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Cover plate: Field camp under baobab tree in Mitangoni, Kilifi Area (photograph T. de Meester).

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Abstract

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The Kilifi Area, named after the Kilifi District, is in the coastal zone of South-East Kenya. The area surveyed covers about 2000 km^2 and includes small parts of Kwale District and Mombasa Municipality. Geology, geomorphology, soil fertility, erosion hazard, climate and ecological zones are described and presented on the basis of thematic maps. Soils are defined by physiography and taxonomy and depicted on a soil map of scale 1 : 100 000. Factors in their formation are also discussed. There is a full chapter on vegetation and land-use with a map on 1 : 100 000. For land evaluation, existing 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, Kenya.

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T.P.I.P. Headquarters at Bofa, Kilifi (photo De Meester, 1980).

Preface

The present report is the eleventh in the Kenya Soil Survey Series of "Reconnaissance Soil Surveys". It is the second prepared jointly by the Kenya Soil Survey and the Training Project in Pedology of the Agricultural University, Wageningen, the Netherlands.

The Training Project in Pedology was approved by the Government of Kenya in 1973. It operated in Kisii between 1973 and 1979. It then moved to Kilifi where it operated between September 1979 and November 1982. After a spell of 2 years, it moved to the Chuka Area (between Embu and Meru) in March 1985.

The project was established jointly by the Agricultural University of Wageningen, the Netherlands, the Ministry of Agriculture of Kenya and the Faculty of Agriculture of the University of Nairobi. Its main aim has been the training of students of the Agricultural University, Wageningen, in soil survey, land evaluation and related subjects. Several MSc-students of the University of Nairobi have participated too.

With deep regret, we announce that in 1985 two reputed members of the project have passed away: the project supervisor Professor Dr. J. Bennema in January and Mr. H.W. Boxem, project manager, in February. Their spirit and dedication have contributed much to the success of the projects in Kisii and Kilifi.

The close cooperation between the Kenya Soil Survey and the Training Project in Pedology, which had been started in 1974, was successfully continued during the Kilifi survey. As a result of this cooperation, the Project has now produced the reconnaissance soil map of Sheet 198 at 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 map and accompanying report have been produced in the Netherlands.

Both the Training Project in Pedology and the Kenya Soil Survey are confident that this report and its maps will serve as a source of information on soils and land use of the Kilifi Area and that it will contribute to the agricultural development of the Kenya Coast.

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List of participants and acknowledgments

The following persons have contributed to the Kilifi Project and to this publication:

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- *Assistants*: Miss Grace Randu (secretary), Shaban Hayimara (mechanic/driver) Alfred Odupa and Joseph (laboratory technicians), Patric Kombe, Martin Kazungu and Benson Ziro (interpreters), Rexton Karissa (botanical assistant), Katana Kaviha, Mohamed Salim, Mohamed Mashin, Mweni Maitha, Stanley Gunga, Miss Esther Kadzo, Newton Nguzo, Josphat Kaingu, Kenneth, Juma and many others, who served the project as field assistant for longer or shorter periods.

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- Divisional Offices at Kaloleni and Ganze.
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- Department of Tropical Crop Science: G.H. de Bruyn, M.F. Flach, H. Waaijenberg (all photographs in this report are by H. Waaijenberg) and J.F. Wienk.
- Department of Agrarian History: J.S. Wigboldus.
- Department of Word processing: Mrs. A. van Wijk-van der Leeden and Mrs. T.T. Neijenhuis-Reijmers.

Summary

The Kilifi Area covers about two thirds of the Quarter Degree Sheet 198 of the Survey of Kenya. This is about 200 000 hectares. The rest is the Indian Ocean. Altitude ranges from sea level in the east to 300 m in the west. Average annual rainfall ranges from 600 mm in the north-west to 1200 mm in the south-east, and average annual evaporation from 2300 mm to 2000 mm. The coastal zone has a marked dry season from January to March and a wet one from April to June. The "hinterland" has a bimodal distribution with a second rainy season between October and December. Variations in total and distribution through the year are large and erratic in the whole area.

Ecological Zone III-1 (CL3) covers the southeastern corner of the area and Zone V-1 the northwestern one. The diagonal belt between, covering about half of the total area, is Zone IV-1. Field observations on natural vegetation and crop performance, and also rain-gauge data collected during the project period suggest a slightly more complicated distribution: the area around Kaloleni seems wetter than its surroundings (Appendix 8).

The Kilifi Area has three major land-forms: the low Coastal Plains along the coast, the high Coastal Plains in the extreme west, and the Coastal Uplands, covering about two thirds of the area, between. The subsurface materials (geology) of the area consist of a succession of sediments and sedimentary rocks, running in zones roughly parallel to the coastline, i.e. north-south.

The soils of the low Coastal Plains are mainly on coarse-grained sands: well drained, very deep yellowish brown and yellowish red soils of sandy to loamy texture. Here and there are shallow clayey soils on coral limestone. The sandy soils are chemically extremely poor. Land-use is mainly for tree crops (coconut, cashew and mango) and food crops in smallholdings. There are also two large sisal and livestock estates and (near Mombasa) several medium sized coconut and vegetable farms.

The soils of the high Coastal Plains in the extreme west are on mainly clayey Bay sediments: moderately well drained, deep to very deep, brown mottled sandy clays. These soils are physically bad and partly rich in exchangeable sodium, often resulting in a soil that is compacted and crusted. Land is under bush and shrub with extensive (over)grazing.

The soils of the Coastal Uplands can be divided into an eastern part (adjacent to the low Coastal Plain) and a western part (adjacent to the high Coastal Plain). The eastern part has soils developed on shales and on limestones, both occurring in north-south running belts. Smaller areas are isolated uplands of unconsolidated sands of the Magarini Formation. The soils

on shales are relatively fertile and moderately well drained, moderately deep, yellowish red and reddish brown clays with vertic properties. The area is strongly dissected and treeless. Land is under food crops, bush fallow and extensive grazing in smallholder farming. The soils on limestone are well drained, deep to very deep, red sandy clays, locally with scattered rock outcrops. The soils are chemically and physically very reasonable. The population is dense there and land is mainly under tree crops (coconut, fruit trees and cashew) with intensive cultivation of food crops and some cash crops underneath in a mixed cropping system. The farmers are smallholders. The soils in the Magarini sandhills are very well drained, very deep and dusky red sands, physically good but chemically very poor. Land is mainly used for smallholder cashew and food crops.

The soils of the western part of the Coastal Uplands are mainly on coarse-grained (Mazeras Formation) and fine-grained (Mariakani Formation) sandstones covering about a quarter of the Kilifi Area. Minor areas in this part have soils on clayey Bay sediments. The soils on sandstones are excessively drained, very deep, white, yellow, and yellowish brown or red sands. Here and there are red sandy clays. These sandy soils are chemically poor and very permeable. In the wetter part of this area, around Kaloleni, land is mainly under coconut ("palm belt", Appendix 8) with fruit trees and cashew. Under the trees intensive mixed food crops and some cash crops are found, for instance sesame and tobacco. In wet years, rice is grown on the valley bottoms. In the drier parts, north and north-west of Kaloleni, coconut gives gradually way to cashew and then to bush and shrubland with extensive grazing and some charcoal production (near Ganze and Bamba) in the north-west. The soils on Bay deposits in this area are mainly imperfectly drained, deep, brown sandy clays. Land is used for extensive grazing with scattered cultivation of food crops.

The present natural vegetation is strongly connected with land use, climate, soil and relief. The seven main vegetation landscapes of the Kilifi Area are named after their common or characteristic plant species (including major tree crops). They show a distribution pattern similar to that of the soil landscapes. Of special interest is the vegetation of the sacred forest patches ("kayas"), which are remnants of the original coastal forest left on the tops of several hills in the Coastal Uplands.

The land of the Kilifi Area was evaluated and classed for a number of relevant land utilization types, defined by various attributes, according to the FAO framework for landevaluation. Results are summarized in Appendix 7. Soil moisture and nutrient availability seemed to be major constraints in the area, one or the other, and often both. Due to the limited (ground) water resources for irrigation and limited possibilities for conservation of rain-water, and because of the prevailing low input farming systems and associated socio-economic conditions, the scope for improved alternative land-uses seems limited too. However, the introduction of small-scale dairy activities, improved livestock keeping, soil conservation, water conservation, the introduction of improved trees and foodcrops (including drought-resistant ones), and the introduction of credit-backed fertilizer programmes seem real possibilities for improvement of agriculture in the Kilifi Area.

1 The environment

1.1 SITUATION, COMMUNICATION AND POPULATION

The reconnaissance soil map (Appendix 1) is named after the Kilifi District, which covers the major part of the sheet. Minor parts in the south belong to the Kwale District and Mombasa municipality (Fig. 1). The whole survey area is part of Coast Province.

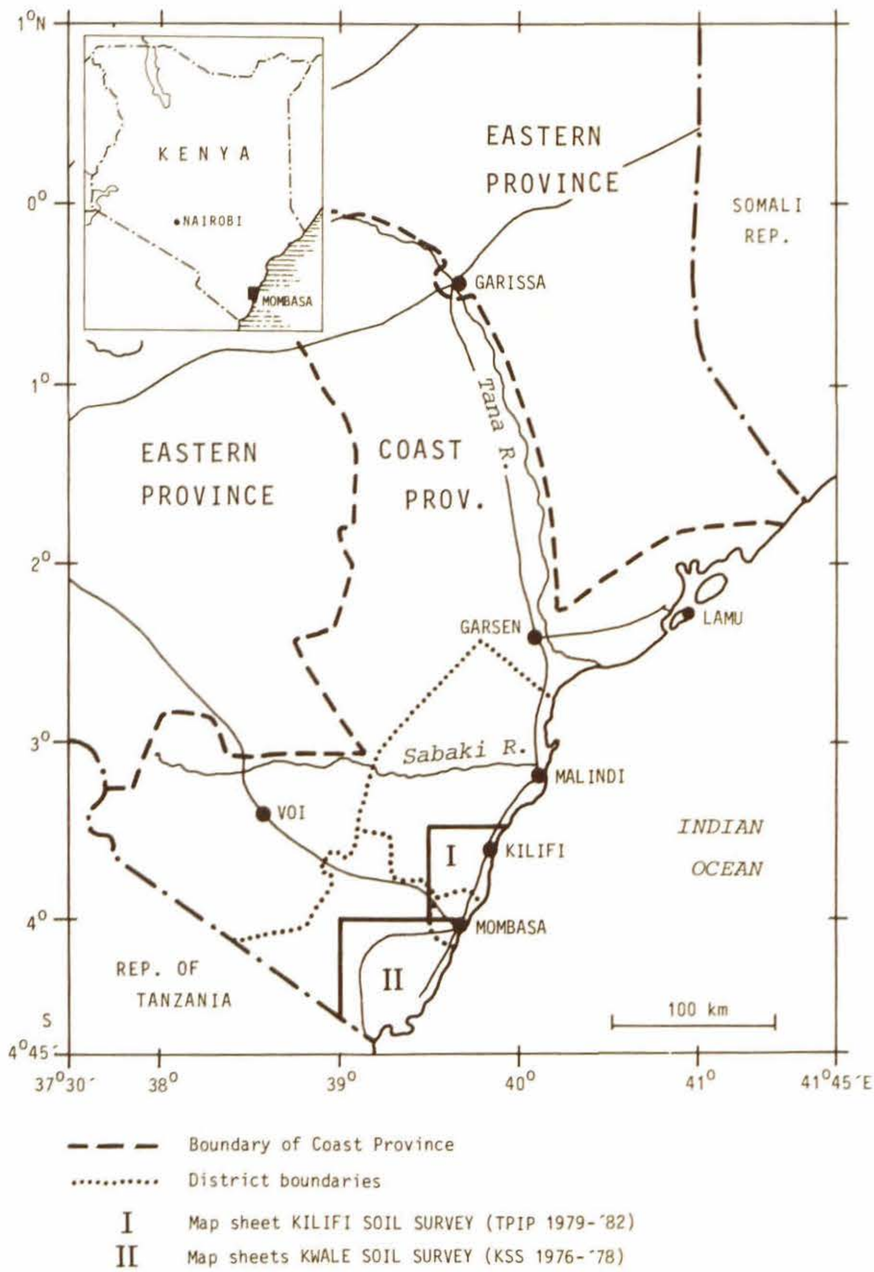


Fig. 1. Map of South-East Kenya.

The survey area is bounded by latitudes 3°30' S and 4°00' S, and longitudes 39°30' E and the Indian Ocean. This area is covered by four topographical maps at scale 1 : 50 000: Bamba (198/1), Kilifi (198/2), Mazeras (198/3) and Vipingo (198/4). Together these four sheets form the quarter-degree sheet 198 of the Soil Map of Kenya (at scale 1 : 100 000). See R11 in Fig. 2. The extent of this area, which in the following is referred to as the Kilifi Area, is approximately 200 000 ha.

Kilifi town is the administrative centre of the Kilifi District. The district is subdivided into three divisions, all occurring in the survey area.

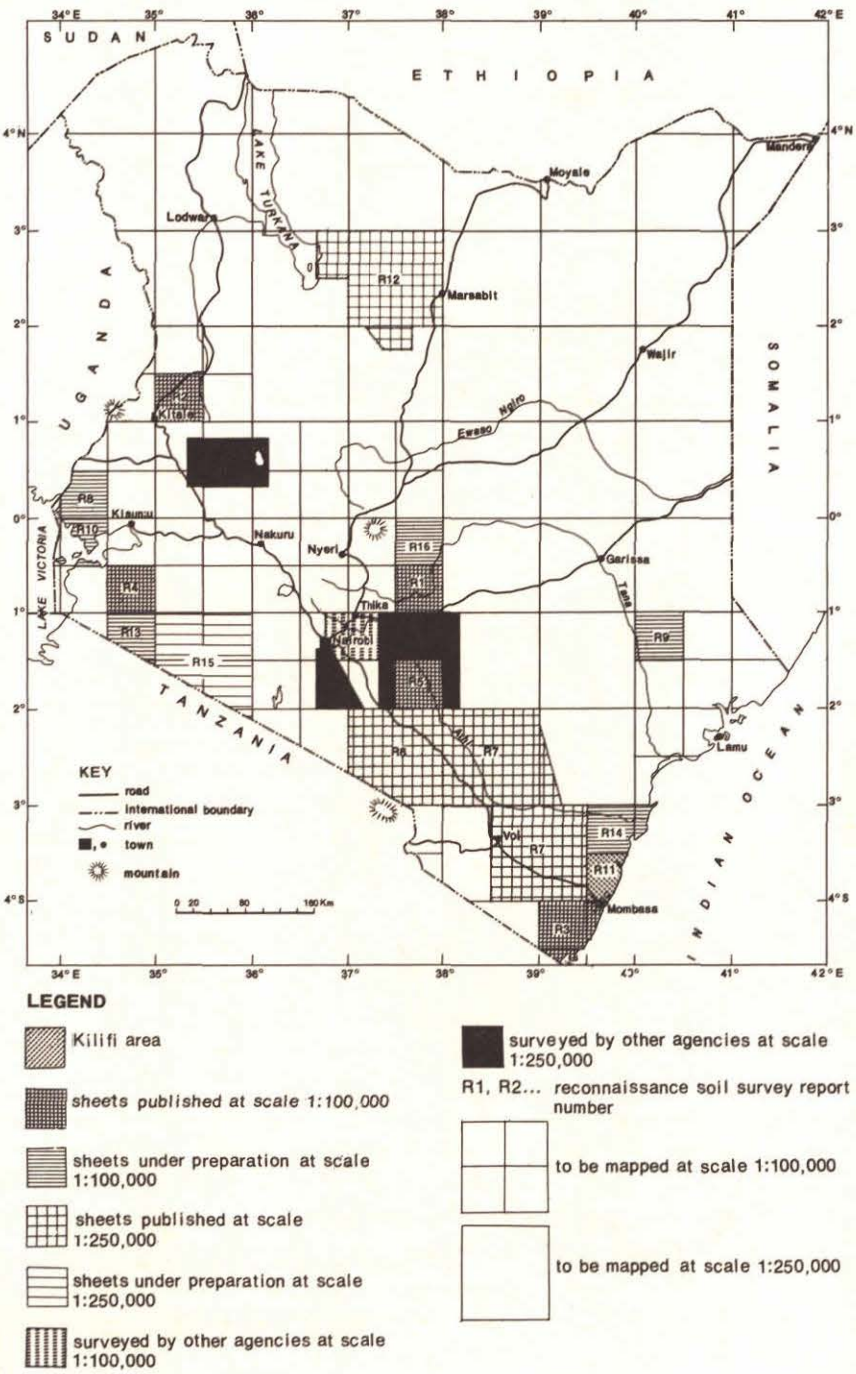


Fig. 2. Situation map and KSS reconnaissance soil survey programme.

Part of the northern half is Ganze Division (divisional headquarter: Ganze), part of the southern half is Kaloleni Division (divisional headquarter: Kaloleni) and the coastal strip is Bahari Division (divisional headquarter: Kilifi). Other villages of importance within the area are: Bamba, Vipingo, Takaungu, Mtwapa, Mazeras and Chonyi. Mariakani is located just outside the Kilifi Area (southwest of Gotani) and is, like Mazeras, situated along the Nairobi-Mombasa road and railway.

The area is well accessible by a network of tracks, murram roads and tarmac roads. A major tarmac road runs along the coast, connecting Mombasa

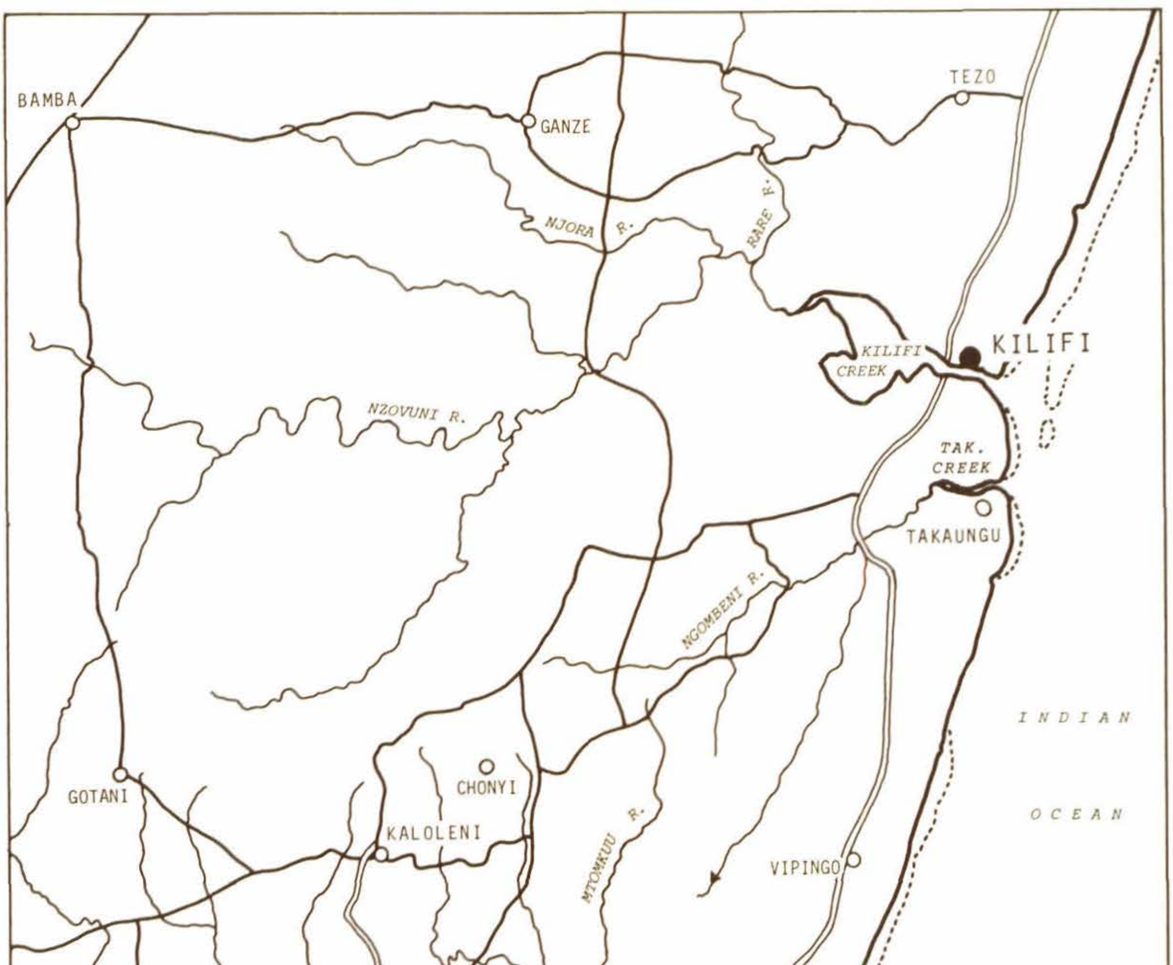


Fig. 3. Geography of the Kilifi Area.

and Malindi via Kilifi. The Mombasa-Nairobi road and railway run parallel and close together through the south-western part of the area. Mombasa has an international airport, at Kilifi there are two airstrips. Main towns, villages and roads have been indicated in Fig. 3.

The project headquarters were located in Kilifi, with substations in Ganze and in Kaloleni.

The main rivers are Rare, Ndzovuni, Mtomkuu, Mleji and Kombeni rivers. They all discharge into one of the four tidal creeks: Kilifi creek, Takaungu creek, Mtwapa creek and Tudor creek (Fig. 3). The elevation of the area

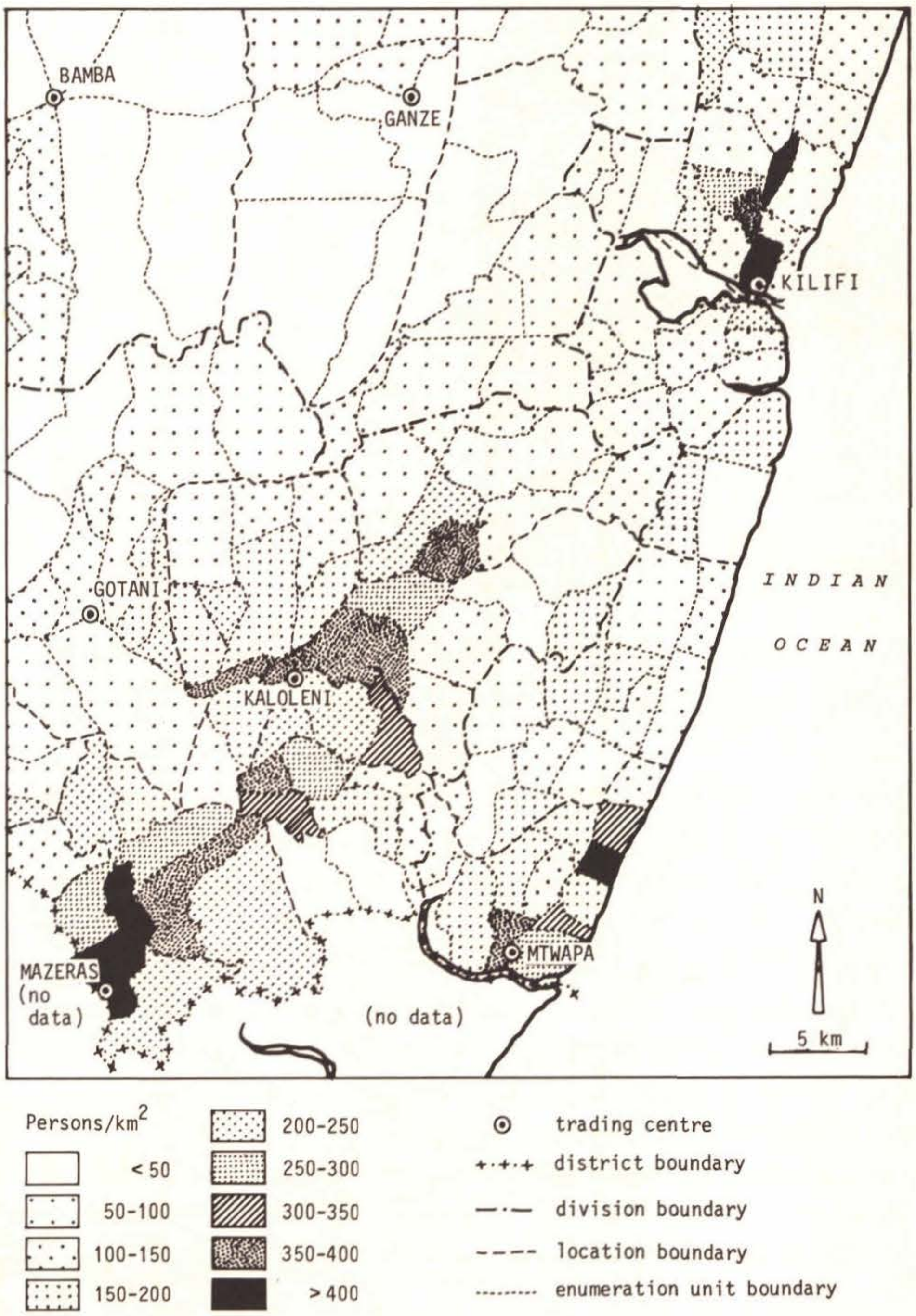


Fig. 4. Approximate population density by sublocation in the Kilifi Area.

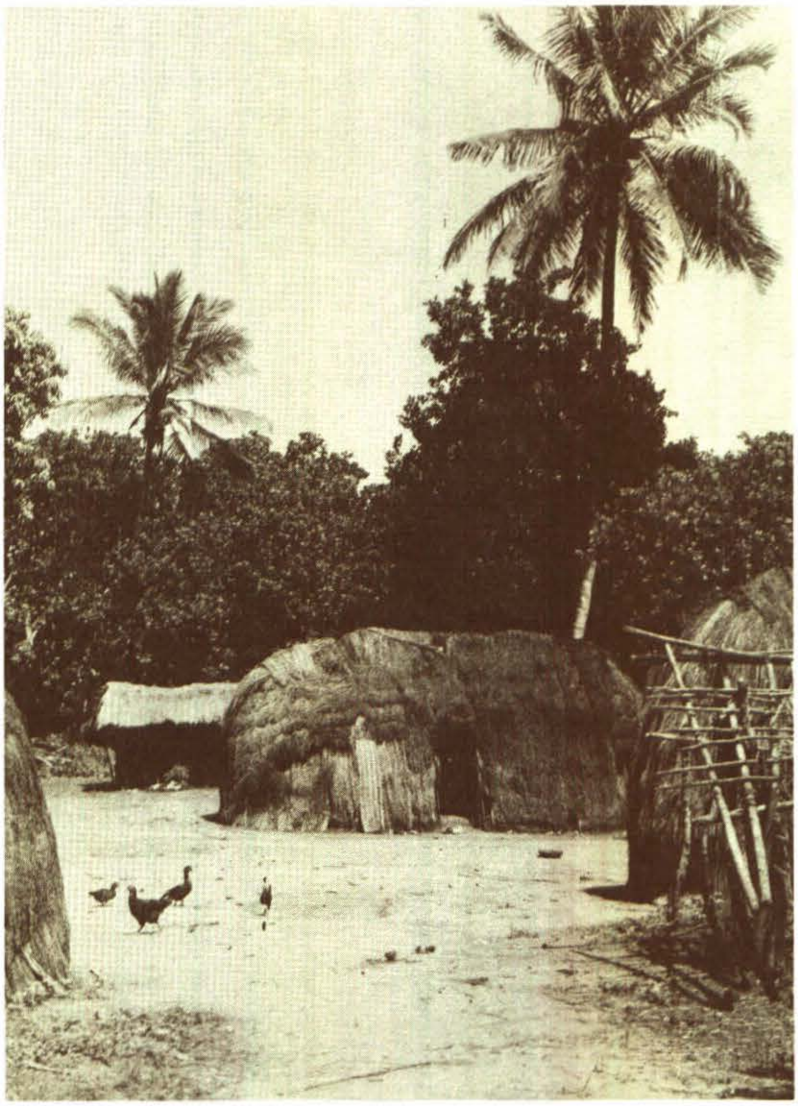


Fig. 5. A traditional grass-covered Mijikenda house in Pingilikani, about 17 km south-south-west of Kilifi. This type of house is becoming rare because of changing preferences, lack of suitable grasses and loss of the craft of making them (photo H. Waaijenberg).

ranges from 0 m at the coastline to about 350 m in the western part. The predominantly undulating to rolling uplands are situated between a higher plain in the west and a lower plain along the coast, which has a width of only several kilometers.

Fig. 4 shows the approximate population density per sublocation in the Kilifi Area, based on preliminary results of the 1979 population census. The highest densities are near Kilifi and around Kaloleni, Ribe and Mazeras. The population density becomes less towards the northwest, because of a gradual deterioration of agricultural opportunities.

The indigenous population belongs mainly to the Mijikenda peoples (Fig. 5), but there are also Swahili's, Arabs and Luo's in the coastal towns The Mijikenda's have nine subtribes, all living within the Kilifi Area: the Giriama, Digo, Duruma, Chonyi, Rabai, Jibana, Kamma, Kambe and Ribe subtribes. The Giriama and the Chonyi are the most important in number. The population increases at a rate of about 3.2% per year.

1.2 CLIMATE AND AGROCLIMATIC ZONATION

1.2.1 *Introduction*

Climate, like geology, geomorphology, hydrology, soils and vegetation, forms one of the constituents of the natural environment, which determines the suitability of land for a specific kind of use.

The major climate-borne growth factors, are rainfall, evaporation, temperature and solar radiation. Rainfall and evapo(transpi)ration are of overriding importance with respect to the agricultural potential in the Kilifi Area. Data were acquired from two main sources: Michieka et al. (1978) and Jätzold & Schmidt (1983).

1.2.2 *Annual rainfall and evaporation averages*

Data from 17 rainfall-recording sites in the survey area were collected (Table 1). The average annual totals provide a first impression of the main water balance characteristics of the Kilifi Area. Figures 6 and 7 show aver-

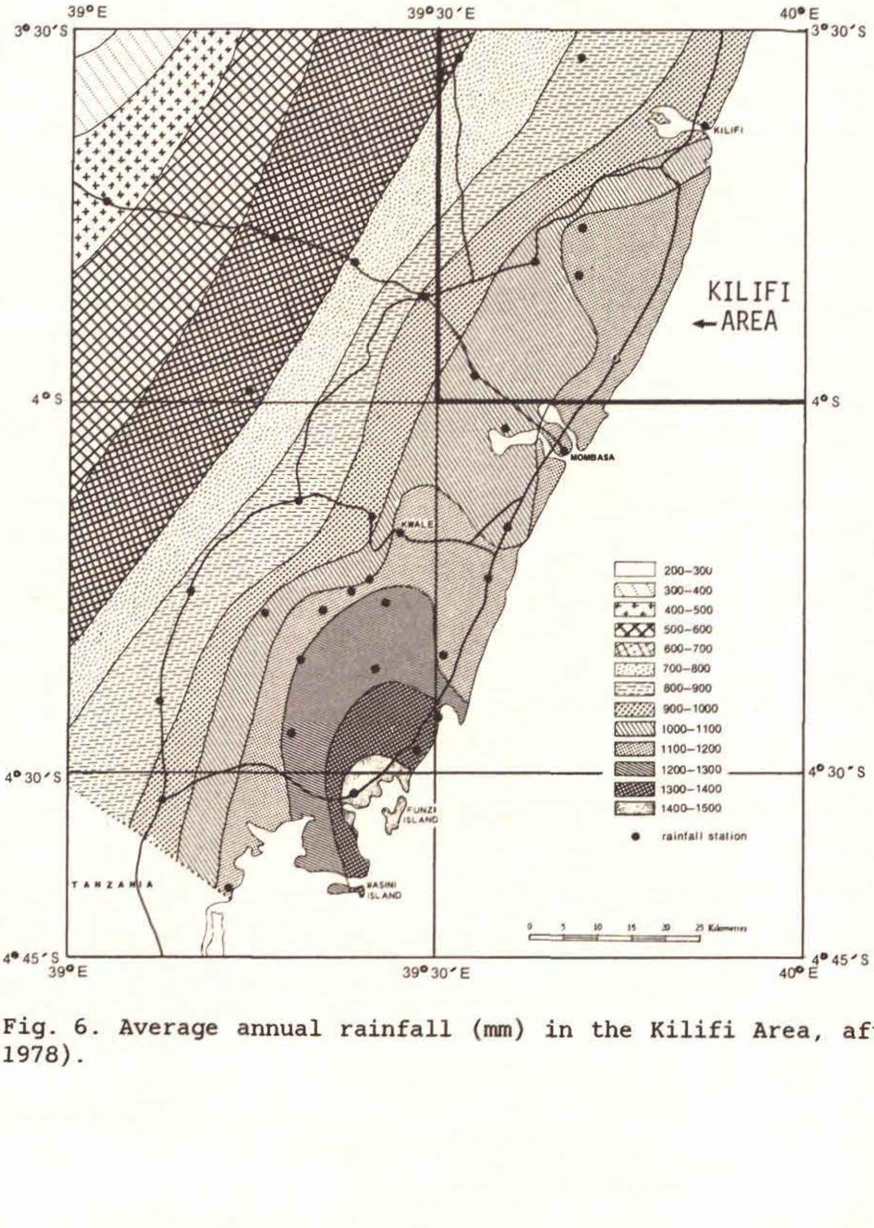


Fig. 6. Average annual rainfall (mm) in the Kilifi Area, after Braun (Michieka et al., 1978).

Table 1. Annual rainfall averages in the Kilifi Area (mm/yr).

	Station	Rec. yrs	J	F	M		A	M	J		J	A	S		O	N	D		Total
Mazeras Railway St.	9339000	59	41	21	60	(122)	147	234	81	(462)	72	54	62	(188)	93	103	82	(278)	1050
Kilifi D.O.	9339004	58	19	15	40	(74)	124	262	116	(502)	80	59	60	(199)	72	72	43	(187)	962
Kilifi-Kibarani	9339009	40	20	13	51	(84)	139	250	119	(508)	92	65	64	(221)	76	83	56	(215)	1028
Ganze	9339012	33	28	12	55	(95)	92	182	59	(333)	38	43	52	(133)	84	103	85	(272)	833
Chonyi	9339013	33	24	21	54	(99)	144	263	92	(499)	89	73	95	(257)	129	105	70	(304)	1159
Bamba	9339016	23	19	14	61	(94)	88	127	31	(246)	28	32	44	(104)	65	79	78	(222)	666
Mariakani*	9339017	31	36	17	71	(124)	115	164	59	(338)	44	51	58	(153)	86	106	79	(271)	886
Jibana	9339030	23	24	19	50	(93)	125	240	106	(471)	83	68	72	(223)	118	114	65	(297)	1084
Takaungu	9339035	14	26	13	37	(76)	172	230	127	(529)	105	73	67	(245)	47	92	49	(188)	1038
Mtwapa	9339036	20	26	23	54	(103)	211	265	148	(624)	104	72	81	(257)	103	111	53	(267)	1251
Mazeras Nurseries	9339047	16	44	17	57	(118)	136	219	92	(447)	72	72	74	(218)	129	111	89	(429)	1112
Kaloleni	9339038	20	37	26	46	(109)	118	204	97	(419)	75	66	91	(232)	125	115	75	(315)	1075
Ruruma	9339039	17	38	19	63	(120)	126	193	87	(406)	82	60	99	(241)	118	119	85	(322)	1089
Gyriama St. George	9339041	16	39	21	41	(101)	110	161	82	(353)	55	59	59	(173)	108	94	51	(253)	880
Rabai Dr.Krapf	9339043	12	29	24	50	(103)	162	209	100	(451)	96	72	82	(250)	114	116	64	(294)	1118
Vipingo	private	20	16	41	47	(104)	193	306	159	(658)	108	86	77	(271)	89	99	51	(239)	1273
Shauri Moyo	private	20	20	32	43	(95)	145	272	153	(570)	99	95	77	(271)	84	95	53	(232)	1166

1. Mariakani does not belong to the Kilifi Area: it is located just west of Gotani, in the Voi Area.
2. Figures between brackets indicate quarterly totals.
3. Sources: EAMD, Nairobi (Annual Reports); Vipingo Sisal Estate Ltd. (1961-1980).

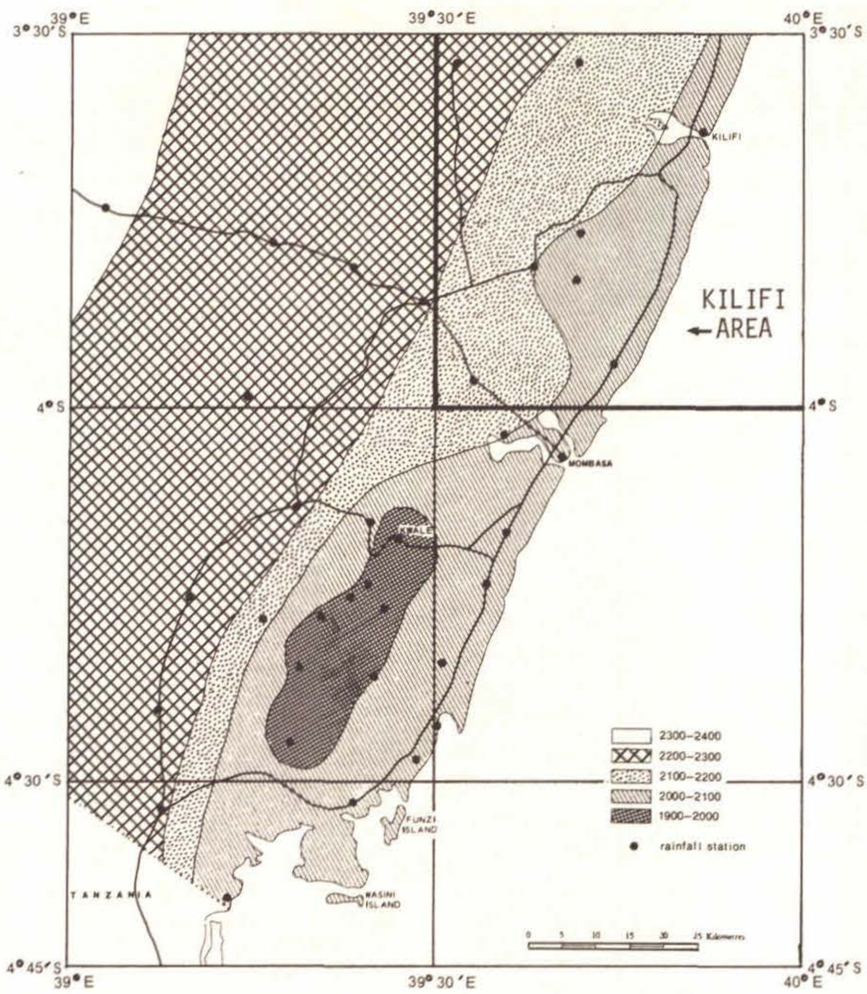


Fig. 7. Average annual evapotranspiration (mm) in the Kilifi Area, after Braun (Michieka et al., 1978).

age annual rainfall and average annual evaporation respectively, based on data of 8 stations.

Within the Kilifi Area the average annual rainfall varies from less than 700 mm in the north-west to more than 1200 mm in the south-east (Fig. 6). Rainfall totals for the individual stations are given in Table 1. Annual evaporation varies between less than 2000 mm in the south-east and more than 2200 mm in the north-west (Fig. 7). The ratio of rainfall and evaporation (r/E_o) is widely applied by agronomists to subdivide an area into so-called agro-climatic or agro-ecological zones (Section 1.2.5).

1.2.3 *Seasonal rainfall and evaporation*

Monthly or even 10-day rainfall totals are of much greater relevance to the agriculturist than annual totals. In semi-arid and subhumid regions, such as the southern part of the Kenya coast, the distribution of rainfall over the year largely determines the agricultural potential.

In the Kilifi Area, two zones are recognized: the coastal zone and the

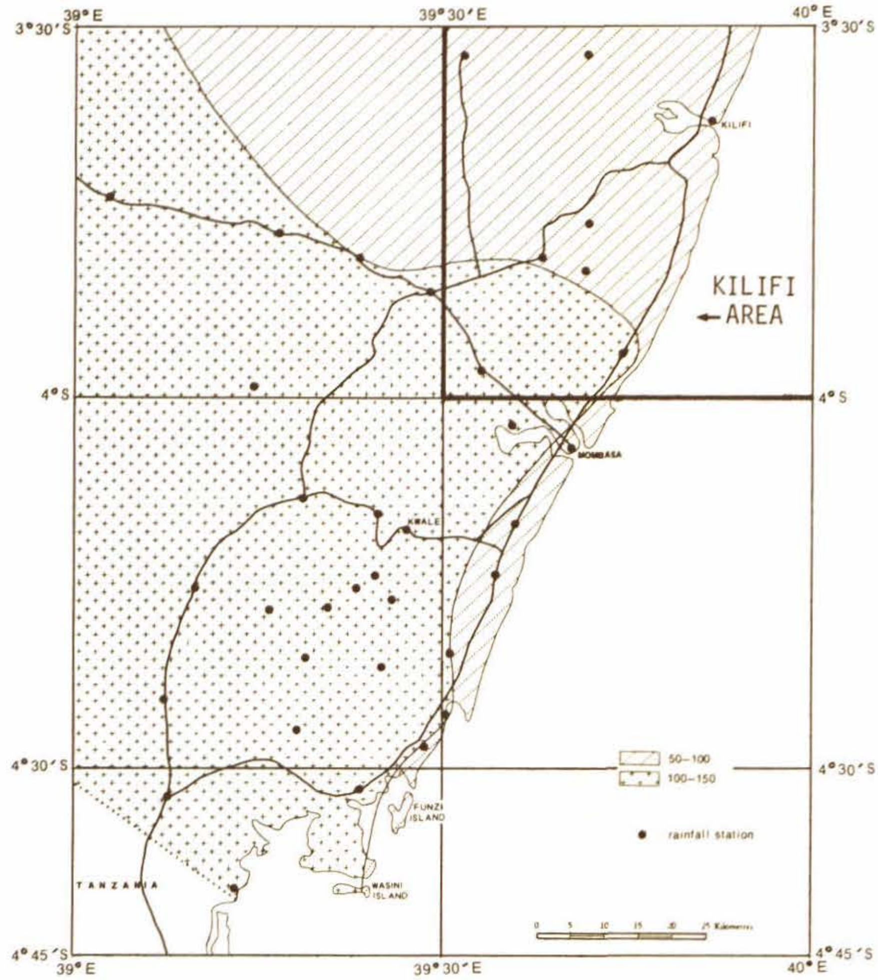


Fig. 8. Average rainfall (mm) during the period January-March, after Braun (Michieka et al., 1978).

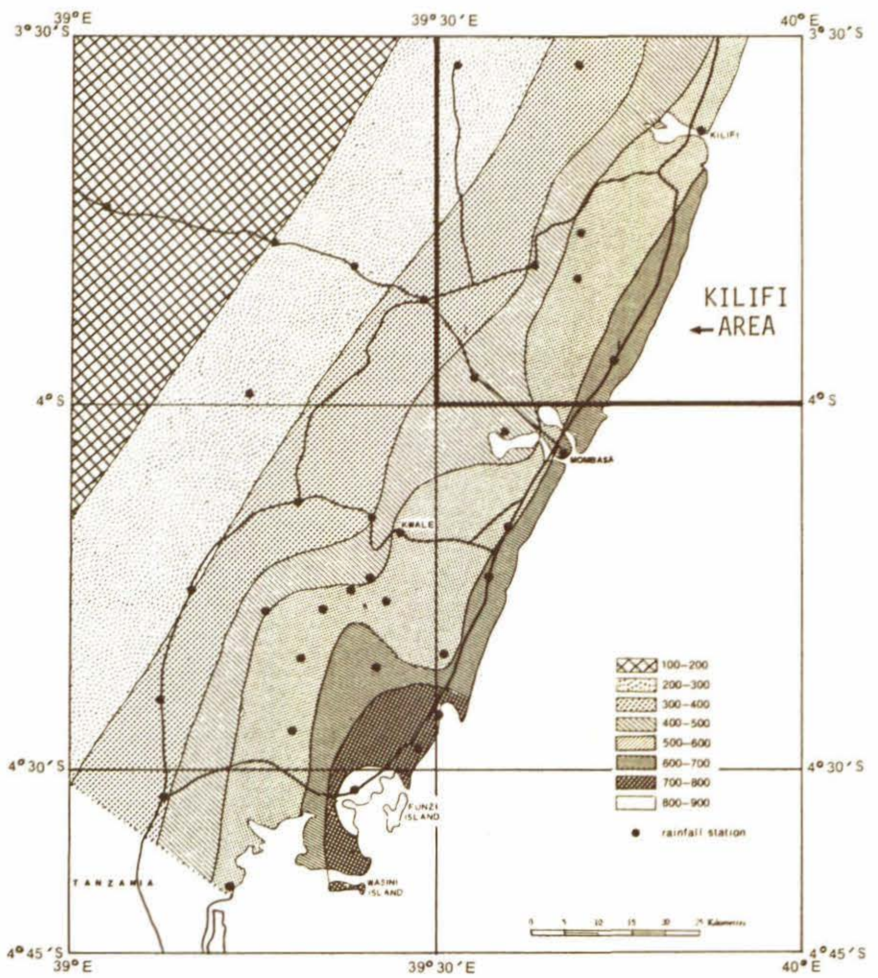


Fig. 9. Average rainfall (mm) during the period April-June, after Braun (Michieka et al., 1978).

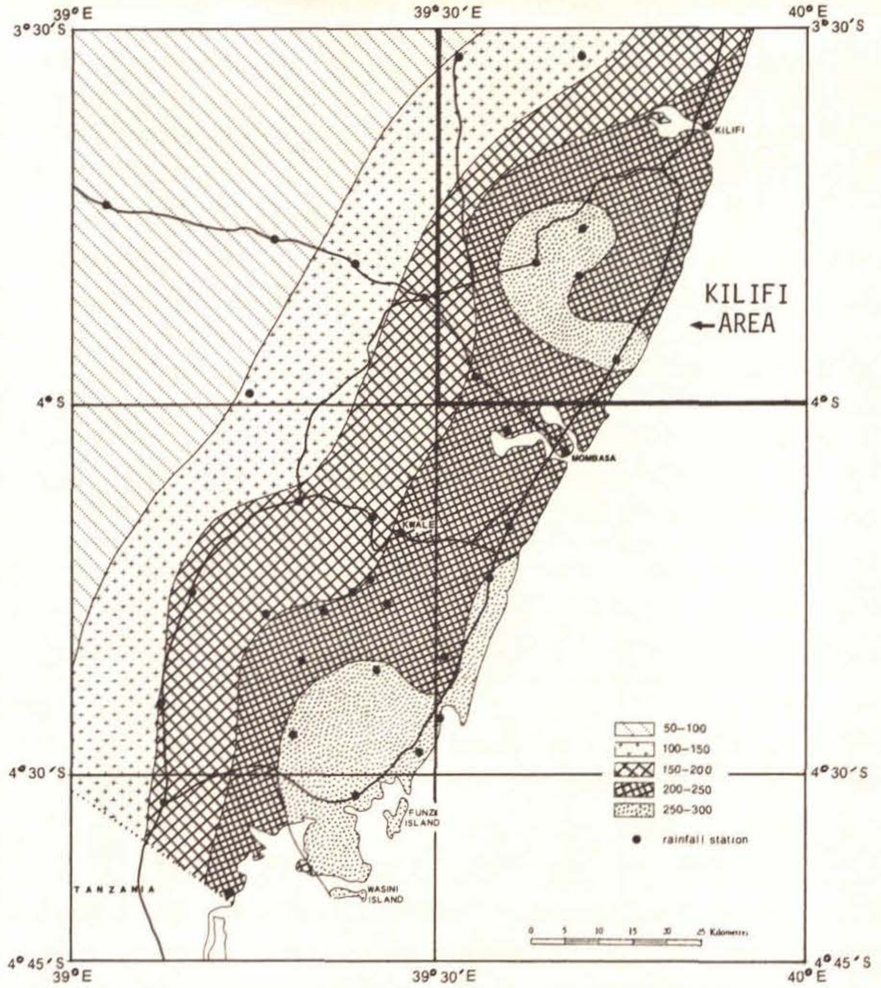


Fig. 10. Average rainfall (mm) during the period July-September, after Braun (Michieka et al., 1978).

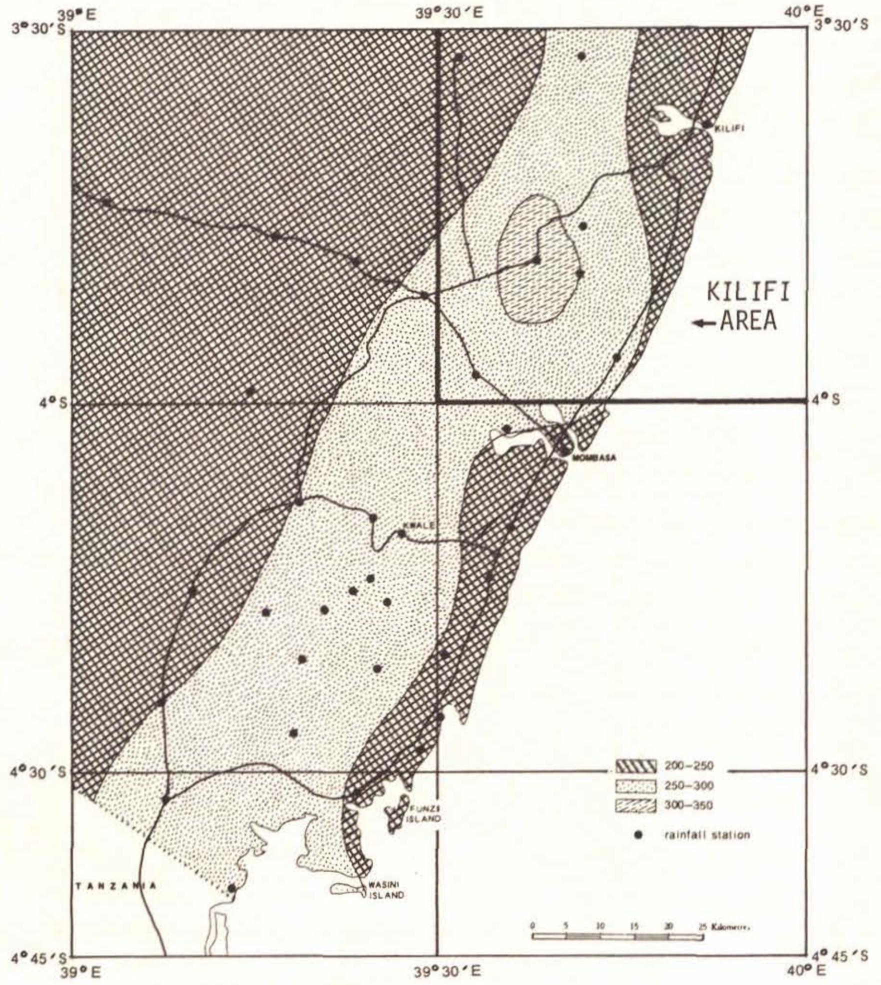


Fig. 11. Average rainfall (mm) during the period October-December, after Braun (Michieka et al., 1978).

Table 2. Relative portions and totals of annual evaporation per 90-day period (adapted from Woodhead (1968).

90-day period	Coast		Hinterland	
	(%)	(mm)	(%)	(mm)
January-March	28.5	570	26.9	590
April-June	21.9	440	24.0	530
July-September	22.4	450	24.1	530
October-December	27.2	540	25.0	550

"hinterland". The coastal zone (Kilifi, Vipingo, Mtwapa), shows one marked dry season (January-March) and one marked wet season (April-June), whereas the intervening period shows intermediate rainfall amounts. The "hinterland", where the rainfall distribution pattern is bimodal, the recording sites at Kaloleni, Chonyi and Mazeras show a rainy season between April and June and a second rainy season between October and December. The period January-March is dry, the period July-September has some intermediate rainfall.

Figures 8, 9, 10 and 11 show 90-day isohyets. The distribution of the rainfall during the first rainy season appears to be quite uneven (Michieka et al., 1978). 50% of the 90-day rainfall (April-June) falls in the first 33 days at the coast and even in the first 18 days in the hinterland, 75% of the 90-day rainfall (April-June) falls in the first 53 days at the coast and even in the first 38 days further inland. Apparently, there is a pronounced concentration of rainfall at the beginning of the April-June rains, particularly in the hinterland.

90-day and monthly evaporation values were calculated by Woodhead (1968) by means of the Penman equation. The relative portions of total annual evaporation per 90-day period are given in Table 2.

1.2.4 *Other climatic parameters*

Winds occasionally reach velocities that are hazardous to agriculture. Maize yield can be depressed because of lodging in the ripening stage.

Temperature is fairly constant throughout the year. The area is mostly warm with only slight variations during the year. Calculation of average annual temperature is generally done by relating temperature to altitude. A modified equation was developed by Braun for the 100 km wide strip along the coast (Sombroek et al., 1982):

$$T_{mean}\ (^{o}C) = 26.1 - 0.0065\ h + 0.041\ d$$

h = altitude (m)
d = distance from the coast (km)

When this equation is used, mean annual temperature averages vary between 25.5 °C (Kaloleni) and 26.5 °C (Mariakani). Mean maximum and minimum temperatures are considered to be 29.5 °C and 22.8 °C respectively. Absolute minimum temperature is 17.5 °C.

Daylength is rather constant throughout the year. The number of sunshine hours also varies slightly: 7-8 hours per day on average.

High humidity (particularly along the coast) and cloudiness are factors that restrict the cultivation of certain crops and further hampers adequate insolation during parts of the years.

1.2.5 *Agro-climatic zonation*

For the defining of the agro-climatic zones two approaches have been used. The first is defined by Braun and used by the Kenya Soil Survey (Sombroek et al., 1982), while the second one is defined by Jätzold & Schmidt (1983).

a. According to Braun

'The purpose of an agro-climatic zones map is to provide a tool for assessing which areas are climatically suitable for various land use alternatives with particular emphasis on the suitability for crops'. The agro-climatic zone map is shown in Appendix 2. The Kenya Soil Survey approach is based on annual averages of rainfall, potential evaporation and temperature. The entire area is covered by three moisture availability zones and by only one temperature zone. Thus, in total three zones can be distinguished in the Kilifi Area: III-1, IV-1 and V-1.

Distinction of moisture availability zones is based on the ratio of annual rainfall and evaporation (r/E_o). Because agro-climatic zonation intends to provide broad zones of climatic land potential, round figures are used to indicate boundary criteria. These criteria, together with those for the temperature zones, are given in Tables 3a and 3b.

Braun related the r/E_o ratios and the moisture availability zones to the soil moisture regimes described in the USDA Soil Taxonomy (Sombroek et al., 1982; Soil Survey Staff, 1975). The following relationship exists:

Soil moisture regime	r/E_o ratio	Moisture availability zone
udic	> 55	I, II, part of III
ustic	31-55	part of III, IV, part of V
aridic	< 31	part of V, VI, VII

Table 3a. Boundary criteria for the moisture availability zones and their climatic designation.

Zone	r/E_o ratio (%)	Climatic designation
III	50-65	semi-humid
IV	40-50	semi-humid to semi-arid
V	25-40	semi-arid

r = average annual rainfall. E_o = average annual potential.

Table 3b. Boundary criteria for the temperature zones: mean annual temperatures and climatic designation.

Zone	Altitude (m)	Mean annual temperature (°C)	Climatic designation
1	0-1000	24-30	fairly hot to very hot

Comparing these groupings with the boundaries in Appendix 2, it can be concluded that almost the entire Kilifi Area possesses an ustic moisture regime, which is defined as follows: the moisture control section is dry in some or all parts for 90 or more cumulative days in most years and moist in some part for more than 180 cumulative days, or it is continuously moist in some part for at least 90 consecutive days. The mean annual soil temperature is 22 °C or higher and mean 'summer' and 'winter' temperature differ by less than 5 °C in the Kilifi Area, which keys out as an isohyperthermic temperature regime.

b. According to Jätzold & Schmidt

The agro-ecological zonation by Jätzold & Schmidt (1983) emphasizes seasonal variation in rainfall and evapotranspiration. The basis of the determination of the zones is formed by temperature and moisture availability zones, more ore less following the subdivision suggested by Braun, but in addition "lengths of the growing period" is taken into account. The main zones occuring in the Kilifi Area are given in Table 4.

Table 4. Agro-ecological zonation according to Jätzold & Schmidt (1983) as compared to Braun (Sombroek et al., 1982).

Braun	Jätzold & Schmidt	Names of potentially leading crops
III-I	CL 3x	Coconut-Cassava
IV-I	CL 4y	Cashewnut-Cassava
V-I	CL 5z	Lowland Livestock-Millet

Table 5. Agro-ecological zonation and 60% probability of rainfall and growing period for the Kilifi Area.

Agro-ecological/climatic zonation		Rainfall recording	Average annual	60%-probability rainfall (mm)		growing period (days)		
Braun,	Jätzold & Schmidt[1)]	site	rainfall (mm)	1st rains	2nd rains	1st rains	2nd rains	total[2)]
III-I	CL 3 m/l i	Mtwapa Vipingo	1050-1230	400-800	50-130	155-175	< 40	-
	CL 3 m i s/vs	Kaloleni Chonyi	1000-1150	400-650	170-220	135-155	75-85	210-240
	CL 4 m i	Kilifi Jibana	850-1100	320-600	50-130	135-155	< 40	-
IV-1	CL 4 m/s i (vs)	-	920-1000	250-380	140-180	115-135	40-55	155-190
	CL 4 s i (vs)	Ganze Gyriama	800-950	200-350	150-180	85-105	40-55	125-160
V-1	CL 5 s/vs i (vs)	Bamba	700-880	170-270	150-170	75-85	40-55	115-140

1. Length of growing period (60% probability)
   - m/l medium to long 155-174 days
   - m medium 135-154 days
   - m/s medium to short 115-134 days
   - s short 85-104 days
   - s/vs short to very short 75- 84 days
   - vs very short 40- 54 days
   - i intermediate rains (at least 5 decades > 0.2 E_o, i.e. moisture conditions are above wilting point for most crops
   - () weak performance of growing period (most decades < 0.8 E_o)

2. Only added if rainfall continues at least for survival (> 0.2 E_o) of most long term crops.

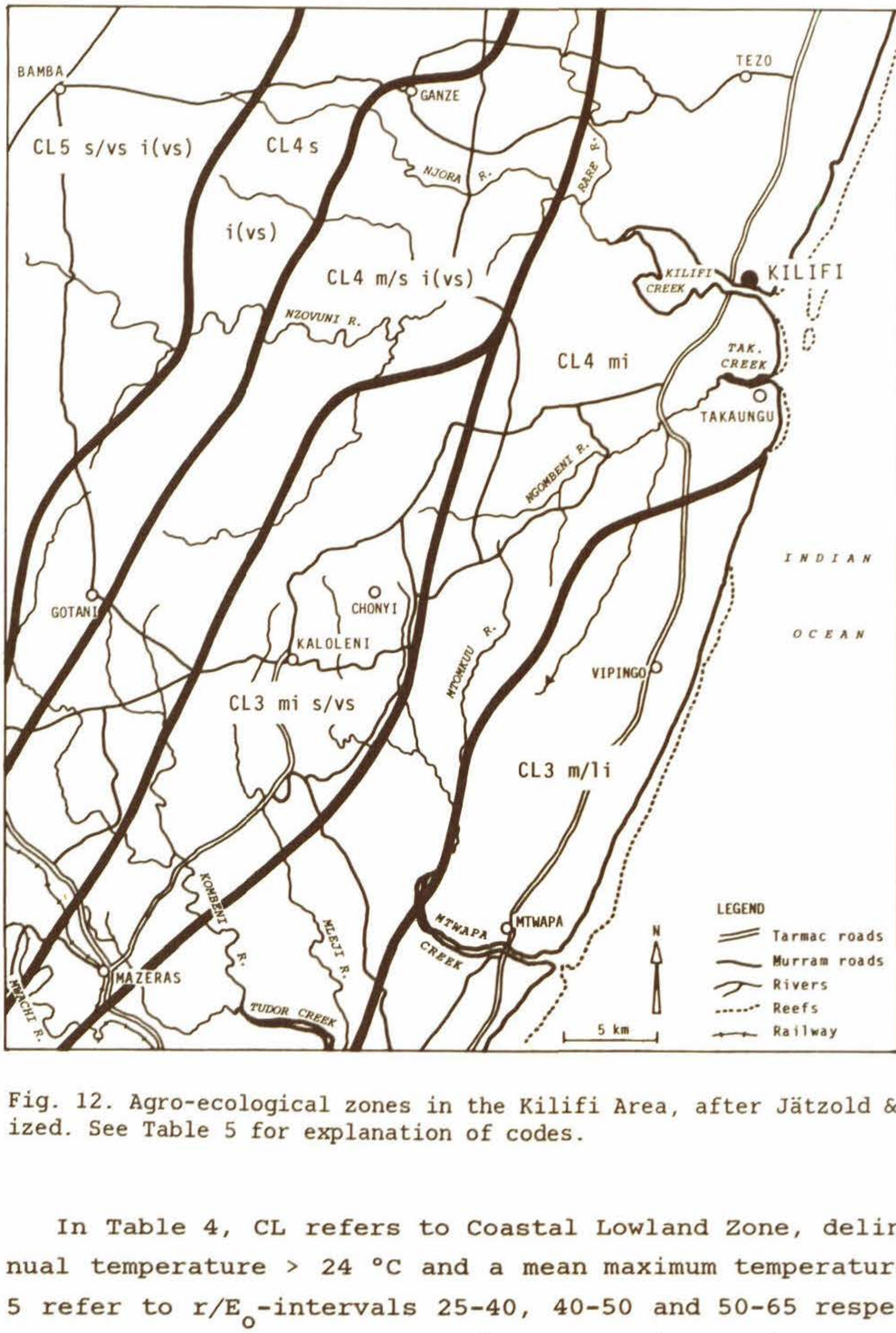


Fig. 12. Agro-ecological zones in the Kilifi Area, after Jätzold & Schmidt (1983), generalized. See Table 5 for explanation of codes.

In Table 4, CL refers to Coastal Lowland Zone, delineated by a mean annual temperature > 24 °C and a mean maximum temperature < 31 °C; 3, 4 and 5 refer to r/E_0-intervals 25-40, 40-50 and 50-65 respectively, x, y and z refer to a subzonation according to growing periods for annual crops, which has not been included in the zonation by Braun.

Table 5 gives values of x, y and z as they refer to the Kilifi Area, and Figure 12 gives a generalized map of the agro-ecological zones in the Kilifi Area according to Jätzold & Schmidt. Table 5 shows the subdivision of the main zones into subzones by the length of growing period, given in a 60% reliability, i.e. the given number of days will be surpassed in at least 6 out of 10 years. This 60% reliability coincides with the lower limit of forecast-security in agro-consulting in most developing countries. Table 5 also shows the monomodal rainfall distribution pattern of the coastal zone (CL 3 m/l i and CL 4 m i) versus the bimodal pattern of the 'hinterland' (CL 3 m i (s/vs), CL 4 m/s i (vs), CL 4 s i (vs), CL 5 s/vs i (vs)). These

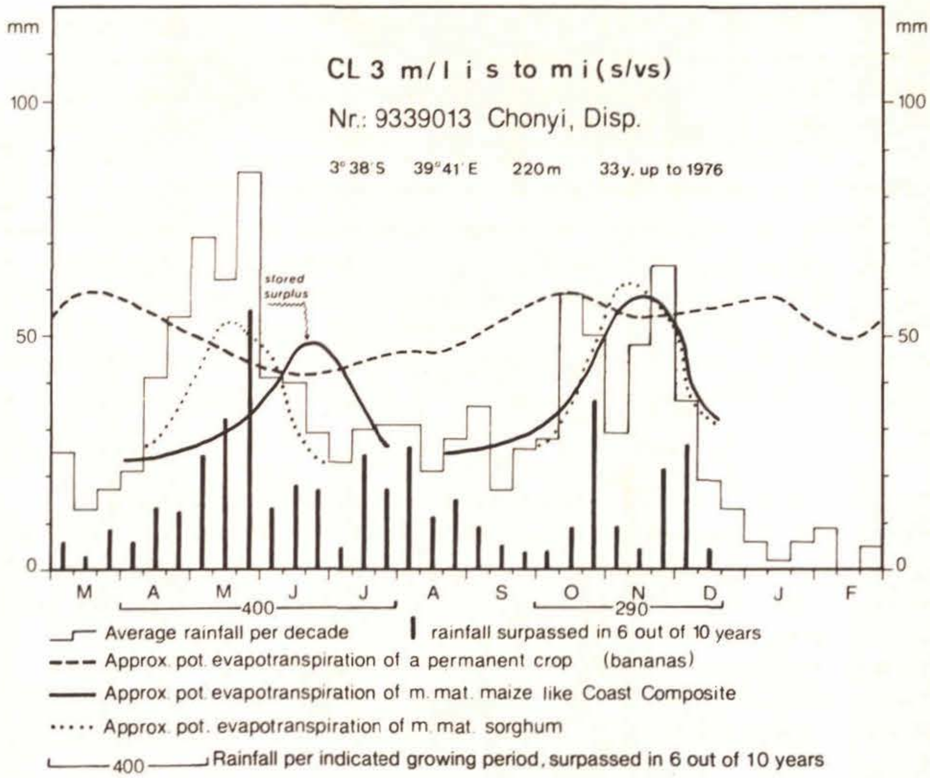


Fig. 13. Average and 60% reliability rainfall and potential evapotranspiration of relevant crops at Chonyi in agro-ecological zones CL3m/lis to CL3mi (S/VS), after Jätzold & Schmidt (1983).

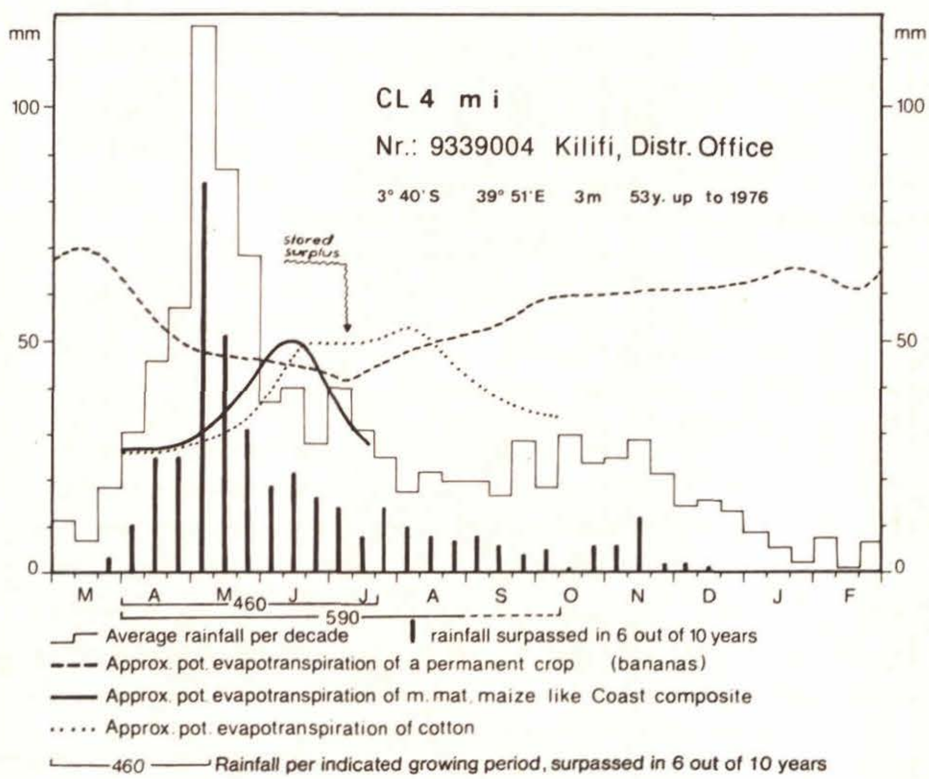


Fig. 14. Average and 60% reliability rainfall and potential evapotranspiration of relevant crops at Kilifi in agro-ecological zone CL4mi, after Jätzold & Schmidt (1983).

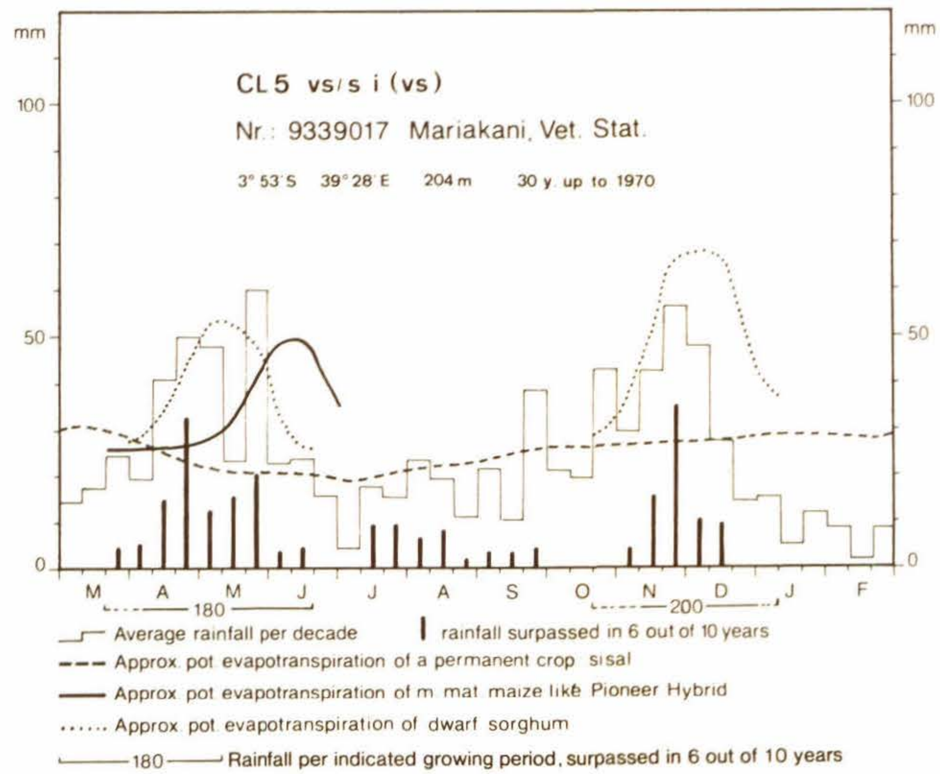


Fig. 15. Average and 60% reliability rainfall and potential evapotranspiration of relevant crops at Mariakani in agro-ecological zone CL5 VS/Si(VS), after Jätzold & Schmidt (1983).

conclusions can also be drawn from the agro-climatic histograms of Kilifi on the one hand, and those of Chonyi and Mariakani on the other hand (Fig. 13, 14 and 15).

Further details on climate-crop-soil relationships in the interest of calculating yield probabilities are given in Chapter 4 (land evaluation).

1.3 GEOLOGY AND GEOMORPHOLOGY

1.3.1 *Geology*

The subsurface materials of the Kilifi Area consist of a succession of sediments and sedimentary rocks. Their stratigraphy and lithology have been established during the geological survey of the Kilifi-Mazeras area (Caswell, 1956). Recent work on the geology of coastal Kenya (i.e. the Kilifi and Kwale 1 : 250 000 mapsheets) has resulted in a revision of the old stratigraphy (Cannon et al., 1981). During the reconnaissance soil survey the revised stratigraphy and the lithological subdivisions have been used in broad outline.

1.3.1.1 Stratigraphy

The sediments and sedimentary rocks are confined to four major chronostratigraphical units (Appendix 5A).

The *Karroo system* of coastal Kenya is represented by the sedimentary rocks of the Duruma Group, which is constituted by four formations. In the survey area two formations are present.

- The Mariakani Formation, thought to have been formed during the mid-Triassic Epoch in a deltaic environment. It is mainly made up of medium grained sandstones, which are exposed in the western part of the Kilifi Area.
- The Mazeras Formation, thought to have been formed during the late Triassic and early Jurassic Epoches in a deltaic environment. It is mainly made up of coarse grained sandstones, which are exposed in the western and central parts of the area.

The *Jurassic system* of coastal Kenya is represented by sedimentary rocks, constituting two formations.

- The Kambe Formation, thought to have been formed during the mid-Jurassic Epoch in a shallow marine environment. It is mainly made up of limestones, which are exposed in a narrow belt in the centre of the Kilifi Area.
- The Mtomkuu Formation, thought to have been formed during the late Jurassic and early Cretaceous Epoches in a deep marine environment. It is mainly made up of shales, which are exposed in a north-south belt in the eastern part of the Kilifi Area.

The *Tertiary system* of coastal Kenya is represented by sediments and sedimentary rocks, constituting three formations.

- The Baratume Formation, thought to have been formed during the Miocene Epoch in a shallow marine environment. It is mainly made up of sandstones and limestones, which are only locally exposed in the eastern part of the area.
- The Marafa Formation, thought to have been formed during the Pliocene period in a fluvial environment. It is mainly made up of sandstones and sands, which are exposed in local erosion alcoves of gullies in the eastern part of the area.
- The Magarini Formation, thought to have been formed during the Plio-Pleistocene Epoch in a fluvio-marine environment. It is mainly made up of medium grained sands, which are exposed in the eastern part of the area.

The *Quaternary system* of coastal Kenya is represented by sediments and sedimentary rocks, constituting four informal lithostratigraphical units.

- The Reef Complex, thought to have been formed during the Pleistocene Epoch in a shallow marine environment. It is mainly made up of limestones which are exposed in a belt along the present shore.
- The Pleistocene Sands, thought to have been deposited during the Pleistocene Epoch in a shallow marine environment. They are mainly made up of medium and coarse grained sands, which are exposed in the eastern part of the area. On the soil map they have been indicated under their old stratigraphical name "Kilindini" sands.
- The Recent Beach Sands, thought to have been deposited during the Holo-

cene Epoch in a marine environment. They are made up of medium to fine grained sands, which are exposed at the present shore.

- The Pleistocene superficial deposits, not indicated in the revised stratigraphy. They are made up of fine sands, silts and clay. On the soil map they have been indicated under the name "Bay deposits".
- The Alluvium, thought to have been deposited during the Holocene Epoch in a fluvial environment. It is mainly made up of fine grained sands, silts and clays, which are exposed in valleys throughout the area.

1.3.1.2 Lithology

The parent materials distinguished during the present survey are (Appendix 1):

SK	fine grained sandstones, siltstones and shales (Mariakani F.)
S	coarse grained sandstones (Mazeras F.)
T1	shales (Mariakani F.)
T2	shales (Mtomkuu F.)
L	(in UL) limestones (Kambe F.)
L	(in P2L) coral limestones and sands (Reef Complex)
W	marls (Baratumu F.)
X	various parent materials
X1	sandstones, shales and limestones (Mtomkuu F.)
X2	coarse and fine grained sandstones (Mazeras and Mariakani F.)
E1	medium grained sandy deposits (Magarini F.)
E2	medium grained sandy deposits (Magarini and Kilindini F.)
E	(in P2E) medium and coarse grained sandy deposits (Kilindini F.)
E	(in DE) recent coastal sands
O	unconsolidated fine sandy and clayey deposits (Bay deposits)
A	(in BA) recent unconsolidated deposits
A	(in AA) recent alluvial deposits
A	(in TA) recent marine deposits

The sandstones and siltstones of the Mariakani F. (SK) consist of:

1. yellowish brown, mottled sandstones, blueish green when fresh (lower member),
2. yellowish brown, flaggy sandstones with shales and micaceous horizons (middle member),
3. yellowish brown sandstones, bluish grey when fresh (upper member).

The rocks of the lower and middle members are essentially composed of quartz and feldspar (oligoclase-andesine), with muscovite dissiminated throughout or concentrated in layers. The cement mainly consists of chlorite. The rocks of the upper member are essentially composed of quartz, with silica or calcite as cement.

The sandstones of the Mazeras F. (S) consist of:

1. yellowish brown, banded arkosic sandstones (lower member),
2. red-yellowish brown arkosic sandstones, with quartz pebbles and shale horizons (middle member),
3. yellowish brown, pebbly, arkosic sandstones, with abundant quartz pebble horizons (upper member).

The rocks are essentially composed of feldspar and quartz. The cement consists of calcite (lower member), muscovite (middle member) and silica (upper member).

The shales of the Mariakani F. (T1) consist of purple green and brown shales with soft silt- and sandstone layers. The rocks are essentially composed of kaolinite and muscovite.

The shales of the Mtomkuu F. (T2) consist of:
1. greenish grey shales (middle member),
2. light grey, calcareous shales (upper member).

The rocks are essentially made up of illite and montmorillonite with some kaolinite.

The limestones of the Kambe F. (L) consist of:
1. dark blueish grey compact limestones,
2. light grey coral limestones,
3. light grey oolitic and pisolitic limestones.

The rocks are essentially composed of calcite, with coral and shell debris.

The limestones and sands of the Reef Complex (L) consist of whitish grey to greyish black coral limestones, white to whitish grey when fresh, with sandy and breccicated horizons. The rocks and unconsolidated deposits are essentially made up of quartz and calcite, with coral and shell debris.

The marls of the (?) Baratume F. (W) consist of yellow and yellowish white marls. The rocks are essentially composed of calcite, shell debris and undifferentiated clay minerals. The presence of abundant Pleistocene foraminifera in the marls indicates that care is needed while using the lithostratigraphical name Baratume Formation. The marls are more likely to belong to the Magarini Formation (Oosterom, in prep.).

The sandstones, shales and limestones of the Mtomkuu F. (X1) consist of dark grey to black, sandy shales, with interbedded micaceous and ferruginous sandstones and limestones (lower member). The rocks are essentially composed of quartz with illite, montmorillonite and some kaolinite.

The coarse and fine grained sandstones of the Mazeras and Mariakani F. (X2) comprise colluvial deposits with blocks of parent rock.

The medium grained sandy deposits of the Magarini F. (E1) consist of dark or dusky red sands, yellow when fresh. The deposits are essentially composed of quartz and kaolinite.

The medium grained sandy deposits of the Magarini and Kilindini F. (E2) consist of brownish yellow to yellowish red sands, dirty white when fresh. The deposits are essentially composed of quartz with some illite and kaolinite. The presence of Levalloisian (Pleistocene) artefacts in the basal conglomerate of most exposures indicates that care is needed while using the lithostratigraphical name Magarini Formation. The sandy deposits are more likely to belong to the Pleistocene sands (Oosterom, in prep.).

The medium and coarse grained sandy deposits of the Kilindini F. (E) consist of:

1. yellowish brown to yellowish red sands, dirty white when fresh, white when leached (beach members),
2. reddish yellow to light brown sands, yellow when fresh (dune members),
3. variegated sands and clays (fan members).

The deposits are essentially composed of quartz with some illite and kaolinite.

The recent coastal sands (E) consist of yellowish white sands, white when fresh. The deposits are essentially composed of shell debris with some quartz

The clayey deposits of the (?) Plio-Pleistocene bay sediments (O) consist of grey to brownish grey clays and silts, with sandy beds and pebble horizons. They are essentially composed of quartz with illite, montmorillonite and some kaolinite. The presence of Levalloisian (Pleistocene) artefacts in the basal conglomerate of most exposures indicates that care is needed while using the name Plio-Pleistocene. The deposits are more likely to be Pleistocene bay sediments, correlatives of the Pleistocene beach and dune sands (Oosterom, in prep.).

The recent alluvial and unconsolidated deposits (A) comprise:

1. stratified sands and silts (floodplains),
2. compact clays (bottom lands).

The deposits are essentially composed of quartz and undifferentiated clay minerals.

The recent marine deposits (A) consist of:

1. olive to greenish grey clays and silts (tidal swamps),
2. olive grey to olive, mottled clays and sands (tidal flats),
3. dark brown to black peaty clay, with peat horizons (tidal swamps).

1.3.2 *Geomorphology*

The surface configuration of the Kilifi Area consists of an association of erosional and depositional landforms. In a first description of the landmass, Gregory (1894) distinguished four physiographic zones:

- the Temborari or Coast Plain: the first and lowest plain or plateau zone occuring along the shore,
- the Foot Plateau: the transitional zone from the Temborari towards the second and higher plateau zone,
- the Nyika: the second and higher plateau zone towards the inland,
- the Gyriama Hill-lands: the tract of upland south of the Sabaki river towards Mombasa with the Nyika in the west and the Foot plateau in the east.

In later publications (a.o. Muffe, 1908; Caswell, 1953 and 1956), the Gyri-

ama Hill-Lands are no longer mentioned and a new zone is defined:
- the Coast range: the zone which is constituted by the steep hills just west of the Foot plateau.

For the purpose of soil mapping, however, the surface configuration has been described in terms of major land units and miscellaneous landtypes, according to the standard definitions used by the Kenya Soil Survey (Van de Weg, 1978).

1.3.2.1 Major land units

The major distinct parts of the area have been mapped (Appendix 5B) as:
- Minor Scarps (H)
- Coastal Uplands (U)
- Coastal Plains (P)
- Floodplains (A)
- Bottomlands (B).

The *Minor Scarps* (H) are made up of erosional and fault scarps, steeply separating areas at different levels, having a relief intensity of 50-200 m/km^2, and a rolling to hilly topography (slopes up to 30%). They are represented by the Kaloleni escarpment, occurring from Kaloleni to Gotani, and the Mazeras escarpment with related river gorges, occurring between Mazeras and Mbuyuni. They have been formed in the rocks of the Mariakani Formation and the Mazeras and Mtomkuu Formations respectively. Erosional hills, prominently rising above the surroundings, have a relief intensity of 50-200 m/km^2 and slopes up to 30%. They are represented by a.o. the Kinangoni hill and the Kizurini hill. On the soil map, they have been indicated by a symbol (Appendix 1). For cartographic reasons the hills have been included in the surrounding upland. They have been formed in rocks of the Mazeras and Mtomkuu Formations.

The *Coastal Uplands* (U) are made up of:
1. Dissected surfaces of erosion and deposition with rounded interfluves, having a relief intensity of less than 100 m/km^2 and an almost flat to rolling ground surface (slopes up to 16%). They are represented by: - The Kaloleni upland, occurring in the norhtwest of the area at an altitude of 250-350 m; it can be correlated with the Gyriama Hill-lands and has been formed in rocks of the Mariakani and the Mazeras Formations,
- the Rabai upland, occurring in the southwest and central north of the area at an altitude of 150-250 m; it can be correlated with parts of the Nyika and has been formed in rocks of the Mariakani Formation, overlain by unconsolidated clayey deposits,
- the Lutsangani upland, occurring in the centre of the area from north to south, at an altitude of 0-150 m; it can be correlated with parts of the

Foot plateau and has been formed in rocks of the Mtomkuu Formation.
2. Dissected surfaces of erosion and deposition, with flat interfluves, having a relief intensity of less than 75 m/km^2, and a flat to rolling topography (slopes up to 16%). They are represented by:
- the Dzitsoni upland, occurring in the centre of the area at an altitude of 100-200 m; it can be correlated with parts of the Foot plateau and has been formed in rocks of the Kambe Formation,
- the Pingilikani upland, occurring in the east of the area at an altitude of 100-200 m; it can also be correlated with parts of the Foot plateaus and has been formed in the unconsolidated deposits of the Magarini Formation.

The *Coastal Plains* (P) are made up of:
1. Non-dissected surfaces of erosion and deposition at low levels, adjacent to the shore, having a relief intensity of less than 10 m/km^2, and a flat to gently undulating topography (slopes up to 5%). They are represented by the Kibarani or low level plain, occurring in the east of the area from south to north, at an altitude of 0-75 m. Its occurrence can be correlated with the Coast plain. The plain has been formed in the rocks and unconsolidated deposits of the Reef Complex and the Pleistocene sands.
2. Non-dissected surfaces of erosion and deposition at higher levels towards the interior, having also a relief intensity of less than 10 m/km^2 and a flat to gently undulating topography (slopes up to 5%). They are represented by the Bamba or high level plain, occurring in the west of the area at an altitude of 150-250 m. Its occurrence can be partly correlated with the Nyika. The plain has been formed in rocks of the Mariakani Formation, overlain by unconsolidated clayey deposits of the (?) Plio-Pleistocene Bay deposits.

The *Floodplains* (A) are made up of non-dissected surfaces of erosion and deposition adjacent to the stream channels, having a relief intensity of less than 30 m/km^2, and a flat to almost flat topography (slopes 0-2%). Lower terraces are also included in this physiographic unit. They are represented by:
- the Mtsapuni floodplain and lower terraces,
- the Kombeni floodplain and lower terraces,
- the Mtomkuu floodplain and lower terraces,
- the Ngombeni and Mtoni floodplain and lower terraces,
- the Ndzovuni floodplain and lower terraces,
- the Rare floodplain and lower terraces.

The floodplains and lower terraces occur at different altitudes throughout the area. They have been formed in rocks of various formations.

The *Bottomlands* (B) are made up of non-dissected surfaces of deposition in valleys and depressions, occurring throughout the area at different altitudes, having a relief intensity of less than 5 m/km^2 and a flat topography. They are represented by the valleybottoms of the coastal plains and uplands. The bottomlands have been formed in unconsolidated deposits of the Recent alluvium.

1.3.2.2 Miscellaneous land types

The minor distinct parts of the area have been mapped as:
- Minor Valleys (V)
- Tidal Flats and Swamps (T)
- Dunes (D).

The *Minor Valleys* (V) are made up of erosional valleys, having a relief intensity of less than 100 m/km^2 and an undulating to hilly topography (slopes up to 30%). They are represented by the minor valleys of the coastal plains and uplands. The minor valleys occur throughout the area at different altitudes. They have been formed in rocks of various formations.

The *Tidal Flats and Swamps* (T) are made up of depositional flats and swamps, having a relief intensity of less than 5 m/km^2 and a flat topography. They are represented by:
- the Tudor tidal flats and swamps,
- the Mtwapa tidal flats and swamps,
- the Kilifi tidal flats and swamps.

The tidal flats and swamps occur in the above named creeks at an altitude of 0-2 m. They have been formed in unconsolidated deposits of the Recent marine deposits.

The *Dunes* (D) are made up of depositional hills and ridges adjacent to present or former shores, having a relief intensity of less than 50 m/km^2 and an undulating to hilly topography (slopes up to 30%). They are represented by:
- the Kikambala dunes, occurring adjacent to the present shore at an altitude of 2-15 m; they have been formed in unconsolidated deposits of the recent beach sands,
- the Makonde dunes, occurring adjacent to the former shore at an altitude of 15-75 m; they have been formed in unconsolidated deposits of the Pleistocene sands.

1.4 HYDROLOGY

1.4.1 *Surface water resources*

The Kilifi Area is naturally drained by the main drainage systems of several intermittent streams, which all discharge into one of the four tidal creeks: the Rare, the Njora and the Ndzovuni rivers into the Kilifi creek, the Ngombeni river into the Takaungu creek, the Mtomkuu river into the Mtwapa creek, and the Mleji and Kombeni rivers into the Tudor creek (Fig. 3). Of all rivers mentioned, only the Rare river has a catchment area that extends far beyond the surveyed area (even as far as Taita hills). All rivers in the area are intermittent and dry up almost completely in the long dry season. Only certain sites, where a river is fed by springs, remain wet throughout the year (mainly in the Kambe limestones and the Mazeras sandstones).

The prevailing drainage direction is northwest to southeast. The uplands of the Magarini Formation form a barrier for the Mtomkuu drainage system, that therefore runs north-south to the Mtwapa creek.

The drainage density of the area varies according to geology and soil. The highest drainage density is in the shale belt (Mtomkuu Formation): 15.2 km/km^2 in the Mtomkuu basin, 13.0 km/km^2 in the Ngombeni basin. The drainage density in the Mazeras and the Mariakani Formations ranges from 6 to 10 km/km^2. The high level Coastal Plains (Bay deposits), the Kambe Formation and the Magarini Formation are slightly incised, and the low level Coastal Plains (Reef complex and Kilindini Formation) are not incised at all, except by the tidal creeks.

Both in the past as well as in the present, several attempts have been made to preserve and store surface water by building small dams, mainly in the Mazeras and the Mtomkuu Formations. Only a few have been successful, such as the one near Lutsangani. There are two bigger dams at the Vipingo estate.

Another way of water storage is practised in so-called waterholes: small muddy ponds, which are abundant in the sodium-rich clayey Bay deposits of the high level Coastal Plains in the westernmost part of the area. Those waterholes remain wet far into the dry season.

The surface water, as it is collected in the natural drainage systems, is nowhere used for irrigation, except at the Vipingo estate. Only small amounts are used for domestic purposes and animal consumption. Major reason is the often insufficient and unreliable precipitation. However, it appears to be opportune to store surface run-off in moist years by small dams, which can be beneficial to the farming population during prolonged dry spells.

A great advantage is the natural storage of water in the bottomlands. These areas remain green and fresh throughout the dry season, and are highly appreciated areas for both grazing and rice cultivation.

1.4.2 *Groundwater resources*

Groundwater resources in the area for human and animal use are very limited, and often of poor quality. In 1950 a major attempt was made to survey the groundwater resources by drilling about 75 boreholes near Bamba, Ganze, the Tezo-Roka settlement scheme, Vipingo, Mtwapa and Mazeras. It appeared that the majority of the holes give saline or brackish water. The majority of the sites that provided water of adequate quality deteriorated after having been used for some time. More recent drillings are reported to have given similar results.

In the past, the water supply of the towns, villages and farms entirely depended on wells, boreholes and storage basins. At present, the eastern half of the area is connected to piped water, partly originating from Mzima Springs (near Voi), partly from the Sabaki Water Supply Scheme near Malindi. This water is too costly to satisfy the growing demand for water for irrigation and animal consumption. It is therefore important that the groundwater resources of the area are assessed on basis of a comprehensive hydrogeological survey.

1.5 VEGETATION

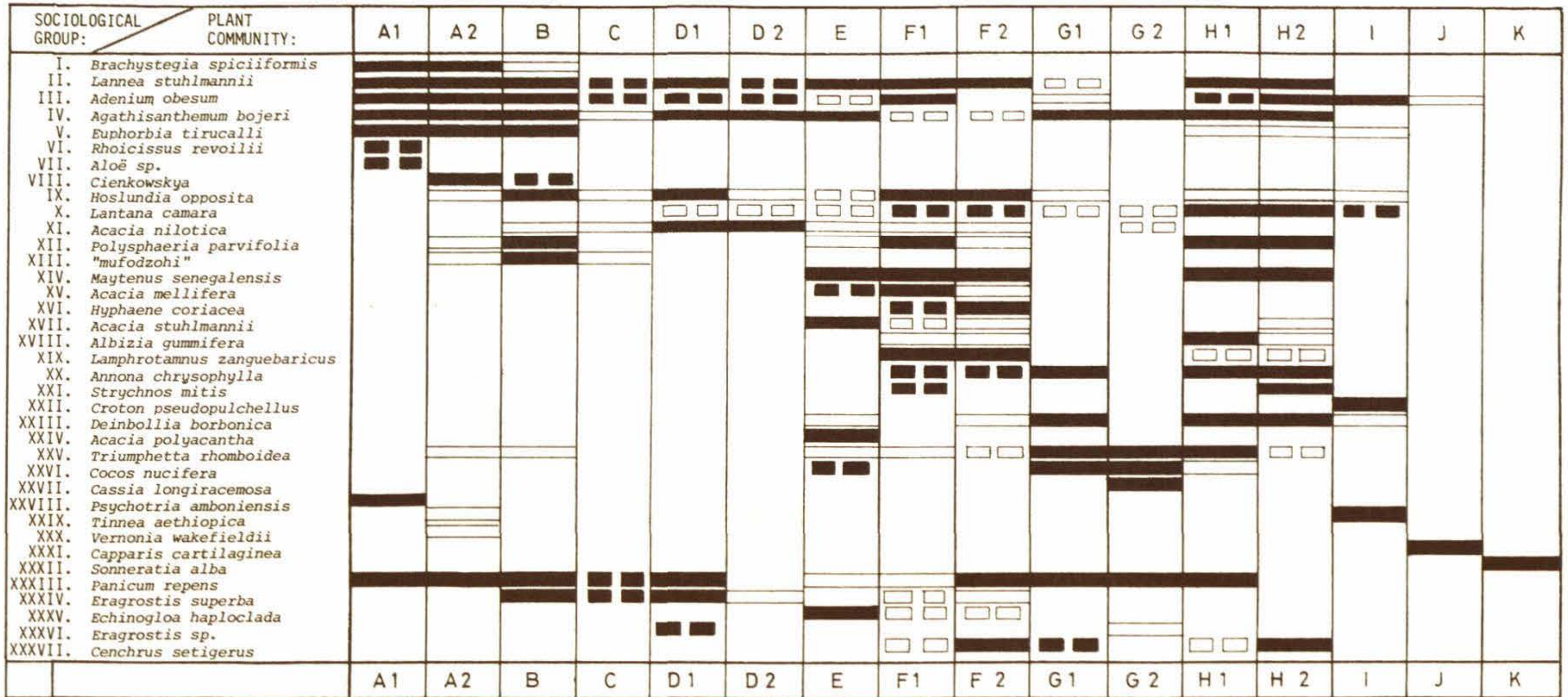
1.5.1 *Introduction*

In the Kilifi Area, human influence on the vegetation is significant, so 'natural' vegetation has almost disappeared in most places. Little is known about the original vegetation of the area, but it appears that only small remnants of it are left. As a consequence, the vegetation in the Kilifi Area ranges from supposedly almost original forest to completely artificially, induced formations, such as a coconut plantation or a large scale sisal estate, with all kinds of semi-natural or semi-degenerated stages in between.

A vegetation and land use map of the Kilifi Area has been compiled (scale 1 : 100 000, Appendix 4A). The survey that preceded this compilation was done according to methods proposed by ITC (Zonneveld et al., 1979). Several landscapes are recognized in the area, which can be subdivided according to vegetation and land-use pattern.

For this study, aerial photographs (scale approx. 1 : 50 000, 1969) were used to determine the so-called vegetation landscapes. The survey consisted of both stratified and preferential sampling. The samples were taken by making vegetation relevés according to principles of the Zürich-Montpellier school (Braun Blanquet, 1972). This means that within a certain relevé area, structure and floristic composition were described as far as possible.

For this particular survey, 225 vegetation relevés were recorded and processed into a vegetation table (Appendix 4B). In this table, the rows represent the plant species, the columns the relevé sites. The sequence of



should occur, with high abundancy/coverage of the composing species
may occur, with high abundancy/coverage of the composing species
should occur, with low abundancy/coverage of the composing species
may occur, with low abundancy/coverage of the composing species
NO BAR: should not occur

PLANT COMMUNITIES:

A1 - *Brachystegia spiciiformis* - *Rhoicissus revoilii*
A2 - *Brachystegia spiciiformis* - *Grewia forbesii*
B - *Dichrostachis cinerea* - *Panicum repens*
C - *Grewia microcarpa* - *Perotis hildebrandtii*
D1 - *Acacia nilotica* - *Salvadora persica*
D2 - *Acacia nilotica* - *Hoslundia opposita*
E - *Acacia stuhlmannii* - *Acalypha fructicosa*
F1 - *Lannea stuhlmannii* - *UPS 11*
F2 - *Lannea stuhlmannii* - *Panicum maximum*
G1 - *Cocos nucifera* - *Deinbollia borbonica*
G2 - *Cocos nucifera* - *Sida cuneifolius*
H1 - *Polysphaeria parvifolia* - *Triumphetta rhomboidea*
H2 - *Polysphaeria parvifolia* - *UPS 11*
I - *Croton pseudopulchellus* - "mukambi"
J - *Capparis cartilaginea* - *Cynanchum tetrapterum*
K - *Sonneratia alba* - *Rhizophora mucronata*

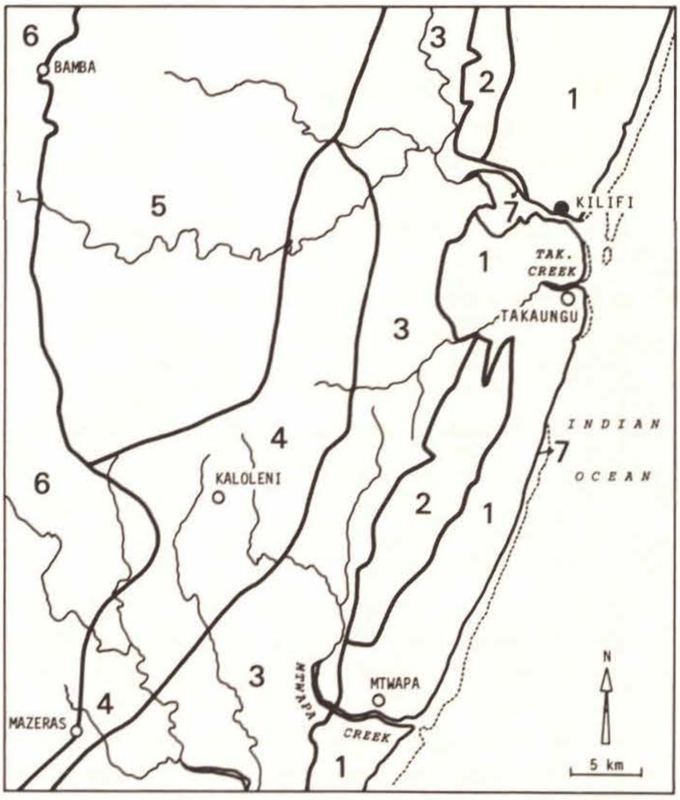
Fig. 16. Bar diagram of plant communities (A-K) for sociological groups I-XXXVII (from M.W.N. van Leeuwen, 1983).

rows and columns is changed repeatedly, until a number of mutually discriminant clusters is obtained. The group of plant species composing such a cluster is called a sociological group. A set of vegetation relevés characterized by the presence or absence of a sociological group (or in some cases a single plant species) is called a plant community. The vegetation table can be compressed into a bar diagram (Fig. 16). In Appendix 4B, the sociological group to which a species belongs has been indicated as well.

The plant communities, which form the backbone for a floristic classification of the area, are described in Section 1.5.3.

1.5.2 *Description of main vegetation landscapes*

In the Kilifi Area, a total of seven main vegetation landscapes (VL) are recognized. A simplified map with these landscapes is given in Fig. 17. The landscapes were named after common or characteristic plant species, including important (introduced) tree crops.



1 = *Sterculia appendiculata - Ceiba pentandra* landscape
2 = *Cynometra suaheliensis - Anacardium occidentale* landscape
3 = *Terminalia spinosa - Maytenus senegalensis* landscape
4 = *Cocos nucifera - Chlorophora excelsa* landscape
5 = *Brachystegia spiciiformis - Manilkara zanzibarica* landscape
6 = *Salvadora perscica - Acacia nilotica* landscape
7 = *Ipomoea pes-capre - Rhizophora mucronata* landscape

Fig. 17. Main vegetation landscapes in the Kilifi Area (present situation).

From the coast landinwards the following main vegetation landscapes have been defined.

(VL 1) *Sterculia appendiculata - Ceiba pentandra* is largely cultivated VL of the Coastal Plain, with large sisal plantations, many tree crops, characterized by the occurrence of *Ceiba pentandra* plantations and (locally) a large yellow-stemmed *Sterculia appendiculata* tree.

(VL 2) *Cynometra suaheliensis - Anacardium occidentale* is developed on the Coastal Uplands, this VL consists mainly of cashewnut trees, with a few coconut plantations, a large (partly neglected) sisal plantation, and a few remnants of the original forests.

(VL 3) *Terminalia spinosa - Maytenus senegalensis* is developed on the strongly dissected parts of the Coastal Uplands. The central parts are cultivated. To the south, *Hyphaene coriacea* grasslands dominate, while to the north, vast ranging areas (*Lannea stuhlmanni - Hibiscus aponeurhus* bushland) appear.

(VL 4) *Cocos nucifera - Chlorophora excelsa* appears on the southern parts of the Coastal Uplands. It consists mainly of coconut plantations and some arable land, notably in valleys. Remnants of the original tropical monsoon forests occur locally on hilltops.

(VL 5) *Brachystegia spiciformis - Manilkara zanzibarica* is developed on the northern parts of the Coastal Uplands. It has a gradual boundary with VL 4. Most of VL 5 is dominated by an open woodland where *Brachystegia spiciformis* and *Afzelia cuanzensis* trees prevail. The woodland is alternated by secondary bush of various types and arable land.

(VL 6) *Salvadora persica - Acacia nilotica* appears in the driest part of the Kilifi Area, on the interior plains. This VL is dominated by cattle ranging on thorny (*Acacia* spp.) bush and *Salvadora persica* grasslands. On sandy hills, a kind of *Brachystegia*-woodland may occur.

(VL 7) *Ipomoea pes-capre - Rhizophora mucronata* appears on the shores of the Kilifi Area. These are dominated by two formations, viz.

- Indian Ocean: a salt spray induced low shrub formation, where *Capparis cartilaginea* occurs, and
- the creeks (and river mouths): *Rhizophora mucronata* swamps.

Table 6. Ecological table, showing relationships between Parent Material, (Soil Facies), Human Influence and Relative Moistness on the one hand, and Floristic Vegetation Type and Map Legend unit on the other, in the Kilifi Area.

MAP LEGEND UNIT	PLANT COMMUNITY	PARENT MATERIAL: GEOLOGICAL FM	PARENT MATERIAL: FACIES (SOIL-)	HUMAN INFLUENCE	RELATIVE MOISTNESS
1.1	I	KILINDINI FM	MAINLY ROCK	LOW	MOIST
1.2a	H2		SAND / ROCK	LOW ↓ HIGH	DRY ↓ MOIST
1.2b					
1.2c					
1.2d	F2				
1.3a	H2		SAND ROCK CLAY	LOW ↓ HIGH	MOIST
1.3b					
1.3c					
1.3d					
1.4	H2		SAND/ROCK	HIGH	N.S.
1.5a	G1, H2, A2		SAND		MOIST
1.5b	G1, H1				
2.1	I	MAGARINI SAND	SAND	LOW	MOIST
2.2a	G1, H1, A2			HIGH	
2.2b	G1, H1				
2.3	H1			LOW	N.S.
2.4	H1, H2			HIGH	
3.1	I	MTO MKUU SHALE FM	CLAY/R.R.	LOW	MOIST
3.2a	F1, F2		CLAYEY	MODERATE ↓ HIGH	DRY ↓ MOIST
3.2b	F1, F2, E				
3.2c					
3.3a	F1			LOW ↓ HIGH	DRY ↓ MOIST
3.3b					
3.3c					
3.3d	F1, E				
3.4				N.S.	MOIST
4.1	I	KL - DS	VARIOUS	LOW	V.MOIST
4.2	E	KL - BS		HIGH	MOIST
4.3a	G2	KL-DS-MS			
4.3b	G2-H1 (A2,D2)	KL - DS		MOD./HIGH	RATHER MOIST
4.4	H1	KL-MS DS		MOD./LOW	
4.5	H1, I				
5.1	A1, A2	DS (KL)	SAND	LOW	DRY/ R. MOIST
5.2					
5.3	C, B, (A2)	DS	SAND/CLAY	R. HIGH	DRY
5.4	B, D1, C	DS/BS	CLAY		
6.1a	D1, D2 C	BAY SEDIMENT	SILT CLAY	R.LOW ↳ R.HIGH	DRY ↳ MOIST
6.1b					
6.2a	D1, D2			LOW ↓ HIGH	DRY ↓ MOIST
6.2b					
6.2c					
6.3	A2, (D1, D2)		SAND	R. LOW	DRY
6.4	B1, D1, E		N.S.	N.S.	MOIST
7.1	J	KFM	C.SAND/ROCK	N.S.	MOIST SALT / TIDAL
7.2	K	-	C. SAND	R. LOW	

FM = (Geological-) Formation
DS = Duruma Sands
BS = (Pleistocene) Bay Sediment
KL = Kambe Limestone FM
KFM = Kilindini FM
MS = Magarini Sands

N.S = Not significant
C. = Calcareous
RR. = Rotten Rock
(-) = and
(/) = and, or, over
R. = Rather
MOD. = Moderate
V = Very

1.5.3 *Description of plant communities*

In the area, 16 plant communities were recognized. Their delineation is based on the presence or absence of sociological groups. The distribution of the communities over the seven vegetation landscapes is given in Table 6. In the following the various communities are described.

(A) The *Brachystegia spiciformis* woodlands are open, evergreen woodlands, with tree heights of about 8-12 m. The distance between the trees can be as much as 10 m. Two types are recognized, differing in structure and in floristic composition:
(A1) *Brachystegia spiciformis* - *Rhoicissus revoilii* with a dense understorey;
(A2) *Brachystegia spiciformis* - *Grewia* cf. *forbesii* woodland with a less well developed understorey.
It is possible that the difference between A1 and A2 is induced by man, e.g. by more intensive grazing or charcoal production.

The woodlands are rich in species: over 300 species were recorded during the survey (which is more than half of the total number of species recorded during the survey). The *Brachystegia* woodlands occur mainly in the drier parts of the area. They are found in VL 5 (Units 5.1 and 5.2) and in VL 6 (Unit 6.3). Remnants are found in VL 2 and isolated spots are found in the drier parts of VL 4. *Brachystegia* woodlands occur on sandy soils (or soils with a sandy surface soil) with generally a low content of weatherable minerals.

(B) The *Dichrostachys cinerea* - *Panicum repens* shrubbed bushland is closely associated with the Brachystegia woodland. It differs from it in structure (shrubbed bush up to 6m) and in floristic composition. It is probably derived from the *Brachystegia* woodland, or it forms an intermediate stage towards it. The following arguments plead for this:
- the *Dichrostachys* bushland shows a high similarity in floristic composition with the Brachystegia woodland, the difference in structure can be explained by more extensive charcoal production and grazing;
- the *Dichrostachys* bushland is found on similar soils as the *Brachystegia* woodland (often in its direct surroundings), and predominantly at the wetter parts (which are likely to be cultivated first);
- the *Dichrostachys* bushland occurs mostly in the immediate vicinity of arable land, where intensive grazing was observed.

The *Dichrostachys* bushland is found in VL 5 (units 5.3 and 5.4) and in valley bottoms of VL 6 (unit 6.4). Unlike the *Brachystegia* woodland, the *Dichrostachys* bushland occurs on sandy as well as on clayey soils.

(C) The *Grewia microcarpa* - *Perotis hildebrandtii* shrubland is simple in both structure and floristic composition. It can be seen as a rest-group, representing formations degenerated from plant communities B and D1. The formations of the *Grewia* shrubland are relatively open, with shrubs generally not exceeding 4 m in height. The *Grewia* shrubland occurs only in VL 5, where it is confined to the most degenerated parts of units 5.3 and 5.4. It is formed on sandy soils, or clayey soils with a sandy topsoil with a low content of weatherable minerals.

(D) The *Acacia nilotica* shrublands are large communities. They occur in the drier western parts of the area and consist of shrub lands with shrubs generally not exceeding 3-4 m in height, ranging from land with scattered shrubs to vast, impenetrable formations. The shrub occurring most commonly is *Acacia nilotica*, followed by *Hoslundia opposita*. In wetter parts *Dichrostachys cinerea* can dominate, while in the large bottomlands *Acacia zanzibarica* is abundant.

There is a large seasonal variation in the understorey. In dry seasons, all grasses and herbs are consumed or dessicated, leaving the soil either bare or with only few *Pipalia lappacea* near the trunks of the shrubs. Upon rainfall, however, the surface becomes covered with a great variety of flowering herbs and grasses.

Two communities, differing mainly floristically, are recognized:
(D1) *Acacia nilotica - Salvadora persica* shrubland contains many species (less intensive ranging; wet positions);
(D2) *Acacia nilotica - Hoslundia opposita* shrubland lacks a few sociological groups occurring in D1 (e.g. XXXIII and XXXVI), while others are less common (e.g. IX, XXXIV).
The *Acacia* shrublands determine the scenery of VL 6 in all units. D2 is confined to the drier parts of this landscape, whereas D1 is found in wetter parts (unit 6.4) and in unit 5.4 of VL 5. The *Acacia* shrublands occur exclusively on loamy and clayey, often poorly structured soils.
In all cases, *Acacia* shrublands occur in dry areas (annual rainfall not exceeding 700 mm) with occasional heavy rains and flooding.

(E) The *Acacia stuhlmannii - Acalypha fructicosa* bush- and shrubland encompasses all kinds of formations in wet positions, e.g. in river valleys. There is a strong variation both in structure (depending mainly on human influence) and in floristic composition. In general, the community consists of low dense shrubland formations with *Acacia stuhlmannii* and *Pluchea dioscorides*, and some single trees such as *Parkia filicoidea* and *Cocos nucifera*. Common grasses are *Echinochloa haploclada* and *Imperata cilindrica*, and in many cases a variety of *Sorghum* spp. is encountered.

The *Acacia stuhlmannii* bush- and shrubland community is found in river valleys and other wet sites of each landscape, except VL 5 (too dry) and VL 7. The community, having a high salt tolerance, occurs on all kinds of soils, provided that they remain wet for a considerable period of the year, or there is a shallow ground water table.

(F) The *Lannea stuhlmannii* plant communities are characterized by a large diversity in structure, ranging from bush- and shrubland to isolated bushes in grassland formations ('bushmounds'). The term bushmounds refers to isolated, often impenetrable spots where the bush has a complex structure and floristic composition. They are formed on slightly elevated parts of the grassland formations. These elevations may be termite mounds.

The floristic composition of the *Lannea* communities gradually changes with rainfall from north to south: e.g. *Hyphaene coriacea* dominates in the southern grasslands, and *Terminalia spinosa* in the middle and northern formations.

The subdivision of *Lannea* is based on probable human influences, which is reflected both in structure and floristic composition:

(F1) *Lannea stuhlmannii* bush- and shrubland, generally consisting of formations with dense structure, induced by a slight pressure of burning and grazing;

(F2) *Lannea stuhlmannii - Panicum maximum* bush-, shrub- and grassland appears in the open formations, with a heavy pressure of burning and grazing.

The *Lannea* communities predominantly occur in VL 3, which is dominated by the *Lannea* communities, develops on heavy clay soils, often with vertic properties and a high natural fertility. Moreover, some of the *Hyphaene coriacea* grassland formations of VL 1 (unit 1.3) are included.

(G) The *Cocos nucifera* communities are entirely induced by mankind. Although the plantations show considerable variation, they mostly consist of a coconut-cashewnut-citrus/mango ratio of approximately 10:2:1, with an additional amount of *Musa* spp. (banana). At the coast (VL 1), *Ceiba pentandra* (Kapok) is seen in and among coconut plantations.

In the northern part of VL 2, cashewnuts dominate the tree crop plantations, resulting in a ratio of approximately 2:10:1. The variation in understorey of the formations mainly depends on human activities. Three main types of tree crop formations are recognized:

1. tree crops + annual crops (maize, cassava, pulses) (VL 4)
2. tree crops + cleared understorey + intensive grazing (VL 4)
3. tree crops + neglected understorey + extensive grazing (VL 1, VL 2)

Two formations occur:

(G1) *Cocos nucifera - Deinbollia borbonica* plantations (type 3);

(G2) *Cocos nucifera - Sida cuneifolius* plantations (type 1 and 2).

Tree crop plantations cover about one quarter of the survey area. Their importance, both economic and in acreage, justifies their position in a plant community. The G1 formations occur in VL 1 and VL 2, the G2 formations are confined to VL 4. Tree crops are found on a scala of preferably medium-textured deep soils (e.g. not in VL 3) with favourable drainage condit

(H) The *Polysphaeria parvifolia* communities consist of secondary bush and shrubland formations, which develop during fallow periods. Immediately after cultivation, a low but dense *Lantana camara* bush appears. The dominant position of this species is taken over by among others *Polysphaeria parvifolia* and *Markhamia zanzibarica* after a couple of years. A dense, impenetrable bush may then be formed, reaching heights of 5-6 m.
Two *Polysphaeria* communities are recognized:
(H1) *Polysphaeria parvifolia - Triumfetta rhomboidea* bush-and shrubland;
(H2) *Polysphaeria parvifolia* bush- and shrubland.

The H1 formations are confined to VL 2 and VL 4, while H2 formations prevail in the secondary bushes of VL 1. The latter is found in VL 2 as well (associated with *Agave sisalana* plantations).

The *Polysphaeria* formations occur on red, deeply weathered soils or (VL 1) on shallow soils over coral rock.

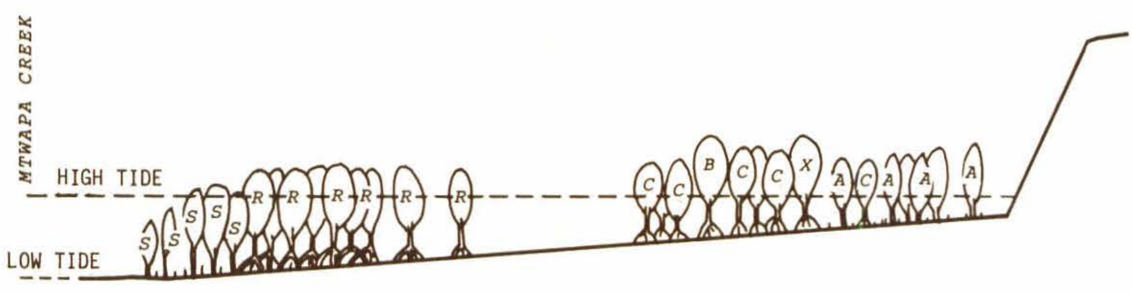
(I) The *Croton pseudopulchellus* (Mukambi forests) community encompasses all (seemingly) original forests of the survey area. Although a number of species is common and some even exclusively occur in these forests, there is a great variation in floristic composition. It differs completely from the surrounding formations. Moreover, it proved to be difficult to identify the composing plant species, also because a number of them have not yet been described conclusively. Structurally, two main types can be recognized:
1. a thin-stemmed coastal forest, with trees up to 15-20 m;
2. a well developed forest, with trees up to 50 m (tropical monsoon forest, e.g. the sacred 'Kaya' forests of VL 4) (Fig. 19).

(Remnants of) original forests are scarce in the survey area. Most of them are found on hilltops in the interior uplands (VL 4, unit 4.1).
VL 2 comprises two kinds of original forest (unit 2.1):
- an extension of the Arabuko Sokoke forest, in the northern parts,
- a sacred forest of the Kaya-type, near Gongoni.

In VL 1, a few remnants of original forests are left (unit 1.1) both located north of Mtwapa creek the Jumba ruins national monument and Kuruwitu.
All these spots are only small, with exotic species such as *Lantana camara* and *Azadirachta indica* as intruders. The (remnants of) original forests are found on a scala of soils.

(J) The *Capparis cartilaginea - Cynanchum tetrepterum* shrub community consists of dense low shrub formations near the beach or on coral rock adjacent to the beach. The development of such communities is influenced by strong salt sprays. This is reflected in their floristic composition, which differs entirely from the inland communities.

(K) The *Sonneratia alba - Rhizophora mucronata* mangrove swamps occur in the tidal creeks of the survey area. The formations consist of low trees



S = *Sonneratia alba*
R = *Rhizophora mucronata*
C = *Ceriops tagal*
B = *Brugiuera gymnorrhiza*
X = *Xylocarpus benadirensis*
A = *Avicennia marina*

Fig. 18. Zonation in a mangrove swamp at Mtwapa Creek.

(2-5 m) or, more towards the inland, of higher trees (up to 10-15 m). In most cases the swamps are difficult to enter because of the immature soils and the intertwinning stilt-roots of the *Rhizophora mucronata* trees. Fig. 18 presents an often observed zonation of these species in the swamps.

1.5.4 *Legend description*

The legend of the vegetation and land use map (scale 1 : 100 000, Appendix 4A), has the following general construction:
1. first level: 7 main vegetation landscapes (VL);
2. second level: structure and floristic composition of the vegetation (seemingly least unnatural vegetation) as follows: original forests (if any), bush and shrublands, and plantations;
3. third level: amount or intensity of arable land or grazing/browsing (as an average of the elements of a unit).

The mapping units, which are shown in Table 6, are briefly described below.

VL 1: *Sterculia appendiculata* - *Ceiba pentandra* VL (plant communities H1, H2, F2, G1, I, A2).
This vegetation landscape was subdivided into:
1.1 Original forest (coastal forest): *I*.
1.2 Shrub- and bushland with increasing amounts of arable land or grazing land; units 1.2.a - 1.2.d, complex with *H2*.
1.3 Comparable, but more humid formations (units 1.3.a - 1.3.d) where *Hyphaene coriacea* (Palmae) occurs; complex with *H2* and *F2* communities.
1.4 *Agave sisalana* (Agavaceae) monoculture plantations; complex with *H2* community.
1.5 Tree crop plantations:
- 1.5.a intermixed with arable or grazing land, complex with *G1*, *H1* and *A2*;

- 1.5.b pure stands, complex with *G1* and *H1*.

Unit 1.2.d comprises a large scale modern dairy farm, which has the appearance of an English park: large single fruit trees (mainly mango) on extensive grasslands. Unit 1.4 consists of large scale sisal estates.

VL 2: *Cynometra suaheliensis - Anacardium occidentale* VL (plant communities G1, H1, H2, I, A2).

2.1 Original forest (tropical monsoon forest), community *I*.

2.2 Cashew - coconut plantations:
  - 2.2.a mixed with arable or grazing land, complex with *G1*, *H1*, and *A2*;
  - 2.2.b pure stands, complex with *G1* and *H1*.

2.3 Secondary shrub- and bushlands, complex with *H1*.

2.4 *Agave sisalana* monoculture plantation, complex with *H1* and *H2* communities.

VL 3: *Terminalia spinosa - Maytenus senegalensis* VL (plant communities F1, F2, E and I).

3.1 Original forest (only very small patches), plant community *I*.

3.2 Wooded, bushed or shrubbed grassland, complex with *F1*, *F2* and *E* (see map legend):
  - 3.2.a *Diospyros cornii - Lannea stuhlmannii* grasslands (in the north);
  - 3.2.b *Terminalia spinosa - Lannea stuhlmannii* grasslands (central VL 3-area);
  - 3.2.c *Hyphaene coriacea - Lannea stuhlmannii* grasslands (southern VL 3-area).

3.3 Shrub- and bushlands, with increasing amounts of arable land, c.q. increasing intensity of ranging (units 3.3.a - 3.3.d), complexes with *F1*, *F2* (unit 3.3.d) and *E*.

3.4 River valleys, with complex patterns of bush-, shrub- and grasslands, or arable land. Locally *Acacia polyacantha* forests occur, e.g. near Sokoke, complex with *F1 and E*.

VL 4: *Cocos nucifera - Chlorophora excelsa* VL (plant communities G2, H1, E, D2, A2, I).

4.1 Original forest (the Kayas Fig. 19), tropical monsoon forest, community *I*.

4.2 River valley complexes, characterized by the cultivation of rice (*Oryza sativa*), complex with community *E*.

4.3 *Cocos nucifera* plantations (mixed with cashewnut, mango, citrus and banana):
  - 4.3.a pure stands, community *G2*;
  - 4.3.b complex with grassland and arable land (on the slopes), plant communities *H1*, *A2*, and *D2*;
    this is a very large unit, which opens gradually and is con-

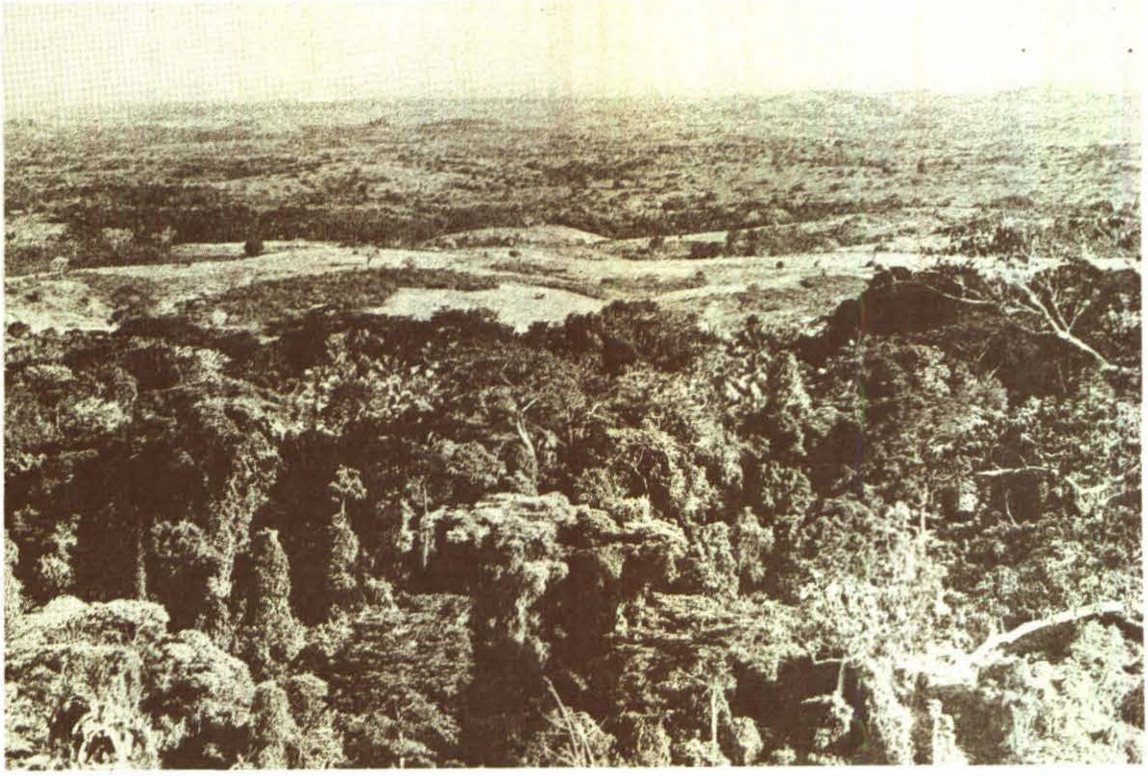


Fig. 19. Kaya Kambe seen from Kinangoni Hill, August 1983. Note cultivated field on soils of the Mtomkuu Formation (photo H. Waaijenberg).

tinuing into units VL 5 and 6.

4.4 Bushland, mixed with arable and grazing land, complex with *H1*.

4.5 Woodland, alternated with arable land, complex with *H1* and *I*; this woodland borders the *Brachystegia* woodland of VL 5, but differs both in structure and floristic composition.

VL 5: *Brachystegia spiciformis - Manilkara zanzibarica* VL (plant communities A1, A2, B, C and D1).

5.1 *Brachystegia* woodland with dense understorey complex of *A1* and *A2* (mainly *A1*).

5.2 *Brachystegia* woodland with open understorey (due to grazing) complex of *A1* and *A2* (mainly *A2*).

5.3 Secondary bush- and shrublands, complex with *A2*, *B* and *C*.

5.4 Bush- and shrubland on clayey, locally saline and/or sodic soils, complex with *B*, *C* and *D1*.

VL 6: *Salvadora persica - Acacia nilotica* VL (plant communities B, C, D1, D2, E and A2).

6.1 Bushed grassland, complex with <u>C</u>, <u>D1</u> and <u>D2</u>:

- 6.1.a less than 1/5 arable land (dryer positions);
- 6.1.b more than 1/5 arable land (moist positions).

6.2 Bush- and shrubland, with increasing amounts of arable land (units

6.2.a. - 6.2.c), complex with *D1* and *D2*.

6.3 *Brachystegia* woodlands and thickets, on sandy hills and elevations, complex with *A2*, *D1* and *D2*.

6.4 River valley complexes, with communities *B* and *D1*.

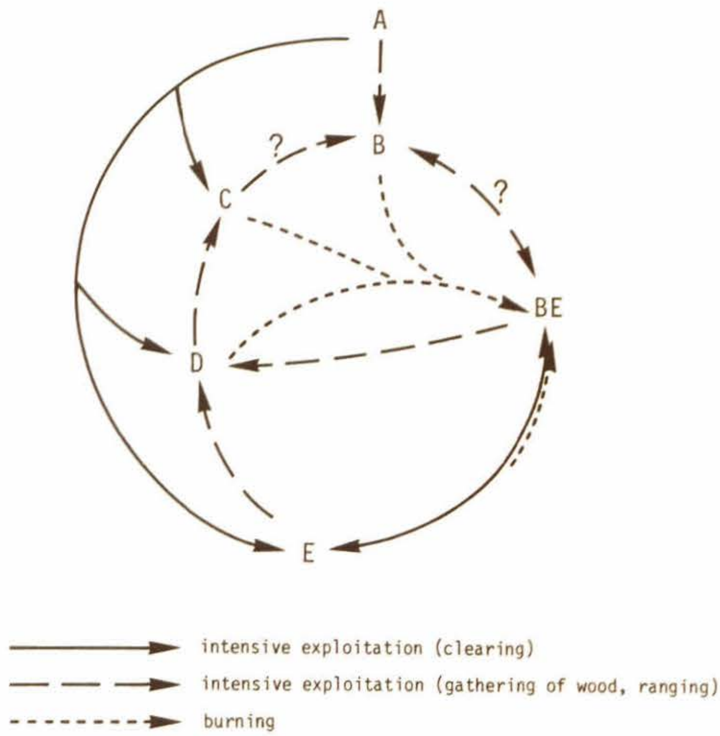
VL 7: *Ipomoea pes-capre* - *Rhizophora mucronata* VL (plant communities J and K).

7.1 Shorelines of the Indian Ocean: plant community *J*; two shore types may be recognized i.e.:
- shores delineated by a coral rock scarp (with *Capparis cartilaginea* shrub formations);
- shores with (minor) dunes (formed out of calcareaous sand).

The off-shore vegetation (subject to tides) is characterized by marine angiosperms belonging to three families: *Potamogetonaceae*, *Hydrocharitaceae* and *Zosteraceae*. Along with these, *Phaephyta*, *Rhodophyta* and *Chlorophyta* represent the seeweeds, of which the *Chlorophyta* seem to form the majority.

7.2 Creek shores: mangrove swamps, plant community *K*.

Fig. 20. Small-scale tomato growing in Pingilikani, about 17 km south-south-west of Kilifi, September 1983. The house is thatched with palm leave tiles (makuti) (photo H. Waaijenberg).



KEY:
A = *Croton pseudopulchellus* FOREST
B = DEGENERATED FOREST
C = *Kleinia pluniordes* BUSHLAND
D = *Thespesia danis* SHRUBLAND
E = *Securenegia veroia* ARABLE LAND
BE = WOODED GRASSLAND

Fig. 21. Vegetation formations evolving into each other.

1.5.5 *Human influence on the vegetation*

As has already been stated in Section 1.5.1, the human influence on land (and thus the vegetation) has been and still is significant in the Kilifi Area (Fig. 20). Table 7 shows agricultural activities and their intensity in the main landscapes. The relation between human activities and the resulting vegetation was studied in detail in the northern part of vegetation unit VL 3 (Kuyper, 1982). This area was selected because:

- geology and soils are rather homogenous (heavy clay soils on shales);
- climatic conditions are uniform;
- human activities are still traditional; the vegetation shows a complex, dense mosaic of formations, ranging from (supposedly) original forest to wooded grassland.

The processing of 50 relevés (river valleys were neglected) resulted in the recognition of six plant communities, each representing a certain degree of human influence. As can be seen from Fig. 21, the vegetation formations evolve into each other in a cyclic way. Return to the original forest takes a very long time and is not likely to occur. Burning of the vegeta-

Table 7. Agricultural activities and their intensity in the main landscapes of the Kilifi Area.

Land-scape	High intensity	Medium intensity	Low intensity	Very low intensity
VL 1	Large scale dairying Irrigated horticulture	Exploitation of coconuts	Cashewnuts Bananas	Cashewnuts Mango Goats, sheep, cows
VL 2	Large scale Sisal production	Coconuts Cashewnuts & Grazing	Timber	Cashew Mango Cows, goats
VL 3	Medium scale dairying	Maize-tractor ploughing		Goats
VL 4		Coconuts Cashcrops Rice (valleys)	Cashewnuts Bananas Citrus	Goats, cows Cashew, mango
VL 5				Cashew, cows Charcoal (timber) Cows, goats
VL 6	Agricultural Research Station		Cows, goats, Sheep ranches Pineapple	
VL 7				Mangrove wood for hous construction

tion apparently results in the formation of wooded grasslands in all cases. These are grasslands with isolated trees or bushes, often situated on slightly higher sites (former termite mounds). For these particular sites, the term 'bushmounds' was introduced (Section 1.5.3).

2 Methods

2.1 INTRODUCTION

This chapter provides information on methods applied for the soil survey, the laboratory testing of soil samples and the cartography. The methods that have been practised for the studies on vegetation and land-use, farming systems and land evaluation have been described in the chapters in question.

2.2 OFFICE METHODS

Prior to the fieldwork all available aerial photographs, topographic and geological maps, reports and other literature about the Kilifi Area were collected and studied.

The area is covered by topographic maps from the Survey of Kenya at a scale of 1 : 50 000, viz. the sheets 198/1 (Bamba), 198/2 (Kilifi), 198/3 (Mazeras) and 198/4 (Vipingo). Together these four sheets form the quarter-degree sheet 198 (Kilifi) of the soil map of Kenya, to be published at scale 1 : 100 000.

The aerial photographs cover the area at a scale of approximately 1 : 50 000. Certain selected areas, to be discussed in the following paragraph, are covered by aerial photographs at a larger scale, mainly approximately 1 : 10 000.

All aerial photographs were acquired from the Survey of Kenya, except those of an area near Ganze, which were ordered from a private firm. Most of the photography was done in 1969, which in some areas brought about confusion, due to changes in roads, land-use etc. The Ganze photos were taken in 1982.

A geological map of the area at a scale 1 : 250 000 existed (Caswell, 1956). Moreover, the project made use of preliminary geological maps (1 : 50 000), which were recently produced by the Ministry of Mines and Geology.

2.3 FIELD METHODS

As a first step in the reconnaissance survey a general inventory on soils, vegetation and land-use was implemented on basis of aerial photo-interpretation and 6 weeks of fieldwork by 5 surveyors and their assistants.
Results have been published by Floor et al. (1980). The soil inventory map was then used to select eight so-called sample areas, indicated in Appendix 5

Between February 1980 and May 1982 a number of surveyors worked on these areas in detail and/or semi-detail. After having accomplished the sample area survey, a much larger area adjacent to and including the sample area was surveyed and mapped on a reconnaissance basis (1 : 50 000). In general, the same surveyor worked on both subjects. In each survey, numerous routine augerings were made with an Edelman soil auger (mostly sand-type), in general to a depth of 120 cm. The sites were chosen from aerial photographs and pinpointed on the photo and the fieldmap. Properties of land, soil and vegetation were recorded on standard forms of the Kenya Soil Survey (KSS), that are based on forms used by FAO (1977). All completed forms are at the disposal of the KSS archives. A great number of soil pits have been described and sampled. Profile descriptions and analytical data of samples from thirty soil pits which can be regarded as representative for the soil unit concerned, are given in Appendix 6. Their location and serial number are given in Appendix 5F.

The separate reconnaissance soil maps were finally compiled into the actual Kilifi mapsheet (1981) and reduced to 1 : 100 000.

A few profiles have been selected by the International Soil Research and Information Centre (ISRIC), Wageningen, The Netherlands, for further analysis and study, particularly including micromorphology. Of these profiles soil monoliths have been prepared for display at ISRIC.

Apart from the soil surveys, a number of related soil, vegetation and crop studies have been carried out by post-graduate students. A few have been published as Preliminary Reports (Kilifi-series).

All other reports are available for restricted use at the KSS, Nairobi.

2.4 LABORATORY METHODS

Most determinations for soil characterization were done at the National Agricultural Laboratories (NAL) in Nairobi. About five hundred soil samples were analysed there. The procedures are summed up below. Moreover, numerous soil samples have been analysed at the TPIP laboratory in Kilifi. Especially soil texture, moisture retention (pF) and organic matter content were determined, partly on behalf of the survey, partly for the benefit of soil research subjects. Most soil mineralogy analysis has been done at the laboratory of the Coast Geoscience Project in Kilifi.

The samples received the following treatments.

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).
TPIP. Destroy organic matter with hydrogen peroxide (volume fraction 0.3);

remove carbonates and iron coatings with HCl (concentration 2 mol/l). Dilute the sample and siphon three times. Sieve wet with a 0.05-mm sieve to separate sand. Collect the rest in a sedimentation cylinder and disperse with sodium pyrophosphate (concentration 120 mmol/l). After shaking, pipette off silt <0.05 mm and clay <0.002 mm. After drying sieve the sand into fractions of 2.0-1.0 mm, 1.0-0.50 mm, 0.50-0.25 mm, 0.25-0.10 mm and 0.10-0.05 mm.

pH and electrical conductivity

NAL. For soils with an electrical conductivity (EC) >120 mS 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 (concentration 1 mol/l) of volume ratio 1 : 1.

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.

Mass fraction of nitrogen

NAL. Semi-micro Kjeldahl on 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 (volume fraction 0.95) and percolate with acidified NaCl. Steam-distil off the ammonia and titrate against HCl (concentration 10 mmol/l) (Houba et al., 1979).

Exchangeable acidity

NAL. Extract soil with $BaCl_2$ (concentration 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 (concentration of HCl 100 mmol/l 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 counteract precipitation of Ca-salts. Estimate Mg by atomic 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, and kaolin box (for pF 2.3 and 2.7) and pressure equipment to pF 3.0, 3.7 and 4.2 (Stakman et al., 1969).

2.5 CARTOGRAPHIC METHODS

The cartographic work was done in the office of the training project (Kilifi), at the Kenya Soil Survey (Nairobi), at ITC (Enschede), at the Agricultural University, Department of Soil Science and Geology (Wageningen) and at the Netherlands Soil Survey Institute (Stiboka) in Wageningen. After preparation of all plates, a proof print of the coloured map on "Kromecote" was produced with a "Cromalin" proofing machine. The maps were printed by Sythoff Printers at Rijswijk, the Netherlands.

For the area surveyed, a base map on scale 1 : 100 000 was not available. So four adjoining sheets (198/1-4) of the Survey of Kenya (1962-3) on 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 topographic details, one with contour lines, and one with drainage aspects. Then each sheet was generalised and reduced to the final scale of 1 : 100 000 and the four sheets were joined together as a positive film. New relevant elements that were not yet featured on the sheets were added, for instance new roads. This additional information was collected during fieldwork and from aerial photographs.

The coloured soil map (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 (Appendix 2) required a fourth plate: a black plate with agro-climatic zones.

3 The soils

3.1 PREVIOUS WORK

Gethin-Jones & Scott (1959) prepared a 1 : 3 000 000 soil map for the first edition of the National Atlas of Kenya. It was reprinted in 1962 (2nd edn) and 1970 (3nd edn). The authors recognized the following soil units within the survey area:

- coral rag, which coincides with the soil developed on coral limestones with sand admixtures (Reef Complex),
- red and yellow sands of the coastal strip (Kilindini Formation),
- dark red loamy sands (latosolic soils), more or less covering the soil of the Magarini Formation,
- brown clays (grumosolic soils), covering the soils of the Mtomkuu Formation,
- yellow-red loamy sands (podsolic soils); the position of this unit on the map of Gethin-Jones and Scott coincides with the soils developed on limestone (Kambe Formation); their description however, does not because the soils of this unit are red to reddish-brown sandy clays to clays and certainly in no way podsolic,
- a complex of dark red loamy sands (latosolic soils), dark red brown loams, brownish yellow loamy sands (with laterite horizon) and brown clays (grumosolic soils); part of this complex covers the soils of the Mazeras Formation,
- a complex of light yellow-brown loamy sands with laterite horizon, brown clays (grumosolic), and shallow stony soils with rock outcrops: part of this complex covers the soils of the Mariakani Formation.

The survey area is also covered by the Exploratory Soil Map (scale 1 : 1 000 000), prepared by the Kenya Soil Survey (Sombroek et al., 1982). While comparing the section of this map which covers the Kilifi Area with the simplified soil map of the Kilifi Area (Appendix 5C), the following remarks can be made:

- the Pc units coincide well with the P2 units of the survey area,
- unit Uc2 coincides with UT2 of the survey area,
- unit Uc9 coincides with parts of US,
- unit Uc4 coincides better with UO and P10 (soils on bay deposits) than with US and USK, which also cover parts of the Uc4 area,
- Uc8 is a compilation error: the unit coincides with an area that is represented by UE1 in the survey area: hence, Lc2 should be read instead of Uc8,

- unit Lc1 coincides well with UL; this area is, however not considered a plateau in this survey,
- unit Lc3 covers part of the USK units, and its description indeed covers the soils of that area; geomorphologically, this area is not considered a plateau in the present survey,
- H20 does not cover a similar unit; it is depicted on the map as a ridge of hills, which is correct, but the soils that have developed here show more ressemblance with the description of unit Uc9,
- unit Ps16 coincides with P10,
- unit A13 concides with AAx and BAc3,
- unit T coincides with TAx and parts of TAc.

The preliminary shape and contents of the Exploratory Soil Map, and also the adjacent mapsheets 200 and 201 of the KSS reconnaissance soil map of the Kwale-Mombasa-Lungalunga Area, were of much help during the initial stages of the survey of the Kilifi Area.
A reconnaissance soil map at scale 1 : 250 000 (Voi Area, Van Wijngaarden & Van Engelen, 1985), borders the Kilifi Area in the west.

3.2 GENERAL PROPERTIES OF THE SOILS

The soils of the Kilifi Area represent a wide range of profile characteristics. Differences in e.g. parent material, age or drainage condition have delivered an array of soils from high to low agricultural potential.

With reference to chapter 1.3 and to Appendix 5A and 5B, the following subdivision into major landforms can be made:
- Minor Scarps,
- Coastal Uplands,
- Coastal Plains,
- Floodplains, Minor Valleys and Bottomlands,
- Tidal Flats and Swamps,
- Dunes.

3.2.1 *Minor Scarps*

The Minor Scarps represent small but prominent features in the landscape with a relief intensity of 50-200 m/km^2 and slopes ranging between 16 and 30%. The soils have developed from various parent materials. The survey area comprises two major escarpments:
- the Kaloleni escarpment (HSKC), running approximately east-west from Kaloleni to Gotani;
- the Mazeras escarpment (HX1C), running approximately northeast-southwest from Mwarakaya/Mbuyuni to Mazeras and including the adjacent river gorges (HX2C).

3.2.2 *Coastal Uplands*

The Coastal Uplands cover approximately two-thirds of the area and have a relief intensity of less than 100 m/km² and slopes that mostly do not exceed 16%.

The soils are grouped according to landform (Chapter 1.3) and to parent material, which also constitutes the basis for the map legend (Appendix 1).

The Kaloleni upland is situated in the northwestern part of the survey area, at altitudes of 250-350 m and with a gently undulating relief. Parent materials: fine grained sandstones and siltstones (Mariakani Formation) and coarse grained sandstones (Mazeras Formation). The soils developed on the Mariakani Formation are predominantly somewhat excessively drained to well drained, very deep, yellow and sandy. Four mapping units have been recognized, USKf being the largest and the sandiest; USKl and the association USKA1 possess subsoils with redder hues and heavier textures (sandy clay (loam)), and the soils of the association USKA2 have hydromorphic properties. The soils developed on the Mazeras formation of the sandy category are (somewhat) excessively drained, mostly very deep and white to yellowish brown (USs1 and USs2p) or yellowish red (USs3). They have a low moisture storage capacity. A large area is occupied by unit USc1, which has deep, red sandy clays, that in places underly a light-textured surface soil; these soils have a somewhat better moisture storage capacity. Units USlp and USc2 cover small areas.

The Dzitsoni upland is situated in the centre of the area as a rather narrow, elongated zone, running approximately north-south. Altitude ranges from 100 to 200 m, relief is (gently) undulating and dissection by rivers is negligible in most places. Parent material is limestone (Kambe Formation). The soils of the two mapping units (ULc1 and ULc2) consist of predominantly well drained, deep to very deep, red sandy clays to clays. Rock outcrops are scattered throughout parts of ULc1. The soils possess a high porosity and are very well structured in both surface soil and subsoil.

The Rabai upland, occurring both in the south-west (very gently undulating relief) and in the central-north (undulating to rolling relief) of the area, at an altitude of about 150-250 m. The soils of the four mapping units have been derived from sandy and clayey Bay deposits. Those in the southwest are moderately well drained to imperfectly drained, deep, brown sandy clay loams (UOl), and often saline and/or sodic clays (UOc2p). Reddish and slightly better drained sandy clays are mostly covered by a sandy surface soil (UOc1). Scattered 'islands' of well drained, pale brown, loamy very fine sands constitute the fourth unit of the Rabai upland (UOf). Clayey soils, developed from Mariakani shales, occupy a small area in the Rabai upland (unit UT1C).

In the central-northern part the moderately well drained, very deep, brown often saline and/or sodic clays occur again (UOc2p). Summits and ridges in this area have sandy soils of the Mazeras Formation (USs1 and USs3).

The Lutsangani upland is represented by a wide zone, which runs north-south, and has a strikingly different appearance from the adjacent Dzitsoni, Rabai and Pingilikani uplands. Altitude ranges from 1-100 m, relief is rolling and the area is strongly dissected. Parent material is shale (Mtomkuu Formation). In the southern and central parts of the Lutsangani upland the soils consist of well drained, moderately deep, yellowish red clays with vertic properties (UT2c1p and UT2C). The northern part of the zone has also shallower soils with reddish brown colours (UT2c2p and UT2c3P). Poorly drained soils occur scatteredly (unit UT2c4). A large portion of the Lutsangani upland is occupied by valleys which have steep sides, shallow soils and narrow valley bottoms with poorly drained clays. Only the larger valleys have been mapped, either as Minor Valleys (VX) or Floodplains (AA). The higher summits and ridges are covered with loamy sand (UE2f) and sandy clay loams (UE2l), which are probably remnants of the Magarini Formation.

The Pingilikani upland occurs as two separate areas in the north eastern and in the eastern part of the area, adjacent to the Lutsangani upland. The altitude ranges between 100-200 m, relief is flat to undulating, dissection is slight to moderate. The parent material is medium-grained unconsolidated sands (Magarini Formation). The major part of the Pingilikani upland has well drained, very deep, mostly dusky red to red, sandy loams (UE1m1) and sandy clays loams to sandy clays (UE1l1, UE1l2).

3.2.3 *Coastal Plains*

The Coastal Plains, cover approximately one-fifth of the survey area. They have a relief intensity of less than 10 m/km^2 and slopes that do not exceed 5%. The 'high level' plain is situated in the extreme western part of the area. It is referred to as the Bamba plain. Altitude ranges from 150 to 250 m. The soils of the three units distinguished here were derived from sandy and clayey bay deposits. The soils of unit P1Ol are moderately well drained, deep to very deep, brown, mottled sandy clays, locally with a fine sandy surface soil. Unit P1Of comprises fine sandy soils, in places with a fragipan. The third unit is an association of P1Of and P1Ol. Part of the soils is rich in exchangeable sodium and has a soil surface that is easily compacted and sealed.

The 'low level' plain which is located as a wide elongated strip along the coast, is referred to as the Kibarani plain. It falls apart into three groups:

- soils developed on marls (Baratume Formation): association of calcareous clay soils that comprise only a small area (P2WA);
- soils developed on medium and coarse grained sands (Kilindini Formation): very deep, yellowish brown and yellowish red soils of sandy to loamy tex-

ture (P2Em1, P2Em2, P2Em3, P2Em4) and of loamy to clayey texture (P2El1, P2El2, P2El3, P2Ec and association P2El1-P2El3); the soils of the first group are somewhat excessively drained to well drained, the soils of the second group contain also hydromorphic soils (P2El3, P2Ec);

- soils developed on coral limestone with sand admixtures (Raised Reefs); well drained, shallow to moderately deep, red sandy clay loams (P2Ll1P, P2Ll2p) and clays (P2Lcp); rock outcrops occur in places.

3.2.4 *Floodplains, Minor Valleys and Bottomlands*

The Floodplains of the major river systems in the area have soils developed on recent alluvial deposits. Lower river terraces are mostly included. In general, the soils are imperfectly to poorly drained, deep, brown to greyish brown sands to sandy clays (AAx). Rivers traversing the clayey Lutsangani upland such as the Rare, the Ngombeni and the Mtomkuu have floodplains with cracking clay soils (AAc).

Minor Valleys contain soils developed on various parent materials, because the mapped valleys include both the flat valley floors and the lower valley slopes. Unit VXA consists of an association of imperfectly to poorly drained, moderately deep, grey sandy clays (valley floors) and well drained, moderately deep, brown sandy loams, often with a sandy surface soil (lower slopes). The minor valleys in the Lutsangani upland have cracking clayey soils of varying drainage condition, depth and colour (VXC).

The Bottomlands are flat areas with no or little external drainage. The soils have developed on various unconsolidated deposits. They are generally moderately well drained to poorly drained, deep, greyish brown, mottled sandy clays (BAc1, BAc2, association BAc1-BAc2). Few bottomlands contain saline and/or sodic soils (BAc3).

3.2.5 *Tidal Flats and Swamps*

Tidal Flats and Swamps are areas fringing the tidal creeks. The soils have developed on recent marine deposits. They are poorly drained, very deep, grey to olive brown, very soft (unripened), saline, sodic and/or sulfidic soils of either various texture (TAx), clays (TAc) or muck (TAo).

3.2.6 *Dunes*

The Dunes are located, either immediately along the shore at an altitude of 0-15 m (Kikambala dunes) or somewhat further inland along the former shoreline at an altitude of 15-50 m (Makonde dunes).

The Kikambala dunes have soils which are (very weakly) developed on recent coastal sands. The sandy soils are excessively drained, very deep, pale brown to light grey and strongly calcareous (DE1).

The Makonde dunes have soils that are well drained, very deep, brown, in places calcareous sands and loamy sands (DE2).

3.3 DESCRIPTION OF MAPPING UNITS

3.3.1 *Codes and terminology*

Soil mapping units are units of land with a particular soil. They can be separated spatially in the field, can be shown on maps, and can be used for land evaluation purposes. All mapping units have been briefly described in the legend to the soil map and have been indicated as such on the map by a code (Appendix 1).

The legend has been set as follows: the main subdivision is based on physiography (first character), the second entry is the parent rock or parent material with indication of geological formation (second character), and at the third level soil properties are diagnostic, in particular texture class (fourth character), (soil drainage) and soil depth (sixth character). Subdivision of the mapping units according to slope classes introduces further detail.

Physiography	*Character*
Minor Scarps	H
Coastal Uplands	U
Coastal Plains	P
Floodplains	A
Minor Valleys	V
Bottomlands	B
Tidal Flats and Swamps	T
Dunes	D

Parent material and/or rock	*Character*
Sandstones	S
Siltstones	K
Shales	T
Limestones	L
Mixed parent rocks	X
Unconsolidated sandy deposits	E
Unconsolidated clayey deposits	O
Undifferentiated, unconsolidated deposits	A
Marls	W

Texture class	*Character*
(loamy) fine sand (50-250 µm)	f
(loamy) medium sand (250-500 µm)	m
(loamy) coarse sand (500-2000 µm)	s
(sandy) loam and (sandy) clay loam	l
sandy clay and clay	c
organic soils (muck)	o
mixed textures, undifferentiated	x

Second serial number

For soils with similar major characteristics a serial number (1, 2, 3) is given, to express minor variations in drainage condition, soil depth, soil texture, soil colour, etc.

Depth class

The depth classes have only been indicated, if the major part of the soil unit has shallow soils (<50 cm) over rock (P) or moderately deep soils (50-80 cm) over rock (p).

Slope class		*Character*
0-2%	flat to very gently undulating	A
2-5%	gently undulating	B
5-8%	undulating	C
8-16%	rolling	D
16-30%	hilly	E
>30%	steeply dissected	F

Slope class is not part of the unit codes. On the soil map, however, slope classes have been indicated in capitals. A soil unit may be subdivided into several sections of different relief.

Example of mapping unit code: $\frac{\text{U T 2 c 3 P}}{\text{BC}}$

U = physiographic unit (uplands)
T = parent rock (shales)
2 = first serial number
c = general texture class (clayey)
3 = second serial number
P = soil depth (shallow over rock)
BC = slope class (gently undulating to undulating)

In the legend, the various characteristics of the mapping units are listed in the following order: drainage condition, soil depth range, soil colour (moist) range, mottling (if any), soil consistence (moist), soil texture range, inclusions (if any, e.g. 'in places saline and/or sodic'), texture of surface soil ('underlying...'), texture of subsoil ('overlying...').

The descriptions denote the characteristics of the subsoil (usually the B-horizon) above 100 cm. Whenever the surface soil and/or the deeper subsoil differ(s) from the subsoil by two or more textural classes, they are also described. In case of a textural change within 150 cm, the texture of the deeper subsoil is also given.

The terminology of the legend is according to the definitions given in the 1962 supplement of the Soil Survey Manual (Soil Survey Staff, 1951), and to the FAO Guidelines for Soil Profile Description (1977). The colour indications are based on the Munsell Color Charts (1975) and are given for moist conditions. The same holds for the description of the individual soil mapping units and the profile descriptions given in Appendix 6. The soils are classified according to the Legend of the FAO/Unesco Soil Map of the World (1974).

Modifications and additions to this system are indicated by an asterisk (Siderius & Van der Pouw, 1989).

3.3.2 *Comprehensive description of mapping units*

The reconnaissance soil map of the Kilifi Area comprises 60 mapping units. In this paragraph, the units have been described comprehensively. The sequence, in which the details have been presented, is more or less according to the sequence given in 'Guidelines for Soil Profile Description' (FAO, 1977).

The following order is maintained throughout the paragraph:

- map unit;
- soil classification (FAO/Unesco, Kenyan Concept, USDA);
- brief map unit description (largely ressembling the description in the map legend);
- representative soil profile(s) (described in Appendix 6);
- environmental characteristics (parent rock/material, physiographic unit, topography and dissection, agro-climatic zone);
- soil characteristics (drainage, depth, colour, texture, structure, consistence, permeability and moisture conditions, chemical properties, mineralogy);
- vegetation and land-use;
- similarity of the mapping unit with other units.

3.3.2.1 Soils of the Minor scarps

Map unit: HSKC

Total area: 635 ha
Soil classification:
FAO/Unesco (1974): chromic Vertisols, vertic and orthic Luvisols
Kenyan Concept: -do-
Soil Survey Staff (1975): udic Chromusterts, vertic and udic Haplustalfs
Brief map unit description: Complex of reddish brown to greyish brown, sandy clay to clay soils of varying drainage condition and depth
Representative soil profile: Profile 1 (198/3-45)
Environmental characteristics:
  Parent material: fine grained sandstones, siltstones and shales
  Physiographic unit: Minor Scarps
  Topography: Sloping to steep scarps;
    slope classes: D,E
  Agro-climatic zone: IV (> 90%)
Soil characteristics:
  Drainage: varying
  Depth: varying
  Colour: dark brown to dark greyish brown surface soil; dark reddish brown to dark yellowish brown and light olive brown subsoil
  Texture: sandy clay to clay, mostly underlying 20-40 cm sandy loam
  Structure: moderate, medium, angular blocky to strong, coarse, prismatic, in places clay cutans or slickensides
  Consistence: firm to very firm (moist);
    sticky and plastic (wet)
  Permeability: initially high, but diminishes rapidly upon sustained wetting;
  Chemical properties: organic matter content of the A horizon is mostly in between 1 and 2%, CEC (pH 8.2) ranges from 100 to 200 mmol/kg soil, base saturation exceeds 50%, pH (H_2O) is generally in between 5.5 and 6.5
  Clay mineralogy: predominantly montmorillonitic clay minerals
Vegetation and land-use: Bushed grassland; extensive grazing
  Annual and semi-annual field crops: maize, cassava (of minor importance)
Similar soils: The soils of units HSKC, P2Lcp, AAc, VXC, P2Ee, P2WA, BAc2 and the UT-units predominantly consist of fine textured, cracking clays

Map unit: HX1C

Total area: 2130 ha
Soil classification:
FAO/Unesco (1974): vertic and eutric Cambisols and Luvisols, partly lithic phase, eutric Regosols
Kenyan Concept: -do-
Soil Survey Staff (1975): typic and lithic vertic Ustropepts, lithic Ustorthents
Brief map unit description: Complex of clay soils of varying drainage condition, depth, colour and rockiness; in places calcareous
Representatieve soil profile: Profile 2 (198/3-72)
Environmental characteristics:
  Parent material: sandstones, shales and limestones
  Physiographic unit: Minor Scarps
  Topography: Sloping to steep scarps;
    slope classes: D,E
  Agro-climatic zone: III (approx. 50%)
    IV (approx. 50%)
Soil characteristics:
  Drainage: mostly well drained, in places poorly drained
  Depth: mostly shallow to moderately deep
  Colour: varying colours
  Texture: clay, underlying 0-40 cm sandy loam to clay loam
  Structure: moderate, medium, subangular blocky to moderate, coarse, prismatic (in places vertic properties)

Consistence: firm (moist); sticky and plastic (wet)
Permeability: initially high, but diminishes rapidly upon sustained wetting;
Chemical properties: organic matter content of the A horizon is about 1%, CEC (pH 8.2) is 130 mmol/kg soil, base saturation exceeds 50%, pH(H_2O) is 6.0 to 6.5
Clay mineralogy: undifferentiated clay minerals
Additional remarks: the shallowest soils are located at the steepest sites
Vegetation and land-use: Bushed grassland
Annual field crops: maize (of minor importance)
Perennial fruits: mango (of minor importance)

Map unit: HX2C

Total area: 1950 ha
Soil classification:
FAO/Unesco (1974): Lithosols, dystric Cambisols, gleyic Acrisols, partly lithic phase
Kenyan Concept: dystric Lithosols, -do-
Soil Survey Staff (1975): typic and lithic Ustropepts, epiaquic and lithic Haplustults
Brief map unit description: Complex of shallow, rocky and stony soils of varying drainage condition, colour and texture
Representative soil profile(s): none
Environmental characteristics:
Parent material: coarse and fine grained sandstones
Physiographic unit: Minor Scarps
Topography: Sloping to steep scarps and valleysides; slope classes: D,E
Agro-climatic zone: IV
Soil characteristics:
Drainage: well drained to imperfectly drained
Depth: shallow to deep
Colour: varying colours
Texture: sandy loam to clay
Consistence: varying with texture
Permeability: lateral drainage predominates because of topography and soil shallowness
Chemical properties: no data
Clay mineralogy: undifferentiated clay minerals
Additional remarks: the shallowest soils are located at the steepest sites
Vegetation and land-use: Bushed grassland and badlands;
Extensive grazing
Annual field crops: maize (of minor importance)

3.3.2.2 Soils of the Coastal uplands

Map unit: USKf (Fig. 22, 23)

Total area: 17470 ha
Soil classification:
FAO/Unesco (1974): albic and luvic Arenosols
Kenyan Concept: -do-
Soil Survey Staff (1975): ustoxic Quartzipsamments, alfic Ustipsamments
Brief map unit description: Somewhat excessively drained, light brown to yellow, fine sand to sandy loam (albic Arenosol); in places with lamellae of clay accumulation (luvic Arenosol)
Profiles with little horizon development, a low nutrient status and a high to very high permeability
Representative soil profiles: Profile 3 (198/1-3) and Profile 4 (198/1-81)
Environmental characteristics:
Parent material: fine grained sandstones and silt stones
Physiographic unit: Coastal Uplands (Kaloleni upland)
Topography and dissection: flat to undulating;
slope class(es): AB, mostly BC;
slightly to moderately dissected by minor valleys (VXA) and bottomlands (BAc2)
Agro-climatic zone: IV (approx. 40%)
V (approx. 60%)

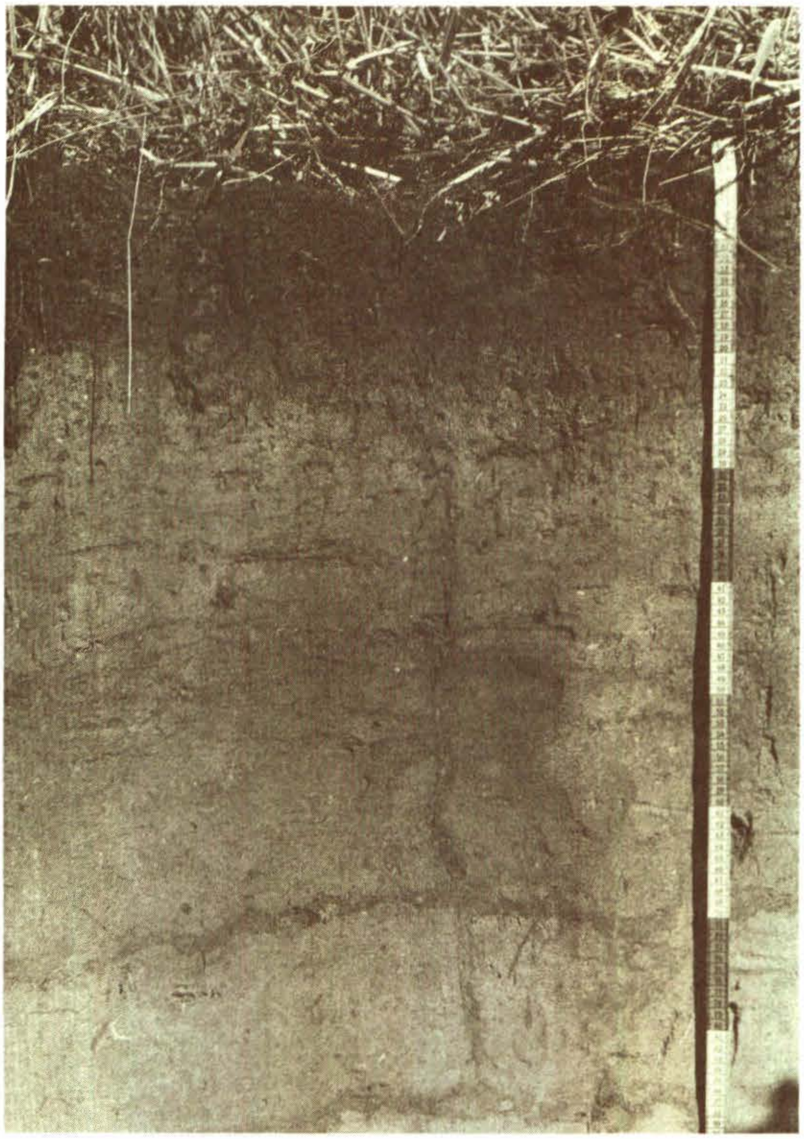


Fig. 22. Soil unit USKf (albic and luvic Arenosols) in Kinarani, about 11.5 km north-west of Kaloleni (photo H. Waaijenberg).

Range of profile characteristics:

Drainage: somewhat excessively drained

Depth: very deep

Colour: very dark greyish brown to light yellowish brown thin surface soil; very pale brown to yellow subsoil

Texture: fine sand to sandy loam

Structure: porous massive, weakly coherent to weak, medium, subangular blocky, locally a fragepan

Consistence: loose to very friable (moist) non-sticky and non-plastic (wet)

Permeability and moisture conditions: permeability is high to very high, unless a shallow fragipan is present
bulkdensity is approximately 1.5 g/cm^3, porosity surface soil 40-50%, porosity subsoil 35-40%, moisture storage (pF 2.3 - pF 3.7) 7-15% by weight

Chemical properties: organic matter content of the A horizon generally does not exceed 1%, CEC (pH 8.2) is 20 to 80 mmol/kg soil, base saturation varies largely, pH(H_2O) ranges from 5.0 to 6.5

Mineralogy: predominantly quartz and feldspars;

Vegetation and land-use: (Brachystegia) bushed woodland; extensive grazing and browsing
To a lesser extent annual and semi-annual fieldcrops (maize, pulses, cassava) and perennial industrial crops (cashew)

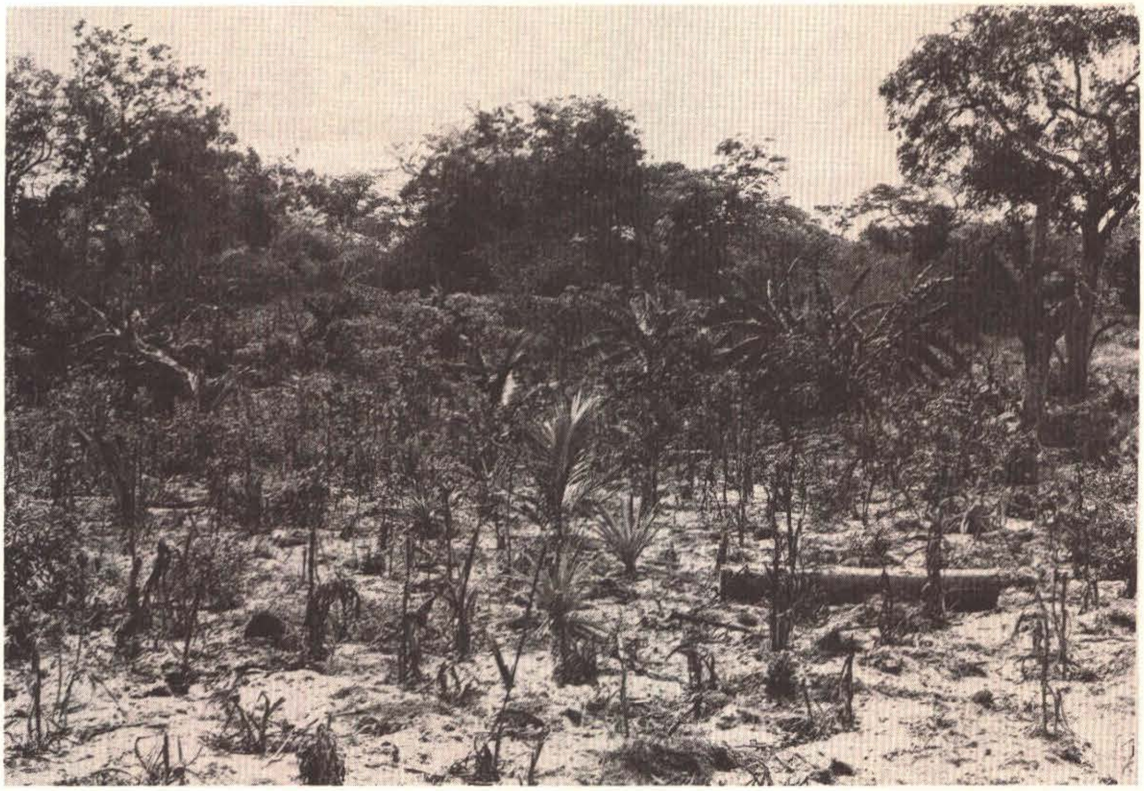


Fig. 23. Shifting cultivation with maize, banana and pineapple near Kwa Demu, about 16 km north-north-west of Kaloleni, February 1983. The fact that, even under the dry conditions of the northwestern part of the Kilifi Area, people try to grow cocospalms illustrates the popularity of the crop (photo H. Waaijenberg).

Similar soils: the soils of unit USKf show resemblance with the following sandy soils:
USs 1 (coarser textured), UE 1m1 (redder) UE 1m2, UE 2f, P2Em1 and P2Em2 (redder)

Map unit: USK1

Total area: 2280 ha
Soil classification:
FAO/Unesco (1974): ferric and chromic Luvisols, orthic Acrisols
Kenyan Concept: chromic Luvisols, orthic Acrisols
Soil Survey Staff (1975): oxic Paleustalfs, Paleustults, typic Haplustults
Brief map unit description: Well drained, deep to very deep, red to yellowish red, sandy clay loam to sandy clay, underlying 20-80 cm fine sand to sandy loam; ABC-profiles, thick B horizons, clear horizon boundaries, a moderate nutrient status and a moderate to high permeability
Representative soil profile(s): none
Environmental characteristics:
- Parent material: fine grained sandstones and siltstones
- Physiographic unit: Coastal Uplands (Kaloleni upland)
- Topography and dissection: gently undulating to rolling;
  - slope classes: mostly BC, locally AB or CD;
  - slightly to moderately dissected by minor valleys (VXA)
- Agro-climatic zone: IV

Soil characteristics:
- Drainage: well drained, locally moderately well drained
- Depth: deep to very deep (Mtsengo area)
  - moderately deep to deep (Ribe area)
- Colour: brown to dark brown surface soil; yellowish red to red subsoil; the higher the clay content, the redder the hue
- Texture: fine sand to sandy loam (20-80 cm), overlying sandy clay loam to sandy clay
- Structure: weak, medium, subangular to angular blocky; the argillic horizon is often porous massive, strongly coherent

Consistence: friable to firm (moist) slightly sticky and slightly plastic (wet)
Permeability: moderate to high: argillic horizon can act as a stagnant layer
Chemical properties: organic matter content of the A horizon is around 1%, CEC (pH 8.2) is 50 to 70 mmol/kg soil, base saturation varies considerably, pH(H_2O) is 5.5 to 6.5
Mineralogy: predominantly quartz and feldspars

Vegetation and land-use: (Brachystegia) bushed woodland; extensive grazing and browsing. Annual and semi-annual field crops: maize, pulses, cassava (to a lesser extent) and perennial industrial crops: coconut, cashew

Similar soils: UScl and UOcl are somewhat heavier textured, UOl is less red, UEl11 and UEl12 are older, P2El2 is less red and P2Ll2p is shallower; still, they show appreciable resemblance with USKl

Map unit: USKA 1

Total area: 3725 ha
Soil classification:
FAO/Unesco (1974): ferric and chromic Luvisols
Kenyan Concept: ferric Luvisols
Soil Survey Staff (1975): oxic Paleustalfs
Brief map unit description: Association of:
Well drained, deep to very deep, yellowish red,
- sandy loam to sandy clay loam, underlying 20-60 cm loamy fine sand (ass. 1)
- sandy clay to clay (ass. 2)

Representative soil profile: Profile 5 (198/3-43) for ass.1
Environmental characteristics:
Parent material: fine grained sandstones and siltstones
Physiographic unit: Coastal Uplands (Kaloleni upland)
Topography and dissection: flat to rolling;
slope classes: AB,AC,BD;
slightly dissected by minor valleys (VXA)
Agro-climatic zone: IV

Soil characteristics:
Drainage: well drained, locally moderately well drained (ass. 2 only)
Depth: deep to very deep, locally shallow to moderately deep (ass. 2 only slope class B
Colour: dark brown to dark yellowish brown surface soil; red to reddish yellow subsoil
Texture: ass.1 loamy fine sand (20-60 cm), overlying sandy loam to sandy clay loam
ass.2 sandy loam (20-60 cm), overlying sandy clay to clay
Structure: ass. 1: weak, medium, subangular blocky surface soil; porous massive, strongly coherent subsoil
ass.2: moderate, coarse, angular blocky; clay cutans
Consistence: ass. 1: friable to firm (moist); slightly sticky and slightly plastic (wet)
ass.2: firm (moist); slightly sticky and slightly plastic (wet)
Permeability and moisture conditions: permeability is high (ass.1) to moderate (ass.2); porosity is 40%, in the surface soil up to 50%, bulkdensity is approximately 1.6 g/cm^3, moisture storage (pF 2.3 - pF 3.7) is 15 to 20% (surface soil) and 6 to 8% (subsoil)
Chemical properties: organic matter content of the A horizon does not exceed 2%, CEC (pH 8.2) ranges from 30 (loamy sand) to 100 (sandy clay) mmol/kg soil, base saturation exceeds 50%, pH(H_2O) is 5.5 to 6.5
Mineralogy: predominantly quartz and feldspars
perennial industrial crops (mainly coconut);
Annual field crops (maize, cowpea and
Perennial industrial crops: mainly coconut

Vegetation and land-use: Grassed bushland and extensive grazing (to a lesser extent)

Map unit: USKA 2

Total area: 1745 ha
Soil classification:
FAO/Unesco (1974): gleyic Luvisols; gleyic Acrisols
Kenyan Concept: -do-

Soil Survey Staff (1975): aquic Paleustalfs; Paleustults
Brief map unit description: Association of:
imperfectly drained, deep to very deep, pale brown to light grey, mottled sandy clay loam to clay; in places underlying 20-40 cm fine sand to sandy loam (ass. 1)
- moderately well drained to imperfectly drained, deep, pale brown to gray, mottled sandy loam (ass. 2)

Representative soil profile: Profile 6 (198/1-11) of ass.2
Environmental characteristics:
Parent material: fine grained sandstones and siltstones
Physiographic unit: Coastal Uplands (Kaloleni upland)
Topography and dissection: gently undulating to undulating; slope class: BC; slightly dissected by minor valleys (VXA)
Agro-climatic zone: V
Soil characteristics:
Drainage: imperfectly drained, ass. 2 also moderately well drained
Depth: deep to very deep
Colour: light yellowish brown surface soil; pale brown to light grey subsoil
Texture: ass.1: sandy clay loam to clay, mostly underlying 20-60 cm fine sand to sandy loam
ass.2: sandy loam throughout
Structure: the upper 10 cm is often platy; moderate, medium, subangular blocky to strong, coarse, prismatic structures prevail in the different soil horizons; clay cutans in ass.1 and 2
Consistence: very firm (moist), slightly sticky and slightly plastic (wet) (ass.1) friable (moist), non-sticky and non-plastic (wet) (ass.2)
Permeability and moisture conditions: permeability is moderate, infiltration is hampered by surface sealing, which is a common feature of the soils of unit USKA 2; porosity is approximately 45% (surface soil) and 35% (subsoil), bulkdensity ranges between 1.5 and 1.7 g/cm^3, moisture storage (pF 2.3 - pF 3.7) is about 12% throughout in ass. 2; detailed data on associate 1 are not available
Chemical properties: organic matter content of the A horizon is about 2%, CEC (pH 8.2) is 100 mmol/kg soil, base saturation exceeds (ass.1)/ does not exceed (ass.2) 50%, pH(H_2O) is 5.0 to 6.0
Mineralogy: predominantly quartz and feldspars
Vegetation and land-use: (Brachystegia) bushed woodland; extensive grazing and browsing

Map unit: USs1

Total area: 9010 ha
Soil classification:
FAO/Unesco (1974): albic and luvic Arenosols
Kenyan Concept: -do-
Soil Survey Staff (1975): ustoxic Quartzipsamments, alfic Ustipsamments
Brief map unit description: excessively drained, very deep, pale brown to white, medium sand (albic Arenosol); in places with lamellae of clay accumulation (luvic Arenosol); AC-profiles with little horizon development, a low nutrient status and a high to very high permeability
Representative soil profile: Profile 7 (198/1-12)
Environmental characteristics:
Parent material: coarse grained sandstones and arkoses
Physiographic unit: Coastal Uplands (Kaloleni upland)
Topography and dissection: flat to undulating;
slope classes: AB, BC;
slightly dissected by minor valleys (VXA)
Agro-climatic zone: V (> 90%)
Soil characteristics:
Drainage: excessively drained on places somewhat excessively drained
Depth: very deep
Colour: dark brown, thin, surface soil; pale brown albic material overlies reddish yellow to white subsoil
Texture: (loamy) coarse to medium sand; lamellae in the subsoil can reach sandy loam texture
Structure: predominantly porous massive, weakly to moderately coherent; single grain and weak, coarse, subangular blocky structures occur to a lesser extent

Consistence: loose (moist); non-sticky and non-plastic (wet)
Permeability and moisture conditions: permeability is high to very high, porosity is 35-40%, bulkdensity 1.5 g/cm^3, moisture storage (pF 2.3 -pF 3.7) is approximately 5-7% throughout the profile
Chemical properties: organic matter content of the A horizon does not exceed 1%, CEC (pH 8.2) is below 10 mmol/kg soil, pH(H_2O) is 5.0 to 5.5
Mineralogy: predominantly quartz and feldspars
Vegetation and land-use: (Brachystegia) bushland; extensive grazing and browsing; annual and semi-annual field crops: (maize, cowpea, cassava) and perennial industrial crops: (cashew)
Similar soils: the following sandy soils show resemblance with those of unit USs 1, although all of them have a finer sandy texture: USKf, UElm2, UE2f, P2Eml and P2Em2; USs 2p diverges only because of soil depth

Map unit: USs2p

Total area: 1770 ha
Soil classification:
FAO/Unesco (1974): luvic and ferralic Arenosols
Kenyan Concept: -do-
Soil Survey Staff (1975): ustoxic Quartzipsamments, alfic Ustipsamments
Brief map unit description: somewhat excessively drained, moderately deep to very deep, reddish yellow to yellowish brown, coarse to medium sand to loamy medium sand (ferralic Arenosols); locally occurrence of lamellae in the subsoil (luvic Arenosols); A(B)C-profiles, weak horizon development, low nutrient status and a high permeability
Representative soil profile: Profile 8 (198/3-74)
Environmental characteristics:
Parent material: coarse grained sandstones and arkoses
Physiographic unit: Coastal Uplands (Kaloleni upland)
Topography and dissection: gently undulating to rolling;
slope classes: AB, AC, BC, BD;
slightly to moderately dissected.
Agro-climatic zone: III (approximately 40%)
V (approximately 60%)
Soil characteristics:
Drainage: somewhat excessively drained
Depth: deep to very deep, with scattered inclusions of shallow and moderately deep soils
Colour: dark yellowish brown surface soil; yellowish red to very pale brown subsoil
Texture: loamy coarse to medium sand; texture of the lamellae, if present, sandy loam
Structure: porous massive, weakly coherent to weak, fine, subangular blocky
Consistence: loose to friable (moist); non-sticky and non-plastic (wet)
Permeability and moisture conditions: permeability is high, porosity is 35 to 40%, bulkdensity is approximately 1.6 g/cm^3, moisture storage is only 7-8% throughout the profile (pF 2.3 - pF 3.7)
Chemical properties: organic matter content of the A horizon is in the vicinity of 1%; CEC (pH 8.2) ranges from 10 to 50 mmol/kg soil, base saturation varies largely, pH(H_2O) is 5.5 to 6.5
Mineralogy: predominantly quartz and feldspars
Vegetation and land-use: (Brachystegia) bushland; sacred Kaja Forests.
Annual and semi-annual field crops (maize, cowpea, cassava) and perennial industrial crops (cashew in the north, coconut in the south)
Similar soils: Apart from local shallowness, units USs1, USs3, UElml, UElm2, UE2f, P2Eml and P2Em2 show resemblance with unit USs2p.

Map unit: USs3

Total area: 5495 ha
Soil classification:
FAO/Unesco (1974): chromic and orthic Acrisols, cambic Arenosols
Kenyan Concept: orthic Acrisols, cambic Arenosols
Soil Survey Staff (1975): Paleustults, typic Ustropepts

Brief map unit description: Somewhat excessively drained, very deep, yellowish red to strong brown, coarse to medium sand to sandy loam; ABC-profiles with gradual and diffuse horizon boundaries, a low nutrient status and a high permeability
Representative soil profile: none
Environmental characteristics:
Parent material: coarse grained sandstones and arkoses
Physiographic unit: Coastal Uplands (Kaloleni upland)
Topography and dissection: flat to undulating; slope classes: AB, AC, BC; slightly dissected
Agro-climatic zone: IV (approx. 25%)
V (approx. 75%)
Range of profile characteristics:
Drainage: somewhat excessively drained (class 5)
Depth: very deep
Colour: strong brown to yellowish brown surface soil; red to reddish yellow subsoil
Texture: loamy coarse to medium sand, overlying sandy loam
Structure: porous massive, weakly coherent, to weak, medium subangular blocky; clay cutans
Consistence: loose to very friable (moist); slightly sticky and non-plastic (wet)
Permeability; high
Chemical properties: organic matter content of the A horizon does not exceed 1%; CEC (pH 8.2) is approximately 10 to 20 mmol/kg soil, pH(H_2O) is 5.5
Mineralogy: predominantly quartz and feldspars
Vegetation and land-use: (Brachystegia) bushland; extensive grazing
Annual and semi-annual field crops (maize, cowpea, cassava) and perennial industrial crops (1. cashew, 2. coconut)
Similar soils: soils of unit USs2p (apart from shallowness) UE2f, P2Em3 and P2Em4 show resemblance

Map unit: US1p

Total area: 350 ha
Soil classification:
FAO/Unesco (1974): gleyic, chromic and orthic Luvisols, partly lithic phase
Kenyan Concept: -do-
Soil Survey Staff (1975): rhodic Paleustalfs, (aqu)ultic and lithic Haplustalfs
Brief map unit description: moderately well drained, moderately deep to deep, reddish brown to yellowish brown, sandy loam to sandy clay, underlying 20-40 cm medium sand to loamy medium sand; in places shallow and rocky; ABC-profiles, gradual horizon boundaries, low nutrient status and high permeability
Representative soil profile: 3-49
Environmental characteristics:
Parent material: coarse grained sandstones and arkoses
Physiographic unit: Coastal Uplands (Kaloleni Uplands)
Topography and dissection: flat to undulating slope calss(es): AC, slightly dissected
Agro-climatic zone: IV
Soil characteristics:
Drainage: moderately well drained, locally imperfectly drained
Depth: moderately deep to deep
Colour: dark reddish brown to dark yellowish brown surface soil; red (moderately a well drained) to mottled, light brownish grey (imperfectly drained) subsoil
Texture: medium to fine sand to sandy loam, overlying sandy loam to sandy clay
Structure: moderate, coarse, subangular blocky (surface soil) to angular blocky (subsoil)
Consistence: friable to firm (moist); slightly sticky and slightly plastic (wet)
Permeability: generally high, but the lithic and aquultic Haplustalfs show significantly lower values
Chemical properties: organic matter content of the A horizon is approximately 1.5%; CEC (pH 8.2) ranges from 60 to 100 mmol/kg soil, base saturation generally exceeds 50%, pH(H_2O) ranges from 5.5 to 6.0
Vegetation and land-use: Remnants of sacred Kaja forest (semi-deciduous tropical lowland forest); annual and semi-annual field crops (maize, cowpea, cassava) and perennial industrial crops (cashew, coconut) both to a limited extent

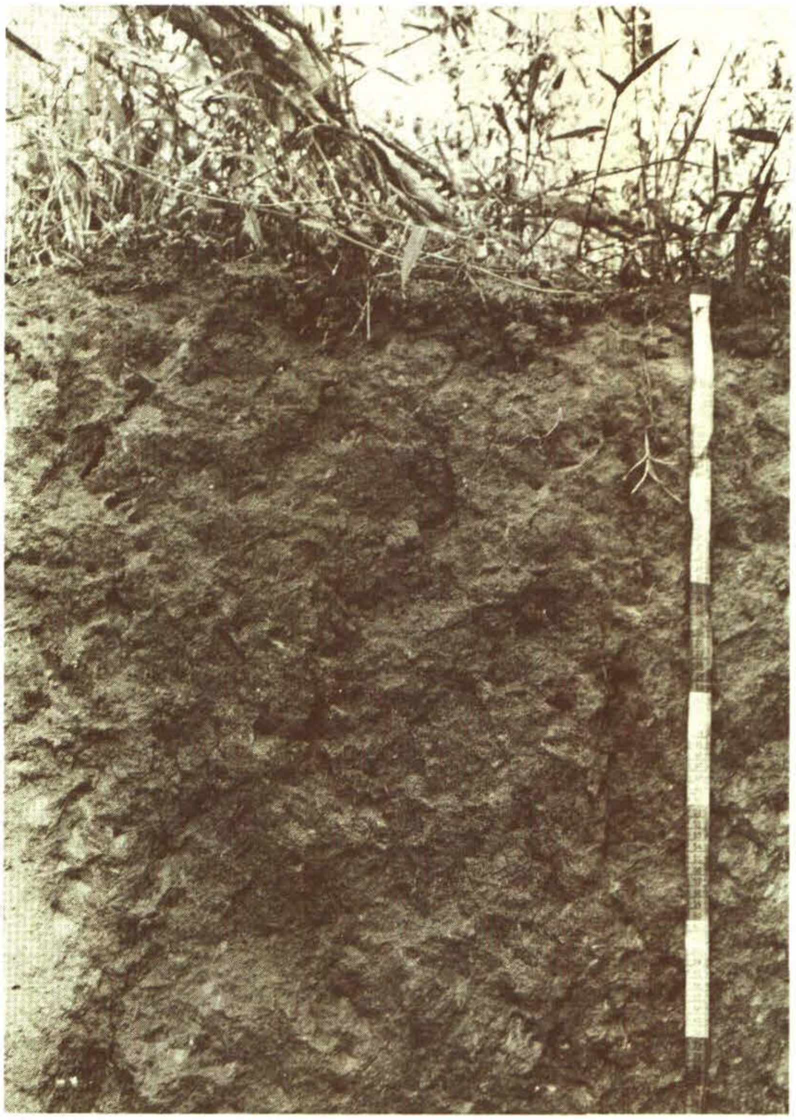


Fig. 24. Soil unit UScl (chromic Luvisols and orthic Acrisols) in Chilulu, about 3.5 km north-north-east of Kaloleni (photo H. Waaijenberg).

Map unit: UScl

Total area: 14010 ha

Soil classification:

FAO/Unesco (1974): ferric and chromic Luvisols; humic, ferric and orthic Acrisols

Kenyan Concept: chromic Luvisols, humic and orthic Acrisols

Soil Survey Staff (1975): oxic and rhodic Paleustalfs, Paleustults, oxic Haplustalfs, typic and oxic Haplustults

Brief map unit description: well drained, deep to very deep, red to yellowish red, sandy clay loam to clay; in places underlying 20-80 cm medium sand to sandy loam; ABC-profiles, BC-profiles in case of topsoil truncation, clear horizon boundaries, low nutrient status and moderate to high permeability

Representative soil profile: Profile 10 (198/3-40) and Profile 11 (198/3-120)

Environmental characteristics:

Parent material: coarse grained sandstones and arkoses

Physiographic unit: Coastal Uplands (Kaloleni upland)

Topography and dissection: varying from flat to hilly, in places even steeply dissected; slope classes: A,B,C,D,E, in various combinations; degree of dissection is quite variable

Agro-climatic zone: III (approx. 20%)
IV (approx. 60%)
V (approx. 20%)

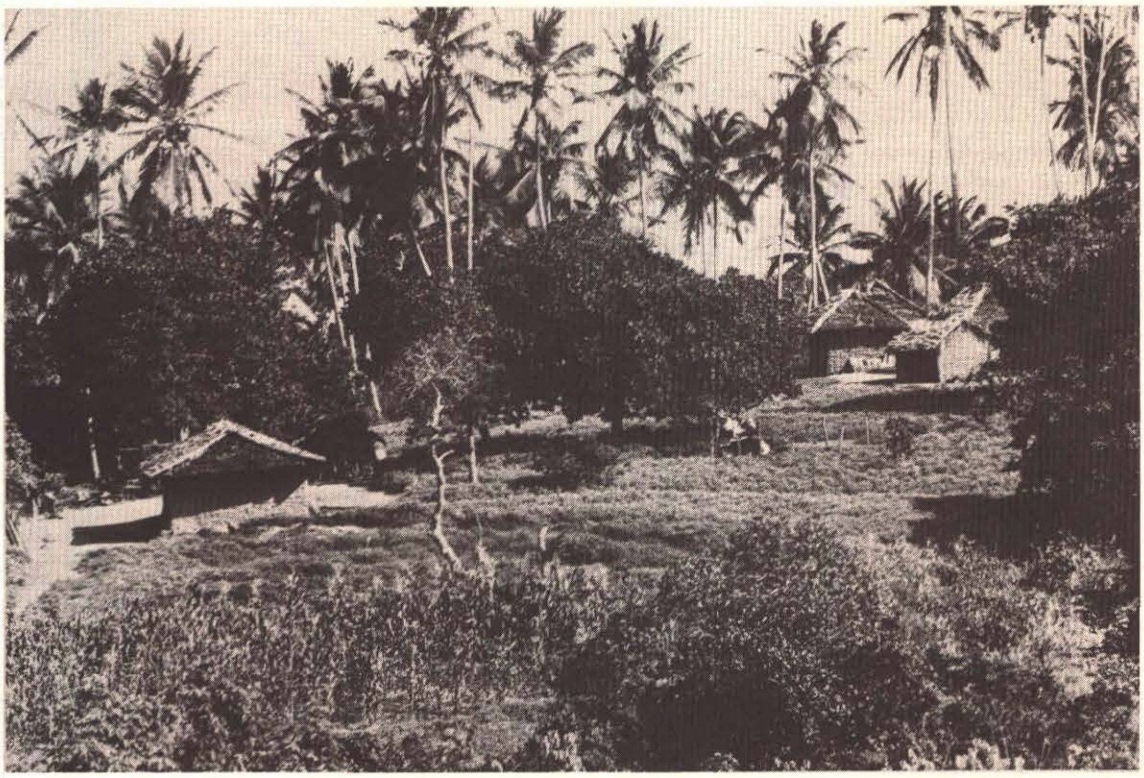


Fig. 25. As on soil units ULc1 and ULc2 the land use on soil unit USc1 is determined by rainfall. In Mikiryani, cocospalm, cashew, maize and grazed fallow occur together. Towards the wetter south cocospalm becomes dominant, towards the drier north and west cashew, grazing and bush exploitation increase in importance. Mikiryani, about 7 km nort-north-east of Kaloleni, July 1984 (photo H. Waaijenberg).

Soil characteristics:
- Drainage: well drained
- Depth: mostly very deep; locally shallow, particularly at steep sites near Mazeras
- Colour: yellowish red to dark brown surface soil; dark red to reddish yellow subsoil
- Texture: medium sand to sandy loam surface soil, 20-80 cm thick, overlies sandy clay loam to clay; in case of topsoil truncation the heavier textures reach the surface
- Structure: generally weak, medium, subangular to angular blocky; in places moderate, coarse, prismatic subsoils; clay cutans
- Consistence: firm (moist); slightly sticky and slightly plastic (wet)
- Permeability and moisture conditions: permeability is moderate to high, bulk density ranges from 1.4 to 1.6, porosity varies from 50% (surface soil) to 35% (subsoil), moisture storage shows considerable variation: 5%-14%
- Chemical properties: organic matter content of the A horizon is 0.8-1.5%, CEC (pH 8.2) ranges from 30 (loamy surface soil) to 140 (sandy clay subsoil) mmol/kg soil, base saturation varies largely, Mg often exceeds Ca at the exchange complex
- Mineralogy: predominantly kaolinitic clay minerals, but also 2:1- clay minerals, that have been derived from arkosic sandstones
- Additional remarks: The thickness of the sandy surface soil shows considerable variation over short distances

Vegetation and land-use: (Brachystegia) bushed woodland
(particularly in the northern parts of the area): intensive and extensive grazing
Annual and semi-annual field crops: maize, cowpea, and cassava (often intercropped);
perennial industrial crops: 1 coconut
2 cashew
(particularly in the southern parts of the area):
perennial fruits: mango, citrus

Similar soils: the soils of unit USc1 show appreciable ressemblance with those of units USK1, UOc1, UE111, UE112, UE21, P2E11, P2E12 (apart from colour) and P2L12p; truncated soils show resemblance with the soils of units ULc1 and ULc2

Map unit: USc2

Total area: 45 ha
Soil classification:
FAO/Unesco (1974): gleyic and orthic Luvisols, gleyic Phaeozems
Kenyan Concept: -do-
Soil Survey Staff (1975): (aqu)ultic Paleustalfs, aquic Argiustolls
Brief map unit description: imperfectly drained, deep to very deep, dark yellowish brown to dark grey, sandy clay to clay; ABC-profiles with clear horizons, low nutrient status and low permeability
Representative soil profile: none
Environmental characteristics:
Parent material: coarse grained sandstones and arkoses
Physiographic unit: Coastal Uplands (Kaloleni upland)
Topography: gently undulating to rolling;
slope classes: BD (Mazeras)
D (Kinagoni Hill)
Agro-climatic zone: III (approx. 60%)
IV (approx. 40%)
Soil characteristics:
Drainage: imperfectly drained
Depth: deep to very deep
Colour: dark brown surface soil; dark yellowish brown to dark grey subsoil
Texture: sandy loam to sandy clay loam, overlying sandy clay
Structure: moderate, coarse, angular blocky; clay cutans
Consistence: firm (moist); sticky and plastic (wet)
Permeability: low;
Chemical properties: organic matter content of the A horizon is 1.5-3.0%, CEC (pH 8.2) is 60 to 110 mmol/kg soil, base saturation exceeds 50%, pH(H_2O) is 5.5-6.0
Mineralogy: mainly kaolinitic clay minerals, but also 2:1-clay minerals derived from arkosic sandstones
Vegetation and land-use: Bushed grassland; extensive grazing perennial industrial crops (coconut) and perennial fruits (mango)

Map unit: ULc1 (Fig. 26, 27)

Total area: 8610 ha
Soil classification:
FAO/Unesco (1974): dystric Nitosols, ferric Acrisols, chromic Luvisols; in places lithic phase
Kenyan Concept: dystric Nitosols, chromic Acrisols, chromic Luvisols; in places lithic phase
Soil Survey Staff (1975): (rhodic-oxic) Paleustults, typic Rhodustults, typic and lithic Rhodustalfs
Brief map unit description: well drained, deep to very deep, red to reddish brown, sandy clay to clay; in places rocky; ABC-profiles, gradual horizon boundaries, mostly thick B-horizon, showing shiny ped faces; moderate nutrient status, high permeability
Representative soil profile: Profile 12 (198/3-8)
Environmental characteristics:
Parent material: limestones
Physiographic unit: Coastal Uplands (Dzitsoni upland)
Topography and dissection: flat to rolling;
hilly to steeply dissected (near Galanema);
slope classes: combinations of A,B,C,D; south of Galanema: EF;
slightly to moderately dissected; south of Galanema: very dissected
Agro-climatic zone: III (approx. 35%)
IV (approx. 65%)
Soil characteristics:
Drainage: well drained
Depth: generally very deep, in steep places shallow
Colour: dark red to brown surface soil; dusky red to dark reddish brown subsoil
Texture: sandy clay to clay
Structure: crumb to moderate, medium, subangular (surface soil) to angular blocky (subsoil); clay cutans with shiny pedfaces locally

Fig. 26. Soil unit ULc1 (dystric Nitosols and chromic* Acrisols) in Mbuyuni, about 7 km east of Kaloleni. Note the porosity and the cassava tubers (photo H. Waaijenberg).

Consistence: friable (moist); (slightly) sticky and plastic (wet)

Permeability and moisture conditions: permeability is high; porosity of the surface soil can be as high as 60%, subsoil 50%; bulkdensity is approximately 1.5, moisture storage (pF 2.3 - pF 3.7) is 10-15%

Chemical properties: organic matter content of the A horizon is 1-2,% CEC (pH 7) ranges from 50 to 120 mmol/kg soil, base saturation can be higher as well as lower than 50%, remarkably high Mn-values occur (more than 10 mmol/kg soil), pH (H_2O) is 5.5 to 6.5

Mineralogy: predominantly kaolinitic clay minerals

Inclusion: Rendzinas occur in the ULc1-area south of Mazeras

Additional remarks: Soil depth can vary significantly within short distances due to irregular karstic features

Vegetation and land-use: (Brachystegia) bushland; extensive grazing. Annual and semi-annual field crops (maize, pulses, cassava, often intercropped) perennial industrial crops (cashew (north) coconut (south)),and perennial fruits (mango, citrus)

Similar soils: the soils of ULc1 show resemblance with the soil of unit ULc2 and with truncated versions of the soils of USc1, and UE111

Fig. 27. Wherever rainfall is high enough, cocospalm is the major tree crop on soil units ULc1 and ULc2; under drier conditions, cashew. Main annual crops are maize and cassava. Mbuyuni, November 1983 (photo H. Waaijenberg).

Map unit: ULc2

Total area: 2070 ha
Soil classification:
FAO/Unesco (1974): ferric Acrisols, dystric Nitosols, ferric Luvisols
Kenyan Concept: FERRAL-chromic Acrisols, dystric Nitosols, FERRAL-chromic Luvisols
Soil Survey Staff (1975): (rhodic-oxic) Paleustults, oxic Haplustults, oxic Rhodustalfs
Brief map unit description: well drained, very deep, red to dark reddish brown, clay loam to clay; ABC-profiles, gradual horizon boundaries, mostly thick B-horizons, in places showing shiny ped faces; moderate nutrient status, high permeability
Representative soil profile: Profile 13 (198/1-47)
Environmental characteristics:
- Parent material: limestones
- Physiographis unit: Coastal Uplands (Dzitsoni upland)
- Topography and dissection: flat to undulating; slope classes: AB,B,BC; slightly dissect
- Agro-climatic zone: III (approximately 20%)
  IV (approximately 80%)

Soil characteristics:
- Drainage: well drained
- Depth: very deep
- Colour: dark red to brown surface soil; dusky red to reddish brown subsoil
- Texture: clay loam to clay; sometimes with sandy loam surface soil
- Structure: crumb to moderate, medium, subangular blocky (surface soil) to angular blocky (subsoil); clay cutans with here and there shiny pedfaces
- Consistence: friable (moist); (slightly) sticky and (slightly) plastic (wet)
- Permeability and moisture conditions: permeability is high; porosity is 45 to 50%, grading to 55% in the surface soil; bulk density is approximately 1.4 g/cm^3, moisture storage (pF 2.3-pF 3.7) is 12-15%
- Chemical properties: organic matter content of the A horizon is 0.8-1.5%, CEC (pH 7) ranges from 50 to 120 mmol/kg soil, base saturation can be higher as well as lower than 50%, remarkably high Mn-values occur (more than 10 mmol/kg soil), pH(H_2O) is 5.0 to 6.0

Mineralogy: predominantly kaolinitic clay minerals
Vegetation and land-use: (Brachystegia) bushland; extensive grazing
Annual and semi-annual field crops (maize, pulses and cassava, often intercropped) perennial industrial crops (cashew, coconut) and perennial fruits (mango, citrus)
Similar soils: the soils of ULc2 show resemblance with those of unit ULc1 and with truncated versions of the soils of USc1, and UE111

Map unit: UOf

Total area: 1850 ha
Soil classification:
FAO/Unesco (1974): luvic and ferralic Arenosols, orthic Acrisols
Kenyan Concept: -do-
Soil Survey Staff (1975): alfic Ustipsamments, ustoxic Quartzipsamments, (arenic) Paleustults
Brief map unit description: somewhat excessively drained to well drained, deep to very deep, very pale brown to light yellowish brown, fine to very fine sand and loamy fine to very fine sand, 80 to 120 cm thick, overlying more than 70 cm sandy loam to sandy clay loam; A(B)C-profiles, the B-horizon, if present, being weakly developed; nutrient status is low, permeability generally high
Representative soil profile(s): Profile 14 (198/3-62)
Environmental characteristics:
Parent material: unconsolidated fine sandy and clayey deposits
Physiographic unit: Coastal Uplands (Rabai Uplands)
Topography and dissection: flat to gently undulating, sometimes undulating slope class(es): AB, sometimes BC not to slightly dissected
Agro-climatic zone: IV
Soil characteristics:
Drainage: somewhat excessively drained to well drained
Depth: deep to very deep
Colour: very pale brown to brown surface soil; brownish yellow to yellowish brown subsoil
Texture: (very) fine sand and loamy (very) fine sand, overlying sandy loam to clay loam, mostly in between 80 and 120 cm.
Structure: single grain surface soil; porous massive, weakly coherent subsoil
Consistence: very friable to friable (moist); slightly sticky and non plastic (wet)
Permeability and moisture conditions: permeability is high; porosity can reach values over 60%, bulkdensity is approximately 1.6 g/cm^3, moisture availability (pF 2.3-pF 3.7) ranges from 8 (Arenosols) to 16% (Acrisols)
Chemical properties: organic matter content of the A horizon does not exceed 1%; CEC (pH 8.2) is 20 to 60 mmol/kg soil, base saturation varies largely, $pH(H_2O)$ is 6.0 to 6.5
Mineralogy: predominantly quartz; feldspars and kaolinitic clay minerals occur to a lesser extent
Inclusion: a fragipan, sometimes mottled, occurs locally in the northern parts of UOf; if so, permeability is low and soil structure is massive, strongly coherent
Vegetation and land-use: Bushed grassland; extensive grazing; annual and semi-annual field crops (maize, cassava) and perennial industrial crops (mainly coconut)
Similar soils: all soils that resemble those of unit UOf contain sands that are coarser than 'very fine', i.e.: USKf, UElm2, UE2f, P2Em1, P2Em3, P2Em4

Map unit: UOl

Total area: 2965
Soil classification:
FAO/Unesco (1974): ferric and orthic Luvisols, humic Acrisols
Kenyan Concept: -do-
Soil Survey Staff (1975): oxic and udic Paleustalfs and Haplustalfs; epiaquic Haplustults
Brief map unit description: moderately well drained, deep to very deep, light yellowish brown, locally mottled, sandy clay loam to sandy clay; in places underlying 20-80 cm very fine sand to loamy very fine sand; ABC-profiles, clear horizon boundaries, low to moderate nutrient status and permeability
Representative soil profile: none
Environmental characteristics:

Parent material: unconsolidated fine sandy and clayey deposits
Physiographic unit: Coastal Uplands (Rabai upland)
Topography and dissection: flat to undulating; slope classes: AB, B, AC; slightly dissected
Agro-climatic zone: IV (more than 90%)

Soil characteristics:
Drainage: moderately well drained, occasionally imperfectly drained (locally saline-alkali in subsoil)
Depth: deep to very deep
Colour: brown to very dark greyish brown surface soil; light yellowish brown to olive brown subsoil
Texture: the surface soil consists of (very) fine sand to loamy (very) fine sand and overlies sandy clay loam to sandy clay
Structure: moderate to strong, coarse angular blocky to coarse prismatic, in places covered by a weak, medium, subangular blocky, surface soil; clay cutans
Consistence: firm (moist); slightly sticky and (slightly) plastic (wet)
Permeability: low to moderate
Chemical properties: organic matter content of the A horizon is 1.0-1.5%, CEC (pH 8.2) ranges from 100 to 160 mmol/kg soil, base saturation is mostly above 50%, pH(H_2O) is 6.0 to 6.5, Mg often exceeds Ca at the exchange complex; locally ESP exceeds 15 in the subsoil; pH(H_2O)-values of 8.0 and higher are not uncommon here
Mineralogy: surface soil: predominantly quartz, subsoil: 1:1- as well as 2:1- clay minerals occur

Vegetation and land-use: Herbland and grassland; extensive grazing
Annual field crops (upland rice) and perennial industrial crops (coconut, along intermittent streams in the broad valleybottoms)

Similar soils: the soil of the following units resemble those of unit UOl: USKl, P1Ol, P2E13

Map unit: UOcl

Total area: 3305 ha
Soil classification:
FAO/Unesco (1974): humic and orthic Acrisols, ferric Luvisols
Kenyan Concept: humic and orthic Acrisols, chromic Luvisols
Soil Survey Staff (1975): epiaquic and typic Haplustults, oxic Rhodustalfs
Brief map unit description: well drained, deep to very deep, yellowish red to yellowish, clay loam to clay, underlying 10 to 60 cm (sandy) loam; ABC-profiles, clear horizon boundaries, moderate nutrient status and permeability
Representative soil profile: Profile 15 (198/3-70)
Environmental characteristics:
Parent material: unconsolidated fine sandy and clayey deposits
Physiographic unit: Coastal Uplands (Rabai upland)
Topography and dissection: gently undulating to undulating, near Mazeras flat to gently undulating; slope classes: mostly BC, near Mazeras AB; slightly dissected
Agro-climatic zone: IV (more than 90%)

Soil characteristics:
Drainage: well drained, locally moderately well drained
Depth: very deep; locally shallow to moderately deep (near Kombeni river)
Colour: yellowish brown to very dark greyish brown surface soil; yellowish red to yellowish brown subsoil
Texture: 10 to 60 cm loamy (very) fine sand to loam overlies clay loam to clay
Structure: moderate, medium, angular blocky, to coarse prismatic; moderate, fine, subangular blocky surface soil
Consistence: firm (moist); sticky and plastic (wet); clay cutans
Permeability: moderate
Chemical properties: organic matter content of the A horizon is in the vicinity of 1%; CEC (pH 8.2) is 70 to 140 mmol/kg soil, base saturation varies largely, Mg often exceeds Ca at the exchange complex, pH(H_2O) is 5.5 - 6.0
Minerology: surface soil: predominantly quartz; subsoil: 1:1-clay minerals and 2:1-clay minerals can both predominate

Vegetation and land-use: Grassland; extensive grazing. Annual and semi-annual field crops (maize, cassava) and perennial industrial crops (coconut)

Similar soils: the soils of unit UOcl show similarity with those of unit USKl, UScl, and USlll

Map unit: UOc2p

Total area: 10945 ha
Soil classification:
FAO/Unesco (1974): gleyic, vertic and ferric Luvisols, partly sodic phase, gleyic Solonetz
Kenyan Concept: verti-gleyic, gleyic and ferric Luvisols, partly sodic phase, gleyic Solonetz
Soil Survey Staff (1975): aquic and udertic Paleustalfs and Haplustalfs, oxic Haplustalfs, aquic Natrustalfs
Brief map unit description: moderately well drained to imperfectly drained, moderately deep to very deep, light yellowish brown to olive grey, mostly mottled, sandy clay loam to clay; ABC-profiles, clear horizon boundaries, moderate nutrient availability, high ESP, low permeability
Representative soil profile: Profile 16 (198/1-43)
Environmental characteristics:
Parent material: unconsolidated fine sandy and clayey deposits
Physiographic unit: Coastal Uplands (Rabai upland)
Topography and dissection: flat to rolling;
slope classes: AB, BC (Rabai area)
BC, CD (Ganze area); slightly dissected
Agro-climatic zone: IV (approximately 70%)
V (approximately 30%)
Soil characteristics:
Drainage: moderately well drained to imperfectly drained (Saline-alkali in places)
Depth: moderately deep to very deep
Colour: yellowish brown to dark greyish brown surface soil; brownish yellow and pale brown to light olive grey subsoil
Texture: sandy clay loam to clay, in places underlying loamy fine sand to sandy loam; the thickness of this coarse-textured surface soil varies largely
Structure: moderate to strong, coarse, angular blocky to prismatic; clay cutans
Consistence: very firm (moist), sticky and plastic (wet)
Permeability and moisture conditions: permeability of the dry soil is initially high, but will decrease rapidly upon sustained wetting; porosity varies from 35 to 50%, bulkdensity ranges from 1.2 to 1.8 (subsoil) g/cm^3; moisture storage (pF 2.3-pF 3.7) ranges from 7% (subsoil) to 13% (surface soil)
Chemical properties: organic matter content of the A horizon is 0.8-1.6%, CEC (pH 7) ranges from 30 (sandy surface soil) to 200 mmol/kg soil, base saturation mostly exceeds 50%, Mg very often exceeds Ca at the exchange complex, pH(H_2O) varies between 5.5 and 7.0; in places ESP exceeds 15
Clay Mineralogy: 1:1- as well as 2:1- clay minerals occur
Vegetation and land-use: Grassland, grassed bushland; intensive as well as extensive grazing; scattered cultivated fields (maize, cassava, pulses)
Similar soils: unit UOc2p shows resemblance with unit P101

Map unit: UT1c

Total area: 225 ha
Soil classification:
FAO/Unesco (1974): vertic and orthic Luvisols, partly lithic phase
Kenyan Concept: -do-
Soil Survey Staff (1975): udertic Paleustalfs, lithic and vertic Haplustalfs
Brief map unit description: well drained to moderately well drained, shallow to deep, dark reddish brown to yellowish brown, cracking clay, in places gravelly; ABC-profiles, clear horizon boundaries moderate nutrient status and low to moderate permeability
Representative soil profile(s): none
Environmental characteristics:
Parent material: shales
Physiographic unit: Coastal Uplands (Rabai upland)
Topography and dissection: gently undulating to undulating; slope class: BC; slightly dissected
Agro-climatic zone: IV
Soil characteristics:
Drainage: well drained to moderately well drained
Depth: varying

Colour: dark greyish brown surface soil; dark reddish brown to light greyish brown subsoil
Texture: clay
Structure: moderate, coarse, angular blocky to strong, coarse prismatic. Clay cutans.
Consistence: very firm (moist); sticky and plastic (wet)
Permeability: initially high along large cracks, but diminishing rapidly upon sustained wetting and soil swelling
Chemical properties: no data available
Mineralogy: probably dominated by 2:1-clay minerals

Vegetation and land-use: Bushed grassland; intensive and extensive grazing
Similar soils: UT1c shows resemblance with the other UT-units; they all consist of cracking clay soils

Map unit: UT2clp (Fig. 28, 29)

Total area: 13720 ha
Soil classification:
FAO/Unesco (1974): gleyic and vertic Cambisols, chromic Vertisols
Kenyan Concept: -do-

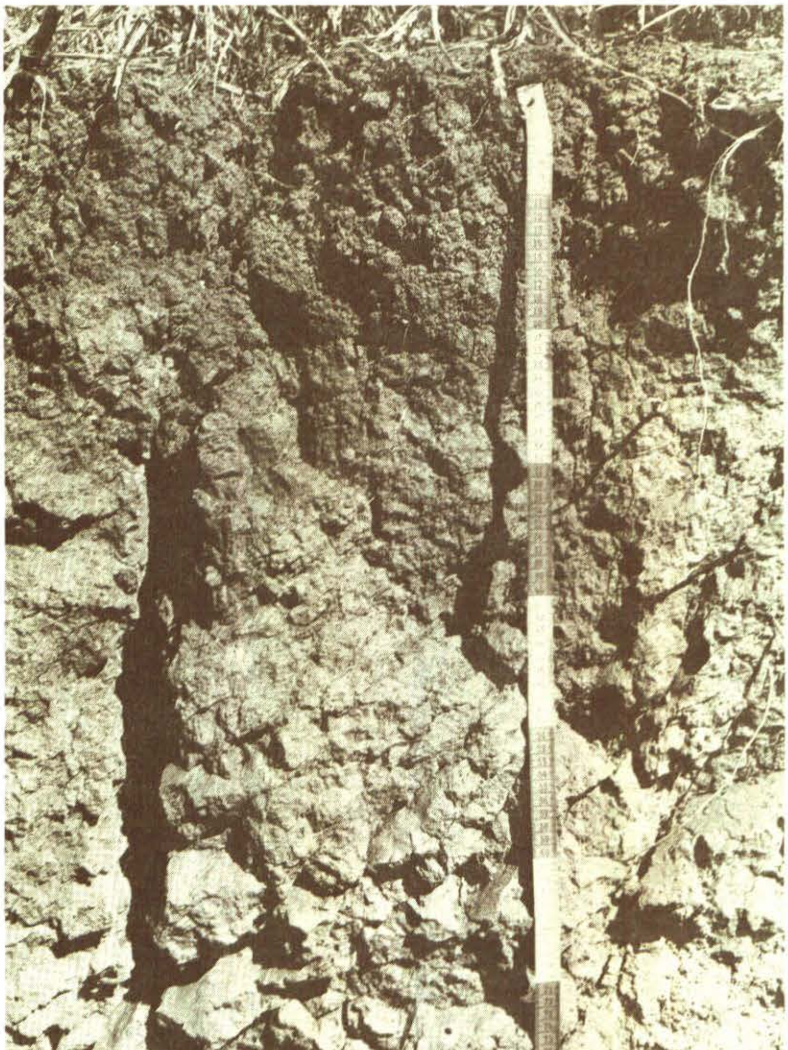


Fig. 28. Soil unit UT2clp (gleyic and vertic Cambisols) east of Mbuyuni, about 8.5 km east of Kaloleni. Note the slickensides and large cracks. The top-soil is self-mulching (photo H. Waaijenberg).

Fig. 29. Maize is the dominant crop on soils developed on shales of the Mtomkuu Formation. Tree crops thrive only on hilltops with sandier covers and on well drained valley bottoms. Lutsangani, about 19 km south-west of Kilifi, July 1985 (photo H. Waaijenberg).

Soil Survey Staff (1975): typic vertic Ustropepts, typic paleustollic and udorthentic Chromusterts

Brief map unit description: well drained to moderately well drained, moderately deep to deep, yellowish red to yellowish brown, cracking clay; in places strongly mottled and/or calcareous; A(B)C-profiles, clear horizon boundaries, high nutrient availability, variable permeability

Representative soil profile: Profile 17 (198/1-9)

Environmental characteristics:

- Parent material: shales
- Physiographic unit: Coastal Uplands (Lutsangani upland)
- Topography and dissection: mostly undulating but ranging from flat to rolling slope classes: mostly BC and CD, occasionally AB and BD; moderately to very dissected
- Agro-climatic zone: III (90%)

Soil characteristics:

- Drainage: moderately well drained; in places well drained or imperfectly drained
- Depth: moderately deep to deep
- Colour: reddish brown to very dark greyish brown surface soil; yellowish red to pale olive subsoil
- Texture: clay, occasionally underlying loam or clay loam surface soil
- Structure: predominantly moderate, coarse, subangular blocky surface soil; strong, coarse, angular blocky to prismatic subsoil. slickensides
- Consistence: firm to very firm (moist); sticky and plastic (wet)
- Permeability and moisture conditions: permeability is initially high along large cracks, but diminish as rapidly upon sustained wetting and soil swelling; porosity is 45-50%, bulkdensity 1.5-1.6 g/cm^3, moisture storage (pF 2.3-pF 3.7) is 7-12%
- Chemical properties: organic matter content of the A horizon ranges between 1 and 3%, CEC (pH 8.2) is 200 to 400 mmol/kg soil, base saturation exceeds 50%, pH (H_2O) is 6.0 to 7.0; ESP is in between 6 and 15 in most subsoils; in places strong HCl-effervescence bears evidence of free carbonates: pH(H_2O) can be 8.5 at these sites
- Clay mineralogy: predominantly montmorillonitic clay minerals

Additional remarks: Determination of pF-values of these cracking clay soils is hardly feasible

Vegetation and land-use:

Grassed bushland and extensive grazing of minor importance

Annual field crops: maize and maize/cowpea or maize/beans intercroppings (mostly mechanical soil tillage); locally upland rice

Similar soils: soils of UT2c1p shows resemblance with the other UT-units and with the soils of HSKC, P2lcp, AAc, VXC, P2Ec, P2WA and BAc2; they all consist of cracking clays

Map unit: UT2c2p

Total area: 2120 ha

Soil classification:

FAO/Unesco (1974): chromic Vertisols and vertic Cambisols

Kenyan Concept: -do-

Soil Survey Staff (1975): paleustollic and udic Chromusterts, vertic Ustropepts

Brief map unit description: well drained to moderately well drained, moderately deep to deep, light olive brown to olive, strongly calcareous, cracking clay; mostly AC-profiles, clear horizon boundaries, high nutrient availability and variable permeability

Representative soil profile: Profile 18 (198/2-39)

Environmental characteristics:

Parent material: shales

Physiographic unit: Coastal Uplands (Lutsangani upland)

Topography and dissection: gently undulating to undulating slope classes: B,BC; moderately to strongly dissected

Agro-climatic zone: III (approximately 25%)
VI (approximately 75%)

Range of profile characteristics:

Drainage: moderately well drained, sometimes well drained

Depth: moderately deep to deep, occasionally shallow

Colour: dark reddish brown to dark brown surface soil; dark yellowish brown to pale olive subsoil

Texture: (locally gravelly or stony clay

Structure: crumb (self-mulching) surface soil; strong, medium to coarse angular blocky to strong, coarse prismatic subsoil; slickensides

Consistence: firm to very firm (moist); sticky and plastic (wet)

Permeability and moisture conditions: permeability is initially high along large cracks, but diminishes rapidly upon sustained wetting and soil swelling; porosity is 40-50%, bulkdensity 1.5-1.7 g/cm^3 moisture storage (pF 2.3-pF 3-7) is 4-10%

Chemical properties: organic matter content of the A horizon ranges between 1.5 and 3%, CEC (pH 8.2) is 250 to 400 mmol/kg soil, base saturation exceeds 50%, pH(H_2O) is 6.5-7.0, in most places strong; HCl-effervescence bears evidence of free carbonates: pH(H_2O) can be 8.5 at these sites

Mineralogy: predominantly montmorillonitic clay minerals

Additional remarks: Determination of pF-values of these cracking clay soils is hardly feasible

Vegetation and land-use: Grassed bushland; extensive grazing; annual field crops (maize, cowpea)

Similar soils: soils of UT2c2p shows resemblance with the soils of the other UT-units and with the soils of HSKC, P2Lcp, AAc, VXC, P2WA, P2Ec, and BAc2; they all consist of cracking clays

Map unit: UT2c3P

Total area: 775 ha

Soil classification:

FAO/Unesco (1974): chromic Vertisols, partly lithic phase

Kenyan Concept: -do-

Soil Survey Staff (1975): udorthentic Chromusterts, lithic vertic Ustropepts

Brief map unit description: moderately well drained, shallow to moderately deep, dark reddish brown to light yellowish brown, cracking clay; AC- and ACR-profiles, gradual to

clear horizon boundaries, high nutrient status and variable permeability
Representative soil profiles: none
Environmental characteristics:
Parent material: shales
Physiographic unit: Coastal Uplands (Lutsangani upland)
Topography and dissection: flat to undulating slope classes: AB, BC; moderately dissected
Agro-climatic zone: IV
Soil characteristics:
Drainage: moderately well drained
Depth: shallow to moderately deep, locally deep
Colour: dark reddish brown to very dark greyish brown surface soil; light yellowish brown to olive grey subsoil
Texture: clay
Structure: strong, coarse, angular blocky, falling apart to medium-sized aggregates in the surface soil; subsoil can be strong, coarse, prismatic; slickensides
Consistence: very firm (moist); very sticky and plastic (wet)
Permeability and moisture conditions: permeability is initially high; upon swelling water can only slowly penetrate into the soil; porosity is 40-50%, bulkdensity 1.4-1.6 g/cm^3, moisture storage (pF 2.3-pF 3.7) is 4-10%
Chemical properties: organic matter content of the A horizon ranges between 1.5 and 3%, CEC (pH 8.2) is 250 to 400 mmol/kg soil, base saturation varies largely, pH(H_2O) is 6.0-6.5, values of 8.5 are reached in case free carbonates prevail
Clay mineralogy: predominantly montmorillonitic clay minerals
Additional remarks: Determination of pF-values of these cracking clay soils is hardly feasible
Vegetation and land-use:
Grassed bushland; extensive grazing; annual field crops (maize, cowpea)
Similar soils: Soils of UT2c3P shows resemblance with the soils of the other UT-units and with the soils of HSKC, P2Lcp, AAc, VXC, P2WA, P2Ec, and BAc2; they all consist of cracking clays

Map unit: UT2c4

Total area: 1395 ha
Soil classification:
FAO/Unesco (1974): chromic Vertisols
Kenyan Concept: -do-
Soil Survey Staff (1975): udic and udorthentic Chromusterts
Brief map unit description: moderately well drained to poorly drained, deep, greyish brown to olive, cracking clay; in places mottled and/or calcareous; AC-profiles, clear horizon boundaries, presumably moderate to high nutrient status and low permability
Representative soil profiles: none
Environmental characteristics:
Parent material: shales
Physiographic unit: Coastal Uplands (Lutsangani upland)
Topography and dissection: flat, occasionally gently undulating; slope classes: mainly A, occasionally AB; not dissected
Agro-climatic zone: III (approximately 40%)
IV (approximately 60%)
Soil characteristics:
Drainage: imperfectly well drained to poorly drained, locally moderately well drained
Depth: deep
Colour: dark greyish brown surface soil; yellowish brown to olive subsoil
Texture: clay
Structure: moderate, coarse, subangular to angular blocky surface soil; strong, coarse, angular blocky to prismatic subsoil; slickensides
Consistence: firm to very firm (moist); sticky and plastic (wet)
Permeability and moisture conditions: permeability is initially moderate but diminishes rapidly upon sustained wetting and soil swelling; in poorly drained soils permeability is low throughout; porosity is 50-60%, moisture storage (pF 2.3-pF 3.7) is 7-14%
Chemical properties: organic matter content of the A horizon ranges between 2 and 4%, pH(H_2O) is around 6.0, but can be as high as 8.5 in case free carbonates prevail

clay mineralogy: predominantly montmorillonitic clay minerals
Additional remarks: Determination of pF-values of these cracking clay soils is hardly feasible
Vegetation and land-use: Grassed bushland; extensive grazing
Annual field crops (maize, cowpea)
Similar soils: UT2c4 shows resemblance with the other UT-units, they all consist of cracking clay soils; however, topography and drainage condition are quite specific for this unit

Map unit: UT2C

Total area: 14870 ha
Soil classification:
FAO/Unesco (1974): chromic Vertisols and vertic Cambisols, partly lithic phase
Kenyan Concept: -do-
Soil Survey Staff (1975): paleustollic and udorthentic Chromusterts, lithic vertic Ustropepts
Brief map unit description: Complex of stony and gravelly, cracking clays of varying drainage condition, depth and colour; ABC-, AC- or A(C)R-profiles, variable distinctness of horizon boundaries, high nutrient status and variable permeability
Representative soil profiles: none
Environmental characteristics:
Parent material: shales
Physiographic unit: Coastal Uplands (Lutsangani upland)
Topography and dissection: gently undulating (southern parts) to rolling (northern parts), sometimes even hilly; slope classes: BC, BD (Mtwapa-Tudor creek area), CE (Sokoke-Mitangoni area); moderately to strongly dissected
Agro-climatic zone: III (approximately 25%)
IV (approximately 75%)
Soil characteristics:
Drainage: well drained to imperfectly drained
Depth: varying
Colour: dark brown to dark yellowish brown surface soil; yellowish red to olive brown subsoil
Texture: mostly gravelly, locally stony clay
Structure: moderate, medium, angular blocky to strong, coarse prismatic; in places slickensides
Consistence: very firm (moist); sticky and plastic (wet)
Permeability: variable, largely depending on actual moisture conditions
Chemical properties: no data available; probably well comparable with chemical properties of UT2c1p
Clay mineralogy: predominantly montmorillonitic clay minerals
Vegetation and land-use: Grassed bushland; extensive grazing
Annual field crops (maize, cowpea, beans, often intercropped) locally rice
Similar soils: Soils of UT2C shows resemblance with the soils of the other UT-units and with the soils of HSKC, P2Lcp, AAc, VXC, P2WA, P2Ec and BAc2; they all consist of cracking clays

Map unit: UE1m1

Total area: 1020 ha
Soil classification:
FAO/Unesco (1974): ferralic Arenosols, rhodic Ferralsols
Kenyan Concept: -do-
Soil Survey Staff (1975): ustoxic Quartzipsamments, typic and ultic Haplorthent
Brief map unit description: somewhat excessively drained, very deep, very dusky red to dark reddish brown, medium sand to loamy medium sand; A(B)C-profiles, low nutrient status, high permeability
Representative soil profiles: none
Environmental characteristics:
Parent material: unconsolidated medium grained sandy deposits
Physiographic unit: Coastal Uplands (Pingilikani upland)
Topography and dissection: flat; slope class: A; not dissected

Agro-climatic zone: III

Soil characteristics:

Drainage: somewhat excessively drained

Depth: very deep

Colour: dark reddish brown to dark brown surface soil; very dusky red to dark reddish brown subsoil

Texture: medium sand to loamy medium sand

Structure: single grain to weak, medium, subangular blocky

Consistence: very friable (moist); non-sticky and non-plastic (wet)

Permeability and moisture conditions: permeability is high, porosity is approximately 40% throughout the profile, bulkdensity is 1.5 g/cm^3, moisture storage ranges between 5 and 10% (pF 2.3-pF 3.7)

Chemical properties: organic matter content of the A horizon does not exceed 1%, CEC (pH8.2) is 20 to 50 mmol/kg soil, base saturation does not exceed 35%, pH(H_2O) is 5.0-6.0, appreciable amounts of exchangeable Mn occur (10 mmol/kg soil)

Mineralogy: predominantly quartz relatively rich in haematite

Vegetation and land-use: Bushland; extensive grazing (to a limited extent)

Perennial industrial crops: sisal (estate)

Perennial fruits: mango

Annual field crops: maize, cowpea

Annual industrial crops: sesame (of minor importance)

Similar soils: Apart from colour, the soils of UElm1 show resemblance with those of unit USKf, USs2p, UElm2, P2Em1 and P2Em2

Map unit: UElm2

Total area: 260 ha

Soil classification:

FAO/Unesco (1974): luvic and cambic Arenosols

Kenyan Concept: luvic and cambic Arenosols

Soil Survey Staff (1975): alfic Ustipsamments, ustoxic Quartzipsamments

Brief map unit description: well drained, very deep, dark brown to dark greyish brown, *medium sand to loamy medium sand; A(B)C-profiles, low nutrient status, high permeability*

Representative soil profile: Profile 19 (198/2-28)

Environmental characteristics:

Parent material: unconsolidated medium grained sandy deposits

Physiographic unit: Coastal Uplands (Pingilikani upland)

Topography and dissection: flat; slope class: A; not dissected

Agro-climatic zone: IV

Soil characteristics:

Drainage: well drained

Depth: very deep

Colour: very dark greyish brown surface soil, dark brown to light olive brown subsoil

Texture: (loamy) medium to fine sand

Structure: single grain to weak, medium, subangular blocky Consistence: very friable (moist); non-sticky and non-plastic (wet)

Permeability: high

Chemical properties: organic matter content of the A horizon does not exceed 1%, CEC (pH 7!) is 20 to 50 mmol/kg soil, base saturation varies largely, pH(H_2O) is 5.5-6.5

Mineralogy: predominantly quartz

Vegetation and land-use: Bushland; extensive grazing

Annual and semi-annual field crops (maize, cassava, pulses) and perennial industrial crops (1 cashew, 2 coconut)

Similar soils: the soils of unit UElm2 show resemblance with those of unit USKf, USs1, USs2p, UOf, UElm1, UE2f, P2Em1 and P2Em2

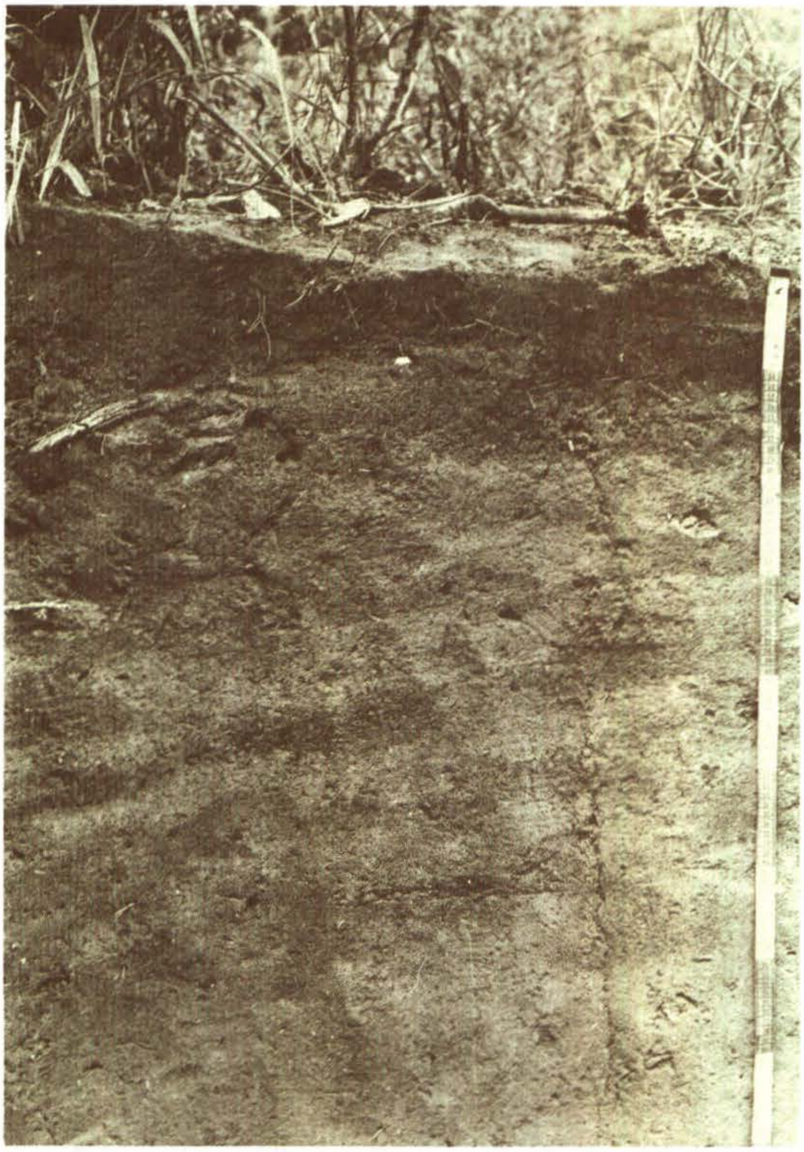


Fig. 30. Soil unit UE11 (chronic Luvisols and rhodic Ferralsols) in Pingilikani, about 17 km south-south-west of Kilifi (photo H. Waaijenberg).

Map unit: UE111 (Fig. 30, 31)

Total area: 1540 ha
Soil classification:
FAO/Unesco (1974): rhodic Ferralsols, ferric and chromic Luvisols
Kenyan Concept: rhodic Ferralsols, chromic Luvisols
Soil Survey Staff (1975): Typic Haplustox (rhodic-oxic) Paleustalfs
Brief map unit description: well drained, very deep, dusky red to reddish brown, sandy loam to sandy clay; in places underlying 20-40 cm loamy medium sand; ABC-profiles, gradual to diffuse horizon boundaries, low nutrient status, high permeability
Representative soil profiles: Profile 20 (198/4-41)
Environmental characteristics:
Parent material: unconsolidated medium grained sandy deposits
Physiographic unit: Coastal Upland (Pingilikani upland)
Topography and dissection: flat to rolling; slope classes: AB, C (northern parts) CD (southern parts); slightly to moderately dissected
Agro-climatic zone: III (approximately 40%)
IV (approximately 60%)
Soil characteristics:
Drainage: well drained, in places somewhat excessively drained
Depth: very deep

Fig. 31. Land-use in Pingilikani: cashew on hill tops and upper slopes (background), fruit crops along valleys (middle), and annual crops in small fields on the slopes (foreground). September 1984 (photo H. Waaijenberg).

Colour: dark reddish brown surface soil; dusky red subsoil

Texture: sandy loam to sandy clay, sometimes underlying 20-40 cm loamy medium sand

Structure: weak, medium, subangular blocky surface soil; weak prismatic, breaking into weak angular blocky subsoil

Consistence: very friable (moist); slightly sticky and non-plastic (wet)

Permeability and moisture conditions: permeability is high; porosity is 45 to 50%; bulkdensity is 1.5 g/cm^3; moisture storage (pF 2.3-pF 3.7) is 4-8%

Chemical properties: organic matter content of the surface soil does not exceed 1%, CEC (pH 8.2) is 20 to 40 mmol/kg soil, base saturation exceeds 50%, pH(H_2O) is 5.5-6.5, appreciable amounts of exchangeable Mn occur (10 mmol/kg soil)

Mineralogy: predominantly kaolinite and quartz with some illite; relatively rich in haematite

Vegetation and land-use:

Grassed bushland; extensive grazing

Annual and semi-annual field crops (maize, pulses, cassava, often intercropped)

Annual industrial crops: sesame (to a lesser extent)

Perennial industrial crops: (1 cashew, 2 coconut)

perennial fruits: mango

Similar soils: the soils of unit UE111 show resemblance with those of units USK1, USc1, UE112, UE21 and P2E11; soils without a coarse grained surface soil show resemblance with soils of the units ULc1 and ULc2

Map unit: UE112

Total area: 4380 ha
Soil classification:
FAO/Unesco (1974): acric and rhodic Ferralsols
Kenyan Concept: -do-
Soil Survey Staff (1975): typic Acrustox and Haplustox
Brief map unit description: well drained, very deep, very dusky red to reddish brown, sandy loam to sandy clay loam, underlying 40-80 cm loamy medium sand to sandy loam; ABC-profiles, gradual and diffuse horizon boundaries, low nutrient status, high permeability
Representative soil profiles: Profile 21 (198/2-3)
Environmental characteristics:
Parent material: unconsolidated medium grained sandy deposits
Physiographic unit: Coastal Uplands (Pingilikani upland)
Topography and dissection: gently undulating to rolling slope classes: B (northern parts); BC, CD (southern parts); slightly to moderately dissected
Agro-climatic zone: III (approximately 65%)
IV (approximately 35%)
Range of profile characteristics:
Drainage: well drained
Depth: very deep
Colour: very dusky red; surface soil can also be reddish brown to dark brown
Texture: sandy loam to sandy clay loam, underlying 40-80 cm loamy medium sand to sandy loam
Structure: granular to weak, fine to medium, subangular blocky
Consistence: very friable (moist); slightly sticky and non-plastic (wet)
Permeability and moisture conditions: permeability is high; porosity is 40-50%; bulkdensity is 1.5-1.6 g/cm^3; moisture storage (pF 2.3-pF 3.7) ranges between 8 and 12%
Chemical properties: no data available; probably well comparable with data of unit UE111
Mineralogy: predominantly kaolinite and quartz with some illite; relatively rich in haematite
Vegetation and land-use:
Grassed bushland; intensive and extensive grazing (of minor importance)
annual and semi-annual field crops (maize, cassava) pulses, (often intercropped)
Annual industrial crops: sesame
Perennial industrial crops: sisal (estate), coconut, cashew
Perennial fruits: mango
Similar soils: the soils of unit UE112 show resemblance with those of unit USK1, USc1 (in case of topsoil truncation of UE112), UE111, UE21 and P2E11

Map unit: UE2f

Total area: 685 ha
Soil classification:
FAO/Unesco (1974): ferralic Arenosols
Kenyan Concept: -do-
Soil Survey Staff (1975): ustoxic Quartzipsamments
Brief map unit description: somewhat excessively drained, very deep, brownish yellow to yellow, fine to medium sand, overlying mottled sandy loam; AC-profiles, low nutrient status, moderate to high permeability
Representative soil profile: none
Environmental characteristics:
Parent material: unconsolidated medium grained sandy deposits
Physiographic unit: Coastal Uplands (Lutsangani upland)
Topography and dissection: flat to gently undulating, occasionally undulating to rolling; slope classes: AB (more than 90%); CD (less than 10%)
Agro-climatic zone: III (50%)
IV (50%)
Soil characteristics:
Drainage: somewhat excessively drained to well drained
Depth: very deep, locally deep

Colour: brown to pale brown surface soil; yellow to light grey subsoil
Texture: (loamy) fine to medium sand, locally overlying mottled sandy loam
Structure: single grain to weak, medium, subangular blocky
Consistence: very friable (moist); non-sticky and non-plastic (wet)
Permeability: moderate to high
Chemical properties: no data available; probably well comparable with data of unit UElm2
Mineralogy: predominantly quartz with some kaolinite and illite

Vegetation and land-use: Bushland, grassland;
Annual and semi-annual field crops (maize, cowpea, cassava, often intercropped), perennial industrial crops (coconut, cashew)

Similar soils: the soils of UE2f more or less resemble those of unit USKf, USs1, USs2p, USs3, UOf, UElm2, P2Em1, P2Em2, P2Em3, P2Em4

Map unit: UE2l

Total area: 1460 ha
Soil classification:
FAO/Unesco (1974): chromic Luvisols
Kenyan Concept: -do-
Soil Survey Staff (1975): rhodic-oxic Paleustalfs

Brief map unit description: well drained, very deep, yellowish red to reddish yellow, sandy clay loam to sandy clay, underlying 40-80 cm medium sand to sandy loam; ABC-profiles, gradual horizon boundaries, low nutrient status, moderate to high permeability

Representative soil profiles: none

Environmental characteristics:
Parent material: unconsolidated medium grained sandy deposits
Physiographic unit: Coastal Uplands (Lutsangani upland)
Topography and dissection: flat to gently undulating; slope classes: AB; not dissected
Agro-climatic zone: III (50%)
IV (50%)

Soil characteristics:
Drainage: somewhat excessively drained to well drained
Depth: very deep
Colour: yellowish red to reddish yellow; subsoil can even be red
Texture: sandy loam to sandy clay, covered by 40-80 cm medium sand to loamy medium sand
Structure: single grain to porous massive, weakly coherent surface soil; weak, medium, subangular blocky subsoil; clay cutans
Consistence: friable (moist); slightly sticky and non-plastic (wet)
Permeability: moderate to high
Chemical properties: no data available; probably comparable with data of unit UE1l1
Mineralogy: predominantly kaolinite and quartz with some illite

Vegetation and land-use: Bushland, grassland;
annual and semi-annual field crops (maize, cassava, cowpea, often intercropped); perennial industrial crops (coconut, cashew)

Similar soils: the soils of unit USKl, UScl, UE1l1, UE1l2, P2El1 show resemblance with those of unit UE2L

3.3.2.3 Soils of the high level coastal plains

Map unit: P1Of

Total area: 1955 ha
Soil classification:
FAO/Unesco (1974): gleyic Luvisols, partly fragipan phase
Kenyan Concept: -do-
Soil Survey Staff (1975): aquic and arenic Paleustalfs and Haplustalfs

Brief soil description: moderately well drained, very deep, brown to light grey, loamy fine sand to sandy loam; in places mottled and/or with a fragipan between 80 and

120 cm; ABC-profiles, the B-horizon being weakly developed; moderate fertility and low to moderate permeability
Representative soil profiles: none
Environmental characteristics:
Parent material: unconsolidated fine sandy and clayey deposits
Physiographic unit: Coastal Plains (Bamba plain)
Topography and dissection: flat to gently undulating; slope class: AB; not dissected
Agro-climatic zone: V
Soil characteristics:
Drainage: moderately well drained
Depth: very deep
Colour: dark brownish grey to light brownish grey surface soil; brown to light grey subsoil
Texture: fine sand to loamy fine sand, mostly overlying sandy loam
Structure: porous massive, weakly to moderately coherent; fragipan: massive; clay cutans
Consistence: friable (moist); non-sticky and non-plastic (wet)
Permeability: moderate, low if a fragipan is present
Chemical properties: no data available
Mineralogy: mainly quartz
Vegetation and land-use: grassed bushland; extensive grazing/browsing
Annual and semi-annual field crops: maize, cassava (to a lesser extent)

Map unit: P101

Total area: 4860 ha
Soil classification:
FAO/Unesco (1974): gleyic and orthic Luvisols, partly sodic phase; solodic Planosols, gleyic and orthic Solonetz
Kenyan Concept: -do-
Soil Survey Staff (1975): aquic, aridic and typic Haplustalfs, aquic and typic Natrustalfs
Brief map unit description: moderately well drained to imperfectly drained, deep to very deep, reddish yellow to brown, mottled, sandy clay; in places underlying 20-80 cm fine sand to loamy fine sand; ABC-profiles, abrupt to clear horizon boundaries, in places saline-sodic, in places with a petrocalcic horizon; variable nutrient status, low permeability
Representative soil profile: Profile 22 (198/3-64)
Environmental characteristics:
Parent material: unconsolidated fine sandy and clayey deposits
Physiographic unit: Coastal Plains (Bamba plain)
Topography and dissection: flat to gently undulating;
slope class: AB;
not dissected
Agro-climatic zone: V (90%)
Soil characteristics:
Drainage: moderately well drained to imperfectly drained
Depth: deep to very deep
Colour: dark brown to dark greyish brown surface soil; reddish yellow to light olive brown and grey subsoils
Texture: 20-80 cm fine sand and loamy fine sand overlies sandy clay loam to sandy clay
Structure: porous massive, in places albic material
Consistence: sealed, platy top layer; porous massive, moderately coherent suface soils; strong, coarse prismatic subsoils
Permeability and moisture conditions: permeability is high in the sandy surface soil, low in the subsoil; porosity is 30% (subsoil) to 50% (surface soil), bulkdensity ranges between 1.4 and 1.8 g/cm^3, moisture storage is 25-30% in the surface soil and 10-15% in the subsoil
Chemical properties: organic matter content of the A horizon mostly does not exceed 1%; CEC (pH 8.2) is 100 to 250 mmol/kg soil, base saturation mostly exceeds 50%, pH(H_2O) shows a wide range: 5.5-9.0 in many soils ESP exceeds 15, at least in the subsoil; free carbonates occur to some extent
Mineralogy: many quartz (surface soil); quartz, 1:1 as well as 2:1-clay minerals and sometimes free carbonates prevail in the subsoils

Vegetation and land-use: Bushland; extensive grazing/browsing
Annual and semi-annual field crops: maize, cassava (to a lesser extent)
Similar soils: Apart from strong alkalinity and the sandy surface soil, the P101-soils show resemblance with those of unit U01 and U0c2p

Map unit: P10f-P101

Total area: 6780 ha
Soil classification:
FAO/Unesco (1974):
Kenyan Concept: see P10f and P101
Soil Survey Staff (1975):
Brief map unit description: Association of:
- soils of unit P10f
- soils of unit P101

Representative soil profile(s): See profile 22 for unit P101
Environmental characteristics:
Parent material: unconsolidated fine sandy and clayey deposits
Physiographic unit: Coastal Plains (Bamba plain)
Topography and dissection: flat to gently undulating;
slope class: AB;
not dissected
Agro-climatic zone: IV (approximately 80%)
V (approximately 20%)
Soil characteristics:
Drainage: see P10f and P101
Depth: -do-
Colour: -do-
Structure: -do-
Consistence: -do-
Permeability and moisture conditions: -do-
Chemical properties: -do-
Mineralogy: -do-
Vegetation and land-use: Bushland; extensive grazing/browsing
Annual and semi-annual field crops: maize, cassava

3.3.2.4 Soil of the Low level coastal plains

Map unit: P2WA

Total area: 230 ha
Soil classification:
FAO/Unesco (1974): calcaric Regosols, paralithic phase; gleyic Luvisols
Kenyan Concept: -do-
Soil Survey Staff (1975): lithic Ustorthents; aquic Haplustalfs
Brief map unit description: Association of:
- moderately well drained, shallow, dark brown, strongly calcareous clay
- imperfectly drained, very deep, light olive brown, mottled, calcareous clay

Representative soil profiles: none
Environmental characteristics:
Parent material: marls
Physiographic unit: Coastal Plains (Kibarani plain)
Topography and dissection: gently undulating to rolling; slope class: BD; slightly to moderately dissected
Agro-climatic zone: III (75%)
IV (25%)
Soil characteristics:
Drainage: moderately well drained (ass. 1)
imperfectly drained (ass. 2)
Depth: shallow (ass. 1), very deep (ass. 2)
Colour: dark brown (ass. 1), light olive brown (ass. 2)
Texture: calcareous clay

Structure: moderate to strong, medium to coarse, angular blocky (ass. 1), grading to strong, coarse, prismatic (ass. 2)
Consistence: very firm (moist); sticky and plastic (wet)
Permeability and moisture conditions: permeability is initially high, but diminish rapidy upon sustained wetting and soil swelling
Chemical properties: no data available
Mineralogy: undifferentiated clay minerals and free carbonates
Vegetation and land-use: Bushland, grassland
Similar soils: the soils of units P2WA are calcareous and do not show the same degree of cracking as those of unit HSKC, P2Lcp, P2Ec, AAc, VCX, BAc2 and the UT-units, but still there is an appreciable interrelationship among these soils

Map unit: P2Eml

Total area: 3885
Soil classification:
FAO/Unesco (1974): luvic and ferralic Arenosols
Kenyan Concept: -do-
Soil Survey Staff (1975): alfic Ustipsamments, ustoxic Quartzipsamments
Brief map unit description: somewhat excessively drained, very deep, reddish yellow to

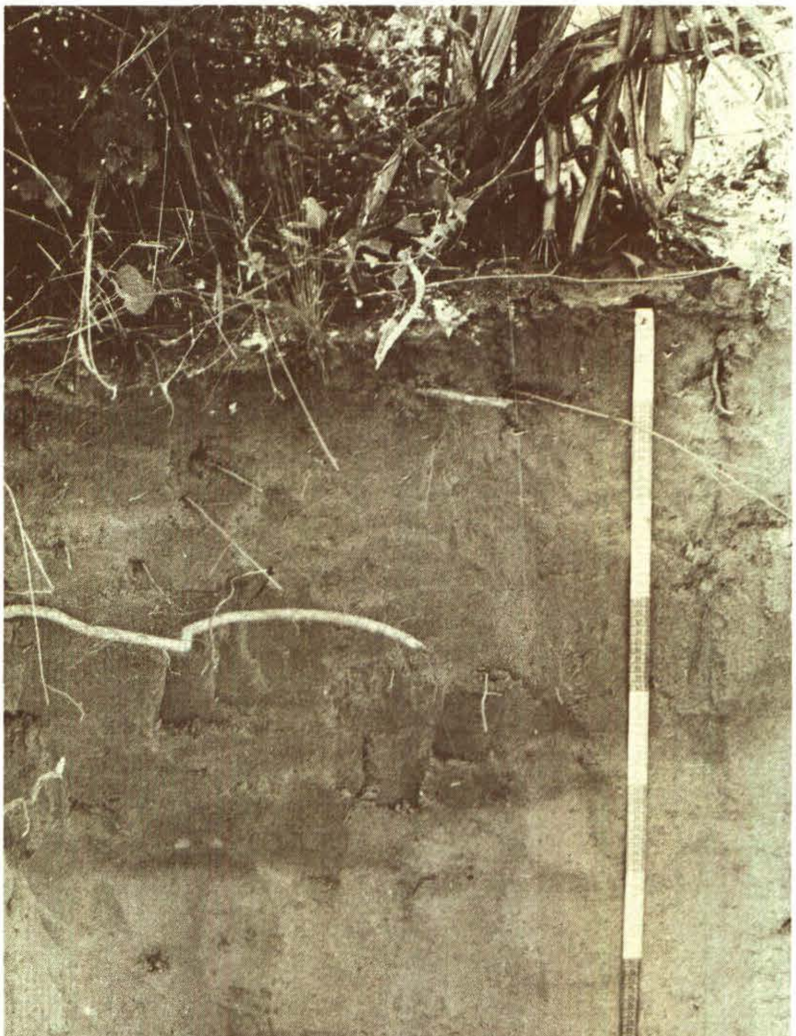


Fig. 32. Soil unit P2Em3 (ferralic and dystric Cambisols) about 3.5 km north of Kilifi (photo H. Waaijenberg).

Fig. 33. Maize, cocospalm and cashew are the major smallholder crops in the low coastal plain. Mavueni, about 8 km south-west of Kilifi, June 1981 (photo H. Waaijenberg).

yellowish brown, medium sand to loamy medium sand, 90-110 cm thick, overlying more than 60 cm sandy loam to sandy clay loam; AC-profiles of low fertility and high permeability

Representative soil profile: Profile 23 (198/2-34)

Environmental characteristics:

Parent material: medium and coarse grained sandy deposits

Physiographic unit: Coastal Plains (Kibarani plain)

Topography and dissection: flat to gently undulating slope classes: A, AB; not dissected

Agro-climatic zone: III (approximately 40%)
IV (approximately 60%)

Soil characteristics:

Drainage: somewhat excessively drained

Depth: very deep

Colour: very dark greyish brown to dark brown surface soil; reddish yellow to brownish yellow subsoil

Texture: (loamy) medium to fine sand, 90-110 cm thick; sandy loam at greater depth

Structure: single grain to porous massive, weakly coherent

Consistence: loose to friable (moist); non-sticky and non-plastic (wet)

Permeability and moisture conditions: permeability is high; porosity is 40-45%, bulk-density is approximately 1.5 g/cm^3, moisture storage 6-12% (pF 2.3-pF 3.7)

Chemical properties: organic matter content of the A horizon does not exceed 1%, CEC (pH 8.2) is 20 to 50 mmol/kg soil, base saturation varies largely, pH (H_2O) is 6.5-7.5

Mineralogy: predominantly quartz

Vegetation and land-use: Wooded bushland; extensive grazing (of minor importance)

Annual industrial crops: 1 cashew; 2 sisal (estate); 3 coconut

Similar soils: the soils of P2Em1 show resemblance with those of unit USKf, USs1, USs2p, UOf, UE1m1, UE1m2, UE2f and P2Em2

Map unit: P2Em2

Total area: 560 ha
Soil classification:
FAO/Unesco (1974): ferralic Arenosols
Kenyan Concept: -do-
Soil Survey Staff (1975): ustoxic Quartzipsamments
Brief map unit description: somewhat excessively drained, very deep, yellowish red, medium sand, 90-110 cm thick, overlying more than 60 cm loamy medium sand; AC-profiles of low fertility and high permeability
Representative soil profiles: none
Environmental characteristics:
Parent material: medium and coarse grained sandy deposits
Physiographic unit: Coastal Plains (Kibarani plain)
Topography and dissection: flat to gently undulating; slope class: AB; not dissected
Agro-climatic zone: III
Soil characteristics:
Drainage: somewhat excessively drained
Depth: very deep
Colour: dark brown surface soil; yellowish red subsoil
Structure: single grain
Consistence: loose (moist); non-sticky and non-plastic (wet)
Permeability and moisture conditions: permeability is high; detailed data on moisture storage are lacking, however, data of unit P2Em1 can safely be applied
Chemical properties: no data available; data of unit P2Em1 are well comparable
Minerology: predominantly quartz
Vegetation and land-use: Perennial industrial crops: sisal (estate)
Similar soils: the soils of unit P2Em2 show resemblance with those of the following units: USKf, USs1, USs2p, UE1m1, UE1m2, UE2f, P2Em1

Map unit: P2Em3 (Fig. 32, 33)

Total area: 3350
Soil classification:
FAO/Unesco (1974): ferralic and dystric Cambisols
Kenyan Concept: -do-
Soil Survey Staff (1975): oxic and typic Ustropepts
Brief map unit description: well drained, very deep, red to dark reddish brown, sandy loam, underlying 60-90 cm loamy medium sand; in places shallow over coral limestone; A(B)C-profiles, thick, weakly developed B-horizon, low fertility and high permeability
Representative soil profile: 2-35
Environmental characteristics:
Parent material: medium and coarse grained sandy deposits
Physiographic unit: Coastal Plains (Kibarani plain)
Topography and dissection: flat, locally gently undulating slope classes: A, AB; not dissected
Agro-climatic zone: III (25%)
IV (75%)
Range of profile characteristics:
Drainage: well drained, locally somewhat excessively drained
Depth: very deep with shallow to deep inclusions
Colour: dark brown surface soil; dark red to red subsoil
Texture: (loamy) medium sand 60-90 cm over sandy loam
Structure: porous massive, weakly coherent
Consistence: very friable to friable (moist); non-sticky and non-plastic (wet)
Permeability and moisture conditions: permeability is high; data on moisture storage are lacking, however, the data of unit P2Em1 can safely be applied
Chemical properties: organic matter content of the A horizon does not exceed 1%; CEC (pH 7) is 40 to 100 mmol/kg soil, base saturation is mostly below 50%, pH (H_2O) is 6.0-7.0
Mineralogy: predominantly quartz; illitie and kaolinitie clay minerals
Vegetation and land-use: Wooded bushland and extensive grazing of minor importance
Annual and semi-annual field crops: maize, cassava, pulses
Annual industrial crops: sesame

Perennial industrial crops: 1 cashew, 2 sisal (estate); 3 coconut
Perennial fruits: mango

Similar soils: the soils of unit P2Em3 show resemblance with those of unit USs3, UOf, UE2f, P2Em4

Map units: P2Em4

Total area: 1290 ha
Soil classification:
FAO/Unesco (1974): ferralic and dystric Cambisols, Cambic Arenosols
Kenyan Concept: -do-
Soil Survey Staff (1975): oxic and typic Ustropepts, typic Ustipsamments
Brief map unit description: well drained, very deep, yellowish red to dark yellowish brown, loamy medium sand to sandy loam; A(B)C-profiles, the B horizon being weakly developed, low fertility, high permeability
Representative soil profile: Profile 25 (198/2-14)
Environmental characteristics:
Parent material: medium and coarse grained sandy deposits
Physiographis unit: Coastal Plains (Kibarani upland)
Topography and dissection: flat; slope class: A; not dissected
Agro-climatic zone: III (approximately 50%)
IV (approximately 50%)
Soil characteristics:
Drainage: somewhat excessively drained to well drained
Depth: very deep with moderately deep to deep inclusions
Colour: brown surface soil, yellowish red to dark yellowish brown subsoil
Texture: (loamy) medium sand to sandy loam
Structure: porous massive, weakly coherent to weak, medium, subangular blocky
Consistence: loose to friable (moist); non-sticky and non-plastic (wet)
Permeability and moisture conditions: permeability is high; porosity is 40-45%, bulk-density is approximately 1.5 g/m^3, moisture storage pF 2.3-pF 3.7) is 6-10%
Chemical properties: organic matter content of the A horizon does not exceed 1%, CEC (pH 8.2) does not exceed 30 mmol/kg soil, pH (H_2O) is 6.5 to 7.5
Mineralogy: predominantly quartz and illitic and kaolinitic, clay minerals
Additional remarks: in places coral rock admixtures prevail
Vegetation and land-use: (Wooded) bushland and extensive grazing of minor importance
Annual and semi-annual field crops: maize, cassava, pulses
Perennial industrial crops: 1 cashew; 2 sisal (estate), 3 coconut
Similar soils: the soils of unit P2Em4 show resemblance with those of unit USs3, UOf, UE2f, P2Em3

Mapping unit: P2El1

Total area: 9120 ha
Soil classification:
FAO/Unesco (1974): ferric Luvisols and Acrisols
Kenyan Concept: chromic Luvisols and Acrisols
Soil Survey Staff (1975): oxic Paleustalfs and Rhodustalfs, Paleustults
Brief map unit description: well drained, very deep, dark red to yellowish red, sandy clay loam to sandy clay, underlying 30-60 cm medium sand to loamy medium sand; ABC-profiles, mostly thick but weakly developed B horizon, low fertility, moderate to high permeability
Representative soil profile: Profile 26 (198/2-1)
Environmental characteristics:
Parent material: medium and coarse grained sandy deposits
Physiographic unit: Coastal Plains (Kibarani plain)
Topography and dissection: flat to gently undulating; slope class(es): A, AB; not dissected
Agro-climatic zone: III (approximately 65%)
IV (approximately 35%)
Soil characteristics:
Drainage: well drained to somewhat excessively drained
Depth: very deep, with moderately deep and deep inclusions

Colour: dark yellowish brown to very dark greyish brown surface soil; dark red to yellowish red and strong brown subsoils
Texture: sandy clay loam to sandy clay, underlying 20-80 cm (loamy) medium sand to sandy loam
Structure: porous massive, weakly coherent surface soil; porous massive, moderately to strongly coherent subsoil; clay cutans
Consistence: friable (moist); slightly sticky and slightly plastic (wet)
Permeability and moisture conditions: permeability is high; porosity is 35-40%, bulk-density is 1.5-1.7 g/cm^3, moisture storage (pF 2.3-pF 3.7) is 6-9%
Chemical properties: organic matter content of the A horizon does not exceed 1%, CEC (pH 8.2) is 20 to 100, occasionally 100 to 180 mmol/kg soil, base saturation varies largely, pH(H_2O) is 6.5-7.5, appreciable amounts of exchangeable Mn sometimes occur (10 mmol/kg soil)
Mineralogy: predominantly kaolinite and quartz; locally free carbonates

Vegetation and land-use:
Grassed bushland and Extensive grazing of minor importance
Annual and semi-annual field crops: maize, cowpea, cassava (often intercropped)
Annual industrial crops: sesame
Perennial industrial crops: 1 coconut; 2 sisal (estate); 3 cashew
Perennial fruits: mango, citrus

Similar soils: the soils of unit P2El1 show resemblance with those of unit USKl, UScl, UEl11, UEl12, UE21, P2El2 (apart from colour) and P2Ll2p (apart from depth)

Map unit: P2El2

Total area: 3010 ha
Soil classification:
FAO/Unesco (1974): ferric and orthic Luvisols
Kenyan Concept: Ferral-orthic Luvisols
Soil Survey Staff (1975): oxic and udic Paleustalfs; ultic Haplustafs
Brief map unit description: well drained, very deep, strong brown to yellowish brown, sandy clay loam to sandy clay, underlying 30-60 cm sand to loamy medium sand; ABC-profiles, often thick, but weakly developed B horizon,low fertility, moderate to high permeability
Representative soil profile: Profile 27 (198/2-44)
Environmental characteristics:
Parent material: medium and coarse grained sandy deposits
Physiographic unit: Coastal Plains (Kibarani plain)
Topography and dissection: flat to gently undulating; slope classes: A, AB; not dissected
Agro-climatic zone: III (approximately 40%)
IV (approximately 60%)

Soil characteristics:
Drainage: well drained
Depth: very deep
Colour: dark brown to brown surface soil; strong brown to yellowish brown subsoil
Texture: sandy clay loam to sandy clay, underlying 30-60 cm medium sand to sandy loam
Structure: single grain to moderate, medium, subangular blocky
Consistence: firm (moist); slightly sticky and slightly plastic (wet)
Permeability and moisture conditions: permeability is moderate to high; porosity is 35%, bulkdensity is 1.5-1.7 g/cm^3, moisture storage (pF 2.3-pF 3.7) is 6-9%
Chemical properties: organic matter content of the A horizon does not exceed 1%, CEC (pH 8.2) is 20 to 80 mmol/kg soil, base saturation exceeds 50% pH(H_2O) is 5.0-6.5, in the subsoil exchangeable Mg sometimes exceeds exchangeable Ca
Mineralogy: predominantly quartz; kaolinite and illite

Vegetation and land-use:
Grassed bushland
Extensive grazing (of minor importance)
Annual industrial crops: sesame
Perennial industrial crops: coconut, cashew
Perennial fruits: mango, citrus

Similar soils: the soils of unit P2El2 show resemblance with those of unit USKl and P2El1, UScl (apart from colour)

Map unit: P2E13

Total area: 1600 ha
Soil classification:
FAO/Unesco (1974): ferric, orthic and gleyic Luvisols
Kenyan Concept: FERRAL*-orthic Luvisols, gleyic Luvisols
Soil Survey Staff (1975): oxic and udic Paleustalfs, aquic and ultic Haplustalfs
Brief map unit description: moderately well drained, very deep, brown to yellowish brown, mottled, sandy clay, underlying 20-70 cm loamy medium sand; ABC-profiles, pronounced B-horizon, low to moderate permeability
Representative soil profile: none
Environmental characteristics:
  Parent material: medium and coarse grained sandy deposits
  Physiographis unit: Coastal Plains (Kibarani plain)
  Topography and dissection: flat to gently undulating; slope classes: A, AB; not dissected
  Agro-climatic zone: III (50%)
  IV (50%)
Soil characteristics:
  Drainage: moderately well drained, locally imperfectly
  Depth: very deep
  Colour: strong brown to very dark greyish brown surface soil; strong brown to yellowish brown subsoil
  Texture: sandy clay loam to sandy clay, underlying 20-70 cm loamy medium sand
  Structure: single grain surface soil; moderate, medium, subangular to angular blocky subsoil
  Consistence: firm (moist); slightly sticky and slightly plastic (wet)
  Permeability low to moderate
  Chemical properties: organic matter content of the A horizon does not exceed 1%, CEC (pH 8.2) is 30 to 80 mmol/kg soil, base saturation exceeds 50%, pH(H_2O) is 6.0, in the subsoil exchangeable Mg exceeds exchangeable Ca
  Minerology: predominantly quartz; some illite and kaolinite
Vegetation and land-use:
  Bushland and Extensive grazing (of minor importance)
  Annual and semi-annual field crops: maize, cassave, cowpea (rainfed) vegetables (irrig
  Annual industrial crops: sesame
  Perennial fruits: banana
  Perennial industrial crops, cashew, coconut

Map unit: P2Ec

Total area: 245 ha
Soil classification:
FAO/Unesco (1974): vertic and gleyic Luvisols, pellic Vertisols
Kenyan Concept: verti-gleyic Luvisols, pellic Vertisols
Soil Survey Staff (1975): aquic; vertic Haplustalfs, udic Pellusterts
Brief map unit description: imperfectly drained to poorly drained, very deep, dark brown to very dark grey, mottled, cracking, sandy clay to clay; A(B)C-profiles and, moderate fertility, low permeability
Representative soil profile: none
Environmental characteristics:
  Parent material: medium and coarse grained sandy deposits
  Physiographic unit: Coastal Plains (Kibarani plain)
  Topography and dissection: flat;
  slope class: A; not dissected
  Agro-climatic zone: III
Soil characteristics:
  Drainage: imperfectly drained to poorly drained
  Depth: very deep
  Colour: dark brown to very dark grey surface soil; yellowish brown to light yellowish grey subsoil
  Texture: sandy clay to clay
  Structure: moderate to strong, coarse, angular blocky to prismatic
  Consistence: firm (moist); sticky and plastic (wet)

Chemical properties: no data available
Mineralogy: presumably a mixture of 1:1- and 2:1- clay minerals
Vegetation and land-use:
Grassland
Extensive grazing
Similar soils: the soils of P2Ec show resemblance with those of units HSKC, P2Lcp, AAc, VXC, P2WA, BAc2 and the UT-units; they all consist of cracking clay soils

Map unit: P2E11-P2E13

Total area: 1220 ha
Soil classification:
FAO/Unesco (1974):)
Kenyan Concept:) see P2E11 and P2E13
Soil Survey Staff (1975):)
Brief map unit description: Association of:
- soils of unit P2E11
- soils of unit P2E13

Representative soil profile(s): See Profile 26 (198/2-1) for Unit P2E11 (none for Unit P2E13)
Environmental characteristics:
Parent material: medium and coarse grained sandy deposits
Physiographic unit: Coastal Plains (Kibarani plain)
Topography and dissection: flat to gently undulating;
slope class: AB;
not dissected
Agro-climatic zone: III
Soil characteristics:
Drainage: see P2E11 and P2E13
Depth: -do-
Colour: -do-
Texture: see P2E11 and P2E13
Vegetation and land-use:
Grassed bushland and Extensive grazing of minor importance
Annual field crops: maize, cowpea (rainfed); vegetables (irrigated)
Annual industrial crops: sesame
Perennial industrial crops: mainly coconut
Perennial fruits: some mangos and citrus

Map unit: P2L11P

Total area: 6755 ha
Soil classification:
FAO/Unesco (1974): Lithosols, haplic Phaeozems, ferralic Cambisols
Kenyan Concept: eutric Lithosols, haplic Phaeozems, ferralic Cambisols
Soil Survey Staff (1975): ruptic-lithic Haplustolls, lithic and oxic Ustropepts
Brief map unit description: well drained, shallow to moderately deep, red to dark reddish brown, extremely rocky, loam to sandy clay loam; ABC-AC- and AR-profiles, abrupt and irregular transition to the coral rock, low to moderate fertility, high permeability
Representative soil profile: none
Environmental characteristics:
Parent material: coral limestone and sands
Physiographic unit Coastal Plains (Kibarani plain)
Topography and dissection: flat to gently undulating; slope class(es): A, AB; not disse
Agro-climatic zone: III (60%)
IV (40%)
Soil characteristics:
Drainage: well drained
Depth: shallow to moderately deep, with deep to very deep inclusions
Colour: dark reddish brown to black surface soil; red to dark reddish brown subsoil
Texture: loamy medium sand to loam, overlying sandy clay loam
Structure: weak and moderate, medium to coarse, (sub)angular blocky
Consistence: friable (moist); slightly sticky and non-plastic (wet)
Permeability: high

Chemical properties: organic matter content of the A horizon varies largely: 1-7%, CEC varies accordingly between 30 and 180 mmol/kg soil, base saturation varies largely $pH(H_2O)$ is 7.5-8.5, HCl-effervescence is strong

Mineralogy: mixture of 1:1-, 21- clay minerals, calcium carbonates and quartz

Vegetation and land-use:

Bushland (Lantana camara)

Extensive grazing

Annual and semi-annual field crops: maize, cassava, cowpea (of minor importance)

Similar soils: apart from shallowness, the soils of unit P2L11P show resemblance with those of unit P2L12p

Map unit: P2L12p

Total area: 1715 ha

Soil classification:

FAO/Unesco (1974): ferric Luvisols, ferralic Cambisols

Kenyan Concept: -do-

Soil Survey Staff (1975): oxic Rhodustalfs, oxic Ustropepts

Brief map unit description: well drained, moderately deep to deep, dark red to yellowish red, sandy clay loam to sandy clay, underlying 20-40 cm loamy medium sand; in places shallow over coral limestone; ABC-profiles, the B-horizon being weakly developed, low fertility, high permeability

Representative soil profile: Profile 28 (198/4-6)

Environmental characteristics:

Parent material: coral limestone and sands

Physiographic unit: Coastal Plains (Kibarani plain)

Topography and dissection: flat to gently undulating
slope classes: A, AB; not dissected

Agro-climatic zone: III (approximately 65%)
IV (approximately 35%)

Soil characteristics:

Drainage: well drained

Depth: moderately deep to deep

Colour: dark brown to brown surface soil; red to yellowish red subsoil

Texture: sandy clay loam to sandy clay, underlying 20-40 cm loamy medium sand to sandy loam

Structure: weak, fine (surface soil) to moderate, medium (subsoil), subangular blocky; in places clay cutans

Consistence: friable (moist); slightly sticky and slightly plastic (wet)

Permeability and moisture conditions: permeability is high; porosity is 50-60%, bulk-density is 1.4-1.6 g/cm^3, moisture storage (pF 2.3-pF 3.7) is 6-9%

Chemical properties: organic matter content of the A horizon is around 1%; CEC (pH 8.2) is 4-7 me/100 g soil, base saturation exceeds 50%, $pH(H_2O)$ is 6.0-7.0 and occasionally HCl-effervescence is strong

Mineralogy: mixture of 1:11-, 2:1-clay minerals, calcium carbonates and quartz

Vegetation and land-use:

Bushland

Extensive grazing

Annual and semi-annual field crops: maize, cassava

Annual industrial crops: sesame)
Perennial industrial crops: cashew) to a lesser extent

Similar soils: the soils of unit P2L12p show resemblance with those of unit USK1, USc1, P2E11 and P2L11P; however, soil depth is different for these units

Map unit: P2Lcp

Total area: 230 ha

Soil classification:

FAO/Unesco (1974): vertic Cambisols

Kenyan Concept: -do-

Soil Survey Staff (1975): vertic Ustropepts

Brief map unit description: well drained, moderately deep to deep, yellowish red to strong brown, cracking clay; ABC-profiles, the B horizon being weakly developed, presumably moderate fertility and variable permeability

Representative soil profile(s): none
Environmental characteristics:
Parent material: coral limestone and sands
Physiographic unit: Coastal Plains (Kibarani plain)
Topography and dissection: flat; slope class: A; not dissected
Agro-climatic zone: IV
Soil characteristics:
Drainage: well drained
Depth: moderately deep to deep
Colour: yellowish red to strong brown
Texture: clay
Structure: strong, coarse, angular blocky to prismatic
Consistence: firm (moist); sticky and plastic (wet)
Permeability: initially high, but diminishes significantly upon sustained wetting and soil swelling
Chemical properties: no data available
Mineralogy: predominantly 2:1-clay minerals and calcium carbonates
Vegetation and land-use:
Bushland
Extensive grazing
Annual and semi-annual field crops: maize, cassava
Similar soils: the soils of unit P2Lcp show resemblance with the soils of the other 'cracking clay' units: HSKC, AAc, VXC, P2WA, P2Ec, BAc2 and the UT-units

3.3.2.5 Soils of the Flood plains

Map unit: AAx

Total area: 705 ha
Soil classification:
FAO/Unesco (1974): eutric Fluvisols, gleyic Cambisols
Kenyan Concept: -do-
Soil Survey Staff (1975): typic Ustifluvents, fluventic Ustropepts
Brief map unit description: moderately well drained, deep to very deep, yellowish brown to dark greyish brown soils of varying texture; in places imperfectly drained and overlying sandy clay; A(B)C-profiles, the B horizon, if present, being weakly developed, fertility and permeability show considerable variation
Representative soil profile(s): none
Environmental characteristics:
Parent material: recent alluvial deposits
Physiographic unit: Floodplains
Topography and dissection: flat; slope class(es): A; not dissected
Agro-climatic zone: III, IV, V
Soil characteristics:
Drainage: moderately well drained, in places well drained or imperfectly drained
Depth: deep to very deep
Colour: dark brown to brown surface soil; yellowish brown to dark greyish brown subsoil
Texture: varying
Structure: varying between weak, medium, subangular blocky and strong, coarse, angular blocky
Consistence: varying with texture
Permeability: varying
Chemical properties: no data available
Mineralogy: undifferentiated clay minerals and quartz
Vegetation and land-use: Grassland
Annual field crops: rice
Perennial industrial crops: coconut

Map unit: AAc

Total area: 3870 ha
Soil classification:
FAO/Unesco (1974): dystric Fluvisols, pellic and chromic Vertisols and vertic Cambisols
Kenyan Concept: -do-
Soil Survey Staff (1975): aquic Ustifluvents, udic Pellusterts, udic Chromusterts, vertic Ustropepts
Brief map unit description: imperfectly drained to poorly drained, deep to very deep, greyish brown to dark grey; mottled, cracking clay; in places calcareous; ABC- and AC-profiles with varying fertility and permeability
Representative soil profile: Profile 29 (198/2-4)
Environmental characteristics:
- Parent material: recent alluvial deposits
- Physiographic unit: Floodplains
- Topography and dissection: flat; slope class: A; not dissected
- Agro-climatic zone: III; IV

Soil characteristics:
- Drainage: imperfectly drained to poorly drained
- Depth: deep to very deep, with shallow and moderately deep inclusions
- Colour: dark brown to dark grey surface soil; dark greyish brown to black subsoil
- Texture: clay
- Structure: strong structures, ranging from medium, subangular blocky to coarse, prismatic; locally slickensides
- Consistence: firm to very firm (moist); sticky and plastic (wet)
- Permeability: initially high but diminishes rapidly upon sustained wetting and soil swelling
- Chemical properties: organic matter content of the A horizon mostly exceeds 2%; moreover, the subsoil can contain appreciable amounts of organic matter; CEC (pH 8.2) is 300 to 400 mmol/kg soil, base saturation exceeds 50%, pH (H_2O) varies largely: 7.5-8.0 in pellic Vertisols, that also show strong HCl-effervescence; locally EC- and ESP-values of subsoils exceed 2 mmho/cm and 15 respectively
- Mineralogy: mostly 2:1-clay minerals

Vegetation and land-use:
- Bushed grassland
- Extensive grazing
- Annual field crops: maize
- Perennial industrial crops: coconut, banana, cotton (of minor importance)

Similar soils: the soils of unit AAc resemble those of unit HSKC, P2Lcp, P2WA, P2Ec, VXC, BAc2 and the UT-units; they all consist of cracking clays

3.3.2.6 Soils of the Minor valleys

Map unit: VXA

Total area: 4410 ha
Soil classification:
FAO/Unesco (1974): albic Arenosols; gleyic Acrisols and Luvisols
Kenyan Concept: -do-
Soil Survey Staff (1975): ustoxic Quartzipsamments; aquultic Haplustults and Haplustalfs
Brief map unit description: Association of:
1- well drained to moderately well drained, deep to very deep, dark brown to light yellowish brown, mottled, sandy loam to sandy clay loam, underlying 60-80 cm fine and medium sand (lower valley slopes)
2- imperfectly drained to poorly drained, shallow to moderately deep, light yellowish brown to light grey, mottled, sandy clay loam to sandy clay (valley floors)

Representative soil profile: none
Environmental characteristics:
- Parent material: varying
- Physiographic unit: Minor Valleys
- Topography and dissection: flat valleybottoms; sloping to steep valley slopes; slope classes: C, D, E
- Agro-climatic zone: IV; V

Soil characteristics:
Drainage: 1: well drained to moderately well drained
2: imperfectly drained to poorly drained
Depth: 1: deep to very deep
2: shallow to moderately deep
Colour: light yellowish brown to dark greyish brown surface soil; dark brown to light yellowish brown (ass. 1) and light yellowish brown to light grey (ass. 2) subsoils
Texture: 1: 60-80 cm fine and medium sand, overlying sandy loam to sandy clay loam
2: sandy loam to sandy clay, occasionally underlying 20-40 cm fine and medium sand
Structure: single grain to weak, medium, subangular blocky surface soil; moderate, medium, subangular blocky subsoil
Consistence: friable (ass. 1), firm (ass. 2) (moist); slightly sticky and non-plastic (ass. 1) to slightly plastic (ass. 2) (wet)
Permeability: high (ass. 1), moderate (ass. 2)
Chemical properties: varying profile 198/3-32 has an organic matter content that just exceeds 1%, CEC (pH 8.2) 70 to 100 mmol/kg soil, high base saturation, pH(H_2O) 6.0-7.0 and high salinity in the subsoil
Mineralogy: undifferentiated clay minerals and quartz
Vegetation and land-use:
1: (Brachystegia) bushed woodland
Annual field crops: maize, cowpea
2: (Unpalatable) grassland
Annual field crops: rice
Semi-annual field crops: sugarcane (of minor importance)

Map unit: VXC

Total area: 2755 ha
Soil classification:
FAO/Unesco (1974): pellic Vertisols, gleyic and vertic Cambisols
Kenyan Concept: -do-
Brief map unit description: complex of cracking clay soils of varying drainage condition, depth and colour; in places calcareous
Representative soil profile(s): none
Environmental characteristics:
Parent material: varying
Physiographic unit: Minor Valleys
Topography and dissection: sloping to steep valley sides slope classes: C, D, E;
Agro-climatic zone: III, IV
Soil characteristics:
Drainage: varying
Depth: varying
Colour: varying
Texture: clay
Structure: strong, coarse, angular blocky to prismatic
Consistence: varying
Permeability: initially high, but will diminish significantly upon sustained wetting and soil swelling;
Chemical properties: no data available; in places strong HCl-effervescence indicates the presence of free carbonates
Mineralogy: predominantly 2:1-clay minerals

3.3.2.7 Soil of the Bottom lands

Map unit: BAc1

Total area: 870 ha
Soil classification:
FAO/Unesco (1974): eutric Gleysols, gleyic Luvisols, Acrisols and Cambisols
Kenyan Concept: -do-
Soil Survey Staff (1975): typic Tropaquepts, typic Tropaqualfs, (epi-) aquic Haplustults, aquic Ustropepts

Brief map unit description: moderately well drained to imperfectly drained, very deep, dark greyish brown, mottled, sandy clay loam to clay, in places calcareous; underlying 40-80 cm loamy fine and medium sand to sandy loam; ABC-profiles, moderate fertility, low permeability
Representative soil profile: Profile 30 (198/2-21)
Environmental characteristics:
Parent material: recent unconsolidated deposits
Physiographic unit: Bottomlands
Topography and dissection: flat; slope class; A not dissected
Agro-climatic zone: III
IV
Soil characteristics:
Drainage: moderately well drained to imperfectly drained: occasionally poorly drained
Depth: very deep
Colour: very dark grey to black surface soil; very dark greyish brown subsoil
Texture: sandy clay loam to sandy clay, mostly underlying 40-80 cm (loamy fine and medium sand to sandy loam
Structure: single grain surface soil; strong, coarse, subangular, angular or prismatic subsoil
Consistence: form (moist); sticky and plastic (wet)
Permeability and moisture conditions: permeability of the sandy surface soil is high, permeability of the clayey subsoil is low; porosity is 40% (subsoil)-50% (surface soil), bulkdensity ranges from 1.5-1.8 g/cm^3, moisture storage (pF 2.3-pF 3.7) is 8-12%
Chemical properties: organic matter content of the A horizon is around 1%, CEC (pH 8.2) is 50 to 120 mmol/kg soil, base saturation varies largely, pH(H_2O) is 5.5-7.5, strong HCl-effervescence occurs in places
Mineralogy: mixture of 1:1-, 2:1-clay minerals, quartz, feldspars and free carbonates

Map unit: BAc2

Total area: 2050 ha
Soil classification:
FAO/Unesco (1974): gleyic Luvisols and Cambisols
Kenyan Concept: -do-
Soil Survey Staff (1975): aquic Haplustalfs and Ustropepts
Brief map unit description: moderately well drained, very deep, brownish yellow to light grey, mottled clay; ABC-profiles, moderate fertility, low permeability
Representative soil profile: none
Environmental characteristics:
Parent material: recent unconsolidated deposits
Physiographic unit: Bottomlands
Topography and dissection: flat; slope class: A; not dissected
Agro-climatic zone: III; IV; V
Soil characteristics:
Drainage: moderately well drained to imperfectly drained
Depth: very deep
Colour: very dark greyish brown surface soil; yellowish brown to light grey subsoil
Texture: sandy loam to loam (0-40 cm) over sandy clay loam to clay
Structure: moderate, medium to coarse, subangular (surface soil) to angular (subsoil) blocky, locally prismatic, locally with clay cutans
Consistence: firm (moist); sticky and plastic (wet)
Permeability and moisture conditions: permeability is low to moderate, porosity is 35-40%, bulkdensity ranges from 1.5 to 1.8 g/cm^3, moisture storage (pF 2.3-pF 3.7) is 5-12%
Chemical properties: organic matter content of the A horizon is 1-2%; CEC (pH 8.2) is 50 to 100 mmol/kg soil, base saturation exceeds 50%, pH (H_2O) is 5.5-7.0 and up to 8.5 in case free carbonates prevail and/or ESP exceeds 15 (as occasionally occurs in subsoils)
Mineralogy: mixture of 1:1-, 2:1-clay minerals, quartz, feldspars and free carbonates
Vegetation and land-use:
Grassland, bushland
Extensive grazing
Annual and semi-annual field crops: upland rice, maize

Similar soils: although the soils of unit BAc2 are not that cracking, they show resemblance with the cracking clay soils of unit HSKC, P2WA, P2Ec, P2Lcp, AAc, VXC and the UT-units

Map unit: BAc3

Total area: 1530 ha
Soil classification:
FAO/Unesco (1974): solodic and mollic Planosols, saline phase
Kenyan Concept: -do-
Soil Survey Staff (1975): typic Argialbolls, udollic Albaqualfs, saline phase
Brief map unit description: imperfectly drained to poorly drained, deep to very deep, light brownish grey, mottled, saline and/or sodic, sandy clay to clay, underlying 20-60 cm fine sand to loamy fine sand; ABC-profiles, abrupt horizon boundaries, low fertility and permeability
Representative soil profile(s): none
Environmental characteristics:
Parent material: recent unconsolidated deposits
Physiographic unit: Bottomlands
Topography and dissection: flat; slope class(es): A; not dissected
Agro-climatic zone: IV, V
Soil characteristics:
Drainage: imperfectly drained to poorly drained
Depth: deep to very deep
Colour: very dark greyish brown surface soil; light brownish grey subsoil
Texture: fine sand to loamy fine sand (20-60 cm) overlying sandy clay to clay
Structure: weak to moderate, coarse, angular blocky to prismatic
Consistence: friable to firm (moist); sticky and slightly plastic (wet)
Permeability: high in the sandy topsoil, but practically zero in the subsoil;
Chemical properties: no data available; EC and ESP will normally exceed 4 mS and 15% respectively
Mineralogy: mixture of 1:1-, 2:1-clay minerals, quartz, feldspars and free carbonates
Vegetation and land-use:
Bushed grassland with Extensive grazing

Map unit: BAc1-BAc2

Total area: 110 ha
Soil classification:
FAO/Unesco (1974):) see BAc1 and BAc2
Kenyan Concept:)
Soil Survey Staff (1975))
Brief map unit description: Association of:
1- soils of unit BAc1 (bottomland fringes);
2- soils of unit BAc2 (bottomland central areas)
Representative soil profile(s): none
Environmental characteristics:
Parent material: recent, unconsolidated deposits
Physiographic unit: Bottomlands
Topography and dissection: flat;
slope class: A; not dissected
Agro-climatic zone: IV
Soil characteristics:
Drainage: see BAc1 and BAc2
Depth: -do-
Colour: -do-
Texture: see BAc1 and BAc2
Permeability and moisture conditions: -do-
Chemical properties: -do-
Mineralogy: -do-
Vegetation and land-use: Annual field crops: upland rice

3.3.2.8 Soils of the Tidal flats and swamps

Map unit: TAx

Total area: 670 ha
Soil classification:
FAO/Unesco (1974): eutric Fluvisols, saline-sodic phase
Kenyan Concept: -do-
Soil Survey Staff (1975): typic Halaquepts and Hydraquents
Brief map unit description: poorly drained, very deep, very dark greyish brown to light olive brown, mottled, half-ripened, saline and sodic soils of varying texture; AC-profiles, low fertility and permeability
Representative soil profile(s): none
Environmental characteristics:
Parent material: recent marine deposits
Physiographic unit: Tidal Flats and Swamps
Topography and dissection: flat; slope class: A; not dissected
Agro-climatic zone: III; IV
Soil characteristics:
Drainage: poorly drained
Depth: very deep, stratified
Colour: very dark greyish brown to light olive brown
Texture: stratified profiles, variable textures
Structure: massive, weakly coherent (high n-value)
Consistence: varying, mostly very sticky, non-plastic (wet)
Permeability: low
Chemical properties: no data available; EC- and ESP exceed 4 mS and 15% respectively
Mineralogy: unspecified
Vegetation and land-use: Barren flats with locally halophytic plants
Similar soils: TAx interferes with TAc

Map unit: TAc

Total area: 1765 ha
Soil classification:
FAO/Unesco (1974): thionic Fluvisols, saline-sodic phase
Kenyan Concept: -do-
Soil Survey Staff (1975): typic Sulfaquents and Sulfaquepts
Brief map unit description: very poorly drained, very deep, dark grey to dark olive, unripened, saline and sodic, sulfuric, sandy clay to clay; no horizon differentiation
Representative soil profile(s): none
Environmental characteristics:
Parent material: recent marine deposits
Physiographic unit: Tidal Flats and Swamps
Topography and dissection: flat; slope class(es): A; not dissected
Agro-climatic zone: III, IV
Soil characteristics:
Drainage: very poorly drained
Depth: very deep
Colour: very dark grey to dark olive
Texture: sandy clay to clay
Structure: massive, weakly coherent
Consistence: very friable (moist); very sticky and slightly plastic (wet)
Chemical properties: no data available EC, ESP and H_2S-concentration exceed toxic levels
Mineralogy: unspecified
Vegetation and land-use: Mangroves
Similar soils: TAc interferes with TAx

Map unit: TAo

Total area: 105 ha
Soil classification:
FAO/Unesco (1974): eutric and dystric Histosols
Kenyan Concept: -do-
Soil Survey Staff (1975): various Tropofibrists and Tropohemists; Sulfihemists
Brief map unit description: imperfectly drained to poorly drained, very deep, dark brown to black, organic material (muck), underlying 10-20 cm calcareous, loamy medium sand; HC-profiles
Representative soil profile(s): none
Environmental characteristics:
Parent material: recent marine deposits
Physiographic unit: Tidal Flats and Swamps
Topography and dissection: flat; slope class: A; not dissected
Agro-climatic zone: IV
Soil characteristics:
Drainage: imperfectly drained to poorly drained (class 2 and 1)
Depth: very deep
Colour: dark brown surface soil; black subsoil
Texture: peat with sandy lamellae, underlying 10-20 cm loamy medium sand
Structure: massive, weakly coherent; single grain surface soil
Consistence: friable (moist); very sticky, slightly plastic (wet)
Permeability: low
Chemical properties: organic matter content of these soils is very high (20-60%) throughout; CEC is 300 to 450 mmol/kg soil, base saturation varies largely, pH (H_2O) is 7.0-8.0, HCl-effervescence can be strong, ESP exceeds 6 but not 15
Mineralogy: unspecified
Vegetation and land-use: Barren flats, locally halophytic plants
Distribution: TAo is a small unit, occurring along the coast, north of Kilifi

3.3.2.9 Soils of the Dunes

Map unit: DE1

Total area: 295 ha
Soil classification:
FAO/Unesco (1974): calcaric Regosols
Kenyan Concept: -do-
Soil Survey Staff (1975): typic Ustipsamments
Brief map unit description: excessively drained, very deep, pale brown to light grey, strongly calcareous, fine sand; AC-profiles, low fertility and high permeability
Representative soil profile: none
Environmental characteristics:
Parent material: recent coastal sands
Physiographic unit: Dunes
Topography and dissection: flat to hilly; slope classes: A, B, C, D, E;
Agro-climatic zone: III, IV
Soil characteristics:
Drainage: excessively drained
Depth: very deep
Colour: grey brown surface soil; very pale brown to light grey subsoil
Texture: loamy fine sand
Structure: single grain
Consistence: loose (moist); non-sticky and non-plastic (wet)
Permeability and moisture conditions: permeability is high, porosity is 50-60%, bulk-density is 1.1-1.2 g/cm^3, moisture storage (pF 2.3-pF 3.7) is 10-14%
Chemical properties: organic matter content of the A horizon generally does not exceed 1%; CEC (pH 8.2) is 20 to 50 mmol/kg soil, base saturation is 75-100%, pH (H_2O exceeds 8.0; strong HCl-effervescence throughout the soil profile
Mineralogy: calcium carbonates and quartz
Vegetation and land-use: Bare land (partly recreation purposes) Perennial industrial crops: coconut

Map unit: DE2

Total area: 334 ha
Soil classification:
FAO/Unesco (1974): cambic Arenosols
Kenyan Concept: -do-
Soil Survey Staff (1975): ustoxic Quartzipsamments and typic Ustropepts
Brief map unit description: well drained, very deep, brown, medium sand to loamy medium sand; in places calcareous; A-profiles, low fertility and high permeability
Representative soil profile: none
Environmental characteristics:
    Parent material: recent coastal sands
    Physiographic unit: Dunes
    Topography and dissection: flat to hilly; slope classes: A, B, C, D, E; not dissected
    Agro-climatic zone: III, IV
Soil characteristics:
    Drainage: well drained, locally somewhat excessively drained
    Depth: very deep
    Colour: dark brown surface soil; yellowish brown to brown subsoil
    Texture: (loamy) fine and medium sand
    Structure: single grain
    Consistence: loose (moist) non-sticky and non-plastic (wet)
    Permeability and moisture conditions: permeability is high; detailed data on moisture availability are lacking, however, data of unit DE1 can be safely applied
    Chemical properties: organic matter content of the A horizon does not exceed 1%; CEC (pH 8.2) is 10 to 20 mmol/kg soil, pH (H_2O) is 6.5, but can be 8.0 in case free carbonates are present (strong HCl-effervescence)
    Mineralogy: predominantly quartz and to a lesser extent, calcium carbonates
Vegetation and land-use:
    Bare land; Bushland;
    Perennial industrial crops: coconut

3.4 SOIL GENESIS AND CLASSIFICATION

3.4.1 *Introduction*

Two internationally recognized classification approaches have been applied for the soils of the Kilifi Area:

- the FAO/UNESCO Legend to the Soil Map of the World (FAO/Unesco 1974);
- the USDA classification as described in Soil Taxonomy (Soil Survey Staff, 1975).

The approach of the Kenya Soil Survey which differs slightly from the FAO/UNESCO legend, the so-called "Kenya Concept" (Siderius & Van der Pouw, 1980), is given as well.

3.4.2 *Soil genesis aspects*

The basis for soil classification is provided by the combined action of soil-forming factors. Some obvious trends in soil genesis of the Kilifi Area are summarized in this section. As its position along the Indian Ocean is well comparable to that of the Kwale-Mombasa-Lunga Lunga Area, reference is made to the corresponding chapter of the report on that survey (Michieka et al., 1978).

Climate

Many loamy and clayey soils of the 'low level' Coastal Plains and the Coastal Uplands are very deep, reddish and non-calcareous and have predominantly kaolinitic clay minerals (large parts of the USK-, USc-, UOc-, UL-, UE- and P2E-units). Bleached sandy soils occur in adjacent areas (USKf, USs, UOf).

The present-day rainfall pattern can not be held responsible for such features of weathering. Is is therefore assumed that soil formation has been influenced by humid and hot conditions in the past, probably during one or more 'pluvial' phases of the Pleistocene era.

Parent material

The occurrence of different parent materials can be read from the codes on the soil map (Appendix 1). In the Kilifi Area the influence of parent material as a soil-forming factor is strong.

The siltstone-sandstone-limestone landscape contains brown and yellow, fine (USKf) and medium to coarse (USs) sandy, as well as red, loamy and clayey soils (USKl, USc, UL), which are quite different from the dark clays that have developed from shales (UT2).

The unconsolidated deposits near the coast (UE and P2E) and the soils developed on coral limestone (P2L) have been weathered strongly and textures show much variation.

Part of the soils of the Bay deposits (UOc2p, P101) contain sodium salts. In part of the sandy and loamy soils of the Bay deposits, the salts have been leached, leaving only a textural relationship with parent material.

Topography and age

The Kaloleni, Dzitsoni and, to a lesser extent, Pingilikani uplands are relatively stable surfaces. Consequently, soils are mostly deep to very deep and old (USK, US, UL, UE1). On the contrary, the Lutsangani upland is unstable. Geological and accelerated erosion have created a highly dissected landscape. The combination of weathering of hard rock and surface soil erosion result in continuous profile rejuvenation. Mostly the soils are only moderately deep (UT2).

In the undulating parts of the Bay deposits (UO), the higher parts are sandy, the lower parts clayey. In the flat areas (P10) locally Planosols could develop. The coral limestones are very porous and are not subject to strong weathering. Consequently, the soils are shallow though old (P2L). The other soils of the Kibarani plain (P2E) are deep and old. Continuous enrichment takes place in the flat areas of the Floodplains (AA) and to a lesser extent in the Bottomlands (BA) and the Minor Valleys (VX).

Hydrology

The influence of the hydrological regime can be seen in soils that have developed:

- on flat land surfaces with imperfect drainage
- in areas that are regularly submerged by rain water
- in areas that are regularly flooded either by river water or by sea water.

Imperfect drainage conditions in combination with fine-textured parent material that is rich in Ca and Mg caused the formation of swelling and shrinking clay soils (Vertisols, particularly the UT2-units). A specific combination of imperfect drainage, climate (seasonal rainfall) and parent material caused gleying and the formation of abrupt clay pans (Planosols, part of P1Ol, UOc2p, BAc3).

Bottomlands and Minor Valleys comprise areas that are regularly submerged. Their soils often show strong mottling. The same is true for some coastal flat surfaces (P2El3, P2Ec). Floodplains are regularly fed by silt-containing river water, causing stratified loamy profiles (Fluvisols, AAx) or cracking and self-mulching clayey profiles (Vertisols, AAc).

In Tidal Flats and Swamps a delicate natural balance exists with respect to elevation, frequency and duration of flooding, salt content and vegetation (TA). The soils of these areas contain sulfidic materials and may acidify strongly upon drainage (catclays, acid sulphate soils).

Soil fauna

The frequent occurrence of termite mounds in the Kilifi Area shows that biological activity is a soil-forming factor of importance. Although the extent to which termites are active is not as significant as in the Kisii Area (Wielemaker & Boxem, 1982) because of poorer and shallower soils, their role in improving the soil physical status is evident. They mix soil materials intensively and promote weathering of rotten rock. On the other hand, they can feed on growing crops. Termite activity seems to be highest in the USK-, USs-, USc-, UL- and UE-units.

Other animals, such as ants and earthworms, occur all over the area, their number decreasing from east to west. Biological activity is lowest in the western Planosols and Solonetz soils. Cockchafers are mainly found in the Lutsangani upland (UT-units).

Human activity

The influence of man on soil formation in the Kilifi Area is obvious. In the coastal and central areas, increasing pressure on scarce land caused strong reduction of organic matter contents in surface soils, due to land clearing and burning, which is a common practice at the beginning of the planting season. In low-input agriculture, such as in the Kilifi Area, maintenance of organic matter content is almost synonymous to maintenance of soil fertility. In the drier western and northern regions serious overgrazing caused substantial soil degradation with accompanying loss of soil fertility.

3.4.3 *Major classification units*

3.4.3.1 Remarks

In the Kilifi Area 37 classification units (FAO/Unesco, 1974) were recognized. They have been grouped in Table 8, together with a list of diagnostic criteria. Some 'tentative' units (Kenya Concept, Section 3.4.4) have been added: three intergrades at the first level (Ferralsols with Luvisols/Acrisols) and one at the second level (chromic Acrisols) and the third level (verti-gleyic Luvisols).

The entire area is considered to have an ustic moisture regime, although the northwestern part tends to aridic and the southeastern part to udic. This is done to simplify the USDA-classification (Ustalfs, Ustults, Ustropepts, Usterts, Ustox). The soil moisture regime is considered aquic in case of impeded drainage.

Paleustults have not been subdivided at subgroup level in Soil Taxonomy. This was felt as a shortcoming for the Kilifi Area.

The subdivision of Quartzipsamments is inaccurate: different soils all key out as ustoxic. This means that soils that do not have an udic moisture regime, are supposed to have properties of an oxic horizon at the same time; since this is not true for each Quartzipsamment in the Kilifi Area it is suggested that terms for the individual deviations are provided.

In Soil Taxonomy, a Vertisol is a soil that does not have a lithic contact. Consequently, shallow chromic Vertisols (FAO/UNESCO) correspond with lithic vertic Ustropepts (USDA). Ultisols key out before Mollisols. In the FAO/UNESCO Legend Phaeozems, however, key out before Acrisols. This discrepancy causes confusion about the mollic horizon.

The two Great Groups occurring most frequently are Arenosols and Luvisols followed by Acrisols, Cambisols and Vertisols. Ferralsols, Nitosols, Solonetz and Planosols are restricted to particular major landforms. In the Kenyan Concept (Siderius & Van der Pouw, 1980) and the Exploratory Soil Map (Sombroek et al., 1982), Nitosols are referred to as Nitisols.
Relatively small areas are covered by Histosols, Lithosols, Fluvisols, Regosols and Phaeozems.

3.4.3.2 FAO-UNESCO classification

In the following, the soils are discussed according to their sequence in the FAO-UNESCO legend.

Table 8 Classification units occurring in the Kilifi Area.

Subgroup / Great group to	Histo-sols	Litho-sols	Verti-sols	Fluvi-sols	Areno-sols	Rego-sols	Ferral-sols	Plano-sols	Solo-netz	Phaeo-zems	Nito-sols	Acri-sols	Luvi-sols	Cambi-sols
Rooting impediment														
gleyic	-	-	-	-	-	-	-	-	x	x	-	x	x	x
albic	-	-	-	-	x	-	-	-	-	-	-	-	-	-
Textural differentiation														
luvic	-	-	-	-	x	-	-	-	-	-	-	-	-	-
vertic	-	-	-	-	-	-	-	-	-	-	-	-	x	x
Salts														
solodic	-	-	-	-	-	-	-	x	-	-	-	-	-	-
thionic	-	-	-	x	-	-	-	-	-	-	-	-	-	-
calcaric	-	-	-	-	-	x	-	-	-	-	-	-	-	-
Humus content and type														
mollic	-	-	-	-	-	-	-	x	-	-	-	-	-	-
humic	-	-	-	-	-	-	-	-	-	-	-	x	-	-
Clay mineralogy														
cambic	-	-	-	-	x	-	-	-	-	-	-	-	-	-
ferric	-	-	-	-	-	-	-	-	-	-	-	x	x	-
ferralic	-	-	-	-	x	-	-	-	-	-	-	-	-	x
acric	-	-	-	-	-	-	x	-	-	-	-	-	-	-
Fertility														
dystric	x	x	-	x	-	-	-	-	-	-	x	-	-	x
eutric	-	x	-	x	-	x	-	-	-	-	-	-	-	x
Colour														
pellic	-	-	x	-	-	-	-	-	-	-	-	-	-	-
rhodic	-	-	-	-	-	-	x	-	-	-	-	-	-	-
chromic	-	-	x	-	-	-	-	-	-	-	-	x[1]	x	-
Other														
orthic	-	-	-	-	-	-	-	-	x	-	-	x	x	-
haplic	-	-	-	-	-	-	-	-	-	x	-	-	-	-

x[1] Kenyan Concept

(a) *Histosols*

Both the dystric and the eutric subgroup occur in some Tidal Swamps (TA), mainly constituted by fibric (Tropofibrists) or hemic (Tropohemists) materia the latter sometimes having sulfidic materials within 1 m of the surface (Sulfihemists).

(b) *Lithosols*

Two units occur: HX2C and P2L11P. They are further classified as dystric and eutric respectively. Soil Taxonomy classifies such soils as lithic Ustropepts. Some mapping units have soils which also fall in lithic phases (HX1C, USlp, UTcl, UT2c3P, UT2C, P2WA).

(c) *Vertisols*

These soils consist of heavy, cracking clays. They can be strongly calcareous. Both subgroups occur within the Kilifi Area, the chromic dominating over the pellic. Chromic Vertisols are widespread in the Lutsangani upland (UT2-units). Vertisols further occur in units HSKC, P2Ec, and AAc. In case not all requirements of a Vertisol are met, the soil belongs to the vertic subgroup of other major classification units (vertic Luvisols and Cambisols).

According to Soil Taxonomy, Vertisols do not have lithic contact. Consequently, in case shallow coherent rock is present (UT2c3P and parts of UT2C), soils classify as lithic vertic Ustropepts.

(d) *Fluvisols*

They occur in two major physiographic units: Floodplains and Tidal Flats and Swamps. In the Floodplains occur the units AAx (predominantly eutric), USDA: typic Ustifluvent and AAc (predominantly distric), USDA: aquic Ustifluvent. In the Tidal Flats and Swamps occur the units TAx (USDA: typic Malaquepts, Hydraquents), eutric, saline-sodic phase, and TAc (USDA: Sulfaquepts, typic Sulfaquents), thionic, saline-sodic phase, potential acid sulphate soils.

(e) *Arenosols*

Extensive units such as USKf, USs1 (albic and luvic), and USs3, UOf, UElml and P2Eml (ferralic and cambic) predominantly consist of well drained, highly porous, deep, coarse-textured Arenosols. The bleached E-horizon is specific for the albic Arenosols, banded layers of clay illuvation for the luvic Arenosols and low CEC of the clay fraction for ferralic Arenosols.

The USDA-classification does not give complete satisfaction. Albic and ferralic Arenosols both classify as ustoxic Quartzipsamments, part of the luvic Arenosols classify as alfic Ustipsamments.

(f) *Regosols*

These are of minor importance. Calcaric Regosols occur in unit P2WA (lithic Ustorthents) and in unit DE1 (typic Ustipsamments); eutric Regosols are common in parts of Minor Scarp-unit HX1C.

(g) *Ferralsols*

These occur in some of the UE-units of the Pingilikani upland. Intergrades to Luvisols and Acrisols occur in units P2E12 and 3, and unit ULc2 respectively. These classifications are discussed in section 3.4.3.4 (Kenya Concept). Rhodic Ferralsols dominate, whereas acric Ferralsols form a minority in unit UE112. USDA-classification: typic and ultic Haplustox for UEm1, UE111 and UE112; moreover, typic Acrustox in UE112.

(h) *Planosols*

These occur in the Bamba plain (units P1O1 and BAc3). The solodic and mollic Planosols are imperfectly drained with a pronounced transition between a relatively light-textured surface soil, part of which is whitish (albic E horizon) and a heavy-textured, compact B horizon. Solodic Planosols have more than 6% sodium in the exchange complex of the slowly permeable layer; in places this layer meets the requirements of a natric B horizon (more than 15% sodium). USDA-classification: typic Natrustalfs, udollic Albaqualfs (solodic Planosols); typic Argialbolls (mollic Planosols).

(i) *Solonetz*

These soils occur in units UOc2p (gleyic), and P1O1 (gleyic and orthic). They always meet the requirements of a natric B horizon. USDA-classification: typic and aquic Natrustalfs. Salinity and sodicity symptoms also occur in the Luvisols of units UOc2p and P1O1, in the subsoils of some UT- and BA-units, and in units TAx and TAc (sodic and saline-sodic phase).

(j) *Dystric Nitosols*

These occur in the UL-units. Shiny ped faces are the remarkable features of these dark red soils which clearly separates them from very deep sandy Acrisols of some P2E-units, that lack these 'nitic' properties. The KSS-interpretation of the Nitosol is dealt with in section 3.4.3.4. In Soil Taxonomy these soils classify as 'rhodic' or 'rhodic-oxic' Paleustults.

(k) *Acrisols*

These soils are strongly weathered and leached ABC-soils, and widespread in the Kilifi Area. The following subgroups occur:

- gleyic (units USKA2, VXA)
- orthic (units USc1, ULc1, UOc1)
- ferric (unit USc1, inclusions)
- orthic (units USK1, USs3, USc1, UOf, UOc1)

- chromic* Acrisols occur in units ULc1.
- ferral-chromic Acrisols (Kenya Concept) are found in unit ULc2; in the FAO/UNESCO Legend the concept of 'ferric' is wider than the Kenyan Concept (section 3.4.3.4). The equivalents in Soil Taxonomy are: typic, epiaquic and oxic Haplustults, (typic, oxic, arenic and rhodic-oxic) Paleustults and Rhodustults. The subgroups in brackets are not official.

(l) *Luvisols*

These soils are widespread in the Kilifi Area. Apart from five FAO/UNESCO subgroups, three "Kenyan Concept" subgroups were recognized as well. Gleyic Luvisols are found in parts of units USKA2, USc2, P2WA, BAc1 and BAc2. Moreover, they occur in units UOc2p and P1O1, partly sodic phase, and in unit P1Of, partly with a fragipan.

In Soil Taxonomy the soils key out as aquic and aquultic Paleustalfs (if the argillic horizon is sufficiently thick), aquic, aquultic, arenic (P1Of), aridic (P1O1) Haplustalfs, typic Tropaqualfs (parts of BAc2) and aquic Natrustalfs (sodic phase of P1O1 and UOc2p). Vertic Luvisols (vertic Haplustalfs and udertic Paleustalfs) only partly meet the requirements of a Vertisol (UTlc). Verti-gleyic Luvisols (Kenyan Concept) are found in units UOc2p and P2Ec (udertic Haplustalfs and Paleustalfs). These soils have both vertic and hydromorphic properties.

Ferric, chromic and orthic Luvisols interfere somewhat. If coarse mottles or nodules are present, the Luvisols are ferric in both the FAO/UNESCO and the KSS Legend. If the soils only have a CEC that does not exceed 24 meq/100 g clay, they are considered ferric in the FAO/UNESCO Legend only. In the KSS Legend these soils are orthic Luvisols, unless they are red enough to become chromic Luvisols. The definition of 'red' also differs for the two classification systems, so a chromic Luvisol in the FAO/UNESCO system can be an orthic Luvisol in the KSS Legend. These discrepancies are discussed in section 3.4.3.4.

The soils occur in the following mapping units:
- ferric: units USKA1, UOc2p, P2L12p (oxic Haplustalfs, Paleustalfs and Rhodustalfs);
- chromic: units USK1, US1p (lithic phase), USc1, UOc1, UE111, UE21, P2E11 (rhodic and oxic Paleustalfs, lithic and typic Rhodustalfs);
- orthic: units HSKC, US1p (lithic phase), USc2, UO1, P1O1(udic and lithic Haplustalfs, udic and ultic Paleustalfs).

KSS-proposed intergrades that occur in the Kilifi Area are:
- ferral-chromic* Luvisols (ULc2, oxic Rhodustalfs);
- ferral-orthic* Luvisols (P2E12, P2E13, oxic and udic Paleustalfs).

(m) *Cambisols*

These are slightly weathered soils that occur rather frequently in the Kilifi Area. Five subgroups were recognized:

- gleyic (units UT2clp, VXC, BAc2),
- vertic (units HX1C, UT2clp, UT2C, P2Lcp, AAc, VXC),
- ferralic (units P2Em3, P2Em4, P2Ll1P, P2Ll2p),
- dystric (units P2Em3, P2Em4),
- eutric (unit HX1C).

In the USDA Legend the soils classify as Ustropepts. At subgroup level, aquic and fluventic correspond with FAO's gleyic, oxic with FAO's ferralic and typic with FAO's dystric and eutric. The vertic subgroup occurs in both legends. Lithic phase (FAO/UNESCO) coincides with lithic and lithic vertic Ustropepts (USDA).

3.4.3.3 Phases

Phases are subdivisions of soil units based on characteristics which are significant to the use or management of the land but are not diagnostic for the separation of soil units themselves (FAO/Unesco, 1974).

Five phases were recognized in the Kilifi Area:

- lithic phase: continuous coherent and hard rock within 50 cm of the surface;
- paralithic phase: underlying material has a hardness by Mohr's scale of less than 3;
- fragipan phase: upper level of the fragipan within 100 cm of the surface (a fragipan is a slowly permeable, loamy subsurface horizon which has a high bulk density relative to the horizons above it, is hard or very hard and seemingly cemented when dry and weakly brittle when moist);
- saline phase: electric conductivity exceeds 4 mmhos/cm within 100 cm of the surface;
- sodic phase: exchangeable sodium percentage exceeds 6 within 100 cm of the surface.

3.4.3.4 Kenyan Concept

The use of the FAO/UNESCO Legend terminology for soil surveys of more detail than the legend was intended for, has revealed the need for greater detail in the existing classification framework. This has led to adaptations of the first and second level terminology, as well as the introduction of the 'unit' (third level terminology). The deviations from and the additions to the FAO/UNESCO classification system as applied by the Kenya Soil Survey are known as the 'Kenyan Concept' (Siderius & Van der Pouw, 1980). They were first applied in the 'Exploratory Soil Map of Kenya' (Sombroek et al., 1982) and 'Soils of the Kisii Area' (Wielemaker & Boxem, 1982).

The following deviations are of particular relevance for the Kilifi Area:

- intergrades between Great Groups,
- an adjusted Lithosol and Nitosol concept,

- new subgroups at the second level of classification,
- 'units' at the third level,
- diagnostic properties.

Intergrades between Great Groups

In some parts of the Kilifi Area soils occur that do not satisfy the existing first level definitions (particularly units UL, P2E12, P2E13). These soils are intergrades between two Great Groups, viz. Luvisols/ Acrisols on the one hand and Ferralsols on the other hand. The soils possess properties that refer to both an argillic and an oxic B horizon: there exists an increase in clay content with depth, high enough to meet the requirements of an argillic horizon, but outspoken signs such as cutans are not or hardly visible. At the same time the soil meets requirements of an oxic horizon, which, however, are not fully met either. An exhaustive list of criteria is given by Siderius and Van der Pouw (1980, p. 4-5).

Two intergrades have been recognized in the Kilifi Area: the FERRAL-chromic* ACRISOLS and the FERRAL-orthic LUVISOLS.

Lithosols

The depth limitation for Lithosols (hard rock within 10 cm of the surface) was found to be too narrow for Kenya conditions and has been set at 25 cm. In addition, Lithosols can be subdivided into dystric (unit HX2C) and eutric (unit P2L1P) subgroups if necessary.

Nitosols

The present definition of the Nitosols in the FAO/UNESCO Legend would have given a considerable extend of dystric Nitosols in the Kilifi Area. Many sandy soils with a slight increase in clay content meet the requirements of an argillic horizon. The thickness requirement is also met. Shiny ped faces, however, the features that gave the Nitosol its name, do not occur at all in these soils. Therefore, a nitic B horizon is proposed by Siderius & Van der Pouw (1980, p. 18-19), whereupon only the sandy clay soils of the ULc2-unit remain Nitosols.

New subgroups at the second level of classification

The meaning of one second level term has been altered in order to make it more meaningful to soils occurring in the Kilifi Area. To differentiate between the brown and red Cambisols and Luvisols, it was felt necessary to use the redefinition of red: the rubbed moist soil has a hue of 5YR and a chroma of more than 4, or a hue redder than 5YR. It is in this context that the chromic Acrisols were introduced. Chromic Acrisols are Acrisols with a red B horizon. The chromic subgroup keys out after the ferric and before the orthic. Intergrades with Ferralsols (FERRAL-chromic ACRISOLS) occur in unit ULc2, 'genuine' chromic Acrisols occur mainly in unit ULc1.

Units at the third level

In the FAO/UNESCO Legend no unit level is recognized. However, the necessity for this category became apparent during the various soil surveys in Kenya. The unit-concept has been applied only once in the Kilifi Area. Because of both vertic and hydromorphic properties occur, the soils of unit P2Ec have been named verti-gleyic Luvisols.

Diagnostic properties

The definition of ferric properties is slightly altered. The original concept of ferric is used in connection with Luvisols and Acrisols, showing one or more of the following:

1. many coarse mottles with hues redder than 7.5YR or chromas more than 5, or both,
2. discrete nodules, up to 2 cm in diameter, the exteriors of the nodules being enriched and weakly cemented or indurated with iron and having redder hues or stronger chromas than the interiors,
3. a cation exchange capacity (from NH_4Cl) of less than 24 me/100 g (= 240 mmol/kg) clay in at least a subhorizon of the argillic B horizon.

According to the Kenyan Concept, the term ferric is used exclusively for the features mentioned under 1 and 2, and does not embrace the CEC requirement.

Proposed alterations

Proposed alterations, which deserve approval after the reconnaissance survey of the Kilifi Area are:

- the narrowing of the concept of the mollic A horizon,
- the definition of a nitic B horizon,
- the separation of vertic (turning and cracking) from rimnic properties (cracking only).

3.5 SOIL FERTILITY

3.5.1 *Introduction*

Fertility of the soils of the Kilifi Area has been evaluated by means of field trials and soil and plant analysis. The fertility assessment has been carried out according to two systems:

- the Quantitative Evaluation of the Fertility of Tropical Soils (QUEFTS), a modification of the Kisii system (Guiking et al., 1982, Janssen et al., 1986);
- the Fertility Capability Classification (Buol et al., 1975).

Table 9. Levels of nutrient availability, corresponding maize yields, and uptake of N, P and K.

Availability level	Yield (tons/ha)	Uptake (kg/ha) N	P	K
1	> 5.0	> 120	> 16	> 120
2	2.5 -5.0	61-120	9-16	71-120
3	1.25-2.5	30- 60	5-8	40- 70
4	< 1.25	< 30	< 5	< 40

3.5.2 *The QUEFTS system*

The Quantitative Evaluation of the Fertility of Tropical Soils (QUEFTS) is based on the interrelations between:

- the uptake of N, P and K by a maize crop during one growing season;
- the corresponding grain yield levels;
- chemical soil properties measured in samples of unmanured soil and suited as N, P and K availability indices.

For each of the nutrients of N, P and K, four levels of availability were distinguished corresponding with maize yield levels as indicated in Table 9. In the Kilifi Area, availability level 1 does not occur; this level has yet been mentioned in Table 9 for the sake of completeness.

The relationship between yield and N- and P-withdrawal for the Kilifi Area appears to fit well in the already established range for the Kisii Area and parts of Surinam (Janssen, unpublished data). Figures 34 and 35 show between which ranges this relationship exists.

From these figures, the following conclusions can be drawn.

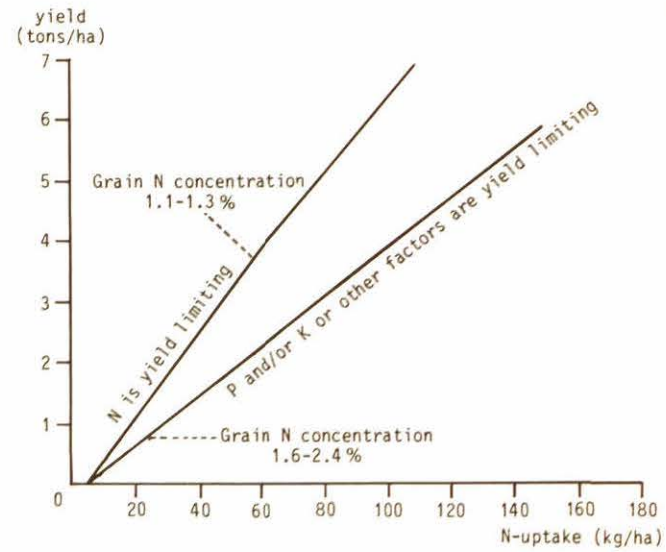


Fig. 34. Relation between total N uptake and maize grain yield.

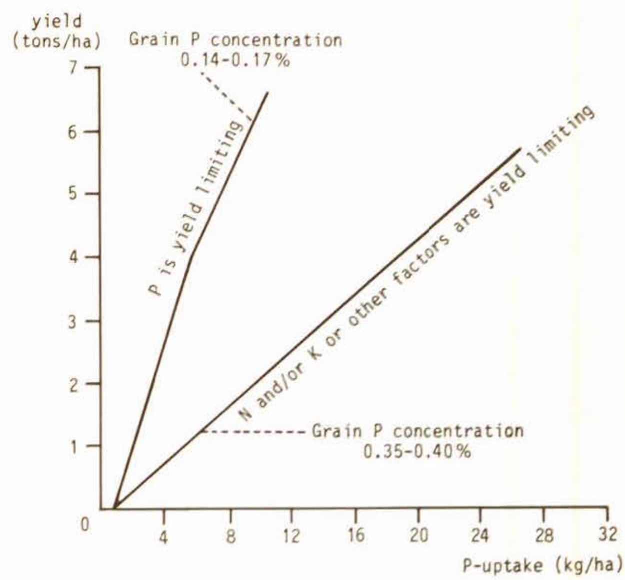


Fig. 35. Relation between total P uptake and maize grain yield.

Each kg N withdrawn from the soil coincides with a 35-65 kg increase of grain yield if:

a. the ratio yield/uptake approximates 65, N-uptake is the main yield limiting factor; grain N concentration is 1.1-1.3%,

b. the ratio yield/uptake approximates 35, N-uptake is relatively excessive: other factors than N are limiting; grain N concentration is 1.6-2.4%.

Each kg P withdrawn from the soil coincides with a 200-600 kg increase of grain yield if:

a. the yield/uptake ratio approximates 600, P-uptake is the main yield limiting factor; grain P concentration is 0.14-0.17%,

b. the yield/uptake ratio approximates 200, P-uptake is relatively excessive: other factors than P are limiting; grain P concentration is 0.35-0.40%.

Moreover, each kg K withdrawn from the soil appeares to coincide with a 20-100 kg increase of grain yield.

The availability levels mentioned in Table 9 are related to chemical properties of topsoils (0-20 cm) as shown in Table 10. The appraisal of a chemical property in terms of nutrient availability depends not just on the value of that property but also on values of other properties. Mineralization of nitrogen, for instance, is governed by, amongst others, pH. In Figure 36, it is shown that at a similar P-Olsen, more P was taken up by maize in the Kisii Area than in the Kilifi Area. Two factors account for this:

- higher N availability in the Kisii Area than in the Kilifi Area (N availability levels 1 and 2 versus 3 and 4),
- higher amounts of total phosphorus in the Kisii soils.

It is impossible to determine which of the two factors is more important, since organic C (or organic N) proved to be rather closely correlated with

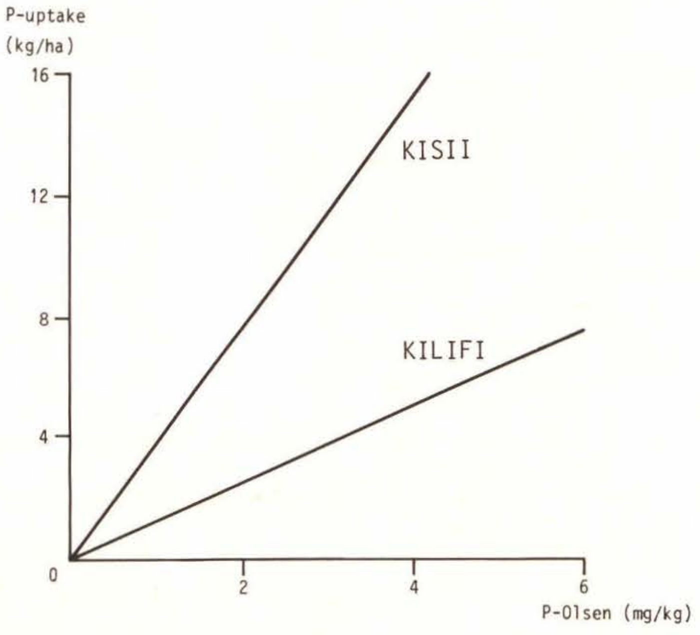


Fig. 36. Relation between content of P-Olsen and P uptake for the Kisii and the Kilifi Area. For N availability see Table 3.5.1.

total phosphorus. Whatever the reason, P-Olsen has to be valued lower in Kilifi than in Kisii. The organic C content proved practical as a second criterion for the valuation of P-Olsen and also of exchangeable K.

The soils of the various mapping units can be grouped according to the nutrient availability levels. Although 36 combinations (3 x 4 x 3) of N-P-K availability levels could be made, only 10 appeared to occur in the Kilifi Area. These 10 combinations and their final fertility class are shown in Table 11. This table also summarizes the diagnostic properties given in Table 10 and two additional properties (CEC and total phosphorus).

Table 10. Ranking of values of diagnostic properties of topsoil (0-20 cm) in terms of nutrient availability in relation to other soil properties for the soils of the Kilifi Area.

Diagnostic property	Range of values	Other conditions	Nutrient availability class
organic carbon[1]	18-28	pH-H_2O > 5.5	2
(g/kg)	9-17	pH-H_2O > 5.5	3
	< 9		4
P-Olsen[2]	> 6	org.C ≦ 28	2
(mg/kg P)	4-6	org.C ≦ 28	3
	≦ 3	org.C ≦ 28	3
	≦ 3	org.C ≦ 17	4
exchangeable K	> 6		2
(mmol/kg K)	2-6	org.C ≦ 28	3
	< 2	org.C ≦ 28	4

1. Organic N can be used instead of organic C; the relationship is organic N = 0.1 * organic C
   Many soils, however, have a C/N-ratio which exceeds 10.
2. For P-Mehlich the corresponding ranges (mg/kg P) are: > 18, 10-18, ≧ 9.

Table 11. Fertility classes for the Kilifi Area.

Diagnostic properties				Additional properties		Combinations of nutrition avail. class (Table 10)			Fert. class
org.C (g/kg)	P-Olsen[1] (mg/kg)	exch.K (mmol/kg)	pH-H_2O (-)	CEC(pH8.2) (mmol/kg)	P-total (mg/kg)	N	P	K	
> 17	> 6	> 6	> 5.5	> 100	> 300	2	2	2	C1
> 8	> 6	> 6	> 5.5	> 100	> 300	3	2	2	C2
> 8	> 3	> 6	> 5.0	> 100	> 300	3	3	2	D2
> 8	> 3	> 2	> 5.0	> 100	> 300	3	3	3	D3
≦ 8	> 6	≧ 2	> 5.0	> 50	> 200	4	2	3	E1
≦ 8	> 6	< 2	> 5.0	> 50	> 300	4	2	4	E1
≦ 8	> 3	≧ 2	> 5.0	> 50	> 300	4	3	3	E2
≦ 8	> 3	< 2	> 5.0	> 50	> 200	4	3	4	E2
≦ 8	≦ 3	≧ 2	> 5.0	< 50	< 200	4	4	3	E3
≦ 8	≦ 3	< 2	> 5.0	< 50	< 200	4	4	4	E3

[1] The corresponding values for P-Mehlich are 18 and 9.

Table 12. Relationship between fertility class, nutrient uptake and maize yield levels in the Kilifi Area. Maize varieties are coast composite and pioneer Hybrid.

Fertility class (Table 11)	Nutrient uptake (kg/ha)			Maize yield level (kg/ha)
	N	P	K	
C1	75	10	90	2750
C2	55	9	80	2250
D2	40	7	70	1600
D3	35	6	50	1300
E1	25	8	40	1000
E2	20	5	30	700
E3	10	3	20	400

To belong to a fertility class, a soil should meet the requirements of all four diagnostic properties. The additional properties will generally but not necessarily confirm the soil fertility classification. The distinguishing criterion between class C and D is availability of P (levels 2 and 3 respectively); between class D and E it is availability of N (levels 3 and 4 respectively). The subdivisions of class C, D and E are based on availability of N, K and P respectively.

Table 12 shows the relationship fertility classes, nutrient uptake and maize yield levels. It should be stressed that the indicated yields and nutrient uptake levels can only be obtained under good crop husbandry; i.e. proper time and spacing of planting, weed control and control of pests and diseases.

3.5.3 *Fertility Capability Classification*

A relatively recent concept to classify topsoil physical performance and fertility is known as the Fertility Capability Classification (Buol et al., 1975; Sanchez et al., 1982). Since it involves soil properties which are relatively permanent and which have a relatively low spatial variability the system is appropriate for classification at scales of 1 : 100 000, such as the reconnaissance map of the Kilifi Area.

It should be noted that recommendations as to fertilizer use should follow from field trials and not just from the FCC, which provides insufficient detail for this purpose. The FCC system provides more qualitative and less quantitative information than the QUEFTS system. A key to the FCC is given in the following. The system consists of three categorical levels: type (topsoil texture), substrata type (subsoil texture), and a set of modifiers.

Type (texture of surface 20 cm).
S=sandy topsoils: loamy sand and sand;
L=loamy topsoils: <35% clay but not loamy sand and sand;
C=clayey topsoils: >35% clay;
O=organic soils: >30% O.M. to a depth of 50 cm or more.

Substrata type (texture of subsoil): are used only if there is a marked textural change from the surface.
S=sandy subsoil: texture as in type S;
L=loamy subsoil: texture as in type L;
C=clayey subsoil: texture as in type C;
R=rock or other hard root-restricting layer.

Modifiers
g= (gley): soil or mottles < 2 chroma within 60 cm of the soil surface and below all A horizons, or soil saturated with water for > 60 days in most years;
e= (low cation exchange capacity): applies only to plow layer or surface 20 cm, whichever is shallower: CEC < 40 mmol/kg soil by Σ bases + KCI-extractable Al + H (effective CEC), or CEC < 100 mmol/kg soil at pH 8.2;
h= (acid): 10-60% Al-saturation of the effective CEC within 50 cm of soil surface, or pH in 1:1 H_2O between 5.0 and 5.5;
v= (vertisol): very sticky and plastic clay: > 50% of 2:1 expanding clays;
k= (low K reserves): < 10% weatherable minerals in silt and sand fraction within 50 cm of the soil surface, or exchangeable K < 2 mmol/kg;
b= (basic reaction): free carbonate within 50 cm of soil surface (effervescence with HCl), or pH > 7.3;
s= (salinity): ≧ 4 mS of electrical conductivity of saturated extract at 25°C within 1 m of the soil surface;
n= (natric): ≧ 15% Na-saturation of CEC within 50 cm of the soil surface;
c= (cat clay): pH in 1:1 H_2O is < 3.5 after drying and jarosite mottles are present within 60 cm of the soil surface;
'= (gravel): a prime (') denotes 15-35% gravel or coarser (> 2 mm) particles by volume to any type or substrata type texture (example: S'L = gravelly sand over loamy; SL'= sandy over gravelly loam).

Examples:
Sek = sandy soil throughout; low CEC and low K-reserve.
(L)C gen = clayey soil, in places loamy surface soil, imperfect drainage, low CEC and high sodium saturation.
L(R)(k)b = loamy soil, in places overlying hard rock within 1 m, in places low K-reserves, high pH (> 7.3).

Table 13. Diagnostic and additional properties of soil mapping unit(s).

Mapping unit		Diagnostic properties					Additional properties	
	number of samples	organic carbon (g/kg)	P-Olsen (mg/kg)	P-Mehlich (mg/kg)	(exch.K) (mmol/kg)	$pH\text{-}H_2O$	CEC(pH 8.2) (mmol/kg)	P-total (mg/kg)
USKf	10	4- 8	10	10-22	1- 3	5.5-6.0	30- 60	n.d
USKl	2	7	n.d.	8-28	2- 4	6.3-7.0	60-100	
USKA1	9	7-10	3-7	7-20	3- 5	5.8-6.2	40- 60	250-350
USKA2 1,2,3	2	8-15	3	20-23	1- 6	5.5-5.8	100	
USs	8	3- 7	n.d.	3-10	1- 4	5.0-6.0	10- 40	n.d.
UScl	10	5- 9	3-5	5-10	3- 4	6.0-6.5	40-100	150-250
ULcl,2	8	9-16	4-7	5-20	7-13	6.2-6.8	100-140	300-450
UOf	4	5- 7	18	14-98	3- 5	6.0-6.2	40	n.d.
UOl, UOcl	4	7-12	30	3-10	4- 8	5.8-6.3	100	250-500
UOc2p	4	4- 8		4-54	2- 5	5.7-6.2	80-100	n.d.
UT2	23	15-21	4-15	15-30	6-15	5.8-6.8	220-350	300-550
UE1	7	3- 5	4	12-18	<1- 3	5.8-6.2	30- 60	100-150
P10	3	4- 8	n.d.	20-30	2- 6	6.0-7.5	100-200	n.d.
P2Em	10	3- 5	8	8-30	2- 4	6.5-7.2	20- 60	100-200
P2El	22	4- 7	4-12	6-25	2- 5	6.2-7.0	50-100	100-200
P2Ll	6	5- 7	4	10-16	2- 6	6.5-8.0	70-120	n.d.
BAcl,2	7	6- 9	5	8-14	2- 6	5.5-7.0	50-150	150
DE1,2	2	3- 6	n.d.	18-22	<1	6.5-8.0	20- 30	n.d.

3.5.4 *Fertility appraisal of the various land mapping units*

The diagnostic and additional properties of soil mapping units are summarized in Table 13.

The fertility appraisal of these units is given in Table 14. Most soils fall in more than one fertility class, because of the relatively wide ranges of soil properties. Yet, a ranking of the soil units by their fertility is possible (Table 15). This table also indicates a relationship between both fertility evaluating systems:

- class C corresponds with high-activity clay soils;
- class D corresponds with low-activity clay soils and loamy soils;
- class E corresponds with sandy and sandy-loamy soils, with e (low CEC) and k (low K reserves) modifiers.

The subdivision in class E of the QUEFTS system, which is mainly based on P availability cannot be indicated in the FCC system.

Appendix 5D shows a soil fertility map based on a combination of both systems.

Table 14. Fertility appraisal of soil mapping units according to both evaluation systems.

Soil mapping unit	Nutrient availability class			Fertility class	Fertility capability class[1]
	N	P	K	(section 3.5.2)	(section 3.5.3)
USKf	4	2	4	E1	S ek
USKl	4	2	3	E1	SL e
USKA1	3/4	3	3	D3 + E2	SLe + Ce
USKA2	3	3	3/4	D3	L(C)ge(k)
USs 1,2,3	4	4	3/4	E3	S(L)e(h)k
UScl	4	4	3	E3	Le + (S)Ce
ULc1,2	3	3	2	D2	(L)C
UOf	4	2	3	E1	Se
UOl, UOcl	3/4	3/4	3	D3-E3	(S)Le + LCe
UOc2p	4	3	3	E2	(L)Cgen + (L)C e(k)
UT2	2/3	2/3	2	C1-C2	C/C'/C'Rv(b) + Cgv
UE	4	3	4	E2	S(L)ek
P1O	4	2	3	E1	Se + SLge(k,b)+ (S)C(g)en
P2Em	4	3	3	E2	S(L)e(k,b)
P2El	4	2/3	3	E1-E2	SL(e,k)+LCg(e,k)
P2Ll	4	3	3	E2	L(R)(k)b + SLe(k,b)
BAcl,2	4	3	3	E2	(S)Lg(e,b) + Cg
DEl,2	4	2	4	E1	S ek (b)
Small units:					
UTlC, P2WA, P2Ec, P2Lcp, VXC, AAc					C (g,v,k,b)
HSKC, HX 1C, HX 2C					LC v(b)/(C)R
USlp, USc2, VXA					(S)L(C) (g)e(k)
BAc3					SCges (k,n)
TAo, TAc, TAx					Cgsnc + Og(k,b)n

[1] FCC-terms in parentheses indicate non-uniformity of the particular characteristic in the soil mapping unit.

3.5.5 *General discussion on the fertility of the soils of the Kilifi Area*

From Table 14, it becomes clear that N-deficiency is the most important soil fertility constraint in the Kilifi Area (strong predominance of N availability class 4).

Table 15 shows that the UT-units have the highest fertility (class C). The UL-units rank second (class D2). Part of the USKA- and UO-units are the remaining units that have soils with an N availability class 3 (fertility class D3). Low nitrogen but reasonable phosphorus availability was recorded on soils of units USKf, USKl, P1O and DE (class E1).
The soils of most UO-units, the UE-units and most P2Em-, P2El and P2Ll-units rank class E2. Lowest fertility was observed in the soils developed on Mazeras sandstones (units USs and USc: fertility class E3).

Many soils, but particularly those of the UO- and P1O-units show quite irregular P-Mehlich and P-Olsen values. It is unclear whether this is to be attributed to the soils origin (bay deposits) or to a random distribution of cattle dung and slurry.

Although availability of K is not high in most soils, yields are not limited by K deficiency as long as no N or NP fertilizers are applied. Once it has become common practice to use these fertilizers, the need for K fertilizers will arise.

CEC (pH 8.2) and total phosphorus have been shown in Table 13 as additional properties. The data show highest cation retention capacity and phosphorus supplying power in the soils of the UT-units and lowest in those of the USs-, UE- and P2Em-units.

Fertility of the individual mapping units is treated as a land quality 'nutrient availability' in the land evaluation (section 4.2.2).

Table 15. Soil mapping units grouped according to soil fertility classes of the *QUEFTS* and the FCC system.

Fertility class		Soil mapping units
QUEFTS	FCC	
C	C, Cgv	UT
D	(L)C	UL
E1	Se(k), SLe	USK, parts of UO, P1O and P2E
E2	Se(k), SLe	UE, P2L, BAc1,2, part of P2E
E3	Se(k), SLe	USs, USc

3.6 EROSION AND LAND DEGRADATION

3.6.1 *General*

The vulnerability of soils to erosion depends on: rainfall erosivity, soil erodibility, slope length and angle, crop cover and management and soil conservation practises. It is usually referred to as *erosion hazard* (Hudson, 1971). Crop and management practices, however, can change markedly with time, and therefore a more inherent characteristic of the potential of soils to erode is given by the rainfall intensity, the soil erodibility and the slope length and angle, the combined effects of which are referred to as the *erosion susceptibility*. Thus, erosion susceptibility provides an indication of the soil loss likely to be expected from bare land.

Erosion can occur as superficial sheet and rill erosion, which is easily obliterated by tillage, or as deep gully erosion. In most soils a certain degree of annual soil loss does not significantly affect productivity and this is called *permissable* or *tolerable soil loss.*

Besides hazard and susceptibility for the loss of soil by erosion, there are related processes causing deterioration of the soil for sustained production, e.g. soil compaction, crust formation, salinization, removal of soluble nutrients, fixation etc. The term *soil degradation* is commonly used for these processes.

The susceptibility to erosion of the soils of the survey area was estimated by combining the effects of the land characteristics related to climate (erosivity), soil (erodibility) and relief. This was done by using the Universal Soil Loss Equation and the soil erodibility nomograph (Wischmeier et al., 1971). Soil information is gathered from selected sites and results were compared with field observations on the spot and rain simulator trials on bare soil (Van Campen, 1983). In a small area near Kaloleni, Gachene (1982) made a detailed assessment of the erosion susceptibility of soils developed on sandstones (Mariakani Formation). Results of both studies were used to establish the rating for the land quality 'resistance to erosion' (section 4.2.8). Appendix 5E shows the erosion susceptibility of the soils of the Kilifi Area.

3.6.2 *Rainfall erosivity*

Erosivity is determined by amount of rainfall and rainfall intensity. Average annual rainfall ranges from about 1200 mm at Mtwapa to 650 mm near Bamba. Amount and distribution vary considerably from year to year (section 1.2). In general, intensity is not recorded in Kenya, but the Project-recorders near Kilifi and Mitangoni recorded intensities up to 60 mm/hr between 1979 and 1983. The question arises which threshold value induces significant erosion. Hudson (1971) gives a figure of 25 mm/hour, based on studies in Zimbabwe. This value also proved appropriate in Tanzania (Rapp et al., 1972) and in Malaysia (Morgan, 1979).

Rainfall erosivity is often expressed as an index based on the kinetic energy of rain. Wischmeier's index $R = EI_{30}/100$, a compound index of kinetic energy and the maximum 30-minute rainfall intensity is used most widely. There are no sufficient data to estimate R for the Kilifi Area, but Roose (1975) has statistically proved that in West Africa R can be satisfactorily approximated by 0.5 times the mean annual rainfall. In fact this means that Wischmeier's erosivity index R ranges from about 600 near the Coast to 300 in the northwestern corner of the Kilifi Area.

3.6.3 *Soil erodibility*

The susceptibility of a soil to detachment and transport by rainsplash and runoff is called 'erodibility'. It varies with a large number of soil characteristics, such as aggregate stability, shear strength, infiltration rate and organic matter content.

Wischmeier et al. (1971) have designed a nomograph for computing the soil erodibility factor K in the Universal Soil Loss Equation. Required data are: percentage of sand (0.1-2 mm), percentage of silt plus very fine sand (0.002-0.1 mm), percentage of organic matter, soil structure and permeability.

According to Roose (1975), Wischmeier's nomograph (and in fact his whole Universal Soil Loss Equation) can well be applied to tropical soils of a ferralitic and/or ferruginous nature, but not to Vertisols. This means that it can be used to estimate and compare soil erodibility in the Kilifi Area, except for the soils of the Mtomkuu Formation (UT-units) and part of the soils of the Bay deposits (UO-, P1O-units). In those areas erodibility was mainly estimated with the help of a rain simulator and sediment traps, by field observations after rainstorms and by laboratory tests on aggregate

Table 16. Assesment of soil erodibility of the major soil mapping units in the Coastal Uplands.

Group of soil mapping units	Erodibility (K-value)
USK	0.25-0.48
USs	0.13-0.48
UL	0.13-0.36
UT	0.25-0.36
UE	0.13-0.36
UO	0.25-0.48

stability (Smaling, 1981; Van Campen, 1983).

Van Campen (1983) compared the K-values, obtained by nomograph computations of rain simulator measurements, with those of the current KSS rating system for erodibility. He concludes that the nomograph results are more reliable than the KSS-rates, because the first proved to be positively correlated to the simulator results whereas the latter were not.

Assessment of the soil erodibility of the major soil mapping units in the Coastal Uplands is given in Table 16. It follows from Table 16, that soil erodibility in the Coastal Uplands is in general moderate or less. Strongly erodible soils are limited to most UO-units and scattered parts of the USK-and USs-units

3.6.4 *Topography*

Erosion normally increases with increased slope steepness and slope length, as a result of enhanced velocity and volume of surface runoff. Besides, on sloping land more soil is splashed downslope than upslope. Changes in slope gradient, smooth or abrupt, and also microtopography have a marked influence on surface runoff. The general effect of slope length and gradient has been subject of study by many authors and can therefore be computed and rated.

During the mapping of the soils of the Coastal Uplands, slope steepness and average slope length have been recorded or estimated. Slope steepness has been indicated on the reconnaissance soil map (Appendix 1). Much land falls in classes A, B, or C (0-8%). Parts of units USc, UO, UT and UL fall in classes DE and EF (up to 25%). The Mtomkuu Formation (UT) has a very high drainage density and thus comprises little land of slope class A or B.

3.6.5 *Vegetal cover*

It is generally recognized and accepted that the effect of vegetal cover overrules all other factors causing erosion. The major role of vegetation is the interception of rain drops. Their energy is dissipated by the plants rather than imparted to the soil.

Vegetation that directly covers the soil reduces the velocity of surface runoff. Moreover, a root system, organic matter and biological activity in a vegetated area opens up the soil and increases its infiltration capacity. Hence, soil erodibility is reduced.

If the land is put to agricultural use, it is of great importance that the crop cover is adequate in periods of sustained rainfall. In this respect annual field crops such as maize and cowpeas are unfavourable compared to perennial crops such as cashew and to a lesser extent coconut. Cropping practices such as intercropping and 'multi-storey'- cropping as well as the application of e.g. straw and trash mulch may well reduce soil erosion.

The Kilifi Area is in general well covered by vegetation. About 50% of the Coastal Uplands is used for small scale farming with much secondary growth on fallow fields. Cultivated fields are small and trash of maize and other crops is often left on the surface. Grass, branches and stubbles are stacked up and burned, leaving the soil bare until the first rains. The most vulnerable period is in the time of land clearing just before the rainy seasons (March-April and August-September). Erosive rain may cause considerable erosion in this period. This hazard is limited in areas where the land is cultivated by hoe, but since tractor ploughing is becoming a common practice in parts of the survey area, resistance to erosion should be regarded as an increasingly relevant land quality.
This holds especially true for the relatively fertile clayey soils of the strongly dissected Mtomkuu Formation (UT-units), where intensive cultivation of annual field crops takes place.

Other factors increasing erosion hazard are the human and animal tracks in areas around villages, near wells and valleys. Overgrazing endangers the dryer northwestern and northern zones of the Coastal Uplands (Units USKf and UOc2p respectively).

3.6.6 *Conservation practices*

Practices such as contour ridging, contour ploughing, strip cropping and terrace construction are done to a limited extent. Old structures are often neglected. Yet, in places farmers put mulch on their fields as an anti-erosion measure deliberately. Particularly in the high-hazard areas, contour ploughing and other simple conservation practices possibly combined with the planting of leguminous crops and shrubs on contour ridges, strongly protects the soil, at the same time providing food, fodder and firewood.

3.6.7 *Crusting and compaction*

Other forms of land degradation that occur in the Kilifi Area are crust formation and compaction. The PO- and UO-soils (on Bay deposits) are quite vulnerable to this type of degradation.

Crust formation and compaction are caused by rainsplash and overgrazing. The final stage is an area with a bare surface with a massive structure and no vegetation left. It was observed that surface porosity in such areas varies from very high under isolated bushes to almost nil in exposed sites. These areas are important browsing grounds, so precautionary measures are necessary to avoid complete degradation. Moreover, there is a high danger of excessive surface run-off during rainstorms.

4 Land evaluation

4.1 INTRODUCTION

Land evaluation is the process of assessing land performance when used for specific purposes. It involves the execution and interpretation of surveys and studies of landforms, soils, vegetation, climate and other aspects of land in order to identify and compare promising kinds of land-use in terms applicable to the objectives of the evaluation (FAO, 1976). The socio-economic context should indicate limitations to agricultural production from a non-physical viewpoint. Problem-oriented land evaluation studies can not be carried out without the integration of sociological and economic data.

Consequently, a land evaluation is generally carried out in two stages, an ecological land evaluation followed by a socio-economic analysis; an approach which requires a multi-disciplinary evaluation team (Beek 1978). In this report, only the results of the ecological land evaluation are indicated.

An ecological land evaluation consists of the following main activities:
- Selection of *land utilization types* (LUTs) in relation to the physical, social and economic conditions of the area and according to the development objectives. The identification of LUTs forms the backbone of the land evaluation. The LUTs are characterized by "key attributes", which reflect biological, socio-economic, technical etc. aspects of the production environment that are relevant to the productive capacity of a land unit (LU). The land evaluation of the Kilifi Area has been carried out for 17 LUTs (see Appendix 7), 9 of which are described in detail in Appendix 8).
- Determination of the requirements of the relevant land uses.

Each crop has minimum needs to survive and higher needs to reach optimum production. A demanding crop has higher requirements than a less demanding crop and thus the land unit under consideration will show a lower suitability for this crop. Requirements of crops are basically differentiated into physical, management and socio-economic requirements.
- Determination of land units and their land qualities/land characteristics

Land units (LU) are areas possessing specified land qualities and land characteristics, which can be demarcated on a map (FAO, 1983). Each LU is an aggregation of one or more soil mapping units occurring in one Agro-ecological zone and possessing the same land quality ratings. The correlation between LU and soil mapping units is indicated in Table 32. A map of LU's is given in Appendix 5G. *Land characteristics* are attributes of land that can be measured or estimated, e.g. slope gradient, soil depth, amount of rainfall, width of a terrace, distance to a market. Land characteristics do not affect the suitability of land for a certain use in an indiscriminate way. Therefore, characteristics are mostly aggregated in such a way that the resulting clusters (land qualities) cover basic requirements of land use and influence land suitability more or less independent of each other (e.g. moisture availability, nutrient availability). Table 18 indicates the land qualities and associated land characteristics that have been recognized in this land evaluation.

- The process of matching and the land suitability classification.

Comparison of the needs of a LUT (land use requirement) with the reality in the field (represented by rated land qualities) is commonly referred to as matching. It is the essential activity in land evaluation. The results of a matching procedure can be visualised as shown in Table 17.

The suffices e, f, m, d refer to the land qualities that are most limiting. They are explained in Table 18. A table for all LU's and LUT's is presented in Appendix 7. The suitability classification comprises four assumed classes:

(S1) *Ecologically highly suitable*: Land with no or slight limitations for the sustained cultivation of a given crop. Yields are 80 to 100% of the normative yields.

(S2) *Ecologically moderately suitable*: Land with moderate limitations for the sustained cultivation of a given crop. Yields are only 40 to 80% of the normative yields.

(S3) *Ecologically poorly suitable* : Land with severe limitations for the sustained cultivation of a given crop. Yields are only 20 to 40% of the normative yields.

(N) *Ecologically not suitable*: Land having limitations which appear so severe as to preclude any possibility of successful sustained use for a given crop. Yields are below 20% of the normative yields.

Table 23 gives normative yields for all LUTs. How these yields were estimated is described in section 4.2.2.

- Comparison of development alternatives. This can be done when the land evaluation has been completed. A thorough socio-economic analysis, including future price development and political factors, should be carried out before development alternatives can be compared properly.

This land evaluation refers to the 'present situation'. Any improvement

Table 17. Suitability classification after matching of LU with LUT.

Land units (LU)	Land utilization types (LUT)		
	I	II	III
1	S1	S3e	Ne
2	S2f	S3f	Nf
3	Nm	S3d	S1

Table 18. Land qualities and associated land characteristics.

Suffix	Land qualities	Land characteristics
m	moisture availibility	agro-climatic subzone (rainfall and evapotranspiration) run-off groundwater (capillary rise) soil moisture storage capacity
f	nutrient availibility	organic carbon content phosphorus availibility potassium availibility pH-H_2O
d	drainage condition	soil drainage class
s	excess of salts - salinity - sodicity	 electrical conductivity exchangeable sodium percentage
p	ease of cultivation possibilities for agricultural implements	slope class surface stoniness/rockiness soil consistence
v/r	adequacy for root growth and tuber expansion: - swelling and shrinkage (v) - shallowness (r)	 vertic properties effective soil depth
fl	flooding hazard	frequency of flooding
e	resistance to erosion and physical land degradation	soil texture slope class susceptibility to sealing and crusting soil cover

(fertilizer application, irrigation, erosion control) requires an adjustment of the suitablility rating in the respective tables in 3.5 and 3.6. It will mostly result in a different, more favourable, aggregate suitability classification than in Appendix 7. Example: application of fertilizer in unit UE1m1 (LEU2) may raise suitability for sunflower from S2f to S1.

This land evaluation has a ecological basis. Translating the suitabilities given in Appendix 7 into socio-economic entities may well show a different picture as regard expected successful enterprises for the farmer.

No mention is made of suitabilities for different types of grasses, which may be in the interest of zero-grazing objectives, or suitability for extensive grazing or browsing. Reference is made to Appendix 8 which describes this category of agricultural enterprises in more detail.

Intercropping systems are not rated as such. Normative yields from such systems should be estimated from the expectances for the individual crops, and adjusted for lower plant density. Possible positive or negative interferences between the different crops are taken for granted.

4.2 LAND QUALITIES AND LAND-USE REQUIREMENTS

In this section, a number of land qualities are dealt with. They are the aggregates of a number of land characteristic, as is shown in Table 18.

In Table 18 only diagnostic land qualities and characteristics have been given. Land qualities such as "climatic hazards affecting plant growth" or "pests and diseases" have not been used in the suitability classification as they are not easily quantified. This does not imply that they may not be important causes of yield reduction.

Two land qualities are recognized as the major environmental limitations to crop production in the Kilifi area:

- moisture availibility,
- nutrient availibility.

The combination of values of the individual water balance factors gives the rating for the land quality "moisture availibility" (sections 1.2.4 and 4.2.1). The Kilifi Area is agro-climatically constituted by zones III, IV and V (Appendix 2), which refer to a transitional zone between semi-arid and subhumid regions.

Apart from moisture stress, low soil fertility seriously hampers satisfactory crop development in extensive parts of the Kilifi Area (section 3.5). This arises from the land quality "nutrient availibility" (section 4.2.2).

4.2.1 *Moisture availability*

4.2.1.1 Growing period as diagnostic factor for moisture availability

If fertilizers are applied yields increase until another land quality, mostly moisture availability, becomes limiting. 'Moisture availability plays a vital role in evaluations within a broad climatic range extending from mean annual rainfall of about 1200 mm down to the climatic limit of cultivation. It is also significant for cultivation of perennials in areas with a substantial dry season' (FAO, 1983). Since both statements apply to the Kilifi Area, moisture availability should be considered a land quality of the utmost importance.

In previous KSS soil survey reports climatic and soil factors were evaluated individually with respect to the land quality moisture availability. Since they can offset each other, integration of the two factors is to be preferred. Such an integration is, to some extent, provided by the computer model of Jätzold & Schmidt (1982/3), who calculated lengths of the growing period exceeded in 6 out of 10 years (60% reliability). The calculation or estimation of the individual water balance factors enabled them to establish agro-ecological zones and subzones (Figure 12).

The classes of lengths of growing periods, which in general consist of 20-day intervals are given in Table 5. Assuming that no other land quality is limiting crop production rather than moisture availability, the authors predict yield probabilities for a variety of crops. The leading parameter for this purpose is the actual water supply, i.e. the ratio between (rainfall + stored soil moisture) and the potential crop water requirements (evapotranspiration) for each decade.

The thus measured effects of water stress on yields lead to the classification of yield probabilities in relation to previously set normative yields:

- Class S1 at least 80% of normative yields (good yield potential),
- Class S2 40-80% of normative yield (fair yield potential),
- Class S3 20-40% of normative yield (poor yield potential),
- Class N less than 20% of normative yield (not suitable).

For maize (Coast Composite) the normative yield is e.g. 3000 kg/ha.

The classes approximately coincide with classes given by Jätzold & Schmidt (1982/3), to which the terminology in parenthesis refers.

4.2.1.2 Matching land quality and land-use requirements

Figure 37 shows the flow chart indicating the subsequent steps in evaluating moisture availability. Down to 'tentative suitability classification' the calculations were made by Jätzold & Schmidt (1983). The land quality moisture availability for a given land mapping unit is given as an agro-ecological subzone, expressed in terms of length of growing period (days). These subzones are constituted by:

- effective rainfall totals (10-day periods),
- (Penman) reference evaporation totals,
- an assumed soil moisture storage capacity of 15 mm/10 cm referring to a medium-textured soil (Jätzold & Kutsch, 1982).

After generalizing Jätzold & Schmidt's maps, six subzones are remaining in the Kilifi Area: two at the coast and four in the hinterland (see Fig. 12 and Table 5). The land units to which they belong have been listed in Table

The land-use requirements are constituted by:

- land utilization type, in this section treated as one or more crop varieties,
- potential evapotranspiration, modified by crop coefficients (kc-values); these coefficients represent the ratio between potential crop evapotranspiration and reference evaporation for a soil-covering annual crop during the different stages (initial, peak, maturity) of the growth cycle: kc (i) = 0.4, kc (p) = 1.0, kc (m) = 0.4; potential crop evapotranspiration is assumed to express the water requirements of a crop that does not suffer from water stress; crop water requirements are given in Jätzold & Schmidt (1982),
- root volume, which is fixed at 60 cm; consequently, actual storage capacity is considered to equal 90 mm (6 x 15); no mention is made of the

LAND

LAND UNIT

LAND QUALITY

Moisture availability of
agro-ecological subzones,
a function of
- rainfall
- evaporation
- moisture storage capacity
  (fixed at 90 mm for most soils)

expressed in terms of
length of growing period
(days, exceeded in 6 out
of 10 years)

LAND USE

LAND UTILIZATION TYPE

LAND USE REQUIREMENT

Moisture requirements of
crop varieties,
a function of
- potential evapotranspiration
  (kc/i, kc/p, kc/m)
- root volume
  fixed at 60 cm)

expressed in terms of
length of growing period
(days, exceeded in 6 out
of 10 years)

MATCHING

TENTATIVE SUITABILITY CLASSIFICATION
(Jätzold & Schmidt, 1983)

= runoff
= groundwater
= measured moisture
  storage capacity

Water balance
modifications
Kilifi Area

LAND QUALITY
Moisture availability
expressed in terms of
modified length of growing period
(days, exceeded in 6 out of 10 years)

FINAL
SUITABILITY
CLASSIFICATION (this report)

Fig. 37. Flow chart for evaluation of moisture availability in terms of length of growing period

depth to which perennial crops withdraw soil moisture; if the figure of 60 cm has also been applied, it has caused an underestimation of length of growing period for this category of crops.

The matching procedure, which is the step following the quantification of land quality and land use requirements involves their comparison and leads to a first tentative suitability classification (Table 19). The de-

Table 19. Tentative suitability classification with respect to moisture (partly adapted from Jätzold & Schmidt 1983).

Agro-ecological subzone	Start of growing periods (5)	Crops 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
CL 3 m/l i	Mar 21-31	S1	S1	-	S2	S1	S1	S1	S2	-	S1	S2	S2	S1	S1	S2	S2	S1
CL 3 mi 8s/vs)	Apr. 11-20	S1	S1	-	S2	S1	S1	S1	S1	-	S1	S2	S2	S1	S2	S2	S1	S1
	Oct. 11-20	S3	S2	-	-	-	S2	S3	-	-	-	-	S2	-	-	-	-	-
CL4 mi	Apr. 1-10	S1	S1	-	S2	S1	S1	S2	S2	-	S1	S2	S2	S2	S1	S3	S2	S1
CL 4 m/si (vs)	Mar. 21-31	S2	S1	-	S3	S2	S1	S1	S1	-	S1*	S2	S1	S2	S2	S3	S1	S1
	Oct. 21-31	S3	S3*	-	-	-	S3	S3	-	S3	-	-	S2	-	-	-	-	-
CL 4 s i (vs)	Apr. 11-20	S2	S1*	S1*	N	S2	S2	S1	S2	S1	S1*	S3	S2	S2	S3	N	S2	S1
	Oct. 21-20	S3	-	S2*	-	-	S3	-	-	S3	-	-	S2	-	-	-	-	-
CL 5 s/vs i (vs)	Apr. 11-20	N	S1*	S1*	N	S2	N	S2	S3	S2	S2*	N	S3	S3	N	N	N	S2
	Okt. 21-31	-	-	S3*	-	-	-	-	-	-	-	-	-	-	-	-	-	

Crops:

1 maize (Coast Composite)
2 sorghum
3 millet
4 rice (not irrigated)
5 cassava
6 sweet potato
7 cowpea
8 french beans
9 green gram
10 sunflower
11 cotton
12 sesame
13 vegetables
14 cashewnut
15 coconut
16 pineapple
18 sisal

Remarks:
- * indicator early maturing varieties
- An S1-maize yield is 2400-3000 kg/ha. Normative yields for other crops are given in Table 23
- Vegetables comprise: tomato, cucumber, eggplant, melon, onion, okra, pepper, cabbages, pumpkin.
- Cowpea, french beans, greengram and sesame are mostly intercropped or relaycropped with maize.

cade in which the growing period starts has also been given in this table, which is adapted from Jätzold & Schmidt (1983).

4.2.1.3 Water-balance modifications for the Kilifi Area

In the model by Jätzold & Schmidt, the impact of some factors of the water balance, such as runoff, groundwater and differences in soil moisture storage capacity, has been simplified.

'Effective' rainfall is considered to amount 90% of total rainfall. Losses through runoff are believed to be eliminated by anti-erosion control. As this assumption is not yet realistic with regard to the prevailing low input conditions in the Kilifi Area, runoff has been treated as a water balance factor that influences the length of the growing period in the following way:

- if slope class is BC or C: length of growing period is reduced by 5%,
- if slope class is CD or D: length of growing period is reduced by 10%,
- if slope class is DE or EF: length of growing period is reduced by 20%.

For soil mapping units belonging to major units UO, UT and PO, the length of the growing period is reduced by another 5% if slope class exceeds A. The soils involved have a low infiltration capacity.

Capillary rise from groundwater into the rooting zone is a moisture source of significance in some soil mapping units.
The growing period for these units is extended as follows:

- soil mapping units UT2c4, P2E13, P2Ec: 10% extension,
- soil mapping units AAc, VXC, BAc1, BAc2: 20% extension.

Jätzold & Schmidt (1983) use a standard soil moisture storage capacity in their model. Storage capacity refers to water retained between suctions that coincide with pF-values 2.3 and 4.2. A medium-textured soil has a storage capacity of 15 mm/10 cm. Since the authors consider a soil depth of 60 cm (assuming that 80% of the root complex of an annual crop has developed down to this depth within 6 decades), the standard soil stores 6 x 15 = 90 mm. It is unnecessary to use this simplification for the Kilifi Area. The fixed amount of 90 mm proved high for most soils.

In Table 20 the measured soil moisture storage capacities are given. It should be stressed that a crop in a wetter zone (CL 3) benefits from a high storage capacity rather than a crop in a drier zone (CL 5) does. In the latter case, the precipitation surplus is often limited and high storage capacities will only occasionnally be saturated. Determination of pF-values in clayey soils faces problems of swelling and shrinkage which is not in line with the fundamentals (constant volume).

The final column of Table 20 shows the adjusted lenghts of the growing period. It ranges between +10 days (units UT, P10) and -20 days (units UE, P2Em).

To calculate the overall modification of the length of the growing pe-

Table 20. Actual soil moisture-storage capacity (pF 2.3-4.2) in the upper 60 cm of the soils of the Kilifi Area and its influence on the length of growing periods.

Clusters of soil mapping units	Soil moisture storage capacity (mm/60 cm soil depth)	Evapotranspiration rate (mm/d)[1]	Modification of growing period (days)
USK	60- 75	3.0	-10 to-5
USs	40- 50	3.0	-17 to-13
USc	50- 80	3.0	-13 to-3
ULc	70- 90	3.0	-7 to-0
UOc	60-100	3.0	-10 to+3
UT	90-120	3.0	0 to+10
UE	40- 60	2.5	-20 to-12
PO	100-120	3.0	+3 to+10
P2Em	40- 70	2.5	-20 to-8
P2El	50- 70	2.5	-16 to-8
P2Ll	50- 70	2.5	-16 to-8
BA	70- 90	3.0	-7 to 0
DE	80-100	2.5	-4 to+4

[1] Daily evaporation is set at 6 mm for the Hinterland, and at 5 mm for the Coast; thus, if kc is assumed to amount 0.5, ET is 3.0 and 2.5 mm/day respectively. Jätzold & Schmidt (1983) use 90 mm as a standard soil moisture storage capacity, which coincides with 30 and 36 days respectively at the suggested evapotransporation rates.

Table 21. Examples of how to calculate modified length of growing period.

Soil mapping unit	Modification factors: runoff[1]	groundwater[1]	storage[2]	Overall modification (days)
USs 1/BC	- 5%(=5 days)	0%	-17 to-13 days	-22 to-18
UT2c1P/CD	-15%(=20-25 days)	0%	0 to+10 days	-15 to-10
P2E13/AB	0%	+10%(=15 days)	-16 to-8 days	-1 to+7
UT2c4/A	0%	+10%(=15 days)	0 to+10 days	+15 to+25
BAc1/A	0%	+20%(=30 days)	-7 to 0 days	+20 to+27

[1] Conversion from percentages into days depends on agro-climatic subzone.
[2] Data calculated in Table 20.

riod per soil mapping unit, the previous data have to be put together. The overall modification for some units is shown in Table 21. A concise list of growing period modifications is given in Table 31. They only apply to the first rains as the second rains nowhere last long enough to make useful modifications.

4.2.1.4 Final suitability classification with respect to moisture availability

The difference between the tentative and the final suitability classification can now be calculated, for each land unit. The overall modifications are added to the particular agro-ecological subzone. This combination represents the land quality "moisture availability" and is as such given for each land unit in Table 31.

4.2.2 *Nutrient availability*

In order to match the land quality "nutrient availability" and the land use requirements, one must know the nutrient availability in the soil and the nutrient requirements of the crops.

The potential amounts of nutrients that can be supplied by the soil during six months was set equal to the amount of nutrients withdrawn by maize during one cropping season. Table 22 shows the one-season potential nutrient supplies.

The nutrient requirements of crops depend on the yield that can be obtained. Therefore one must know the magnitude of the expected yield. For that purpose "normative yields" were defined for the major crops in the Kilifi Area. For maize, 3000 kg/ha per growing season is considered normative (Coast Composite). This is half the yield that was considered normative in the Kisii area (Guiking et al., 1982).

For other crops than maize, normative yields were set at half the values mentioned for Kisii as well (Table 23). Data for cashewnut, coconut, simsim and rice (crops not grown in Kisii) were collected and adapted from Acland (1971), Floor (1980), De Geus (1973) and Purseglove (1968, 1972). These yields will be attained in monocropping and not in multiple cropping systems, e.g. maize under coconut seldom yields more than 1.5 tons/ha, even if fertilizers are being applied.

In order to match nutrient supply and nutrient requirements, an equally long period should be considered: the growing period of maize. Thus, requirements of crops growing longer or shorter than maize were adjusted to "one season requirements" by dividing the growing season durations of the two crops (Guiking et al., 1982). For perennial crops the "one season requirement" was assumed to be 0.5 times the annual requirement.

Crops were divided into three groups, according to their one season nu-

Table 22. Potential one season nutrient supply and corresponding maize yields for the soil fertility classes according to the QUEFTS system.

Soil fertility class	Nutrient supply (kg/ha)			Maize grain yield (tons/ha) (12% moisture)
	N	P	K	
C	65	10	85	2.5
D	35	7	60	1.4
E1	25	8	40	1.0
E2	20	5	30	0.7
E3	10	3	20	0.4

Table 23. Normative yields of marketable product (kg/ha) and estimated nutrient requirements for a growing season (kg/ha). Crops are arranged in the order of N requirement.

Crop group	Crop	Normative yield	Nutrient requirements N	P	K
I	cashewnut	750	20	4	20
	coconut	2 500[1]	20	4	25
	vegetables[2])	5 000	20	6	30
	sisal	10 000[3]	25	3	35
	millet	750	25	6	20
	simsim	500	25	7	30
	cowpea/green gram	500[5]	25[6]	7	35
II	sunflower	750[4]	35	5	35
	cassava	15 000	35	8	70
	pineapple	20 000	40	4	70
	rice	2 000	40	6	60
	sweet potato	8 000	40	7	65
III	french beans	2 000[5]	50[6]	12	70
	cotton	600[4]	55	9	50
	sorghum	2 250	60	8	55
	maize	3 000	75	12	70

[1] nuts per ha., [2] egg-plant, cumcumber, squash, pumpkin, [3] leaves, [4] seeds, [5] pulses, [6] N absorbed from soil.

Table 24. Suitability rating with respect to nutrient availability without fertilizer application; maximum yield is S1: > 80%, S2: 40-80%; S3: 20-40% and N < 20% of the normative yields mentioned in Table 23.

Soil fertility class	Crop group I	II	III
C	S1	S1	S1
D	S1	S1	S2
E1	S1	S2	S3
E2	S1	S2	S3
E3	S2	S3	N

trients requirements. Since nitrogen is the major limiting nutrient (section 3.5), N requirement forms the main criterion for this division (Table 23). Moreover, the nutrient availability of the soil fertility classes (QUEFTS system, Table 22) was evaluated for the three crop groups (Table 24). It should be stressed that this classification holds for crops receiving no fertilizers and no organic manure.

Recovery of fertilizer nutrients were rather low (about 25% for N and about 7% for P). Because also the price ratios of food crops and fertilizers are rather low, fertilizer application will often not pay. This severely hampers improvement of agricultural production.

Table 25. Suitability rating with respect to the land quality "drainage condition".

Soil drainage	Drainage requirement groups		
	rice	other crops	Table 31
well - excessive	S3-N	S1	d_0
moderately well	S2	S1	d_1
imperfect	S1	S2	d_2
poor	S1	S3	d_3
very poor - waterlogged	S1	N	d_4

4.2.3 *Drainage conditions*

Impeded drainage hampers proper crop development. The influx and efflux of gases (oxygen, carbon dioxide) is essential to almost every crop and must proceed uninterrupted. Crop drainage requirements are given in Table 25, which moreover shows the suitability rating with respect to the land quality drainage condition. Soil drainage class is the only land characteristic applied in the suitability determination.

Rice is an exceptional crop with respect to drainage requirements. Its aerenchyma cells in the stem make the plant well adapted to wet conditions. For other crops, soil aeration is a strict requirement.

The soil drainage class is listed for each land unit (Table 31). Since the majority of the soils of the Kilifi Area is well to excessively drained or moderately well drained, "drainage condition" is only limiting in small areas. Rice, on the other hand, is best grown on imperfectly or poorly to very poorly drained soils.

4.2.4 *Excess of salts*

Salinity of soil and water is expressed in terms of electrical conductivity (ECE). Sodicity is measured by calculation of the relative amount of exchangeable sodium (Na) at the exchange complex: the exchangeable sodium percentage (ESP).

"Tolerance to excess of salts" is the crop requirement in the matching process. Three tolerance groups were recognized. In Table 26, they are matched against the land quality "excess of salts".

The column "excess of salts" in Table 31 shows that only a restricted number of land units experience salinity and/or sodicity problems. The soils of the UT-units have sodic subsurface horizons in places, whereas the soils of the UO- and P10-units and BAc3, which have developed from bay sediments, show more serious salinization. Only leaching and improved drainage might alleviate salt problems here, unlike in the TA-units, where high salt concentrations are maintained through periodical flooding by salt seawater.

Table 26. Suitability rating with respect to the land quality "excess of salts".

Salinity/sodicity class 0-30 cm ECe	ESP	30-100 cm ECe	ESP	Salt tolerance groups S-I	S-II	S-III	Table 31
< 2	< 6	2-4	6-15	S1	S1	S2	X_1
2-4	6-15	4-8	15-40	S1	S2	S3	X_2
4-8	15-40	8-15	15-40	S2	S3	N	X_3
> 8	> 40	any	any	S3-N	N	N	X_4

S-I : cotton, coconut
S-II : maize, sorghum, rice, sunflower, sweet potato, pineapple
S-III: simsim, millet, vegetables, cassava, cowpea, greengram, french beans, cashewnut, sisal.

Table 27. Landquality "Ease of cultivation": rating of the separate land characteristics.

Rating	Slope class and gradient	Surface stoniness/rockiness	Soil consistence
1	ABC < 8%	non-stony/rocky	loose
2	CD 8-16%	fairly stony/rocky	very friable
3	DE 16-30%	stony/rocky	friable/slightly sticky
4	F 30-70%	- -	(very) firm/(very)sticky and (very) plastic

4.2.5 *Ease of cultivation and possibilities for agricultural implements*

4.2.5.1 Manual cultivation

Three land characteristics have been used to assess the workability of soils by hoe (Braun & Van de Weg, 1977): slope class, surface stoniness/ rockiness and soil consistence (moist and wet). Their rating is given in Table 27.

Extensive parts of the Kilifi Area rank consistence class 4, which also implies high labour requirements if tillage is done manually. Oxen are hardly used as a means of draught power.

4.2.5.2 Mechanical cultivation

Tillage efforts can be alleviated by using mechanical draught power. This particularly applies to soils with a high "consistence" rating (UT-units), but *not* to soils with a high "slope gradient" (HSK-, VXA-units) or a high "surface stoniness/rockiness" (ULc1, P2L11P) rating. The soils of the UT-units have the most difficult tillage properties, notably when they are either very wet or very dry. Therefore, it is not surprising that trac-

Table 28. Suitability rating with respect to the land quality "ease of cultivation possibilities for agricultural implements for annual crops".

Rating	Slope gradient		Surface stoniness/ rockiness		Soil consistence		Table 31
	hand	mech.	hand	mech.	hand	mech.	
1	S1	S1	S1	S1	S1	S1	P1
2	S1	S2	S1	S2	S1	S1	P2
3	S1	S3	S1	S3	S1	S1	P3
4	S2	N	-	-	S2	S1	P4

tor ploughing has become a common feature in this part of the Kilifi Area. Table 28 shows the suitability classification with respect to the land quality 'ease of cultivation and possibilities for agricultural implements'. It is assumed that all annual crops have similar requirements. The most limiting land characteristic determines the rating of the aggregate land quality, e.g.:

combination	hand	mech
1-1-4	S2p	S1
2-3-4	S2p	S3p
2-1-3	S1	S2p

In the land evaluation key, the land quality is given the suffix p. In the examples ease of cultivation (manually) keeps out S2 because of soil consistence. Ease of cultivation (mechanically) varies between S1 and S3 because of the topography and stoniness/rockiness limitations.

4.2.6 *Adequacy of root growth and tuber expansion*

Tree crops and tuber crops can not grow satisfactorily in case certain adverse physical properties prevail: swelling and shrinkage and shallowness.

Soils that are classified as Vertisols and vertic Cambisols and Luvisols are very sticky and plastic clay soils, containing over 35% clay and over 50% of 2:1 expanding clay minerals, which causes severe swelling and shrinkage. The soils of the UT-units have most pronounced swelling properties. In Appendix 7, tuber crops and treecrops rank S3v if the soil has vertic properties.

Few soils are shallow over rock and do not allow adequate root or tuber development. Shallowness occurs in units HX2C, ULc1 (small parts), UT2c3P, UT2C (partly) and P2L11P. A 'planic' contact as occurs in the soils of units P1Of and P1Ol (partly) and BAc3 is also considered 'shallowness'.

In Table 31, shallowness is indicated by suffix r (rooting impediment). Tuber crops and tree-crops are downgraded to S3r if shallowness occurs.

4.2.7 *Flooding hazard*

The AA-, VX-, BA- and TA-units and occasionally units P2E13 and P2Ec suffer from more or less temporary flooding. In Tabel 31, flooding hazard has been indicated by the suffix "fl" in case the land quality is considered relevant.

4.2.8 *Resistance to erosion and physical land degradation*

The susceptibility of the different parts of the Kilifi Area to sheet, rill and gully erosion has been visualized in Appendix 5E. This susceptibility refers to bare soil. In the land quality rating, however, 'resistance' against erosion involves climate type, texture profile, slope class, susceptibility to surface sealing and crusting, *and* soil cover. As many parts of the survey area are permanently covered by tree crops, mainly cashewnut or coconut trees, it is not realistic to evaluate these areas as if

Table 29. Land characteristics involved in the suitability rating of the land quality "resistance to erosion and land degradation".

Rating	Climate type (Braun in Michieka et al., 1978)	Texture profile* (F.C.C.-terminology of section 3.5.3)	Slope class (App.1)	Susc. to sealing and crusting
0	III,IV,V	S	A	none
1	-	SL,L,C_1	AB,B	slight to moderate
2	-	C_2,SC,LC,C',CR C'R,LR	BC,C	severe
3	-	-	CD	-
4	-	-	DE	-
5	-	-	EF	-

* C_1: kaolinitic clays; C_2: illitic and montmorillonitic clays;
S : sand; L: loam; SL: sand over loam; C'R: gravelly clay over rock.

Table 30. Suitability rating with respect to the land quality "resistance to erosion and land degradation".

Sum of ratings	Soil cover class			Table 31
	<20%	20-70%	>70%	
0-2	S 1	S 1	S 1	-
3	S 2	S 2	S 1	-
4	S 2	S 2	S 2	-
5	S 3	S 2	S 2	e_1
6-7	N	S 3	S 3	e_2

Table 31. Land units and their land quality ratings.

Land unit	moisture availability (m)	nutrient availability (f)	drainage conditions (d)	excess. of salts (x)	ease of cultv. (p)	swelling/ shrinkage (v)	shallow-ness (r)	flooding hazard (fl)	resist. to erosion and land degrad. (e)
1	CL3m/li -0/-10days	C1-C2	0-2	0-1	4	+	-	-	1
2	CL3m/li -15/35days	E1-E2	0	0	3	-	-	-	0-1
3	CL3m/li -15days	E3	0	0	3	-	+	-	0
4	CL3m/li -0days	E1-E2	2-3	0	3-4	+	-	-	0
5	CL3m/li+CL4mi -0/-5days	E1-E2	0-2	0	3-4	-	-	(+)	0
6	CL3m/li+CL4mi +++days	n.d.	2-4	4	4	-	-	+	0
7	CL4mi +20days	C1-C2	2-3	0	4	+	-	(+)	0
8	CL4mi -0/-20days	C1-C2	0-2	1	4	+	+	-	1-2
9	CL4mi -15/-35days	E1-E2	0	0	3	-	-	-	0-1
10	CL4mi -15days	E2-E3	0	0	3	(+)	+	-	0
11	CL3mi (s/vs)-5/-10 days	D2	0	0	3-4	-	(+)	-	0
12	CL3mi(s/vs) -10/-20days	D3-E1	0	0	2-3	-	-	-	0-1
13	CL3mi(s/vs)+ CL4m/si(vs) -10-20days	D3-E3	0-2	0	2-4	-	-	-	0-1
14	CL3mi(s/vs)+ CL4m/si(vs) -10/-30days	E3	0-2	0	2-4	-	-	-	1-2
15	CL4m/si(vs) -10/-20days	C1-C2	0-2	1	4	+	(+)	-	1-2
16	CL4m/si(vs) -5/-15days	D2	0	0	3	-	(+)	-	0-1
17	CL4m/si(vs) -10/-20days	D3-E1	0	0	2-3	-	-	-	0-1
18	CL4m/si(vs) -10/-20days	E2	0	0	2-3	-	-	-	0
19	CL4m/si(vs)+ CL4si(vs) -10/-20days	E2	0-2	3	4	-	-	-	1-2
20	CL4m/si(vs) -20days	E3	0	0	1	-	-	-	1-0
21	CL4si(vs) -20days	E3	0	0	1-2	-	-	-	0
22	CL4si(vs) +5days	E1	0-2	2-3	3	-	+	-	1
23	CL4si(vs) -10days	E1	0	0	1	-	-	-	0
24	CL4si(vs)+ CL5 s/vsi(vs) -10days	E1	2-3	3	3	-	+	-	0
25	CL5s/vsi(vs) +5days	E1	0-2	2-3	3	-	+	-	1
26	CL5s/vsi(vs) -10days	D3	0-2	0	2-3	-	-	-	1
27	CL5s/vsi(vs) -10days	E1	0	0	1-2	-	-	-	0-1
28	CL5s/vsi(vs) -20days	E3	0	0	1	-	-	-	0
29	variable	n.d.	0-3	0-1	4	(+)	-	+	0
30	variable	n.d.	0-3	1	4	(+)	-	+	2
31	variable	E2	0-3	1	2-4	-	-	+	0
32	CL3mi(s/vs)+ CL4m/si(vs) -30days	n.d.	0-2	0	4	(+)	(+)	-	2
33	CL4mi+ CL4m/si(vs) -5/-15days	n.d.	0-2	n.d.	0-4	-	-	-	1

Note: Land units 8, 14, 15, 19 are named 8e, 14e, 15e, 19e in case "resistance to erosion and physical land degradation" ranks 2 (see also Appendix 7).

they were bare. The basis for the suitability rating is given in Table 29. The suitability classification with respect to resistance to erosion and physical land degradation is shown in Table 30.

From Table 29, it can be derived that climate type is not diagnostic. Therefore, texture profile and slope class determine the final suitability in the first place. Susceptibility to sealing and crusting is used as a modification.

The combined impact of these three land characteristics is ultimately rated for three soil cover classes: <20%, 20-70%, >70% Table 30. Suitability is downgraded by one class if the land mapping unit shows susceptibility to sealing and crusting class 2.

In Table 31, resistance to erosion and physical land degradation has only been indicated for the two lowest classes (sum of ratings 5, 6 or 7). It is believed that this land quality, which in part depends on the level of management, should not be quantitatively evaluated at the same level of detail with moisture and nutrient availability. These qualities have a more direct and measurable effect on crop performance.

In section 3.1 and 3.2 resistance to erosion and physical land degradation is stressed if appropriate.

Table 32. Correlation of soil mapping units and land-evaluation units.

SMU	LU			SMU	LU	
HSKC	32			UE2l	9	18
HX1C	32			P1Of	22	25
HX2C	32			P1Ol	22	25
USKf	23	27		P1Of-P1Ol	22	25
USKA1	12	17		P2WA	33	
USKA2	26			P2Em1	2	9
USs1	20	28		P2Em2	2	
USs2p	14	28		P2Em3	2	9
USs3	21	28		P2Em4	2	9
USlp	14			P2El1	2	9
USc1	14			P2El2	2	9
USc2	14			P2El3	5	
ULc1	11	16		P2Ec	4	
ULc2	11	16		P2El1-P2El3	2	5
UOf	12	17		P2L11P	3	10
UOl	13			P2L12p	2	9
UOc1	13			P2Lcp	10	
UOc2p	19			AAx	29	
UT1c	33			AAc	29	
UT2c1p	1	8		VXA	30	
UT2c2p	1	15		VXC	30	
UT2c3P	8			BAc1	31	
UT2c4	1	7		BAc2	31	
UT2C	1	8	15	BAc3	24	
UE1m1	2			BAc1-BAc2	31	
UE1m2	9			TAx	6	
UE1l1	2	9		TAc	6	
UE1l2	2	9		TAo	6	
UE2f	9	18		DE1	2	9
				DE2	2	9

4.3 SUITABILITY CLASSIFICATION

4.3.1 *Description of land units*

The soil mapping units can be grouped according to their potential for specific land uses. The resulting clusters, referred to as land units, have similar or practically similar land quality ratings, as shown in Table 31. A total of 33 land units were recognized. In this section the land units are described briefly.

Table 32 gives a correlation for soil mapping units (Appendix 1) and land units (Appendix 7). Many soil mapping units occur in more than one land unit.

LU 1

Favourable moisture conditions and soil fertility status put maize, sorghum and sunflower in suitability class S1. Restricted drainage and slight sodicity are minor causes of yield reduction. Because of vertic properties, tuber crops and treecrops were given the rating S3v. Rice ranks S2 in the narrow valleybottoms (Fig. 38). Resistance to erosion is moderate (e_1) and manual land preparation is quite laborious.

Fig. 38. In the valleys around Kaloleni, rice is grown. Usually yields of maize under cocospalms are low because of competition for light, water and nutrients. Kaloleni, July 1984 (photo H. Waaijenberg).

Fig. 39. Maize, rice (valley bottom) and cocospalm. Chilulu, about 5 km north-east of Kaloleni, mid 1982 (photo H. Waaijenberg).

LU 2

Many soil mapping units are grouped in LU 2 (Fig. 39). Soil fertility is the major yield-limiting factor for most annual crops: cassava, sweet potato and sunflower rank S2f, maize, sorghum, beans and cotton rank S3f. Treecrops with low nutrient requirements rank high (cashew: S1) or rank lower because of moisture stress (coconut: S3m). Moderate resistance to erosion should be reckoned with when slope class CD prevails.

LU 3

Shallowness requires adjustments for unit P2L11P: tuber crops and treecrops are rated S3r.

LU 4

Impeded drainage seriously restricts satisfactory growth of most crops. Only rice and simsim rank S2, the other crops are in S3 throughout.

LU 5

This LU can in principle be compared to LU 2, but the modifications to the agro-ecological subzones are more favourable for LU 5.

Cowpea, vegetables and coconut rank one class higher, the other crops remain in the same class. Rice is upgraded from Nd to S2m, which is only applicable to the imperfectly drained soils of LU5 (if d ranks 2).

LU 6

The soils of the tidal swamps are prone to high salinity, precluding satisfactory growth of any crop.

LU 7

Imperfectly to poorly drained soils: S1 for rice, S2d for sorghum, S3d for all other crops, except cashew and coconut (Nd).

LU 8

Suitability for the various crops is similar to the suitabilities given for LU 1. Resistance to erosion is low in unit UT 2C, slope class CE and moderate in the other units. In the UT2c3P-units, shallowness may be limiting crop performance rather than vertic properties (r instead of v-suffix).

LU 8e

Annual crops Ne, perennial crops S3e ("erosion" ranks class 2).

LU 9

The somewhat drier equivalent of LU 2 shows similar suitabilities except for cashew, which is downgraded to S2m. Moderate resistance to erosion should be reckoned with when slope class CD prevails.
Shallowness (P2L1P) and vertic properties (P2Lcp) hamper optimal growth of tuber crops and tree crops (S3r and S3v respectively).

LU 11

A number of crops rank S1 in this LU: cassava, sweet potato, cowpea, sunflower, vegetables, pineapple and sisal. Suboptimal moisture or fertility status puts among others maize, sorghum, beans, cashew and coconut in class S2. In the second rains, reasonable yields can be expected from sorghum, sweet potato, green gram and simsim (S2).

Lu 11e

Slope class EF gives rise to suitability classes S3e for perennial crops and NE for annual crops.

LU 12

Lower fertility status than LU 11 downgrades cassava, sweet potato and sunflower to S2f. Maize and sorghum are marginal (S3f), but low nutrient requirement crops such as cowpea and simsim still rank S1. Moisture limitation puts cashew in S2m and coconut in S3m. Sweet potato and simsim give reasonable yields in the second rains (S2). Moderate resistance to erosion should be reckoned with in soil mapping unit USK1, slope class CD.

LU 13

Suitability has been established for fertility class E 3, which resulted in many S2f and S3f ratings. The treecrops are exceptions: cashew and coconut rank S2m. If fertility class D 3 prevails, suitability for many crops ranks higher. Moderate resistance to erosion should be reckoned with in soil mapping unit UO1, slope class BC.

LU 14

Very low soil fertility turns cultivation of maize, sorghum and even cassava into marginal enterprises if no fertilizers are applied. The S2-crops for this LU are millet, cowpea, green gram, simsim, vegetables and cashew. Millet, cowpea and simsim can even give an S2-yield in the second rains.

LU 14e

Low to moderate resistance to erosion plays a role in the units with slope classes C, D or E (S3e for perennial crops, Ne for annual crops).

LU 15

Sorghum, millet, sunflower and simsim rank S1. Maize, beans and cotton rank S2m. Tuber crops and treecrops rank S3v. S2-yields for millet and simsim can be obtained in the second growing period.

LU 15e

Low resistance to erosion and physical land degradation (S3e for perennial crops, Ne for annual crops).

LU 16

This LU can be well compared to LU 11. Moisture stress comes out more pronounced in LU 16. Millet, sweet potato, cowpea and simsim still rank S1, maize, sorghum and beans still rank S2f, cashew still ranks S2m, but coconut is downgraded to S3m. S2-yields for the second growing period are only to be expected from millet and simsim. Soil mapping unit ULc1, slope class CD, has a moderate resistance to erosion.

LU 17

This LU can be well compared to LU 12. Differences in cropping possibilities are only slight. Soil mapping unit USKA 1, slope class BD has a moderate resistance to erosion.

LU 18

This LU covers a small area near Sokoke and north of Jaribuni. Nutrient demanding crops rank S2f or S3f, less demanding crops rank S2m or S3m.

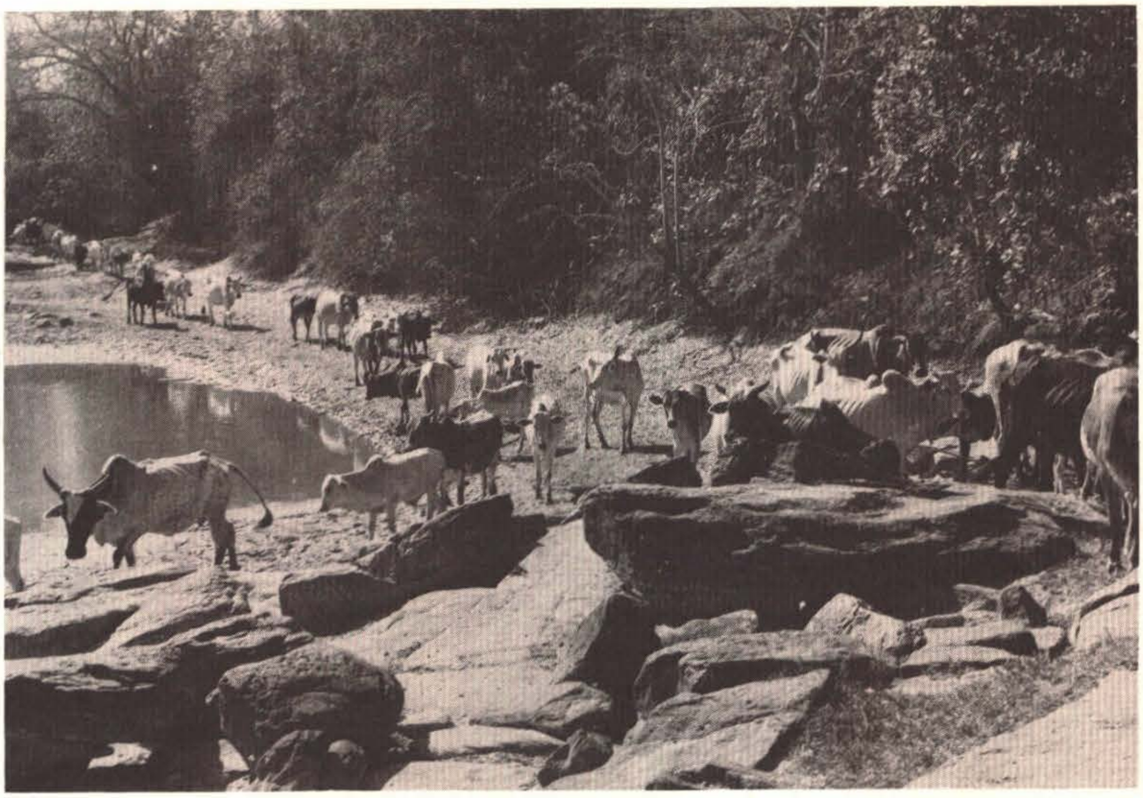


Fig. 40. Scarcity of drinking water is a severe problem in the Kilifi Area: cows at the Ndzovuni river, which for most of the year consists of isolated pools of dirty water, only "suitable" for consumption because there is no choice. North of Kwa Demu, February 1984 (photo H. Waaijenberg).

LU 19

Most soils of soil mapping unit UOc2p are in salinity class 2-3, which clearly comes out in the suitability classification. All crops are in S3 or N. Low resistance to erosion and physical land degradation even makes the area quite vulnerable to overgrazing (Fig. 40).

LU 19e

In this LU erosion and physical land degradation preclude any intensive agricultural practice.

LU 20

In this dry and low fertility area, millet, cowpea and simsim still give S2-yields. Cashew balances between S2 and S3m. Coconut ranks Nm. Maize, sorghum and beans rank Nf, indicating that modest amounts of fertilizer or manure may give yield increases until moisture takes over as the limiting factor.

LU 21

Suitability for all crops are similar or even slightly less favourable than in LU 20.

LU 22

Most soils of the P10-soil mapping units are in salinity class 2-3. The suitability classification refers to X_2 only. If salinity class 3 prevails, the classification of LU 19 can be used. Only sunflower and pineapple rank S2. Low to moderate resistance to physical land degradation makes the LU quite vulnerable to overgrazing.

LU 23

Millet (S1!), cassava, cowpea, sunflower and simsim can give reasonable yields in this LU. Cashew (S3m) and coconut (Nm) will suffer severely from moisture stress, but yields from maize, sorghum and beans (S3f) can be increased by application of modest amounts of fertilizer or manure until moisture takes over as yield-limiting factor.

LU 24

Restricted drainage and high salinity precludes any successful crop performance in this LU.

LU 25

Very limited prospects due to low moisture availability and high salinity (cf. LU 22).

LU 26

This LU is concentrated around Bamba. Sorghum, millet, cassava, cowpea, green gram and sunflower can give S2-yields in the first growing period. Maize and sweet potato, however, rank Nm. LU 26 has a moderate resistance to physical land degradation.

LU 27

Millet, cowpea and green gram are the crops that can give reasonable yields in this LU, which is too dry for any other profitable agricultural enterprise. Soil mapping unit USKA 1, slope class BD has a moderate resistance to erosion.

LU 28

Very marginal area, only allowing S2-yields from millet, cowpea and green gram.

LU 29

Temporary flooding makes the AA-units exclusively suitable for rice. Lack of data does not allow a comprehensive suitability classification.

LU 30

Low resistance to erosion on the sideslopes. In the valleybottoms rice can do well. Lack of data does not allow a comprehensive suitability classification.

LU 31

Rice is the most promising enterprise in the bottomlands (S1-2).
Other crops are in S2 or S3 because of impeded drainage. In very wet years, excess water can cause complete crop failure to other crops than rice.

LU 32

Low resistance to erosion is the overriding land quality in this LU (S3e for perennial crops, Ne for annual crops). Watershed protection should be the major aim.

LU 33

Lack of data does not allow any suitability classification for these minor units, which are therefore grouped in 'dustbin' LU 33.

4.3.2 *Summary*

In the following, the soil mapping units are evaluated and correlated with land units (see also Table 32).

The *H*-units are all in LU 32. Steep slopes preclude arable cropping and soil conservation should be the main concern.

The *USK*-units occur in LU 12, 17, 23, 26 and 27, all in the area of bimodal rainfall patterns. In LU 12, 17 and 23, low soil fertility is the major constraint to maize, sorghum and beans (S3f). Response to fertilizer or manure can be expected. Units 26 and 27 are too dry for maize. Small legumes and millet stand the dry conditions better. Cashew is S2m, coconut S3m in LU 12 and 17.

The *US*-units occur in LU 14, 20, 21 and 28, all in the area of bimodal rainfall pattern. It is the group with the lowest soil fertility (E3). This can be deducted from the ratings in Appendix 7, which very often show the f-suffix. Response to fertilizer can be strong in LU 14, moderate in LU 20 and 21, but very low in LU 28. Unfertilized yields of maize and beans are very low (Nf). Small pulses and millet are best adapted to conditions in LU 28. Cashew ranks S2 in LU 14 and S23 in LU 20 and 21.

The *UL*-units occur in LU 11 and 16, all in the area of bimodal rainfall patterns. Many S1-yields are obtained in LU 11 and, to a lesser extent, in LU 16. Present unfertilized yields of maize, sorghum, cassava and beans (S2f) can be raised to S1 by applying fertilizer or manure, notably in LU 11. Cashew and coconut are S2 in LU 11 and S2 and S3 respectively in LU 16. Very steep slopes preclude arable cropping in unit ULc1, slope class EF (LU 11e).

The *UO*-units are in LU 12 and 12 (UOf only, see remarks on USK-units), LU 13 (UO1 and UOc1) and LU 19 (UOc2p), all in the area of bimodal rainfall patterns. Short-distance variabilities with respect to soil fertility cause difficulties in classifying LU 13 satisfactorily. It follows from the ratings in Appendix 7, however, that application of fertilizer or manure will show yield responses. Cashew and coconut rank S2 for LU 13. LU 19 is characterized by high salinity and high susceptibility to land degradation.

The *UT*-units occur in LU 1, 7, 8 and 15, partly in the almost monomodal, partly in the bimodal rainfall pattern area. High maize and sorghum yields (S1) are obtained in LU 1 and 8, moderate maize yields in LU 15 (S2m). Poorly drained unit UT2c4, slope class A (LU 7) permits good rice yields. This is also possible in the many narrow valley bottoms which occur throughout the UT-units. Tuber crops and treecrops suffer from adverse soil physical status (S 3v) and low resistance to erosion and laborious tillage properties further preclude optimal performance of crops.

The *UE*-units are in LU 2, 9 and 18, predominantly in the coastal, almost monomodal rainfall distribution area. In LU 2, cashew ranks S1. In the other LU's, cashew ranks S2m. Coconut ranks S3m throughout. Growth of maize, sorghum and beans is restricted by low fertility (S3f), but cassava and sweet potato can reach S2f. Application of fertilizer or manure will definitely show yield responses. Resistance to erosion is moderate in units with slope class CD, unless protected by an adequate vegetal cover.

The *P1O*-units are in LU 22 and 25, both in the area of bimodal rainfall patterns. Drought stress and salinity/sodicity turn the P1O-units into areas of minor agricultural significance.

The *P2Em*-units are in the coastal LU's 2 and 9 (cf. UE-units).

The *P2E1*-units are in the coastal LU's 2, 5 and 9. For LU 2 and 9 reference is made to the UE-units. LU 5 represents the better moisture conditions, resulting amongst others in S2-yields for coconut and S1-yields for vegetables.

Unit *P2Ec* is in coastal LU 4. Impeded drainage favours rice cultivation (S2f), while the performance of other crops does not exceed S3.

The *P2L1*- and *P2Lc*-units are in coastal LU's 2, 3, 9 and 10. For LU's 2 and 9 reference is made to the UE-units. Suitability classification for P2L11P needed to be revalued because of shallowness and P2Lcp because of its vertic properties (LU 3 and 10).

The *AA*-units (LU 29) and the *VX*-units (LU 30) could not be properly rated due to lack of data. Rice is probably the most promising agricultural enterprise. Low resistance to erosion is a serious constraint regarding the slopes of the VX-units.

The *BA*-units occur in LU 24 (saline-sodic) and LU 31 (non- to slightly saline-sodic). For LU 31 rice ranks S1-S 2, other crops are in S2 or S3.

The *TA*-units are grouped in LU 6. They are in the highest salinity class (X_4), in other words, far below any agricultural significance.

The *DE*-units are in LU 2 and 9. Reference is made to the UE-units.

Appendix 6(a)
Detailed description of representative profiles

Unit HSKC, Profile 1

Soil classification	chromic Vertisol; udic Chromustert
Agro-climatic zone	IV-1
Observation	198/3-45, Kilifi District, E 5.68.4 N 95.79.3, 195 m, 30-10-1980
Parent material	shales
Physiography	Minor Scarp
Surrounding landform	undulating upland and flat plain are separated by this scarp
Meso-relief	middle part of the straight slope
Slope gradient	18%
Land use/land cover	100% grasses and herbs; extensive grazing and scattered cultivated fields
Drainage class	well drained
Depth of groundwater table	below 120 cm
Presence of surface stones/rock outcrops	stoniness class 1; rockiness class 1
Evidence of erosion	moderate to severe sheet erosion; slight rill erosion

Ah1 0- 25 cm: Dark brown (10YR 3/3) sandy clay loam; moderate to strong medium angular blocky; continuous moderate clay skins; very hard, firm, sticky and plastic; common fine, many very fine pores; common fine and very fine roots; clear and smooth transition to:

Ah2 25- 90 cm: Dark reddish brown (5YR 3/3) clay; moderate very coarse prisma-tic; intersecting slickensides; very to extremely hard, very firm, sticky and very plastic; few fine and very fine pores; few fine and very fine roots; few fine black manganese concretions; few boulders; cracks exceeding 1 cm diameter up to 1 m. depth; diffuse transition to:

AC 90-120+cm: Dark reddish brown (5YR 3/3) clay; moderate very coarse angular blocky; continuous moderate clay cutans; very hard, very firm, sticky and very plastic; few very fine pores.

Unit HX1C, Profile 2

Soil classification	vertic Luvisol; vertic Haplustalf
Agro-climatic zone	IV-1
Observation	198/3-72, Kwale District, E 5.60.2 N 95.59.5, 165 m, 19-8-1980
Parent material	shales and limestones
Physiography	Minor Scarps
Surrounding landform	rolling to hilly
Meso-relief	middle part of the straight slope
Slope gradient	6%
Land use/land cover	grassland and extensive grazing; maize fields and scattered mangoes
Drainage class	moderately well drained
Depth of groundwater table	below 90 cm
Presence of surface stones/rock outcrops	nil

Ah 0- 40 cm: Dark yellowish brown (10YR 3/4) clay loam; moderate medium sub-angular blocky; friable; few fine and very fine pores; abrupt and wavy transition to:

Bt 40- 90 cm: Yellowish brown (10YR 5/6) clay; many fine distinct mottles; moderate medium prismatic; moderately thick patchy clay cutans; firm; many very fine and few fine pores; diffuse transition to:

Btg 90+cm: Light olive brown (2.5Y 5/4) clay; many medium prominent mottles; moderate medium to coarse prismatic; moderately thick patchy clay skins; firm; few fine and very fine iron/manganese concretions; few fine pores.

Unit USKf, Profile 3

Soil classification	albic Arenosol; ustoxic Quartzipsamment
Agro-climatic zone	V-1
Observation	198/1-3, Kilifi District, E 5.60.0 N 96.09.1, 300 m, 4-1-1980
Parent material	fine grained sandstones and siltstones
Physiography	Coastal Uplands (Kaloleni upland)
Surrounding landform	gently undulating
Meso-micro-relief	summit; scattered termite mounds; slope
gradient	0-1%
Land use/land cover	bushed grassland and extensive grazing/ browsing; scattered cultivated fields
Drainage class	excessively drained
Depth of groundwater table	below 140 cm
Presence of surface stones/rock outcrops	nil
Evidence of erosion	moderate active rill and gully erosion
Soil fauna	termites

C1 0- 14 cm: Light yellowish brown (10YR 6/4) loamy sand; porous massive, weakly coherent; soft, loose, non-sticky and non-plastic; few fine, common very fine pores; few coarse medium and fine, common very fine roots; diffuse transition to:

C2 14-140+cm: Brownish yellow (10YR 6/4-6/6) loamy sand; porous massive, weakly coherent; slightly hard, loose, non-sticky and non-plastic; common very fine pores; very few medium, few fine and very fine roots.

Unit USKf, Profile 4

Soil classification	Luvic Arenosol; alfic Ustipsamment
Agro-climatic zone	IV-1
Observation	198/1-81, Kilifi District, E 5.61.9 N 95.86.4, 300 m, 19-5-1982
Parent material	fine grained sandstones and siltstones
Physiography	Coastal Uplands (Kaloleni upland)
Surrounding landform	gently undulating
Meso-micro-relief	upper part of the slightly convex slope; scattered termite mounds
Slope gradient	2%
Land use/land cover	semi-permanent cultivation of maize and cassava
Drainage class	somewhat excessively drained
Depth of groundwater table	below 150 cm
Presence of surface stones/rock outcrops	nil
Evidence of erosion	slight sheet erosion
Soil fauna	termites

Ah 0- 20 cm: Very dark greyish brown (10YR 3/2) sandy loam; weak medium subangular blocky; loose, very friable, slightly sticky and slightly plastic; common medium, fine and very fine, few coarse pores; few medium, common fine, many very fine roots; small charcoal particles (< 1 cm) and some pottery fragments; clear and smooth transition to:

E 20- 60 cm: Brown (10YR 5/3) sandy loam; weak medium subangular blocky; soft, very friable, slightly sticky and slightly plastic; few medium and coarse, common fine, many very fine pores; many very fine roots; gradual and smooth transition to:

C/B 60-130 cm: Yellowish brown (10YR 5/4) loamy sand; weak fine subangular blocky; soft, very friable, slightly sticky and slightly plastic; few coarse, medium and fine, many very fine pores; common very fine roots; gradual and smooth transition to:

C 130-150+cm: Brownish yellow (10YR 6/6) loamy sand; weak fine subangular blocky; soft, very friable, slightly sticky and slightly plastic; few fine many very fine pores; faint saprolite mottling below 150 cm.

Note: At 70 cm, 95 cm, 113 cm and 125 cm horizontal lamellae of smooth and wavy, brown (10YR 4/3) sandy loam occur.

Unit USKA1, Profile 5

Soil classification	chromic Luvisol; oxic Paleustalf
Agro-climatic zone	IV-1
Observation	198/3-43, Kilifi District, E 5.68.7 N 95.81.7, 250 m, 29-10-1980
Parent material	fine grained sandstones and siltstones
Physiography	Coastal Uplands (Kaloleni upland)
Surrounding landform	rolling
Meso-relief	upper part of the slightly convex slope
Slope gradient	2%
Land use/land cover	coconuts (80%); underneath: browsing goats, grasses and herbs
Drainage class	well drained
Depth of groundwater table	below 200 cm
Presence of surface stones/rock outcrops	nil
Evidence of erosion	nil

Ah 0- 18 cm: Dark brown (7,5YR 4/4) loamy sand; weak medium subangular blocky; soft, very friable, non-sticky and non-plastic; many very fine, common fine pores; many very fine and fine roots; clear and smooth transition to:

AB 18- 42 cm: Reddish brown (5YR 4/4) sandy clay loam; moderate coarse sub-angular blocky; slightly hard, friable, non-sticky and non-plastic; many very fine and fine pores; many very fine roots; gradual and smooth transition to:

Bt1 42-105 cm: Yellowish red (5YR 4/6) sandy clay loam; porous massive; slightly hard, friable, slightly sticky and slightly plastic; common very fine, few fine pores; common very fine, medium and coarse roots; diffuse transition to:

Bt2 105-145 cm: Yellowish red (5YR 5/8) sandy clay loam; porous massive; slightly hard, very friable, non-sticky and slightly plastic; common very fine pores; common very fine, medium and coarse roots; diffuse transition to:

BC 145-200 cm: Yellowish red (5YR 5/8) sandy clay loam to sandy loam; porous massive; slightly hard, very friable, non-sticky and non-plastic; few very fine pores; few roots.

Unit USKA2, Profile 6

Soil classification	gleyic Acrisol; 'epiaquic' Paleustult
Agro-climatic zone	V-1
Observation	198/1-11, Kilifi District, E 5.57.0 N 96.07.1, 270 m, 25-11-1980
Parent material	fine grained sandstones and siltstones
Physiography	Coastal Uplands (Kaloleni upland)
Surrounding landform	gently undulating
Meso-relief	almost flat part of a complex slope
Slope gradient	1%
Land use/land cover	*Brachystegia* bushed woodland; browsing (goats)
Drainage class	moderately well drained
Depth of groundwater table	below 110 cm
Presence of surface stones/rock outcrops	nil
Evidence of erosion	nil
Human activities	charcoal production

Ah	0- 13 cm:	Yellowish brown (10YR 5/4) loamy sand; few faint reddish yellow fine iron mottles; single grain; very friable, non-sticky and non-plastic; many very fine to fine pores; many fine medium roots; abrupt and smooth transition to:
BAg	13- 35 cm:	Very pale brown (10YR 7/4) loamy sand; common faint reddish yellow fine iron mottles; very weak subangular blocky; very friable, non-sticky and non-plastic; many very fine pores; common coarse roots; clear and smooth transition to:
Btg1	35- 88 cm:	Light grey (10YR 7/2) sandy loam; common prominent red medium to coarse iron mottles; moderate medium subangular blocky; friable, non-sticky and non-plastic; many very fine to fine pores; few medium roots; abrupt and smooth transition to:
Btg2	88-110+cm:	Light grey (10YR 7/2) sandy clay; common prominent reddish yellow medium to coarse iron mottles; moderate coarse prismatic; clay skins; very hard, extremely firm, non-sticky and non-plastic; common very fine to medium pores; no roots.

Unit USs1, Profile 7

Soil classification	albic Arenosol ustoxic Quartzipsamment
Agro-climatic zone	V-1
Observation	198/1-23, Kilifi District, E 5.67.1, N 95.98.1, 235 m, 8-6-1981
Parent material	coarse grained sandstones and arkoses
Physiography	Coastal Uplands (Kaloleni Upland)
Surrounding landform	undulating
Mesorelief	middle part of the slightly convex slope
Slope gradient	7%
Land use/land cover	mixture of *Brachystegia* bushed woodland with extensive browsing and cashew with scattered cultivated fields
Drainage class	excessively drained
Depth of groundwater table	below 320 cm
Presence of surface stones/rock outcrops	nil
Evidence of erosion	slight rill and gully erosion
Human activities	charcoal production

C1	0- 90 cm:	Brownish yellow (10YR 6/6) loamy sand; very few distinct very coarse (10YR 8/2) iron mottles; porous massive, weakly coherent; loose, non-sticky and non-plastic; common biopores; many very fine poots; few 1-2 mm quartz minerals; clear and smooth transition to:
C2	90-152 cm:	Yellow (10YR 8/6) loamy sand; very few distinct very coarse (10YR 8/2) iron mottles; porous massive, moderately coherent; slightly hard, loose, non-sticky and non-plastic; common biopores; few fine and medium roots; few 1-2 mm quartz minerals; gradual and smooth transition to:
C3	152-200 cm:	very pale brown (10YR 8/3) loamy sand; porous massive, weakly coherent; soft, loose, non-sticky and non-plastic; few fine and medium roots.
C4	200-320 cm:	very pale brown (10YR 8/3) loamy sand

Unit USs2p, Profile 8

Soil classification	luvic Arenosol; alfic Ustipsamment
Agro-climatic zone	IV-1
Observation	198/3-74, Kilifi District, E 5.61.8 N 95.61.9, 200 m, 20-8-1980
Parent material	coarse grained sandstones and arkoses
Physiography	Coastal Uplands (Kaloleni upland)
Surrounding landform	rolling to hilly
Meso-relief	middle part of the convex slope
Slope gradient	12%
Land use/land cover	grassland and scattered shrubs; scattered cultivated fields

Drainage class	somewhat excessively drained
Depth of groundwater table	below 140 cm
Presence of surface stones/rock outcrops	nil
Evidence of erosion	nil

Ah	0- 28 cm:	Reddish brown (5YR 4/4) loamy medium sand; weak fine subangular blocky; loose, non-sticky and non-plastic; many micropores; gradual and wavy transition to:
E	28- 70 cm:	Pale red (2.5YR 6/2) medium sand; weak fine subangular blocky; loose, non-sticky and non-plastic, many micropores; diffuse transition to:
C/B	70-140 cm:	Pale red (2.5YR 6/2) medium sand; every 10-15 cm lamellae (1-2 mm thick): loamy medium sand; weak fine subangular blocky; loose, non-sticky and non-plastic; many micropores; gradual and wavy transition to:
C	140+cm:	Yellowish red (5YR 5/6) medium sand; weak fine subangular blocky; loose, non-sticky and non-plastic; many micropores.

Unit USlp, Profile 9

Soil classification	gleyic Luvisol; aquultic Haplustalf
Agro-climatic zone	IV-1
Observation	198/3-49, Kilifi District, E. 5.77.1 N 95.89.0, 290 m, 19-6-1981
Parent material	coarse grained sandstones and arkoses
Physiography	Coastal Uplands (Kaloleni upland)
Surrounding landform	rolling
Meso-relief	lower part of a convex slope
Slope gradient	16%
Land use/land cover	grassland (60%); cultivated fields (maize, cassava, pulses, 40%)
Drainage class	imperfectly drained
Depth of groundwater table	perched groundwater at 70 cm
Presence of surface stones/rock outcrops	nil
Evidence of erosion	nil

Ah	0- 15 cm:	Dark brown (10YR 3/3) sandy clay loam; weak medium subangular blocky; slightly hard, friable, non-sticky and non-plastic; many very fine and fine pores; few medium, many very fine and fine roots; clear and smooth transition to:
BA	15- 35 cm:	Dark yellowish brown (10YR 4/6) sandy loam; moderate coarse subangular blocky; slightly hard, friable, slightly sticky and slightly plastic; common very fine and fine pores; common very fine and fine roots; gradual and smooth transition to:
Bt1	35- 70 cm:	Brownish yellow (10YR 6/6) sandy clay loam; common distinct fine red iron mottles; moderate coarse angular blocky; thin patchy clay cutans; hard, firm, sticky and plastic; common very fine pores; few roots; diffuse transition to:
BC	70-120+cm:	Light brownish grey (2.5Y 6/2) sandy clay loam; many prominent medium red iron mottles; moderate coarse subangular blocky; very few patchy clay cutans; hard, firm, slightly sticky and plastic; common very fine pores.

Unit UScl, Profile 10

Soil classification	humic Acrisol; 'oxic' Paleustult
Agro-climatic zone	III-1
Observation	198/3-40, Kilifi District, E 5.74.5 N 95.79.2, 230 m, 29-10-1980
Parent material	coarse grained sandstones and arkoses
Physiography	Coastal Uplands (Kaloleni upland)
Surrounding landform	rolling
Meso-relief	upper part of the slope
Slope gradient	8%
Land use/land cover	bush-fallow: cultivation of annual field crops (50%) and browsing (50%)

Drainage class	well drained
Depth of groundwater table	below 200 cm
Presence of surface stones/rock outcrops	nil
Evidence of erosion	slight to moderate sheet erosion (topsoil truncation)

Ah 0- 18 cm: Dark brown (10YR 3/3) loamy medium sand; weak medium subangular blocky; loose, very friable, non-sticky and non-plastic; very porous; clear and smooth transition to:

Bw 18- 35 cm: Strong brown (7.5YR 5/6) sandy loam; weak coarse subangular blocky; soft, friable, non-sticky and non-plastic; common very fine and fine porous; common very fine and fine roots; gradual and smooth transition to:

Bt1 35- 75 cm: Strong brown (7.5YR 5/8) sandy clay; moderate medium subangular blocky; slightly hard, friable, non-sticky and slightly plastic; patchy thin clay cutans; common very fine pores; few fine and medium roots; diffuse transition to:

Bt2 75-200+cm: Yellowish red (5YR 5/8) sandy clay to clay; moderate medium angular blocky; slightly hard, friable, slightly sticky and slightly plastic; broken thin clay cutans; few very fine and fine pores; few fine roots.

Unit USc1, Profile 11

Soil classification	chromic Luvisol; oxic Haplustalf
Agro-climatic zone	IV-1
Observation	198/3-120, Kilifi District, E 5.71.5 N 95.83.0, 270 m, 19-5-1982
Parent material	coarse grained sandstones and arkoses
Physiography	Coastal Uplands (Kaloleni upland)
Surrounding landform	rolling
Meso-relief	flat plateau
Slope gradient	0%
Land use/land cover	multiple cropping. cashew/coconut with annual field crop (maize) underneath
Drainage class	well drained
Depth of groundwater table	below 150 cm
Presence of surface stones/rock outcrops	nil
Evidence of erosion	slight sheet erosion
Surface sealing/crusting	thin, weak

Ah 0- 15 cm: Dark reddish brown (2.5YR 3/4) sandy clay loam; weak medium granular to angular blocky; hard, friable, slightly sticky and slightly plastic; no cutans; many very fine and fine, common medium, few coarse pores; many very fine, few fine roots; some small (<2 cm Ø) charcoal particles; clear and smooth transition to:

BA 15- 55 cm: Dark red (2.5YR 3/6) sandy clay loam; moderate medium to coarse prismatic, breaking into moderate medium to coarse angular blocky; hard, firm, slightly sticky and plastic; very patchy thin clay cutans in pores; many very fine, medium fine, common medium, few coarse pores; common very fine, few fine roots; some burrows (2 cm Ø), partly filled with topsoil; gradual and smooth transition to:

Bt 55-105 cm: Red (2.5YR 4/8) sandy clay; moderate medium to coarse prismatic, breaking into moderate medium to coarse angular blocky; hard, friable to firm, slightly sticky, plastic; patchy thin clay cutans in pores; many very fine, many fine, few medium, and coarse pores; common very fine, few fine roots; diffuse transition to:

BC 105-150+cm: Red (2.5YR 4/8) sandy clay loam; moderate medium to coarse prismatic breaking into moderate medium to coarse angular blocky; hard, firm, slightly sticky to sticky, plastic; many very fine, common fine, few medium, few coarse pores; common very fine, few fine roots.

Unit ULc1, Profile 12

Soil classification	dystric Nitosol; 'rhodoxic' Paleustult
Agro-climatic zone	III-1
Observation	198/3-8, Kilifi District, E 5.79.7 N 95.84.5, 220 m, 13-11-1980
Parent material	limestones
Physiography	Coastal Uplands (Dzitsoni upland)
Surrounding landform	gently undulating
Meso-relief	middle part of the convex slope
Slope gradient	2%
Land use/land cover	multiple cropping; coconut with annual field crops (maize, cassave, pulses) underneath
Drainage class	well drained
Depth of groundwater table	below 200 cm
Presence of surface stones/rock outcrops	rockiness: class 2
Evidence of erosion	nil
Surface sealing/crusting	thin, weak sealing

Ah 0- 25 cm: Dusky red (2.5YR 3/2) sandy clay; moderate fine to medium crumb; slightly hard, friable, sticky and plastic; many fine pores; many very fine to fine, common medium roots; gradual and smooth transition to:

Bt1 25- 55 cm: Dark red (10R 3/4) sandy clay; moderate medium subangular blocky; hard, friable, sticky and plastic; few thin clay cutans; many fine, few medium to coarse pores; many fine and medium roots; gradual and smooth transition to:

Bt2 55-200+cm: Dusky red (10YR 3/4) sandy clay; weak to moderate, medium subangular blocky tending to prismatic; hard, friable, sticky and plastic; many moderately thin clay cutans; many fine pores; common medium roots; abrupt transition to:

R 200+cm: solid limestone.

Unit ULc2, Profile 13

Soil classification	dystric Nitosol; 'rhodoxic' Paleustult
Agro-climatic zone	V-1
Observation	198/1-47, Kilifi District, E 5.80.7 N 96.08.5, 125 m, 2-11-1981
Parent material	limestones
Physiography	Coastal Uplands (Dzitsoni upland)
Surrounding landform	undulating
Meso-relief	lower part of the convex slope
Slope gradient	4%
Land use/land cover	*Brachystegia* bushland with patches of grassland and bare land; extensive grazing and browsing
Drainage class	well drained
Depth of groundwater table	below 150 cm
Presence of surface stones/rock outcrops	few surface stones (class 0)
Evidence of erosion	nil
Surface sealing/crusting	thin, weak sealing
Soil fauna	termites

Ah 0- 30 cm: Dark reddish brown (2.5YR 3/4) loam; weak medium subangular blocky; slightly hard, very friable, slightly sticky and slightly plastic; continuous thin manganese cutans; many very fine and fine, few medium and coarse pores and roots; few small (1-2 mm Ø) hard spherical black manganese nodules; numerous (3-5/m^2) big (5-15 cm Ø) insect chambers; gradual and smooth transition to:

BA 30- 80 cm: Red (10R 4/6) clay loam; moderate medium subangular blocky; slightly hard, very friable, slightly sticky and slightly plastic; continuous thin manganese cutans; many very fine and fine, common medium pores and roots; few small (1-2 mm Ø) hard spherical manganese nodules; numerous (3/m^2) big (5-15 cm Ø) insect chambers; gradual and smooth transition to:

Bt 80-150+cm: Dark red (10R 3/6) clay loam; moderate medium angular blocky; slightly hard, very friable, slightly sticky and slightly plastic; continuous thin manganese cutans; many very fine and fine, common medium pores; common very fine and fine roots; few small (1-3 mm Ø) hard spherical manganese nodules.

Unit UOf, Profile 14

Soil classification	ferralic Arenosol; typic Ustipsamment
Agro-climatic zone	IV-1
Observation	198/3-62, Kilifi District, E 5.59.5 N 95.83.5, 190 m, 20-10-1980
Parent material	unconsolidated fine sandy and clayey deposits
Physiography	Coastal Uplands (Rabai upland)
Surrounding landform	gently undulating
Meso-relief	hilltop
Slope gradient	3%
Land use/land cover	bushed grassland with extensive grazing and browsing; scattered fields
Drainage class	well drained
Depth of groundwater table	below 90 cm
Presence of surface stones/rock outcrops	nil
Evidence of erosion	slight sheet erosion

Ah 0- 18 cm: Dark greyish brown (10YR 4/2) sandy loam; weak fine subangular blocky; loose, non-sticky and non-plastic; many very fine and fine common medium pores; many fine and very fine roots; clear and smooth transition to:

AC 18- 40 cm: Dark greyish brown (10YR 4/2) loamy sand; porous massive, weakly coherent; loose, non-sticky and non-plastic; common very fine and fine pores; few medium, common very fine and few fine roots; gradual and smooth transition to:

C 40- 90+cm: Light yellowish brown (10YR 6/4) loamy sand; porous massive, weakly coherent; loose, non-sticky and non-plastic; few very fine and fine pores; few very fine roots.

Note: texture below 150 cm sandy loam

Unit UOc1, Profile 15

Soil classification	orthic Luvisol; udic Haplustalf
Agro-climatic zone	IV-1
Observation	198/3-70, Kwale District, E 5.59.5 N 95.61.6, 175 m, 18-8-1980
Parent material	unconsolidated fine sandy and clayey deposits
Physiography	Coastal Uplands (Rabai upland)
Surrounding landform	undulating to rolling
Meso-relief	middle part of the slightly convex slope
Slope gradient	8%
Land use/land cover	multiple cropping: mangoes with maize underneath
Drainage class	well drained
Depth of groundwater table	below 100 cm
Presence of surface stones/rock outcrops	nil
Evidence of erosion	nil

Ah 0- 13 cm: Dark greyish brown (10YR 4/2) sandy loam; moderate fine to medium subangular blocky; friable; many very fine and fine pores; clear and smooth transition to:

AB 13- 28 cm: Dark greyish brown (10YR 4/2) loam; continuous organic cutans; moderate medium angular blocky; friable; many very fine and fine pores; clear and smooth transition to:

Bt1	28- 53 cm:	Brown (10YR 4/3) loam to clay loam; continuous mainly organic cutans; moderate to strong medium prismatic; firm; many very fine pores; clear and smooth transition to:
Bt2	53-100 cm:	Strong brown (7.5YR 5/8) clay to clay loam; continuous clay skins; moderate to strong medium prismatic; firm; common very fine and fine pores; abrupt and broken transition to:
R/C	100+cm:	weathered fine-grained sandstone (Fe-Mn-micaceous); quartzpebbles are found at the transition of the unconsolidated parent material and the bedrock.

Unit UOc2p, Profile 16

Soil classification	verti-gleyic Luvisol, sodic phase; aquic Haplustalf
Agro-climatic zone	V-1
Observation	198/1-43, Kilifi District, E 5.75.2 N 96.10.2, 165 m, 7-8-1981
Parent material	unconsolidated fine sandy and clayey deposits
Physiography	Coastal Uplands (Rabai upland)
Surrounding landform	gently undulating to undulating
Meso-relief	straight lower slope; scattered termite mounds
Slope gradient	4%
Land use/land cover	grassed bushland, intense grazing and browsing
Drainage class	moderately well drained
Depth of groundwater table	temporarily shallow (40 cm)
Presence of surface stones/rock outcrops	nil
Evidence of erosion	moderate to severe rill and gully erosion
Salinity/alkalinity	ESP exceeds 15 (below 40 cm)
Soil fauna	termites
Human activities	retarded growth of bushes due to over-grazing and erosion

Ah	0- 9 cm:	Dark yellowish brown (10YR 3/4) loamy sand; common small faint yellowish red iron mottles; porous massive, weakly coherent; slightly hard, loose, slightly sticky and non-plastic; many very fine and fine pores and roots; few iron-manganese nodules (1-5 mm); abrupt and wavy transition to:
BA	9- 37 cm:	Yellowish brown (10YR 5/6) sandy loam; common small faint yellowish red iron mottles; weak very coarse subangular blocky; slightly hard, loose, sticky and slightly plastic; many very fine and fine pores and roots; very few iron-manganese nodules (1-5 mm); clear and wavy transition to:
Btg1	37- 63 cm:	Grey (5YR 6/1) sandy clay loam; many coarse distinct iron mottles; strong very coarse prismatic; extremely hard, very firm, sticky and plastic; many very fine pores and roots; few iron-manganese nodules (1-5mm); gradual and wavy transition to:
Btg2	63- 90+cm:	Brownish yellow (10YR 6/8) sandy clay to clay; many coarse faint brownish yellow iron mottles; strong coarse prismatic; extremely hard, very firm, sticky and plastic. Thick continuous clay skins and slickensides; many very fine pores; frequent iron-manganese nodules (5mm); few calcium carbonate nodules.

Unit UT2c1p, Profile 17

Soil classification	chromic Vertisol; typic Chromustert
Agro-climatic zone	III-1
Observation	198/1-9, Kilifi District, E 5.82.7 N 95.85.6, 105 m, 17-1-1980
Parent material	shales
Physiography	Coastal Uplands (Lutsangani upland)
Surrounding landform	rolling
Meso-relief	middle part of the convex slope; some gilgai

Slope gradient	8%
Land use/land cover	maize/sesame rotation; in places bushed grassland with extensive grazing
Drainage class	moderately well drained
Depth of groundwater table	below 112 cm
Presence of surface stones/rock outcrops	nil
Evidence of erosion	slight to moderate sheet, rill and gully erosion
Surface sealing/crusting	moderately thick, medium sealing
Human activities	soils are tilled mechanically

Ap 0- 21 cm: Very dark greyish brown (10YR 3/2) cracking clay; strong coarse subangular blocky; very hard, very firm, sticky and plastic; few small iron concretions; few medium and fine common very fine pores; few coarse, medium, fine and very fine roots; abrupt and smooth transition to:

Ah 21- 32 cm: Dark brown to brown (7.5YR 4/4) cracking clay; few fine faint brownish yellow iron mottles; strong coarse angular blocky; very hard, very firm, sticky and plastic; common moderately thick clay skins; few small to medium iron and manganese concretions; few medium, fine and very fine pores; few medium, fine and very fine roots; clear and wavy transition to:

AC 32- 62 cm: Yellowish brown (10YR 5/6) cracking clay; common fine distinct yellowish red iron mottles; strong very coarse angular blocky; very hard, very firm, sticky and plastic; common thick clay skins; intersecting slickensides; few, small manganese concretions; few medium pores; no roots; clear and smooth transition to:

C1 62-112+cm: Brownish yellow (10YR 6/6) cracking clay; strong very coarse angular blocky to prismatic; very hard, very firm, sticky and plastic; abundant thick clay skins, intersecting slickensides; no pores; few small manganese concretions; no roots.

Unit UT2c2p, Profile 18

Soil classification	chromic Vertisol; udic Chromustert
Agro-climatic zone	IV-1
Observation	198/2-39, Kilifi District, E 5.84.4 N 96.06.7, 75 m, 21-6-1982
Parent material	shales
Physiography	Coastal Uplands (Lutsangani upland)
Surrounding landform	rolling
Meso-relief	upper part of the convex slope
Slope gradient	10%
Land use/land cover	wooded grassland, strongly degraded; extensive grazing
Drainage class	moderately well drained
Depth of groundwater table	below 115 cm
Presence of surface stones/rock outcrops	nil
Evidence of erosion	moderate sheet, rill and gully erosion
Salinity/alkalinity	soft powdery lime in the subsoil

Ah1 0- 20 cm: Very dark greyish brown (10YR 3/2) cracking clay; strong very coarse angular blocky, falling apart into medium-sized aggregates; very hard, firm, sticky and plastic; few to common fine and very fine pores; few fine and very fine roots; clear and smooth transition to:

Ah2 20- 40 cm: Dark greyish brown (2.5YR 4/2) cracking clay; strong very coarse angular blocky to columnar; very hard, very firm, very sticky and plastic; few fine and very fine pores; few ferro-manganese nodules; continuous intersecting slickensides; gradual and wavy to irregular transition to:

Ccs 40- 75 cm: Olive grey (5YR 4/2) cracking clay; strong very coarse columnar to angular blocky; very hard, very firm, very sticky and plastic; few very fine biopores; low HCl-effervescence; continuous intersecting slickensides; many ferro-manganese nodules; diffuse transition to:

Cca/cs 75-115+cm: Olive (5YR 4/3) cracking clay; strong very coarse angular blocky to columnar or prismatic; very hard, very firm, very sticky and plastic; no biopores; intersecting slickensides; many ferro-manganese nodules; strong HCl-effervescence; presence of secondary carbonates in the form of powdery lime.

Unit UElm2, Profile 19

Soil classification	Cambic Arenosol; typic Ustipsamment
Agro-climatic zone	IV-1
Observation	198/2-28, Kilifi District, E 5.90.5, N 96.10.4, 80 m., 19-6-1981
Parent material	Unconsolidated medium grained sandy deposits
Physiography	Coastal Uplands (Pingilikani uplands)
Surrounding landform	flat minor 'depression' between UE111 and UE 112
Meso-/microrelief	flat; common termite mounds
Slope gradient	0-1%
Land use/land cover	Multiple (perennial) cropping: cashew and coconut; bushy undergrowth (browsing)
Drainage class	somewhat exessively drained
Moisture conditions in profile	
Depth of groundwater table	below 150 cm
Presence of surface stones/rock outcrops	nil
Evidence of erosion	nil
Soil fauna	termites

A1 0- 13 cm: Very dark greyish brown (10YR 3/2) medium to fine sand; single grain; soft very friable non sticky and non plastic; many very fine, common fine and medium pores; common very fine, fine and medium roots; clear and smooth transition to:

CA 13- 50 cm: Brown to dark brown (10YR 4/3) medium to fine sand; few faint fine iron mottles; single grain; soft, very friable non sticky and non plastic; many very fine, common fine, few medium pores; common very fine, fine and medium roots; gradual and smooth transition to:

C1 50-150+cm: Dark brown (10YR 4/4), (loamy) medium to fine sand; single grain; patchy thin clay cutans; slightly hard, very friable, non sticky, non plastic; common very fine and fine pores; few very fine roots.

Unit UE111, Profile 20

Soil classification	chromic Luvisol; "rhodoxic" Paleustalf
Agro-climatic zone	III-1
Observation	198/4-41, Kilifi District, E 5.87.0 N 95.84.5, 105 m, 18-5-1982
Parent material	unconsolidated medium grained sandy deposits
Physiography	Coastal Uplands (Pingilikani upland)
Surrounding landform	rolling to hilly
Meso-relief	upper part of linear slope
Slope gradient	6%
Land use/land cover	multiple cropping: cashew/maize
Drainage class	somewhat excessively drained
Depth of groundwater table	below 150 cm
Presence of surface stones/rock outcrops	nil
Evidence of erosion	moderate to severe sheet, rill and gully erosion

Ah 0- 28 cm: Dark reddish brown (2.5YR 3/4) sandy loam; weak medium subangular blocky to granular; slightly hard, very friable, slightly sticky and slightly plastic; many very fine, few fine, medium and coarse pores; common very fine, few fine, medium and coarse roots; many charcoal particles; gradual and smooth transition to:

BA 28- 62 cm: Dark reddish brown (2.5YR 3/4) sandy clay loam; weak medium prismatic, breaking into weak medium angular to subangular blocky; slightly hard, friable, slightly sticky and slightly plastic; many very fine and fine, common medium, few coarse pores; common very fine, few fine, medium and coarse roots; many charcoal particles; gradual and smooth transition to:

Bt1 62-113 cm: Dusky red (10YR 3/4) sandy clay loam; weak medium prismatic, breaking into weak medium angular blocky; friable, slightly sticky and slightly plastic; patchy thin clay skins; many very fine, common fine and medium pores; few very fine, fine, medium and coarse roots; few charcoal particles; diffuse transition to:

BC 113-150+cm: Dusky red (10YR 3/4) sandy clay loam; weak medium prismatic, breaking into weak medium angular blocky; friable, slightly sticky and slightly plastic; patchy thin clay skins; many very fine, common fine, few medium and coarse pores; few roots.

Unit UE112, Profile 21

Soil classification	rhodic Ferralsol; typic Haplustox
Agro-climatic zone	IV-1
Observation	198/2-3, Kilifi District, E 5.89.9 N 96.05.7, 95 m, 9-1-1980
Parent material	unconsolidated medium grained sandy deposits
Physiography	Coastal Uplands (Pingilikani upland)
Surrounding landform	gently undulating
Meso-relief	flat-topped ridge; many termite mounds
Slope gradient	0%
Land use/land cover	multiple landuse: cashew, scattered coconut (former plantation) and bushland with extensive grazing underneath
Drainage class	well drained
Depth of groundwater table	below 150 cm
Presence of surface stones/rock outcrops	nil
Evidence of erosion	nil
Soil fauna	termites

Ah 0- 13 cm: Very dusky red (2.5YR 2/2) loamy sand; very weak fine subangular blocky to granular; loose, very friable, non-sticky and non-plastic; common very fine, fine and medium pores; many (15-40%) black spherical Mn-concretions; gradual and smooth transition to:

Bt 13- 98 cm: Dusky red (10YR 3/4) loamy sand to sandy loam; very weak fine subangular blocky to granular; soft, friable, non-sticky and non-plastic; many very fine and fine pores; common very fine and fine roots; many small Mn-concretions; clear and smooth transition to:

BC 98-150 cm: Dusky red (10YR 3/4) sandy loam; very weak medium subangular blocky; soft, friable, slightly sticky and non-plastic; common very fine and few fine pores; no roots; many small Mn-concretions.

Unit P101, Profile 22

Soil classification	solodic Planosol; typic Natrustalf
Agro-climatic zone	IV-1
Observation	198/3-67, Kilifi District, E 5.6.6 N 95.74.5, 175 m, 18-8-1980
Parent material	unconsolidated fine sandy and clayey deposits
Physiography	Coastal Plains (Bamba plain)
Surrounding landform	flat to almost flat
Meso-relief	flat plain
Slope gradient	0%
Land-use/land cover	shrubland (*Acacia*, *Euphorbia*) and bare soil; extensive grazing and browsing
Drainage class	moderately well drained to imperfectly drained

Depth of groundwater table	below 105 cm
Presence of surface stones/rock outcrops	nil
Evidence of erosion	moderate sheet erosion (due to overgrazing
Salinity/alkalinity	EC and ESP presumably exceed critical values in the subsoil

Ah 0- 6 cm: Dark greyish brown (10YR 4/2) sandy loam; few fine faint iron mottling along roots; porous massive; soft, very friable, non-sticky and non-plastic; many very fine and fine, common medium, few coarse pores; common very fine and fine roots; clear and smooth transition to:

Eg 6- 40 cm: Dark greyish brown (10YR 4/2) sandy loam; few fine faint iron mottling along roots; porous massive; slightly hard, very friable, non-sticky and non-plastic; many very fine, common fine, few medium pores; common very fine roots; abrupt and wavy transition to:

Btg1 40-105 cm: Greyish brown (10YR 5/2) sandy clay loam; common fine distinct yellowish red iron mottles; moderate very coarse prismatic to columnar; few patchy clay skins; very to extremely hard, friable, non-sticky and non-plastic; common very fine pores; common to few very fine roots.

Unit P2Em1, Profile 23

Soil classification	orthic Luvisol;udic Haplustalf
Agro-climatic zone	IV-1
Observation	198/2-34, Kilifi District, E 5.94.6 N 96.00.3, 15 m, 12-2-1982
Parent material	medium and coarse grained sandy deposits
Physiography	Coastal Plains (Kibarani plains)
Surrounding landform	flat to almost flat
Meso-relief	flat plain
Slope gradient	0%
Land use/land cover	multiple (perennial) cropping: cashew/ coconut; bushy undergrowth with some browsing
Drainage class	somewhat excessively drained
Depth of groundwater table	below 160 cm
Presence of surface stones/rock outcrops	nil
Evidence of erosion	slight sheet erosion
Surface sealing/crusting	thin, weak sealing and crusting

Ah 0- 40 cm: Dark brown (10YR 3/3) loamy sand; porous massive, weakly coherent; soft to slightly hard, loose, non-sticky and non-plastic; common many pores; smooth and gradual transition to:

AB 40- 80 cm: Brown (10YR 4/4) loamy sand; porous massive, weakly coherent; slightly hard to hard, loose, non-sticky and non-plastic; common to many pores; smooth and gradual transition to:

Bt1 80-115 cm: Strong brown (7.5YR 4/6) sandy loam; porous massive, moderately coherent; slightly hard to hard, loose to very friable, non-sticky and non-plastic; common pores; gradual and smooth transition to:

Bt2 115-160 cm: Same as Bt1 except for texture: sandy clay loam; smooth and gradual transition to:

Bt3 160+cm: Strong brown (7.5YR 5/6) sandy clay loam; porous massive, strongly coherent; hard, loose to very friable, non-sticky and non-plastic; few pores.

Unit P2Em3, Profile 24

Soil classification	chromic Luvisol; rhodic Paleustalf
Agro-climatic zone	IV-1
Observation	198/2-35, Kilifi District, E 5.96.3 N 96.02.1, 15 m, 1-2-1982
Parent material	medium and coarse grained sandy deposits
Physiography	Coastal Plains (Kibarani plains)

Surrounding landform	flat to almost flat
Meso-relief	flat plain
Slope gradient	0%
Land use/land cover	multiple cropping: cashew/coconut/mango; underneath: bush-fallow (maize/cassava/ sesame or farm bush with browsing)
Drainage class	somewhat excessively drained
Depth of groundwater table	below 200 cm
Presence of surface stones/rock outcrops	nil
Evidence of erosion	nil

Ah 0- 10 cm: Dark brown (7.5YR 3/4) loamy sand; porous massive, weakly coherent; soft, very friable, non-sticky and non-plastic; common medium, many fine and very fine pores; few coarse, common medium and fine, many very fine roots; clear and smooth transition to:

AB 10- 50 cm: Yellowish red (5YR 4/6) loamy sand; porous massive, weakly coherent; slightly hard, very friable, non-sticky and non-plastic; common medium, fine and very fine pores; few medium and fine, common very fine roots; diffuse transition to:

Bt1 50-100 cm: Red (2.5YR 4/8) sandy loam; porous massive, moderately coherent; slightly hard, very friable, non-sticky and non-plastic; few fine and very fine roots; diffuse transition to:

Bt2 100-200+cm: Red (2.5YR 4/8) sandy loam; porous massive, moderately coherent; hard, friable, non-sticky and non-plastic; common fine and very fine pores; few very fine roots; strong H_2O_2-effervescence (Mn).

Unit P2Em4, Profile 25

Soil classification	cambic Arenosol;typic Ustipsamment
Agro-climatic zone	IV-1
Observation	198/2-14, Kilifi District, E 5.98.0 N 96.13.0, 15 m, 19-8-1980
Parent material	medium and coarse grained sandy deposits
Physiography	Coastal Plains (Kibarani plains)
Surrounding landform	flat to almost flat
Meso-relief	flat plain
Slope gradient	2%
Land use/land cover	multiple cropping: coconut/annual field crops (maize/cowpea/cassava)
Drainage class	somewhat excessively drained
Depth of groundwater table	below 160 cm
Presence of surface stones/rock outcrops	nil
Evidence of erosion	nil

Ah 0- 20 cm: Brown (7.5YR 4/3) sand; weak medium to coarse subangular blocky; loose to very friable; common very fine, few to common fine and medium pores; many very fine and fine, common medium roots; clear and smooth transition to:

AB 20- 44 cm: Brown (7.5YR 4/4) sand; weak medium to coarse subangular blocky; loose to very friable; common very fine, few to common fine and medium pores; many very fine, common fine and medium roots; gradual and wavy transition to:

Bw1/R 44- 73 cm: Strong brown (7.5YR 5/6) sand; weak medium to coarse subangular blocky; loose to very friable; common very fine, few fine and medium pores; many very fine, common fine and medium roots; clear and smooth transition to:

Bw2/R 73-160+cm: Yellowish red (5YR 5/8) sand; weak medium to coarse subangular blocky; loose to very friable; common very fine and few to common fine and medium pores; few very fine and fine roots.

Note: Large pieces of unweathered, fresh coral rock are found in the profile between depths of 40 cm and 150 cm.

Unit P2E11, Profile 26

Soil classification	chromic Luvisol; "rhodoxic" Paleustult
Agro-climatic zone	IV-1
Observation	198/2-1, Kilifi District, E 5.94.2 N 96.00.7, 30 m, 16-1-1980
Parent material	medium and coarse grained sandy deposits
Physiography	Coastal Plains (Kibarani plains)
Surrounding landform	flat to almost flat
Meso-relief	flat plain
Slope gradient	1%
Land use/land cover	annual field crops (maize/cowpea); patches of herb- and grassland
Drainage class	somewhat excessively drained
Depth of groundwater table	below 145 cm
Presence of surface stones/rock outcrops	nil
Evidence of erosion	nil

Ah 0- 22 cm: Dark brown (7.5YR 4/4) loamy sand; porous massive, weakly coherent; slightly hard, very friable, non-sticky and non-plastic; few, thin iron coatings; few fine, common very fine pores; few fine and very fine roots; abrupt and smooth transition to:

Bt1 22- 50 cm: Dark red, (2.5YR 3/6) sandy loam; porous massive, moderately coherent; slightly hard, very friable, non-sticky and non-plastic; few, thin iron coatings; common very fine pores; few fine and very fine roots; clear and smooth transition to:

Bt2 50- 99 cm: Red (2.5YR 4/6-4/8) sandy clay loam; porous massive, strongly coherent; hard, friable, slightly sticky and plastic; common thin iron coatings; few fine, common very fine pores; no roots; diffuse transition to:

Bt22 99-145+cm: Red (2.5YR 4/6) sandy clay loam; porous massive, strongly coherent; hard, friable, slightly sticky and plastic; common, thin iron coatings; few fine, common very fine pores; no roots.

Unit P2E12, Profile 27

Soil classification	orthic Luvisol; ultic Haplustalf
Agro-climatic zone	IV-1
Observation	198/2-44 Kilifi District, E 5.88.7 N 95.93.0, 60 m, 15-7-1982
Parent material	medium and coarse grained sandy deposits
Physiography	Coastal Plains (Kibarani plains)
Surrounding landform	flat to almost flat
Meso-relief	flat plain
Slope gradient	0%
Land use/land cover	treecrops: cashew/coconut/mango; undergrowth of grasses and herbs
Drainage class	well drained
Depth of groundwater table	at approximately 100 cm
Presence of surface stones/rock outcrops	nil
Evidence of erosion	nil

Ah 0- 19 cm: Dark brown (10YR 3/3) medium to fine sand; single grain; loose, non-sticky and non-plastic; common medium, fine and very fine pores; few medium, common fine and very fine roots; clear and wavy transition to:

AB 19- 60 cm: Brown (10YR 4/3) loamy sand; single grain; loose, non-sticky and non-plastic; common medium, fine and very fine pores; few fine and very fine roots; abrupt and smooth transition to:

Bt1 60- 82 cm: Dark yellowish brown (10YR 4/6) sandy clay loam; weak to moderate medium sub-angular blocky; very friable to friable, slightly sticky and non-plastic; broken clay skins, moderately thick; common medium, fine and very fine pores; no roots; gradual and smooth transition to:

Bt2 82-150cm: Yellowish brown (10YR 5/6) sandy clay loam; other characteristics are similar to those of the Bt1.

Unit P2L12p, Profile 28

Soil classification	ferric Luvisol; oxic Rhodustalf
Agro-climatic zone	III-1
Observation	198/4-6, Kilifi District, E 5.84.6 N 95.64.5, 15 m, 26-9-1980
Parent material	coral limestone and sands
Physiography	Coastal Plains (Kibarani plain)
Surrounding landform	flat to almost flat
Meso-relief	flat plain
Slope gradient	0%
Land use/land cover	grassland with scattered treecrops (cashew, coconut)
Drainage class	well drained
Depth of groundwater table	below 80 cm
Presence of surface stones/rock outcrops	nil
Evidence of erosion	nil

A1 0 - 18 cm: Dark brown (7.5 YR 3/2) loamy sand; porous massive, weakly coherent to weak fine subangular blocky; hard, very friable, non-sticky and non-plastic; many very fine pores; many very fine, fine and medium roots; gradual and wavy transition to:

AB 18- 46 cm: Reddish brown (5 YR 4/3) loamy sand; porous massive, weakly coherent to weak fine subangular blocky; slightly hard, very friable, non-sticky and non-plastic; common very fine and fine pores; many very fine, common fine, few medium roots; diffuse transition to:

Bt1 46- 60 cm: Red (2.5 YR 5/6) sandy loam; moderate fine subangular blocky; slightly hard, very friable, slightly sticky and non-plastic; common very fine pores; many very fine and few medium roots; diffuse transition to:

Bt2/R 60- 80 cm: Red (2.5 YR 4/6) sandy clay loam; moderate fine to medium subangular blocky; slightly hard, very friable, slightly sticky and non-plastic; common very fine pores; common rock fragments; abrupt and broken transition to:

R 80+cm: Coral rock.

Unit AAc, Profile 29

Soil classification	pellic Vertisol; udic Pellustert
Agro-climatic zone	IV-1
Observation	198/2-4, Kilifi District, E 5.86.3 N 96.07.6, 10 m, 9-1-1980
Parent material	recent alluvial deposits
Physiography	Floodplains
Surrounding landform	flat elongated strip bordering rolling upland
Meso-relief	flat plain; gilgai
Slope gradient	0%
Land use/land cover	bushed grassland; extensive grazing
Drainage class	imperfectly drained
Depth of groundwater table	temporarily shallow (rainy season)
Presence of surface stones/rock outcrops	nil
Evidence of erosion	riverbank erosion during high discharges
Evidence of flooding	common during the rainy season

Ah1 0- 3 cm: Brown to dark brown (10YR 4/3) cracking clay; strong fine granular to subangular blocky; very hard, very firm, slightly sticky and plastic; slightly calcareous; common fine and very fine pores; few medium, common fine and very fine roots; abrupt and smooth transition to:

Ah2 3- 25 cm: Dark grey (10YR 4/1) cracking clay; very strong fine subangular blocky; very hard, extremely firm, slightly sticky and plastic; slightly calcareous; few very fine pores; few very fine roots; clear and smooth transition to:

AC 25- 56 cm: Greyish brown (2.5Y 5/2) cracking clay; very strong coarse prismatic; very hard, extremely firm, sticky and plastic; abundant thin intersecting slickensides; strong HCl-effervescence; few $CaCO_3$-concretions (2-5 mm ϕ); few small molluscs; common very fine pores; few very fine roots; gradual and smooth transition to:

Clca 56- 85 cm: Dark greyish brown (2.5Y 4/2) cracking clay; very strong coarse prismatic; very hard, extremely firm, sticky and plastic; abundant thick intersecting slickensides; strong HCl-effervescence; few $CaCO_3$-concretions (2-5 mm ϕ); no biopores; no roots; diffuse transition to:

C2ca 85-135+cm: Black (2.5Y 2/1) cracking clay; very strong medium prismatic; very hard, extremely firm, sticky and plastic; abundant thick intersecting slickensides; strong HCl-effervescence; few $CaCO_3$-concretions (2-5 mm Φ); no biopores; no roots.

Unit BAcl, Profile 30

Soil classification	gleyic Luvisol; aquic Haplustalf
Agro-climatic zone	III-1
Observation	198/3-80, Kilifi District, E 5.80.5, N 95.66.4, 20 m, 31-7-1980
Parent material	recent unconsolidated deposits
Physiography	Bottomlands
Surrounding landform	flat to almost flat plains
Meso-relief	depression
Slope gradient	0%
Land use/land cover	grassland
Drainage class	imperfectly drained
Depth of groundwater table	range: 60-160 cm
Presence of surface stones/rock outcrops	nil
Evidence of erosion	nil
Evidence of flooding	occasional

Ahl 0- 5 cm: Very dark greyish brown (10YR 3/3) loam; weak medium crumb; slightly hard, friable, non-sticky and slightly plastic; many very fine and fine pores; many very fine roots; abupt and smooth transition to:

Ah2 5- 30 cm: Very dark greyish brown (10YR 3/2) loam; moderate medium subangular blocky; hard, friable, non-sticky and slightly plastic; many very fine and fine pores; few very fine roots; abrupt and wavy transition to:

Btgl 30- 60 cm: Dark brown (10YR 4/3) sandy clay loam; common medium distinct very dark greyish brown mottles; moderate medium and coarse angular blocky; very hard, friable, slightly sticky and slightly plastic; many very fine and fine pores; many very fine and fine roots; common small manganese concretions; diffuse transition to:

Btg2 60-150+cm: Greyish brown (10YR 5/2) sandy clay; many coarse prominent yellowish brown iron mottles; moderate medium to coarse prismatic; very hard, firm, sticky and plastic; moderately thick clay skins; common very fine and fine pores; no roots; common small ferro-manganese concretions (5 mm ∅).

Appendix 6(b)
Analysis results

All data expressed in me/100 g should be read as mmol/kg and multiplied by 10 accordingly.

Profile 1

Laboratory no. 1980	11993	11994	11995
Horizon	Ah1	Ah2	AC
Depth (cm)	0-25	25-90	90-120
pH-H_2O(1:2.5 v/v)	5.7	5.8	6.0
pH-KCl "	4.6	4.5	5.0
EC(mS/cm) "	0.05	0.10	0.55
C (%)	1.0	1.0	0.7
N (%)	0.14		
P-Mehlich (mg/kg)	20		
CEC (me/100g), pH 8.2	9.6	21.0	24.4
Exch.Ca (me/100g)	1.8	6.6	8.9
Exch.Mg "	2.8	7.4	10.9
Exch.K "	0.1	0.2	0.2
Exch.Na "	tr	1.0	3.2
Sum of bases	4.7	15.2	23.2
Base sat.%, pH 8.2	49	72	95
Exch. Al+H (me/100g)	0.3		
ESP at pH 8.2			13
Gravel %	<2	<2	<2
Texture, limited pretreatment:			
Sand % 2.0-0.05 mm			
Silt % 0.05-0.002 mm		n.d.	
Clay % 0.002-0 mm			
Texture USDA:			
Sand % 2.0 - 1.0 mm	2	2	1
Sand % 1.0 - 0.50 mm	2	2	2
Sand % 0.50-0.25 mm	6	4	3
Sand % 0.25-0.10 mm	43	14	8
Sand % 0.10-0.05 mm	14	5	2
Total sand %	67	27	16
Silt %	12	21	26
Clay %	21	52	58
Texture class	SCL	C	C
Bulk density	n.d.		
Moisture % w/v at:	not determined		
pF 0			
pF 2.0			
pF 2.3			
pF 2.7			
pF 3.0			
pF 3.7			
pF 4.2			

Profile 2

Laboratory no. 1980	12543	12544	12545	12546	12547	12548
Horizon	Ah	Ah	Bt	Bt	Bt	Btg
Depth (cm)	0-20	20-40	50-60	60-70	70-80	100-120
pH-H_2O(1:2.5 v/v)	6.1	6.2	6.1	6.0	6.4	6.4
pH-KCl "	5.0	4.8	4.9	4.8	5.0	5.4
EC(mS/cm) "	0.10	0.10	0.08	0.08	0.09	0.12
C (%)	0.7	0.4	0.2	0.2	0.2	0.2
N (%)	n.d.	n.d.				
P-Mehlich (mg/kg)	n.d.					
CEC (me/100g), pH 8.2	12.1	13.5	12.7	12.7	13.4	15.2
Exch.Ca (me/100g)	2.2	5.5	4.6	5.2	5.7	6.5
Exch.Mg "	4.3	4.8	4.9	5.3	6.0	7.4
Exch.K "	0.2	0.8	0.4	0.3	0.3	0.3
Exch.Na "	tr	0.1	0.1	0.1	0.2	0.1
Sum of bases	6.7	11.2	10.0	10.9	12.2	14.3
Base sat.%, pH 8.2	56	83	78	86	91	94
Exch. Al+H (me/100g)	nd					
ESP at pH 8.2						
Gravel %	<2	<2	<2	<2	<2	<2
Texture, limited pretreatment:						
Sand % 2.0-0.05 mm						
Silt % 0.05-0.002 mm			n.d.			
Clay % 0.002-0 mm						
Texture USDA:						
Sand % 2.0 - 1.0 mm	1	1	1	1	1	1
Sand % 1.0 - 0.50 mm	4	3	3	3	3	3
Sand % 0.50-0.25 mm	15	10	11	11	10	10
Sand % 0.25-0.10 mm	18	14	17	16	15	15
Sand % 0.10-0.05 mm	5	4	6	5	6	5
Total sand %	43	32	38	36	35	34
Silt %	28	21	22	18	18	15
Clay %	29	47	40	46	47	51
Texture class	CL	C	C	C	C	C
Bulk density	n.d.					
Moisture % w/v at:	not determined					
pF 0						
pF 2.0						
pF 2.3						
pF 2.7						
pF 3.0						
pF 3.7						
pF 4.2						

Profile 3

Laboratory no. 1980	1728	1729	1730	1731		
Horizon	C1	C2	C2	C2		
Depth (cm)	0-14	14-50	50-100	100-140		
pH-H_2O(1:2.5 v/v)	5.0	5.0	4.9	5.0		
pH-KCl "	3.8	3.9	3.8	3.7		
EC(mS/cm) "	0.03	0.02	0.02	0.01		
C (%)	tr	0.1	0.1	0.2		
N (%)	n.d					
P-Mehlich (mg/kg)	8					
CEC (me/100g), pH 8.2	8.1	9.2	8.1	9.5		
Exch.Ca (me/100g)	0.9	0.1	1.1	1.4		
Exch.Mg "	2.2	0.3	0.6	0.8		
Exch.K "	0.1	0.1	0.1	0.1		
Exch.Na "	0.3	0.4	0.5	0.5		
Sum of bases	3.5	0.7	2.3	2.8		
Base sat.%, pH 8.2	43	8	28	29		
Exch. Al+H (me/100g)	0.7					
ESP at pH 8.2	4					
Gravel %	<2	<2	<2	<2		
Texture, limited pretreatment:						
Sand % 2.0-0.05 mm						
Silt % 0.05-0.002 mm		n.d.				
Clay % 0.002-0 mm						
Texture USDA:						
Sand % 2.0 - 1.0 mm	1	2	1	1		
Sand % 1.0 - 0.50 mm	10	11	12	9		
Sand % 0.50-0.25 mm	29	29	31	28		
Sand % 0.25-0.10 mm	37	38	36	38		
Sand % 0.10-0.05 mm	9	7	4	8		
Total sand %	86	87	84	84		
Silt %	3	3	5	5		
Clay %	11	10	11	11		
Texture class	LS	LS	LS	LS		
Bulk density	1.53	1.50	1.55	1.55		
Moisture % w/v at:	5-10	20-25	60-65	90-95	120-125	160-165 cm
pF 0	37.9	40.3	42.4	38.3	40.6	39.7
pF 2.0	16.7	17.5	18.6	19.4	20.3	20.0
pF 2.3	13.2	15.3	15.7	16.5	18.5	15.7
pF 2.7	10.5	12.5	10.4	13.1	12.4	9.9
pF 3.0	3.0	3.4	3.9	3.7	5.2	4.9
pF 3.7	2.1	2.2	2.6	2.2	3.0	3.6
pF 4.2	1.9	2.1	2.1	2.2	2.6	3.0

Profile 4

Laboratory no. 1982	7243	7244	7245	7247
Horizon	Ah	E	C/B	C
Depth (cm)	5-15	35-45	90-100	135-145
pH-H_2O(1:2.5 v/v)	6.6	6.1	6.0	7.0
pH-KCl "	4.9	5.4	5.1	5.5
EC(mS/cm) "	0.07	0.06	0.05	0.30
C (%)	0.6	0.1	0.1	tr
N (%)	n.d.			
P-Mehlich (mg/kg)	45			
P-Olsen (ppm)	29	24	23	15
CEC (me/100g), pH 8.2	3.8	1.1	1.1	0.5
Exch.Ca (me/100g)	1.5	0.7	0.8	0.3
Exch.Mg "	0.4	0.2	tr	0.1
Exch.K "	0.9	0.2	0.2	0.1
Exch.Na "	0.2	0.2	0.2	0.1
Sum of bases	3.0	1.3	1.2	0.6
Base sat.%, pH 8.2	79	100	100	100
Exch. Al+H (me/100g)	n.d.			
ESP at pH 8.2	5	9	9	n.r.
Gravel %	<2	<2	<2	<2
Texture, limited pretreatment:				
Sand % 2.0-0.05 mm				
Silt % 0.05-0.002 mm		n.d.		
Clay % 0.002-0 mm				
Texture USDA:				
Sand % 2.0 - 1.0 mm	tr	0	0	0
Sand % 1.0 - 0.50 mm	tr	tr	tr	tr
Sand % 0.50-0.25 mm	11	8	8	8
Sand % 0.25-0.10 mm	58	58	59	56
Sand % 0.10-0.05 mm	10	11	10	11
Total sand %	79	77	77	75
Silt %	11	12	14	16
Clay %	10	11	9	9
Texture class	SL	SL	LS	LS
Bulk density	1.15	1.42	1.48	1.41
Moisture % w/v at:	5-10	35-40	90-95	140-145 cm
pF 0	52.9	41.8	37.3	38.7
pF 2.0	28.3	23.3	23.7	27.1
pF 2.3	13.6	11.9	10.9	11.2
pF 2.7	13.0	10.8	10.2	10.2
pF 3.0	7.6	5.8	5.5	3.5
pF 3.7	5.1	4.1	4.0	n.d.
pF 4.2	4.1	3.1	2.6	1.0

Profile 5

Laboratory no. 1980	11983	11984	11985	11986	11987
Horizon	Ah	AB	Bt1	Bt2	BC
Depth (cm)	0-18	18-42	42-105	105-135	160-170
pH-H_2O(1:2.5 v/v)	5.8	5.7	5.5	5.5	5.4
pH-KCl "	4.8	4.7	4.5	4.3	4.1
EC(mS/cm) "	0.03	0.02	0.03	0.02	0.02
C (%)	0.4	0.6	0.5	0.6	0.5
N (%)	n.d.				
P-Mehlich (mg/kg)	5				
CEC (me/100g), pH 8.2	3.0	4.0	5.8	4.6	4.6
Exch.Ca (me/100g)	0.7	1.4	1.4	0.3	0.7
Exch.Mg "	0.5	0.7	2.2	2.0	1.2
Exch.K "	0.2	0.1	0.2	0.2	0.2
Exch.Na "	tr	0.1	0.1	tr	0.1
Sum of bases	1.4	2.3	3.9	2.5	2.2
Base sat.%, pH 8.2	47	58	67	54	48
Exch. Al+H (me/100g)	n.d.				
ESP at pH 8.2	<1	3	2	<1	2
Gravel %	<2	<2	<2	<2	<2
Texture, limited pretreatment:					
Sand % 2.0-0.05 mm					
Silt % 0.05-0.002 mm			n.d.		
Clay % 0.002-0 mm					
Texture USDA:					
Sand % 2.0 - 1.0 mm	0	0	0	tr	0
Sand % 1.0 - 0.50 mm	tr	tr	tr	tr	tr
Sand % 0.50-0.25 mm	2	2	2	2	2
Sand % 0.25-0.10 mm	64	49	49	52	52
Sand % 0.10-0.05 mm	14	11	11	12	12
Total sand %	80	62	62	66	66
Silt %	8	4	8	8	10
Clay %	12	34	30	26	24
Texture class	LS	SCL	SCL	SCL	SCL
Bulk density	n.d.				

Moisture % w/v at: not determined

pF 0
pF 2.0
pF 2.3
pF 2.7
pF 3.0
pF 3.7
pF 4.2

Profile 6

Laboratory no. 1980				
Horizon	Ah	BAg	Btg1	Btg2
Depth (cm)	0-13	13-35	35-88	88-110
pH-H_2O(1:2.5 v/v)	n.d.			
pH-KCl "	n.d.			
EC(mS/cm) "	n.d.			
C (%)	n.d.			
N (%)	n.d.			
P-Mehlich (mg/kg)	n.d.			
CEC (me/100g), pH 8.2	n.d.			
Exch.Ca (me/100g)	n.d.			
Exch.Mg "	n.d.			
Exch.K "	n.d.			
Exch.Na "	n.d.			
Sum of bases	n.d.			
Base sat.%, pH 8.2	n.d.			
Exch. Al+H (me/100g)	n.d.			
ESP at pH 8.2	n.d.			
Gravel %	<2			
Texture, limited pretreatment:				
Sand % 2.0-0.05 mm				
Silt % 0.05-0.002 mm			n.d.	
Clay % 0.002-0 mm				
Texture USDA:				
Sand % 2.0 - 1.0 mm	n.d.	tr	tr	tr
Sand % 1.0 - 0.50 mm	n.d.	tr	1	tr
Sand % 0.50-0.25 mm	n.d.	5	6	4
Sand % 0.25-0.10 mm	n.d.	59	32	32
Sand % 0.10-0.05 mm	n.d.	16	15	24
Total sand %	n.d.	80	74	60
Silt %	n.d.	6	7	35
Clay %	n.d.	14	19	5
Texture class		LS	SL	SL
Bulk density	1.46	1.57	1.67	1.77
Moisture % w/v at:	5-10	30-35	80-85	90-95 cm
pF 0	44.3	40.5	36.2	40.2
pF 2.0	17.8	22.9	31.4	35.9
pF 2.3	16.1	n.d.	28.7	32.0
pF 2.7	15.1	n.d.	28.1	31.4
pF 3.0	6.9	8.5	21.4	26.3
pF 3.7	4.7	6.6	16.9	21.2
pF 4.2	2.8	5.0	14.2	16.3

Profile 7

Laboratory no. 1981	76	77	78	79	80	81
Horizon	C1	C1	C2	C2	C3	C4
Depth (cm)	0-45	45-90	90-125	125-160	160-200	200-240
pH-H_2O(1:2.5 v/v)	5.1	5.0	5.1	5.5	5.8	5.0
pH-KCl "	3.8	3.8	3.9	3.8	4.0	4.0
EC(mS/cm) "	0.01	0.01	0.02	0.02	0.01	0.01
C (%)	0.1	0.1	0.1	0.1	0.1	0.1
N (%)	n.d.					
P-Mehlich (mg/kg)	n.d.					
CEC (me/100g), pH 8.2	0.6	0.3	0.5	0.2	0.3	0.3
Exch.Ca (me/100g)	0.2	0.2	0.2	tr	0.2	0.1
Exch.Mg "	0.1	0.1	tr	tr	0.1	0.1
Exch.K "	0.08	0.10	0.08	0.08	0.08	0.08
Exch.Na "	0.1	tr	0.1	tr	0.1	tr
Sum of bases	0.5	0.4	0.4	0.1	0.5	0.3
Base sat.%, pH 8.2	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.
Exch. Al+H (me/100g)	n.d.					
ESP at pH 8.2	n.r	n.r.	n.r.	n.r.	n.r.	n.r.
Gravel %	<2	<2	<2	<2	<2	<2
Texture, limited pretreatment:						
Sand % 2.0-0.05 mm						
Silt % 0.05-0.002 mm			n.d.			
Clay % 0.002-0 mm						
Texture USDA:						
Sand % 2.0 - 1.0 mm	1	1	1	1	1	1
Sand % 1.0 - 0.50 mm	3	3	3	4	3	3
Sand % 0.50-0.25 mm	30	19	30	24	21	26
Sand % 0.25-0.10 mm	42	47	37	46	49	42
Sand % 0.10-0.05 mm	12	13	14	9	10	13
Total sand %	88	83	85	84	84	85
Silt %	7	12	10	12	11	11
Clay %	5	5	5	4	5	4
Texture class	S	LS	LS	LS	LS	LS
Bulk density	1.52	1.46	1.48			
Moisture % w/v at:	10-15	40-45	100-105 cm			
pF 0	39.6	38.6	37.2			
pF 2.0	19.1	23.8	24.9			
pF 2.3	7.9	8.2	8.8			
pF 2.7	7.6	8.2	7.4			
pF 3.0	2.9	2.9	2.7			
pF 3.7	2.2	1.9	1.8			
pF 4.2	n.d.	n.d.	n.d.			

Profile 8

Laboratory no. 1980	12931	12932	12933	12934	12035	12936/7
Horizon	Ah	Ah	E	C/B	C/B	C/B
Depth (cm)	0-20	20-40	40-60	60-80	80-90	100-140
pH-H_2O(1:2.5 v/v)	6.7	6.2	6.0	5.8	5.5	5.6
pH-KCl "	5.0	4.5	4.4	4.4	4.4	4.5
EC(mS/cm) "	0.01	0.01	0.01	0.01	0.01	0.02
C (%)	0.3	0.2	0.1	0.2	0.1	0.1
N (%)	n.d.					
P-Mehlich (mg/kg)	6					
CEC (me/100g), pH 8.2	2.3	1.4	1.1	0.9	1.0	1.2
Exch.Ca (me/100g)	1.6	0.8	0.5	0.4	0.4	0.6
Exch.Mg "	0.6	0.3	0.2	0.1	0.1	0.3
Exch.K "	0.1	0.1	0.1	0.1	0.1	0.1
Exch.Na "	0.2	0.1	0.1	tr	tr	0.1
Sum of bases	2.5	1.3	0.9	0.55	0.6	1.1
Base sat.%, pH 8.2	100	94	82	61	60	91
Exch. Al+H (me/100g)	n.d.					
ESP at pH 8.2	9	7	9	<4	<4	8
Gravel %	<2	<2	<2	<2	<2	<2
Texture, limited pretreatment:						
Sand % 2.0-0.05 mm						
Silt % 0.05-0.002 mm			n.d.			
Clay % 0.002-0 mm						
Texture USDA:						
Sand % 2.0 - 1.0 mm	5	5	7	6	10	8
Sand % 1.0 - 0.50 mm	24	23	24	22	32	26
Sand % 0.50-0.25 mm	32	34	32	31	31	32
Sand % 0.25-0.10 mm	18	22	21	22	15	28
Sand % 0.10-0.05 mm	4	6	6	7	3	5
Total sand %	83	90	90	88	91	89
Silt %	4	5	6	8	5	7
Clay %	13	5	4	4	4	4
Texture class	LS	S	S	S	S	S
Bulk density	n.d.					
Moisture % w/v at:	not determined					
pF 0						
pF 2.0						
pF 2.3						
pF 2.7						
pF 3.0						
pF 3.7						
pF 4.2						

Profile 9

Laboratory no. 1980	12007	12008	12009	12010
Horizon	Ah	BA	Bt1	BC
Depth (cm)	0-15	15-35	35-70	70-120
pH-H_2O(1:2.5 v/v)	5.6	5.7	5.9	6.2
pH-KCl "	4.5	4.4	4.1	4.1
EC(mS/cm) "	0.04	0.03	0.04	0.04
C (%)	0.9	0.8	0.6	0.3
N (%)	n.d.			
P-Mehlich (mg/kg)	4			
CEC (me/100g), pH 8.2	5.8	6.4	7.6	8.2
Exch.Ca (me/100g)	1.6	0.5	0.9	0.9
Exch.Mg "	1.8	2.7	3.2	3.9
Exch.K "	0.2	0.1	0.1	0.1
Exch.Na "	0.1	tr	0.2	0.7
Sum of bases	3.7	3.3	4.4	5.6
Base sat.%, pH 8.2	64	52	58	68
Exch. Al+H (me/100g)	0.3			
ESP at pH 8.2	2	<1	3	9
Gravel %	<2	<2	<2	<2
Texture, limited pretreatment:				
Sand % 2.0-0.05 mm				
Silt % 0.05-0.002 mm		n.d.		
Clay % 0.002-0 mm				
Texture USDA:				
Sand % 2.0 - 1.0 mm	1	tr	0	tr
Sand % 1.0 - 0.50 mm	2	tr	1	1
Sand % 0.50-0.25 mm	14	7	7	7
Sand % 0.25-0.10 mm	34	53	37	42
Sand % 0.10-0.05 mm	9	13	10	12
Total sand %	60	73	55	62
Silt %	18	14	15	16
Clay %	22	13	30	22
Texture class	SCL	SL	SCL	SCL
Bulk density	n.d.			
Moisture % w/v at:	not determined			
pF 0				
pF 2.0				
pF 2.3				
pF 2.7				
pF 3.0				
pF 3.7				
pF 4.2				

Profile 10

Laboratory no. 1980	11969	11970	11971	11972	11973
Horizon	Ah	Bw	Bt1	Bt2	Bt2
Depth (cm)	0-18	18-35	35-75	75-140	140-160
pH-H_2O(1:2.5 v/v)	6.0	5.9	5.0	4.6	4.7
pH-KCl "	5.0	4.7	3.7	3.7	3.6
EC(mS/cm) "	0.05	0.04	0.03	0.04	0.04
C (%)	1.0	0.2	0.7	0.7	0.7
N (%)	n.d.				
P-Mehlich (mg/kg)	7				
CEC (me/100g), pH 8.2	4.0	3.4	7.4	8.0	8.8
Exch.Ca (me/100g)	2.1	tr	tr	tr	tr
Exch.Mg "	1.0	0.9	0.6	0.5	0.8
Exch.K "	0.2	0.1	0.2	0.1	0.1
Exch.Na "	0.1	tr	tr	tr	0.1
Sum of bases	3.4	1.0	0.8	0.6	1.0
Base sat.%, pH 8.2	85	29	11	7	11
Exch. Al+H (me/100g)	n.d.				
ESP at pH 8.2	3	<1	<1	<1	<1
Gravel %	<2	<2	<2	<2	<2
Texture, limited pretreatment:					
Sand % 2.0-0.05 mm					
Silt % 0.05-0.002 mm			n.d.		
Clay % 0.002-0 mm					
Texture USDA:					
Sand % 2.0 - 1.0 mm	2	1	2	2	2
Sand % 1.0 - 0.50 mm	9	9	8	7	5
Sand % 0.50-0.25 mm	38	35	25	20	17
Sand % 0.25-0.10 mm	28	27	19	17	13
Sand % 0.10-0.05 mm	6	6	4	5	5
Total sand %	83	78	58	51	42
Silt %	6	9	7	8	9
Clay %	11	13	35	41	49
Texture class	LS	SL	SC	SC	C
Bulk density	n.d.				
Moisture % w/v at:	not determined				
pF 0					
pF 2.0					
pF 2.3					
pF 2.7					
pF 3.0					
pF 3.7					
pF 4.2					

Profile 11

Laboratory no. 1982	7248	7249	7250	7251
Horizon	Ah	BA	Bt	BC
Depth (cm)	0-15	30-40	80-90	120-130
pH-H_2O(1:2.5 v/v)	6.0	7.4	7.5	7.5
pH-KCl "	5.4	6.5	6.3	6.3
EC(mS/cm) "	0.35	0.08	0.06	0.05
C (%)	0.5	0.1	0.1	0.1
N (%)	n.d.			
P-Mehlich (mg/kg)	11			
P-Olsen (ppm)	5	2	2	2
CEC (me/100g), pH 7.0	2.9	2.3	2.7	2.7
Exch.Ca (me/100g)	1.5	1.5	1.9	1.9
Exch.Mg "	0.3	0.5	0.6	0.6
Exch.K "	0.5	0.3	0.2	0.1
Exch.Na "	0.2	0.1	0.1	0.2
Sum of bases	2.5	2.4	2.8	2.8
ESP at pH 7.0	8	4	3	6
Exch. Al+H (me/100g)	n.d.			
Base satur.% pH 7.0	86	100	100	100
Gravel %	<2	<2	<2	<2

Texture, limited pretreatment:

Sand % 2.0-0.05 mm				
Silt % 0.05-0.002 mm		n.d.		
Clay % 0.002-0 mm				

Texture USDA:

Sand % 2.0 - 1.0 mm	8	7	7	6
Sand % 1.0 - 0.50 mm	25	19	15	15
Sand % 0.50-0.25 mm	25	21	18	20
Sand % 0.25-0.10 mm	7	9	10	6
Sand % 0.10-0.05 mm	1	2	3	3
Total sand %	66	58	53	50
Silt %	11	10	2	13
Clay %	23	32	45	37
Texture class	SCL	SCL	SC	SC
Bulk density	1.44	1.59	1.64	1.59

Moisture % w/v at:	5-10	30-35	80-85	125-130 cm
pF 0	41.1	35.0	34.9	35.1
pF 2.0	22.8	28.1	30.1	30.8
pF 2.3	19.5	25.3	27.7	28.3
pF 2.7	18.4	23.9	26.9	26.7
pF 3.0	15.1	22.8	26.0	n.d.
pF 3.7	14.2	20.9	23.0	21.4
pF 4.2	11.6	18.2	21.1	20.0

Profile 12

Laboratory no. 1981	51	52	53	54
Horizon	Ah	Ah	Bt1	Bt2
Depth (cm)	0-10	10-25	25-55	55-100
pH-H_2O(1:2.5 v/v)	5.6	5.9	6.2	6.2
pH-KCl "	4.9	5.1	5.2	5.3
EC(mS/cm) "	0.09	0.04	0.04	0.03
C (%)	0.93	0.35	0.23	0.23
N (%)	n.d.			
P-Mehlich (mg/kg)	5			
CEC (me/100g), pH 8.2	9.4	6.0	4.5	4.8
Exch.Ca (me/100g)	4.9	3.4	3.4	1.5
Exch.Mg "	1.4	0.1	0.5	tr
Exch.K "	0.5	0.1	0.1	tr
Exch.Na "	0.4	0.3	0.3	0.2
Sum of bases	7.2	3.9	4.3	1.7
Base sat.%, pH 8.2	77	65	96	35
Exch. Al+H (me/100g)	n.d.			
ESP at pH 8.2				
Gravel %	<2	<2	<2	<2
Texture, limited pretreatment:				
Sand % 2.0-0.05 mm	56	52	52	52
Silt % 0.05-0.002 mm	6	4	4	4
Clay % 0.002-0 mm	38	44	44	44
Texture class	SC	SC	SC	SC
Texture USDA:	not determined			
Sand % 2.0 - 1.0 mm				
Sand % 1.0 - 0.50 mm				
Sand % 0.50-0.25 mm				
Sand % 0.25-0.10 mm				
Sand % 0.10-0.05 mm				
Total sand %				
Silt %				
Clay %				
Bulk density	n.d.			
Moisture % w/v at:	not determined			
pF 0				
pF 2.0				
pF 2.3				
pF 2.7				
pF 3.0				
pF 3.7				
pF 4.2				

Profile 13

Laboratory no. 1981	12347	12348	12349	12350
Horizon	Ah	BA	Bt	Bt
Depth (cm)	0-30	30-80	80-110	110-150
pH-H_2O(1:2.5 v/v)	5.8	5.9	5.3	5.1
pH-KCl "	4.0	4.7	4.3	4.2
EC(mS/cm) "	0.15	0.05	0.04	0.04
C (%)	0.4	0.2	0.4	0.2
N (%)	n.d.			
P-Mehlich (mg/kg)	6			
CEC (me/100g), pH 8.2				
CEC " " pH 7.0	6.6	12.3	12.3	11.5
Exch.Ca (me/100g)	1.1	0.6	0.8	0.5
Exch.Mg "	1.1	0.7	1.2	1.6
Exch.K "	0.4	0.1	0.1	0.1
Exch.Na "	0.2	0.2	0.2	0.2
Sum of bases	2.7	1.6	2.3	2.4
Base sat.%, pH 7.0	41	13	19	21
Exch. Al+H (me/100g)	n.d.			
ESP at pH 7.0	3	2	2	2
Gravel %	<2	<2	<2	<2
Texture, limited pretreatment:				
Sand % 2.0-0.05 mm				
Silt % 0.05-0.002 mm		n.d.		
Clay % 0.002-0 mm				
Texture USDA:				
Sand % 2.0 - 1.0 mm	1	2	2	tr
Sand % 1.0 - 0.50 mm	2	2	2	1
Sand % 0.50-0.25 mm	5	4	3	4
Sand % 0.25-0.10 mm	17	7	9	11
Sand % 0.10-0.05 mm	15	23	18	11
Total sand %	40	38	34	27
Silt %	37	32	30	45
Clay %	23	30	36	28
Texture class	L	CL	CL	CL
Bulk density	1.38	1.31	1.43	1.44
Moisture % w/v at:	5-10	20-25	60-65	125-130 cm
pF 0	49.9	50.3	48.4	45.7
pF 2.0	32.1	32.9	36.8	37.7
pF 2.3	26.0	26.4	31.2	32.6
pF 2.7	22.5	21.1	25.0	35.0
pF 3.0				
pF 3.7		n.d.		
pF 4.2				

Profile 14

Laboratory no. 1980					
Horizon	Ah	AC	C	C	2Bt
Depth (cm)	0-18	18-40	40-90	90-147	147-215
pH-H_2O(1:2.5 v/v)	6.1	n.d.	n.d.		
pH-KCl "	n.d.	n.d.	n.d.		
EC(mS/cm) "	n.d.	n.d.	n.d.		
C (%)	0.2				
N (%)	0.06				
P-Mehlich (mg/kg)	14				
CEC (me/100g), pH 8.2	n.d.				
Exch.Ca (me/100g)	1.6				
Exch.Mg "	1.1		n.d.		
Exch.K "	0.2				
Exch.Na "	0.1				
Sum of bases	3.0				
Base sat.%, pH 8.2	n.d.				
Exch. Al+H (me/100g)	n.d.				
ESP at pH 8.2	n.d.				
Gravel %	<2	<2	<2	<2	<2
Texture, limited pretreatment:					
Sand % 2.0-0.05 mm					
Silt % 0.05-0.002 mm			n.d.		
Clay % 0.002-0 mm					
Texture USDA:					
Sand % 2.0 - 1.0 mm	tr	0	0	0	0
Sand % 1.0 - 0.50 mm	tr	tr	0	tr	0
Sand % 0.50-0.25 mm	3	3	3	3	2
Sand % 0.25-0.10 mm	50	52	49	48	32
Sand % 0.10-0.05 mm	24	23	26	28	35
Total sand %	77	78	78	79	69
Silt %	13	9	13	14	15
Clay %	10	13	9	7	16
Texture class	SL	LS	LS	SL	SL
Bulk density	n.d.				
Moisture % w/v at:	not determined				
pF 0					
pF 2.0					
pF 2.3					
pF 2.7					
pF 3.0					
pF 3.7					
pF 4.2					

Profile 15

Laboratory no. 1980	12527	12528	12529	12530	12531
Horizon	Ah	AB	Bt1	Bt2	Bt2
Depth (cm)	0-10	15-25	35-45	60-80	80-100
pH-H_2O(1:2.5 v/v)	5.6	5.5	5.4	5.3	5.4
pH-KCl "	4.4	4.1	4.1	4.1	3.9
EC(mS/cm) "	0.04	0.06	0.06	0.05	0.07
C (%)	0.5	0.3	0.3	0.3	0.1
N (%)	n.d.				
P-Mehlich (mg/kg)	n.d.				
CEC (me/100g), pH 8.2	7.3	10.0	11.3	14.2	14.5
Exch.Ca (me/100g)	1.3	1.8	1.3	1.1	1.8
Exch.Mg "	2.1	3.5	5.7	6.2	5.9
Exch.K "	0.5	0.4	0.3	0.3	0.5
Exch.Na "	0.1	0.1	0.1	0.2	0.3
Sum of bases	7.0	5.8	7.4	7.8	8.5
Base sat.%, pH 8.2	55	58	65	55	59
Exch. Al+H (me/100g)	n.d.				
ESP at pH 8.2					
Gravel %	<2	<2	<2	<2	<2
Texture, limited pretreatment:					
Sand % 2.0-0.05 mm					
Silt % 0.05-0.002 mm			n.d.		
Clay % 0.002-0 mm					
Texture USDA:					
Sand % 2.0 - 1.0 mm	1	1	1	1	1
Sand % 1.0 - 0.50 mm	1	1	1	tr	tr
Sand % 0.50-0.25 mm	1	1	1	1	1
Sand % 0.25-0.10 mm	17	13	13	9	7
Sand % 0.10-0.05 mm	33	27	25	20	12
Total sand %	53	43	41	31	21
Silt %	33	34	29	25	42
Clay %	14	23	30	44	37
Texture class	SL	L	CL	C	CL
Bulk density	n.d.				
Moisture % w/v at:	not determined				
pF 0					
pF 2.0					
pF 2.3					
pF 2.7					
pF 3.0					
pF 3.7					
pF 4.2					

Profile 16

Laboratory no. 1981	52	53	54	126/127
Horizon	Ah	BA	Btg1	Btg2
Depth (cm)	0-9	9-37	37-63	63-90
pH-H_2O(1:2.5 v/v)	5.6	5.6	6.1	6.3
pH-KCl "	4.9	4.6	5.1	5.2
EC(mS/cm) "	0.06	0.05	0.07	0.65
C (%)	0.5	0.4	0.3	0.3
N (%)	n.d.			
P-Mehlich (mg/kg)	6			
CEC (me/100g), pH 7.0	2.8	10.0	11.7	18.6
Exch.Ca (me/100g)	1.8	1.7	3.3	4.1
Exch.Mg "	0.9	1.2	4.9	6.9
Exch.K "	0.1	0.1	0.3	0.3
Exch.Na "	tr	0.3	1.8	4.0
Sum of bases	2.8	3.3	10.3	15.3
Base sat.%, pH 7.0	51	51	88	82
Exch. Al+H (me/100g)	n.d.			
ESP at pH 7.0			15	22
Gravel %	<2	<2	<2	<2
Texture, limited pretreatment:				
Sand % 2.0-0.05 mm				
Silt % 0.05-0.002 mm		n.d.		
Clay % 0.002-0 mm				
Texture USDA:				
Sand % 2.0 - 1.0 mm	1	1	1	2
Sand % 1.0 - 0.50 mm	4	5	3	3
Sand % 0.50-0.25 mm	28	30	18	15
Sand % 0.25-0.10 mm	39	34	20	14
Sand % 0.10-0.05 mm	9	8	10	10
Total sand %	81	78	52	44
Silt %	10	12	23	15
Clay %	9	10	25	41
Texture class	LS	SL	SCL	SC/C
Bulk density	1.66	1.54	1.71	1.79
Moisture % w/v at:	5-10	20-25	40-45	70-75 cm
pF 0	37.3	40.9	35.6	36.9
pF 2.0	25.2	25.6	31.0	35.5
pF 2.3	13.0	12.9	27.4	34.1
pF 2.7	12.3	12.3	25.4	32.9
pF 3.0	8.6	7.7	23.8	32.0
pF 3.7	5.6	4.7	19.4	26.4
pF 4.2	5.0	4.3	16.2	21.3

Profile 17

Laboratory no. 1980	1742	1743	1744	1745
Horizon	Ap	Ah	AC	C1
Depth (cm)	0-22	22-32	32-62	62-112
pH-H_2O(1:2.5 v/v)	6.2	6.2	6.7	6.8
pH-KCl "	5.1	4.8	4.9	5.4
EC(mS/cm) "	0.75	0.21	0.22	0.24
C (%)	2.1	0.7	0.5	0.6
N (%)	n.d.			
P-Mehlich (mg/kg)	33			
CEC (me/100g), pH 8.2	37.0	32.0	37.0	32.0
Exch.Ca (me/100g)	24.4	15.8	17.1	22.4
Exch.Mg "	13.3	14.1	14.1	15.3
Exch.K "	1.8	0.5	0.3	0.4
Exch.Na "	1.1	1.3	2.3	3.8
Sum of bases	40.6	31.7	33.8	41.9
Base sat.%, pH 8.2	100	99	94	100
Exch. Al+H (me/100g)	2.1			
ESP at pH 8.2	3	4	6	12
Gravel %	<2	2-15	2-15	2-15
Texture, limited pretreatment:				
Sand % 2.0-0.05 mm	10	12	12	12
Silt % 0.05-0.002 mm	26	22	18	16
Clay % 0.002-0 mm	64	66	70	72
Texture class	C	C	C	C
Texture USDA:	not determined			
Sand % 2.0 - 1.0 mm				
Sand % 1.0 - 0.50 mm				
Sand % 0.50-0.25 mm				
Sand % 0.25-0.10 mm				
Sand % 0.10-0.05 mm				
Total sand %				
Silt %				
Clay %				
Texture class				
Bulk density	n.d.			
Moisture % w/v at:	not determined			
pF 0				
pF 2.0				
pF 2.3				
pF 2.7				
pF 3.0				
pF 3.7				
pF 4.2				

Profile 18

Laboratory no. 1982	7357	7358	7359	7360
Horizon	Ah1	Ah2+Ccs	Cca/cs	Cca/cs
Depth (cm)	0-20	20-75	75-102	102-115
pH-H_2O(1:2.5 v/v)	6.7	6.7	7.3	7.5
pH-KCl "	5.6	5.1	6.1	5.9
EC(mS/cm) "	0.09	0.29	0.12	0.45
C (%)	1.4	0.9	0.7	1.5
N (%)	n.d.			
P-Mehlich (mg(kg)	16			
CEC (me/100g), pH 8.2	31.1	32.7	32.7	24.3
Exch.Ca (me/100g)	5.5	7.4	9.9	3.1
Exch.Mg "	2.2	2.6	2.8	2.2
Exch.K "	1.3	0.5	0.5	0.5
Exch.Na "	0.1	0.2	0.3	0.3
Sum of bases	9.1	10.7	13.5	6.1
Base sat.%, pH 8.2	29	33	41	25
Exch. Al+H (me/100g)	n.d.			
ESP at pH 8.2				
Gravel %	<2	2-15	15-50	15-50
Texture, limited pretreatment:				
Sand % 2.0-0.05 mm				
Silt % 0.05-0.002 mm		n.d.		
Clay % 0.002-0 mm				
Texture USDA:				
Sand % 2.0 - 1.0 mm	2	2	3	4
Sand % 1.0 - 0.50 mm	2	3	2	2
Sand % 0.50-0.25 mm	1	1	1	1
Sand % 0.25-0.10 mm	1	1	1	1
Sand % 0.10-0.05 mm	1	tr	1	1
Total sand %	7	7	8	9
Silt %	20	15	18	26
Clay %	73	78	74	65
Texture class	C	C	C	C
Bulk density	n.d.			
Moisture % w/v at:	not determined			
pF 0				
pF 2.0				
pF 2.3				
pF 2.7				
pF 3.0				
pF 3.7				
pF 4.2				

Profile 19

Laboratory no. 1981	6494	6495	6496	6497
Horizon	Ah	CA	C1	C1
Depth (cm)	0-13	13-50	50-100	100-150
pH-H_2O(1:2.5 v/v)	6.7	5.6	5.2	5.1
pH-KCl "	4.2	4.0	4.1	4.0
EC(mS/cm) "	0.03	0.02	0.03	0.02
C (%)	0.5	0.3	0.4	0.4
N (%)	n.d.			
P-Mehlich (mg/kg)	n.d.			
CEC (me/100g), pH 7.0	4.2	4.8	1.8	1.4
Exch.Ca (me/100g)	1.6	0.6	1.0	1.0
Exch.Mg "	0.6	1.2	0.1	0.1
Exch.K "	0.1	0.1	0.1	0.1
Exch.Na "	0.2	0.1	tr	tr
Sum of bases	2.5	2.4	0.8	1.2
Base sat.%, pH 7.0	59	50	44	86
Exch. Al+H (me/100g)	n.d.			
ESP at pH 7.0				
Gravel %	<2	<2	<2	<2
Texture, limited pretreatment:				
Sand % 2.0-0.05 mm	96	92	88	86
Silt % 0.05-0.002 mm	2	2	4	2
Clay % 0.002-0 mm	2	6	8	12
Texture class	S	S	S	LS
Texture USDA:	not determined			
Sand % 2.0 - 1.0 mm				
Sand % 1.0 - 0.50 mm				
Sand % 0.50-0.25 mm				
Sand % 0.25-0.10 mm				
Sand % 0.10-0.05 mm				
Total sand %				
Silt %				
Clay %				
Texture class				
Bulk density	n.d.			
Moisture % w/v at:	not determined			
pF 0				
pF 2.0				
pF 2.3				
pF 2.7				
pF 3.0				
pF 3.7				
pF 4.2				

Profile 20

Laboratory no. 1982	7239	7240	7241	7242
Horizon	Ah	BA	Bt1	BC
Depth (cm)	5-15	40-50	80-90	120-130
pH-H_2O(1:2.5 v/v)	6.5	6.6	6.4	5.7
pH-KCl "	5.1	5.3	5.2	5.0
EC(mS/cm) "	0.03	0.03	0.04	0.04
$CaCO_3$ (%)	n.d.			
C (%)	0.4	0.2	0.1	0.1
N (%)	n.d.			
P-Mehlich (mg/kg)	16			
P-Olsen (ppm)	3	2	1	1
CEC (me/100g), pH 7.0	2.5	1.3	1.5	1.5
Exch.Ca (me/100g)	0.9	0.8	0.8	0.6
Exch.Mg "	0.3	0.2	0.2	0.2
Exch.K "	0.5	0.3	0.2	0.2
Exch.Na "	0.1	tr	0.1	0.1
Sum of bases	1.8	1.3	1.3	1.1
Base sat.%, pH 7.0	72	100	81	73
Exch. Al+H (me/100g)	n.d.			
ESP at pH 7.0	4	<3	7	8
Gravel %	<2	<2	<2	<2
Texture, limited pretreatment:				
Sand % 2.0-0.05 mm	84	76	72	74
Silt % 0.05-0.002 mm	2	2	0	2
Clay % 0.002-0 mm	14	22	28	24
Texture class	SL	SCL	SCL	SCL
Texture USDA:	not determined			
Sand % 2.0 - 1.0 mm				
Sand % 1.0 - 0.50 mm				
Sand % 0.50-0.25 mm				
Sand % 0.25-0.10 mm				
Sand % 0.10-0.05 mm				
Total sand %				
Silt %				
Clay %				
Texture class				
Bulk density	1.38	1.34	1.52	1.52
Moisture % w/v at:	5-10	40-45	85-90	125-130 cm
pF 0	46.9	44.1	39.3	38.7
pF 2.0	16.1	18.7	23.3	22.3
pF 2.3	13.1	15.2	18.4	17.6
pF 2.7	12.5	14.9	18.1	16.2
pF 3.0	10.1	11.4	14.2	12.5
pF 3.7	8.6	10.2	12.6	11.1
pF 4.2	7.8	9.6	12.3	10.5

Profile 21

Laboratory no.					
Horizon	Ah	Bt	Bt	BC	CB
Depth (cm)	0-13	13-50	50-98	98-150	150-175
pH-H_2O(1:2.5 v/v)	n.d.				
pH-KCl "	n.d.				
EC(mS/cm) "	n.d.				
C (%)	n.d.				
N (%)	n.d.				
P-Mehlich (mg/kg)	n.d.				
CEC (me/100g), pH 8.2	n.d.				
Exch.Ca (me/100g)	n.d.				
Exch.Mg "	n.d.				
Exch.K "	n.d.				
Exch.Na "	n.d.				
Sum of bases	n.d.				
Base sat.%, pH 8.2	n.d.				
Exch. Al+H (me/100g)	n.d.				
ESP at pH 8.2					
Gravel %	<2	<2	<2	<2	<2
Texture, limited pretreatment:					
Sand % 2.0-0.05 mm					
Silt % 0.05-0.002 mm			n.d.		
Clay % 0.002-0 mm					
Texture USDA:					
Sand % 2.0 - 1.0 mm	1	1	1	1	1
Sand % 1.0 - 0.50 mm	12	16	16	12	14
Sand % 0.50-0.25 mm	51	50	48	42	45
Sand % 0.25-0.10 mm	19	16	16	20	16
Sand % 0.10-0.05 mm	1	tr	1	1	1
Total sand %	84	83	82	76	77
Silt %	5	3	3	17	18
Clay %	11	14	15	7	5
Texture class	LS	LS	SL	SL	SL
Bulk density	1.62	1.53	1.58	1.56	1.64
Moisture % w/v at:	5-10	20-25	60-65	120-125	160-165 cm
pF 0	38.9	44.9	41.6	41.7	35.4
pF 2.0	18.6	16.2	21.0	22.1	23.3
pF 2.3	15.9	13.8	17.9	19.4	20.1
pF 2.7	12.2	11.0	13.5	14.1	14.7
pF 3.0	8.6	6.6	9.1	8.1	7.5
pF 3.7	5.5	5.3	6.2	7.3	8.3
pF 4.2	5.4	5.2	6.1	7.4	7.4

Profile 22

Laboratory no.					
Horizon	Ah	Eg	Btg1	Btg2	Btg2
Depth (cm)	0-6	6-40	40-105	105-130	130-190
pH-H_2O(1:2.5 v/v)	6.3	6.0	6.0	6.4	6.1
pH-KCl "	n.d.				
EC(mS/cm) "	n.d.				
C (%)	0.4	0.3	0.2	0.1	0.2
N (%)	0.07				
P-Mehlich (mg/kg)		3			
CEC (me/100g), pH 8.2	n.d.	n.d.			
Exch.Ca (me/100g)		0.6			
Exch.Mg "		0.9			
Exch.K "		0.09			
Exch.Na "	n.d.	n.d.			
Sum of bases	n.d.	n.d.			
Base sat.%, pH 8.2	n.d.	n.d.			
Exch. Al+H (me/100g)	n.d.	n.d.			
ESP at pH 8.2					
Gravel %	<2	<2	<2	<2	<2

Texture, limited pretreatment:					
Sand % 2.0-0.05 mm					
Silt % 0.05-0.002 mm			n.d.		
Clay % 0.002-0 mm					

Texture USDA:	5-10	20-25	40-45	80-85	100-105	140-145 cm
Sand % 2.0 - 1.0 mm	tr	tr	0	0	0	tr
Sand % 1.0 - 0.50 mm	tr	tr	tr	tr	tr	tr
Sand % 0.50-0.25 mm	1	1	1	1	1	1
Sand % 0.25-0.10 mm	43	38	46	34	32	28
Sand % 0.10-0.05 mm	28	25	25	24	19	19
Total sand %	72	64	72	59	52	48
Silt %	16	25	20	16	17	20
Clay %	12	11	8	25	31	32
Texture class	SL	SL	SL	SCL	SCL	SCL
Bulk density	1.43	1.38	1.41	1.79	1.87	1.81

Moisture % w/v at:						
pF 0	47.5	47.5	46.1	35.4	39.3	41.6
pF 2.0	34.8	37.8	37.6	34.4	38.1	39.8
pF 2.3	31.1	23.8	27.0	34.1	37.3	39.2
pF 2.7	24.4	18.6	24.3	33.6	36.9	38.3
pF 3.0	8.8	6.2	6.2	33.6	35.6	36.2
pF 3.7	6.1	4.3	4.2	21.5	26.0	28.0
pF 4.2	4.8	3.5	3.2	17.6	21.3	21.6

Profile 23

Laboratory no. 1982	5159	5160	5161	5162	5163
Horizon	Ah	AB	Bt1	Bt2	Bt3
Depth (cm)	0-40	40-80	80-115	115-160	160-210
pH-H_2O(1:2.5 v/v)	7.3	7.4	7.6	7.0	7.0
pH-KCl "	6.7	6.5	6.5	6.4	6.2
EC(mS/cm) "	0.10	0.09	0.06	0.07	0.09
C (%)	0.3	0.2	0.1	0.2	0.3
N (%)	n.d.				
P-Mehlich (mg/kg)	38 (0-20 cm)				
CEC (me/100g), pH 8.2	3.2	2.2	3.4	4.0	5.0
Exch.Ca (me/100g)	1.7	1.3	1.1	0.7	0.9
Exch.Mg "	0.7	0.5	1.5	1.8	0.8
Exch.K "	0.3	0.3	0.8	1.1	2.3
Exch.Na "	tr	tr	tr	tr	0.2
Sum of bases	2.7	2.1	3.4	3.6	4.2
Base sat.%, pH 8.2	84	95	100	90	84
Exch. Al+H (me/100g)	n.d.				
ESP at pH 8.2					
Gravel %	<2	<2	<2	<2	<2
Texture, limited pretreatment:					
Sand % 2.0-0.05 mm					
Silt % 0.05-0.002 mm			n.d.		
Clay % 0.002-0 mm					
Texture USDA:					
Sand % 2.0 - 1.0 mm	tr	tr	1	1	1
Sand % 1.0 - 0.50 mm	3	4	4	5	4
Sand % 0.50-0.25 mm	35	36	35	35	35
Sand % 0.25-0.10 mm	40	39	35	31	31
Sand % 0.10-0.05 mm	7	7	7	5	5
Total sand %	85	86	82	77	76
Silt %	4	2	2	3	2
Clay %	11	12	16	20	22
Texture class	LS	LS	SL	SCL	SCL
Bulk density	1.27	1.42	1.40	1.56	1.49
Moisture % w/v at:	5-10	20-25	60-65	120-125	160-165 cm
pF 0	45.3	44.4	43.1	42.0	45.8
pF 2.0	21.5	21.3	23.6	27.0	29.3
pF 2.3	10.0	9.1	12.7	18.9	19.1
pF 2.7	9.4	8.5	10.5	17.1	16.8
pF 3.0	4.1	3.7	5.9	9.8	8.6
pF 3.7	3.7	3.1	4.4	8.1	7.2
pF 4.2	3.3	2.1	3.1	5.9	5.8

Profile 24

Laboratory no. 1982	5164	5165	5166	5167	
Horizon	Ah	AB	Bt1	Bt2	Bt2
Depth (cm)	0-10	10-50	50-100	100-150	150-200
pH-H_2O(1:2.5 v/v)	7.1	7.1	7.0	6.9	
pH-KCl "	6.1	6.2	6.2	6.1	
EC(mS/cm) "	0.07	0.06	0.05	0.05	
C (%)	0.3	0.2	0.3	0.1	
N (%)	n.d.				
P-Mehlich (mg/kg)	8 (0-20 cm)				
CEC (me/100g), pH 8.2	2.5	2.0	2.5	1.9	
Exch.Ca (me/100g)	1.9	1.5	1.5	1.3	
Exch.Mg "	0.5	0.3	0.6	0.8	
Exch.K "	0.2	0.1	0.2	0.2	
Exch.Na "	tr	tr	tr	tr	
Sum of bases	2.6	1.9	2.3	2.3	
Base sat.%, pH 8.2	100	100	92	100	
Exch. Al+H (me/100g)	n.d				
ESP at pH 8.2					
Gravel %	<2	<2	<2	<2	
Texture, limited pretreatment:					
Sand % 2.0-0.05 mm					
Silt % 0.05-0.002 mm		n.d.			
Clay % 0.002-0 mm					
Texture USDA:					
Sand % 2.0 - 1.0 mm	tr	tr	tr	tr	tr
Sand % 1.0 - 0.50 mm	1	1	2	1	2
Sand % 0.50-0.25 mm	20	20	27	22	27
Sand % 0.25-0.10 mm	43	46	39	40	39
Sand % 0.10-0.05 mm	15	14	9	11	8
Total sand %	79	81	77	74	76
Silt %	9	8	5	8	6
Clay %	12	11	18	18	18
Texture class	LS	LS	SL	SL	SL
Bulk density					
Moisture % w/v at:	not determined				
pF 0					
pF 2.0					
pF 2.3					
pF 2.7					
pF 3.0					
pF 3.7					
pF 4.2					

Profile 25

Laboratory no. 1980	12959	12960	12961	12962	12963
Horizon	Ah	AB	Bw1	Bw2/R	Bw2/R
Depth (cm)	0-20	20-60	60-100	100-140	140-160
$pH-H_2O$(1:2.5 v/v)	7.6	7.6	7.5	7.7	7.8
pH-KCl "	7.0	6.6	6.4	6.5	6.4
EC(mS/cm) "	0.05	0.04	0.03	0.04	0.04
C (%)	0.5	0.4	0.2	0.2	0.2
N (%)	0.06				
P-Mehlich (mg/kg)	n.d.				
CEC (me/100g), pH 8.2	3.1	3.0	2.3	2.2	2.4
Exch.Ca (me/100g)	2.8	2.6	2.0	1.8	2.0
Exch.Mg "	0.3	0.2	0.3	0.3	0.4
Exch.K "	0.2	0.1	0.1	0.1	0.1
Exch.Na "	tr	tr	0.05	0.1	tr
Sum of bases	3.3	2.9	2.45	2.3	2.5
Base sat.%, pH 8.2	100	99	100	100	100
Exch. Al+H (me/100g)	n.d.				
ESP at pH 8.2					
Gravel %	<2	<2	<2	<2	<2
Texture, limited pretreatment:					
Sand % 2.0-0.05 mm					
Silt % 0.05-0.002 mm			n.d.		
Clay % 0.002-0 mm					
Texture USDA:					
Sand % 2.0 - 1.0 mm	tr	tr	tr	tr	tr
Sand % 1.0 - 0.50 mm	3	3	3	3	4
Sand % 0.50-0.25 mm	32	31	31	31	29
Sand % 0.25-0.10 mm	51	51	51	51	52
Sand % 0.10-0.05 mm	5	5	5	4	2
Total sand %	91	90	90	89	87
Silt %	1	3	2	2	3
Clay %	8	7	8	9	10
Texture class	S	S	S	S	S
Bulk density	1.45	1.46	1.61	1.63	1.63
Moisture % w/v at:	5-10	20-25	60-65	120-125	160-165 cm
pF 0	43.0	38.2	34.3	32.2	33.6
pF 2.0	15.7	14.9	13.4	12.6	14.7
pF 2.3	12.7	11.2	10.0	8.8	10.7
pF 2.7	11.3	10.1	8.5	7.4	9.1
pF 3.0	4.5	3.9	4.4	4.9	5.3
pF 3.7	2.9	2.9	3.2	3.5	3.4
pF 4.2	2.0	2.2	2.3	2.8	3.1

Profile 26

Laboratory no. 1980	1746	1747	1748	1749	
Horizon	Ah	Bt1	Bt21	Bt22	
Depth (cm)	0-22	22-50	50-99	99-145	
pH-H_2O(1:2.5 v/v)	6.4	6.2	6.4	6.2	
pH-KCl "	5.2	4.8	5.0	5.1	
EC(mS/cm) "	0.60	0.04	0.05	0.03	
C (%)	0.3	0.6	0.2	0.5	
N (%)	n.d.				
P-Mehlich (mg/kg)	6				
CEC (me/100g), pH 8.2	6.1	4.8	8.29	7.1	
Exch.Ca (me/100g)	3.2	2.1	4.0	3.6	
Exch.Mg "	1.1	0.9	1.7	1.5	
Exch.K "	0.2	0.2	0.3	0.1	
Exch.Na "	0.7	0.6	1.0	0.4	
Sum of bases	5.2	3.8	7.0	5.6	
Base sat.%, pH 8.2	85	7.9	85	79	
Exch. Al+H (me/100g)	n.d.				
ESP at pH 8.2	6	5	5	3	
Gravel %	<2	<2	<2	<2	
Texture, limited pretreatment:					
Sand % 2.0-0.05 mm					
Silt % 0.05-0.002 mm		n.d.			
Clay % 0.002-0 mm					
Texture USDA:					
Sand % 2.0 - 1.0 mm	7	4	6	4	
Sand % 1.0 - 0.50 mm	22	14	17	15	
Sand % 0.50-0.25 mm	22	20	17	18	
Sand % 0.25-0.10 mm	27	31	25	28	
Sand % 0.10-0.05 mm	6	8	15	5	
Total sand %	84	77	80	70	
Silt %	6	6	3	5	
Clay %	10	17	27	25	
Texture class	LS	SL	SCL	SCL	
Bulk density	1.50	1.76	1.64	1.67	1.64
Moisture % w/v at:	5-10	25-30	50-55	80-85	120-125 cm
pF 0	40.9	32.0	34.6	34.0	36.8
pF 2.0	12.6	19.6	24.2	23.4	22.7
pF 2.3	10.1	17.0	21.4	19.9	18.1
pF 2.7	9.6	16.4	20.9	19.3	17.2
pF 3.0	6.2	13.3	19.6	16.9	14.9
pF 3.7	4.4	9.4	13.4	12.3	12.0
pF 4.2	4.0	8.6	12.6	11.2	10.5

Profile 27

Laboratory no. 1982	7376	7377	7378	7379	7380
Horizon	Ah	AB	Bt1	Bt2	Bt2
Depth (cm)	0-19	19-60	60-82	82-102	102-150
pH-H_2O(1:2.5 v/v)	6.1	5.8	5.0	6.1	6.6
pH-KCl "	5.2	4.8	4.4	4.9	4.9
EC(mS/cm) "	0.04	0.05	0.04	0.04	0.05
C (%)	1.1	0.3	0.2	0.1	0.1
N (%)	n.d.				
P-Mehlich (mg/kg)	8				
CEC (me/100g), pH 8.2	2.2	2.9	7.3	5.7	5.7
Exch.Ca (me/100g)	0.8	1.3	2.7	2.5	1.4
Exch.Mg "	0.4	0.2	0.5	0.6	0.3
Exch.K "	0.2	0.5	0.5	0.6	0.4
Exch.Na "	tr	tr	tr	tr	tr
Sum of bases	1.4	2.0	3.7	3.7	2.1
Base sat.%, pH 8.2	64	69	51	65	36
Exch. Al+H (me/100g)	n.d.				
ESP at pH 8.2					
Gravel %	<2	<2	<2	<2	<2
Texture, limited pretreatment:					
Sand % 2.0-0.05 mm	92	88	74	74	78
Silt % 0.05-0.002 mm	4	4	4	4	4
Clay % 0.002-0 mm	4	8	22	22	18
Texture class	S	LS	SCL	SCL	SL
Texture USDA:	not determined				
Sand % 2.0 - 1.0 mm					
Sand % 1.0 - 0.50 mm					
Sand % 0.50-0.25 mm					
Sand % 0.25-0.10 mm					
Sand % 0.10-0.05 mm					
Total sand %					
Silt %					
Clay %					
Texture class					
Bulk density	n.d.				
Moisture % w/v at:	not determined				
pF 0					
pF 2.0					
pF 2.3					
pF 2.7					
pF 3.0					
pF 3.7					
pF 4.2					

Profile 28

Laboratory no. 1980				
Horizon	Ah	AB	Bt1	Bt2/R
Depth (cm)	0-18	18-46	46-60	60-80
pH-H_2O(1:2.5 v/v)	6.5	6.9	6.2	6.2
pH-KCl "	5.6	5.9	4.8	4.9
EC(mS/cm) "	0.04	0.05	0.03	0.02
C (%)	0.7	0.2	0.5	0.5
N (%)	n.d.			
P-Mehlich (mg/kg)	n.d.			
CEC (me/100g), pH 8.2	4.3	6.4	6.4	5.8
Exch.Ca (me/100g)	3.7	4.8	3.3	3.3
Exch.Mg "	0.6	0.9	1.5	1.6
Exch.K "	0.2	0.2	0.2	0.2
Exch.Na "	0.1	0.2	0.2	0.3
Sum of bases	4.6	6.1	5.2	5.4
Base sat.%, pH 8.2	87	95	81	79
Exch. Al+H (me/100g)	n.d.			
ESP at pH 8.2	2	3	3	4
Gravel %	<2	<2	<2	2-15
Texture, limited pretreatment:				
Sand % 2.0-0.05 mm				
Silt % 0.05-0.002 mm		n.d.		
Clay % 0.002-0 mm				
Texture USDA:				
Sand % 2.0 - 1.0 mm	n.d.			
Sand % 1.0 - 0.50 mm	n.d.			
Sand % 0.50-0.25 mm	n.d.			
Sand % 0.25-0.10 mm	56	59	48	48
Sand % 0.10-0.05 mm	5	10	8	9
Total sand %	86	81	79	77
Silt %	5	9	3	0
Clay %	9	19	19	23
Texture class	LS	LS	SL	SCL
Bulk density	1.38	1.45	1.43	1.43
Moisture % w/v at:	5-10	30-35	45-50	85-90 cm
pF 0	44.4	44.9	41.3	39.8
pF 2.0	15.4	17.2	16.6	20.4
pF 2.3	11.8	13.7	13.2	15.3
pF 2.7	11.7	13.4	13.1	15.7
pF 3.0	6.9	9.1	9.6	10.5
pF 3.7	4.4	4.2	8.6	8.0
pF 4.2	3.1	3.4	7.8	7.3

Profile 29

Laboratory no. 1980	1756	1757	1758	1759
Horizon	Ah1/Ah2	AC	C1ca	C2ca
Depth (cm)	0-25	25-56	56-85	85-135
pH-H_2O(1:2.5 v/v)	7.8	8.1	8.1	8.1
pH-KCl "	7.0	7.1	7.2	7.3
EC(mS/cm) "	0.35	0.45	1.60	3.00
C (%)	1.4	1.9	1.2	1.0
N (%)	0.2			
P-Mehlich (mg/kg)	23			
CEC (me/100g), pH 8.2	36.5	31.5	35.3	34.3
Exch.Ca (me/100g)	28.0	24.4	18.0	17.4
Exch.Mg "	9.8	11.7	12.7	13.7
Exch.K "	0.7	0.4	0.4	0.7
Exch.Na "	2.2	3.9	4.4	5.7
Sum of bases	40.7	40.4	35.5	37.5
Base sat.%, pH 8.2	100	100	100	100
Exch. Al+H (me/100g)	n.d.			
ESP at pH 8.2	6	12	12	17
Gravel %	<2	<2	<2	<2
Texture, limited pretreatment:				
Sand % 2.0-0.05 mm	10	10	8	10
Silt % 0.05-0.002 mm	35	36	26	20
Clay % 0.002-0 mm	55	54	66	70
Texture class	C	C	C	C
Texture USDA:	not determined			
Sand % 2.0 - 1.0 mm				
Sand % 1.0 - 0.50 mm				
Sand % 0.50-0.25 mm				
Sand % 0.25-0.10 mm				
Sand % 0.10-0.05 mm				
Total sand %				
Silt %				
Clay %				
Texture class				
Bulk density	n.d.			
Moisture % w/v at:	not determined			
pF 0				
pF 2.0				
pF 2.3				
pF 2.7				
pF 3.0				
pF 3.7				
pF 4.2				

Profile 30

Laboratory no. 1980	12468/9	12470	12471	
Horizon	Ah	Btg1	Btg2	
Depth (cm)	0-30	30-60	60-150	
pH-H_2O(1:2.5 v/v)	5.8	5.5	5.2	
pH-KCl "	4.2	3.9	3.8	
EC(mS/cm) "	0.02	0.02	0.03	
C (%)	0.7	0.2	0.3	
N (%)	n.d.			
P-Mehlich (mg/kg)	n.d.			
CEC (me/100g), pH 8.2	n.d.	5.8	10.0	
Exch.Ca (me/100g)	n.d.	1.8	2.5	
Exch.Mg "	n.d.	0.9	2.5	
Exch.K "	n.d.	0.2	0.2	
Exch.Na "	n.d.	0.1	0.3	
Sum of bases	n.d.	3.0	5.5	
Base sat.%, pH 8.2	n.d.	52	55	
Exch. Al+H (me/100g)				
ESP at pH 8.2				
Gravel %	<2	2-15	2-15	
Texture, limited pretreatment:				
Sand % 2.0-0.05 mm				
Silt % 0.05-0.002 mm		n.d.		
Clay % 0.002-0 mm				
Texture USDA:				
Sand % 2.0 - 1.0 mm	1	1	2	
Sand % 1.0 - 0.50 mm	3	3	2	
Sand % 0.50-0.25 mm	14	14	11	
Sand % 0.25-0.10 mm	29	28	26	
Sand % 0.10-0.05 mm	6	6	5	
Total sand %	53	53	46	
Silt %	32	19	16	
Clay %	15	29	38	
Texture class	L	SCL	SC	
Bulk density	1.53	1.67	1.63	1.79
Moisture % w/v at:	5-10	25-30	58-63	90-95 cm
pF 0	37.0	33.8	32.5	31.0
pF 2.0	27.8	24.6	23.1	25.7
pF 2.3	24.1	22.2	20.6	25.8
pF 2.7	23.3	21.6	20.0	25.2
pF 3.0	18.2	16.1	16.6	24.8
pF 3.7	12.5	10.9	13.5	21.9
pF 4.2	8.8	7.5	8.9	17.9

Appendix 7. Land-evaluation key

Land unit	Maize	Sorghum	Millet	Rice	Cassava	Sweet	Cowpea	French beans	Green gram	Sun-flower	Cotton	Simsim	Vege-tables	Cashew	Coco-nut	Pine-apple	Sisal
1	S1-2d	S1	-	S2d	S3v	S3v	S2s	S2s	-	S1-2d	S2m	S2ms	S2s	S3v	S3v	S2m	S2s
2	S3f	S3f	-	Nd	S2f	S2f	S2m	S3f	-	S2f	S3f	S2m	S2m	S1	S3m	S2m	S1
3	Nf	Nf	-	Nd	S3r	S3r	S2m	Nf	-	S2f	Nf	S2m	S2m	S3r	S3mr	S3f	S2r
4	S3df	s3df	-	S2f	S3d	S3d	S3d	S3df	-	S3d	S3f	S2d	S3d	S3d	S3d	S3d	S3d
5	S3f	S3f	-	S2m	S2f	S2f	S1	S3f	-	S2f	S3f	S2m	S1	S1	S2m	S2m	S1
6	Nds	Nds	-	Ns	Nds	Nds	Nds	Nds	-	Nds	Nds	Nds	Nds	Nds	Nds	Nds	Nds
7	S3d	S2d	-	S1	S3d	S3d	S3d	S3d	-	S3d	S3d	S3d	S3d	Nd	Nd	S3d	S3d
8	S1-2d	S1	-	S2d	S3v	S3v	S2s	S2s	-	S1-2d	S2m	S2ms	S2ms	S3v	S3v	S2m	S2vs
9	S3f	S3f	-	Nd	S2mf	S2f	S2m	S3f	-	S2f	S3f	S2m	S2m	S2m	S3m	S2m	S1
10	Nf	Nf	-	Nd	S3vr	S3vr	S2m	Nf	-	S2f	Nf	S2m	S2m	S3vr	S3vr	S3f	S2vr
11	S2f/3m	S2f/2f	-	S3d	S1	S1/2m	S1/3m	S2f	-/S2f	S1	S2mf	S2m/2m	S1	S2m	S2m	S1	S1
12	S3f/3f	S3f/3f	-	S3d	S2f	S2f/2f	S1/3m	S3f	-/S3m	S2f	S3f	S1/2m	S2m	S2m	S3m	S2f	S1
13	S3f/3f	S3f/3f	S2f	Nm	S2f	S2f	S2f/3m	S3f	-/S3m	S2f	S3f	S2f/2f	S2f	S2m	S2m	S2f	S2f
14	Nf	Nf	S2f/2f	Nd	S3f	S3f/3f	S2f/2f	Nf	S2f/3m	S3f	Nf	S2f/2f	S2f	S2f	S3m	S3f	S2f
15	S2m/3m	S1/3m	S2s/2mș	S3m	S3v	S3v	S2s/3m	S2ms	-/S3m	S1	S2m	S2s/2ms	S2ms	S3v	S3v	S2m	S2v
16	S2f/3m	S2f/3m	S1/2m	S3d	S2m	S1/3m	S1/3m	S2f	-/S3m	S1	S2mf	S1/2m	S2m	S2m	S3m	S1	S1
17	S3f/3f	S3f/3f	S1/2m	Nm	S2f	S2f/3m	S1/3m	S3f	S1/3m	S2f	S3mf	S1/2m	S2m	S2m	S3m	S2mf	S1
18	S3f/3f	S3f/3f	S2f/2f	Nd	S2mf	S2f/3m	S2m	S3f	S2f/3m	S2f	S3f	S2m/2m	S2m	S2m	S3m	S2m	S1
19	S3s/3s	S3s/3s	Ns	S3s	Ns	S3s	Ns	Ns	Ns	S3s	S3f	Ns	Ns	Ns	S3m	S3s	Ns
20	Nf	Nf	S2f/2f	Nm	S3f	S3f/3f	S2f/2f	Nf	S2f/3m	S3f	Nf	S2f/2f	S3m	S2mf	Nm	S3f	S2f
21	Nf	Nf	S2f/3m	Nm	S3f	S3f/Nm	S2f/3m	Nf	S2f/Nm	S3f	Nf	S2f/3m	S3m	S3m	Nm	S3m	S2f
22	S3f/3f	S3f/3f	S3s/3s	Nm	S3sr	S3r/3r	S3s/3s	S3s	S3s/3s	S2s	S3mf	S3s/3s	S3s	S3sr	S3r	S2ms	S3s
23	S3f	S3f	S1/2m	Nm	S2f	S3m	S2m/3m	S3f	S2m/3m	S2f	Nm	S2m/3m	S3m	S3m	Nm	S3m	S2m
24	S3s	S3s	Ns	Nm	Ns	S3s	Ns	Ns	Ns	S3s	S3m	Ns	Ns	Ns	Nm	Ns	Ns
25	Nm	S3f/3f	S3s/3ms	Nm	S3sr	Nm	S3s/3s	S3ms	S3s/Nm	S2m5	Nm	S3rs	S3ms	Nm	Nm	Nm	S3s
26	Nm	S2f	S2d/3m	Nm	S2m	Nm	S2m/3m	S3m	S2m/Nm	S2m	Nm	S3m	S3m	Nm	Nm	Nm	S2m
27	Nm	S3f	S2m/3m	Nm	S3m	Nm	S2m/3m	S3mf	S2m/Nm	S3m	Nm	S3m	S3m	Nm	Nm	Nm	S2m
28	Nm	Nf	S2f/Nm	Nm	S3f	Nm	S2f/Nm	Nm	S2mf/Nm	S3f	Nm	Nm	Nm	Nm	Nm	Nm	S2m
29	not classified																
30	not classified																
31	S3df	S3df	-	S1-2d	S3df	S3df	S2-3d	S3df	-	S2-3d	S3df	S2-3d	S2-3d	S3d	S3d	S2-3d	S2-3d
32	not classified																
33	not classified																

LUTS CLASSIFICATION

Appendix 8
Agriculture in the Kilifi Area (Mapsheet 198), Kenya

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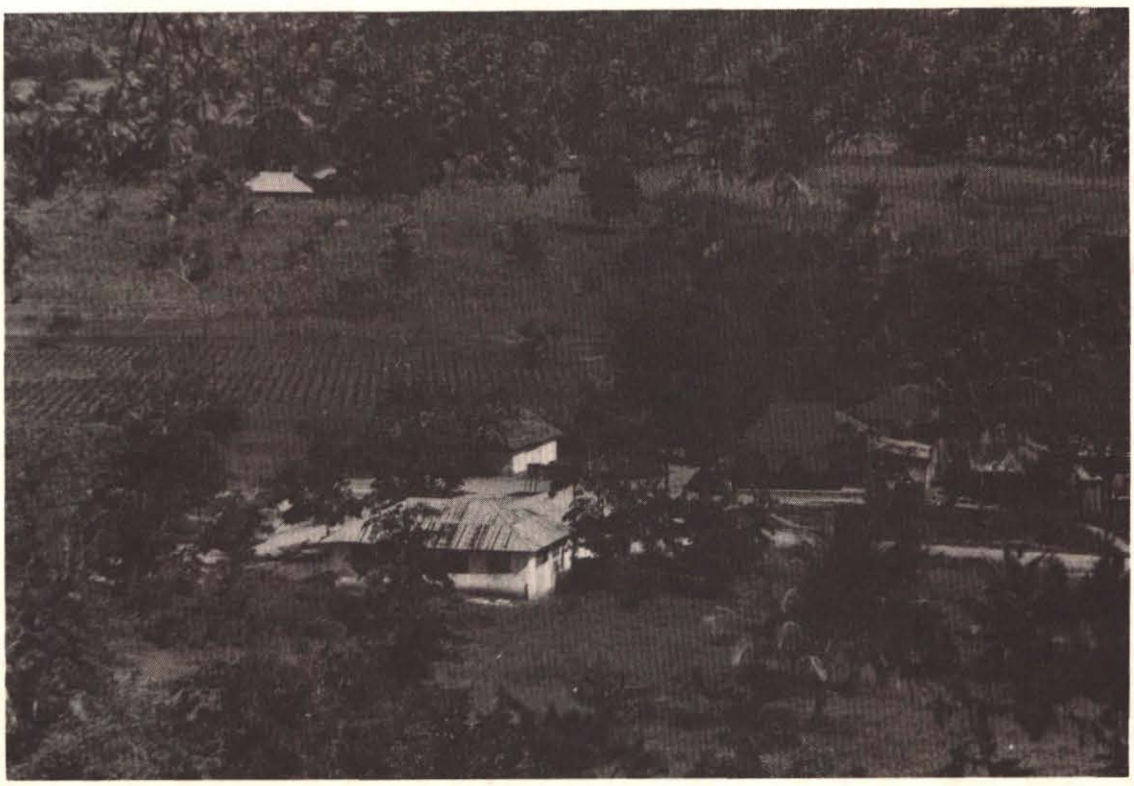
In: BOXEM, H.W., T. de MEESTER & E.M.A. SMALING (Eds) 1987.
Soils of the Kilifi area (mapsheet 198), Kenya.
PUDOC, Wageningen.

1 INTRODUCTION

This paper presents a condensed overview of present day agriculture in the Kilifi area, Kenya, with emphasis on small scale agriculture practised by the Mijikenda, the largest population group in the area. In chapter 2 their agro-economic history is described. Chapter 3 shows the actual land use as the result of historical processes in interaction with the natural environment. Chapters 4 to 6 give information on respectively farming systems, cropping systems and livestock systems. Chapter 7 deals with some aspects of the socio-economic environment: infrastructure and services. For further study the paper is completed with an extensive bibliography and table A1 with descriptions of 9 major Land Utilisation Types (LUT's).

The information presented in this paper is based on preliminary analysis of (field) studies carried out by the author and students of the Wageningen Agricultural University, the Netherlands, between 1981 and 1985. Methods employed range as wide as literature review, archival research, formal and informal interviews, surveys and trials in farmers's fields. Where appropriate, sources of data and methods have been indicated in text, tables and figures.



PHOTOGRAPH 1. Agriculture in the Kilifi area: maize and coconut palms in Kizurini, just west of Kaloleni.

2 AGRO-ECONOMIC HISTORY

Introduction: 'we came from Shungwaya'

The Mijikenda were first mentioned in 16th and 17th century Portuguese records. Little is known about their early history, and views on it are conflicting. Most oral traditions of the Mijikenda tell: 'we came from Shungwaya'.

SPEAR (1978) locates Shungwaya somewhere behind the southern Somalia coast. Mijikenda ancestors lived there with those of a.o. the Pokomo and some groups of the Taita and Swahili peoples. They grew crops, collected fruits and greens, and kept livestock. They were chased from Shungwaya by Galla nomads, and around 1600 entered the Kilifi-Mombasa-Vanga hinterland, until then empty apart from a few nomadic hunters. They settled themselves in 'kayas', fortified villages on forested hill tops, absorbed other people and gradually differentiated into the nowadays nine Mijikenda tribes. These are the Digo (southern Mijikenda), the Duruma and Rabai (central Mijikenda) and the Ribe, Kambe, Jibana, Chonyi, Kauma and Giriama (northern Mijikenda). The Digo and Duruma live in Kwale District, the others in Kilifi District. Each tribe has its own history, but the short outline presented in this chapter applies more or less to all of them.

ALLEN (1983) argues that ancestors of the Mijikenda had been living in the Kilifi-Mombasa-Vanga hinterland long before 1600, and that only small groups of immigrants actually came from Shungwaya. They mixed with the local population, who gradually accepted the 'we came from Shungwaya' legend as their own history.

SPEAR (1978) and ALLEN (1983) also differ on the location and nature of Shungwaya. Both, however, agree that the present Mijikenda are the result of integration of several groups of people with different cultural backgrounds: gatherers, hunters, pastoralists and agriculturalists.

Traditional agriculture

From the 16th to the mid 19th century the Mijikenda lived in kayas, as defense against Galla raids. The kayas were governed by councils of elders who regulated a.o. communal rights to land and relations with the outside world. From the kayas the Mijikenda practised shifting cultivation in the surroundings, growing finger and pearl millet, sorghum, simsim, cowpea, eggplant, and later also sweet potato, rice, cassava and maize. The last two crops, probably introduced by the Portuguese (MIRACLE, 1965; PURSEGLOVE, 1976), gradually replaced sorghum and millets as staple foods. The diet was supplemented with the gathering of wild plants, hunting and fishing. Periodic famines occurred, but in most years the Mijikenda were self sufficient in food production and they even produced surplusses for sale. Further they collected honey, gum copal, wild rubber and other forest products. They kept goats, sheep and chicken, and since the early 19th century increasing numbers of cattle.

Trade

The keeping of cattle was made possible by the ending of the Galla raids and by the fact that many Mijikenda had collected considerable wealth in trade. Among themselves they traded in grain, clay pots, salt and palm wine. With the coastal Swahili and Arabs they exchanged simsim and grain surplusses, tobacco and forest products (see above) for cloth, beads and wire. These goods and their own famous arrow poison they traded with the Waata, Galla and Kamba who lived farther in the interior for ivory, rhinohorn and cattle. These again they sold to the Swahili and Arabs. In the second half of the 19th century they gradually lost this profitable middlemen position due to direct trading contacts between coast and interior, the construction of the Mombasa-Nairobi-Kisumu railway (completed in 1901), and the prohibition of the ivory trade by the colonial government (after 1895).

Territorial expansion

In the middle of the 19th century the Mijikenda left their kayas, as a result of population pressure, economic expansion and relative safety. They spread over the surrounding areas, expanded westwards to the Taru desert and to north of the Sabaki river. Around 1900 they started to move into the '10 mile coastal strip', the sphere of influence of the Sultan of Zanzibar and his subjects, the Arabs and Swahili of the coastal towns. During the second half of the 19th century these had extensive slave worked plantations there, producing sorghum, simsim and coconuts for the local market and for export. After 1890 these plantations broke down due to lack of slave labour. The land reverted to bush or was occupied by ex-slave and Mijikenda squatters. The colonial government at first tried to stop the Mijikenda inflow, but without success. From the 1930's onwards they tried to regularise it by the establishment of settlement schemes, a.o. Gedi. After independence this policy was continued by the Kenya government: the settlement schemes Ngerenya, Tezo/Roka, Mtondia, Mtwapa and Vipingo. Part of the land in the coastal strip has been acquired by foreigners: Vipingo Sisal Estate Ltd. and Kilifi Plantations Ltd., which produce sisal, milk, beef and mangoes for export and local markets.

Coconut palms and cash crops

The present distribution of the Mijikenda population has been strongly influenced by the coconut palm, in the past mainly grown for palm wine, nowadays more for copra, fresh nuts and roofing material. The Digo were the first to grow the palm, at the end of the 18th century the Rabai started planting, and by 1850 the palm was observed in most kayas. Since then the palm has spread into any suitable place and even into quite many ecologically not suitable places. The population tended to concentrate where coconut palms could be grown. During the 1920's and 1930's the government promoted cotton and cashew as cash crops. The labour intensive and risky cotton never became popular in the Kilifi area. Cashew by now is an important cash crop, although it never gained the popularity the coconut palm has with farmers.

Land

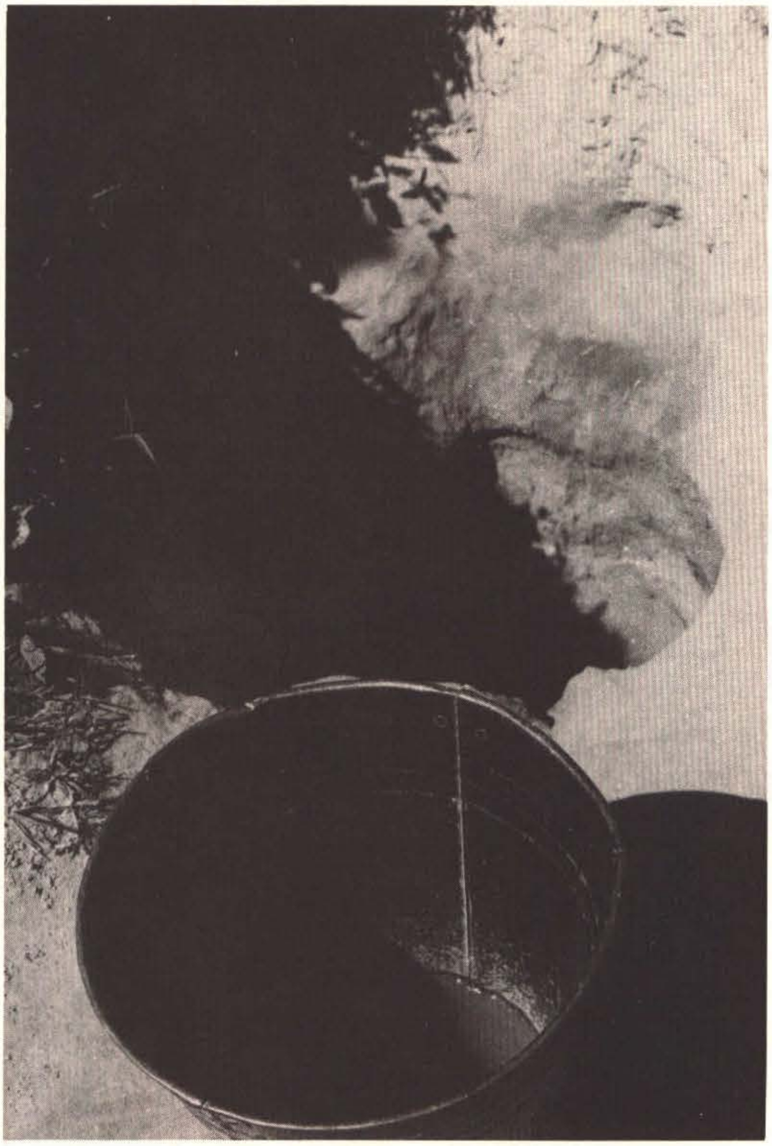
The abandonment of the kayas and their central government and the introduction of permanent crops induced a change from communal land use rights to individual ownership of land. Other factors in this process were the increasing scarcity of land and the (post)colonial government (see chapters 4 and 5).

Labour: off-farm work

During the early colonial period (1895-1920) the Mijikenda were reluctant to do wage labour. Apparently they did not feel the need for it, as they were self sufficient in food production and many conducted a flourishing trade in grain with the people of the coastal towns. Forceful attempts to remove them from their land and into wage labour resulted in the Giriama rising of 1914. Since the 1920's the number of people engaged in - at first mainly casual - wage labour increased. Nowadays in most households one or more members, often including the 'farmer', have a non-farm job, in many cases far away from home.

Food production

The increase of off-farm work is the result of dire need. Until circa 1925 the Mijikenda generally were capable of producing food surplusses, although in many years they suffered from natural and man-made famines. They had been able to balance these by the collection of wild food plants, the collection and sale of forest products, by trade and by the social ties among themselves and with neighbouring peoples. By the 1920's trade and the demand for forest products had declined. The production of grain for local markets and export was discouraged by government measures and decreased. From the 1930's shortages of food appear to have become common. Colonial officials report drougths, famines, famine relief and population movements towards the wetter coastal strip. During the 1940's cassava, before the staple food of the Digo only, became more important as maize harvests failed to feed the population (NGALA, 1949). In the 1960's most households around Kaloleni ran out of maize before the next harvest (PARKIN, 1972). In the early 1980's Kilifi District imported 50,000 tons of grain per year (NEHSS, 1984), more than 100 kg per head of the population. Food deficits are likely to increase unless there is a substantial improvement in agricultural productivity (TARDA, 1983).



PHOTOGRAPH 2. Good drinking water always has been scarce in the Kilifi area, although the piped water network has been increased in recent years. Droughts and famines are a major theme in oral history and lack of water for crops, livestock and people still is one of the problems most frequently mentioned by farmers.

Among the causes of low food production are the scarcity of good land and the exhaustion of land due to population growth and the introduction of cash crops. In order to provide cash for food, school fees, etc. many people - often the best - were forced in off-farm work. This drain on labour and managerial ability further aggravates the situation. Most of the food is grown by women, but men who are often away on off-farm work still control most of the resources: land and cash for hired labour, tools, tractor ploughing, chemical inputs.

Recent changes

Tractor ploughing, which facilitates the cultivation of the heavy clay soils in 'Ngamani' (see chapter 3), became popular in the 1960's, but is plagued by permanent lack of tractors and spare parts. A recent and not yet widespread innovation is ploughing with oxen or donkeys.
A major disappointment for many farmers was the prohibition in 1980 of tapping and selling palm wine. At present consumption of palm wine is only allowed at traditional occasions like funerals. Before 1981 there was a blooming trade in palm wine between the countryside and towns like Mombasa, Kilifi and Malindi, providing town dwellers with cheap liquor and farmers with cash for food, clothes and schooling.

Summary

The Mijikenda household economy has been in continuous evolution since 1600:

- o from collection to cultivation;
- o from sorghum and millets to maize and cassava as staple foods;
- o from annual crops to more and more tree crops;
- o from shifting cultivation to (semi)permanent cultivation as a result of tree crop planting and land scarcity;
- o from communal rights to use land to individual land ownership;
- o from collection and trade to cash crops and off-farm work.

Sources

The above is a summary of WAAIJENBERG (1987).Extensive use has been made of a.o. ALLEN (1983), BRANTLEY (1981), COOPER (1981), FREEMAN-GRENVILLE (1975), GERLACH (1965), KRAPF (1860), MARTIN (1973), MWANGUDZA (1983), NGALA (1949), PARKIN (1972), PATTERSON (1970), PRINS (1952), SALIM (1973), SPEAR (1978).

3 LAND, VEGETATION AND LAND USE

The present land use in the Kilifi area is the result of the described historical processes interacting with the environmental conditions soil, climate and natural vegetation (see figure 1). Most soils are chemically rather poor, so that generally their physical properties, notably drainage and water retention, together with the climate determine their suitability for natural vegetation and land use.

Rainfall is the most important climatic factor; the variations in evaporation and temperature are much smaller. From the coast towards the interior the average annual rainfall decreases and the seasonal distribution becomes more bimodal; the short rains increase in relative importance. This general pattern is disturbed locally by the effects of the topography: steep eastern slopes cause an increase in rainfall (compare the rainfall in figure 1c with the topographic cross-section in figure 1a). Therefore the area around Kaloleni has higher rainfall than one would expect in view of the distance to the coast. Moreover the short rains are most reliable around Kaloleni (OKOOLA, 1978).

There is a marked soil effect on the natural vegetation; comparison of figures 1b and 1d shows that many boundaries correspond with each other. The effect of rainfall is less evident as some isohyetes roughly run parallel with soil boundaries, but for example the transition from lowland rain forest (V) to lowland dry forest (IIA and III) clearly reflects the rainfall-vegetation relationship. Vegetation type V is exacting with regard to moisture availability and it can only be found where both rainfall and soil conditions are favourable: in the area around Kaloleni.

Most of the natural vegetation has been replaced temporarily or permanently by annual and tree crops or is affected by grazing and burning. Natural and man-made vegetations are strongly correlated, as comparison of figures 1d and 1e shows, for example:

- o Most coconut palms are found in vegetation type V and in the wetter parts of vegetation type III.
- o Largest concentrations of cashew trees occur in vegetation type IIA.
- o The parts of vegetation type IIB that are on deep soils and receive sufficient rainfall have been replaced by intensive annual crop growing.
- o Vegetation types I and II are being used for extensive grazing and browsing.

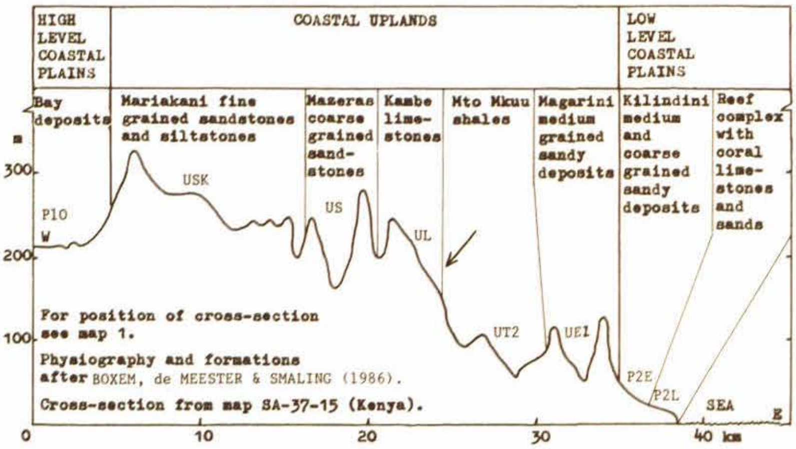
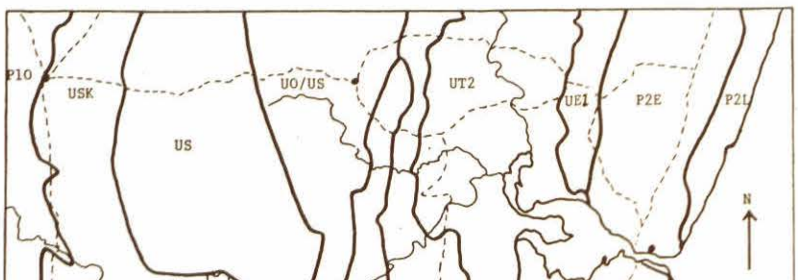


FIGURE 1a. Cross section of the Kilifi area (mapsheet 198), Kenya: physiography and formations (BOXEM, de MEESTER & SMALING, 1987). Steep eastern slopes (↙) promote rainfall.



P2 LOW LEVEL COASTAL PLAINS (altitude 0-75 m)

P2L Soils developed on coral limestones and sands (Reef Complex)

P2E Soils developed on medium and coarse grained sandy deposits (Kilindini Formation)

U COASTAL UPLANDS (relief intensity less than 100 m, slopes predominantly 0-16 %)

UE1 Soils developed on unconsolidated medium grained sandy deposits (Magarini Formation)

UT2 Soils developed on shales (Mto Mkuu Formation)

UL Soils developed on limestones (Kambe Formation)

US Soils developed on coarse grained sandstones (Mazeras Formation)

USK Soils developed on fine grained sandstones and siltstones (Mariakani Formation)

UO Soils developed on unconsolidated fine sandy and clayey deposits (Bay Deposits)

P1 HIGH LEVEL COASTAL PLAINS (altitude 150-250 m)

P10 Soils developed on unconsolidated, fine sandy and clayey deposits (Bay Deposits)

FIGURE 1b. Simplified soil map of the Kilifi area (mapsheet 198), Kenya. The E-W line indicates the cross section of figure 1a.

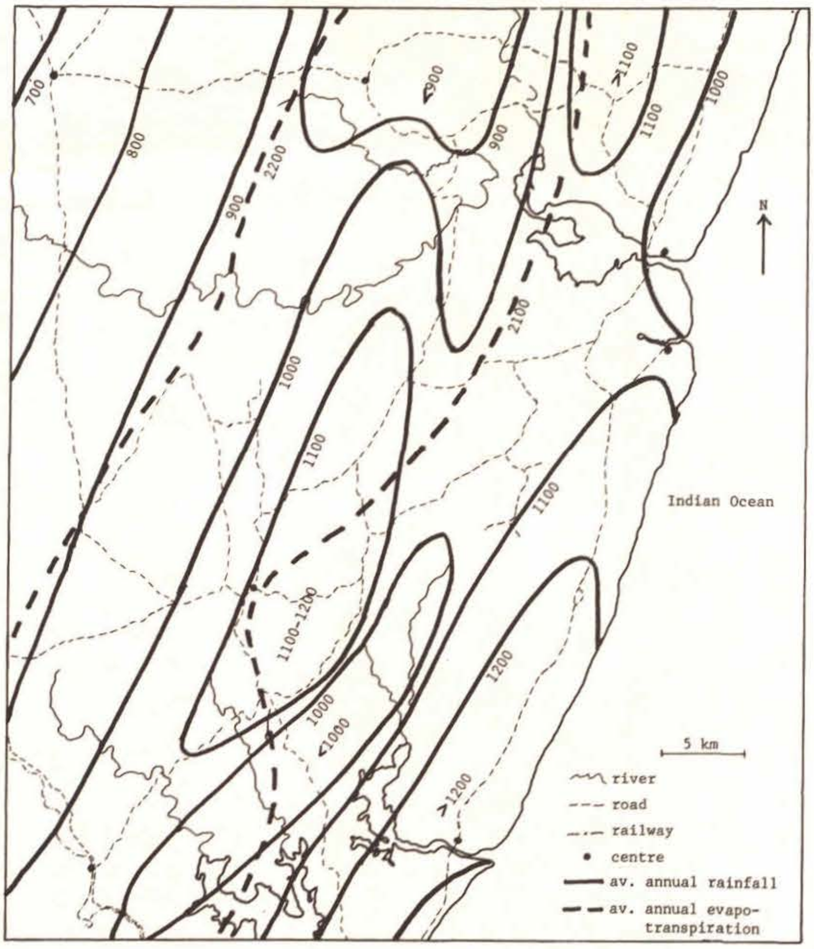
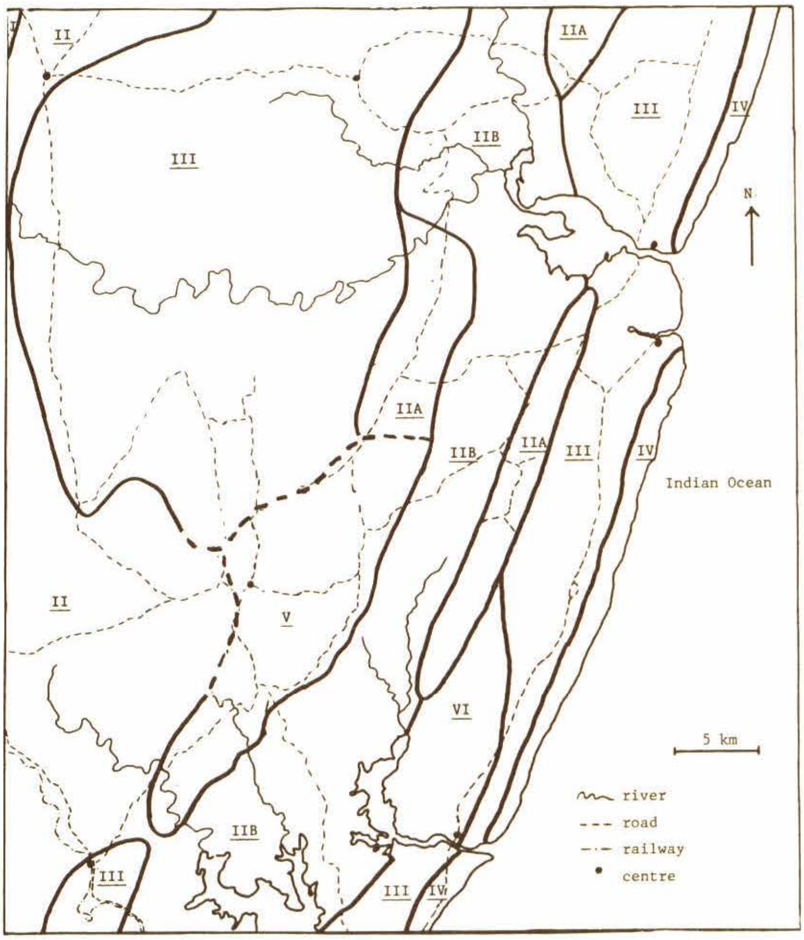


FIGURE 1c. Approximate annual rainfall and evapo-transpiration (mm/year) of the Kilifi area (mapsheet 198), Kenya; after JAETZOLD & SCHMIDT (1983) and BOXEM (1982, pers. comm.).

Figure 1e depicts the present land use in the Kilifi area. From east to west six main land use zones can be distinguished. Their boundaries often coincide with those of soil units. Most zones show gradual changes from southeast to northwest due to a decrease in the amount of rainfall.

I This zone is composed of the low level coastal plain and parts of the Magarini formation. The population density averages 140 persons/km2, but varies between 50 and 300 persons/km2 due to a.o. the spatial distribution of the three distinct farming systems (LIESHOUT & STRAVER, 1984):

- o Small scale farms, less than 10 ha but most between 3 and 6 ha, with coconut, cashewnut, maize, cowpea and simsim production occupy about 60 % of the zone. Most lie in settlement schemes which have been established since 1962. Before the many farmers squatted on the land.
- o Medium scale farms, 10 to 100 ha, with vegetable, fruit, milk, poultry and coconut production cover about 10 % of the zone,



VEGETATION TYPES

I	Acacia-Euphorbia	Acacia thorn-bushland
II	Manilkara-Diospyros	Lowland dry forest
IIA	Cynometra-Manilkara (Sokoke)	Lowland dry forest
IIB	Manilkara-Dalbergia/Hyparrhenia	Lowland cultivation savanna
III	Brachystegia-Afzelia	Lowland woodland
IV	Combretum schumanii Cassipourea	Lowland dry forest on coral rag
V	Sterculia-Chlorophora/Memecylon	Lowland rain forest
VI	Afzelia-Albizia/Panicum	Lowland moist savanna

FIGURE 1d. (Semi)natural vegetation of the Kilifi area (mapsheet 198), Kenya; adapted after MOOMAW (1960).

mainly along the Mombasa-Malindi road.

o Large scale farms, more than 1000 ha, with sisal, milk, beef and mango production use the remaining 30 % of the land.

II Zone II consists of the remaining parts of the Magarini formation. The population density is about 100 persons/km2. The homesteads, surrounded by some coconut palms, are concentrated along the roads on the narrow tops of the steep hills. Most of the tops and upper slopes are covered by cashew trees. Some semi-permanent annual crop growing takes place on the lower slopes. On the valley bottoms rice is grown. The majority of the farmers have land in the adjacent zone IIIB where they grow annual crops, of which maize is the most important.

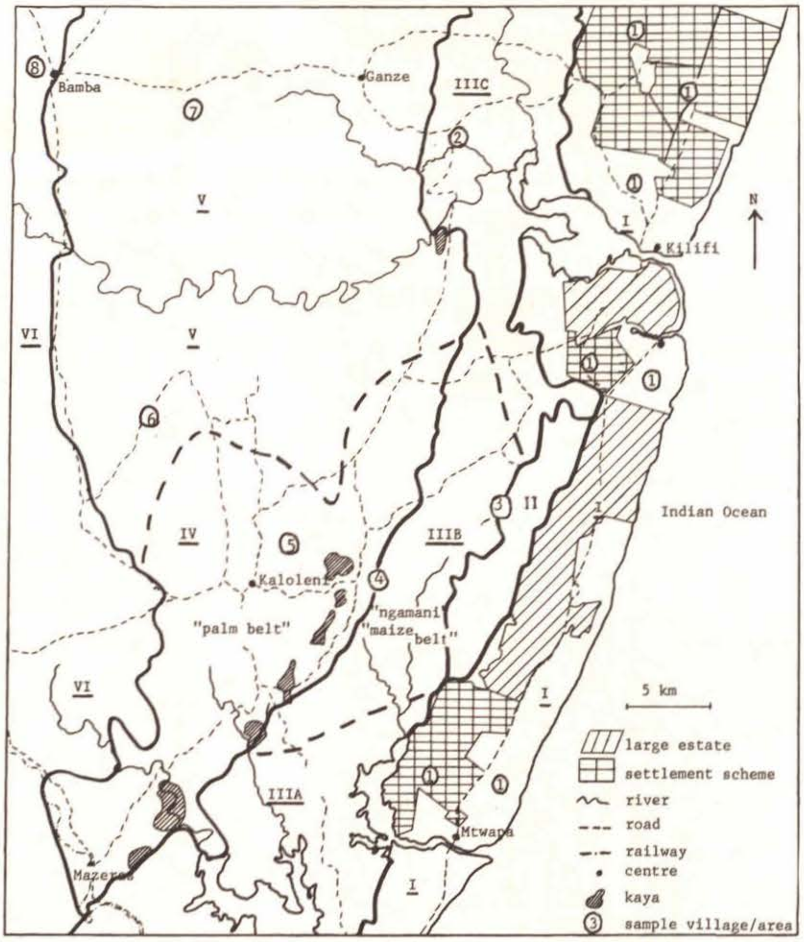


FIGURE 1e. Land use zones of the Kilifi area (mapsheet 198), Kenya. For explanation see chapters 3 and 4.

PHOTOGRAPH 3. Cowpea and cassava in Pingilikani (zone II).

III Zone III, 'Ngamani', despite the fertility of the soils developed on shales, is a thinly populated area with about 50 persons/km2. Most people with land in this zone live in the surrounding zones II and IV where they can grow tree crops. In zone III these are hardly grown due to rooting problems related to the poor drainage and cracking of the soils. Only on sandy hill tops and in some places on valley bottoms they can be grown successfully.
In the southern part (IIIA), with rather shallow soils in a dissected landscape, the land use is a mixture of extensive grazing, a.o. by a large private ranch, coconut growing on the sandy hill tops, and some maize growing.
In the central part (IIIB), with deeper, fertile soils, the

PHOTOGRAPH 4. Tractor ploughing in Mbuyuni. Note the sharp soil related transition between Ngamani (zone IIIB) and the palm belt (zone IV).

cultivation of arable crops is of rapidly growing importance, especially since the introduction of tractor ploughing in the 1960's. This area might appropriately be called the 'maize belt' of the Kilifi area. In good years, with moderate rainfall, yields of 2000 kg/ha are obtained without fertilizers. Part of the maize is intercropped with rice or cassava. Other crops are cowpea, simsim, green gram, bambara nut and some cotton, all grown as relay crops.

In the northern part (IIIC) of the zone the growing of crops is hindered by the low (800-950 mm/year) and unreliable rainfall. The population density is no more than 30 persons/km2. The main forms of land use are extensive grazing/browsing by goats and fallow cultivation, with maize and cassava as main crops.

PHOTOGRAPH 5. Land use in Mikiriani, about 7 km north of Kaloleni. Coconut palms gradually make place for cashew, maize and fallow vegetation (the transition from zone IV to V).

IV Zone IV, mainly on soils developed on Kambe limestones and Mazeras and Mariakani siltstones and sandstones, forms a densely populated 'palm belt' with 150 to 250 persons/km2. The western and northern boundaries roughly coincide with the 1000 mm annual rainfall line (BROM, 1981). Apart from coconut palms also mangoes, bananas, Citrus spp., other fruit trees and cashew trees are found. The last gradually become more important towards the north. Maize is the main annual crop, followed by cassava and rice. The last is grown wherever suitable valleys or bottom lands are found. Further some cowpea, simsim and bambara nuts are grown.
In this zone land is becoming scarce and many fields have been exhausted by too long periods of cropping. Part of the farmers of the palm belt have land in Ngamani, zone IIIB.

V Zone IV gradually changes into the dry (700-900 mm/year) and thinly populated (50-100 persons/km2) zone V. Cashew is here the dominant cash crop. Maize, cassava and some simsim are grown. Part of the farmers have livestock. Where this is still possible timber, firewood, charcoal, honey and other products are extracted from the bush and woodland (SCHREURS, 1982). However, in most places crop growing (shifting and fallow cultivation), overgrazing and the above forms of exploitation have severely degraded the vegetation cover.

VI In zone VI, with soils developed on bay sediments, the possibilities for crop growing are restricted by the low rainfall of less than 800 mm/year and by the poor physical and chemical properties of the soils. This is reflected by a low population density of less than 50 persons/km2. Most of the zone is covered by Acacia-Euphorbia bushland. Ranging (grazing/browsing), partly organised in group ranches, and locally the growing of maize and cassava are the dominant land use. Outside the mapsheet there are large commercial ranches. Lack of water and overgrazing are serious problems in zone VI.

4 FARMING SYSTEMS

Table 1 presents general information on Mijikenda farms throughout the Kilifi area. Most data were obtained by interviewing and therefore might be somewhat inaccurate, but they fairly well correspond with later detailed field observations. The information was collected in 1981 and 1982 in 8 sample villages/areas characterised below. Their locations are indicated in figure 1e.

1 Bahari represents small settlement and non-settlement farms in zone I. Farmers grow maize, cowpea, simsim, coconut palms and cashew trees. North of Kilifi creek farmers have more coconut palms than south of the creek (notably Mtwapa settlement scheme), where cashew trees are more numerous. Around Mtwapa the proximity to Mombasa favours the production of fruits and vegetables.

2 Pingilikani lies on the ridges of the Magarini formation (zone II). Most homesteads lie on the tops of the ridges, which are covered with cashew trees. Some farmers grow annual crops near the homesteads or on the slopes of the hills. Most (also) grow them on land in Ngamani, zone IIIB.

3 Konjora represents the northern part of zone III. Soils are hard to work and rainfall is low and unreliable. People grow some maize and cassava. Most farmers have some goats. Tree crops have little importance. There is a tendency to migrate out of this hardship area.

4 Mbuyuni is situated on the eastern border of the palm belt (zone IV). About three quarters of the farmers live in the palm belt itself, the others live in Ngamani, zone IIIB. Most of the farmers grow one or more tree crops, and nearly all have land in Ngamani for annual crops.

5 Chilulu is in the centre of the palm belt (zone IV), in a varied landscape where parts densely planted with coconut palms alternate with annual crop land. Only one fifth of the farmers have crop land in Ngamani.

6 Kinarani lies on the dry western edge of the coastal uplands (zone V). Main farming activities are the growing of maize and cashew trees, and grazing. Coconut palms are mainly grown for home consumption; yields are low due to lack of rain. Possibilities for forest exploitation are limited as the area has been largely deforestated.

TABLE 1. Characteristics of farms/households in the Kilifi area (mapsheet 198), Kenya.

	1 Bahari Division	2 Konjora	3 Pingilikani	4 Mbuyuni	5 Chilulu	6 Kinarani	7 Katofeni	8 Bamba	Remarks and references
Main soil units	P2El1,2,3 P2Em1,3 P2Ll1p UEl11 UT2C BAc1	UT2c2p UT2C AAc	UT2c1p UE1l1 UE1m1	ULc1 UT2c1p VXC	USc1 BAc1,2	USKf VXA	USs1 VXA	P101 USKA2	After BOXEM, MEESTER & SMALING (1986); in order of decreasing importance.
Average annual rainfall (mm/year)	900-1250	800-950	1000-1200	950-1200	1000-1200	800-1000	700-850	600-750	Ranges indicate interpolation errors and variation within areas; a.o. JAETZOLD & SCHMIDT (1983).
Main population groups	Giriama Chonyi	Kauma	Chonyi	Chonyi	Giriama Jibana	Giriama	Giriama	Giriama	In 1979 Kilifi District had 431000 inhabitants (CBS, 1981), of those about 65 % were Giriama, 19 % Chonyi, 2 % Kauma, 3 % Jibana (SPEAR, 1978).
Approximate population density (persons/km²)	100-200	40	80	140	280	90	40	60	CBS (1981), interview data.
Number of households	79	30	121	91	99	91	26	25	In Pingilikani, Mbuyuni and Kinarani 1 household was left out because of missing and/or too strange data. Large "households" in Bamba may have to do with cattle herding.
Average composition									
Men	-	4.3	2.6	3.4	3.0	3.2	3.3	7.1	
Women	-	3.9	3.4	4.0	3.5	3.7	4.0	7.4	
Children (≤15 years)	-	5.9	6.2	7.2	6.1	5.6	6.3	12.4	
Total	12.4	14.1	12.2	14.6	12.6	12.5	13.6	26.9	
Number of households	79	-	31	37	32	31	-	-	
% of households with one or more off-farm workers	61	-	>52	≥67	≥72	≥47	-	-	Includes part-time work excludes occasional "vipande" for farmers.
Number of farms	78	4	22	12	14	22	4	4	Most data were obtained by interviewing. In Kinarani only land in use for crops was included.
Average farm size (ha)	5.0	4.0	4.0	2.9	3.0	2.4	7.7	13.0	
Number of farms	20/79	4	4	5	4	5	4	4	
Area maize per farm per year (ha)	1.6/2.3	2.7	1.6	1.9	2.0	2.2	3.7	4.2	Nearly all farmers grow maize.
Number of farms	78	30	121	91	99	91	26	25	
% of farms growing rice	13	few	50	49	58	48	very few	very few	
% of farms growing coconut palms	78	27	59	88	74	71	81	8	Often numbers of trees and in few cases of livestock were given as "more than x". In these cases x was used in the calculations. Tree crop numbers of one Kinarani farmer have been excluded.
Average number of palms per owner	122	few	18	38	59	21	c. 31	-	
% of farms growing cashewnut trees	84	23	83	73	57	77	96	8	
Average number of trees per owner	156	few	99	12	12	21	c. 59	-	
% of farms having cattle	9	3	6	8	5	27	31	64	About 1/3 of Bamba cattle belong to other people, so the real average is about 25 instead of 34.
Average number of cattle per owner	17	35	10	7	6	24	16	34	
% of farms having goats or sheep	73	63	26	58	38	66	81	72	
Average number of goats+sheep per owner	21	24	6	7	6	10	10	16	In samples 1, 2, 7, 8 only goats were included; sheep are far less common and numerous than goats.
References	LIESHOUT & STRAVER (1984)	SCHREURS (1982)	WAAIJENBERG (1981, 1983, 1984 and unpublished data)				SCHREURS (1982)	SCHREURS (1982)	

7 Katofeni (zone V) is comparable with Kinarani. However, rainfall and therefore average yields are lower. People get some extra income from timber, firewood and charcoal production.

8 Bamba, on the eastern edge of the high level coastal plain, is a centre for the auction of livestock. The sample area was just west of Bamba centre, where population density is higher than average

for zone VI. Most farmers keep livestock, for themselves and for others who live elsewhere. Some maize and cassava are grown, but most years yields are very low.

Some of the above villages, e.g. Pingilikani and Mbuyuni, do not correspond with one specific land use zone. A feature of many farming systems in the Kilifi area is that they have subsystems (crop, livestock, off-farm) in several places, and so combine the advantages of more than one land use zone. Therefore the boundaries between land use zones often offer good opportunities to study farming systems. For the interpretation of table 1 some remarks follow about the major components of farming systems: land, household, labour, crops, livestock.

- o Land. The farm sizes are related to the population density and to the productivity of the land. In zones I and IV much land has been adjudicated to individual farmers. Land in zone VI has been allotted to group ranches, and outside the mapsheet also to commercial ranches. In the other zones only part of the land has been adjudicated. The other land is county council (trust) land and state land, on which farmers/squatters have little security, even if they have been living there for many years. In all sample areas/villages only part of the farm area is in use for crops. The rest lies fallow and/or is being used for grazing. In dry, thinly populated areas more land than the farm sizes indicate is available, for grazing and forest exploitation. There are less strong individual claims on this land.

- o A household was defined as a group of people who live and eat together, nearly always linked by family ties. A farm is their joint agricultural enterprise. In table 1 household numbers are presented as given by interviewees. These may include large extended families, which in many cases consist of several partly or fully economically independant subunits. Family members working in town were often mentioned as household members. This view can be justified if they are absent for only fart of the time and/or contribute to the household income. For the above reasons the numbers of households may have been underestimated and the sizes of the households overestimated, compared to CBS (1981). That there are more women than men may be explained by the absence of men on off-farm work, longer life expectancy for women, and maybe girls are considered to be adults at a younger age than boys.

PHOTOGRAPH 6. A Giriama household.

o Labour. Men are in charge of land tenure arrangements, house building, tree crops (cash) and livestock, although part or all of the work may be done by women, e.g. making 'makuti' (roofing tiles of palm leaf), collecting cashewnuts, herding, watering, milking. Men are also responsible for the clearing of new fields, cutting and burning of trees and shrubs, but as land use becomes more intensive, these activities decrease in importance. Women do the household work and nearly all annual crop production activities: cultivation, planting weeding, harvesting, processing. Children go to school and help their parents.

o Most (semi)permanent off-farm work is done by men. Some can work from their homes, but many live at the places where they work and visit their farms only occasionally. This means that much of the money they earn does not benefit the household, but is spent on housing, food, drink and women elsewhere. Opportunities for off-farm employment are concentrated in the coastal strip, notably in the towns Malindi, Kilifi and Mombasa, where people find work in the tourist industry, factories, shops, government offices, etc. In the past years it has become increasingly difficult to find off-farm employment. This has stimulated male (school leavers') interest in agriculture: many engage in e.g. growing vegetables for the market. Women often do 'vipande', piece work for other farmers, especially land preparation and weeding. Around Kilifi many women find work in the Kilifi Cashewnut Ltd. factory, low paid work for which little schooling is needed. Most male off-farm workers also fall into low income categories, (far) less than Ksh. 1000/= per month; they are unskilled due to poor education facilities in the rural areas of Kilifi District.

- The areas of annual crops average 1.6 to 4.2 ha per farm per year. They are limited by the availability of labour, the tools and the workability of the soils. The main farming tools are the 'panga' (cutlass) and a small 'jembe' (hoe), suitable only for weeding and shallow cultivation. In zone IIIB much land is tractor ploughed.

PHOTOGRAPH 7. Fire is a frequently used 'tool' in small scale Mijikenda agriculture: farmer preparing a valley bottom for rice planting, Kaloleni.

Ploughing is slightly cheaper than hand preparation by casual labour, but tractors are scarce. A recent innovation is the introduction of ploughing with oxen or donkeys. It remains to be seen how these will perform on soil units UT2c1p (sticky when wet, hard when dry) or USc1 (hard when dry).

- The distribution of tree crops is very skew. In many areas they cannot be grown successfully, and even in areas where they can be grown only part of the farmers have them. The average numbers of trees per owner also give an unrealistic impression; many farmers have few and few farmers have many trees.

- The distribution of livestock is not better. Most farmers have a few goats, but apart from the Bamba area very few farmers have cattle. On most homesteads there are some chicken or ducks. Very few farmers collect honey with local hollowed tree log hives or top bar hives (MANN, 1976).

At first view the small farms in the Kilifi area look rather uniform: household and farm sizes are not very different, all farms grow maize as staple food, all (would like to) grow coconut palms, most have some

PHOTOGRAPH 8. Forbidden prosperity: the tapping of a palm for 'uchi' (tembo ya mnazi, toddy, palmwine).

cashew trees, goats and chicken or duck. Closer examination shows considerable skewness in the distribution of tree crops and livestock, notably cattle, with many farmers having none or few.

The high percentage of farms with one or more off-farm workers reflects the difficulty to obtain enough food and an adequate cash income for clothes, housing, schooling, etc. by farming. Farms with no off-farm workers usually have larger than average numbers of tree crops, including fruit trees, or cattle, or they continue to tap and sell palm wine, although this is illegal since 1981.

5 CROPPING SYSTEMS

Main crops

Tables 2 and 3 indicate the importance of annual and tree crops. Maize and cassava are the staple food crops, cowpea the most important pulse crop and simsim the only significant annual cash crop. Most maize cultivars are local: 'Mingawa', 'Mdzihana', 'Mugao' and many others. Few farmers grow the 'improved' 'Coast Composite' maize, which in fact never proved to be superior with regard to yield level and reliability. Popular rice cultivars are a.o. 'Kathele', 'Ambari', 'Pishori' and 'Sindano'. 'Kabandameno', sweet and non-poisonous, is by far the main cassava cultivar. Common cowpea cultivars are the semi-erect 'Karingongo' and the creeping 'Mnyenze' or 'Mbomu'. All observed simsim was brown seeded, no cultivars were distinguished.

Coconut and cashew are the main tree crops, although some farmers have large numbers of _Citrus_, mango or banana trees. Most coconut palms are 'East African talls'. At present no cashew cultivars are distinguished. Main _Citrus_ spp. are _C. reticulata_ and _C. sinensis_. The 'old' mango cultivars with small or fibrous fruits, like 'Mdodo' and 'Mkimji', are most common in the hinterland, whereas the 'new' cultivars with large and less fibrous fruits, like 'Apple', 'Ngowe' and 'Boribo' are mainly found near the coast and around Kaloleni. Sweet bananas, cultivars a.o. 'Msukari' and 'Mukiche', are common. Plantains are not popular as a food crop; the main cultivar is 'Mboki'. For more information on fruit crops see HEMPENIUS (1983).

Mixed cropping

If Mijikenda crop growing would have to be characterised with one word, 'mixed cropping' would be an appropriate choice. On one piece of land many crops may be found, of all ages, and belonging to many farmers. For example the land may belong to farmer _A_, who has mortgaged it to _B_ who grows maize and cassava on it. The cashew trees have been planted by _C_, the coconut palms belong to _D_, who has mortgaged their production to farmer _E_. The palms may be tapped by _F_, and so on. The formal Kenyan laws on land rights can not cope with such situations, and in cases of land registration the government stimulates the owners of tree crops to sell them to the land owner.

Although crops do occur in any place and in any possible combination, there is a correlation with the topography which becomes stronger where climatic conditions, notably rainfall, become worse. For example, around Kaloleni, where rainfall is relatively high, coconut palms are found on hill tops and along valley bottoms, but often also

TABLE 2. Main annual crops: percentage of farms growing them and average area per farm which grows them.

	Bahari	Pingilikani	Mbuyuni	Chilulu	Kinarani	Remarks and references
No. of farms	79	31	37	32	31	
Maize						
% of farms	95	97	100	100	100	
ha/farm	1.6/2.3	1.6	1.9	2.0	2.2	WAAIJENBERG (1984).
Rice						
% of farms	13	45	38	72	45	GENT (1983).
ha/farm	-	0.24	0.59	0.13	0.14	
Cassava						
% of farms	54	94	95	100	74	0.1-0.5 ha per farm expressed as pure stand.
Cowpea						
% of farms	67	94	84	100	90	LEEUWEN (1984); areas 0.1-1.0 ha.
Simsim						
% of farms	59	45	51	31	29	WASSINK (1983),
ha/farm	-	0.29	0.06	0.25	0.02	most less than 0.1 ha.
Tobacco						
% of farms	35	4	6	28	58	In Kinarani grown as
ha/farm	-	30	10	100	600	cash crop (HEMPENIUS, 1982).

Sources: Data for Bahari are from LIESHOUT & STRAVER (1984); percentages for other villages from November/December 1981 baseline interviews of subsamples of the farms in table 1; areas of crops are based on observations on 5 farms per village, so they are indicatory only.

TABLE 3. Main tree crops (including banana): percentage of farms growing them and average number of trees per farm which grows them.

	Bahari	Pingilikani	Mbuyuni	Chilulu	Kinarani
No. of farms	78	31	37	32	31
Coconut					
% of farms	78	84	86	87	81
palms/farm	122	40	90	136	44
Cashewnut					
% of farms	84	97	78	88	90
trees/farm	156	114	15	28	46
Citrus spp.					
% of farms	-	42	70	75	19
trees/farm	-	14	15	32	8
Mango					
% of farms	-	52	65	78	52
trees/farm	-	11	8	8	5
Banana					
% of farms	-	27	84	91	32
stands/farm	-	23	15	35	13

Sources: Data for Bahari are from LIESHOUT & STRAVER (1984); percentages for other villages from November/December 1981 baseline interviews of sub-samples of the farms in table 1; less than 5 % of the farms, with unlikely numbers of (young) plants, have been excluded as a few farms with hundreds or thousands of trees easily distort averages.

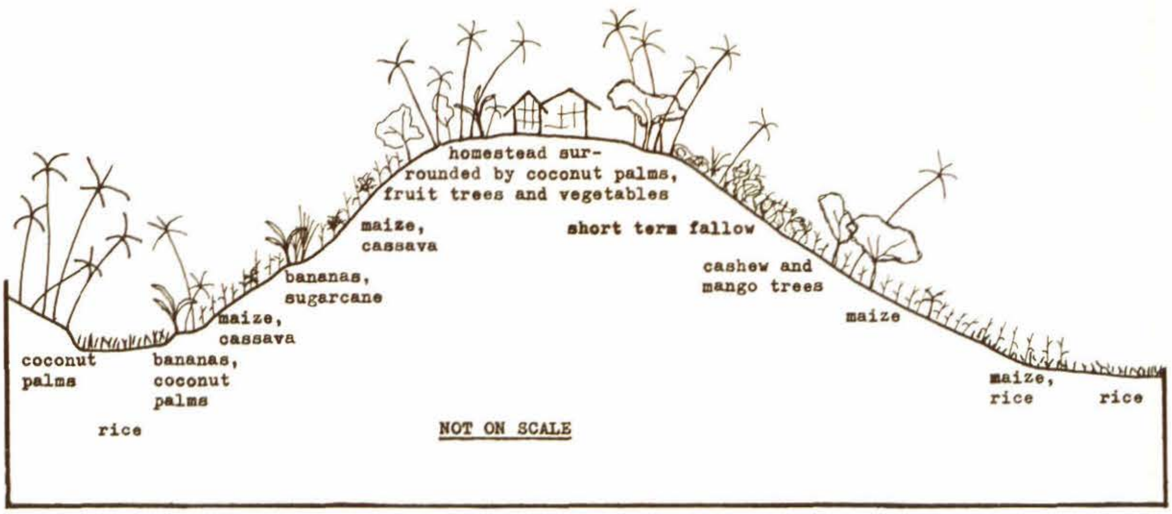


FIGURE 2. A typical toposequence in the Chilulu area.

on slopes. In Kinarani, where rainfall is low, palms can only survive where most water is available: on flat tops and on valley bottoms.

In zone II (Pingilikani) cashew is found mainly on the tops of the hills, as dense plantations, but elsewhere the trees are dispersed between other tree crops, annual crops and fallow land.

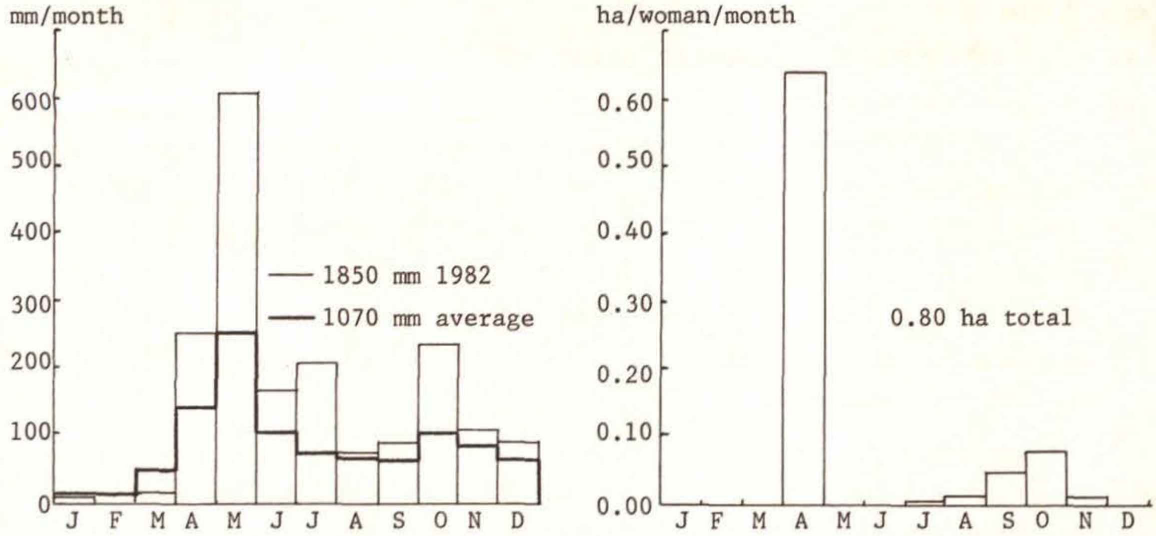
Usually rice is grown in bottom lands and valley bottoms, but in zone IIIB large areas are grown as intercrop between maize, on slopes and on tops. Yields are often low and sometimes zero, but this can also happen with rice in bottom lands and valley bottoms. In wet years rice will do relatively well, in drier years maize. The total yield of both crops appears to be enough to make the combination attractive to farmers. Rice somehow acts as a weed in the maize crop.

Maize is grown anywhere, although under dry conditions more attention seems to be paid to the choice of land, as far as there is any choice. Under coconut palms the yields of maize are low, but the labour input for weeding often also. The coconut palm may benefit from intercropping as maize during the rainy season followed by some weeds in the dry season is less competitive for water and nutrients than the alternative: weeds and notably shrubs all year round (FLOOR, 1981).

Crop patterns

Basically two annual crop patterns can be distinguished, see figure 3. Near the coast where rainfall is unimodal, maize is planted at the start of the long rains. About one month later, during weeding, cassava is interplanted. Plants are spaced far apart and often only in a part of the field cassava is planted. After silking a small part of

Pingilikani and Mbuyuni: n = 9 farms, 20 women



Chilulu and Kinarani: n = 9 farms, 22 women

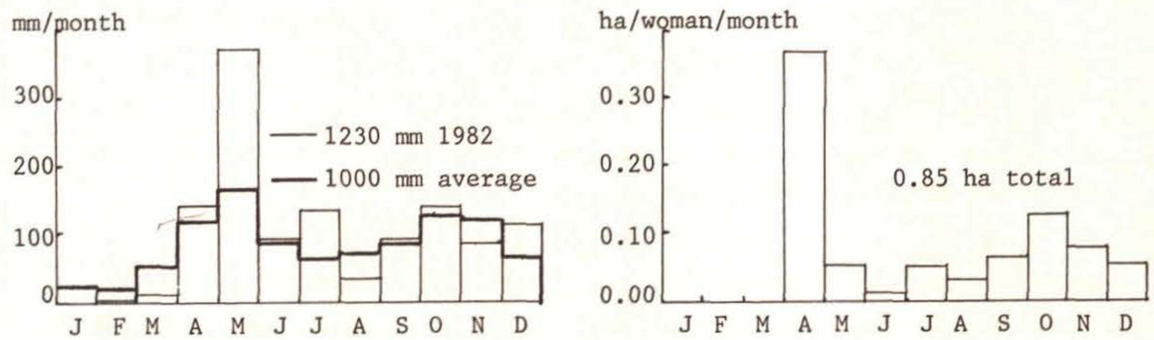


FIGURE 3. Average and 1982 monthly rainfall and average area planted with maize per working woman per month in 1982; rainfall averages are by interpolation from JAETZOLD & SCHMIDT (1983), the 1982 data are averages of 3 rain gauges per village, measured weekly.

the maize is weeded again and that area is interplanted with a relay crop which takes over after the harvest of the maize: cowpea, simsim, bambara, bean, etc. During the short rains little maize and other annual crops are planted.

Further inland, where rainfall is lower and more bimodal, maize is planted in both seasons and relay crops are less important. Cowpeas are often planted together with the maize, spread in low density throughout the maize field.

Crop performance

Table 4 gives a rough impression of the performance of some unfertilized crops, for comparison between soil/rainfall combinations and not for absolute evaluation. For coconut palms e.g. all soil/rainfall combinations are considered marginal or unsuitable if compared with conditions elsewhere in the world. In table 4 the emphasis is on the performance of the crop (yield) in relation to e.g. drainage, water retention and fertility of the soil, rainfall, weeds, pests and diseases. For the farmer factors that not so much affect the crops themselves, but interfere with operations like cultivation and harvesting, may be as much or more important. Some examples that may be encountered: weeding on a sticky soil (UT2c1p after rain), harvesting groundnuts in a dry, hard soil (UT2c1p, USc1), weeding a field full of 'Mwamba nyama' (Rottboellia exaltata; common in zone IIIB) or 'Ndago' (Cyperus spp.; common in Chilulu). Performance indications for Citrus, mango and banana are very tentative, as under marginal conditions these crops may do well on the special spots selected for them, but this says nothing about the land unit as a whole.

In table 5 some quantitative yield data for the major food crop maize are presented. The data show considerable variation between soils and years, but generally yields are very low. Causes of low yields are too much, too little or inadequately distributed rainfall, low soil fertility, weed problems, pests and diseases. The unreliability of the rainfall is one of the factors which discourage the use of fertilizers and pesticides, still very low in the area, and interferes with proper weeding, one of the most crucial factors for maize yields.

Self sufficiency

With the discussed low yields it is not surprising that most farmers are not self sufficient in maize, as shown by figure 4. The deficits clearly follow the annual crop cycle. About 60 % of the time people do not have their own maize. Part of the shortage is solved by eating cassava, but most households buy maize flour in the shop. An average household in the villages of figure 4 consists of 3.1 young children (0-6 years), 2.3 children of primary school age (7-14 years), 0.1 child of secondary school age (15+ years), 3.0 women (15+ years) and 2.0 men (15+ years). Children more than 15 years old and not going to secondary school have been included in men and women. To cover 75 % of the daily energy requirement this household would need 5 kg maize per day or 1800 kg per year (WAAIJENBERG, 1984). Comparison with figure 4 learns that up to 1000 kg of maize has to be bought per year, for prices between 2 and 4 Ksh. per kg. This would not be so serious if there would always be food in the shops, in 1980 there were shortages, and if it would be easy to earn a cash income.

TABLE 4. Crop performance in relation to land: tentative classification based on field trials and observations on occurrence and productivity in farmers' fields in and around Pingilikani, Mbuyuni, Chilulu and Kinarani.

	Land (combination of soil climate, weeds, pests, etc.)					
Crop	UE111	UT2clp	ULcl	UScl	USKf	Remarks
Maize	-	++	++	+	+	Has to be grown everywhere: staple food
Sorghum	+	++	++	+	+	Susceptible to bird attacks; humidity may cause mouldy heads.
Cassava	+	+	++	+	+	Harvest problems on UT2clp; on UScl under dry conditions.
Cowpea	+	++	+	+	+	Yields variable due to insect pests.
Green gram	+	++	+	+	+	Susceptible to mildew and aphids.
Bambara nut	+	++	++	++	-	Wilting disease observed on USKf and UScl: severe damage.
Groundnut	+	++	+	++	+	Harvest problems on UT2clp; on UScl under dry conditions.
Simsim	+	++	+	+	++	
Sunflower	-	++	++	+	++	No bird damage observed; on UT2clp rats may eat planted seeds.
Coconut	-	-	+	++	+	Distribution limited by rainfall, drainage, cracking of soil.
Cashew	+	-	++	+	+	High rainfall (>1000 mm/year) harmful for yield (EIJNATTEN & ABUBAKER, 1983).
Citrus spp.	-	-	++	++	+	Fruit trees are often planted around homesteads (household refuse!) and along valley bottoms where moisture availability and fertility are better than average.
Mango	++	-	++	++	++	
Banana	+	-	++	++	+	
Remarks	very poor, quickly exhausted soil	poor workability and crop germination	good physical properties	hard when dry, often exhausted by long use	rainfall limiting factor	Explanation: - = (very) poor, + = moderate, ++ = good performance.

TABLE 5. Average maize yields of farmers (kg/ha at 13 % moisture content): preliminary analysis of available data based on visual estimations and measurements in and around villages/areas Bahari, Pingilikani, Mbuyuni, Chilulu, Kinarani.

Season	Soil unit (part of units in tables 4 and 5 are subdivisions of the units listed in figure 1a and 1b, see BOXEM, MEESTER & SMALING (1986)						Remarks
	P2E	UE1	UT2clp	ULc1	USc1	USKf	
Long rains 1981	800-1200	800-1200	1700-2300	800-1300	900-1500	600-1000	Well distributed rainfall.
Long and short rains 1982	-	400	700	500	400	300	Excessively heavy rains during long rainy season.
Long rains 1984	-	500	700	700	600	1200	Good rainfall, but many places suffered armyworm damage.

Sources: 1981 figures for P2E from LIESHOUT & STRAVER (1984), others soils from WAAIJENBERG (1982); 1982 figures after WAAIJENBERG (1984); 1984 figures from unpublished data from WAAIJENBERG & VERVOORN). It should be realised that part of the maize fields contained tree crops, notably coconut palms.

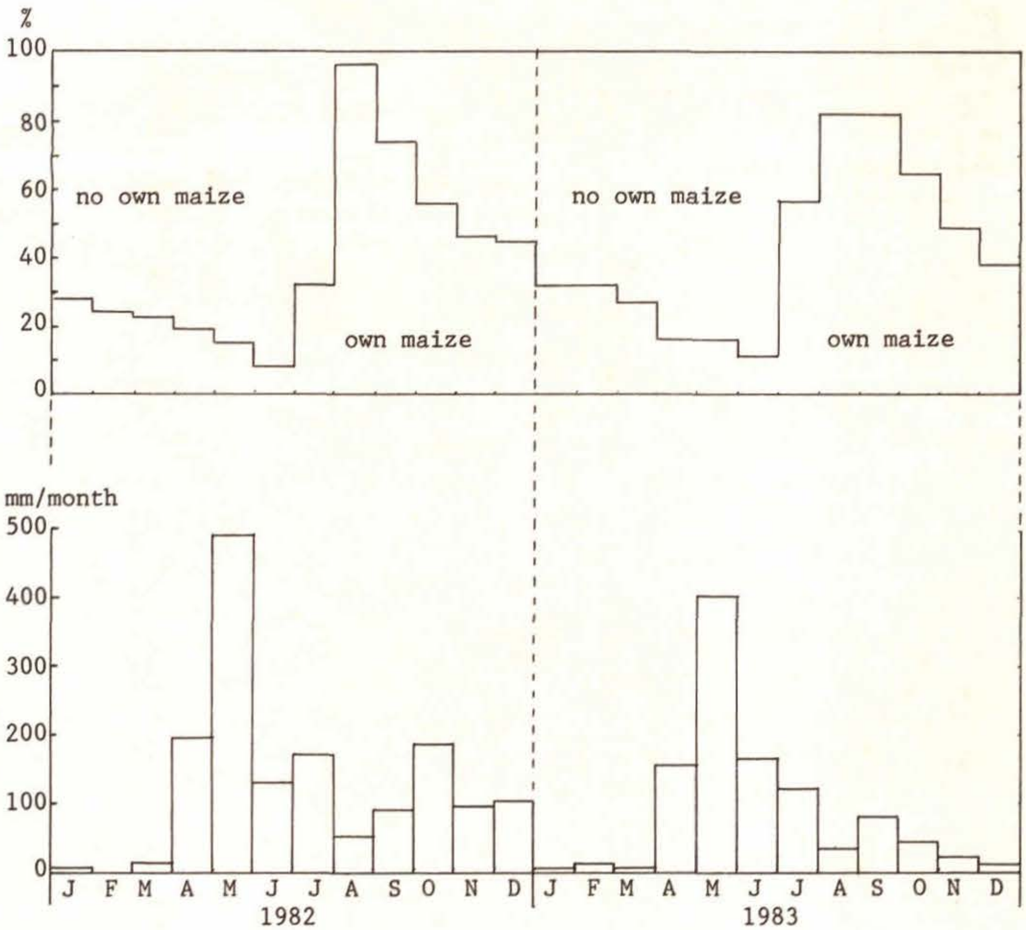


FIGURE 4. Monthly rainfall (A) and percentage of households eating maize from own harvest (B), 1982-1983. Pooled data for Pingilikani, Mbuyuni, Chilulu and Kinarani: n = 4 * (8-10) = 37-39 households interviewed about food situation; rainfall recorded weekly in 2-3 rain gauges per village.

<u>Farm cash income</u>

Usually the production of cash crops and livestock is too low to cover expenses for food, housing, clothes and schooling:

- o Hectarages (<0.3 ha), yields (0-400 kg/ha) and prices (c. Ksh. 4/=/kg) of simsim are too low to contribute much to the income of the households who grow it.

- o Farmers with large numbers of fruit trees or bananas are a small minority. The production is very sensitive to the weather, often limited to a short period of the year, and varies strongly from year to year. In productive years prices tend to be low.

- o Cashewnut yields are low, about 4 kg/tree or 450 kg/ha (EIJNATTEN & ABUBAKER, 1983), confined to a short period of the year, and very variable. Poor yields in past years and a price drop in January 1983 caused many farmers to cut their trees to make place for

PHOTOGRAPH 9. Most shops in Kilifi District sell maize meal, an illustration of the shortcoming of local food production.

maize. The district government prohibited this practice and so tries to preserve a stock of already too old and low productive cashew trees.

- o Coconut palms are the farmers' favourites: they always yield at least something. The annual production is about 10 to 40 nuts per palm (EIJNATTEN, GURNAH & NIEDERSTUCKLE, 1977; FLOOR, 1981, WASSINK, 1983). The income from copra is about 30 nuts/tree * 1 kg copra/7 nuts * Ksh. 5/=/kg copra = Ksh. 21/= per palm per year. The sale of fresh nuts (nazi, madafu) may give somewhat higher returns, but also more problems with marketing. Most nuts have to be sold in Mombasa, where prices are highest during the month of Ramadhan. Apart from nuts a palm produces about 10 leaves per year, of which about 15 makuti can be made, sold at Ksh. 0/50 each. Even then the total annual income per palm is no more than Ksh. 30/=. Part of the production is needed for the household. Therefore one needs more than the average number of palms to cover also household cash needs. Tapping toddy may yield 10 times more, but this lucrative enterprise can only be carried out illegally.

- o Only few farmers have livestock in significant numbers and livestock productivity generally is low.

6 LIVESTOCK SYSTEMS

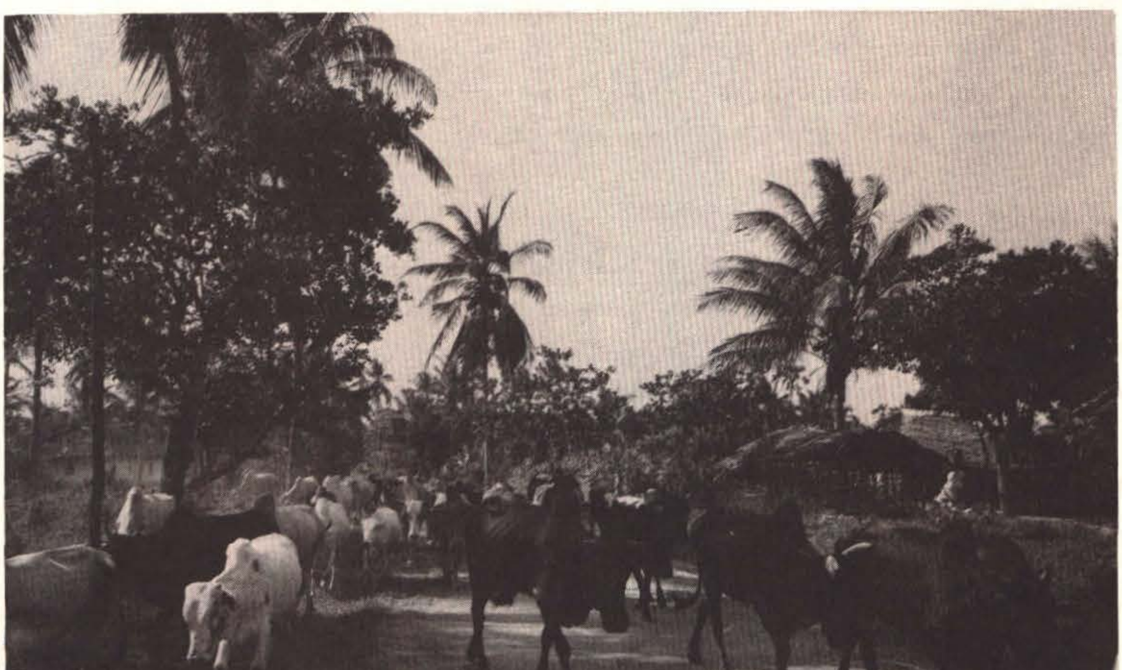
Some quantitative data on livestock are presented in table 1. For more quantitative and qualitative information one is referred to BARTMAN (1984). Points to be touched on in this chapter are the purposes of keeping livestock, systems for keeping them, pooling of herds, and consumption and marketing of livestock products.

Purposes

Livestock is kept to earn an income and to act as saving/security fund. For large commercial farms/ranches the first reason is the main if not the only one. For small household farms the second may be as much or more important. People keep livestock to sell them when money is urgently needed for schooling, funerals, dowry, etc., or to slaughter them at funerals.

Large farms

Kilifi Plantations Ltd. and Vipingo Estate Ltd. have large dairy herds, the latter also a herd of beef cattle. The herds consist of graded or cross-bred animals: Brown Swiss, Ayrshire, Guernsey, Sahiwal for milk, and Boran for beef. The animals graze in pastures of native grasses and receive supplementary food, mainly sisal waste. Artificial



PHOTOGRAPH 10. A herd of Small East African Zebu cattle; only few farmers own so much wealth.

insemination (A.I.) or improved bulls are used. In spite of better than average management the milk production per animal is still low, less than 10 litres/day. Vipingo Estate Ltd. sells the milk and meat to the local market. Kilifi Plantations Ltd., which has a milk pasteurizing and packaging plant, sells part of the milk on the local market and part to the Kenya Cooperative Creameries (KCC).

Extensive grazing

Extensive grazing of herds of cattle and/or goats and sheep is common in the dry areas of Kilifi District. The animals wander around with one or more herdsmen or -women, grazing and browsing on fallow land and more natural vegetations. Most common breeds are the Small East African Zebu and the East African Goat. Fodder and water are often scarce. The animals receive little veterinary care apart from (ir)regular dipping against tick borne diseases. The productivity of the animals is low and losses are high. In the western part of Kilifi mapsheet and outside of it there are several group ranches. Their condition can best be described as 'dormant' (TARDA, 1983). Many farmers do not even realise that they are living in a group ranch. Farther west there are some large commercial ranches, a.o. Giriama Ranch and Kulalu Ranch with Boran cattle.

Small livestock

Many households have some goats or sheep. These graze on fallow land, road sides, in tree crop plantations, herded by children or tied with long ropes. Chicken and duck walk around the homesteads. They live on household waste and whatever else they can find.

Small-scale dairy

A few small farms, most in the coastal strip or Kaloleni area, have dairy cattle. Most animals are cross breeds between the Small East African Zebu and Friesian, Jersey or one of the other above mentioned dairy breeds. They are kept in pastures or stall fed with Napier grass under the in 1981 introduced zero grazing system of the Dairy Development Programme of the Ministry of Agriculture and Livestock Development. The cattle are housed, fed and watered well and receive adequate veterinary attention. The average milk production per cow is up to 6-8 litres/day. For more information on zero grazing systems in Kenya one is referred to STOTZ (1977, 1983a,b).

Pooling of herds

An important feature of cattle and to a lesser degree of sheep and goat keeping is pooling of animals: one herd may consist of animals of several owners and one owner may have his animals distributed over several herds, sometimes far away. There are several reasons for this practice:

- o Livestock may be kept for security, but their own lives from all evidence appear to be very insecure, threathened by hunger, thirst and diseases. By spreading the animals over several herds the risk of loosing all of them at once is reduced.

- o The owner may live in an area with little place for livestock, e.g. the densely populated palm belt.

- o One may have too few or too many animals to herd them himself.

- o People do not like to look very prosperous, as this will cause many claims for support, jealousy and witchcraft.

Consumption and marketing
Many animals are slaughtered at special occasions like funerals, weddings and important visits. As a result people get meat intermittently, but this irregularity is reduced as people are used to visit many of such occasions. Further animals are sold to local butchers and at auctions at Mariakani and Bamba. Milk can profitably be sold to neighbours, in villages and towns. Demands and prices are high, up to Ksh. 4/= per litre, about double the price the KCC factory in Mariakani pays. Hides and skins are sold to local traders; their quality in general is poor.

7 INFRASTRUCTURE AND SERVICES

The government plays a key role in the infrastructure and services in the Kilifi area: many services are rendered directly by ministries, others by parastatals or by organisations in which the government has a major influence, e.g. the Farmers' Cooperative Societies.

Research

Most agricultural research in Coast Province is carried out by the Coast Agricultural Research Station (CARS) at Mtwapa, established in 1958, with substations at Matuga (Kwale District), Kimala (Taita District), Msabaha (Kilifi District), Ngao (Tana River District) and Mpeketoni (Lamu District). Most of these stations lie near the coast, where rainfall is relatively high. Therefore research findings often may not be relevant for the drier hinterland. The Animal Production Research Station at Mariakani, with a substation at Bamba, deals with livestock, pasture and rangeland research. Further research is carried out at the Magarini Land Settlement Scheme.
Much useful research has been done, but overall research has failed to solve the present incapability of agriculture to support the population, as voiced by BOOKER (1982): 'with the exception of small holder dairying in the coastal strip the preparation mission was unable to identify or recommend viable packages to improve the productivity of rangeland production' and 'the potential for on-farm development throughout the Districts is severely constrained by the lack of viable technical packages based on applied research undertaken in the project area'. So a critical reorientation of research appears essential. For an overview of past research at CARS one is referred to MAJISU *et al*. (1980), and for one of the views on the links between research and extension in Coast Province to van EIJNATTEN (1983).

Extension

Agricultural extension activities are carried out by the Ministry of Agriculture and Livestock Development, and in the settlement schemes also by the Department of Settlement. They find place by 'barazas' (public meetings), individual farm visits, courses at the Mtwapa Farmers' Training Centre (FTC), and since 1984 particularly through the Training and Visits (T&V) programme. The Department of Livestock Development further provides A.I. and veterinary services, of which the operating of cattle dips is the most prominent, and vigorously promotes the zero grazing system. Tree crop nurseries, the major one near the Mtwapa Research Station, provide farmers with young trees, varying from coconut palm to *Leucaena*. Many nurseries are inaccessible for farmers (e.g. by being far from roads) and the quality of the

planting material is often worse than farmers' materials. See a.o. van EIJNATTEN (1979) and van EIJNATTEN & KARISA (1980) for a description of the past situation and proposals for improvement.
Bottlenecks for successfull extension are:

- The poor accessibility of many farmers. Frontline extension staff hardly have any transport facilities and have to concentrate on farmers near roads and administrative centres. The T&V programme experienced that farmers frequently did not turn up at demonstrations and meetings due to other obligations, often funerals.

- Too few and lowly qualified frontline extension staff. The newly constructed Agricultural Training Institute in Kilifi may be a solution for this problem.

- Bias on extension by men and for men. Most extension workers are men who direct themselves to men, in a situation where women do most farm work. Female extension workers occupy themselves with home economics and instruct women, the real farmers, about nutrition, child care, sewing and home gardening, instead of crop and livestock production as well.

- The largest bottleneck is that there is no message, no economically viable technical packages, as mentioned under research. Therefore the emphasis is on line planting, use of fertilizer and crop protection chemicals, proper and timely weeding, deeper cultivation, etc. Many of these advises farmers knew already from experience, others cannot be followed due to lack of cash, or should not be followed because they are better from a technical viewpoint only, and not from an economical one. This may explain why many farmers show little interest in extension.

Credit

Agricultural credit could be obtained via the Integrated Agricultural Development Program (IADP) (NAUTA, POSTMA & WINKELHORST, 1981; VERBEEK, 1982), and can be obtained from the Agricultural Finance Cooperation (AFC). Problems are lack of security (e.g. land with a title deed) and again lack of safe and profitable agricultural enterprises in which to invest the money.

Farm inputs

The major supplier of farm inputs like crop seeds, tools, fertilizers, crop and livestock protection chemicals was the Kenya Farmers'

Association (KFA), recently taken over by the Kenya Grain Growers Cooperative Union (KGGCU). Their effectivity is limited by lack of sale outlets (Mombasa only), irregular supply, and personnel with insufficient knowledge for advising farmers on what to buy and what not to buy. The quality of maize seeds improved considerably since the introduction of cold storage in the KFA godown. Pangas and jembes can be bought in shops throughout the Kilifi area. Most jembes are made by local blacksmiths, and are good for weeding, but unsuitable for deep cultivation.

Marketing

Since 1965 Farmers' Cooperative Societies, associated in the Kilifi District Cooperative Union (KDCU), are the main outlet for farm produce. They have a legal monopoly for the marketing of copra, cashewnuts, simsim, cotton and castor seeds. The KDCU has shares in the Kilifi Oil Mill, which processes copra into oil, and in the Kilifi Cashewnut Ltd. factory which started operating in 1975. The factory has a capacity to roast, shell, grade and sell about 15000 tons of raw nuts per year, but has been working under its capacity for most of the years (OLTREMARE, 1983). The lack of competition did not stimulate the efficiency in the KDCU: farmers complain of low prices and late payments (KORTRAM, 1983). In 1984 the smuggling of copra to Mombasa, where oil-millers paid better prices on delivery, forced the KDCU to increase the price of copra! Milk can be delivered to the KCC factory in Mariakani, but farmers prefer to sell their milk to neighbours and others who pay better prices. Moreover the factory has a bad reputation due to non-payment in the past.

Tapioca Ltd. in Mazeras provides a market for cassava tubers. In 1984 the farmers' price was about Ksh. 0/60 per kg fresh tuber. The Tapioca Ltd. produces about 50-60 tons starch per month for the production of glue. For fruits, vegetables and other farm produce there is no organised market. Produce is bought by traders or brought to Malindi, Kilifi or Mombasa by the farmers themselves. Decennia of talks about the establishment of a fruit processing factory so far have yielded no results.

Transport

The Kilifi area has a rather dense and well functioning network of bus connections. Most buses belong to private companies. All buses go to or come from Mombasa; Kilifi and Kaloleni are major, Mazeras, Mariakani and Bamba are minor transfer bus stages. The buses transport farm products to the cooperative societies or their agents, and to Malindi, Kilifi and Mombasa. Daily they ferry thousands of off-farm workers between the rural areas and the coastal towns.

TABLE A1. Some major Land Utilization Types (LUT's) of small farms in the Kilifi area (mapsheet 198), Kenya, 1.

Names	Maize, Mahindi (*Zea mays*)	Sorghum, Mtama (*Sorghum bicolor*)	Rice, Mpunga, Mchele (*Oryza sativa*)
Products/ uses/ marketing	Grain for home consumption as "ugali" (thick porridge).	Grain for home consumption as "uji" (thin porridge) and for production of alcoholic drinks; promoted with little success as staple food crop in dry areas.	Grain for home consumption and local market.
Cultivars	Modern: Coast Composite, Pioneer Hybrid (high requirements, often not available), Katumani B Composite (rather poor performance). Local: Mingawa, Mdzihana, Mugao, etc., better adapted to unfavourable conditions, also perform well under higher input levels.	Modern: a.o. Serena (medium height, compact heads, brown, bitter seeds), 2KX17 (dwarf, compact heads, white seeds), NES7360 (medium height, compact heads, white seeds). Local: Muhama mbomu (tall, loose heads, white seeds), grown since at least mid 19th century.	"Modern": Basmati, Sindano. "Local": Kathele, Ambari, Pishori, Mchetseka, numerous others. In much of the area rice is not a very old crop.
Seasons (growing & production)	Most planted in April, just after start of long rains, see figure 4.3.	Like maize, the crop may be ratooned. Muhama mbomu may take up to 6 months to maturity.	Seeds planted just before start of long rains (March, April), harvest from August to October.
Labour intensity	119 days per ha, of which 22 % for land preparation, 17 % for planting, 33 % for weeding (and thinning) and 26 % for harvesting (KOECH, 1983).	Comparable with maize; young crop more sensitive to weeds; harvest and processing more labour intensive.	High labour input for planting, weeding and harvest; at least double of that for maize.
Capital intensity	Per ha: hired tractor ploughing Ksh. 620/=; hired oxen ploughing Ksh. 375/=; 2 x 4.25 kg Dipterex or Ksh. 153/=; 15 kg Coast Composite seed or Ksh. 112/50; 20 kg P (as TSP) and 50 kg N (as CAN) or Ksh. 925/=. Casual labour Ksh. 10/= per day or Ksh. 1/= per 10 m² cultivating.	See under maize.	Use of fertilizer, insecticide, etc. is rare. Seeds may be bought.
Management & Technology	Most farmers cultivate by hand, use no fertilizer, insecticide, bought seeds. Some use varying combinations of the above inputs.	Local cultivars mostly grown without fertilizer, insecticides, etc. Modern cultivars: see maize.	No levelling; fields often separated by small bunds, grown in pure stand on valley bottoms or as intercrop in maize, see par. 4.5.
Plant density/ spacing	Most farmers 2-4 plants/stand and 20-30000 plants/ha; recommended 1-2 plants/stand and 37000 plants/ha.	For short cultivars 40-80000 plants/ha recommended; Muhama mbomu usually 15-30000 plants/ha.	About 10 stands/m² (most 5-15) with up to 10 plantsØstand.
Scale	Most farms have 1-3 ha in 1-5 fields.	All fields observed (far) less than 0.5 ha.	Most farmers have less than 0.25 ha on valleybottoms and/or up to 1 ha on slopes and tops as intercrop in maize.
Pests & diseases	Stalk borer (*Chilo* spp. and some *Sesamia calamistes*), occasionally armyworm (*Spodoptera exempta*), on USc1 some termite damage observed. Locally there may be nematode damage. Streak virus. See references.	Birds, stalk borer (see under maize). Mouldy heads due to high humidity.	Stalk borers and leaf diseases have been observed, but are unimportant compared to weed, moisture and fertility problems.
Yields	See tables 4.6 and 4.7.	Comparable with those of maize, in dry years maybe better.	Valley bottoms: 500-1500 kg paddy/ha, with fertilizers up to 2500 kg paddy/ha. As intercrop 0-1000 kg paddy/ha. Very large differences between years.
Prices	National Cereals and Produce Board (NCPB) pays Ksh. 2/= per kg; in shops maize is sold for Ksh. 2/75 per kg and maize flour for Ksh. 4/10 per kg. Very few farmers produce surplusses.	NCPB pays Ksh. 1/= per kg.	
Economics	Absolute and relative costs and returns vary between soils and years. MBINGA (1983): variable costs Ksh. 1652/=, gross returns Ksh. 4500/=, net returns Ksh 2848/= per ha for Coast Composite with fertilizer and insecticide.		
Remarks & References	MAJISU *et al.* (1980), MATHEZ (1972), RUBUI (1983), SCHELTES (1978), WAAIJENBERG (1982, 1984), WARUI & KURIA (1983).	MAY, SIVAKUMAR & VIRMANI (1981), NDFRS (1981, 1982), WANG'ATI *et al.* (1982).	GENT (1983), MoA (1981), MAKUMI (1982), TAMURA (1980, 1981).

TABLE A1. Some major Land Utilization Types (LUT's) of/for small farms in the Kilifi area (mapsheet 198), Kenya, 2.

Names	Cassava, Muhogo (Manihot esculenta)	Cowpea, Mkunde (Vigna unguiculata)	Simsim, Ufuta (Sesamum indicum)
Products/ uses/ marketing	Tubers for home consumption, boiled roasted or fried; leaves as potherb. Tubers sold at local markets and to Tapioca Ltd., Mazeras.	Seeds and leaves for home consumption as "mboga", relish eaten with "ugali". Seeds sold locally.	Cash crop: seeds sold to Farmers' Cooperative Societies.
Cultivars	Local: Kabandameno (sweet) by far most common. Modern: Kaleso (46106/27) and 5543/156 are recommended with little succes. Kaleso is popular in Kwale District and shows field resistance against CMV.	Karingongo, Mnyenze (Mbomu), Mwandatu, mainly for seeds. Charika is popular for leaf production. Many others. Most creeping to semi-erect.	Farmers don't distinguish cultivars; all plants have dark brown seeds.
Seasons (growing & production)	Most cassava is interplanted in maize fields during first weeding (April/ May) and harvested between December and March.	Planted as relay crop in long rains maize, in June or July, or planted as intercrop in both seasons.	Planted as relay crop in long rains maize, in June or July. and harvested in November or December.
Labour intensity	Low, apart from harvesting.	Planting, and especially harvesting and processing are labour intensive.	Planting, harvesting and threshing are labour intensive.
Capital intensity	Low.	Hardly any capital input.	Very low.
Management & technology	Crop receives little attention: no pest and disease control, hardly any selection of plant material.	(Knowledge of) cultivars appear to be disappearing.	Suboptimal plant arrangement and poor weeding.
Plant density/ spacing	Most farms 1000-3000 plants/ha; in pure stand 10000 plants/ha.	As relay crop: 15-35000 stands/ha, 2-6 plants/stand. As intercrop: usually no more than 5000 stands/ha.	About 30000 stands/ha and about 9 plants/stand.
Scale	Most farmers about 0.5 ha with 1000-3000 plants/ha.	Most farmers less than 0.25 ha.	Ususally less tha 0.25 ha per farmer.
Pests & diseases	Cassava Mosaic Virus (CMV) spread by white fly; red spider mite.	Pod borer (Maruca testulalis), Legume bud thrips (NGANGA, 1980), unidentified leaf eating beetle.	Webworm (Antigastra cataunalis) Some leaf spot.
Yields	1-2 kg of fresh tubers per plant or (far) less than 10000 kg per ha.	Relay crop 100-500 kg/ha, varying between 0 and more than 1500 kg/ha.	0-400 kg/ha.
Prices	Tapioca Ltd. pays Ksh. 0/60 per kg fresh tubers; at local markets fresh tubers fetch Ksh. 1-3/= per kg.	Farmer may receive Ksh. 3-6/= per kg.	About Ksh. 5/= per kg.
Economics	KOECH (1983): costs Ksh. 3032/=, returns Ksh. 10200/= (yield 17 tons tubers), gross margin Ksh. 7168/= per ha grown according to CARS recommendations. MBINGA (1983): costs Ksh. 3520/=, returns Ksh. 9000/= (yield 16 tons tubers), gross margin Ksh. 5480/= per ha, without use fertilizer and herbicide.		Risky and not very profitable crop.
Remarks & references	GITHUNGURI (1983), MAGARINI (1983), OMONDI (1979).	CHESOLI & WARUI (1980), LEEUWEN (1984), NGANG'A (1980).	W'OPINDI (1980).

TABLE A1 Some major Land Utilization Types (LUT's) of/for small farms in the Kilifi area (mapsheet 198), Kenya, 3.

Names	Cotton, Pamba (Gossypium hirsutum)	Cocos, Mnazi (Cocos nucifera)	Cashew, Mkorosho (Anacardium occidentale)
Products/ uses/ marketing	Cash crop: seeds sold via Farmers' Cooperative Societies to Cotton Seed and Lint Marketing board.	For home consumption (fresh nuts, cooking oil, palmwine, makuti) and for sale (fresh nuts, copra, palmwine, makuti).	Cash crop sold via Farmers' Cooperative Societies and NCPB to Kenya Cashewnuts Ltd., Kilifi. Most of production is exported.
Cultivars	UK/59/240 and IL62; the first is being replaced by BPA/175.	Most palms belong to group "East African tall coconut palm", less than 1 % of all palms are dwarves.	No cultivars distinguished; part of stock is rather old and should be replaced by genetically better material.
Seasons (growing & production)	April to November.	Optimal periods for harvesting nuts for copra and for making amkuti are the dry seasons.	Harvest from October to February.
Labour intensity	High: 165 days/ha, of which 21 % for land preparation, 16 % for planting, 2 % for spraying, 26 % for harvesting, 9 % for grading and packing (KOECH, 1983).	Labour input for husbandry low: undergrowth is grazed and often palms are intercropped with maize, banana, Citrus spp.	Low: young trees are planted in maize fields, before harvest the undergrowth may be cleared, nuts are collected, dried and sold, often lower branches are pruned for easy collection of nuts and intercropping with maize.
Capital intensity	If recommendations are followed: Ksh. 550/= for ploughing and harrowing, Ksh. 475/= for fertilizer, Ksh. 528/= for insecticide, Ksh. 15/= for hired sprayer, per ha KOECH, 1983).	Restricted to seedlings (sometimes bought), knife for harvesting nuts or tapping palmwine, iron for dehusking, panga for cutting nuts, "spoon" for removing copra.	Very low.
Management & technology	Most farmers can't afford to follow recommendations, so that both costs and returns are lower.	Palms receive little attention; some farmers apply mulch, clear undergrowth yearly and/or apply sand in Rhino beetle holes; unproductive palms are seldomly cut.	Low level.
Plant density/ spacing	Recommendations are more or less followed: 22000 plants/ha by planting 90 x 45 cm, 4-6 seeds per stand, later thinned to 2 plants per stand.	About 80-100 palms/ha; often shambas contain only few very widely spaced palms.	6 x 6 to 12 x 12 m^2 are recommended, but often spacings are much wider.
Scale	Most farmers less than 0.2 ha.	Most farmers less than 100 palms, few have several hundreds.	Most farmers have less than 100 trees, few have several hundreds.
Pests & diseases	Numerous, a.o. cutworms, grass hoppers, crickets, leaf suckers, fruit suckers, boll worms; see MWANGI (1980) and PURY (1968).	Rhinoceros beetle (Oryctes monoceros), Coreid bug (Pseudotheraptus wayi). Bole rot (Marasmiellus cocophilus).	Cashew Helopeltis (Helopeltis anacardii) and Coreid bug (Pseudotheraptus wayi) cause dieback. Under wet conditions blossom rot is a problem. See a.o. WHEATLEY (1961) and EIJNATTEN (1979).
Yields	Under current management 500 kg AR and 150 kg BR per ha; under recommended management 1000 kg AR per ha (KOECH, 1983).	About 30 nuts or 4.6 kg copra per palm per year. Up to 20 makuti per palm per year.	About 4.5 kg/tree or 450 kg/ha, both per year, under current management. By planting clonal material in hedgerows yields as high as 4000 kg/ha can be reached (EIJNATTEN & ABUBAKER, 1983).
Prices	AR Ksh. 3/80 per kg and BR Ksh. 1/80 per kg (KOECH, 1983); Ksh. 4/80 in 1984 (SAUTI YA PWANI 45, June 1984).	Copra Ksh. 5/= per kg; nuts Ksh. 0/60 to Ksh. 2/= per nut. Makuti Ksh. 0/40-0/60 each.	FAQ Ksh. 3/50 per kg and UQ Ksh. 2/75 per kg in 1983.
Economics	Present management: costs Ksh. 1013/= of which Ksh. 434/= to Ksh. 834/= can be household labour, returns Ksh. 2155/=, gross margin Ksh. 295/=. Recommended management: costs Ksh. 2844/= of which Ksh. 1244/= to Ksh. 1644/= can be family labour, returns Ksh. 3800/=, gross margin Ksh. 956/= (KOECH, 1983).	See EIJNATTEN, GURNAH & NIEDERSTUCKE (1977); note that prices have changed considerably and that his sample consisted of larger than average farmers.	Under current management gross margin is about Ksh. 550/= per ha per year. By planting clonal material in hedgerows and by producing charcoal gross margins as high as Ksh. 6800/= per ha per year are possible (EIJNATTEN, 1983?; EIJNATTEN & ABUBAKER, 1983).
Remarks & references	Much of extra costs of recommended management go to agro-chemical industries. KOECH (1983), MWANGI (1980), MUGO (1982).	BROM (1982), EIJNATTEN (a.o. 1979), FLOOR (1981), OHLER (1984), SPRENKELS (1984), WASSINK (1983).	The EIJNATTEN & ABUBAKER system still has to be tested under (farmers') field conditions. OHLER (1979), OLTREMARE (1982), WARUI (1979), WASSINK (1983).

8 LITERATURE

ACLAND, J.D., 1971. East African crops; an introduction to the production of field and plantation crops in Kenya, Tanzania and Uganda. FAO/Longman, London. 252 pp.

AIC, 1980. Field crops technical handbook. Agricultural Information Centre, Ministry of Agriculture and Livestock Development, Nairobi. 183 pp.

AIC, n.d. Fruit and vegetable technical handbook. Agricultural Information Centre, Ministry of Agriculture and Livestock Development, Nairobi. 81 pp.

AIC, n.d. Livestock development technical handbook. Agricultural Information Centre, Ministry of Agriculture and Livestock Development, Nairobi. 191 pp.

ALLEN, J. de V., 1983. Shungwaya, the Mijikenda, and the traditions. Review of SPEAR (1982). International Journal of African Historical Studies 16, 3 (1983), 455-484; reply by SPEAR p. 484, response by ALLEN p. 485.

ANONYMOUS, 1981. Instructions for rice farmers 1981. Ministry of Agriculture and Livestock Development, Kilifi. 2 pp.

BARTMAN, C., 1984. Livestock and small scale farmers a description of the situation around Kilifi. TPIP, Kilifi, Kenya & Agricultural University, Wageningen, The Netherlands. 75 pp. Unpublished.

BIE, C.A.J.M. de, 1982. A fertility research of the Kilifi soils, Kenya; NPK trials with maize and sorghum on soils of six formations in the Coast Province of Kenya. 76 + XVIII pp. TPIP, Kilifi, Kenya & Agricultural University, Wageningen, The Netherlands. Unpublished.

BOOKER, 1982. Kwale Kilifi Integrated Development Project; Supplementary report project costs. Booker Agriculture International Ltd., London. 10 + III pp.

BRANTLEY, C., 1981. The Giriama and colonial resistance in Kenya, 1800-1920. University of California Press, Berkeley, etc. 196 pp.

BROM, A., 1981. Soil-coconut relationships in the Kilifi area. Coconut growing in the Kilifi area, chemical and physical aspects, with special emphasis on the Kaloleni and coastal area. TPIP, Kilifi, Kenya & Agricultural University, Wageningen, The Netherlands. 80 + L pp.

CARS, 1984. Newsletter 29, August 1984. Supplementary newsletter with crop recommendations for 1984 Mombasa National Show. See also Visitors Guide, Annual Reports, Communications, and other Newsletters for information on current research in Coast Province.

CBS, 1981. Kenya population census, 1979. Volume I. Central Bureau of Statistics, Ministry of Economic Planning and Development, Nairobi. 326 pp.

CBS, 1981. Compendium to volume I, 1979 population census. Central Bureau of Statistics, Ministry of Economic Planning and Development, Nairobi. 24 pp.

CHAMPION, 1914/67. The Agiriama of Kenya. Written around 1914. Edited by J. Middleton and published in 1967 by the Royal Anthropological Institute of Great Britain and Ireland, London. 56 pp. + map.

COOPER, F., 1981. From slaves to squatters; plantation labour and agriculture in Zanzibar and coastal Kenya, 1890-1925. Kenya Literature Bureau, Nairobi. 328 pp.

EIJNATTEN, C.L.M. van, 1979. Summary of information on coconuts in Coast Province and proposals for future work. Communication 4, CARS, Mtwapa. 31 pp.

EIJNATTEN, C.L.M. van, 1979. Notes on tree crop nursery activities in Coast Province. Communication 8, CARS, Mtwapa. 14 pp.

EIJNATTEN, C.L.M. van, 1983? Gross margins of cashew cultivation in Kenya. Indian Cashew Journal 15 (3), 7-11.

EIJNATTEN, C.L.M. van, 1983. Agricultural research and extension in support of farmers' development, Coast Province, Kenya. Agricultural University, Wageningen, The Netherlands. 59 pp.

EIJNATTEN, C.L.M. van & A.S. ABUBAKER, 1983. New cultivation techniques for cashew (Anacardium occidentale L.). Neth. J. agric. Sci. 31 (1983), 13-26.

EIJNATTEN, C.L.M. van, GURNAH, A.M. & K.H. NIEDERSTUCKE, 1977. A study of coconuts in Kenya's coastal strip. Technical Communication 19, Department of Crop Science, University of Nairobi. 58 pp.

EIJNATTEN, C.L.M. van & S.J. Karisa, 1980. Proposal for the development of nursery activities on perennial crops in Coast Province and its cost of implementation. Communication 9, CARS, Mtwapa. 38 pp.

FLOOR, J., 1981. Coconuts around Kaloleni (Kilifi District, Kenya). Study on some aspects of coconut growing in the area of Kaloleni with special references to plant characteristics and nutrient status in relation to soil type and type of intercrop and undergrowth. Preliminary report 2 (Kilifi series), TPIP, Kilifi, Kenya & Agricultural University, Wageningen, The Netherlands. 52 + VI pp.

FREEMAN-GRENVILLE, G.S.P., 1975. The East African Coast. Select documents from the first to the earlier nineteenth century. Rex Collins, London. 314 pp.

GENT, P.A.M. van, 1983. Upland rice cultivation in the Kilifi area, Kenya. A. Soils and yields; B. Soil physical characteristics. Volume I, 64 pp.; Volume II, 46 pp. appendices. TPIP, Kilifi, Kenya & Agricultural University, Wageningen, The Netherlands. Unpublished.

GERLACH, L.P., 1965. Nutrition in socio-cultural matrix; food getting and using along the East African coast. pp. 245-268 in BROKENSHA, D. (ed.), 1965. Ecology and economic development in tropical Africa. Institute of International Studies, Berkeley. 268 pp.

GITHUNGURI, C.M., 1983. Revised cassava standard recommendations. Edited by A.M. Rubui. Msabaha (substation of CARS). 5 pp. mimeographed.

GOLDSON, J.R., 1970. Coast agriculture and its future in Kenya. World crops 22 (5), 330-331.

GURNAH, A.M., 1973. Agricultural terms in Kiswahili. Part I: crop science. Msamiati wa elimu ya ukulimu. Sehemu I: elimu ya mapando. Technical Communication 9, Department of Crop Science, University of Nairobi. 19 pp.

HEMPENIUS, E.J., 1982. Tobacco growing in the Kilifi area. TPIP, Kaloleni, Kenya & Agricultural University, Wageningen, The Netherlands. 10 + IV pp. Unpublished.

HEMPENIUS, E.J., 1983. Fruits among the Giriama and Chonyi (Kilifi

District, Kenya). TPIP, Kaloleni, Kenya & Agricultural University, Wageningen, The Netherlands. 48 + VII pp. Unpublished.

HENDRICKX, H., 1981. The marketing of coconuts and copra, Kenya. Viability of the proposed oil-mill of the Kilifi District Co-operative Union. Marketing Research and Development Section, Ministry of Co-operative development & FAO Marketing Development Project, Nairobi. 11 pp. + 1 pp. tables. Mimeographed.

HEYER, J., MAITHA, J.K. & W.M. SENGA, 1976. Agricultural development in Kenya; an economic assessment. Oxford University Press, Nairobi. 327 pp.

IVENS, G.W., 1967. East African weeds and their control. Oxford University Press, Nairobi, etc. 1982 corrected reprint. XIV + 250 pp.

JAETZOLD, R. & H. KUTSCH, 1982. Agro-ecological zones of the tropics with a sample from Kenya. Der Tropenlandwirt, Zeitschrift für die Landwirtschaft in den Tropen und Subtropen 83 (1982), 15-34.

JAETZOLD, R. & H. SCHMIDT, 1983. Farm management handbook of Kenya. Volume II: Natural conditions and farm management information. Volume IIC: East Kenya (Eastern and Coast Provinces). Farm management branch, Ministry of Agriculture, Nairobi.

JONG, C. de, 1977. Land utilization types of the medium potential areas of low altitude. The Kwale area. Misc. Soil Paper 4, Kenya Soil Survey, Nairobi. 82 pp.

KHAEMBA, B.M., 1984. Recognising simsim pests. Kenya Farmer, January 1984, 20.

KHAEMBA, M.L., 1982. The role of women groups in agriculture and home economics. Newsletter 21, pp. 11-12, CARS, Mtwapa.

KHAEMBA, M.L., 1982. Obstacles that make women agriculturally less productive in Coast Province. Newsletter 22, pp. 4-5, CARS, Mtwapa.

KILIFI DISTRICT, 1984. Kilifi District development plan 1984/1988. Rural Planning Division, Ministry of Finance and Planning, Nairobi. 56 + XX pp.

KOECH, L.C.A., 1983. Economics of cassava production, literature review. pp. 21-26 _in_ MAGARINI (1983).

KOECH, L.C.A., 1983. Identification of farmer target groups in Kilifi District. Communication 24, CARS, Mtwapa. 13 pp.
KOECH, L.C.A., 1983. The economics of cotton production in the coastal region of Kenya. Communication 25, CARS, Mtwapa. 30 pp.

KOECH, L.C.A., 1985. Farming systems in Kwale District; baseline study of agricultural production for national extension programme. Communication 31, CARS, Mtwapa. 38 pp.

KRAPF, J.L., 1860. Travels, researches and missionary labours during an eighteen years residence in Eastern Africa. Frank Cass & Co. Ltd., London, 1968, 2nd. edition. 566 pp.

KORTRAM, J., 1983. De betekenis van de coöperatieve marketing organisatie in het Kilifi District. TPIP, Kaloleni, Kenya & Agricultural University, Wageningen, The Netherlands. 52 + VII pp. Unpublished.

KWALE DISTRICT, 1984. Kwale District development plan 1984/1988. Rural Planning Division, Ministry of Finance and Planning, Nairobi. 88 pp. + 5 pp. maps + XXVIII pp.

KSC, 1979. Maize handbook. Kenya Seed Company, Kitale. 19 pp.

LEEUWEN, S. van, 1984. Cowpea and green gram; a report on the growth and yields of the two most important pulse crops in the Kilifi area, Kenya, during 1982. TPIP, Kaloleni, Kenya & Agricultural University, Wageningen, The Netherlands. 46 + XVII pp. Unpublished.

LIESHOUT, O. van & G. STRAVER, 1984. A description of the agriculture along the Kenyan coast between Mtwapa and Chumani, focused on the Mijikenda farming system. TPIP, Kilifi, Kenya & Agricultural University, Wageningen, The Netherlands. 100 + LXXI pp. Unpublished.

MAGARINI, 1982. Proceedings pigeon pea workshop 15th_16th November 1982. Magarini Land Settlement Project, Malindi. 41 pp.

MAGARINI, 1983. Proceedings cassava workshop 7th-8th February 1983. Magarini Land Settlement Project, Malindi. 92 pp.

MAGARINI, ----. Annual reports, a.o. about agronomic research. Magarini Land Settlement Project, Malindi.

MAJISU, B.N. et al., 1980. Report of the ad hoc committee on maize and pasture research. Ministry of Agriculture, Nairobi. 207 pp. + 10 annexes.

MAKUMI, P., 1982. Upland rice cultivation in the Coast Province. Newsletter 21, pp. 7-8, CARS, Mtwapa.

MANN, I., 1976. Bees are wealth; a handy guide to bee-keeping in East Africa. Nyuki ni mali; maelezo mepesi kwa wafugaji nyuki wa Afrika ya Mashariki. East African Literature Bureau, Nairobi, etc. 301 pp.

MATHEZ, R.C., 1972. Chilo partellus Swinh., C. orichalcociliellus Strand and Sesamia calamistes Hmps. on maize in the Coastal Province, Kenya. Bul Soc. Ento. Suisse 45 (1972), 267-289.

MAY, I.L.C. M.V.K. SIVAKUMAR & S.M. VIRMANI, 1981? Agricultural potential of Magarini in relation to climate and soils. Agroclimatology Progress Report 6, ICRISAT, Patancheru. 40 + XVII pp.

MBINGA, M.J., 1983. Cassava acceptance by farmers in the Coast Province and expected economic returns. pp. 43-50 in MAGARINI (1983).

MIRACLE, M.P., 1965. The introduction and spread of maize in Africa. Journal of African History 6 (1965), 39-55.

MoA&LD, 1984. Farm management handbook of Kenya. Volume IIIB: Agricultural costs and prices 1984. Farm Management Branch, Ministry of Agriculture and Livestock Development, Nairobi.

MOOMAW, J.C., 1960. A study of the plant ecology of the coast region of Kenya Colony, British East Africa. Government Printer, Nairobi. 54 pp. + 2 loose maps.

MUGO, C.N., 1982. Cotton growing in Kilifi District. Newsletter 21, pp. 8-9, CARS, Mtwapa.

MUGO, C.N., 1984. Kilifi District annual report 1983. Ministry of Agriculture and Livestock Development, Kilifi. 117 pp.

MUKABI, P. & H. HENDRICKX, 1980. Production and marketing of coconuts and copra in Kilifi District, Kenya. Results of survey in August/ September 1980; communication paper 1. Marketing Research and Development Section, Ministry of Co-operative Development & FAO Marketing Development Project, Nairobi. 11 + VII pp.

MUTURI, S.N., 1981. Agricultural research at the coast. National Council for Science and Technology (NCST), no. 6. X + 58 pp.

MWANGI, K. 1980. Control of cotton pests in Coast Province of Kenya. Communication 13, CARS, Mtwapa. 17 pp.

MWANGUDZA, J.A., 1983. Kenya's people: Mijikenda. Evans Brothers Ltd., London. Edited by M. Sharman. 37 pp.

NAUTA, H.H., J.H. POSTMA & G.J. WINKELHORST, 1981. Report on farming systems research in Kilifi District. Volume I. TPIP, Kilifi, Kenya & Agricultural University, Wageningen, The Netherlands. 102 +VI pp. Unpublished.

NDAMBUKI, F.N., 1981. A maize tour report of Coast Province, 2-6th June 1981. NARS, Kitale. 13 pp. Mimeographed.

NDFRS, ----. Several hand-outs during 1981 and 1982. National Dryland Farming Research Station, Katumani.

NEHSS, 1984. Kilifi District environmental assessment report. National Environment and Human Settlement Secretariat in cooperation with ETMA & USAID, Nairobi. 226 + XL pp. Draft publication.

NEHSS, 1984. Proceedings of a workshop held in Malindi 13th-16th March 1984. Kilifi District environment assessment project. National Environment and Human Settlement Secretariat, Nairobi. 44 pp. Mimeographed.

NGALA, R.G., 1949. Nchi na desturi za Wagiriama. Eagle Press, Nairobi. 41 pp. + 6 pp. photographs.

NG'ANG'A, P., 1980. Pod borers on cowpeas. Newsletter 11, pp. 9-10, CARS, Mtwapa.
NG'ANG'A, P., 1980. Legume bud thrips - the unseen enemies in cowpeas. Newsletter 9, pp. 4-5, CARS, Mtwapa.

NOLL, I.E. van der, 1983. N, P, S fertilizers and manure on upland rice, Columbus grass, Napier grass, Kilifi, Kenya. Part I: Influence of N-, P-, S-fertilizers on the growth of upland rice in the Kilifi area, Kenya. TPIP, Kilifi, Kenya & Agricultural University Wageningen, The Netherlands. 31 pp. + appendices.

NYANGE, H.J., 1982. Coconut rehabilitation programme. Newsletter 19, pp. 4-7, CARS, Mtwapa.

OGUTU, M.A., 1981. Coconut the coast's dormant crop. Kenya Farmer, November 1981, pp. 21, 25, 27.

OHLER, J.G., 1979. Cashew. Communication 71. Department of Agricultural Research, Royal Tropical Institute, Amsterdam. 260 pp.

OHLER, J.G., 1984. Coconut, tree of life. Plant production and protection paper 54. FAO, Rome. 446 pp.

OKOOLA, R.E.A., 1978. Spatial distribution of rainfall in the Mombasa area of Kenya. East African Institute for Meteorological Training and Research. Kenya Meteorological Department Research Report 1/78. 17 pp.

OLTREMARE, 1982. Feasibility study for cashewnut production in the coastal region of Kenya. Oltremare, Zola Predosa (Bologna).

OMONDI, O.C., 1979. Cassava diseases and their control. Newsletter 6, pp. 10-11, CARS, Mtwapa.

OMONDI, O.C. & C.L.M. van EIJNATTEN, 1980. The coreid bug of coconuts; a review of the literature. Communication 17, CARS, Mtwapa. 13 pp.

PARKIN, D.J., 1972. Palms, wine and witnesses. Public spirit and private gain in an African farming community. Intertext Books, London. 113 pp.

PATTERSON, K.D., 1970. The Giriama risings of 1913-1914. African Historical Studies (Boston) III (1970) 3, 89-99.

PRINS, A.H.J., 1952. The coastal tribes of the north-eastern Bantu (Pokomo, Nyika, Teita). ethnographic survey of Africa: East Central Africa, part 3. International Africa Institute, London.

PURSEGLOVE, J.W., 1976. The origins and migrations of crops in tropical Africa. pp. 291-309 in HARLAN, J.R., J.M.J. de WET & A.B.M. STEMLER, 1976. Origins of African plant domestication. Mouton Publishers, The Hague and Paris. 498 pp.

PURY, J.M.S. de, 1968. Crop pests of East Africa. Oxford University Press, Nairobi. 227 pp.

REEVES, T.G., 1979. Crop production handbook for extension workers.

Magarini Land Settlement Scheme, Malindi. 71 pp.

RUBUI, A.M., 1983. Maize growing - coastal strip. Msabaha (sub-station of CARS). 7 pp. Mimeographed.

SALIM, A.I., 1973. The Swahili-speaking peoples of Kenya's coast, 1895-1965. East African Publishing House, Nairobi. 272 pp.

SCHELTES, P., 1978. Ecological and physiological aspects of aestivation-diapause in the larvae of two Pyralid stalk borers of maize in Kenya. Ph.D. thesis, Agricultural University, Wageningen, The Netherlands. 110 pp.

SCHMIDT, H. & R. SWOBODA. 1979. Farm management handbook of Kenya. Volume I: Labour requirement/availability and economics of mechanisation. Farm Management Section, Ministry of Agriculture, Nairobi. 191 pp.

SCHREURS, W.J.H., 1982. Farming systems in the Bamba-Ganze area, Kilifi District, Kenya. TPIP, Kilifi, Kenya & Agricultural University, Wageningen, The Netherlands. 62 + XIX pp. Unpublished.

SCHREURS, W.J.H., 1984. N, P and S fertilizer trials on Jurassic shales and coastal sands in Kilifi District, Kenya. TPIP, Kilifi, Kenya & Agricultural University, Wageningen, The Netherlands. 30 + VI pp. Unpublished.

SOMBROEK, W.G. H.M.H. BRAUN & B.J.A. van der PAUW, 1982. Exploratory soil map and agro-climatic zone map of Kenya, 1980. Scale 1:1,000,000. Exploratory Soil Survey Report E1, Kenya Soil Survey, Nairobi. 56 pp. + 4 separate maps.

SPEAR, T.T., 1978. The kaya complex; a history of the Mijikenda peoples of the Kenya coast to 1900. Kenya Literature Bureau, Nairobi. 172 pp.

SPRENKELS, C., 1985. Aspects of maize growth under coconut palms in the Kaloleni area, Kilifi District, Kenya. TPIP, Kaloleni, Kenya & Agricultural University, Wageningen, The Netherlands. 44 + XL pp. Unpublished.

STOTZ, D. & B., 1977. All about milk production in a zero grazing system. Livestock Recording Centre, Ministry of Agriculture, naivasha. July 1979 reprint. 8 pp.

STOTZ, D., 1983a. Farm management handbook of Kenya. Volume IV: production techniques and economics of smallholder livestock production systems in Kenya. Animal Production Division, Ministry of Livestock Development, Nairobi. 140 pp.

STOTZ, D., 1983b. Zero grazing farm demonstration extension package. A guideline for extension workers. Animal Production Division, Ministry of Livestock Development & Agricultural Information Centre, Nairobi. 15 pp.

TAMURA, T., 1980. Rice culture. Ministry of agriculture, Kilifi. 7 + I pp.

TAMURA, T., 1981. Handing over report of Japanese rice culture volunteer, Kilifi District, October 1981. Ministry of Agriculture, Kilifi. 6 pp.

TARDA, 1983. Resource development proposals, Kilifi District. Tana and Athi River Development Authority, Nairobi. 126 pp.

VERBEEK, A.C., 1982. Report on farming systems research in Kilifi District. Volume II. TPIP, Kilifi, Kenya & Agricultural University, Wageningen, The Netherlands. 112 pp. Unpublished.

VERVOORN, M.J.A.F., 1986. Cropping systems research (trials). In preparation.

WAAIJENBERG, H., 1981. A cross section of Mijikenda agriculture in the coastal uplands of Kenya. I: Preliminary data and sampling procedure. TPIP, Kilifi, Kenya & Agricultural University, Wageningen, The Netherlands. 14 pp. Unpublished.

WAAIJENBERG, H., 1982. A cross section of Mijikenda agriculture in the coastal uplands of Kenya. II: Some maize yield estimations in 'mwaka'1981. TPIP, Kilifi, Kenya & Agricultural University, Wageningen, The Netherlands. 14 + VIII pp. Unpublished.

WAAIJENBERG, H., 1984. A cross section of Mijikenda agriculture in the coastal uplands of Kenya. VII: Aspects of maize production and consumption. TPIP, Kaloleni, Kenya & Agricultural University, Wageningen, The Netherlands. 15 + III pp. Unpublished.

WAAIJENBERG, H., 1987. An agro-economic history of the Mijikenda of Kenya. In preparation.

WAAIJENBERG, H. & M. SALIM, 1983. Land and farming systems in Kilifi District, Kenya. Paper for a farming systems workshop, Magarini Land Settlement Scheme, Malindi, 7-9th December 1983. 20 + I pp.

WAMARI, P.A., 1982. Bole-rot of coconuts. Newsletter 21, pp. 5-7, CARS, Mtwapa.

WAMBUA, P.A., 1982. Revised farm budget 1982. Magarini Land Settlement Scheme, Malindi. 6 pp. Mimeographed.

WANG'ATI, F.J. <u>et al</u>., 1982. Report of the ad hoc committee on sorghum and millet research and development. Ministry of Agriculture, Nairobi.

WARUI, C.M., 1979. Developments in cashew cultivation and research in Kenya. Communication 2, CARS, Mtwapa. 14 pp.

WARUI, C.M. & J.N. KURIA, 1983. Population incidence and the control of maize stalk-borers <u>Chilo partellus</u> (Swinh.), <u>C. orichalcociliellus</u> Strand and <u>Sesamia calamistes</u> HMPS, in Coast Province, Kenya. Insect Sci. Application 5 (1/2), 11-18.

WASSINK, G.H., 1983. Simsim growing in the Kilifi area. TPIP, Kaloleni, Kenya & Agricultural University, Wageningen, The Netherlands. 11 + VI pp. Unpublished.

WASSINK, G.H., 1983. Cashew growing in the Kilifi area. TPIP, Kaloleni, Kenya & Agricultural University, Wageningen, The Netherlands. 16 + XI pp. Unpublished.

WASSINK, G.H., 1983. The influence of coconut palms upon maize and sorghum growth and yield. Maize and sorghum trial in the Kaloleni area, Kilifi District. Kenya. TPIP, Kaloleni, Kenya & Agricultural University, Wageningen, The Netherlands. 36 + XX pp. Unpublished.

WHEATLEY, P.E., 1960/61. The insect pests of agriculture in the Coast Province of Kenya. I: Mango. E. Afr. agric. & For. J. 26 (1960), 129-131. II: Cashew. E. Afr. agric. & For. J. 26 (1961), 178-181. III: Sweet potato. E. Afr. agric. & For. J. 26 (1961), 228-229. IV: Coconut. E. Afr. agric. & For. J. 27 (1961), 33-35. V: Maize and sorghum. E. Afr. agric. & For. J. 27 (1961), 105-107.

WHEATLEY, P.E. & T.J. CROWE, 1967. Pest handbook; The recognition and control of the more important pests of agriculture in Kenya. Government Printer, Nairobi. 33 pp.

W'OPINDI, H.A.E., 1980. How to grow simsim. Newsletter 9, pp. 2-4, CARS, Mtwapa.

References

Acland, J.D., 1971. East African crops. Longman, London, 252 pp.

Beek, K.J., 1978. Land evaluation for agricultural development: some explorations of land-use systems analysis with particular reference to Latin America. ILRI-publication 23. Wageningen, the Netherlands, 333 pp.

Black, C.A., 1965. Methods of soil analysis. Agronomy No. 9 Am. Soc. of Agron. Inc.

Braun Blanquet, J., 1972. Plant sociology. The study of plant communities. Hafner, New York 1972.

Braun, H.M.H & R.F. van de Weg, 1977. Proposals for rating of land qualities (second approx). Int. comm No. 7. KSS Nairobi.

Buol, S.W., P.A. Sanchez, R.B. Cate & M.A. Granger. Soil fertility capability classification: a technical soil classification for fertility management. In: Bornemisza, E. & A. Alvarado (Eds): Soil management in Tropical America. North Carolina State University, Raleigh: 126-141.

Campen, W. van, 1983. Assessment of soil erodibility in the coastal uplands near Kilifi Kenya. Internal report, Dept. of Rural Engineering, Agric. Univ. Wageningen.

Cannon, R.T., W.M.N. Simiya Siambi & F.M. Karanja, 1981. The proto-Indian Ocean and a probable Palaeozoic/Mezozoic tri-radical rift system in East-Africa. Earth and Planetary Science Letters 52: 419-426.

Caswell, P.V., 1953. The geology of the Mombasa-Kwale Area. Report no. 24 Geological Survey, Kenya, 64 pp.

Caswell, P.V., 1956. Geology of the Kilifi-Mazeras Area. Report no. 34 Geological Survey of Kenya, 54 pp.

FAO-Unesco, 1974. Soil map of the World, 1 : 5 000 000, vol I legend. Unesco. Paris.

FAO, 1976. A framework for landevaluation. Food and Agricultural Organisation, Rome. Soils Bull. 32.

FAO, 1977. Guidelines for soil profile descriptions (second edition). Food and Agricultural Organisation, Rome.

FAO, 1983. Guidelines: Land evaluation for rainfed agriculture. FAO, Rome.

Floor, R., R. Onck, E. Smaling, J. van der Lek & J. Reitsma, 1980. A Preliminary Reconnaissance Soil Survey of the Kilifi Area. Prelim. Report no. 1 (Kilifi Series). Training Project in Pedology, Kilifi, Kenya. Agricultural University, Wageningen, the Netherlands

Floor, J., 1980. Coconuts around Kaloleni. Preliminary Report no. 2 (Kilifi series). Training Project in Pedology, Kilifi, Kenya. Agricultural University Wageningen, The Netherlands, 59 pp.

Fournier, F., 1960. Climat et érosion. Presses Universitaires de France, Paris.

Gachene, C.K.K., 1982. Relative erodibility of some Kenyan soils using a rainfall simulator. Paper, presented at the Soil and Water Conservation Workshop, Nairobi 3-6 March 1982.

Gethin-Jones, G.H. & R.M. Scott, 1959. Soilmap of Kenya. In: Survey of Kenya 1959, National Atlas of Kenya (1st.edn), Govt. of Kenya, Nairobi.

Geus, J. de. Fertilizer guide for the tropics and subtropics. Centre d'étude de l'azote, Zürich, 774 pp.

Gregory, J.W., 1896. The great Rift Valley. London.

Guiking, F.C.T., B.H. Janssen & D. van der Eijk. Soil fertility. Nutrient availability. In: Wielemaker, W.G. and H.W. Boxem (Eds): Soils of the Kisii area, Kenya. Agric. Res. Rep. 922. Pudoc, Wageningen: 36-38, 76-89, 110-111, 194-196.

Houba, V.J.G., J. Ch van Schouwenburg & I. Wallinga, 1979. Methods of analysis of soils. MSc-course in Soil Science and Water Management, Dept. of Soil Science, Agric. Univ. Wageningen, the Netherlands.

Hudson, N.W., 1971. Soil Conservation. Batsford, London.

Janssen, B.H., F.C.T. Guiking, D. van der Eijk, E.M.A. Smaling & H. van Reuler, 1986. A new approach to evaluate the chemical fertility of tropical soils. Vol III, p. 791-792 Tramsact. XIII Congress ISSS Hamburg.

Jätzold, R & H. Kutsch, 1982. Agro-ecological zones of the tropics with a sample from Kenya. Der Tropenlandwirt 83: 15-34.

Jätzold, R. & H. Schmidt, 1983. Farm management handbook of Kenya. Volume II: Natural conditions and farm management information. Volume IIC East Kenya. Eastern and Coast Provinces Farm Management Branch, Min of Agric., Nairobi.
Kuijper, J.V.J.M., 1982. The human influence on the vegetation in a part of the Kilifi Area. Preliminary Report 4 (Kilifi Series). Training Project in Pedology, Kilifi, Kenya. Agricultural University, Wageningen, the Netherlands.
Leeuwen, M.W.N. van, 1982. Vegetation and landuse map (1 : 100 000) of the Kilifi Area. Preliminary Report 3 (Kilifi Series). Training Project in Pedology, Agricultural University, Wageningen, the Netherlands.
Mehlich, A.A., Pinkerton, W. Robertson & R. Kempton, 1962. Mass analysis methods for soil fertility evaluation. Internal report NAL, Min. of Agr., Nairobi.
Michieka, D.O., B.J.A. van der Pouw & J.J. Vleeshouwer, 1978. Soils of the Kwale-Mombasa-Lungalunga Area, Volume I and II and Soilmaps 1 : 100 000. Kenya Soil Survey, Min. of Agric. Kenya.
Morgan, R.P.C., 1979. Soil Erosion. Longman, London.
Muff (Maufe), H.B., 1908. Report relating to the geology of the East African Protectorate. Col. Rep. Misc. No. 45 (Cd 3828), London.
Munsell Color Chart, 1971. Munsell Color, Macbeth, A-division of Kollmorgen Corp. Baltimore, Maryland 21218.
Oosterom, A.P. (in prep). The morphogenesis of South-East Kenya.
Purseglove, J.W., 1968. Tropical crops. Dicotyledons (2 Volumes). Longman, London.
Purseglove, J.W., 1972. Tropical crops. Monocotyledons (2 Volumes). Longman, London.
Rapp, A., L. Berry & P. Temple, 1972. Studies of Soil erosion and sedimentation in Tanzania. Geografiska Annaler, 54 A: 3-4.
Richards, L.A. (Ed.), 1954. Diagnosis and improvement of saline and alkali soils. Agricult. Handbook 60, USDA, Washington D.C.
Roose E.J., 1975. Application of the Universal Soil-loss Equation in West Africa. In: Greenland & Lal (editors): Soil conservation and Management in the humid tropics. John Wiley and Sons, Chichester.
Sanchez, P.A., W. Conto & S.W. Buol, 1982. The fertility capability soil classification system: interpretation, applicability and modification. Geoderma 27: 283-309.
Siderius, W., & B.J.A van der Pouw, 1980. The application of the FAO/Unesco terminology to the Soil Map of the World legend for Soil classification in Kenya. Misc. Soil Paper M15, KSS Nairobi.
Smaling, E.M.A., 1981. Erosion hazard and moisture availability - a study on two landqualities in the Shale belt of the Kilifi District (internal report). TPIP Kilifi, Soils Dept., Agric. Univ. Wageningen.
Soil Survey Staff, 1951. Soil Survey Manual and Supplement (1962). Handbook 18 USDA Washington DC.
Soil Survey Staff, 1975. Soil Taxonomy. A basic system of soil classification. USDA Agric. handbook No 436, Government Printing Office, Washington DC, USA.
Sombroek, W.G., H.M.H. Braun & B.J.A. van der Pouw 1982. Exploratory soil map and agroclimatic zone map of Kenya 1980, scale 1 : 1 000 000. Kenya Soil Survey Report No. E1, Nairobi 1982.
Stakman, W.P., G.A. Valk & G. van der Hirst, 1969. Determination of soil moisture retention curves (3d edition). Vol 1: Sandbox apparatus, Vol 2: Pressure membrane app. Institute for Land and Water Management Research, Wageningen, the Netherlands.
Weg, R.F. van de, 1978. Guidelines for subdivision of geology (based mainly on lithology) in relation to soil mapping and legend construction. Internal Communication no. 13, Kenya Soil Survey, Nairobi.
Wielemaker, W.G., & H.W. Boxem, 1982. Soils of the Kisii Area. Pudoc, Wageningen, and Kenya Soil Survey Report No. R4, Government Printer, Nairobi, Kenya, 208 pp.
Wischmeier, W.H. & J.V. Mannering, 1969. Relation of soil properties to its erodibility. Soil Sci. Soc. Amer. Proc. vol. 33.
Wischmeier W.H., C.B. Johnson & B.V. Cross, 1971. A soil erodibility nomograph for farmland and construction sites. J. of Soil and Water Conservation Sept-Oct.
Wischmeier W.H. & D.D. Smith 1978. Predicting rainfall erosion losses, a guide to conservation planning. Agr. Handbook 537, USDA, Washington DC.
Woodhead, I., 1968. Studies of potential evapotranspiration in Kenya. EAAFRO, Nairobi.
Wijngaarden W. van & V.W.P. van Engelen 1985. Soils and vegetation of the TSAVO area. Report R7, Kenya Soil Survey, Nairobi.
Zonneveld I.S., H.A.M.J. van Gils & D.C.P.Thalen, 1979. Aspects of the ITC approach to vegetation survey. Documents phytosociologiques N.S. Vol IV.

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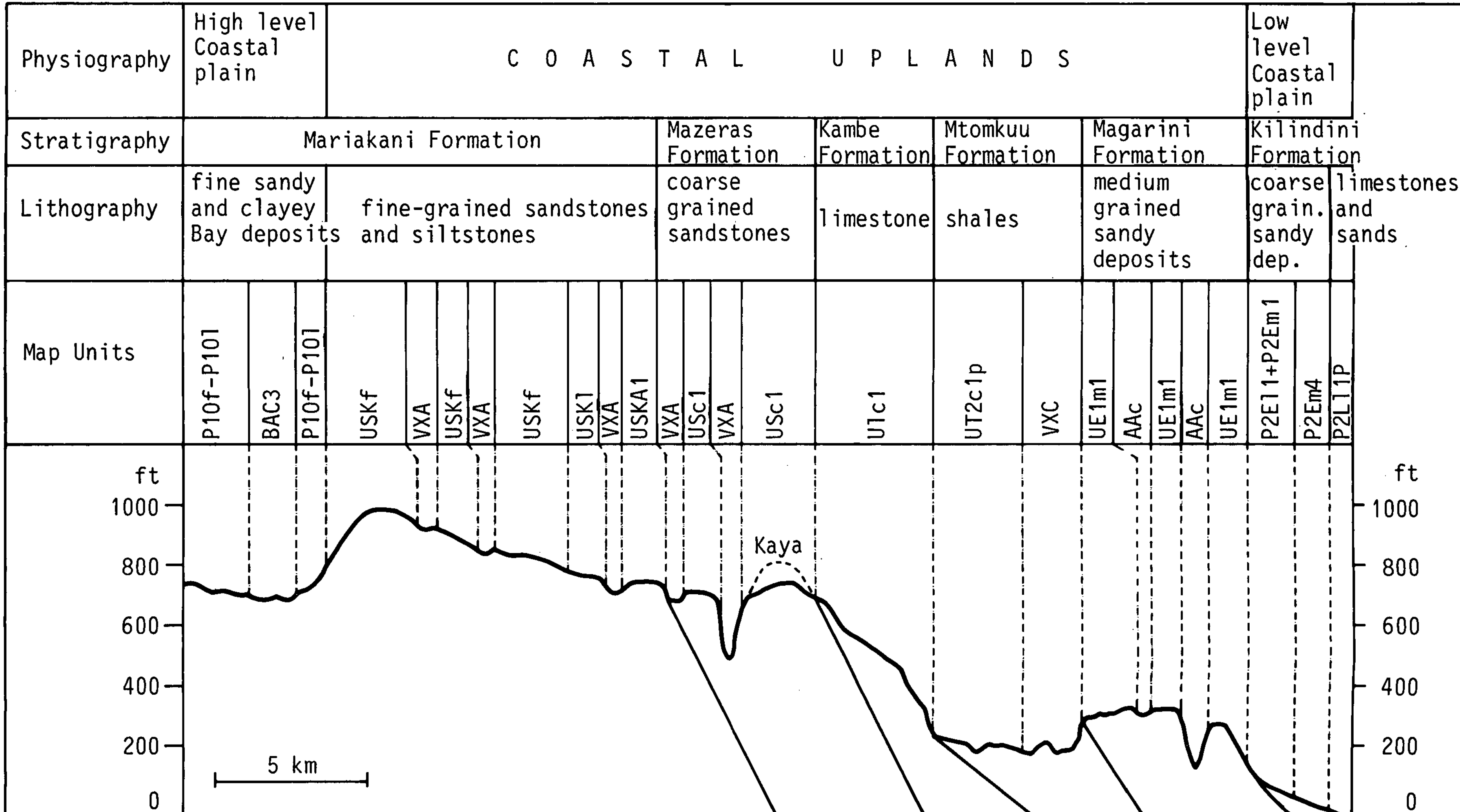
Appendix 3 to Report No. R11 "Soils of the Kilifi Area"

SIMPLIFIED CROSS-SECTION EAST-WEST at 3°45′



Plant species:
Afzelia cuanzensis
cf Landolphia petersiana
Achyrothalamus marginatus
Haplocoelum inoploeum
Euphorbia grandicornis
Zamioculcas zamiifolius
Uvaria acuminata
Suregada zanzibarensis
Phyllanthes reticulatus
Lannea stuhlmannii
Heinsia jasminiflora
Vernonia hildebrandtii
Hibiscus aponeurus s.l.
Manilkara zanzibarica
Adenium obesum
Dichrostachis cinerea
Ochna sp.
Cissus rotundifolius
Ransonia sp.
Canthium bibracteatum
Cissus quadrangularis
Memecylon sp.
Commelina sp.
Agathisanthemum bojeri
Tephrosia sp.
Phyllanthes sp.
Premna chrysoclada
Euphorbia tirucalli
Asparagus cf racemosa
Muria
Lagynias littoralis
Meyna tetraphylla
Enneastemon fornicatus
UPS 2
Gonatopus boivinii
Strychnos cf innocua
Mutiri
Aerva lanata
Manilkara sulcata
Heeria mucronata
UPS 3
UPS 4
Monodora grandidieri
Capparis stuhlmannii
Muungo
Rhoicissus revoilii
UPS 6
Aloë sp.
Sansevieria kirkii
Muthuri thuri
Teclea trichocarpa
Cucurbitaceae sp
UPS 9
Hoslundia opposita
Munyanga kitswa
Grewia cf bicolor
Grewia cf ectasicarpa
Thespesia danis
Commiphora africana s.l.
UPS 10
Lantana camara
Securinega virosa
Terminalia spinosa
Mukami
Sida cordifolia
Acacia nilotica
Ocimum hadiense
Achyranthes aspera
Xerophis nilotica
Sida cuneifolius
Solanum incanum
UPS 11
Commiphora boiviana
Grewia cf microcarpa
Tragiella natalensis
UPS 14
Myrica kilimandscharika
Asparagus sp.
Bridelia cathartica ssp. melanthesoides
Polysphaeria parvifolia
Fagara chalybea
Ehretia bakeri
Ehretia petiolaris
Mutanda ufu
Vitex cf mombasiana
Oxygonum salicifolium
Grewia cf holstii
Ageratum conyzoides
Grewia cf truncata
Ximenia americana
Emilia javanica
Grewia cf forbesii
UPS 15
Manilkara mochisia
Acacia cf etbaica
Grewia cf stuhlmannii
UPS 18
Talinum portulacifolium
Bombax rhodognaphalon
UPS 20
Maytenus senegalensis
UPS 21
Harrisonia abyssinica
Ormocarpum kirkii
Guizotia scabra
UPS 22
cf Glycine wightii
Hyphaene coriacea
Sphenostylis briartii
Karembo
Dalbergia vacciniifolia
Fernandoa magnifica
Kitola
Cyphostemma adenocaule
Sterculia rhynchocarpa
Deinbollia sp.
UPS 23
UPS 24
Albizia gummifera
Cissampelos sp.
UPS 25
Allophylus pervillei
Murono koma
Strychnos cf rysophylla
Adansonia digitata
Diospyros sp.
Clerodendrum glabrum
Vitex strickeri
Grewia cf villosa
Lamprothamnus zanguebaricus
Piliostigma thonningii
Musasa
Grewia sp 3
Encephalartos hildebrandtii
Kakira kaloma
Acacia senegal
UPS 32
UPS 34
Hunteria zeylanica
Celosia schweinfurthiana
Pseudarthria confertiflora
UPS 35
Secamone sp. 2
Phyllanthes sp. 2
Markhamia zanzibarica
Annona chrysophylla
Azadirachta indica
Notobuxus obtusifolia
Pappilionaceae sp 1.
Epinetum delagoensis
Cassytha sp.
Strychnos mitis
Tarrena nigrescens
UPS 36
Indigofera sp.
UPS 37
Asteranthe asterias
Lubugu 2
Mambo tsaka
Annona sp.
cf Dioscouros sp.
Clerodendrum luseum
Heeria reticulata
UPS 39
Arum sp.
Kadunga tundu
Croton pseudopulchellus
Cynometra suahelensis
Combretum butyrosum
Gloriosa simplex
Deinbollia borbonica
Machembe gamura
UPS 41
Tridax procumbens
Rauwolfia mombasiana
Tetracera boiviana
UPS 79
Heliotropium sp.
Acalypha fructicosa
Triumphetta rhomboidea
UPS 42
Pupalia lappacea
Cyssampelos
Anacardium occidentale
Cocos nucifera
Mangifera indica
UPS 43
Helixanthera kirkii
Cassia sp.
UPS 48
UPS 49
Tamarindus indica
Ficus bussei
UPS 50
Mwalaga kuku
Clausena anisata
Carisa bispinosa
Ricinus communis
UPS 51
Mwiya 2
Vigna unguiculata
cf Asystasia gangetica
UPS 54
Thevetia peruviana
Cassia longiracemosa
Citrus sinensis
Zea mays
UPS 67
UPS 55
Anchomanes dubium
UPS 61
Sansevieria sp.
Kafiozo fiozo
Mukambi
Pleurostylia africana
UPS 65
Trema orientalis
UPS 66
Hugonia sp.
Erythrococca sp 2
Holarrhena sp.
Erythrococca sp. 1
Strychnos spinosa
Gesneria sp.
Polypodiaceae sp.
Drypetes reiseleyi
Lilium sp.
Dalechampia ipomoifolia
Vitex cf danione
UPS 74
Tradescantia sp.
Clerodendrum eriophyllum
Sterculia appendiculata
Grewia glandulosa
Agave sisalana
Capparis cartilaginea
cf Scilla kirkii
Plectanthus flaccidus
Pentodon pentandrus
Cynanchum tetrapterum
Tephrosia purpurea
Cordia somaliensis
Justiciana flava
Cordia subcordata
Jasminum fluminens
Tribulus terrestris
Sonneratia alba
Bruguiera gymnorhiza
Avicennia marina
Rhizophora mucronata

G1 G2 H1 H2 I J K

Appendix 4b-II to Report No. 11 "Soils of the Kilifi Area" VEGETATION TABLE (Part 2 of 3)

from: M van Leeuwen, Kilifi-Vegetation

Plant species:
Brachystegia spiciformis
Afzelia cuanzensis
cf Landolphia petersiana
Uvaria acuminata
Suregada zanzibarensis
cf Phyllanthes reticulatus
Lannea stuhlmannii
Vernonia hildebrandtii
Hibiscus aponeurus s.l.
Manilkara zanzibarica
Dichrostachis cinerea
Ochna sp.
Cissus rotundifolius
Ransonia sp.
Canthium bibracteatum
Cissus quadrangularis
Commelina sp.
Agathisanthemum boseri
Tephrosia sp.
Phyllanthes sp.
Premna chrysoclada
Euphorbia tirucalli
Asparagus racemosa
Muria
Lagynias littoralis
Meyna tetraphylla
Enneastemon fornicatus
Gonatopus boivinii
Strychnos innocua
Aerva lanata
Manilkara sulcata
Heeria mucronata
Capparis stuhlmannii
Rhoicissus revoilii
Aloë sp.
Sansevieria kirkii
Muthuri thuri
Teclea trichocarpa
Cucurbitaceae sp
UPS 9
Hoslundia opposita
Munyanga kitswa
Grewia cf bicolor
Grewia cf ectasicarpa
Thespesia danis
Commiphora africana s.l.
UPS 10
Lantana camara
Securinega virosa
Terminalia spinosa
Mukami
Sida cordifolia
Acacia nilotica
Endostemon tereticaulis
Ocimum hadiense
Achyranthes aspera
Albizia anthelmintica
Xeromphis nilotica
Sida cuneifolius
Solanum incanum
UPS 11
Mutunguru
Commiphora boiviana
Salvadora persica
Grewia cf microcarpa
Tragiella natalensis
UPS 13
UPS 14
Myrica kilimandscharica
Asparagus sp.
Bridelia cathartica ssp melanthesoides
Polysphaeria parvifolia
Fagara chalybea
Ehretia bakeri
Ehretia petiolaris
Mutanda ufu
Vitex cf mombasiana
Grewia cf holstii
Ageratum conyzoides
Grewia cf truncata
Emilia javanica
Vangueria tomentosa
Grewia cf forbesii
Grewia sp 1
Manilkara mochisia
Lantana viburnoides
Acacia zanzibarica
Acacia cf etbaica
Euphorbia candelabrum
Grewia cf stuhlmannii
Conyza pyrrhopappa
Erythrococca kirkii
UPS 18
Veronica sp.
Talinum portulacifolium
Bombax rhodognaphalon
UPS 19
UPS 20
Maytenus senegalensis
UPS 21
Harrisonia abyssinica
Ormocarpum kirkii
Guizotia scabra
UPS 22
Acacia mellifera
cf Glycine wightii
Hyphaene coriacea
Sphenostylis briartii
Acacia stuhlmannii
Pluchea dioscorides
Karenda
Dalbergia vacciniifolia
Fernandoa magnifica
Kitola
Cyphostemma adenocaulis
Sterculia rhynchocarpa
Deinbollia sp.
UPS 23
Cissampelos sp.
Allophylus pervellei
Diospyros cornii
Mubono mona
UPS 26
Mwiya
Strychnos byeophylla
Secamone sp.
Adansonia digitata
Diospyros sp.
Clerodendrum glabrum
UPS 27
Vitex strickeri
Grewia cf villosa
Lamprothamnus zanguebaricus
Piliostigma thonningii
UPS 28
UPS 29
Musaga
Leucas kilifiensis
UPS 31
Grewia sp 3
Encephalartos hildebrandtii
Kakira kalona
Adenia globosa
Kitunguu
Acacia senegal
UPS 33
UPS 34
Zyziphus mauritania
Hunteria zeylanica
Celosia schweinfurthiana
cf Clitoria sp
Pseudarthria confertiflora
Capparidaceae sp 1
UPS 35
Secamone sp 2
Phyllanthes sp 2
Markhamia zanzibarica
Annona chrysophylla
Azadirachta indica
Notobuxus obtusifolia
Pappilionaceae sp 1
Epinetum delagoensis
Cassytha sp.
Strychnos nitis
Tarrena nigrescens
UPS 36
Indigofera sp.
UPS 37
Asteranthe asterias
UPS 38
cf Dioscoreos sp
Clerodendrum luteum
Cassia sanguinea
Parkia filicoidea
Heeria reticulata
UPS 39
UPS 40
Arum sp.
Kadunga tundu
Gloriosa simplex
Deinbollia borbonica
Machenge gamura
UPS 41
Tridax procumbens
Rauvolfia mombasiana
Tetracera boiviana
UPS 79
Heliotropium sp.
Acacia polyacantha
Ficus sycomorus
Acalypha fruticosa
Triumfetta rhomboidea
UPS 42
Pupalia lappacea
Cyssampelos
Cocos nucifera
Mangifera indica
UPS 43
UPS 44
UPS 45
Helixanthera kirkii
UPS 46
Cassia sp
UPS 47
UPS 48
UPS 49
Tamarindus indica
Ficus bussei
UPS 50
Mwalaga muhu
Clausena anisata
Carissa edulis
Ricinus communis
Mulungu
Mwiya 2
Mukambi
Holarrhena sp.
UPS 68
Erythrococca sp. 1
Lilium sp.
Sterculia appendiculata
Blepharospermum zanguebaricum

Gramineae and Cyperaceae

Gramineae and Cyperaceae
Eragrostis ciliaris
Cyperaceae sp 1
Cyperaceae sp 2
Panicum repens
Panicum maximum
Eragrostis superba
Chloris roxburgiana
Chloris virgata
Heteropogon contortus
Dactyloctenium geminatum
Sporobolus pyramidalis
Echinochloa haploclada
Leptochloa panica
Sorghum sp
Cyperaceae sp 3
Eragrostis sp.
Cyperaceae sp 4
Cyperaceae sp 6
Cyperaceae sp 7
Cenchrus setigerus
Cenchrus ciliaris
Paspalum geminatum
Dichanthium radicans
Themeda triandra
Cyperus articulatus
Imperata cylindrica
Tetrapogon tenellus
Cyperaceae sp 8
Sporobolus marginatus
Aristida adscensionis
Perotis hildebrandtii
Graminae sp 1

D2 E F1 F2

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Appendix 4b-I to Report No. 11 "Soils of the Kilifi Area" VEGETATION TABLE (Part 1 of 3)

Plant species:	A1 – A2 – B – C – D1
Brachystegia spiciformis	[illegible]
Afzelia cuanzensis	[illegible]
F Landolphia petersiana	[illegible]
Achyrothalamus marginatus	[illegible]
UPS 1	[illegible]
Euphorbia sp.	[illegible]
Haplocoelum inoploeum	[illegible]
Euphorbia grandicornis	[illegible]
Zamioculcas zamiifolius	[illegible]
Phymatodes scolopendria	[illegible]
Uvaria acuminata	[illegible]
Suregada zanzibarensis	[illegible]
F Phyllanthes reticulatus	[illegible]
Lannea stuhlmannii	[illegible]
Heinsia jasminiflora	[illegible]
Vernonia hildebrandtii	[illegible]
Hibiscus aponeurus s.l.	[illegible]
Manilkara zanzibarica	[illegible]
Adenium obesum	[illegible]
Dichrostachys cinerea	[illegible]
Ochna sp.	[illegible]
Cissus rotundifolius	[illegible]
Rawsonia sp.	[illegible]
Canthium bibracteatum	[illegible]
Cissus quadrangularis	[illegible]
Memecylon sp.	[illegible]
Commelina sp.	[illegible]
Acathisanthemum bojeri	[illegible]
Tephrosia sp.	[illegible]
Phyllanthes sp.	[illegible]
Premna chrysoclada	[illegible]
Euphorbia tirucalli	[illegible]
Asparagus racemosa	[illegible]
Muria	[illegible]
Lagynias littoralis	[illegible]
Meyna tetraphylla	[illegible]
Enneastemon fornicatus	[illegible]
UPS 2	[illegible]
Gonatopus boivinii	[illegible]
Strychnos spinnocua	[illegible]
Mutiri	[illegible]
Aerva lanata	[illegible]
Manilkara sulcata	[illegible]
Hewria mucronata	[illegible]
UPS 3	[illegible]
UPS 4	[illegible]
Monodora grandidieri	[illegible]
Capparis stuhlmannii	[illegible]
Muungo	[illegible]
UPS 5	[illegible]
Rhoicissus revoilii	[illegible]
UPS 6	[illegible]
UPS 7	[illegible]
Kalanchoe sp.	[illegible]
Jatropha spicata	[illegible]
Aloë sp	[illegible]
Sansevieria kirkii	[illegible]
Flagaria guineense	[illegible]
Muthuri thuri	[illegible]
Slechterina mitostemmatoides	[illegible]
Cienkowskya sp.	[illegible]
Teclea trichocarpa	[illegible]
Cucurbitaceae sp. 1	[illegible]
UPS 9	[illegible]
Hoslundia opposita	[illegible]
Munyanga kitswa	[illegible]
Grewia cf bicolor	[illegible]
Grewia cf ectasicarpa	[illegible]
Thespesia danis	[illegible]
Commiphora africana s.l.	[illegible]
UPS 10	[illegible]
Lantana camara	[illegible]
Securinega virosa	[illegible]
Terminalia spinosa	[illegible]
Mukami	[illegible]
Sida cordifolia	[illegible]
Acacia nilotica	[illegible]
Endostemon tereticaulis	[illegible]
Ocimum hadiense	[illegible]
Achyranthes aspera	[illegible]
Albizia anthelmintica	[illegible]
Xeromphis nilotica	[illegible]
Sida cuneifolius	[illegible]
Solanum incanum	[illegible]
UPS 11	[illegible]
Mutunguru	[illegible]
Commiphora boiviana	[illegible]
Salvadora persica	[illegible]
Grewia cf microcarpa	[illegible]
Tragiella natalensis	[illegible]
UPS 14	[illegible]
Asparagus sp.	[illegible]
Bridelia cathartica ssp. melanthesoides	[illegible]
Polysphaeria parvifolia	[illegible]
Fagara chalybea	[illegible]
Ehretia bakeri	[illegible]
Ehretia petiolaris	[illegible]
Mufuozoni	[illegible]
Mutanga upu	[illegible]
Vitex cf mombasiana	[illegible]
Oxygonum salicifolium	[illegible]
Grewia cf holstii	[illegible]
Ageratum conyzoides	[illegible]
Grewia cf truncata	[illegible]
Ximenia americana	[illegible]
Emilia savanica	[illegible]
Vangueria tomentosa	[illegible]
Grewia cf forbesii	[illegible]
Mutupa	[illegible]
UPS 15	[illegible]
UPS 16	[illegible]
Grewia sp. 1	[illegible]
Manilkara mochisia	[illegible]
Acacia zanzibarica	[illegible]
Acacia cf etbaica	[illegible]
Euphorbia candelabrum	[illegible]
Grewia cf stuhlmannii	[illegible]
Conyza pyrrhopappa	[illegible]
Erythrococca kirkii	[illegible]
UPS 18	[illegible]
Talinum portulacifolium	[illegible]
Bombax rhodognaphalon	[illegible]
UPS 20	[illegible]
Maytenus senegalensis	[illegible]
UPS 21	[illegible]
Harrysonia abyssinica	[illegible]
Dobocarpum kirkii	[illegible]
Guizotia scabra	[illegible]
Acacia mellifera	[illegible]
Hymenaea coriacea	[illegible]
Sphenostylis briartii	[illegible]
Karemba	[illegible]
Dalbergia vaccinifolia	[illegible]
Fernandoa magnifica	[illegible]
Kitola	[illegible]
Cyphostemma adenocaulis	[illegible]
Sterculia rhynchocarpa	[illegible]
Deinbollia sp.	[illegible]
UPS 23	[illegible]
UPS 24	[illegible]
Cissampelos sp.	[illegible]
Allophylus pervillei	[illegible]
Diospyros cornii	[illegible]
Mubono kona	[illegible]
Mwiya	[illegible]
Secamone sp.	[illegible]
Adansonia digitata	[illegible]
UPS 27	[illegible]
Vitex strickeri	[illegible]
Grewia villosa	[illegible]
Lamprothamnus zanguebaricus	[illegible]
UPS 29	[illegible]
Leucas kilifiensis	[illegible]
UPS 31	[illegible]
Grewia sp. 3	[illegible]
Encephalartos hildebrandtii	[illegible]
Hunteria zeylanica	[illegible]
Capparidaceae sp. 1	[illegible]
UPS 35	[illegible]
Secamone sp. 2	[illegible]
Phyllanthes sp. 2	[illegible]
Markhamia zanzibarica	[illegible]
Annona chrysophylla	[illegible]
Notobuxus obtusifolia	[illegible]
Pappilionaceae sp 1	[illegible]
Epinetum bolagoensis	[illegible]
Strychnos mitis	[illegible]
UPS 36	[illegible]
Indigofera sp.	[illegible]
UPS 37	[illegible]
Asteranthe asterias	[illegible]
Cassia sanguinea	[illegible]
Parkia filicoidea	[illegible]
Hewria reticulata	[illegible]
Arum sp 2	[illegible]
Kadunga tundu	[illegible]
Combretum butyrosum	[illegible]
Gloriosa simplex	[illegible]
Deinbollia borbonica	[illegible]
Machenga gakura	[illegible]
UPS 41	[illegible]
Rauvolfia mombasiana	[illegible]
Tetracera boiviana	[illegible]
Heliotropium sp.	[illegible]
Acalypha fruticosa	[illegible]
Triumphetta rhomboidea	[illegible]
UPS 42	[illegible]
Pupalia lappacea	[illegible]
Cyssampelos	[illegible]
Anacardium occidentale	[illegible]
UPS 43	[illegible]
UPS 44	[illegible]
Helixanthera kirkii	[illegible]
UPS 48	[illegible]
Ficus bussei	[illegible]
Mwalaga muku	[illegible]
Clausena anisata	[illegible]
Carisa bispinosa	[illegible]
Hulungu	[illegible]
Mniya 2	[illegible]
UPS 52	[illegible]
Vigna unguiculata	[illegible]
UPS 53	[illegible]
Anchomanes dubium	[illegible]
UPS 57	[illegible]
UPS 58	[illegible]
Psychotria amboniensis	[illegible]
UPS 59	[illegible]
UPS 60	[illegible]
UPS 61	[illegible]
UPS 62	[illegible]
UPS 63	[illegible]
UPS 64	[illegible]
Tinnea aethiopica	[illegible]
Sansevieria sp.	[illegible]
Kapiozo piozo	[illegible]
Mukambi	[illegible]
Pleurostylia africana	[illegible]
UPS 65	[illegible]
Tacca orientalis	[illegible]
Hugonia sp.	[illegible]
Erythrococca sp.	[illegible]
Holarrhena sp.	[illegible]
UPS 68	[illegible]
Erythrococca sp 1	[illegible]
Strychnos spinosa	[illegible]
Vernonia wakefieldii	[illegible]
Gesneria sp.	[illegible]
Polypodiaceae sp.	[illegible]
UPS 69	[illegible]
Drypetes reiseleyi	[illegible]
Lilium sp.	[illegible]
UPS 70	[illegible]
UPS 71	[illegible]
Justicia § Angellia	[illegible]
UPS 72	[illegible]
Mlolo-Mbuzi	[illegible]
Portulacca sp	[illegible]
UPS 73	[illegible]
Dalechampia ipomoifolia	[illegible]
Vitex cf doniana	[illegible]
UPS 74	[illegible]
UPS 76	[illegible]
Clerodendrum eriophyllum	[illegible]
Annonaceae sp.	[illegible]
UPS 78	[illegible]

Gramineae and Cyperaceae

Gramineae and Cyperaceae	A1 – A2 – B – C – D1
Eragrostis ciliaris	[illegible]
Cyperaceae sp 1.	[illegible]
Cyperaceae sp 2.	[illegible]
Panicum repens	[illegible]
Panicum maximum	[illegible]
Eragrostis superba	[illegible]
Chloris roxburghiana	[illegible]
Chloris virgata	[illegible]
Heteropogon contortus	[illegible]
Dactyloctenium geminatum	[illegible]
Sporobolus pyramidalis	[illegible]
Echinochloa haploclada	[illegible]
Leptochloa panila	[illegible]
Eragrostis sp.	[illegible]
Cyperaceae sp. 4	[illegible]
Enteropogon macrostachyus	[illegible]
Cyperaceae sp. 5	[illegible]
Cyperaceae sp. 6	[illegible]
Cyperaceae sp. 7	[illegible]
Cenchrus ciliaris	[illegible]
Paspalum geminatum	[illegible]
Cyperus articulatus	[illegible]
Imperata cylindrica	[illegible]
Cyperaceae sp. 8	[illegible]
Cyperaceae sp. 9	[illegible]
Sporobolus marginatus	[illegible]
Aristida adscensionis	[illegible]
Digitaria macroblephara	[illegible]
Perotis hildebrandtii	[illegible]
Digitaria abyssinica	[illegible]
Dactyloctenium aegyptium	[illegible]
Graminae sp 1	[illegible]

A1	A2	B	C	D1