidelines. Farm Management Division, Ministry of Agriculture, Kisii, Kenya.

Mourik, D. van, 1974. Detailed soil survey of the Irigonga area. Preliminary Report 2. Department of Soil Science and Geology, Agricultural University, Wageningen, the Netherlands. 39 pp.

Mourik, D. van, 1974. Climate. In: Wielemaker, W.G., Climate, physiography and land-use of south western Kenya. Preliminary Report 1. Department of Soil Science and Geology, Agricultural University, Wageningen, the Netherlands. 47 pp.

Müller, A.M., 1978. Animal husbandry in the Kisii and South Nyanza Districts. Preliminary Report 22. Department of Soil Science and Geology, Agricultural University, Wageningen, the Netherlands. 66 pp.

Novozamsky, I., R. van Eck, J.Ch. van Schouwenburg & I. Walinga, 1974. Total nitrogen determination in plant material by means of the indophenol-blue method. Netherlands Journal of Agricultural Science 22:3-5.

Kokwaro, J.O., 1972. Luo-english botanical dictionary, East African Publishing House, Nairobi, Kenya.

Ochse, J.J., M.J. Soule, M.J. Dijkman & C. Wehlburg, 1961. Tropical and subtropical agriculture, Volume I and II, MacMillan, New York. 1446 pp.

Oenema, O., 1978. Reconnaissance survey concerning soil temperature in South Nyanza, Kenya. M. Sc. thesis. Department of Soil Science and Geology, Agricultural University, Wageningen, the Netherlands. 50 pp.

Oenema, O., 1980. Combined application of organic manure and triple superphosphate to hybrid maize in S.W. Kenya. Internal report. Department of Soil Science and Plant Nutrition, Agriucultural University, Wageningen, the Netherlands. 125 pp.

Plaizier, A.C., 1980. An inventory of grasslands in the Kisii and part of the South Nyanza Districts. Preliminary Report 23. Department of Soil Science and Geology, Agricultural University, Wageningen, the Netherlands. 41 pp.

Purseglove, J.W., 1968. Tropical crops. Dicotyledons. Longman, London. 2 Volumes. 719 pp.

Purseglove, J.W., 1972. Tropical crops. Monocotyledons. Longman, London. 2 Volumes. 607 pp.

Richards, L.A. (Ed.), 1954. Diagnosis and improvement of saline and alkali soils. Agricultural Handbook 60. United States Department of Agriculture, Washington, DC.

Sanchez, P.A., 1976. Properties and management of soils in the tropics. Wiley, New York. 618 pp.

Scholten, J.H.M., S. ter Maat, K. van der Torren & D. Vuyk, 1975. Detailed soil survey of the Magombo area. Preliminary Report 9. Department of Soil Science and Geology, Agricultural University, Wageningen, the Netherlands. 76 pp.

Schouwenburg, J.Ch. van & I. Walinga, 1978. Methods of analysis for plant material. M.Sc. Course Soil Science and Water Management. Agricultural University of Wageningen, the Netherlands.

Scott, R.M., R.Webster & C.J. Lawrance, 1971. A land system atlas of western Kenya. Christchurch, Hampshire, England. 363 pp. 2 maps.

Shackleton, R.M., 1946. The Geology of the Migori gold belt. Geol. Surv. Kenya 10.

Siderius, W. & B.J.A. van der Pouw, 1980. The application of the FAO/Unesco terminology of the soil map of the world legend for soil classification in Kenya. Miscellaneous Soil Paper M15, Ministry of Agriculture, National Agricultural Laboratories, Kenya Soil Survey, Nairobi. 21 pp.

Soil Survey Staff, 1975. A basic system of soil classification for making and interpreting soil surveys. United States Department of Agriculture, Agricultural Handbook No. 436. Government Printing Office, Washington D.C., U.S.A.

Stakman, W.P., G.A. Valk & G. van der Harst, 1969. Determination of soil moisture retention curves. Vol. 1. Sandbox apparatus range pF 0-2.7 (19 pp.). Vol. 2. Pressure membrane apparatus range pF 3.0-4.2 (10 pp.). 3rd edition. Institute for Land and Water Management Research, Wageningen, the Netherlands.

Survey of Kenya, 1962. Kenya 1:50 000, sheets 130/2 Kisii; 130/3 Kitere and 130/4 Nyansiongo, Series Y731, Survey of Kenya, Nairobi, Kenya.

Survey of Kenya, 1963. Kenya 1:50 000, sheet 130/1 Gem, Series Y731, Survey of Kenya, Nairobi, Kenya.

Survey of Kenya, 1970. National Atlas of Kenya, Third Edition, Survey of Kenya, Nairobi.

Trapnell, J.G. & J.F. Griffiths, 1960. The rainfall-altitude relation and its ecological significance in Kenya; East African Agriculture Forestry Research Organisation. 25: 207-213.

Trapnell, J.G., M.A. Brunt & W.R. Birch, 1970. Map of vegetation. Land Use Survey of S.W. Kenya. Sheets 1-3, Survey of Kenya, Nairobi.

Wielemaker, W.G. (Ed.), 1974. Climate physiography and land-use of South Western Kenya. Preliminary Report 1. Department of Soil Science and Geology, Agricultural University, Wageningen, the Netherlands. 31 pp.

Wielemaker, W.G. & G.R. van Dijk, 1981. Mapping and correlation of erosion surfaces, variously affected by volcanic ash, tectonism and lava flows. A case study in south western Kenya. Zeitschrift für Geomorph. Neue Folge 25: 54-72.

Wissen, H.L.M. van, 1974. The influence of cultivation practices on organic matter content of deep soils in the Kisii District. Preliminary Report 4. Department of Soil Science and Geology, Agricultural University, Wageningen, the Netherlands. 45 pp.

Woodhead, T., 1968. Studies of potential evaporation in Kenya. East African Agriculture Forestry Research Organisation, Nairobi, Kenya.

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Soil classification according to FAO/UNESCO (1974): main unit	subunit[1]	Mapping unit	number of profiles analysed	A horizon: moist colour, descriptive	A horizon: organic C %[6]	A horizon: clay %[6]	A horizon: base saturation at pH 7.0[6]	A/B horizon: transition A/B horizons	A/B horizon: clay ratio B/A horizons	B horizon: clay %[6]	B horizon: silt/clay ratio	B horizon: structure	B horizon: moist consistence	B horizon: cutans	B horizon: base saturation at pH 7.0[6]	Clay fraction: CEC of clay at pH 7.0[2]	Clay mineralogy: kaolinite	Clay mineralogy: halloysite	Clay mineralogy: illite	Clay mineralogy: montmorillonite	Substance ratios: SiO2/Al2O3	Substance ratios: SiO2/Al2O3+Fe2O3	Fe2O3 % (mmol)	B horizon: moist colour, descriptive	bulk density Mg/m³	free carbonates (reaction of HCl)	Weatherable primary minerals laboratory W,P(0)[5] topsoil	Weatherable primary minerals laboratory W,P(0)[5] subsoil	Soil classification according to "Soil Taxonomy" (Soil Survey Staff, 1975)
Ferralsols	humic	U1Qh	2	5YR 3/3, dark reddish brown	2.8	65	1	g	1	68	0.3	sb	fr	C1	0	12.6	+++	0	0	0	2.2	1.6	99	2.5YR 3/6-5YR 4/6 reddish brown to dark reddish brown	1.18	0	0	0	typic Haplohumox
Nitosols	mollic*(dystro*-mollic*)	U3Bhn	2	5YR 3/2-3, dark reddish brown	3.5	65	80	c-g	1.3	80	0.3	ab	fr	C3	75(25)	16	·	·	·	·	2.1	1.6	96	2.5YR 3/6-2.5YR 3/4, dark red to dark reddish brown	1.25	0	1,13(94)	2,2(49)	typic Paleudoll and (orthoxic Palehumult)
	dystro*-mollic* (mollic*)	U1Ihn	1	7.5-5YR 3/2, dark brown to dark reddish brown	3.5	63	100	g	1.3	83	0.2	ab-sb	fr	C3	33	11	+++	0	0	0	2.1	1.5	102	2.5YR 3/4, dark reddish brown	1.16	0	·	·	orthoxic Palehumult (typic Paleudoll)
		U2Ihn	3	5YR 3/2, dark reddish brown	3.0	60	65	g	1.2	68	0.5	ab	fr	C2	30	18	+++	0	tr	0	2.3	1.7	100	5YR 3.5/4, yellowish red to dark reddish brown	1.11	0	13,31(78)	18,25(52)	orthoxic Palehumult
	mollic* and humic	U3Ihn	5	5YR 3/3, dark reddish brown	2.3	50	70 32	c-g	1.2	63	0.2 0.3	ab-sb	fr	C2	75 20	14-6.5	+++	0	0	0	2.4 4.0	1.9 3.0	71-87	2.5YR 4/5, reddish brown to red	1.17	0	1,3(41)	2,15(24)	typic Paleudoll and orthoxic Palehumult
	humic	U3Ghn	1	5YR 3/3, dark reddish brown	2	35	14	g	1.2	43	0.3	sb	fr	·	33	10	+++	0	0	0	1.3	1.1	80	5YR 4/6, yellowish red	1.5	0	1,0(5)	tr,tr (2)	orthoxic Palehumult
Phaeozems and Nitosols	luvic and mollic*	FBh	1	5YR 3/2, dark reddish brown	1.7	57	54	c	1.3	75	0.2	ab	fr	m2	50	21	·	·	·	·	·	·	·	2.5YR 3/6, dark red	1.25	0	·	·	oxic Argiudoll and typic Paleudoll
		FYh	2	5YR 3-4/2.5, dark reddish grey	2.0	33	64+	c	1.8	59	0.5	ab-sb	vfr-fr	m3	73+	16	·	·	·	·	·	·	·	2.5YR 4/4, reddish brown	1.16	0	·	·	oxic Argiudoll and typic Paleudoll
		U1Bh	1	5YR 3/3, dark reddish brown	2.0	56	53	g	1.4	80	0.2	ab	vfr-fr	c2	51	11	·	·	·	·	·	·	·	2.5YR 3/6, dark red		0	·	·	oxic Argiudoll and typic Paleudoll
		U3Bh	4	7.5-5YR 3/2, dark brown to dark reddish brown	3.0	40 60	58	c	0.8-1.3	30 70	0.3 1.2	ab	vfr	f1	50	16-24	·	·	·	·	2.1-2.5	1.6-1.7	96-114	5YR 3/2-2.5YR 3/6, dark reddish brown to dark red	1.25	0	·	·	oxic Arguidoll and typic Paleudoll
	luvic, haplic and mollic*	FBht	1	5YR 3/2, dark reddish brown	2.3	55	63	c	1.3	70	0.3	ab	fr	c2	54	15	·	·	·	·	·	·	·	2.5YR 3/6, dark red	·	0	·	·	oxic Argiudoll, oxic Hapludoll and typic Paleudoll
Acrisols	humic	FQh	1	5YR 2/2, dark reddish brown	2.9	43	41	c	1.4	61	0.4	ab	fr	C1	47	20	+++	0	tr	tr	·	·	·	5YR 4/4, reddish brown	·	0	·	·	oxic Tropudalf
		U4Gh	2	5YR 3/2, dark reddish brown	1.9	19	43	c	1.4	27	0.7	ab	fr	c2	27	15	·	·	·	·	·	·	·	5YR 5/6, yellowish red	1.3	0	1,1(9)	4,3(38)	orthoxic Tropudult
	Ferral*-humic	U3Gh	5	5YR 3/2, dark reddish brown	1.7	38	18+	c	1.3	48	0.2	ab-sb	vfr-fr	f1	18+	11	+++	0	0	0	2	1.6	69	5YR 4/8, yellowish red	1.3	0	1,0(5)	tr,tr(2)	orthoxic Tropohumult
Phaeozems Nitosols and Acrisols	luvic dystro*-mollic* humic (some)	U1Xh	3	5YR 3/2, dark reddish brown	4	40 65	25 70	c	1.2	65 70	0.35	ab	fr	f1 c2	15 40	16	+++	0	tr	0	2.1	1.6	102	2.5YR 4/6 red to reddish brown 5YR 4/4, red to reddish brown	1.1-1.3	0	15,13(76)	7,8(78)	oxic Argiudoll, Orthoxic Palehumult and orthoxic Tropohumult
Luvisols	gleyic	FPg	1	5YR 3/2, dark reddish brown	1.8	41 27	57	c	1.8	50	0.7	sb	fr	f1	53	18	++	0	+	0	2.8	2.1	86	2.5YR 4/4, reddish brown	·	0	·	·	aquic thapto albic tropaqualfic Tropudalf
Phaeozems	luvic	U1Ph	2	5YR 3/2-3, dark reddish brown	2.7	25	85	c	1.3	32	1.6	sb	fr	c2	83	21	++	0	+	0	3.2	2.2	95	5YR 3/3-2.5YR 3/4 to 2.5YR 3/6, dark	1.1	0	58,8(25)	9,10(37)	oxic Argiudoll
		U4Yhp	2	5YR 3/2, dark reddish brown	2.3	50	84	g	1.2	61	0.5	ab	fr	c2	68	18	-	0	-	0	2.3	1.7	107	reddish brown to dark red		0	2,0(29)	1,2(12)	oxic Argiudoll
	Verti*-luvic	U4Bh	1	10YR 3/1, very dark grey	2	37	100	c	1.4	58	0.3	ab	fi	c2	100+	64	+	0	+	++	·	·	·	10YR 4/1, dark grey	1.3	0	·	·	vertic Argiudoll
	Vertic*	BBh	1	5YR 2/1, black	1.5	56	100	g	1.3	70	0.37	ab	fr-fi	·	100	54	·	·	·	·	·	·	·	5YR 3/1, very dark grey	·	3 subsoil	·	·	vertic udic Argiudoll
	Gleyic	U4Yg	1	5YR 4-3/2, dark reddish grey to dark reddish brown	1.4	24	90	c	1.2	28	0.7	sb	fr	·	100	39	·	·	·	·	·	·	·	5YR 3.5/1, dark grey to dark reddish brown	1.35	0	·	·	aquic Hapludoll
	haplic (paralithic phase)	U4YhP	1	7.5YR 4/2, dark brown to brown	2.3	33	80	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·			0	·	·	typic Hapludoll
	haplic (petroferric phase)	PXhM	1	10YR 3/2, very dark greyish brown	3	30	90	g	1	30	0.96	sb	1	·	100	·	+	0	+	0	·	·	·	7.5YR 4/2, dark brown to brown		0	·	·	typic Hapludoll and Hapludoll
Luvisols & Phaeozems	orthic and luvic	U4Ybp	3	7.5YR 3/2-5YR 4/2, dark brown to dark reddish grey	2.5	43	90	g	1.3	50	0.25	ab-sb	fr-fi	·	80	20	·	·	·	·	·	·	·	7.5YR 4/3-5YR 4/3, brown to reddish brown	1.3	0	2,0(29)	1,2(12)	oxic Arguidoll and mollic Hapludalf
Cambisols	humic	HBhP	1	5 YR 3/3, dark reddish brown	2.4	66	34	c	1.0	63	0.5	ab	fr	c1	54	17	·	·	·	·	·	·	·	5YR 4/6, yellowish red	1.12	0	·	·	typic Eutropept
	humic and ferralic	U4GhM	1	7.5YR 3/2-7.5YR 4/4 brown to dark brown	1.5	27	29	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·		0	tr,0(8)		oxic Dystropept and oxic Humitropept
Cambisols & Arenosols	ferralo*-humic and ferralic	U4GM·	1	7.5YR 3/2, dark brown	1.6	19	40	·	·	·	·	·														0	·		oxic Humitropept and typic Ustipsamment
Phaeozems & Lithosols	haplic	VXP		see units U4Yhp and HXP																							0	·	typic Hapludoll and lithic Troporthent
Rankers and Lithosols		U1XhP	4	5YR 3/3, dark reddish brown	2.5	35	19	·	·	·	·	·															0	·	lithic oxic Humitropept
		HXP	2	5YR 3/2-3, dark reddish brown	2.4	37	10	·	·	·	·	·															0	·	lithic Troporthent and lithic Humitropept
Planosols	eutric	PXa	2	10YR 3/1, very dark grey	3	25	50	a	2.5	65	0.2	pr-ab	fi	c2	70	60	+	0	+++	·	·	·	·	10YR 5/1-N 2/0, grey to black	1.15	0	·	·	abruptic Tropaqualf
		PPa	1	5YR 2.5/1, black	2	29	72	a	1.8	54	0.4	ab	vfi	m3	100	75	·	·	·	·	4.7	3.5	66	10YR 2.5/1 black	1.4	2 subsoil	·	·	abruptic Tropaqualf
		PGa	2	10YR 3/1-2, very dark grey to very dark greyish brown	3	24	28	a	3	73	0.17	ab	fi	m3	70	32	++	0	0	+	2.9	2.3	70	10YR 2/2 very dark brown	1.38		0,3(2)	0,0(100)	abruptic Tropaqualf
		BXa2	2	7.5YR 2-3/1, very dark brown to greyish brown	3.5	28	15-35	a	2.7	72	0.19	pr/ab	fi	c2	42-66	52	++	0	+	+++	3.3	2.5	76	10YR 4/1-7.5YR 4/1, dark grey to dark greyish brown	1.27	0	·	·	aquic abruptic Tropaqualf
		BGa	1	10YR 3/2, very dark greyish brown	1.1	17	75	c	3.6	61	0.12	cpr/ab	vfi	c2	96	46	·	·	·	·	·	·	·	10YR 3/1, very dark grey	1.31	0	·	·	abruptic Tropaqualf
	solodic	BXa1	4	10YR 2.5/1-10YR 4/1, black to very dark grey to dark grey	2.3	28	40	a	2.5	67	0.4 0.6	cpr/ab	fi	m3	75	60	+	0	tr	+++	3.6	2.7	68	10YR 5/1-10YR 4/2, grey to dark greyish brown	1.31	0	17,8(18)	·	abruptic Tropaqualf
Solonetz	gleyic	BXg	1	10YR 2.5/2, very dark brown to very dark greyish brown	2.1	38	54	a	1.2	44	0.7	cpr/ab	fi	c3	90	90	+	0	0	+++	·	·	·	10YR 4-5/2 dark grey to greyish brown	1.31	0	0,0(15)	2,-(52)	typic Natraqualf
Vertisols	pellic	PBd4	2	10YR 2/2, very dark brown	2.6	38	84	a	1.4	53	0.17	pr/ab	fi	sc	100	80	+	0	0	+++	·	·	·	10YR 4.5/1, dark grey to grey	1.27	0	7,4(66)	·	typic Pelludert
		BBd	2	10YR 4/1, dark grey	2.5-1.8	45	74	c-a	1.5	65	0.4	pr/ab	fi	m3-fi	88	57	·	·	·	·	4.4	3.2	·	10YR 4/1-3/2, dark grey to very dark greyish brown	1.27	3 in C horizon	·	·	entic Pelludert
Histosols	dystric	BXo	2	5YR 3/3-10YR 2/2, dark reddish brown to very dark greyish brown	10- >30	·	·	·	·	·	·	pr/ab-sb	fr	·	·	·	+(+)	0	0	++	·	·	·	·	0.2-1.0	0	20,40(74)	7,5(86)	typic Tropohemist

1. Prefixes marked with * are tentative terms, awaiting international agreement on nomenclature for intergrading soil units
2. Calculated from CEC soil and clay % and corrected for presence of organic matter and expressed as meq/100 g clay. Numbers of meq should be multiplied with 10 to find number of mmol/kg clay as given in text
3. Data refer to the subsoil (50-100 cm), unless the soil is shallow
4. The data for the B horizon refer to the B2 and B3 horizon
5. s.g.<2.9 g/cm³; fraction 50-250 μm
   percentages: W, Weatherable primary minerals
   P, Plant opal
   (0), number of opaque minerals per 100 translucent grains
6. Expressed as percentages. Numbers should be multiplied by 10 to find mass fraction of organic C and divided by 100 to find weight fraction of clay and base saturation as given in text.

Explanation of abbreviations

transition A/B
a, abrupt
c, clear
g, gradual
d, diffuse

structure
pr, prismatic
cpr, columnar
ab, angular blocky
sb, subangular blocky

consistance
fr, friable
vfr, very friable
fi, firm
1, loose

clay cutans (field observation)
(See however micromorphological laboratory data in report)

quantity: f, few; c, common; m, many
grade: 1, weak/thin; 2, moderate; 3, strong

clay minerals
+++, predominant
++, common
+, few
tr, traces

free carbonates
0, no effervescence with HCl
2, moderate effervescence with HCl
3, strong effervescence with HCl
·, not determined
blanc, not existant

Appendix 5 to Report No. 4 "Soils of the Kisii area" by W.G. Wielemaker and H.W. Boxem.
Soil profile characteristics significant for soil classification.

Ministry of Agriculture-Kenya Soil Survey and Agricultural University, Department of Soil Science and Geology, Wageningen, the Netherlands.

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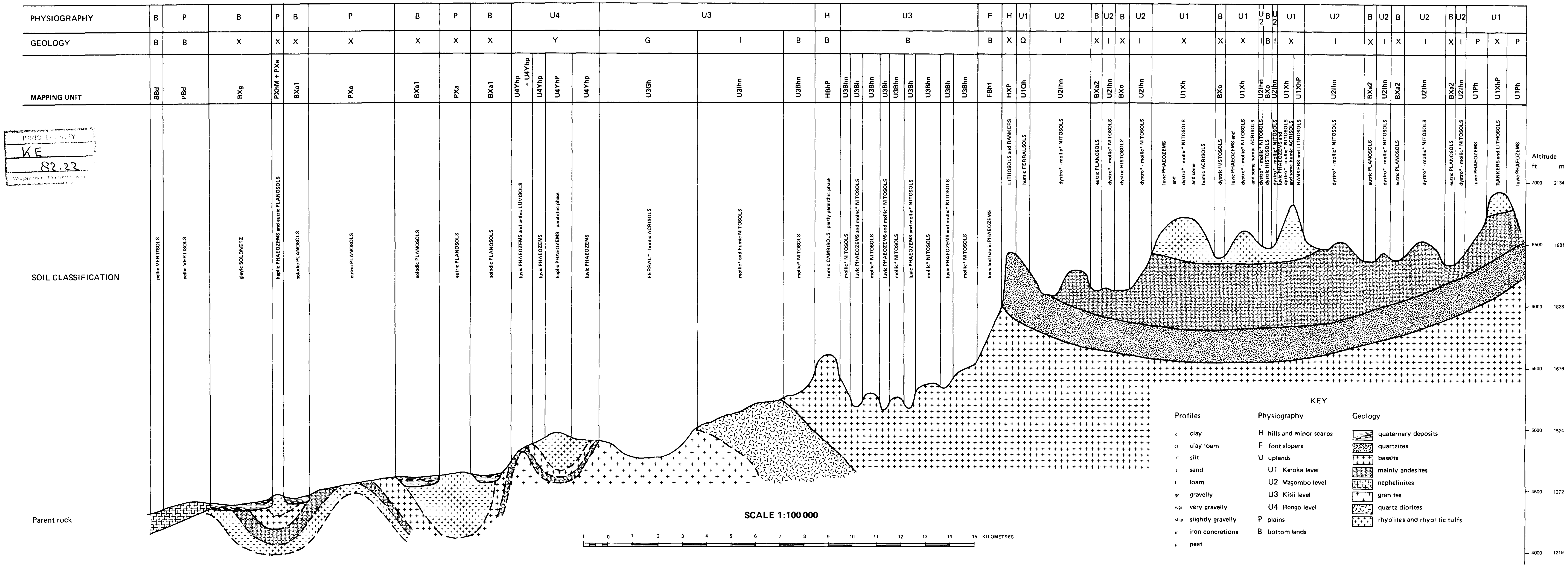
MAP SHEET 130

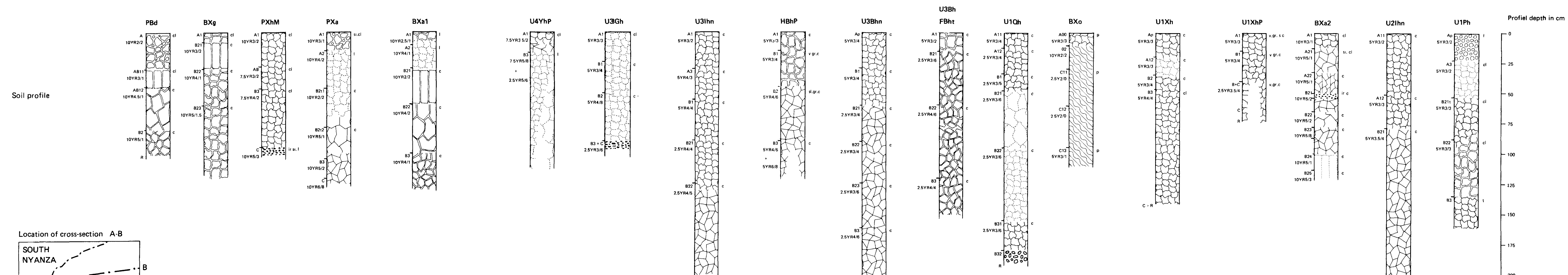
Appendix 3 to Report No. 4 "Soils of the Kisii area"

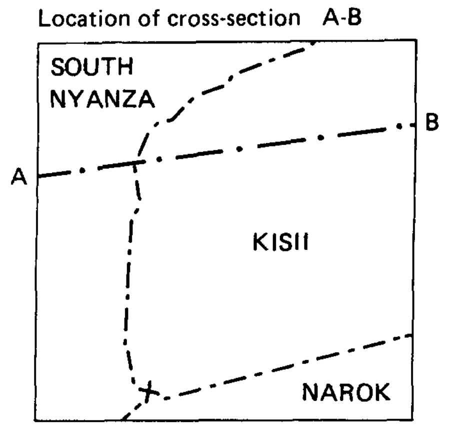
CROSS - SECTION A-B

Compiled by W.G. Wielemaker

Ministry of Agriculture - Kenya Soil Survey and Agric. University, Dept. of Soil Science, Wageningen, The Netherlands







Cartography by P.G.M. Versteeg and G. Buurman

Appendix 8 to Report No. R4: "Soils of the Kisii area"

LAND EVALUATION KEY

Ministry of Agriculture – Kenya Soil Survey and Agricultural University, Department of Soil Science, Wageningen, The Netherlands.

Ecological Zone IIa smallholder rainfed farming

Land utilization type	Crop		Tea	Pyrethrum		Maize		European potatoes		French beans		Tomatoes		Papaya		Bananas		Grazing/Dairy		
	Capital input		H	M	H	L	M/H	L	H	L	M,H	L	H	M	H	L,M	H	L	M	H
Mapping unit	Slope class	Area in hectares																		
FPg	CD	1550	1.20	2e	1.3e	2e	1.3ne	2ec	1.3ne	2e	1.3e	2ec	1.3ec	1.2ceo	1.2ceo	1.2cen	1.3cne	1.1	1.2n	1.3n
FQh	CD	954	1.1	1.2e	1.1	1.3en	1.2n	1.3cen	1.2ne	1.3ne	1.2ne	1.3ce	1.2nc	1.2c	1.2c	1.2cn	1.2cn	1.1	1.2n	1.3n
	DE	1836	1.1	1.3e	1.2e	2en	1.3en	2ecn	1.3en	2en	1.3ne	1.3ecn	1.2nce	1.2ce	1.2c	1.2cn	1.2cn	1.1	1.2n	1.3n
U1XhP,VXP	BC,CD	760	1.3w	1.1	1.1	1.1 ×1.2w	1.1 ×1.2w	1.2c	1.2c	1.1	1.1	1.2c	1.2c	1.3wc	1.3wc	1.2cw	1.2cw	1.1	1.1	1.1
U1XhP,HXP	DE,EF	14100	1.3w	2e	2e	2e	2e	2e	2e	2e	2e	2e	2e	2e	2e	1.3ecw	1.3ecw	1.1	1.1	1.1
U1Ph	BC	400	1.1	1.1	1.1	1.1	1.1	1.2c	1.2c	1.1	1.1	1.2c	1.2c	1.2c	1.2c	1.2c	1.2c	1.1	1.1	1.1
	DE	10860	1.1	2e	1.3e	1.3e	1.2e	1.3e	1.2ce	1.3e	1.2e	1.3ec	1.2ec	1.2c	1.2c	1.2c	1.2c	1.1	1.1	1.1
U1Xh	CD	3150	1.1	1.2e	1.1	1.1	1.1	1.2c	1.2c	1.1	1.1	1.2c	1.2c	1.2c	1.2c	1.2c	1.2c	1.1	1.1	1.1
	DE,E	28020	1.1	1.3e	1.2e	2en	1.3en	2ecn	1.3en	2en	1.3ne	1.3ecn	1.2nce	1.2ce	1.2c	1.2cn	1.2cn	1.1	1.2n	1.3n
U1Bh	BC	450	1.1	1.1	1.1	1.1	1.1	1.2c	1.2c	1.1	1.1	1.2c	1.2c	1.2c	1.2c	1.2c	1.2c	1.1	1.1	1.1
U1Ihn	BC,CD	790	1.1	1.1	1.1	1.1	1.1	1.2c	1.2c	1.1	1.1	1.2c	1.2c	1.2c	1.2c	1.2c	1.2c	1.1	1.1	1.1
U1Qh	BC,CD	790	1.1	1.2e	1.1	1.3en	1.2n	1.3cen	1.2ne	1.3ne	1.2n	1.3ce	1.2nc	1.2c	1.2c	1.2cn	1.2cn	1.1	1.2n	1.3n
U2Ihn	BC,CD	41720	1.1	1.1	1.1	1.1	1.1	1.2c	1.2c	1.1	1.1	1.2c	1.2c	1.2c	1.2c	1.2c	1.2c	1.1	1.1	1.1
U3Bhn	BC,CD	7210	1.1	1.1	1.1	1.1	1.1	1.2c	1.2c	1.1	1.1	1.2c	1.2c	1.2c	1.2c	1.2c	1.2c	1.1	1.1	1.2n
BXa2	AB	12630	2o	2o	2o	2o / A–B / 1.3no	2o / A–B / 1.3no	2o	2o	2o	2o	2o	2o	2o	2o	2o	2o	1.2o / A–B / 1.1	1.3o / A–B / 1.2n	2of / A–B / 1.2n
BXo	A	2450	2of	2of	2of	2of / B / 1.2n	2of / B / 1.2n	2of / B / 1.2c	2of / B / 1.2c	2of / B / 1.1	2of / B / 1.1	2of / B / 1.2c	2of / B / 1.2c	2of / B / 1.2c	2of / B / 1.2c	2of / B / 1.2c	2of / B / 1.2c	2of / B / 1.1	2of / B / 1.1	2o / B / 1.2n

Ecological Zone III smallholder rainfed farming

Land utilization type	Crop		Tobacco	Cotton		Maize		Sorghum		Groundnuts		Sunflower	Cassava		Tomatoes		Guava		Grazing/Dairy		
	Capital input		H	L	H	L	M,H	L	H	L	M	H	L	H	L	H	M	H	L	M	H
Mapping unit	Slope class	Area in hectares																			
U4YhP	BC, CD	590	1.3we ×2w	2ce	1.2ce	2e ×2w	1.3nwe ×2w	2e ×2w	1.3we ×2w	2e ×2w	1.3we ×2w	1.2e	2e	1.3wn	2e ×××2w	1.2e ×××2w	1.2e	1.1	1.2w	1.2w	1.3wn
U4Yg	BC	200	1.2w ×2w	1.2ce	1.2ce	1.2we ×2w	1.2w ×2w	1.2e ×2w	1.1 ×2w	1.2w ×2w	1.2w ×2w	1.1	1.2w	1.2w	1.2e ×××2w	1.1 ×××2w	1.1	1.1	1.2w	1.2w	1.2wn
U4Yhp–U4Ybp	BC	180	1.2w ×2w	1.2c	1.2c	1.2e ×2w	1.2n ×2w	1.2e ×2w	1.1 ×2w	1.2w ×2w	1.2w ×2w	1.1	1.2w	1.2w	1.2e ×××2w	1.1 ×××2w	1.1	1.1	1.2w	1.2w	1.2wn
U4YC	BC	870	1.2w ×2w	1.2ce	1.2ce	1.2e ×2w	1.2n ×2w	1.2e ×2w	1.1 ×2w	1.2w ×2w	1.2w ×2w	1.1	1.2w	1.2w	1.2e	1.1	1.1	1.1	1.2w	1.2w	1.2wn
U4GM	AB	790	1.2wt ×2w	2w	2w	2w	2w	2w	2w	1.3we ×2w	1.2w ×2w	1.1 ×2w	1.3w	1.3w	1.2te ×××2w	1.1 ×××2w	1.3	1.3	1.3w	1.3w	2wn
BBh	AB	570	1.2o / A / 1.1 ×2w	1.3co / A / 1.2c	1.3co / A / 1.2c	1.3opt / A / 1.2pt ×2w	1.2o / A / 1.1 ×2w	1.2pt ×2w	1.1 ×2w	1.3ow / A / 1.2wpt ×2w	1.2ow / A / 1.1 ×2w	1.2o / A / 1.1	1.3o / A / 1.2o	1.3o / A / 1.2o	1.3opt / A / 1.2pt ×××2w	1.2o / A / 1.1 ×××2w	1.2o / A / 1.1	1.2o / A / 1.1	1.1	1.1	1.2n
BXa1, BGa	AB	1700	2o / B / 1.3wn ×2w	2o / B / 1.3cto	2o / B / 1.2co	2o / B / 1.3wte ×2w	2o / B / 1.3wtn ×2w	1.3oe / B / 1.2te ×2w	1.3o / B / 1.2n ×2w	2o / B / 1.3tew ×2w	2ow / B / 1.3wto ×2w	2o / B / 1.2to	2o / B / 1.3oe	2o / B / 1.2on	2o / B / 1.3ote ×××2w	1.3o / B / 1.2t ×××2w	2o / B / 1.2o	2o / B / 1.2o	1.3wo / A / 1.2w	1.3wo / A / 1.2wn	2wo / A / 1.3nw
BXa1	BC	620	2o / B / 1.3wn ×2w	2oe	2o / B / 1.3coe	2ce ×2w	2o / B / 1.3tne ×2w	2oe ×2w	1.3o / B / 1.3en ×2w	2oe	2ow / B / 1.3we ×2w	2o / B / 1.3toe	2oe	2o / B / 1.3oen	2oe ×××2ew	2oe / B / 1.3oet ×××2w	2oe / B / 1.2oe	2oe / B / 1.2o	1.3wo / A / 1.2w	1.3wo / A / 1.2wn	2wo / A / 1.3nw

Ecological Zone IIb smallholder rainfed farming

Land utilization type	Crop		Coffee		Sugarcane		Tobacco	Maize		Groundnuts		Sunflower	Cassava		Tomatoes		Bananas		Papaya		Grazing/Dairy		
	Capital input		L,M	H	L	H	H	L	M,H	L	M	H	L	H	L	H	L,M	H	M	H	L	M	H
HBhP	EF	3470	1.3e	1.2e	2c	2c	2e	2e	2e	2e	2e	2e	2e	2e	2e	2e	2e	2e	2e	2e	1.1	1.1	1.2n
HXP, VXP	F	9030	2e	2e	2e	2e	2e	2e	2e	2e	2e	2e	2e	2e	2e	2e	2e	2e	2e	2e	1.2m	1.2n	1.3n
FBh	CD	480	1.1	1.1	2c	2c	1.2c	1.1	1.1	1.2c	1.2c	1.1	1.2c	1.2c	1.2c	1.2c	1.1	1.1	1.1	1.1	1.1	1.1	1.2n
	DE	1540	1.1	1.1	2c	2c	1.2c	1.2e	1.1	1.2c	1.2c	1.1	1.2ce	1.2c	1.2ce	1.2c	1.1	1.1	1.1	1.1	1.1	1.1	1.2n
FBht	DE	5820	cf. FBh/DE for major part of mapping unit and HBhP for smaller part of mapping unit with shallow soils.																				
FYh			cf. U4Yhp																				
U3Bhn	BC,CD	24760	1.1	1.1	2c	2c	1.2c	1.1	1.1	1.2c	1.2c	1.1	1.2c	1.2c	1.2c	1.2c	1.1	1.1	1.1	1.1	1.1	1.1	1.2n
U3Bh	BC,CD	830	1.1	1.1	2c	2c	1.2c	1.1	1.2n	1.2c	1.2c	1.1	1.2c	1.2c	1.2c	1.2c	1.1	1.1	1.1	1.1	1.1	1.1	1.2n
	DE	14770	1.1	1.1	2c	2c	1.2c	1.2e	1.2n	1.2c	1.2c	1.1	1.2ce	1.2c	1.2ce	1.2c	1.1	1.1	1.1	1.1	1.1	1.1	1.2n
U3Ihn	BC,CD	4000	1.1	1.1	1.2cw	1.2cn	1.2n	1.2e ×2w	1.2n ×2w	1.2e ×1.2w	1.1 ×1.2w	1.1	1.2e	1.2n	1.2e ××2w	1.1 ××2w	1.2n	1.2n	1.1	1.1	1.1	1.1	1.2n
U3Ghn	BC,CD	1400	1.1	1.1	1.2cwn	1.2cwn	1.2n	1.3ne ×2w	1.2n ×2w	1.2e ×1.2w	1.1 ×1.2w	1.1	1.2ne	1.2n	1.2e ××2w	1.1 ××2w	1.2n	1.2n	1.1	1.1	1.1	1.1	1.2n
U3Gh	CD	2270	1.1	1.1	2c	2c	1.3cn	1.3ne ×2w	1.2n ×2w	1.2e ×1.2w	1.1 ×1.2w	1.1	1.2ne	1.2n	1.2ce ××2w	1.1 ××2w	1.2n	1.2n	1.1	1.1	1.1	1.1	1.2n
U4Bh	AB	50	1.1	1.1	1.2w	1.2w	1.1 ×1.2w	1.1 ×1.2w	1.1 ×1.2w	1.1	1.1	1.1	1.1	1.1	1.1 ××1.2w	1.1 ××1.2w	1.3w	1.3w	1.3w	1.3w	1.1	1.1	1.1
U4YhP	BC	390	1.1	1.1	2w	2w	1.2n ×1.3wn	1.2en ×2w	1.2en ×2w	1.2e	1.1 ×1.2w	1.1	1.2e	1.2n	1.2e ××2w	1.1 ××2w	2w	2w	2w	2w	1.1	1.1	1.2n
	CD	890	1.1	1.1	2w	2w	1.3ne ×1.3ewn	2e	1.2en ×2w	2e	1.2e ×1.2w	1.2e	2e	1.2ne	2e ××2w	1.2e ××2w	2w	2w	2w	2w	1.1	1.1	1.2n
U4Yhp, FYh	BC,CD	11910	1.1	1.1	1.2c	1.2cn	1.1	1.1	1.2n	1.1	1.1	1.1	1.1	1.1	1.1 ××1.2w	1.1 ××1.2w	1.2w	1.2w	2w	2w	1.1	1.1	1.2n
U4Ybp	BC	590	1.1	1.1	1.2c	1.2cn	1.1	1.1	1.2n	1.1	1.1	1.1	1.1	1.1	1.1 ××1.2w	1.1 ××1.2w	1.2w	1.2w	2w	2w	1.1	1.1	1.2n
U4YhP-U4Yhp	DE	4410	1.1	1.1	2w+1.2c	2w+1.2cn	1.2n+1.1 ×1.3wn+1.1	1.2en+1.1 ×2w+1.1	1.2en ×2w+1.2n	2e+1.2e	1.2e	1.2e	2e+1.1	1.2ne+1.1	1.2e+1.1 ××2w+1.2w	1.1 ××2w+1.2w	2w+1.2w	2w+1.2w	2w	2w	1.1	1.1	1.2n
U4Yhp-U4Ybp	AB,BC	13960	1.1	1.1	1.2c	1.2cn	1.1	1.1	1.2n	1.1	1.1	1.1	1.1	1.1	1.1 ××1.2w	1.1 ××1.2w	1.2w	1.2w	2w	2w	1.1	1.1	1.2n
U4Yhp–U4Yg	B	5750	1.1	1.1	1.2c	1.2cn	1.1	1.1+1.2o	1.2n(o)	1.1+1.2o	1.1+1.2o	1.1+1.2o	1.1+1.2o	1.1+1.2o	1.1 ××1.2w	1.1 ××1.2w	1.2w+2w	1.2w+2w	2w	2w	1.1	1.1	1.2n
U4YC	CD	1090	1.1	1.1	1.2c	1.2cn	1.1	1.1	1.2n	1.1	1.1	1.1	1.1	1.1	1.1 ××1.2w	1.1 ××1.2w	1.2w	1.2w	2w	2w	1.1	1.1	1.2n
U4Gh	BC,CD	9340	1.1	1.1	1.2cwn	1.2cwn	1.2n ×1.3nw	1.3ne ×2w	1.2n ×2w	1.2e ×1.2w	1.1 ×1.2w	1.1	1.2ne	1.2n	1.2e ××2w	1.1 ××2w	2w	2w	2w	2w	1.1	1.1	1.2n
U4GhM	AB	1960	2ow	2ow	2w	2w	2o ×1.3wo	2o ×2w	2o ×2w	2o ×1.3wo	2o ×1.3wo	2o ×1.2o	2od	2od	2o ××2w	2o ××2w	2wo	2wo	2wo	2wo	1.2o	1.2on	1.3on
PBd, BBd	AB	1690	2o	2o	1.3o / A / 1.1	1.3o / A / 1.1	1.3ot / A / 1.2o	1.3opt / A / 1.2pt; 1.2opt × / A / 1.2pt	1.3o / A / 1.2o; 1.2o × / A / 1.1	1.3opt / A / 1.2pt	1.3opt / A / 1.2pt	1.3o / A / 1.1; 1.2o × / A / 1.1	1.3o / A / 1.2o	1.3o / A / 1.2o	2opt / A / 1.2ptc; 1.3opt ×× / A / 1.2pt	1.3oc / A / 1.2c; 1.2o ×× / A / 1.1	1.2wo	1.2wo	2wo	2wo	1.2o / A / 1.1	1.2o / A / 1.1	1.2o / A / 1.1
PXhM	A	1450	2o	2o	1.3cwo / A / 1.2cw	1.3cwo / A / 1.2cw	2o / A / 1.1; 1.3wo × / A / 1.2w	2o / A / 1.2n ×2w	2o / A / 1.1 ×2w	2o / A / 1.1; 1.2o × / A / 1.1	2o / A / 1.1; 1.2o × / A / 1.1	2o / A / 1.1; 1.2o × / A / 1.1	2o / A / 1.1	2o / A / 1.1	2o / A / 1.2c; 1.2co ×× / A / 1.1	2o / A / 1.2c; 1.2co ×× / A / 1.1	2wo	2wo	2wo	2wo	1.2o / A / 1.1	1.2o / A / 1.1	1.2o / A / 1.1
PXa	A	1580	2o	2o	1.3w	1.3w	2o / B / 1.2opt; 1.3opt × / B / 1.2opt	2o	2o / B / 1.3no; 1.3won × / B / 1.3no	2o	2o / B / 1.2opt; 1.3wo × / B / 1.2opt	2o / B / 1.2op; 1.3o × / B / 1.1	2o	2o / B / 1.2on	2o ××1.3o	2o / B / 1.2opt; 1.3opt ×× / B / 1.2opt	2wo	2wo	2wo	2wo	1.2o / A / 1.1	1.3o / A / 1.1	1.3o / A / 1.2n
PXhM – PXa	AB	2720	2o	2o	1.3cwo / A / 1.2cw	1.3cwo / B / 1.2cw	2o / A / 1.2opt; 1.3wo × / A / 1.2o	2o / A / 1.2n	2o / B / 1.3no	2o / A / 1.2opt	2o / B / 1.2opt; 1.3o × / B / 1.2opt	2o / B / 1.2op; 2o × / B / 1.1	2o / A / 1.1	2o / B / 1.2on	2o ××1.3o	2o / B / 1.2op; 1.3o ×× / B / 1.2op	2wo	2wo	2wo	2wo	1.2o / A / 1.1	1.2o / A / 1.1	1.3o / A / 1.2n
PPa	AB	2890	2o	2o	2c	2c	2c	1.3opt / B / 1.2pt; 1.2opt × / B / 1.2pt	1.3o / B / 1.2op; 1.2o × / B / 1.1	2c	2c	1.3o / B / 1.1	2o	2o / B / 1.3cp	2opt / B / 1.2pc	2op / B / 1.2pc	2wo	2wo	2wo	2wo	1.2o / A / 1.1	1.3o / A / 1.1	1.3o / A / 1.2n
BXa1 (BXa2)	AB	16000	2o	2o	1.3w	1.3w	2o / B / 1.2op; 1.3opt × / B / 1.2opt	2o / B / 1.3no	2o / B / 1.3no	2o	2o / B / 1.2opt; 1.3wo × / B / 1.2opt	2o / B / 1.2op; 1.3o × / B / 1.1	2o	2o / B / 1.2o	2o ××1.3o	2o / B / 1.2opt; 2o ×× / B / 1.2opt	2wo	2wo	2wo	2wo	1.2o / A / 1.1	1.3o / A / 1.1	1.3o / A / 1.2n
BXg	A	690	2oa	2oa	2ao	2ao	2ao	2ao	2ao	2ao	2ao	2ao	2ao	2ao	2ao	2ao	2wao	2wao	2wao	2wao	1.2aof / A / 1.1	1.3aof / A / 1.2an	2 / A / 1.3an

Ecological Zone IIc smallholder rainfed farming

Land utilization type	Crop		Tobacco	Cotton		Maize		Sorghum		Groundnuts		Sunflower	Cassava		Tomatoes		Guava		Grazing/Dairy		
	Capital input		H	L	H	L	M,H	L	H	L	M	H	L	H	L	H	L	H	L	M	H
Mapping unit	Slope class	Area in hectares																			
HXP	EF	1290	2ew	2ew	2ew	2ew	2ew	2ew	2ew	2ew	2ew	2ew	2ew	2ew	2ew	2ew	2w	2w	1.3me	1.3nw	2nw
U4Bh	AB, BC	760	1.1 ×2w	1.2ce	1.2c	1.2e ×2w	1.1 ×2w	1.2e ×1.2we	1.1 1.2w	1.2e ×1.2we	1.1 ×1.2w	1.1	1.2e	1.1	1.2ep ××2w	1.1 ××2w	1.1	1.1	1.1	1.1	1.1
U4YhP	BC, CD	2380	1.2e ×2w	2ce	1.2ce	2e ×2w	1.3ne ×2w	2e	1.2e ×2w	2e ×2w	1.2e ×2w	1.2e	2e	1.3wn	2e ××2w	1.2e ××2w	1.2e	1.1	1.2w	1.2w	1.3wn
U4Ybp	BC	580	1.1 ×2w	1.2ce	1.2c	1.2e ×2w	1.2n ×2w	1.2e	1.1	1.2e ×1.2we	1.1 ×1.2w	1.1	1.2e	1.1	1.2e ××2w	1.1 ××2w	1.1	1.1	1.1	1.1	1.2n
U4Yg	BC	550	1.1 ×2w	1.2ce	1.2c	1.2e ×2w	1.2n ×2w	1.2e	1.1	1.2e ×1.2we	1.1 ×1.2w	1.1	1.2e	1.1	1.2e ××2w	1.1 ××2w	1.1	1.1	1.1	1.1	1.2n
U4Yhp-U4Ybp	AB, BC	1690	1.1 ×2w	1.2ce	1.2c	1.2e ×2w	1.2n ×2w	1.2e	1.1	1.2e ×1.2we	1.1 ×2w	1.1	1.2e	1.1	1.2e ××2w	1.1 ××2w	1.1	1.1	1.1	1.1	1.2n
U4YC	BC	4690	1.1 ×2w	1.2ce	1.2c	1.2e ×2w	1.2n ×2w	1.2e	1.1	1.2e ×1.2we	1.1 ×2w	1.1	1.2e	1.1	1.2e ××2w	1.1 ××2w	1.1	1.1	1.1	1.1	1.2n
U4Gh	BC	1840	1.2n ×1.3wn	1.3ce	1.3cn	1.3ne ×2w	1.2n ×2w	1.2e ×1.3we	1.2n ×1.3nw	1.2e 1.3we	1.1 1.2w	1.1	1.2ew	1.2new	1.2e ××2w	1.1 ××1.2w	1.1	1.1	1.2w	1.2wn	1.3wn
	CD	480	1.3ne ×2wne	2e	1.3cne	2e ×2we	1.3ne ×2w	2e	1.3ne	2e	1.2e ×1.2we	1.2e	2e	1.2new	2e ××2w	1.2e ××2w	1.1	1.1	1.2w	1.2wn	1.3wn
U4GhM	BC	930	1.2w ×2w	1.3cwt	1.3cw	1.3wn ×2w	1.3wn ×2w	1.2wt ×2w	1.2w ×2w	1.2te ×1.3we	1.1 ×1.2w	1.1	1.2wt	1.2wn	1.2te ×××1.3wt ××2w	1.1 ×××1.2w ××2w	1.1	1.1	1.2wn	1.2wn	1.3wn
PBd BBd BBh	AB	2090	1.2o / A / 1.1 ×1.2w	1.3co / A / 1.2c	1.3co / A / 1.2c	1.3opt / A / 1.2pt ×2w	1.2o / A / 1.1 ×2w	1.2pt	1.1	1.3opt / A / 1.2pt ×1.2w	1.2o / A / 1.1 ×1.2w	1.2o / A / 1.1	1.2o / A / 1.1	1.2o / A / 1.1	1.3opt / A / 1.2pt ××2w	1.2o / A / 1.1 ××2w	1.2o / A / 1.1	1.2o / A / 1.1	1.2o / A / 1.1	1.2o / A / 1.1	1.2o / A / 1.1
PGa	AB	1060	2o / B / 1.3on ×1.3own	2o / B / 1.3cto	2o / B / 1.3co	2o / B / 1.3ote ×2w	2o / B / 1.3tn ×2w	1.3oe / B / 1.2te ×1.3we	1.3o / B / 1.2n; 1.3wo × / B / 1.2wn	2o / B / 1.3ote ×1.3tew	2o / B / 1.2to; 2ow × / B / 1.3wto	2o / B / 1.2to	2o / B / 1.3oe	2o / B / 1.2on	2o / B / 1.3te ××2w	1.3o / B / 1.2t ××2w	2o / B / 1.2o	2o / B / 1.2o	1.3wo / A / 1.2w	1.3wo / A / 1.2wn	2wo / A / 1.3wn
BXa1	AB	3090	2o / B / 1.3on ×1.3own	2oe	2o / B / 1.3coe	2oe ×2we	2o / B / 1.3tne ×2we	2oe	2o / B / 1.3en	2oe	2o / B / 1.3toe ×2owe	2o / B / 1.3toe	2oe	2o / B / 1.3oen	2oe ××2ew	2oe / B / 1.3oet ××2ew	2oe / B / 1.2o	2oe / B / 1.2o	1.3wo / A / 1.2w	1.3wo / A / 1.2wn	1.3wo / A / 1.3nw

NOTES AND EXPLANATION

Explanation of land suitability symbols

class	Suitability	Suggested colour
1.1	highly suitable	dark green
1.2	moderately suitable	medium green
1.3	marginally suitable	light green
2	not suitable	red

current suitability subclass — 1.3o / B / 1.2n — potential suitability subclass

required major improvement/capital input

Input levels
A low
B moderate
C high
D very high

Suitability subclass: indicated by letter suffix(es), which stand for the most deficient land quality(ies)—(cf. section 4.3 and appendix 9):
- c— climatic hazards , affecting plant growth (e.g. hail) temperature regime, pests and diseases related to the land (cf. Table 15)
- w— availability of water
- o— availability of oxygen
- n— availability of nutrients
- p— workability of the land
- t— conditions for germination (tilth)
- e— resistance to soil erosion
- a— alkalinity
- f— flooding hazard
- m— presence of overgrazing

The suitability subclass refers to the principal growing season of an annual crop. Only if the second or third growing season is different from the principal one, this is indicated by:
- x followed by a suitability subclass for the drier 6-months period
- xx followed by a suitability subclass for the driest 4-months period
- xxx followed by a suitability subclass for the driest 8-months period

Note: where a current and potential suitability subclass are given, the symbol x, xx or xxx is put inside the box

This key to be used in conjunction with appendix 2

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