TRAINING PROJECT IN PEDOLOGIE

KILIFI KENYA

A PRELIMINARY RECONNAISSANCE SOIL SURVEY OF THE KILIFI AREA

PRELIMINARY REPORT NO 1

(KILIFI SERIES)

AGRICULTURAL UNIVERSITY

WAGENINGEN - THE NETHERLANDS

A PRELIMINARY RECONNAISSANCE SOIL SURVEY OF THE KILIFI AREA

by

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Preliminary Report no. 1
(Kilifi Series)
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TRAINING PROJECT IN PEDOLOGY, KILIFI KENYA
Agricultural University, Wageningen - The Netherlands

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Preface

This is a Preliminary Report of the Training Project in Pedology (T.P.I.P.) at Kilifi (Kenya),of the Section in Tropical Soil Science of the Agricultural University at Wageningen (the Netherlands).It is the first of a new series to be presented to Kenya Officials.

The Training Project in Pedology was started in 1972 in the Kisii area.The soil studies in that area resulted in the publication of mapsheet 130 (mapsheet Kisii) of the soil map of Kenya, scale 1:100,000 and a report on its soils,with chapters on geology,vegetation,agriculture and land evaluation (in print).Some 30 preliminary reports on varying subjects were issued or are in preparation.

In 1979 the project was transferred to the Kilifi area at Kenya's Coast,and project activities started in September.Also this project has as its major aim the production of a mapsheet (Kilifi) on scale 1:100,000 in the frame of the Soil Map of Kenya in cooperation with the Soil Survey of Kenya (Ministry of Agriculture).There are also links with the faculty of Agriculture of the University of Nairobi.

The project is meant for training of postgraduate students of the Agricultural University at Wageningen and for furnishing research opportunities of the staff.The activities of students and staff are directed to obtain a better knowledge of the soils, and the agricultural conditions of the project area to provide a basis for further agricultural development of the area.

The project at Kilifi is conducted by:

DR. IR T. de Meester (Principal)
Teaching and research

ING. H. W. Boxem (Manager)
Management and teaching

Visiting specialists from the Agricultural University at Wageningen help to resolve special problems.

This report is the result of a preliminary Soil Survey of the entire Kilifi area.The text was written by Messrs. J. Floor, R. Onck, E. Smaling, J. van der Lek and J. Reitsma.It was edited and compiled by Mr. R. Onck, who did also most of the cartographic work, and the typing of the final manuscript.

Special acknowledgement should be made of the kind help and cooperation received from the D.C.,Mr. Omuse and the D.A.O. , Mr. Were of the Kilifi District.The Director Mr. Muchena and his staff of the Kenya Soil Survey, Mr. P.Oosterom of WOTRO, and Dr. R. Cannon (geologist) helped very much by introducing us to the soils,geomorphology and geology of the area.

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

the supervisor of the project,

J.Bennema
(Professor in tropical soil science)

Summary

This preliminary reconnaissance Soil Survey of the Kilifi-area (mapsheet 198) was carried out from December 1979 to February 1980 and has to serve as a basis for further studies and detailed surveys.

The Kilifi area is situated north of Mombasa along the coast until some ten kilometres beyond Kilifi and westwards until Mariakani and Bamba (Fig. 1). The main town in its centre is Kaloleni.

Annual average rainfall is about 1200 mm near the sea and 600 mm near Bamba. The average annual evaporation is between 2000 and 2200 mm.

Geologically, the area is part of a system of Mesozoic and Cainozoic rocks, with a general Northeast- Southwest strike, deposited against the African shield. Outcrops of different ages and nature have boundaries, which run almost parallel to the coastline and so have landforms and soils.

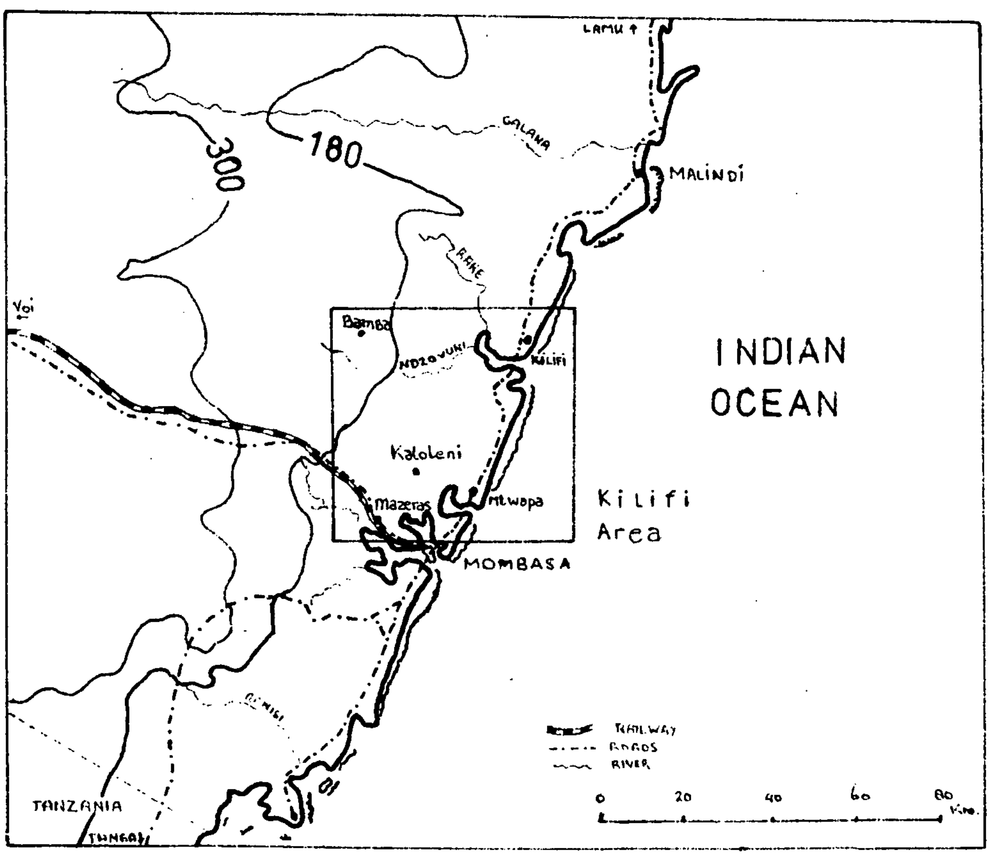


Fig. 1 : situation of the surveyed area

Geomorphologically the area can be divided into:
the Coastal Plain with shallow to moderately deep soils,developed on coral limestone, sandy and clayey, and very deep sandy and loamy sandy soils developed on coastal sands of windblown and lagoonal origin (mainly Lithosols, ferric Acrisols and dystric Nitosols)
the Coastal Uplands with a large variety of soils, developed on five different parent rock formations viz:

- In Magarini sands, which are extremely well drained, very deep, sandy clay soils (mainly rhodic Ferralsols and dystric Nitosols)
- In Jurassic shales with shallow and moderately deep heavy clay soils (mainly chromic Luvisols and chromic Vertisols)
- In Kambe limestone, with well drained with deep to very deep friable clays (mainly eutric Nitosols and ferric Acrisols)
- In Mazeras sandstone, with well drained sandy loamy and clayey soils (mainly ferralic Arenosols and dystric Nitosols)
- In Mariakani sandstone, with well drained sandy and loamy soils (mainly ferric Acrisols and dystric Nitosols)

the Erosional Plain with clayey and sandy soils,developed from Pleistocene bay sediments.The soils of the erosional plain are deep sandy or sandy with a clayey saline or sodic subsoil, and saline heavy clay soils (respectively ferralic Arenosols,solodic Planosols and orthic Solonchaks)
the Alluvial Plains with poorly drained heavy clay soils with vertic properties (mainly pellic Vertisols)
miscellaneous landforms like tidal flats and swamps (thionic Fluvisols), sand dunes (cambic Arenosols),alluvial fans (dystric Cambisols) and valley bottoms with a variety of poorly drained soils.

Vegetation and landuse are very much interrelated as can be expected in a cultivated area. The Coastal Plain has mainly a secondary bush vegetation with cultivated areas with fieldcrops (maize, cassava, simsim) and treecrops (coconut,cashew,mango and citrus). A large area is occupied by sisal monoculture and there is some cultivated grassland for dairy cattle. The Coastal Up - lands have area's with intensive treecrop culture (coconut , cashew and banana) mixed with food crops. Here and there are isolated patches of original tropical monsoon forests (kaja's).In the northern part of the Coastal Uplands is Brachystegia bushed woodland with grazing. The Erosional Plain is mainly Acacia Euphorbia bushland with predominant grazing and some treecrops (coconut). The tidal flats and swamps have a dense mangrove vegetation.

No analysis data are yet available for information on soil fertility.

NOTICE

In this Preliminary Report and map on the soils of the Kilifi - area, the soils have been tentatively classified according to the original text of the FAO/UNESCO legend for the soilmap of the world.

However, it happens that the Kenya Soil Survey Staff has developed in the past years several new concepts for the definition of Nitosols, Ferralsols and Acrisols. This was done to adept them to conditions in Kenya.

These adopted concepts were used in our final report and map on the soils of the Kisii area (mapsheet 130), tobe issued in 1980. But it was decided to stick to the original concepts in this preliminary report pending more detailed studies, and future developments in the KSS-versions. see also section 4.4 of this report.

We like to state however, that it is our intent to fully include the prevailing KSS - views on soil classification in the final report and map of the Kilifi area (mapsheet 198), expected to be issued in 1982.

1. Introduction

This is a report with a preliminary Soil Map on scale 1:100,000 of the Kilifi area (mapsheet 198). The survey activities started in October 1979 and ended in December.Map and report were compiled in the first two months of 1980.The work was carried out under the supervision of the projectstaff by 5 post-graduate students viz-

J. Floor	Tropical Soil Science
R.F.M. Onck	" " "
E. Smaling	" " "
J.J. van der Lek	Vegetation
J.M. Reitsma	Botany

The very purpose of this report and map is to serve as a general basis for further mapping and research of the area. The next stage will be the study of soils,landuse and vegetation of so called Sample Area's and the detailed mapping of such area's, which have to be representative for the region.The final result to be attained within the project period of the 3 years,will be a soil map on scale 1:100,000 ,according KSS-standards,with an extensive report, including a study on landevaluation of the same area.Fig. 1 is a key map of the area,indicating the position of mapsheet 198, major villages and acces roads.

A number of results,mentioned in the report are to be considered as tentative only;analysis data and results of detailed studies will be needed for confirmation or revision.

2. The environment

2.1. Location and extent of the surveyed area

Kilifi District is part of the Coast Province,which further comprises the Districts Lamu,Tana River,Taita/Taveta, Kwale and the Mombasa municipal.

The surveyed area is bounded by latitudes $3^{0}30'$ S and $4^{0}00'$ S,and longitude $39^{0}30'$ E and the Indian Ocean. The area comprises four topographic 1:50,000 mapsheets: Bamba (198/1), Kilifi (198/2), Mazeras (198/3) and Vipingo (198/4). The four sheets together form mapsheet 198 of the Soil Map of Kenya 1:100,000. The total surveyed area covers approximately 200,000 hectares. The elevation ranges between 0 and 382 m. above Mombasa sealevel.

Main villages are Kilifi, Ganze, Bamba, Vipingo, Kaloleni, Mazeras and Mtwapa. Two tarmac roads traverse the surveyed area: the Mombasa-Malindi road (along the coast) and the Mombasa-Nairobi road (in the southwestern part). The roads Kilifi-Kaloleni, Kaloleni-Mazeras (tarmac) are good roads,providing E-W connections. The pipelineroad (that follows approximately the limestonebelt) and the road Bamba-Gotani/Mariakani are important N-S roads in the "hinterland".

The main rivers are the Ndzovuni, the Rare, the Mtomkuu and the Kombeni; there are three important tidal creeks, Kilifi-creek Mtwapa-creek and Tudor-creek. The area is mainly inhabited by the Giriama tribe.

Fig. 1 shows the situation of the project-area at Kenya's coast.

2.2. Climate

2.2.1. General

Rainfall, humidity, temperature, sunshine and air- circulation are some of the factors that make up the climate of a site. Climatic conditions and particularly the annual and seasonal balance between rainfall and evaporation,together with the soil-resources, are the main factors determining the agricultural potential of an area.

The weather of the Kenya coast is largely controlled by the great monsoonal air currents of the Indian Ocean in combination with orographic effects of the coastal hills and convection over the hot, dry hinterland immediately to the west.

Because of Kenya's position across the equator, the area is mostly sunny and generally warm,with only slight variations during the year.There are therefore no real seasons in the sense of temperate spring,summer,autumn and winter.

Indeed it is because of this uniformity and rather high rates of evaporation that rainfall and rainseasons have such importance in the climatic spectrum.

In the following paragraphs, details are given of the different climatic factors in Kenya's coastal region,in particular the Kilifi District.

2.2.2. Rainfall and evaporation

As can be derived from the following hydrological equation:

Precipitation= Evaporation + Run-off + Drainage + Storage , the total average annual rainfall and total annual evaporation provide a first impression of the main water balance characteristics of a site (Fig. 2 and 3).In our case however,like in most parts of the tropics, figures for average annual rainfall are of limited value to the agriculturist.In the first place it provides no indication of seasonal occurence of rainfall. Secondly the factors runoff and evaporation are of much more importance than in the temperate regions and thirdly there is a great variation in precipitation from year to year,so there is no indication of the expectation of rainfall during any period.

Much of the rainfall of the Kenya coast is associated with the Intertropical Low or Convergence Zone, which lies over South Tanzania in January, and over Mid-Sudan in July.

In our area the year starts dry and remains so until March when rainfall gradually increases.A fairly rapid increase occurs through April and builds up to a maximum of rainfall in May. Then rainfall decreases steadily but significant amounts are still recorded in October and November.During December a decrease is registered that leads to the rainfall minimum in January and February (Fig. 4,5,6 and 7).

This pattern of rainfall is called bimodal,because of its two rainy seasons and pronounced intervening dry seasons.

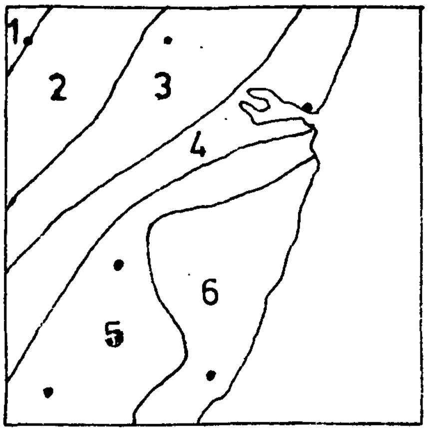
As can be seen from the data of Table 1, May is the wettest month all around.The short rains period is less pronounced at the Coast than in the "hinterland". In Ganze and Kaloleni, November is the second wettest month, while in Kilifi and to a lesser extent Mtwapa,there is no significant difference between July-September and October-December (Table 2).

	JAN-MAR	APR-JUN	JUL-SEP	OCT-DEC	TOTAL
BAMBA	78	270	103	226	677
GANZE	87	340	140	265	832
MARIAKANI	125	342	156	273	896
KILIFI	71	507	190	187	955
KALOLENI	99	398	254	337	1088
MAZERAS	104	444	202	344	1094
MTWAPA	103	640	265	268	1267

Table 2: rainfall (mm) and - distribution per season

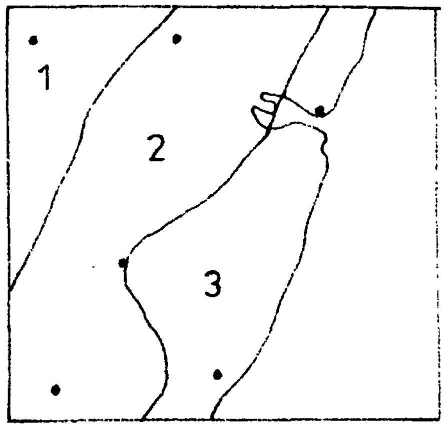
In some places the bimodal rain distribution type may enable two cropping seasons a year for annuals,which may increase agricultural productivity significantly. However crop production in the short rains period can be greatly restricted by the low amount and the low reliability of the rainfall.Exact uniformity or exact prediction are nowhere to be expected, and in Kilifi area we deal with quite unreliable rainfall. The variation in annual or seasonal totals around its mean is considerable, as well as the variation in the time at which expected seasons actually materialize.The latter strongly affects planting dates and the general timing of farm operations

Evaporation is more a property of the climate than a climatic factor. The evaporative potential of a climate is a function of incoming radiation and temperature of humidity and wind. Currently the Penman formula is regarded as providing the most reliable estimation on evaporation,because of its proper physical



1	600 - 700
2	700 - 800
3	800 - 900
4	900 - 1000
5	1000 - 1100
6	1100 - 1200

Fig.2 : average annual rainfall (mm)



1	2200-2300
2	2100-2200
3	2000-2100

Fig. 3: average annual evaporation

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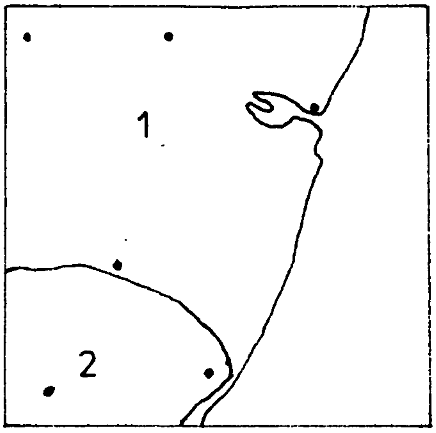
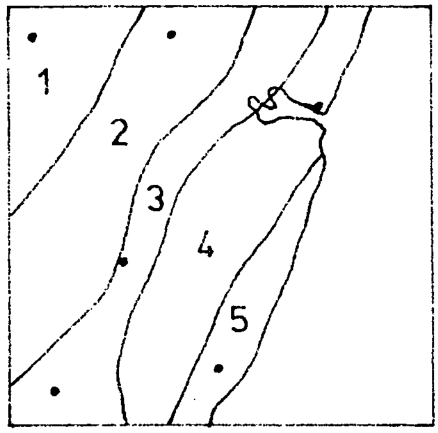
basis.In contrast to rainfall, evaporation varies little from year to year.Evaporation tends to be greatest when and where rainfall is lowest,due to clear skies, high temperatures and relatively low elevations, as for instance in Bamba (Fig. 2 and3)

Actual evapotranspiration is well below potential evaporation,because of limitation of water supply.Besides, the vegetation does not form a complete cover.



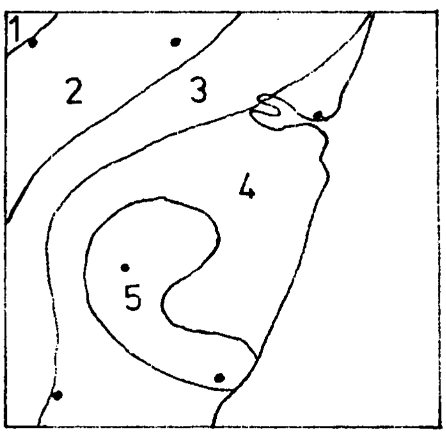
1	50-100
2	100-150

Fig.4 : average rainfall January-March



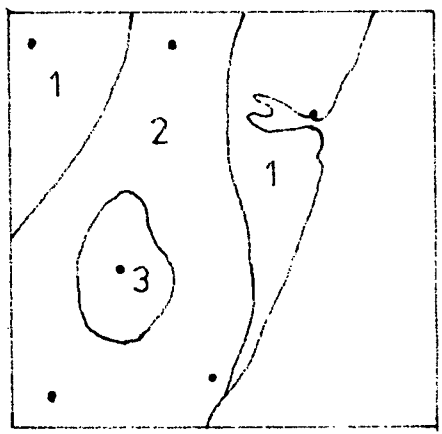
1	200-300
2	300-400
3	400-500
4	500-600
5	600-700

Fig.5 : average rainfall April-June



1	50-100
2	100-150
3	150-200
4	200-250
5	250-300

Fig.6: average rainfall July-September



1	200-250
2	250-300
3	300-350

Fig. 7: average rainfall October-December

STATION, ALTITUDE, AMOUNT OF RAINFALL

	J	F	M	A	M	J	J	A	S	O	N	D	Total
BAMBA (1) (240 m., 14 yrs.)	10	15	53	104	137	29	27	30	46	74	78	74	677
GANZE (2) (180 m., 25 yrs.)	25	14	48	97	187	56	42	44	54	84	103	78	832
MARIAKANI (3)* (195 m., 30 yrs.)	35	18	72	118	166	58	44	53	59	89	108	76	896
KILIFI (4) (3 m., 49 yrs.	18	15	38	122	268	117	78	56	56	71	73	43	955
KALOLENI (5) (220 m., 11 yrs.)	31	25	43	121	175	102	77	81	96	141	134	62	1088
MAZERAS (6) (160 m., 9 rs.)	25	22	57	150	194	100	59	81	62	130	145	69	1094
MTWAPA (7) (21 m., 13 yrs.)	21	26	56	235	246	159	106	80	70	104	123	41	1267
Wettest spot:	3	7	3	7	4	7	7	5/6	5	5	6	2	
	(35)	(26)	(72)	(235)	(268)	(159)	(106)	(81)	(96)	(141)	(145)	(78)	
Driest spot:	1	2	4	2	1	1	1	1	1	4	4	7	
	(10)	(14)	(38)	(97)	(137)	(29)	(27)	(30)	(46)	(71)	(73)	(41)	

* Mariakani does not belong to the surveyed area; it is situated just outside mapsheet 198/3

TABLE 1 :RAINFALL DATA

2.2.3. Wind

Kilifi District is situated between latitudes $3^{0}30'$ and $4^{0}00'$ S of the equator.Prevailing winds blow between South and East, and the mean run is about 160 kilometres per day.The SE-monsoon is reponsible for the long rains period in April and May. The winds originating from the Southern Indian Ocean are saturated with water vapour. When the airmasses reach the heated land, or when they are being lifted up on encountering hills or mountains,the watervapour is condensating. From May to October winds blow from the South, still causing rain around Lake Victoria,but at the Coast this period will be somewhat drier.

From November to March winds blow into the equatorial low pressure belt (Intertropical Low or Convergence Zone), from Northeastern direction. The axis of the low pressure belt tends to follow the sun, moving southward in November and December and returning slowly from its extreme position (15^{0} S) in January to Approximately 15^{0} N in July.

From May to November the Convergence Zone is obliterated and there is a great airstream across the Indian Ocean from the South to the North.

2.2.4. Radiation and temperature

Daylength is rather constant; hours of sunshine may vary somewhat, the average is about 7 to 8 hours per day. High humidity and cloudiness are factors that boost net radiation.

Temperature is not a very important factor. Of course there is a suitable temperature for plant growth, but the seasonal variation is just slight. Average minimum temperatures in Kilifi District are about 22^{0}C ,average maximums grade from $26-30^{0}$C in the coastal belt up to $30-34^{0}$C in the environment of Bamba

2.2.5. Humidity and dew

The amount of water vapour that is carried in the air is important to both plant and animal life. In particular, it affects the rate of transpiration in plants and the rate of surface evaporation in soils .High atmospheric humidity helps to conserve water. As a general rule, humidity is highest near to the sea. Absolute humidity is the expression for the temperature, to which air must be cooled for condensation to occur (dew-point). Mean annual dewpoint at the coast amounts 23^{0}C, and it will drop at a rate of 5,5^{0}C per 1000 m ascent.

2.2.6. Relation climate and soil

Post and present climate is an important factor in soil formation. First it is involved in weathering processes (decay of rock by hydrolysis, removal of carbonates, weathering of primary minerals), second its function with respect to soil forming processes like oxidation and humification of organic matter and heterogenisation processes in the soil profile is clear.

The moisture regime of a soil is an important property of the soil, often used as a criterium for processes in the soil. However during past eras there have been significant changes in climate, so not every soil type is formed under the present climatic circumstances. The present day soil moisture regime in our area is mainly an ustic moisture regime. The concept is one of limited moisture, but the moisture is present at a time when conditions are suitable for plant growth. The mean annual soil temperature is 22^{0}C or higher and the mean summer and winter soil temperatures differ by less than 5^{0}C at a depth of 50 cm (isohyperthermic temperature regime); moreover if the soil possesses an ustic moisture regime the soil moisture control section is moist in some part for more than 180 cumulative days, or it is continuously moist in some part for at least 90 consecutive days.

In tropical and subtropical regions that have either one or two dry seasons, summer and winter have little meaning. In those regions, the ustic regime is that typified in a monsoon climate that has at least one rainy season of three months or more. The soil moisture regime at the western part of the area tends to become drier, i.e. almost aridic. In the following, examples are given of soil units in our area which have been developed in former climates.

In the plain, where bay-sediments are deposited,west from Bamba-Gotani, calcic horizons occur in the soils (soil description 23), being a symptom of net upward watertransport in those profiles. This corresponds with the almost aridic moisture regime in that area.

The shale belt, especially north of Kilifi-creek, seems to receive less rain in the long rains period because it is situated in the rainshed of the hills on either side.The Magarini sands must have been subject to wetter moisture regimes in the past,because Oxisols and Ultisols have been developed (soil profile description 7). Ultisols are also found on the Kilindini sands (Coastal sands), indicating periods of a net downward waterflow through the soil.

The planosols (soil description 22) may have been subject to ferralysis due to former reduced conditions.

2.2.7. Rain intensity and erosion hazard

Most of the rain falls in heavy showers, peak rates may reach up to 100 mm/hour. A high rain intensity and thus a high kinetic energy of the rain may cause splash erosion, when the soil has a low aggregate stability and is not covered with vegetation. By the impact of rain drops, the soil aggregates desintegrate and after having dried up the soil surface is sealed and becomes almost impermeable. Much of the rain, so important for crop growth,will then disappear as surface run-off, and the storage is nearly zero.

Water erosion phenomena were observed in the following soil units:

Usm, Magarini sands:	Slight rill- and gully erosion
UT, Shales:	Splash erosion, sealing and run-off is moderately severe, when there is an incomplete vegetation cover
USs 2, Mazeras sandstone:	Slight sheet and rill erosion; in case of a rather high slope gradient and the absence of a surface covering crop, moderate sheet- and gully erosion
USK 1, Mariakani sandstone:	The fine grained sands are susceptible to slight rill erosion, gra-

ding to moderate when there is no
efficacious vegetation cover

2.3. Geology and geomorphology

2.3.1. Introduction

The coastal zone is one of low relief; a coastal plain with altitudes up to 60 m (200 ft) above sealevel, and an adjacent zone of undulating coastal uplands, up to 300 m (1000 ft).Only few summits exceed the 300 m contour, of which the highest is Simba Hill (347 m). Along the coast a fringing reef is developed, with marked gaps at the mouth of the rivers.

Geologically, the area is a part of a system of Mesozoic and Cainozoic sedimentary rocks, with a generally NE-SW strike, deposited against the African shield.The sediments, i.e. sandstones, siltstones, shales and limestones, representing continental, lacustrine and marine facies, were deposited along the margins of a trough, subject to flexures and fractures (Caswell, 1956).

This chapter deals with a brief description of the geological history of the Kilifi district, and some attention is paid to the geomorphology of the area, especially with regard to the coastal terraces. A simplified geological map is presented in Fig. 8. For a stratigraphical summary reference is made to Table 3 ; also the geological map symbols are given in this table.

The oldest rocks in the surveyed area belong to the Duruma Sandstone Series. Only upper-Duruma (Mazeras formation) and middle-Duruma (Mariakani formation) are exposed in the surveyed area.

2.3.2. Triassic rocks

Mariakani sandstone

These are fine grained deltaic and lacustrine sandy deposits ("flagstones") of lower-Triassic age, derived from the Paleozoic rocks. Locally,bands of more resistant,massively bedded sandstone occur, forming a well marked step, as can be traced

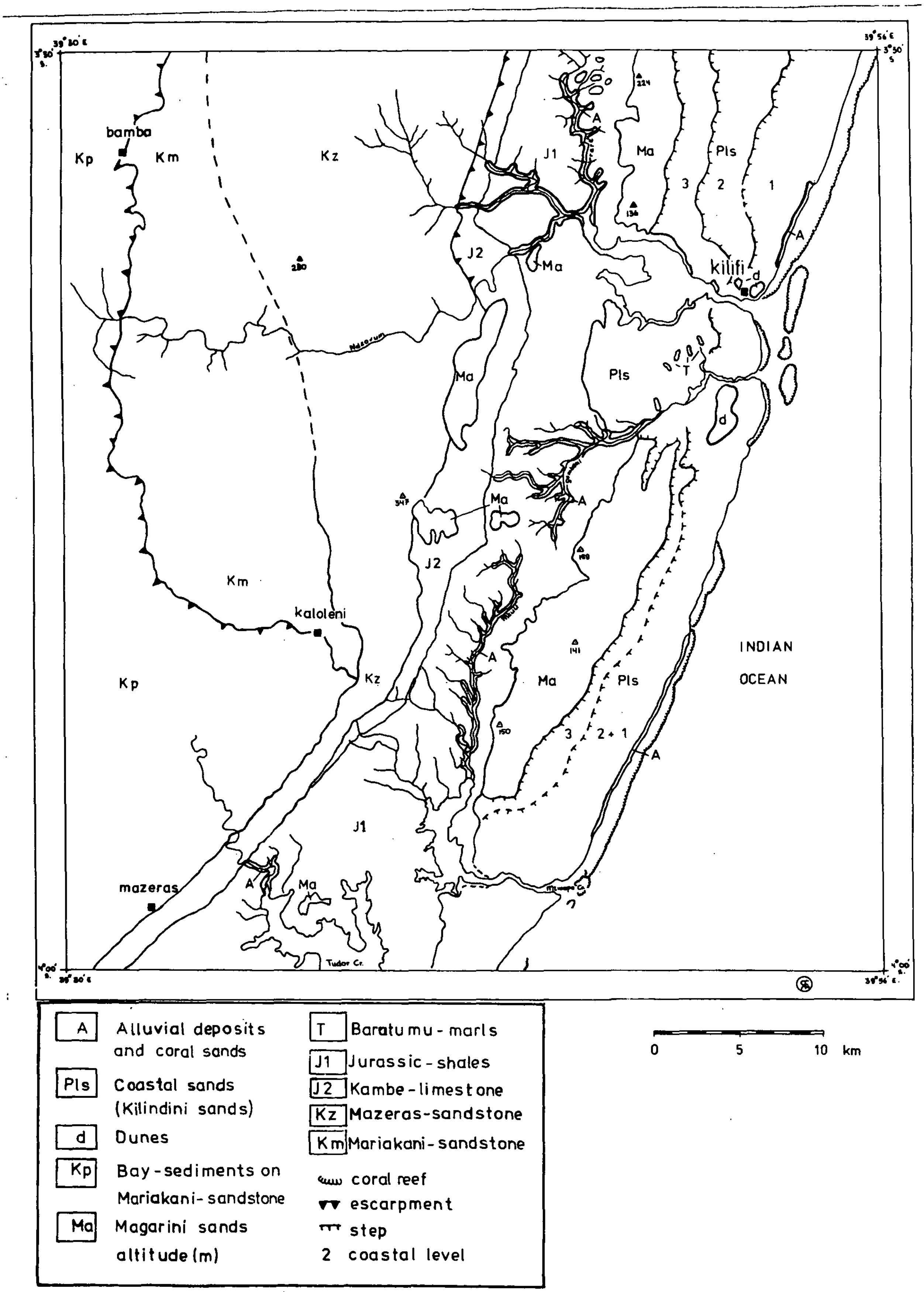


Fig. 8 Geological map of the Kilifi area

era	period		age (yr)	map symbol	deposits		
CAINOZOICUM	Holocene		10^4	A	recent coral sands sandy and clayey alluvial deposits		
	Pleistocene		2.10^6	Pls Ma	coastal sands windblown and fluviatile deposits (Magarini sands)		
	Pliocene		7.10^6				
	Miocene		26.10^6	T	yellow marls (Baratumu beds)		
MESOZOICUM			136.10^6				
	Jurassic	upper	162.10^6	J1	shales		
		middle	172.10^6	J2	Kambe limestone		
		lower	195.10^6	Kz	Duruma Sandstone Series	Mazeras-sandstone shale-bands	covered with quaternary medium-textured sands
	Triassic	upper					
		lower	225.10^6	Km Kp #		Mariakani-sandstone	pleistocene bay-sediments #

Table 3 :stratigraphy of Kilifi area (from Caswell et.al.1956)

from Kaloleni westward to Gotani, and further northward towards Bamba.

According to F.M. Karanja (Geol.Surv. of Kenya,1979), the Mariakani sandstones and siltstones can be divided into upper-, middle-, and lower-Mariakani, consisting of fine grained sandstones with shale intercalations at their bases. From pedological point of view this is of little importance as most of the Mariakani area is covered with younger deposits.

The area on the west- and southwest side of the Kaloleni-Bamba escarpment forms a broad flat lowlying plain, covered with salty,fine sandy, Pleistocene bay-sediments (P.Oosterom,pers. comm.). These sediments were dissected in a later stage, thus partly exposing the underlying Mariakani sandstone. The contact between the bay-sediments and the sandstone is marked by a pebble layer at 180 m (600 ft) containing artefacts, which according to J. Bennema (pers.comm.) may originate from the Mousterien (upper-Pleistocene) period. However,taking into consideration, the similarity with the artefacts found on the 3d coastal level (see chapter 2.3.4.) they may well be older.

The area east and northeast of the escarpment consists of medium textured sands of which the greater part can be ascribed to the late-Cainozoic era (Thompson,1956). The landform is gently undulating,with few moderate deep (up to 90 m) incised rivers, for example the Ndzovuni river. Slopes are generally convex and about 20%. P.Oosterom (pers.comm.) distinguishes three different levels, either erosional or depositional,i.e. at 225 m (750 ft), 245 m (850 ft) and 300 m (1000ft) with well defined differences in soil development. However this was only partly confirmed by our records. The origin of these levels, which definitely do exist, either erosional or depositional, remains yet obscure.On the other hand, the 300 m (1000 ft) level may be likely to correspond with the so-called sub-Miocene erosion bevel, a gently SE-sloping downwarped peneplain which outstretched over large parts of Africa (Ojany,1973;see also W. Pulfrey,1960). Possibly the 245 m and 225 m levels correspond to terraces of a "primitive" Athi-river or tributaries (see: W. Pulfrey,1960).

Mazeras sandstone

These are coarse grained sandstones alternated with yellow to purple shale-bands, deposited under continental, lacustrine and deltaic conditions; they overlie the Mariakani sandstones, often with a faulted contact.The Mazeras sandstones locally contain silicified wood.

The eastern flank of the formation gives rise to a range of hills, up to 300 m(1000 ft) ; westwards it forms gently undulating ground, with convex slopes.

As outcrops are rare and indistinct, the exact boundary between Mazeras- and Mariakani sandstones is not very clear. This probably accounts for the differences between the geological maps of Caswell(1956) and Karanja(1973). From a pedological point of view the exact boundary is of minor importance as both formations are partly covered with younger sediments.A distinction was made between soils developed on coarse to medium grained sands (Mazeras formation) and on medium to fine grained sands (Mariakani formation).

In the Mazeras formation, a belt of brown shales can be distinguished, forming a well defined depression at approximately 150 m (500 ft), extending from Ganze in southern direction. According to P. Oosterom (pers.comm.) this could be a tributary of the Pleistocene bay. Unfortunately no clear evidence for this hypothesis could be found, yet soils in this part appeared to be salty.

On few places the Mazeras sandstone is covered with shallow red Pliocene sandy deposits (Magarini sands).In a quarry southeast of Ganze the contact between Magarini sands and underlying Mazeras sandstone can be studied (Fig. 9).

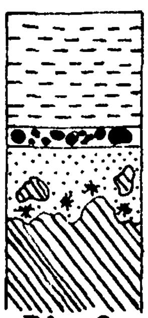


Fig.9

At the base,unweathered Mazeras sandstone is exposed. On top of this, a 80 cm deep, sandy,weathered sandstone residue occurs,with some partly weathered sandstone fragments.This layer also contains plinthite and some angular quartz fragments. This layer is covered by a well marked, 25 cm. thick, layer containing rounded sandstone pebbles,ironstones, and rounded quartzite pebbles,the latter obviously derived from the hinterland, and suggesting a fluviatile origin.This layer underlies a 1.5 m deep clayey Magarini deposit in which a soil profile has been developed.

2.3.3. Jurassic rocks

The Jurassic transgression affecting the Kenyan coast resulted in the deposition of thick (about 300 m) strata of limestones and shales. The Jurassic rocks form a continuous belt between the Cainozoic deposits and the Duruma Sandstone Series, on which they rest unconformly, generally with a faulted contact (Caswell,1956).

Kambe limestone

In the north the limestone forms a well marked escarpment, overlooking shales, with altitudes of about 180 m (600 ft), and some deeply incised river valleys (Njora:120 m, Ndzovumi:180 m). South of Jaribuni the limestone has given rise to a flat topped topography with Karst features such as hums (small, dome-like residual limestone mounds), rill-lapie's ("Karren"),solution caverns, and steep sided canyons. The eastern flank of the limestone ridge is thought to represent a former coastal cliff,in which some caverns were formed.

On several places the Kambe limestone is capped with dark reddish clayey sands, representing remnants of a former outstretched cover of Magarini sands. The distinction between Magarini sands and the in situ weathered limestone, giving rise to "terra rossa", is not always clear; generally the latter has a less defined red colour and a lower sand content.

Jurassic shales

These upper-Jurassic deposits form a strongly dissected depression between both the older and the younger deposits.

The shales attain maximum altitudes of approximately 120 m (400 ft). According to Thopmpson (1956) this corresponds with a Tertiairy erosional plain. Several watersheds at 75 m (250 m) have a flat topped topography, due to a cover of Magarini sands. Near Sokoke plantation a section can be seen in a roadcut,showing

Magarini sands with a basal pebble-layer, containg ironstones, resting unconformly upon the Jurassic shales. These Magarini sands once covered an outstretched area, but as a result of Pleistocene erosion which dissected the shales, only remnants can be found.

The river Rare is 60 m deep incised; it has a broad flat valley bottom showing small levees and backswamps. The ideal slope profile consists of a slightly convex watershed at 75 m , a rectilinear upper part (17 %), a knickpoint at 30 m (100 ft) probably related to marine terraces at the coastal plain, a rectilinear lower part (20 %) and a relatively short concave knick to the flat alluvial plain. The smaller contributaries have V-shaped valleys, occasionally with small flat valley bottoms.

In recent times the tidal creeks could easily penetrate into the shales.

As the shales are very susceptible to erosion, nowadays gully erosion takes place on the steeper valley sides, probably accelerated by human influences.

2.3.4. Cainozoic rocks

Cainozoic rocks represent a broad variety of consolidated and unconsolidated Tertiairy and Quaternary rocks, deposited in different sedimentational environments.

Cretaceous and early Tertiairy times are being considered as periods of predominant erosion,which formed possibly a 120 m (400 ft) level in the shale belt.

Baratumu beds

The Baratumu beds comprise the yellow sandy marls that are believed to be of Miocene age and deposited under littoral or neritic conditions (Thompson,1956). Generally these marls are covered with Pliocene and Pleistocene deposits.Probably the Baratumu beds rest unconformly on the shales with a slight inclining, almost horizontal dip. Their horizontal extension may well be as far as the present coastline thus underlying the Pleistocene coral reefs.

The tidal creeks cut deep channels in the coastal plain,and it is there where major outcrops of the Baratumu beds can be observed. Furthermore they are occasionally exposed at the rim of the 3d coastal level (see page 20). The contact between the Jurassic shales and the marls can be studied at the Mitangoni-Mbuyuni road, 7 km. south of Kilifi creek.

From pedological point of view the Baratumu beds are of minor importance as they are generally covered with younger sediments.

Magarini sands

These are red to dusky red sandy deposits, mainly derived from the Duruma Sandstone Series, and exposed in a NS ridge. Their base is marked by a pebble layer containing rounded Archeian quartzite pebbles, ironstones and sandstone pebbles. The nature of this base suggests a deposition of river gravels of a piedmontlike type, probably during a period of sudden uplift of the hinterland combined with an intensive erosion.The sediments are thought to be of Pliocene age. The lower limit of the Magarini sands occurs on a rather uniform altitude of about 75 m (250 m) indicating a relatively flat plain during deposition. Probably this plain represents a late Tertiairy peneplain.

The Magarini sands do not entirely consist of fluviatile deposits; also aeolian sediments occur, thought to be of lower-Pleistocene age. According to Caswell (1956) the upper limit for the fluviatile deposits being placed at about 90-100 m, results in a total thickness of 15-25 m fluviatile strata. It has previously been indicated that several outliers of this formation occur on both Jurassic rocks,Miocene rocks and Duruma Sandstone Series. A possible level of 135 m (450 ft) of which remnants can be found at Sokoke and Vipingo Estate, should then be looked upon as aeolian deposits. Near Sokoke, the existence of a ridge of higher hills (up to 225 m) also suggests an aeolian origin (Caswell,1956). Thompson (1956) splits the Magarini sands, according to their origin in Pliocene fluviatile sands, the so called Marafa beds, and the Pleistocene wind blown deposits, the Magarini sands proper sense. However, as this terminology is rather confusing in respect to other publications, we will not adopt it.

The Magarini sands form a flat topped ridge, with an undulating topography suggesting either fluviatile dissection or aeolian redistribution or both. Locally a belt of prominent white sands occurs, at an altitude of about 90 m (300 ft), situated at the flank of higher hills, a feature that will be discussed later.

Pleistocene and Holocene deposits

These deposits have built up the coastal plain,and are generally under 50 m (170 ft) in altitude. Generally these deposits are referred to as "Kilindini lagoonal and windblown deposits". As there are many doubts about the origin of these deposits and very little uniformity on this term, we prefer to use the term "coastal sands", comprising all deposits between the ridge of Magarini sands and the Indian Ocean (except for the tidal flats).

The coastal sands are built up by sediments of varying origins,i.e.

- recent,generally shallow red clays, derived from in situ weathered coral limestone
- recent beaches and dunes consisting of calcareous sands
- Pleistocene red lagoonal deposits,either sandy or clayey;these deposits contain fluviatile and aeolian redistributed Magarini sands, sands and breccia derived from coral rock, in varying and indistinct proportions
- Pleistocene windblown deposits forming minor ridges and isolated dunes, consisting mainly of quartz sands.
- Pleistocene (?) ,bleached white sands forming a belt on the eastern flank of the Magarini sands, at 45 m (150 ft)

The geology and geomorphology of the coastal plain is obviously related to the Pleistocene sea level changes.

As a result of the intermittent growing and diminishing of the polar ice-caps during Pleistocene times, represented by an alternation of glacial and interglacial periods in the temperate latitudes, the sea level was subject to considerable changes. In tropical areas however, the climatic variations express themselves in another way,i.e. wet phases(pluvials) and dry phases (interpluvials). Evidence which correlates the East African pluvial phases with the temperate glacial phases, and the interpluvial phases with the interglacial phases has not been proven beyond doubt. For the picturing of the geomorphological events however, this correlation is a very useful one. For a schematic review reference is made to Table 4, derived from Caswell (1956), Thompson (1956) and Ojany (1973)

In late-Pliocene times the sea level stood at 90-100 m OD, in accordance with the upper limit of the fluviatile Magarini-beds (Caswell,1956). The onset of the first pluvial period (Kageran pluvial) during a period of marine recession caused a drop in sea level to below its present level, and the Magarini sands were subject to severe erosion, hence, no marked erosion surface was developed (Caswell,1956).

During the following interpluvial the sea level rose to about 60 m OD and it was then that the bulk of the Magarini dune-sands accumulated (Caswell,1956), owing to a much drier climate and an ill-developed vegetation cover. I suppose that it was during this period that a marine terrace was developed at an altitude of about 50 m (170 ft), the so-called 3d level. On several places the contact between the sandy marine deposits and the underlying Baratumu beds can be studied. It is marked by a thin layer of rounded quartz pebbles and ironstones, and containing Pleistocene artefacts.On top of this a plinthitelayer occurs. On the western part of the 3d level, near Sokoke, a narrow belt of brilliant white sands occur,locally called Timboni sands. According to P. Oosterom this feature is due to intensive pdsolisation processes (removal of sesquioxydes) as a result of wet conditions in the past.Nearby, identical white sands occur at the 90 m level,probably owing to comparable hydrological conditions. Both belts are notable situated at the topographical flanks of higher ridges, which may have caused these specific hydrological conditions.These Timboni sands do not occur on the southern mapsheet (Vipingo).

At the end of the lower-Pleistocene,during the Kamasian pluvial, the sea dropped by some 60 m (200 ft) below its present level. A marine platform was cut at this low level on which coral

Table 4 :Pleistocene development of the coastal plain

period		pluvial/interpl.	Alpine sequense	sealevel	major events in coastal plain	level
Pleistocene	upper	Post-Pluvial	Post-Glacial	rise to OD	drowning of old river courses forming of mangrove swamps	
		Gamblian-Pluvial	Würm-Glaciation	-8 m OD	cutting of present coastal cliff	
		3rd Interpluvial	Last Intergl.	8 m OD	8 m platform	1
	middle	Kanjeran-Pluvial	Riss-Glaciation	-40m OD	platform cut at -40 m OD	
		2nd Interpluvial	Great Inter-glacial	30 m OD	growth of coral reef;barrier reef lagoonal sands accumulate windblown sands accumulate 15-30 m terrace 30 m knickpoint(?)	2
	lower	Kamasian-Pluvial	Mindel-Glaciation	-60m OD	cutting of marine platform upon which corals grow cutting of deep channels	
		1st Interpluvial	1st Interglacial	60m OD	50 m terrace;wind blown sands	3
		Kageran Pluvial	Günz-Glaciation	?	marine recession end of fluviatile Magarini sands accumulation	
Pliocene	upper			100m OD	fluviatile Magarini sands	
	lower				erosion	

polyps grew. Coral polyps tend to live in colonies; when they die their skeletons, made of calciumcarbonate, accumulate with other organisms to form coral limestone. In this way large banks of rock are gradually built up called coral reefs.Coral thrive best in warm,clear, salt water with a temperature of $20-30^{o}C$.
The fall in sea level enabled the rivers to cut deep channels, which reached their maximum extent in the then sea level (Ojany, 1973).

With the onset of the 2nd interpluvial in middle-Pleistocene times,the sea level rose to 30 m OD; simultaneously coral polyps grew on the marine platform, forming a barrier reef. Behind the reef a coastal lagune developed in which fluviatile and aeolian sediments accumulated, together with coral sands. These lagoonal deposits form a marine terrace at about 15-30 m (50-100 ft) OD,the so called 2nd level;in a later stage it was partially covered with windblown sands. The lagoonal deposits represent a range of different sediments.They comprise:

- fluviatile sands and clays originating from respectively the Magarini sands and the Jurassic shales
- windblown fine sands from the Magarini sands and hinterland
- calcareous sands and breccia, derived from the coral reef by wave action

Generally, the lagoonal deposits in the southern part of the surveyed area are more clayey than in the northern part.This may well be attributed to differences in depositional environments and erosional conditions (in the hinterland),as indicated above. According to Caswell(1956) the dunes near Kilifi and Takaungu are also of middle-Pleistocene age.
On the slopes in the belt of the Jurassic shales,frequently knick-points can be seen appearing at altitudes of about 30 m (100 ft) which may possibly be linked with the 2nd level.The knick-points then represent a former base level of erosion, evoked by rejuvenation of the stream courses as sea level dropped.

During the Kanjeran pluvial, a marine recession caused a drop of the sea level to about 40 m below its present level. The rivers were rejuvenated and a marine platform was cut at about -40 m OD. As the sea-floor sediments became exposed to subaerial erosion, the wind built up fine sandy dunes (Thompson,1956).

In the 3rd interpluvial, a platform was cut at about 8 m OD along the coast line; it was covered with marine sands, lagoonal deposits and windblown sands (1st level). According to P. Oosterom their thickness is generally less than 5 m. In these deposits artefacts (Neolithic potsherds) were found. Near the coastline, the clayey material seems mainly to be derived from in situ weathered coral limestone. Frequently this terrace is covered with both upper-Pleistocene and Holocene dunes, the latter being calcareous.

From a pedological point of view, there is a marked increase in soil profile development and profile differentiation from the 1st to the 3rd coastal level.

A slight marine recession, represented by the Gamblian pluvial, caused the cutting of cliffs on the seaward side of the coral reef (Thompson,1956). Probably, a platform was cut at -8 m OD (Caswell,1956).

The final phase was a rise of the sea to its present-day level in the post-pluvial period; the old river courses were drowned to form the present tidal creeks.

In recent times, the formation of tidal flats took place, on which mangrove forests developed. The alluvial fill of the valleys, especially in the shale belt, started already in upper-Pleistocene times but continued in recent times, giving rise to marked levees and backswamps bordering the tidal creeks and the major rivers.

2.3.5. Summary

Taking into consideration the geological and geomorphological setting, as pictured above, one may well divide the surveyed area into three major geomorphological zones, roughly running parallel to the coast:

<u>the Coastal Plain</u>,

a flat to gently undulating plain,consisting of sediments of varying origin, and of Pleistocene and Holocene age. It's seaward margin is generally formed by a well marked cliff; the western boundary with the Coastal Uplands is represented by a scarp.

The plain is built up by three distinct marine terraces, of which the lower two are developed on coral limestone, and the upper one on sandy marls. The Coastal Plain is dissected by some tidal creeks, representing drowned river courses ("ria's "), and some minor valleys. Other meso-relief features are formed by several dunes and an alluvial fan.

the Coastal Uplands,

consisting of a wide range of different Tertiairy and Mesozoic rocks,i.e.

- Magarini sands: fluviatile and windblown, Cainozoic deposits, forming a prominent ridge with an undulating to rolling character
- Jurassic shales: occurring as a strongly dissected depression, with mainly V-shaped valleys; they also comprise distinct alluvial plains, relatively broad,flat valley-bottoms, ending at the tidal flats
- Kambe limestone: a rectilinear escarpment in the north, and a plateau-like topography in the south,covered with "terra rossa"
- Mazeras- and Mariakani sandstone: forming undulating (N) to hilly (S) ground, with generally convex slopes, and mainly sandy soils; the main rivers are deeply incised, with indistinct terraces

the Erosional Plain,

a flat, low-lying, salty plain below an escarpment,and representing a Pleistocene bay; it extends far beyond the surveyed area.

2.3.6. Present coastal morphology

The present coastline shows features of both submergence (ria's) and emergence, the latter being represented by raised beaches and cliffs.

During post-Pluvial and Holocene times, the sea level did not reach the level of the 3rd interpluvial,thus abandoned cliff-lines and raised beaches are well displayed along the coast. The cliff has an undercut notch, which regularly is enlarged into caves. Abrasion and hydraulic force are both vital to cave formation. Hydraulic forces occur as a result of the impact of breaking waves, causing air in crevices to be suddenly compressed thus loosening rocks and enlarging cracks. The overhang above the notch is a zone subject to sea spraying, resulting in the formation of sharp jagged ridges and pinnacles, known as coastal lapie's.

The present coral reef, a so called fringing reef consists of a coral platform with some channels and smaller lagoons. The reef's seaward edges are steep, owing to the more active development of the coral, where the braking waves bring in a regular supply of oxygen and plankton for coral growth (Ojany,1973). There are marked gaps in the reef at the mouth of more or less muddy rivers and creeks.

2.4. Vegetation and landuse

2.4.1. Introduction

In a cultivated area, natural vegetation and agricultural landuse both depend on physical factors (such as climate, soil and topography) as well as on human factors (such as clearing, burning and ploughing). Landuse may also be influenced by other factors, like pests, tradition or government policy. Vegetation and landuse were therefore studied and surveyed in combination.

The most important climatic factors for plantgrowth are rainfall, evaporation and temperature. Their interaction can best be expressed by defining bioclimatic zones. Fig. 10 shows their boundaries;the boundery criteria as calculated for the Kilifi area by the Kenya Soil Survey are given in Table 5

zone III :	r/Eo	= 50 - 65
zone IV :	r/Eo	= 40 - 50
zone V :	r/Eo	= 25 - 40
2 :	average annual temperature is 24-27^{o}C	

r = average annual rainfall (mm)

Eo= average annual potential evaporation (mm)

Table 5 : boundary criteria of bioclimatic zones

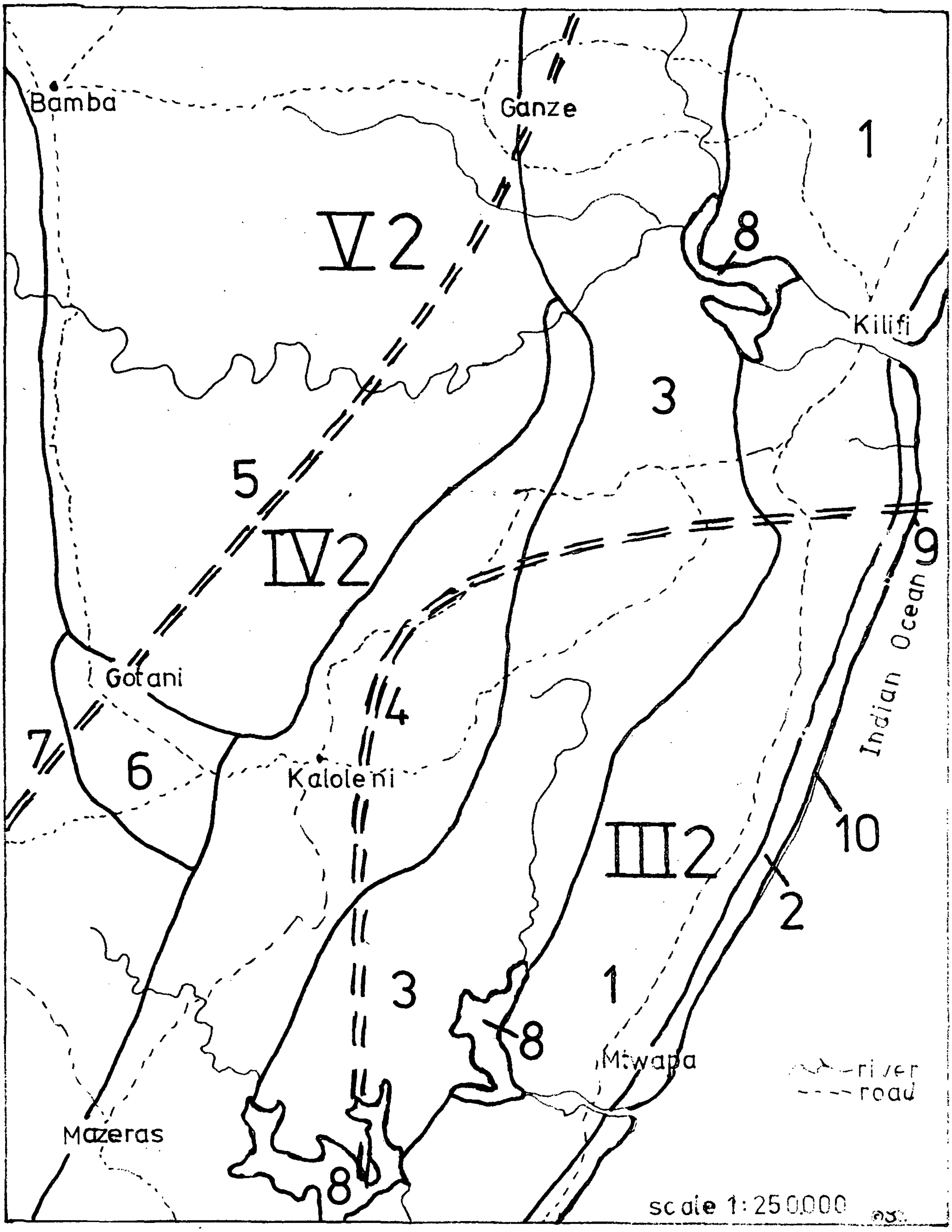


Fig. 10 : main vegetation zones (1 - 10 ; for explanation see text) and bioclimatic zones (III 2, IV 2, V 2 ; see Table 5)

However, soil conditions (such as soil profile, chemical and physical properties, and topography) are also important factors affecting vegeation and landuse in the Kilifi area.

The bio-climatic zones and the major soil groups (see soil map) have roughly the same pattern, parallel to the coastline, which makes it possible to draw a tentative map, showing some ten zones with different vegetation and landuse, as shown in Fig. 10.

2.4.2. The main vegetation and landuse types

The ten zones mentioned above have been typified by their characteristic natural vegetation or the remnants of it. The ten main vegetation types have been subdivided into complexes of natural vegetation and various forms of agricultural landuses. The resulting tentative legend to be used for a future vegetation and landuse map on scale 1: 100,000 is given below:

1 Lowland dry forest (Arabuko-Sokoke forest)

1A 20-50 % forest;50-80 % cashew;20-50 % fieldcrops(settlements)
1B 0-5 % forest; " " "
1C cultivated grassland
1D sisal monoculture

2 Lowland dry forest on coral rag

2A secundair bush vegetation
2B secundair bush vegetation + 20-50 % fieldcrops

3 Manilkara-Acacia cultivated savannah

3A 80-100 % savannah
3B valley bottoms
3C savannah + 80-100 % grazing
3D savannah + 50-80 % grazing + 20-50 % fieldcrops
3E savannah + 20-50 % grazing + 80-100 % fieldcrops

4 Tropical monsoon forest

4A kaja forests

4B 50-80 % fieldcrops + 20-50 % treecrops (coconut)

4C 20-50 % fieldcrops + 50-80 % treecrops (coconut)

4D 20-50 % fieldcrops + 80-100 % treecrops (coconut)

5 Brachystegia bushed woodland

5A Brachystegia bushed woodland with grazing

5B " " " + 50-80 % grazing

5C " " " + 20-50 % grazing+20-50% fieldcr.

6 Acacia Hyphaene savannah SW of Kaloleni

6A " + 20-50 % grazing + 20-50 % fieldcrops

7 Acacia-Euphorbia bushland W of Bamba

7A " + grazing

7B " + grazing + 20-50 % fieldcrops

8 Mangrove + swamps

9 Coastal vegetation on bare coral rock along the coast

10 Coastal vegetation on sand dunes and beach littoral

Type 1

Of this type only little remnants are present in our area, because of cultivation with cashew (Anacardium occidentale); mango (Mangifera indica); cocos (cocos nucifera) or fieldcrops. Directly north of our map area th forest is still intact, however Brachylena hutchensii is mostly cut for timber wood. South of Kilifi creek there is cultivated grassland (1C), where Hyparrenia rufa is an important grass. South of this there is a big sisal (agave spp.) estate.

In the cultivated parts of this type occurs ofcourse secondary bush (Hoslundia opposita); Harrisodia abyssinia; Premna chrysoclada; and others.

This type covers mainly the soils of the Coastal plains; including the Magarini sands. Some of the important species are: (in the natural forest):

Brachylaena hutchensii
Cynometra webberi
Afzelia cuanzensis
Brachystegia spiciformis
Trachylobium verrucosum
Manilkara pseudopulchellus

understory;
Strychnos drysophylla
Combretum hildebrandtii
Encephalartos hildebrandtii
Croton pseudopulchellus

Type 2

Lowland dry forest on coral rag.

This type grows on the very shallow sandy soils overlying coral rock. No natural remains are found in our area. Near Gede a natural forest remnant is found. Dominant species are:

Gyrocarpus americanus
Ficus bussei
Ficus spp.
Combretum schumannii.

Cassipourea euryoides
Adansonia digitata

Actually the coral rag is covered largely by dense thicket with scattered cultivated plots beteen it (mainly maize). This thicket can be considered as mainly secondary vegetation. The major species are:

Lantana camara
Securinega virosa
Hoslundia opposita
Grewia glandulosa
Combretum spp.
Premna chrysoclada
Phyllanthus spp.
Acalypha longipedunculata
Rhus natalensis
Dichrostachys cinera

Type 3

This type is growing in the clayey soil of the Jurassic shales, which have a bad drainage and a lot of surface runoff. That is why there are a lot of succulent species growing on this soil. To the south there is more cultivation on the shales (maize). Important species are:

Acacia mellifera
Ac. zansibarica
Ac. stuhlmannii
Ac. spp.
Manilkara zansibarensis
Diospyros cornii
Sterculia rhynchocarpa
Terminalia spinosa
Terminalia prunoides
Commiphora campestrus
Commiphora spp.
Piliostigma thonningii
Grewia villosa
Grewia plagiophylla

Vannila zoscheri
Cissus quadrangularis
Euphorbia tirucallii
Adenia globosa

grasses:
Themeda triadra
Digitaria mombasana
Hyparhennia rufa
H. filipendula
Heteropogon contortus
Chloris roxburghiana

Type 4: Tropical Monsoon Forest:

The forest was growing on the Limestone and the wetter part of the Mazeras sandstone. Nowadays only the "Kaja" forests are remnants of the former forest. These"Kaja" forests are sacred, but even inside these little forest firewood is cut out. Between the Kaja forests there is an intensive cultivation with mainly coconut and/or fieldcrops. Some remnants of the natural vegetation which are scattered between the cocos are (solitary trees):

Gyrocarpus americanus
Sterculia appendiculata
Ficus spp.
Chlorophora exelsa

Of the weeds growing beneath the cocos can be mentioned:

Stachyfarfera jamaizensis
Bidens spp.
Commelina spp.
Aneleina spp.
Tupalea lappacea
Achyranthes aspera
Alternanthera pungens
Ageratum conyzoides
Abutilon mauritianum

Type 5: Brachystegia bushed woodland

This type occurs on the drier part of the sandstone (Mazeras and Mariakani). Grazing is the main landuse in this part, and on the lower parts fieldcrops (maize). Some parts on the slopes are inte nsively grazed, and bare soil can be seen both in the field and on the aerial photographs.

Important species on the Brachystegia bushed woodland:

overstory:
Brachystegia spiciformis
Trachylobium verrucosum
Paramacrolobium coeruleum
Julbernardia magnistipulata
Afzelia cuanzensis
Lannea stuhlmannii

understory:
Combretum spp.
Vitex mombassae Vatke
Tinnea aethiopica
Heinsia crinata
Hugonia castaneifolia
Manilkara sulcata
Acridocarpus zansibaricus
Uvaria acuminata
U. leptocladon
Ozoroa obovata

Type 6: Acacia Hyphaene savannah.

This type is growing on the clays SW. of Kaloleni. Only a few shrubs or treelets are present (few individuals and few species):

Albizia anthelmintica
Hyphaene coriacea
Acacia zansibarica
A. spp.
Commiphora boiwiniana

grasses:

Themeda triandra

Sporobolus pyramidalis

Cymbopogon caesius

Type 7: Acacia Euphorbia bushland W of Bamba-Gotani.

Most of this type gets less than 600 mm rain a year. Halophytes are expected in this area but are not found. Most important tree is:

Dobera glabra

shrubs+treelets:

Acacia zanzibarica

A. seyal

A. senegal

Euphorbia tirucallii

E. spp.

Opunzia sp.

Commiphora spp.

Boscia spp.

Sanseveria kirkii

Adenia globosa

For type 8; 9 see paragraph 2.4.3

2.4.3. Small vegetation units with a specific flora

Kaja's or sacred forests (unit 4A)

These kaja's, which are situated mainly on the sandstone and the limestone in the southern part of the surveyed area, are the only remnants of a formerly closed monsoonforest. In fact it is the best developed forest type in our area. Its flora is very rich and specific and many endemics can be found there. It is because of this and because of the cultural-historical value of these forests that it is worthwile to protect them against further exploitation. Some interesting and characteristic species have been found

High trees:
- Chlorophora excelsa
- Sterculia apendiculata
- Antiaris toxicaria
- Gyrocarpus americana
- Newtonia paucijuga

Smaller trees:
- Macrolobium coeruleum
- Cynometra suaheliensis

Shrubs:
- Memecylon sp.
- Ximenia caffra
- Securidaca longipedunculata
- Dracaena usambarensis
- Monodora grandieri

Coastal vegetation on bare coral rock along the coast (unit 9)

Due to the specific habitat, the flora of these coastal rocks is very typical. Many plants with fleshy leaves occur. The species composition consists of:
- Sideroxylon inerme ssp. diospyroides
- Salvadora persica
- Cynanchum tetrapterum
- Cissus rotundifolius

Sphenostylis briartii
Indigofera cliffordiana
Cordia somalensis
Pemphis acidula
Azima tetracantha
Barleria sp.
Capparis cartilaginea
Asparagus racemosus
Portulaca oleracea
Sesuvium portulacastrum

Coastal vegetation on sand dunes and beach littoral

Little recent dunes are only present on a few places,and mostly they are overgrown. The leading seaward plant on the beach is Ipomoa pescaprae. It is frequently associated with:

Cyperus maritimus
Halopyrum mucronatum
Sporobolus virginicus
Lepturus repens
Zaleya pentandra

Behind this zone we can find:

Scaevola plumieri
S. taccada
Tephrosia noctiflora
Cordia subcordata
Dodonaea viscosa
Atriplex farinosa
Cistanche tubulosa
Wedelia sp.

In the real dunes again other plants will occur,for instance:

Hyphaene parvula
Casuarina equisetifolia
Flacourtia indica
Ehretia petiolaris
Croton sp.
Maytenus senegalensis
Crotalaria sp.

Mangrove forests and swamps (unit 8)

The major mangrove stands occur at Mtwapa-, Tudor-, and Kilifi creek.There are only few species which form dense mangrove forests;the most important ones are:

Rhizophora mucronata
Avicennia marina
Sonneratia alba
Ceriops tagal
Bruguiera gymnorrhiza

Less important are:

Lumnitzera racemosa
Xylocarpus benadirensis

At the border of the mangrove forest we can find:

Sporobolus virginicus
S. kentrophyllus
Hibiscus tiliaceus
Suaeda monoica

Vegetation on the present coastal platform,subject to tides

A characteristic feature of tropical coasts is the abundance of marine angiosperms , the so-called "sea grasses". Along the coast these marine angiosperms are represented by three families:

Potamogetonaceae
Hydrocharitaceae
Zosteraceae

Of the first family there are six species registered along the Kenyan coast. The most important ones are Cymodocea ciliata and C. rotunda. Of the second family are five species known of which the most abundant one is Thalassia hemprichii. The third one is in fact a family of the temperate zones. Here it is only represented by one species,Zostera capensis. The marine angiosperms form a big part of the total biomass in the ocean along the coast. The real sea-weeds (Algae) however,show a greater amount of different species. They belong to the Phaeophyta ("brown sea-weeds") Rhodophyta ("red sea-weeds") and the Chlorophyta ("green sea-weeds"). The Chlorophyta seems to be in the majority.

Most of the sea-weeds and also marine angiosperms are attached to rocks, but some appear also on sand,e.g. Halomeda macroloba.

2.4.4. Landuse and crop pattern

In anticipation of a final vegetation and landuse map on scale 1: 100,000 (see draft legend in section 2.4.2.) a description will be given on landuse and crop pattern within each vegetation zone.

Zones 1, 2, 9 and 10 combined

The landuse of these zones can be differentiated on basis of soil depth. On the very shallow soils overlying the coral limestone, close to the Ocean (zone 2), only a few fields occur with maize, cassava and cowpeas generally mixed together in one field. Also some fields with tobacco were observed in this area. However, most of the land is covered with bush and is used for extensive grazing.

On the deep and very deep soils more inland (zone 1) the landuse is much more intensive. Two main types of land can be distinguished there. The landuse with treecrops and that with foodcrops. Cashew and coconut are the dominant treecrops in this zone and to a lesser extent mango and a few citrus. Often these trees are planted together in one field. Generally, the foodcrops are grown in one field together with the treecrops. The main foodcrops (subsistance farming) are maize, cassava and cowpeas, grown together with simsim and some crops of minor importance, including bananas, vegetables, pigeon peas, pineapple, sweet potatoes in a mixed cropping system. The maize is planted in the beginning of the long rains (March) and in this zone sometimes during the short rains in october. Planting time is often spread over a longer period, giving an irregular stand of the maize,and yields are, especially, the ones of the short rains, low to very low. The simsim (mainly grown as a cash crop) is sometimes interplanted with the maize during the long rains, but mostly planted after the maize harvest or during the ripening stage of the maize. A rotation pattern is mostly absent ; maize is planted every year, but some farmers have a sort of rotation pattern with other crops. Very often the fields are abandoned after 4-6 years of cultivation, and the farmer is leaving this part fallow for several years. Most of the farmers have some goats and chicken, and sometimes one or more cows. The landuse around Mtwapa is different from the rest of this zone. Here more clayey soils occur and bananas and rice are also important crops; the close distance to the Mombasa market plays also an important role. Zones 9 and 10 have no agricultural significance.

The landuse of zone 3 is completely different compared to the coastal zones. Most of the land is used for extensive grazing, with goats and cows. However,especially in the southern part,there are some fields with maize and cassava. Occasionally cotton is grown as well. With the introduction of a tractor in the area the number of the maize plots (single stand or together with cotton) is increasing, and even during the short rains these plots seem to give a rather good yield.

Zones 4 and 6 are very important agricultural zones, especially zone 4. Here coconut is the main treecrop, often mixed with cashew, mango and citrus, while in the north you can find more cashew. Food crops are mostly planted in a mixed cropping system as well as under the coconut trees,as on special plots. In general, in this area maize is planted twice a year. The crops are mostly the same as in zone 1.A few Bixa trees occur in this area. Compared to the coastal zones, the farmers have generally more livestock, including cows.
In this zone about ten % of the coconut trees are tapped in order to obtain toddy (palmwine), which is sold locally to middlesman who transport it to Mombasa and Voi. Going northwards in zone 4, the climate seems to become drier because agriculture is less intensive. As said before cashew is the dominant crop; grazing increases in this area.

Zone 5 and 6 begins where the coconuts fail to grow (except for some valleys). Most of the land is used for grazing (goats and cows) while locally the bush is cleared and burned to make a plot for foodcrops (maize, cassava, and peas). Bananas and tobacco are grown around the scattered houses, as well as sweet potatoes.

Zone 7 is a transitional zone to the very poor grazing areas west of the Kilifi area.

2.4.5. List of crops and crop yields

The following fieldcrops have been recorded during the survey. The list may not be complete

Maize - Zea mais
Cassava - Manihot spp.
Simsim - Sesanum indicum
Cowpeas - Vigna unguiculata
Beans - Phaseolus vulgaris
Pigeon peas - Cajanus cajan
Grams - Vigna aureus
Grams - Vigna mungo
Rice - Oryza sativa
Tobacco - Nicotiana tabacum
Napier (elephant grass) - Pennisetum purpureum
Sweet potatoes - Ipomoa batatus
Sugar cane - Saccharus spp.
Bananas - Musa spp.
Sorghum - Sorghum vulgare
Pine apple - Annanos comosus
Pawpaw - Carica papaya
Mango - Mangifera indica
Citrus - Citrus spp.
Bitter gourd - Momordica charantia
Tropical spinach - Amaranthus spp.
do - Phseolus vulgaris
Tomato - Lycopersicon esculentum
Onion - Allium spp.
Pile pile - Capsicum annuum
Calabash - Gescentia cujete
Bixa - Bixa annato
Coconut - Cocos nucifera
Cashew - Anacardium occidentale
Kapok - Ceiba pentandra

Sisal - Agave spp.
Passionfruit - Passieflora spp.
Cotton - Gossypium spp.
Okra - Hybiscus sabdariffa
Castor - Ricinus communis

The yields of various crops are very difficult to obtain, but as an example can serve the results for the year 1977, as given in the annual report of the Ministry of Agriculture. When reading these figures one has to realize that the yields are overall yields from the whole Coastal Province and that the year 1977 has been a wet year, with prolongated rains during both the short rains period and the long rains period.

Maize: 800-2800 kg/ha	Sweet potatoes: 8-14 ton/ha
Cassava: 4 ton/ha	Bananas: 22-30 ton/ha
Simsim: 400 kg/ha	Pineapple: 22-25 ton/ha
Cowpeas: 450-600 kg/ha	Cashew: 158 kg/ha
Green grams: 450-600 kg/ha	

Yields for cashew are also calculated and discussed by Prof. van Eynatten (1979). The average yields for cashew amounts up to 450 kg/ha. In years with over 1000 mm rainfall, the yield of cashew decreases enormously, while in drier years the yields are relatively high and show a corelation with the rainfall.

The coconut yields are also low, about 30 nuts per tree. The copra derived from one nut is about 140 grams. In the whole area the combination of coconut and cashew is very often seen. According to Ackland (1971) a predator of the coreid bug (Pseudotheraptus wayii), next to the Rhinoceros beetle the most important pest in coconut trees, is said to be encouraged by planting of cashew or citrus in between the coconut trees. An important factor seems to be the income-insurance of a farmer, by using two different crops; while in a dry year the cashew give a good yield the coconut will do best after wetter years. The importance of these treecrops is indicated by the following figures: about 33% of the cultivated lands in the Kilifi District is used for tree crops , and 80% of it is occupied by cashew (40%) and coconut (40%).

3. Working methods

As pointed out in the introduction, this survey was carried out to obtain a preliminary soil map of the Kilifi area (Kenya Soil Survey mapsheet no. 198) in a short time. The fieldwork took 6 weeks only. The working methods of survey and map compilation therefore are by no means representative for a regular 1:100,000 soil survey according to the Kenya Soil Survey standards.

3.1. Office methods

The entire area was studied by means of streoscopic analysis of aerial photographs at scale 1:50,000 in the Netherlands, prior to the fieldwork. This was done by students, participating in a photo-interpretation course, who had not seen the area. Their "photo-interpretation maps for soil surveying purposes " and accompanying legend served as a reference only, and proved to be of little help in the field. During the soil survey however, aerial photo-interpretation was intensively practised by the surveyors, however always in combination with fieldwork. The preliminary soil boundaries were plotted first with coloured pencil on the photographs and then,with ink onto non-coloured copies of the topographic mapsheets. After a field-check, the boundaries were plotted on transparent films.

3.2. Field methods

The fieldwork was carried out by three Dutch students and two Kenyan field assistants operating in small terrain vehicles (Suzuki 4wh). As most roads and tracks run parallel to the coast, and only a few perpendicular to it, the survey was carried out in two stages: first the coastal strip, 10 km wide and 50 km long, (about 50,000 ha),east of the shale belt, and second the hinterland,including the shales (about 150,000 ha). Each stage took about three weeks fieldwork, because the hinterland is less complicated than the coastal strip and because the surveyors became more experienced with the time. In the second stage the base camp was put at Kaloleni to save time and transport. The soil was studied mainly by means of augerings (total about 800) and soil pits (total 27). All soil pits were described, but only ten were sampled for soil analysis by the NAL in Nairobi. Results are not yet available.

3.3 Laboratory methods

As no analysis data are available yet, no details on laboratory methods will be given in this report.

3.4. Cartographic methods

The soil boundaries, major topographic features and contour lines at intervals of 200 ft were copied from the fieldsheets (1:50,000) onto two separate transparent maps (Herculene drafting film) . These maps were reduced by photographic means to scale 1:100,000 at the Kenya Soil Survey in Nairobi, and assembled to one map. This assembly was multiplied by photo-print.

A schematic crossection was compiled from soil-, topographic -, and geological data directly at the published scale (Appendix 3).

4. The soils

4.1. Introduction

With reference to the general introduction, it has to be emphasized again that this report is one of a preliminary Soil Survey. This chapter on the soils should therefore be regarded as tentative. However, the adopted methodology for legend construction as well as the soil descriptions are all according to KSS directives (see KSS Internal Communications nos. 13 and 17).

The soils were classified according to the FAO/Unesco (Soil Map of the World legend) as well as to the US Soil Taxonomy system. This also was a tentative effort, based on estimates, because chemical analysis results are not yet available.

Soil fertility aspects and land evaluation are subjects which have not been discussed at all in this chapter, because a lack of data so far. Their treatment will certainly be covered extensively in the final report.

The legend of the soil map can be found on the map which is Appendix 1 to this report. The soil profile descriptions of representative profiles are Appendix 2. Ten of these profiles are sampled, and will be analysed by the National Agricultural Laboratories (NAL) in Nairobi, in cooperation with the Kenya Soil Survey.

4.2. General characteristics of the soils

The soils of the Kilifi area differ widely in depth,texture physical and chemical properties, mainly due to differences in parent material (see section 2.3.). Moreover, soil forming factors like climate, topography and time play an important role. The area can be divided in three main physiographic units:

- the Coastal Plain
- the Coastal Uplands
- the Erosional Plain

the Coastal Plain

The soils of the Coastal Plain can be subdivided in

1. Soils developed on coral limestone (units PL 1- PL 2)

They are generally well drained and of loamy sand to sandy clay texture. The soils range from shallow to deep, but are never very deep. Soil depth differs significantly over relative short distances, mainly due to the original relief of the coral limestone itself. The soils are considered being developed from the coral rock, though allochtone sand admixtures may be present. pH - measurements in the field by means of Hellige pehameter indicated values of 5 -5,5 which is lower than might be expected.

2. Soils developed on coastal sands (Kilindini sands), (units PA 1 - PA 2)

They are also well drained and generally very deep. The PA 1- units are sandy to sandy loamy and are subdivided on account of their colour. The PA 2- units have a sandy clay loam subsoil, while the PA 3- units, that mainly occur in the southeastern part (Vipingo mapsheet) have a sandy clay subsoil, while their drainage conditions may vary from well drained to poorly drained in places where seasonal flooding occurs. A large part of the soils has well defined reddish colours, owing to their " pre-weathered" origin. As explained in section 2.3.4 , the coastal sands are partially derived from the hinterland (Magarini sands). This also accounts for the low chemical fertility of the soils. The clayey soils have poor physical properties, resulting in a poor workability. Generally profile development and horizont differentiation increase in western direction, analogue with the different coastal levels.

<u>the Coastal Uplands</u>

The soils of the Coastal Uplands also vary considerably. They can be grouped, according to their parent material:

1. Soils developed on Magarini sands (units USm 1 - USm 3)

They are excessively drained to well drained very deep soils with a sandy clay loam subsoil (on the higher topographical positions ; USm 1) to sandy clay subsoil (on the lower parts; USm 2). Their physical properties are quite favourable, but chemically , they are poor. The strongly weathered parent material was derived from weathered sandstones in the hinterland (Duruma Sandstone series and Basement Complex); besides these soils are subject to weathering since Late-Pliocene times, thus being the "oldest" soils in the surveyed area. In spite of their dusky red colours however, the total amount of iron seems to be low. The iron is mainly concentrated as cutans around the single sand grains. The USm 3- unit comprises the bleached sands. These sands seem to be subjected to intensively podsolisation processes. Locally some thin clay-lamellae occur, indicating recent clay illuviation. On other places, mainly small depressions, a slightly indurated iron bank can be seen.

2. Soils developed on Jurassic shales (units UT 1- UT 2)

These are very heavy clay soils; the higher parts are deep to very deep in the southernmost part of the area, and moderately deep in the stronger dissected northern area. On the slopes the soils are shallower. The valleybottoms are put in a separate physiographical group. Due to their heavy texture and their poor physical properties water penetrates very slowly in the subsoil. On the other hand, although we cannot confirm, their chemical properties seem rather favourable. Tillage is difficult on these soils and there is a rather high susceptibility to gully erosion, especially where there is no closed vegetation cover; surface runn-of will then be much during rain.
Several hilltops are covered with Magarini sands; they are cultivated far more intensively than the lowlying surroundings. Also remnants of these sands (ferruginous gravel) are found in some shale profiles.

3. Soils developed on Kambe limestone (units UL 1- UL 2)

These are well drained, generally very deep, red, silty clayey to clayey soils with reasonable physical and chemical properties (UL 1). Many soils have sand admixtures of a former Magarini sandcover or Mazeras colluvium. Such soils are sandy clayey, while remnants, like ferruginous gravel are found in the profiles sometimes (UL 2). A remarkable feature in the landscape is the occurrence of karstic limestone outcrops, which restricts tillage somewhat.

4. Soils developed on Mazeras sandstone (units USs 1- USs 3)

There is a great variation in the soils on the Mazeras sandstone. On the steeper slopes in the southern part and to a larger extent in the northern area the soil depth ranges from shallow to very deep and generally coarse sandy soils (USs 1). North of Kaloleni soil profiles grade from a loamy sand topsoil to a sandy clay subsoil on the upperslopes and plateus; the middle slope profiles have been truncated, so they have a sandy clay loam topsoil which may give rise to surface sealing and erosion, but from agricultural point of view these soils seem physically and chemically not too bad (USs 2).
USs 3 contains heavy clayey soils with the same properties and hence the same agricultural restrictions as the Jurassic shales.

5. Soils developed on Mariakani sandstone (USK 1 - USK 4)

On the Mariakani sandstone four different soils have been distinghuished. USK 1 covers a large part of the northern area. These very deep, well drained soils are developed in medium to fine grained sands with a very low clay content. USK 2 contains the soils with a sandy loamy or somewhat heavier subsoil,mostly with a porous massive, strongly coherent structure. USK 3 contains the sandy profiles that are rather abruptly overlying sandy loam to clay, e.g. at the brink of the escarpment to the erosional plain. These soils have somewhat better moisture conditions than the sandy soils of USK 1 . The small USK 4 unit comprises shallow to moderately deep sandy or clayey soils overlying Mazeras sandstone.

<u>the Erosional Plain</u>

These soils have a completely different history. The sandy and clayey soils are developed on Pleistocene bay sediments.
A distinction is made between three units, excessively to imperfectly drained. PO 1 are sandy soils, non saline. Probably these soils have been saline in the past, but due to their sandy texture the salts could easily leach out.

PO 2 are soils with a fine sandy topsoil on sandy clay loam to clay, with a strongly saline and sodic subsoil. PO 3, the real plain soils consists of cracking clay, in which sometimes a calcic horizon has been formed, occasionally underlying a shallow sandy loamy topsoil. Due to the presence of significant amounts salts and a Na-dominated adsorption complex, these soils are at the moment totally unproductive; only salt tolerant vegetation survives.

4.3 Description of mapping units

PL 1

Parent material:	Coral limestone
Relief:	Flat to gently undulating
Vegetation/landuse:	Most Lantana bush, with some fields of foodcrops, extensive grazing
Soils:	The soils are well to excessively drained; generally very shallow to moderately deep, overlying coral limestone
Colour:	Topsoil: dark reddish brown (5YR3/2,3/3) to dark brown (7.5YR 3/2) Subsoil: yellowish red (5YR 5/6, 5/8)
Texture:	Topsoil: loamy sand Subsoil: loamy sand to sandy loam
Structure:	Generally moderate to medium subangular and angular blocky
Soil classification:	FAO: Lithosols USDA: lithic Ustorthent

PL 2

Parent material:	Coral limestone
Relief:	Very gently undulating to gently undulating with some depressions
Vegetation/landuse:	Smallholder rainfed arable farming with coconut and cashew as main tree crops, and maize, cassava and peas as the main foodcrops

	Some coconut plantations. Natural vegetation is bushland
Soils:	Well drained, moderately deep to deep, strongly weathered soils, few thick clay skins are observed in the subsoil
Colour:	Topsoil: dark brown to brown (10YR 4/3, 3/3) or (dark)brown (7.5YR 3/2,4/2,5/4) Subsoil: yellowish red (5YR 5/6,5/8)
Texture:	Topsoil: sandy loam Subsoil: sandy clay loam to sandy clay
Structure:	Medium to very coarse subangular and angular blocky in subsoil;sometimes a weak prismatic structure.
Consistence:	Slightly hard to hard when dry,friable when moist, and slightly sticky and slightly plastic when wet
Soil classification:	FAO: ferric Acrisol USDA: typic Rhodustult
Inclusions:	On some places the coral limestone is very near to the surface

PA 1.1.

Parent material:	Coastal sands
Relief:	Flat to gently undulating
Vegetation/landuse:	Perennial crop cultivation (cashew) and shifting cultivation of annual crops (maize,cowpeas) and semi-annual crops (cassava)
Soils:	generally well drained very deep,bleached,rapidly permeable soils;clay fibers and some eluviation of sesquioxydes occur occasionally
Colour:	Topsoil: brown (10YR 5/3) Subsoil: reddish yellow to yellow (10YR 7/6 - 7.5 YR 7/6)
Texture:	Topsoil: sand, subsoil: sand to loamy sand

Structure:	Porous massive, weakly coherent to structureless
Consistence:	Loose when dry and moist,non sticky and non plastic when wet
Classification:	FAO: albic and luvic Arenosol USDA: ustoxic Quartzipsamment

PA 1.2.

Parent material:	Coastal sands
Relief:	Very gently undulating
Vegetation/landuse:	Smallholder rainfed arable farming with coconut and cashew as main tree crops, and maize, cassava and cowpeas as main foodcrops
Soils:	Excessively well drained soils, deep to very deep, rapidly permeable,and gradual transitions between soil boundaries
Colour:	Topsoil: reddish brown (5YR 4/3,4/4) Subsoil: yellowish red (5YR 5/6,5/8)
Texture:	Topsoil:loamy sand Subsoil:loamy sand to sandy loam
Structure:	Porous massive to weak fine subangular blocky,weakly coherent
Consistence:	Soft when dry,very friable when moist, non sticky and non plastic when wet
Soil classification:	FAO: ferralic Arenosol USDA: ustoxic Quartzipsamment
Inclusions:	Some moderately deep soils

PA 1.3

Parent material:	Coastal sands
Relief:	Undulating
Vegetation/landuse:	Most of these soils are part of the Vipingo Sisal Estate or are in use by the Coastal Agricultural Research Station
Soils :	Excessively to well drained,rapidly permeable, very deep soils

Colour:	Topsoil: brown,dark yellowish brown to yellowish brown (10YR 4/3,4/4,5/6) Subsoil: yellowish brown (10YR 5/6), sometimes strong brown (7.5YR 5/6,5/8)
Texture:	Topsoil: sand (M 210-300 um) Subsoil: sand to loamy sand
Structure:	Very weak angular blocky structure
Consistence:	Soft when dry,very friable when moist, non sticky and non plastic when wet
Soil classification:	FAO: cambic Arenosol USDA: ustoxic Quartzipsamment

PA 2.1

Parent material:	Coastal sands
Relief:	Flat to gently undulating
Vegetation/landuse:	Perennial crop cultivation (coconut, cashew) and shifting cultivation of maize, cassava and simsim
Soils:	Well drained,very deep, strongly weathered soils,thin clay skins in subsoil
Colour:	Topsoil: brown to dark brown(7.5YR 5/6, 3/2); subsoil:light red to yellowish red (5YR 5/6,2.5YR 6/6)
Texture:	Topsoil:loamy sand to sandy loam Subsoil: sandy clay loam
Structure:	Topsoil: weak,fine to medium,subangular to angular blocky; subsoil: porous massive, moderately coherent
Consistence:	Slightly hard to hard when dry,friable to firm when moist,slightly sticky and slightly plastic when wet
Classification:	FAO: dystric Nitosol USDA: oxic Paleustult

PA 2.2

Parent material:	Coastal sands

Relief:	Flat to undulating
Vegetation/landuse:	In the southern part intensively cultivated but in the northern part less intensive smallholder rainfed arable farming.Treecrops:coconut,cashew,mango and citrus;foodcrops/cashcrops: maize, cassava,cowpeas,bananas,simsim
Soils:	Well drained,very deep,strongly weathered profiles, with few thin clay skins in the lower part of the B horizon,clear smooth and gradual boundaries between the soil horizons
Colour:	Topsoil: dark brown to brown (10YR 3/3, 5/3 and 7.5YR 3/4); subsoil:yellowish brown to strong brown (10YR 5/6;7.5 YR 5/6) sometimes up to yellowish red (5YR 4/6)
Texture:	Topsoil: loamy sand to sandy loam Subsoil: sandy clay loam,sometimes sandy clay
Structure:	Medium to coarse, moderately and strong subangular blocky grading to porous massive
Consistence:	Slightly hard to hard when dry,firm to friable when moist,slightly sticky and plastic when wet
Soil classification:	FAO: dystric Nitosol USDA: oxic Paleustult

PA 3.3

Parent material:	Coastal sands
Relief:	Undulating
Vegetation/landuse:	Smallholder rainfed arable farming
Soils:	Moderately well to well drained,very deep soils; mostly a distinct ABC profile with sometimes some waterstagnation on the slowly impermeable B horizon

	Abundant, moderately thick clay skins and humus coatings in the B2 horizon
Colour:	Topsoil:very dark grey to very dark reddish brown (10YR 3/1, 3/2) Subsoil: yellowish brown to brownish yellow (10YR 5/6, 6/6)
Texture:	Topsoil: loamy sand Subsoil: sandy clay to clay
Structure:	Medium to coarse, subangular and angular blocky; in the B2 coarse prismatic moderately developed structure
Consistence:	Friable to firm when moist, non sticky and non plastic (topsoil);sticky and plastic in B2
Soil classification:	FAO: dystric Nitosol USDA: oxic Paleustult

<u>PA 3.1</u>

Parent material:	Coastal sands
Relief:	Flat to very gently undulating
Vegetation/landuse:	Shifting cultivation of annual crops
Soils:	Well drained, strongly weathered, very deep soils,clay skins in subsoil
Colour:	Topsoil: dark brown (7.5YR 3/2, 4/2) Subsoil: red (2.5YR 3/6, 4/7)
Texture:	Topsoil: loamy sand Subsoil: sandy clay loam to clay
Structure:	Porous massive,strongly coherent
Consistence:	Hard when dry,friable when moist, slightly sticky and plastic subsoil when wet
Classification:	FAO: dystric Nitosol USDA: rhodoxic Paleustult

<u>PA 3.2</u>

Parent material:	Coastal sands
Relief:	Flat to very gently undulating

Vegetation/landuse:	Perennial crop cultivation (mango,cashew) and semi-annuals (sisal)
Soils:	Well drained, very deep soils; thin clay skins in subsoil
Colour:	Yellowish red to brown (5YR 5/6-7.5YR 4/2)
Texture:	Sandy clay loam to clay
Structure:	Medium angular blocky to porous massive, moderately coherent
Consistence:	Hard when dry,friable to firm when moist slightly sticky and plastic when wet
Classification:	FAO: dystric Nitosol USDA: oxic Paleustult

PA 3.4

Parent material:	Coastal sands
Relief:	Flat to very gently undulating
Vegetation/landuse:	Shifting cultivation of annual crops/ perennials (mango,cashew)
Soils:	Moderately well to imperfectly drained, very deep soils, few faint to distinct mottles
Colour:	Yellowish brown (10YR 5/4,5/6) to dark brown (10YR 3/3, 7.5YR 3/3)
Texture:	Sandy clay to clay
Structure:	Moderate, medium subangular to angular blocky;in places porous massive
Consistence:	Slightly hard when dry,friable to firm when moist,slightly sticky and plastic when wet
Classification:	FAO: dystric Nitosol USDA: oxic Paleustult

PA 3.5

Parent material:	Coastal sands
Relief:	Gently undulating

Landuse/vegetation:	Bushland,the lands are used for small-holder arable farming;also bananas take an important place in the farming system
Soils:	Imperfectly drained, very deep soils, common and many, medium, faint mottling, broken to continuous,moderately thick clayskins in the B2 horizon;some small manganese concretions in B2 horizon
Colour:	Topsoil: dark grey (10YR 4/1) to dark reddish brown (10YR 4/2) Subsoil: dark brown to colours 10YR 3/3
Texture:	Topsoil:sandy loam Subsoil: steadily increasing to sandy clay and clay
Structure:	Subangular to angular blocky, mostly coarse and moderate
Consistence:	Friable when moist, wet consistency ranging from non sticky and non plastic in topsoil to sticky and plastic subsoil
Classification:	FAO: dystric Nitosol USDA: aquic Paleustult
Inclusions:	Some poorly drained soils on lower spots, too small to map separately

PA 3.6

Parent material:	Coastal sands
Relief:	Flat to very gently undulating;depression
Vegetation/landuse:	Grassland, used for extensive grazing, some arable land
Soils:	Poorly drained, very deep soils, with pronounced mottling throughout the whole profile
Colour:	Topsoil: very dark gray to very dark grayish brown (10YR 3/2, 3/1) Subsoil:dark yellowish brown to yellowish brown (10YR 4/4,4/6,5/4,5/6)

Texture:	Topsoil:sandy clay Subsoil: sandy clay to clay
Classification:	FAO: dystric Gleysol USDA: typic Tropaquept,tropic Fluvaquent

USm 1

Parent material:	medium grained,red sands; Magarini sands
Relief:	Gently undulating
Vegetation/landuse:	Shifting cultivation of annual and perennial crops;grazing
Soils:	Well drained, very deep, strongly weathered soils, common manganes and few ironconcretions throughout the profile
Colour:	Topsoil: dark red (2.5YR 3/6,10R 3/6) Subsoil: dark red (10R 3/6)
Texture:	Sandy loam to sandy clay loam
Structure:	Weak, medium, subangular blocky
Consistence:	Soft when dry, very fraible when moist, non sticky non plastic when wet
Classification:	FAO: rhodic Ferralsol USDA: typic Haplustox

USm 2

Parent material:	Medium grained,red sands; Magarini sands
Relief:	Gently undulating to rolling
Vegetation/landuse:	Natural vegetation (Junju Kaya forest) is lowland semideciduous tropical rain forest. Most of the lands are very intensively cultivated with annual en perennial crops; grazing
Soils:	Well drained, very deep, strongly weathered soils, individual sandgrains coated with Mn and Fe
Colours:	Topsoil: dark reddish brown (5YR 3/2, 3/3) to very dusky red (2.5YR2/2) Subsoil: dark reddish brown (2.5YR 3/4)

	to dusky red (10R 3/2)
Texture:	Topsoil: loamy sand to sandy loam Subsoil: sandy clay loam to sandy clay
Structure:	Moderate, medium to coarse angular and subangular blocky
Consistence:	Slightly hard when dry, friable when moist, slightly sticky and slightly plastic when wet.
Classification:	FAO: dystric Nitosol USDA: rhodoxic Paleustult

<u>USm 3</u>

Parent material:	Medium grained sands; Magarini sands
Relief:	Very gently to gently undulating
Vegetation/landuse:	Shifting cultivation of annual and perennial crops; grazing
Soils:	Well to moderately well drained, strongly weathered, very deep, bleached soils
Colour:	Light olive brown (2.5Y 5/4, 5/6) to grayish brown (10YR 5/2)
Texture:	Sand to sandy loam
Structure:	Weak, medium, subangular blocky
Consistence:	Soft when dry, very friable when moist, non sticky and non plastic when wet
Classification:	FAO: albic and ferralic Arenosol USDA: ustoxic Quartzipsamment

<u>UT 1</u>

Parent material:	Jurassic shales
Relief:	Undulating to rolling; locally hilly
Vegetation/landuse:	Manilkara-Acacia cultivated savannah; bushed grassland, used for extensive grazing; some scattered fields with maize mixed with cotton and simsim
Erosion:	When the natural vegetation is removed the soils are very susceptible for gully erosion

Soils:	Moderately well to imperfectly drained, shallow to very deep soils. The soils have generally an ABC profile. Soils on top of small plateaus are mostly very deep, have abundant slickensides, broken clay skins and large cracks; soils on the slopes lack vertic properties, have a weaker developed ABC profile, and are shallow to modearately deep. Mottling due to waterstagnation occurs in most profiles; some profiles contain ferruginous gravel in the topsoil
Colour:	Topsoil: very dark grey, very dark grayish brown to dark brown (10YR 3/2, 3/3) Subsoil: dark brown to yellowish red (10YR 4/4, 7.5YR 4/4, 5YR 4/5) Near the contact with the shales colours tend to olive yellow (2.5Y 6/6)
Texture:	Heavy clay
Structure:	Moderate to strong, medium to coarse, angular blocky; moderate coarse prismatic structure in B horizon
Consistence:	Very hard to extremely hard when dry, firm to very firm when moist, very sticky and very plastic when wet
Soil classification:	FAO: eutric Cambisol, chromic Luvisol, chromic Vertisol USDA: udic Ustochrept, udic Rhodustalf, typic Chromustert
Inclusions:	Soils with a Magarini sand cover, well over 2 m deep; too small units to be mapped at 1:100,000

UL 1

Parent material:	Kambe limestone
Relief:	Undulating to hilly on transition to the Jurassic shales

Vegetation/landuse:	Partly tropical monsoon forest (kaja's); intensively cultivated area: coconut mixed with cashew, also citrus and mango; main foodcrop maize
Erosion:	Soils are generally not very susceptible to erosion, except when soil is bare and situated on steep slopes
Soils:	Well drained, deep to very deep, non-calcareous soils with an ABC profile; generally some clay skins in B horizon; some profiles contain ferruginous gravel in the topsoil
Colour:	Topsoil: dark reddish gray to dark reddish brown (5YR 4/2, 3/2, 3/3,3/4) Subsoil: yellowish red to dark red (5YR 5/6, 5/8 to 2.5YR 3/6, 5/6
Texture:	Topsoil: silty clay loam to clay Subsoil: clay
Structure:	Moderate to weak, fine angular blocky
Consistence:	Friable when moist, slightly sticky and slightly plastic when wet
Classification:	FAO: eutric Nitosol, ferric Acrisol USDA: udic Paleustalf,typic Rhodustult

<u>UL 2</u>

Parent material:	Kambe limestone with admixtures of Magarini sand and erosional products of Mazeras sandstone
Relief:	Undulating to rolling
Vegetation/landuse:	As UL 1
Erosion:	As UL 1
Soils:	Well drained, deep to very deep, non calcareous soils, weak ABC profile development; soils contain 25-75% ferruginous gravel and sandstone boulders (5-15 cm);generally some clay skins in B horizon

Colour:	Topsoil: weak red to dark reddish brown (2.5YR 4/2, 3/4 to 10R 4/2, 4/3) Subsoil: dark red (2.5YR 3/6, 5/6 to 10R 4/6, 4/7)
Texture:	Topsoil: sandy loam to sandy clay Subsoil: sandy clay to clay
Structure:	As UL 1
Consistence:	As UL 1
Classification:	FAO: ferric Acrisol USDA: typic Rhodustult

USs 1

Parent material:	Medium to coarse grained sandstone (Mazeras sandstone)
Relief:	Undulating to rolling
Vegetation/landuse:	Brachystegia bushed woodland; smallholder rainfed arable farming with coconut and cashew as treecrops,and maize and cassava as main foodcrops
Erosion:	Severe on places where the vegetation is cleared
Soils:	Well drained, moderately deep to very deep soils;weak or absent profile development; no clay skins
Colour:	Topsoil: very dark reddish brown,yellowis red to dark brown (5YR 3/2, 3/4, 7.5YR 3/2, 10YR 3/3) Subsoil: light yellowish brown to brownish yellow (10YR 6/4, 7/6) and yellowish red (5YR 5/8)
Texture:	Topsoil: sand to loamy sand Subsoil: loamy sand to sandy loam
Structure:	Very weak, medium to coarse subangular blocky,grading to granular structure
Consistence:	Soft when dry, very friable when moist, non sticky and non plastic when wet
Classification:	FAO: ferralic Arenosol USDA: ustoxic Quartzipsamment

USs 2

Parent material:	Medium to coarse grained sandstone (Mazeras sandstone)
Relief:	Rolling, locally hilly
Vegetation/landuse:	As USs 1
Erosion:	Moderately susceptible, depending on position on slope and landuse
Soils:	Well drained, deep to very deep soils with ABC profile development;the B horizon is very deep extended; soils on slopes are generally truncated; B horizon contains few, thin clay skins
Colour:	Topsoil: dark reddish brown (5YR 3/2,3/4) to dark brown (7.5YR 4/4) Subsoil: yellowish red to red (5YR 4/6, 5/6 to 2.5YR 4/6, 5/6)
Texture:	Topsoil: loamy sand to sandy loam, with distinct transition to Subsoil: sandy clay
Structure:	Medium, moderate subangular and angular blocky; topsoil has fine to medium granular structure
Consistence:	Slightly hard to hard when dry,friable when moist, slightly sticky and plastic in subsoil when wet
Classification:	FAO: dystric Nitosol USDA: oxic Paleustult

USs 3

Parent material:	Salty brown clays
Relief:	Gently undulating to rolling
Vegetation/landuse:	Wooded bushland
Soils:	Moderately well drained, very deep soils moderately to strongly affected by salts in places strongly calcareous subsoil, abundant intersected slickensides, frequent manganese concretions

Colour:	Light olive brown (2.5Y 5/4, 5/6) to brown (10YR 4/3, 5/3)
Texture:	Heavy clay
Structure:	Strong, medium angular blocky to coarse prismatic
Conisistence:	Very hard when dry,extremely firm when moist, slightly sticky and plastic when wet
Classification:	FAO: orthic Solonchak USDA: typic Natrustalf

USK 1

Parent material:	Medium to fine grained sands (Mariakani sandstone)
Relief:	Gently undulating to undulating
Vegetation/landuse:	Brachystegia bushed woodland; used for extensive grazing (northern part) and annual and perennial crops (southern part)
Erosion:	Moderate sheet and gully erosion
Soils:	Very well drained,very deep,weathered soils, hardly any profile development
Colour:	Topsoil: light yellowish brown (10YR 6/4) to dark brown (10YR 3/3) Subsoil: light red (2.5YR 6/6) to brown (7.5YR 5/4)
Texture:	Sand to sandy loam
Structure:	Single grain structure to very weak, medium subangular blocky
Consistence:	Slightly hard when dry, very friable when moist, non sticky and non plastic when wet
Classification:	FAO: albic Arenosol USDA: ustoxic Quartzipsamment
Inclusions:	In rolling terrain, sandy clay soils

USK 2

Parent material:	Fine grained sandstone with shale bands (Mariakani sandstone)
Relief:	Undulating to rolling
Vegetation:	Tropical monsoon forest;most of the land is intensively cultivated; treecrops coconut and cashew, foodcrops as maize and cassava
Erosion:	Moderately susceptible to erosion,depending on slope and land use
Soils:	Well drained, very deep soils,with well developed ABC profile; few clay skins
Colour:	Topsoil: dark grayish brown, dark brown to dark yellowish brown (10YR 4/2, 4/5) Subsoil: strong brown (7.5YR 5/6) to yellowish red(5YR 5/6, 5/8) to red (2.5YR 4/6)
Texture:	Topsoil: loamy sand to sandy loam Subsoil: sandy clay loam to sandy clay
Inclusions:	Profiles with sandy loam subsoil
Classification:	FAO: dystric Nitosol USDA: oxic and rhodoxic Paleustult

USK 3

Parent material:	Fine grained sandstone with shale bands (Mariakani sandstone)
Relief:	Gently undulating to undulating
Vegetation/landuse:	Bushed grassland; extensive grazing; few cultivated plots with maize,cassava
Soils:	Moderately well to imperfectly drained, very deep soils
Colour:	Olive yellow (2.5Y 6/6) to grayish brown (10YR 5/2)
Texture:	Topsoil: sand to sandy loam Subsoil: sandy clay loam to clay
Structure:	Topsoil: granular to weak,fine,

	subangular blocky Subsoil: moderate to strong, coarse, prismatic structure
Consistence:	Slightly hard when dry, very friable to friable when moist, slightly sticky and slightly plastic when wet
Inclusions:	Profiles with thick sandy topsoil
Classification:	FAO: dystric Nitosol and luvic Arenosol USDA: oxic Paleustult and ustoxic Quartzipsamment

USK 4

Parent material:	Fine grained sandstone (Mariakani sandstone)
Relief:	Hilly
Vegetation/landuse:	Tropical monsoon forest; most parts are cultivated, mainly coconut
Erosion:	Due to relief, these soils are very susceptible to sheet and gully erosion, especially when cultivated
Soils:	Well drained, shallow to moderately deep, stony soils; weak profile development
Colour:	Topsoil: dark brown, brown to reddish brown (10YR 3/3; 7.5YR 3/2; 5YR3/4, 4/4) Subsoil: yellowish brown to yellowish red and strong brown (10YR 5/4, 5/6; 7.5YR 5/6; 5YR 5/6, 5/8)
Texture:	Topsoil: sandy loam to sandy clay loam Subsoil: sandy clay loam to sandy clay
Structure:	Subangular to blocky
Inclusions:	Sandy profiles
Classification:	FAO: dystric Cambisol, dystric Regosol USDA: lithic Dystropept, - Quartzipsamment

PO 1

Parent material:	Fine sandy bay sediments
Relief:	Gently undulating to undulating
Vegetation:	Acacia bushland; extensive farming
Erosion:	Very susceptible,especially when overgrazed
Soils:	Moderately to excessively well drained, very deep soils with weak horizon development;non-calcareous except for some concretions in subsoil;surface sealing occurs
Colour:	Topsoil: (dark) brown to yellowish brown (10YR 3/3, 4/3, 5/4) Subsoil: yellowish brown (10YR 5/4, 5/6)
Texture:	Topsoil: fine sand Subsoil: sand to sandy loam
Structure:	Crumble and weak subangular blocky
Consistence:	Very hard when dry,very friable to friable when moist, non sticky and plastic when wet
Classification:	FAO: ferralic Arenosol USDA: ustoxic Quartzipsamment

PO 2

Parent material:	Fine sandy bay sediments
Relief:	Gently undulating
Vegetation:	Acacia bushland;extensive grazing
Erosion:	Severe in case of overgrazing
Soils:	Imperfectly to moderately well drained, very deep,moderately to strongly salt-affected soils; abrupt transition to B horizon
Colour:	Topsoil: dark grayish brown, brown,dark brown (10YR 4/2, 4/4, 5/3) Subsoil: dark yellowish brown to yellowish brown (10YR 5/4, 4/4 ,5/6)

Texture:	Topsoil: sand to sandy loam Subsoil: sandy clay loam to sandy clay and clay
Structure:	Moderate,medium angular blocky topsoil to strong compound massive structure with tendency to break into prisms; sometimes columnar
Consistence:	Hard to very hard when dry,friable to very firm when moist, sticky and plastic when wet
Classification:	FAO: solodic Planosol USDA: typic Natrustalf

PO 3

Parent material:	Fine sandy and clayey bay sediments
Relief:	Flat to very gently undulating
Vegetation/landuse:	Acacia bushland; extensive grazing
Erosion:	very slight
Soils:	Deep to very deep, poorly drained soils; many faint mottles,long wide cracks; moderately to strongly affected by salts sometimes a calcic horizon occurs
Colour:	Topsoil: dark gray to very dark grayish brown (10YR 4/1, 3/2, 4/2) Subsoil: yellowish brown to light olive yellow (10YR 5/6; 2.5Y 6/6)
Texture:	Topsoil: loamy sand to clay Subsoil: heavy clay
Structure:	Medium to very coarse angular blocky to columnar structure in B horizon
Consistence:	Slightly hard to extremely hard when dry, firm to very firm when moist, very sticky and very plastic when wet
Classification:	FAO: orthic Solonchak USDA: ustochreptic Calciorthid

A

Parent material:	Recent alluvial deposits
Relief:	Flat alluvial plain; levees/backswamps; gilgai
Vegetation:	Bushed grassland; grazing, small plots of cotton and rice
Erosion:	Nil
Flooding:	In long rains period
Soils:	Imperfectly drained, deep, calcareous, cracking clay soils; slickensides throughout whole profile
Colour:	Topsoil: brown to darkbrown (10YR 4/3) Subsoil: black (2.5Y 3/2)
Texture:	Heavy clay
Structure:	Topsoil: strong fine subangular blocky Subsoil: medium to coarse prismatic
Consistence:	Very hard when dry, very firm when moist, sticky and plastic when wet
Classification:	FAO: pellic Vertisol USDA: typic Pellustert

T

Parent material:	Recent alluvial, marin and organic deposits (sandy, clayey and peaty)
Relief:	Flat; levees; hummocky (peat)
Vegetation:	Mainly mangrove; grass in coastal swamps
Flooding:	Regularly
Soils:	Very poorly drained, deep, sulfuric, unripened clays; no profile development
Colour:	Black
Structure:	Structureless
Classification:	FAO: thionic Fluvisols, dystric Histosols USDA: Sulfaquept,Sulfihemist

4.4. Note on soil classification

The soils in the surveyed area were classified according to the FAO/Unesco Soil Map of th World legend (1973) and U.S. Soil Taxonomy. Once again must be emphasized that the classification is provisional as no analytical data were available.
Most of the mapping units in the surveyed area are in fact associations of different soils For the determination of the different soils - the " diagnostic horizon " concept was followed. The most important diagnostic horizon in the surveyed area is without doubt the argillic B horizon. According to U.S. Soil Taxonomy an argillic B horizon is defined as a horizon that contains illuviated clay; it has the following properties (summarized)

1. The argillic horizon contains more clay than the eluvial horizon and the increase in clay are reached within a vertical distance of 30 cm or less
a. If any part of the eluvial horizon has less than 15 % total clay, the argillic horizon must contain at least 3 % more clay
b. If the eluvial horizon has more than 15 % and less than 40 % total clay, the argillic horizon must contain at least 1.2 times as much clay
c. If the eluvial horizon contains more than 40 % total clay, the argillic horizon must contain at least 8 % more clay

2. An argillic horizon should be at least one tenth as thick as the sum of all overlying horizons, or it should be 15 cm or more thick if the eluvial and the illuvial horizons are more than 1.5 m thick. If the argillic horizon is sand or loamy sand it should be at least 15 cm thick; if it is loamy or clayey it should be more than 7.5 cm thick.

3. In structureless soils the argillic horizon has oriented clay bridging the sand grains and also in some pores.

4. If peds are present, and the surface horizon has more than 40 % clay dominated by kaolinite, the argillic B horizon should have clay skins on peds and in pores.

In the surveyed area, a greater part of the soils have an argillic B horizon consisting of sandy loam to sandy clay loam (less than 40 % clay). Because of this sandy character and the dominance of 1:1 lattice clays, clay skins are hardly ever visible. However the clay bulge normally meets the requirements for an argillic horizon. The argillic B horizon has generally " oxic " properties, i.e. a low CEC, and a low amount of weatherable minerals. The presence of an argillic B horizon though, excludes a classification as Oxysols. Therefore most of these soils were classified as Ultisols. The argillic B horizon is generally very deep; its clay content does not decrease from its maximum amount by as much as 20 % throughout 150 cm of the surface. Therefore these soils should then be classified as Paleustults; according to the FAO/Unesco legend these soils belong to the dystric Nitosols (dystric indicating their low base saturation). According to the KSS concept, Nitosols ought to be restricted to the clayey soils (see: Michieka et al, 1978). This can also be found in Buringh(1979). In the FAO/Unesco legend 1973, which we followed to the letter, however, these restrictions are not made.

In U.S. Soil Taxonomy the Paleustults are not subdivided; it is proposed that subgroups should be made, parallel with the definitions of the Haplustult subgroups. However, we found a further division more or less parallel with the Paleustalfs more satisfactory for this area. We distinguished:

1. oxic Paleustult: these soils have a CEC (by NH_4OAc) less than 24 meq per 100 g clay or a cation retention from NH_4Cl less than 12 meq per 100 g clay. The argillic horizon has a color hue of 5YR or yellower in some part, or has a value, moist of 4 or more in some part, or has a value, dry that is more than one unit higher than the value moist

2. rhodoxic Paleustult: these soils are like the oxic Paleustults except the argillic horizon has a color hue redder than 5YR in all parts, and has a color value, moist less than 4 and a color value, dry that is one unit or less higher than the value moist

3. aquic Paleustults: these soils are like the oxic Paleustults except they have, within 75 cm of the surface mottles that have chroma's of 2 or less, and the mottled horizon is saturated with

water at some time during the year.

There are three groups of soils on which problems arise with respect to their classification.

1. Some sandy soils, developed on Mazeras and Mariakani sandstone with a sandy loam to sandy clay loam B horizon. In these soils the increase in clay content has probably only little agricultural significance, but as it generally meets the requirements for a deep argillic B horizon, these soils ought to be classified as Nitosols (see foregoing). According to U.S. Soil Taxonomy these soils are classified mainly as oxic Paleustults. Possibly the use of an arenic subgroup (or arenic-oxic) would give a better picture of these soils.

2. Soils developed on the coastal red sands.
Similar soils in the Kwale area were classified as Acrisols and Ferralsols. Despite their oxic properties, most of these soils have a well developed deep argillic B horizon (sandy clay loam to sandy clay). According to the letter of the FAO/Unesco legend these soils should be classified as Acrisols (on the youngest marine terraces) and Nitosols (on the older, higher ones).
According to our records Ferralsols proper sense do not occur on the coastal sands. This also supports the general concept of Ferralsols as being exclusively limited to the stable old landscapes.
Apart from this, here again, the problem arises that some of the soils on the coastal sands are rather light textured and have a light textured argillic B horizon.
According U.S. Soil Taxonomy soils in the coastal zone were mainly classified as ustoxic Quarzipsamment, oxic-, rhodoxic-, and aquic Paleustult.

3. Soils developed on the Magarini sands.
On the Magarini sands some Ferralsols occur; they lack the features of an argillic B horizon, they have a low amount of weatherable minerals, a low CEC and gradual/diffuse horizon boundaries. The Ferralsols seem to be limited to the older (Pliocene) parts whereas the younger (Pleistocene; see 2.3.4.) are mainly occupied by dystric Nitosols.

Here, another theoretical problem arises. Soils developed on the Magarini sands are all strongly weathered. Even when they contain more than 40 % clay, clayskins are rarely visible, despite a sometimes marked increase in clay content in the B horizon. This results in the fact that any clayey soil in this material stands a better chance to be classified as a Ferralsol than a sandy soil.

According to recent visions on Soil Taxonomy, these strongly weathered soils, with an increase in clay content, represent intergrades between Oxysols and Ultisols, and they should be classified as Kandiustalfs, Kandiudults and Kandiustults (im accordance with their base saturation and soil moisture regime).

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Appendix 2 Soil profile descriptions

Profile description 1

Observation:	198/4-2; Kilifi District; E 5.87.5 N 95.72.8; 20 m; 08-01-1980
Unit:	PL 2
Provisional soil name:	FAO: chromic Luvisol USDA: typic Rhodustult
Parent material:	Coral limestone with sand admixtures
Physiography:	Coastal plain
Relief:	Gently undulating
Vegetation/landuse:	Bushland with lantana camara, coconut plantations
Erosion:	Very slight
Suface stoniness/rockiness:	Fairly rocky, stony
General groundwater level:	Very deep
Slope gradient:	0%
Surface sealing/crusting/cracking:	No s.s; no crusting; cracks: 30-40cm deep, 30-50 cm apart and 3 mm wide.
Root distribution:	Most roots in topsoil and common roots in subsoil up to rock (80 cm) allseizes of roots
Drainage class:	Well drained (4)
Human influences:	Clearing and burning
Effective soil depth:	Moderately deep (80 cm

A_{11}	0- 15 cm	Very dark gray (10 YR $^3/1$ when moist, 10 YR $^3/2$ when dry); sandy loam; moderate medium subangular blocky and granular structure; slightly hard when dry, friable when moist and slightly sticky and slightly plastic when wet; very porous; some charcoal; abrupt and smooth transition to:
A_{12}	15- 26 cm	Dark reddish brown (5 YR $^3/1.5$ 1nd 5 YR $^3/2$); sandy clay loam; coarse moderate subangular blocky structure; slightly hard to hard when dry, firm when moist; plastic and slightly sticky when wet, few very fine, fine and coarse pores; many medium, charcoal and small crotovina clear and smooth transition to:

B_1	26- 38 cm	Reddish brown (5 YR $^4/4$ when moist, 5 YR $^4/6$ when dry); very coarse, strong angular blocky structure; slightly hard to hard when dry, firm when moist and slightly sticky and plastic when wet, very few , thin clay skins, few very fine fine and coarse, common medium pores; some small quartz (+5%) particles; gradual and smooth transition to:
B_2	38-80 cm	Yellowish red (5 YR $^5/8$ when moist, 5 YR $^{5.5}/8$ when dry); sandy clay; coarse strong angular blocky to prismatic structure; slightly hard when dry, friable when moist, slightly sticky and slightly plastic when wet, few; thin clay skins; only common medium pores, very few of the others, some coral stones; abrupt and irregular transition to:
R	80	Coral

Profile description 2

Observation:	198/2-10; Kilifi District; E 5.88.8 N 95.92.7; 47 m; 10/1/1980
Unit:	PA 2.2
Provisional soil anme:	FAO: dystric Nitosol USDA: typic Paleustult
Parent material:	Coastal sands (Kilindini sands)
Physiography:	Coastal Plain
Relief:	Flat (slope class A)
Vegetation/landuse:	Grassland underneath perennial crop cultivation (mango, cashew, coconut)
Erosion:	Nil
Surface stoniness/rockiness:	Nil
General groundwater level:	Deep
Slope gradient:	0-2%
Surface sealing/crusting:	Nil
Drainage class:	Moderately well drained
Effective soil depth:	Moderately deep

A_1	0- 22 cm	Dark brown (10 YR 4/3 dry, 10 YR 3/3 moist); loamy sandy; weak, fine, subangular blocky structure; slightly hard when dry, very friable when moist, non sticky and non plastic when wet, few fine and many very fine pores; few coarse, medium, fine and very fine roots, clear and smooth transition to:
A_3/B_1	22- 47 cm	Dark grayish brown (10 YR 5/6 dry, 10 YR 4/2 moist); loamy sand; weak; fine, subangular blocky structure; soft when dry, very friable when moist, non sticky and non plastic when wet; few fine and many very fine pores; few coarse; medium, fine and very fine roots; gradual and wavy transition to:
B_{21t}	47- 74 cm	Yellowish brown (10 YR 5/7 dry,10 YR 55/5 moist); sandy loam; moderate, medium, angular blocky structure; slightly hard when dry, friable when moist, slightly sticky and slightly plastic when wet, few thin clay skins; few fine and many very fine pores; few coarse, fine and very fine

roots; clear and smooth transition to:

B_{22t}	74-145 cm^{+}	Yellowish brown (10 YR $^{6}/7$ dry, 10 YR $^{5}/6$ moist); sandy clay loam; porous massive structure; strongly coherent; hard when dry, firm when moist, slightly sticky and slightly plastic whem wet, few thin clay skins, few thin iron coatings; few fine and very fine pores; no roots.

Profile description 3

Observation:	198/2-1; Kilifi District; E 5.94.2; N 96.00.7; 30 m; 16/1/80
Unit:	PA 3.1
Provisional soil name:	FAO: dystric Nitosol USDA: rhodoxic Paleustult
Parent material:	Red lagoonal deposits (Kilindini sands)
Physiography:	Coastal plain, 2nd level
Relief:	Flat (slope class A)
Vegetation/landuse:	Herbs - and grassland/shifting cultivation of annual crops
Erosion:	Nil
Surface stoniness/rockiness:	Nil
General groundwater level:	Always very deep
Slope gradient:	0-2%
Surface sealing/crusting:	Nil
Drainage class:	Somewhat excessively drained
Human influences:	Clearing, cultivation
Effective soil depth:	Shallow

AP	0- 22 cm	Dark brown (7.5 YR 4/4 dry and moist); loamy sand; porous massive structure; slightly hard when dry, very friable when moist; non sticky and non plastic when wet, few, thin iron coatings; few fine, common very fine pores; few fine and very fine roots; abrupt and smooth transition to: (sample no. 19)
B_1	22-45 cm	Dark red (2.5 YR 4/6 dry, 2.5 YR 3/6 moist); sandy clay loam; porous massive structure; slightly hard when dry, very friable when moist, non sticky and non plastic when wet, few, thin ironcoatings; common very fine pores; few fine and very fine roots; clear and smooth transition to: (sample no 20)

B_{21t}	45- 99 cm	Red (2.5 YR $^{4}/6$ dry, 2.5 YR $^{4}/7$ moist); sandy clay; porous massive structure; hard when dry, friable when moist, slightly sticky and plastic when wet, common, thin ironcoatings; few fine common very fine pores; no roots; diffuse and smooth transition to: (sample 21
B_{22t}	99-145^{+}cm	Red (2.5 YR $^{5}/8$ dry, 2.5 YR $^{4}/6$ moist); sandy clay; porous massive structure; hard when dry, friable when moist, slightly sticky and plastic when wet, common, thin ironcoatings; few fine, common very fine pores; no roots. (sample no.22)

Profile description 4

Observation:	198/3-14; Kilifi District; E 5.82.2; N 95.72.7; 65 m; 11/1/1980
Unit:	PA 2.2
Provisional soil name:	FAO: dystric Nitosol USDA: oxic Palestult
Parent material:	Coastal sands
Physiography :	Coastal plain, (3rd level)
Relief:	Undulating locally rolling
Vegetation/landuse:	Bushland, shifting cultivation of annual crops, treecrops including coconut, cashew, mango and citrus, some grazing.
Erosion:	Slight sheet erosion
Surface stoniness/rockiness:	Nil
General groundwater level:	Always very deep
Slope gradient:	1%
Surface sealing/crusting/cracking:	Few cracks, over 1 m long and 0.3 to 0.5 cm wide
Root distribution:	Restricted to upper 60 cm, common roots of all types; after 60 cm only few roots
Drainage class:	Well drained
Human influences:	Clearing and cultivation
Effective soil depth:	Deep

A_{11} 0-23 cm

Dark brown (10 YR $^3/_3$ when moist, 10 YR $^5/_3$ when dry); loamy sand; medium, weak subangular blocky and angular structure; soft when dry, very friable when moist, and non sticky and non plastic when wet, very many fine and medium pores; few coarse; clear and smooth transition to:

(sample no. 41)

A12 23-34 cm

(sample no 42)

Dark yellowish brown (10 YR $^4/_4$ when moist, 10 YR $^5/_4$ when dry); loamy sand; medium, moderate subangular blocky structure; slightly hard when dry, friable when moist, and non sticky and non plastic when wet, common fine, medium moderate and few coarse pores; clear and smooth transition to:

B_1	34- 55 cm	Dark yellowish brown (10 YR $^4/4$ when moist, 10 YR $^5/5$ when dry); sandy loam; medium and coarse, strong subangular and angular blocky structure; hard when dry, friable when moist, and non sticky and non plastic when wet, common pores of all types; clear and smooth transition to: (sample no 43)
B_{21}	55- 83 cm	Dark yellowish brown (10 YR $^4/6$ when moist, 10 YR $^5/6$ when dry); sandy clay loam; coarse moderate angular blocky structure; with tendency to break into prisms; few clay bridges; slightly hard when dry, friable when moist, and slightly sticky and plastic when wet, common fine pores; and few of other sized pores; some charcoal, gradual and smooth transition to: (sample no. 44)
B_{22}	83-150$^+$ cm	Yellowish brown to strong brown (10 YR$^5/6$ -7.5 YR $^5/6$ when moist, 10 YR$^5/8$ -7.5 YR $^5/8$ when dry); sandy clay loam; coarse, moderate angular blocky structure with tendency to break into prisms, hard when dry, firm when moist and slightly sticky and plastic when wet, few fine and medium sized pores (sample no 45)

Profile Description 5

Observation: 198/4-1 Kilifi District; E 5.86.4; N 95.71.6;25 m; 11-01-1980

Unit: PA 3.5

Provisional soil name: FAO: dystric Gleysol
USDA:

Parent material: Coastal sands

Physiography: Coastal plain, depression

Relief: Gently undulating

Vegetation/landuse: Bushland, intensively cultivated with cashew and coconut as main tree crops, bananas & maize as main food-crops.

Erosion: Very slight sheet erosion

Surface stoniness/rockiness: Nil

General groundwater level: Depending on time of the year; between 200 m and 60 cm (code 2)

Slope gradient: 0%

Surface sealing/crusting/cracking: Some cracks, 50 cm long, 15-30 cm from each other and 2-4 mm width

Root distribution: Common roots, of all size, in first 50 cm very fine and medium roots after 50 cm

Drainage class: Imperfectly drained (code 3)

Human influences Clearing and cultivation

Effective soil depth Generally deep

A_1 0-22 cm Very dark gray (10 YR $^3/1$ when moist, 10 YR $^4/1$ when dry); sandy loam; fine and medium, moderate subangular blocky structure; soft when dry, very friable when moist, and non sticky and non plastic when wet. Many very fine, fine and medium common coarse pores; abrupt and smooth transition to:

B_{1g} 22-46 cm Dark brown (10 YR $^3/3$ when moist); with common, medium, faint mottling (10 YR $^6/3$) $^5/4$); sandy clay loam; medium and coarse, moderate, subangular and angular blocky structure; friable when moist, slightly sticky and slightly plastic when wet, many very fine and fine pores; common medium and few coarse, gradual

		and smooth transition to:
B_{21g}	46-85 cm	Dark brown to brown (10 YR $^4/3$ when moist) with many, medium, faint mottling (10 YR $^5/4$, $^3/2$); sandy clay; coarse, moderate angular blocky structure; very firm when moist, slightly sticky and plastic when wet, broken, moderately thick clay skins; very few pores; few Mn concretion (1-3 mm in diameter) gradual and smooth transition to:
B_{22g}	85-115$^+$ cm	Dark brown to brown (10 YR $^4/3$ when moist) with many, large faint mottles (10 YR $^5/4$, $^3/2$, $^5/6$); clay; coarse moderate angular blocky structure; firm when moist, sticky and plastic when wet, abundant, moderately thick clay skins; very few pores few Mn concretions (2-3 mm), the yellowish mottles spots have a more silty texture.

Profile description 6

Observation:	198/3-13; Kilifi District; E 5.82.4 N 95.68.4;30 m; 3- 1-1980
Unit:	PA 3.3
Provisional soil name:	FAO: dystric Nitosol USDA: oxic Paleustult
Parent material:	Lagoonal deposits(Coastal sands)
Physiography:	Coastal plain
Relief:	Undulating
Vegetation/landuse:	Bushland, mixed arable farming with coconut and cashew as main treecrops few foodcrops
Erosion:	Very slight to moverate, water (sheet) erosion depending of position and landuse
Surface stoniness/rockiness:	Nil
General groundwater level:	Always deep (> 120 cm.)
Slope gradient:	Top of plateau, with slopes up to 5% eastwards
Surface sealing/crusting cracking:	No ss ; no crusting; few cracks; 20-50 cm apart; 3-5 mm wide
Root distribution:	Very many very fine, medium and coarse in roots in upper 40 cm of the profile, between 40 and 110 cm few very fine and fine roots and very few medium roots, no coarse roots, after 110 cm only very few very fine and fine roots.
Drainage class:	Well drained (4)
Human influences	Clearing and burning, the farmer fertilized his coconuttrees and cashewtrees with cowdung mixed with straw.
Effective soil depth:	Deep (> 120 cm,)

A_{11} 0- 38 cm

Very dark gray (10 YR $^3/1$ when moist, 10 YR $^5/1$ when dry); loamy sand; weak to moderate, fine and medium,subangular blocky structure; soft when dry, very friable when moist and non sticky and non plastic when wet; many very fine

		fine medium and coarse pores; not very well sorted sand with M 210 - 420 mu; smooth and abrupt transition to:
A_{12}	38- 46 cm	Dark yellowish brown (10 YR $^{4}/4$ when moist); sandy clay loam; medium, moderate sub-and angular blocky structure; friable when moist; slightly sticky and slightly plastic when wet, common very fine, fine, medium and coarse pores; clear and smooth transition to:
B_1	46- 70 cm	Yellowish brown (10 YR $^{5}/6$ when moist); sandy clay; medium to coarse, moderate, sub- and angular blocky, friable when moist, sticky and plastic when wet, few, thin humus coatings and clay skins; common fine and very fine pores; clear and wavy transition to:
B_{2t}	70-110 cm	Yellowish brown (10 YR $^{5}/6$ when moist); sandy clay; coarse to very coarse, moderate to strong prismatic structure; firm when moist, sticky and plastic when wet, abundant, moderately thick humus coating and clay skins, few fine and very fine pores; clear and smooth transition to:
B_3	110-150^{+} cm	Brownish yellow(10 YR $^{6}/6$ when moist); sandy clay; medium, moderate angular blocky structure; friable when moist; sticky and plastic when wet, few, thin clay skins; common fine and very fine pores; up to 5% white coloured quartz particles
Augered	up to 270 cm:	Yellowish brown, sandy clay

Profile description 7

Observation:	198/2-2, Kilifi District, E 5.90.9, N 96.08.2, 80m, 9/1/1980
Unit:	Usm 1
Provisional soil name:	FAO: rhodic Ferralsol
	USDA: typic Haplustox
Parent material:	Medium-grained, well sorted, red sands
Physiography:	Coastal uplands
Relief:	Gently undulating (slope class B), flat topped ridge, many termitemounds
Vegetation/landuse:	Bushland alternated by both perennial crop cultivation (cashew, coconut) and shifting cultivation of annual crops (maize, cowpeas)
Erosion:	Slightly active gully erosion
Surface stoniness/rockiness:	Nil
General groundwater level:	Always very deep
Slope gradient:	0%
Surface sealing/crusting:	Nil
Drainage class:	Excessively drained
Effective soil depth:	Very deep

A_{11} sample 23	0-10 cm	Dark red (2.5YR 4/6 dry, 2.5YR 3/6 moist), sandy loam, very weak, medium, granular to subangular blocky structure, soft when dry, very friable when moist, non sticky and non plastic when wet, few medium, common fine, many very fine roots, abrupt and smooth transition to:
A_{12} sample 24	10-31 cm	Dark red (2.5YR 4/6 dry, 2.5YR 3/6 moist), sandy loam, very weak, medium, subangular blocky structure, soft when dry, very friable when moist, non sticky and non plastic when wet, few medium, common fine, many very fine pores, gradual and smooth transition to:
$B_{ox(1)}$ sample 25	31-80 cm	Dark red (2.5YR 4/6 dry, 2.5YR 3/6 moist), sandy clay loam, very weak, medium, subangular blocky structure, soft when dry, very friable whem moist, non sticky and non plastic when wet,

common fine, many very fine pores, few fine and very fine roots.

$B_{ox(2)}$ sample 26	80–120 cm	see $B_{ox(1)}$
$B_{ox(3)}$ sample 27	120–145 cm^{+}	see $B_{ox(1)}$

Profile description: 8	198/2-3, Kilifi District, E 5.89.9, N 96.05.7; 95m, 9/1/1980
Unit:	Usm 2
Provisional soil name:	FAO: dystric Nitosol USDA: rhodoxic Paleustult
Parent material:	Medium-grained, well sorted, red sands
Physiography:	Coastal uplands
Relief:	Gently undulating (slope class B), flat topped ridge, many termite mounds
Vegetation/landuse:	Abondoned coconut plantation, at the moment mainly used for grazing of cattle and goats and cashew-cultivation
Erosion:	Nil
Surface stoniness/rockiness:	Nil
General groundwater level:	Always very deep
Slope gradient:	0-1%
Surface sealing/crusting:	Nil
Drainage class:	Excessively drained
Effective soil depth	Very deep

A_1	0-13 cm	Very dusky red (2.5YR 3/6 dry, 2.5YR 2/2 moist), sandy clay loam, weak, fine, granular to subangular blocky structure, loose when dry very friable when moist, non sticky and non plastic when wet, frequent, small manganese concretions, few fine, common very fine pores, few medium, common fine, frequent very fine roots, gradual and smooth transition to:
B_1	13-98 cm	Dusky red (10 R 3/4 dry, 10 R 3/3 moist), sandy clay loam, weak, fine, granular to subangular blocky structure, soft when dry, friable when moist, non sticky and non plastic when wet, frequent, small manganese concretion, few fine, common very fine pores, few medium and fine, frequent very fine roots, clear and smooth transition to:

B_2	98-150$^+$ cm	Dusky red (10 R $^3/6$ dry, 10 R $^3/2$ moist), sandy clay loam, weak, medium, subangular blocky structure, soft when dry, friable when moist, slightly sticky and non plastic when wet, frequent, small manganese concretions, common fine and very fine pores, few very fine roots.

Profile description 9

Observation: 198/3-11; Kilifi District; E 5.82.5 N 95.74.4; 105 m; 11-01-1980

Unit: USm 2

Provisional soil name: FAO: dystric Nitosol
USDA: rhodoxic Paleustult

Parent material: Medium grained, well sorted, red sands (Magarini sands)

Physiography: Coastal uplands

Relief: Rolling; small ridges

Vegetation/landuse: Intensive cultivation of treecrops cashew, coconut, banana)

Erosion: Slighty susceptible to gully erosion

Surface stoniness/rockiness: Nil

General groundwater level: Always very deep

Slope gradient: 2%, upper slope

Surface sealing/cracking: Few cracks (width< 0,5 cm; depth 40 cm)

Drainage class: Well drained

Effective soil depth: Very deep

Reaction HCl: Nil

A_1 0- 23 cm

Dark reddish brown (5 YR $^4/_2$ dry, 5 YR $^3/_2$ moist); loamy sand, fine angular to weak fine subangular blocky structure; soft when dry, very friable when moist, non sticky and non plastic when wet, many fine manganese concretions, many very fine, fine and medium pores, abundant roots; smooth clear transition to:

A_{12} 23- 36cm

Dark reddish brown (5 YR $^4/_3$ dry, 5 YR $^3/_2$ moist); sandy loam; moderate, coarse subangular blocky structure; slightly hard when dry, friable when moist, non sticky and non plastic when wet, many fine manganese concretions; many fine, common medium and few large pores; many roots; clear and smooth transition to:

B_1	36- 69 cm	Dark reddish brown (2.5 YR $^3/5$ dry, 2.5 YR $^3/4$ moist); sandy clay loam; moderate coarse angular blocky structure; slightly hard when dry, friable when moist, slightly sticky and slightly plastic when wet; many fine manganese concretions; many very fine, common medium pores; common roots; gradual and weak transition to:
B_2	69-145$^+$ cm	Dark reddish brown (2.5 YR $^3/6$ dry, 2.5 YR $^3/4$ moist); sandy clay; moderate coarse angular blocky structure; slightly hard when dry, friable whem noist, slightly sticky and slightly plastic when wet, thin patchy clay skins; common fine and medium pores; common roots
	Remarks:	Clay content decreases at 190 cm

Profile description 10

Observation:	198/2-5; Kilifi District; E 5.85.1; N 96.07.4; 75m; 9/1/1980.
Unit:	UT 1
Provisional soil name:	FAO: chromoc Luvisol USDA: udic Rhodustalf
Parent material:	Shales
Physiography:	Coastal uplands, strongly dissected plain.
Relief:	Hilly (slope class E); few V - shaped gullies
Vegetation/landuse:	Thorned bushland, used for grazing. very locally small maize shambas.
Erosion:	Slightly to moderate, active and fossil, rill to gully erosion
Surface stoniness/rockiness:	Nil
General groundwater level:	Always very deep
Slope gradient:	2%
Surface sealing/cracking:	Moderate, 0,5 - 1,5 cm in size / few narrow cracks
Drainage class:	Moderately well drained
Effective soil depth:	Moderately deep

A	0- 14 cm	Dark brown (7.5 YR 5/4 dry, 7.5 YR 4/4 moist); clay; moderate; fine, angular blocky structure; hard when dry; friable when moist, sticky and slightly plastic when wet, few medium and fine, common very fine pores; few small manganese concretion few fine roots; clear and wavy transition to:
B	14- 65 cm	Yellowish red (5 YR 4/6 dry, 5 YR 4/5 moist); clay; moderate, medium subangular blocky structure; very hard when dry, friable when moist, sticky and slightly plastic when wet, fine thin clay skins; few fine and very fine pores; frequent small manganese concretions; few very fine roots; abrupt and wavy transition to:
R	65 cm+	Unweathered shales

Profile description 11

Observation:	198/1-9, Kilifi District, E 5.82.7, N 95.85.6, 105 m, 17/1/1980
Unit:	UT 1
Provisional soil name:	FAO: chromic Vertisol USDA: typic Chromustert
Parent material:	Shales
Physiography:	Coastal uplands
Relief:	Rolling (slope class D), some gilgai
Vegetation/landuse:	Bushed grassland/mainly used for grazing locally shambas, where maize, cotton and simsim are interplanted
Erosion:	Slight to moderate, active and fossil, rill and gully erosion
Surface stoniness/rockiness:	Nil
General groundwater level:	Always very deep
Slope gradient:	8%
Surface sealing:	Moderate, 0,5 - 1,5 cm in size
Cracking:	Distance: 40 cm, depth: > 1 m, width: 1cm
Drainage class:	Moderately well drained
Effective soil depth:	Shallow to moderately deep

A_1 0- 21 cm (sample 37)

Very dark grayish brown (10 YR $^{3}/2$ dry and moist), clay, strong, coarse, subangular blocky structure, very hard when dry, very firm when moist, sticky and plastic when wet, few medium and fine, common very fine pores, few small iron concretions, few coarse, medium, fine and very fine roots, abrupt and smooth transition to:

B_1 21-32 cm (sample 38)

Dark brown to brown (7½ YR $^{4}/4$ dry and moist), few fine faint, brownish yellow (10 YR $^{6}/8$) mottles, clay, strong, coarse, angular blocky structure, very hard when dry, very firm when moist, sticky and plastic when wet, common moderatelt thick, clay skins, few small to medium iron and manganese concretions, few medium, fine and very fine pores, few medium, fine fine and very fine roots, clear and wavy transition to:

B_{21} (sample 39)	32-62 cm	Yellowish brown (10 YR $^5/6$ dry and moist), common fine distinct, yellowish red(5 YR $^6/8$) mottles, clay, strong, very coarse, angular blocky structure, very hard when dry, very firm whem moist, sticky and plastic when wet, common, thick, clay skins, intersected slickensides, few medium pores, few, small manganese concretions, no roots, clear and smooth transition to:
B_{22} (sample 40)	62-112 cm +	Brownish yellow (10 YR $^6/6$ dry and moist), clay, strong, very coarse, angular blocky prismatic structure, very hard when dry, very firm when moist, sticky and plastic when wet, abundant thick clay skins, intersected slickensides, no pores, few small manganese concretions, no roots.

profile description 12

Observation:	198/1-8; Kilifi District; E 5.84.5; S 96.11.4;3/1/1980
Unit:	UT 1
Provisional soil name:	FAO: eutric Cambisol USDA: udic Ustochrept
Parent material:	Jurassic shales
Physiography:	Coastal uplands
Relief:	Hilly (slope class E): few V shaped gullies
Vegetation/landuse:	Acacia thorned bushland, used for grazing
Erosion:	Slight to moderate, active gully erosion
Surface stoniness/rockiness:	Nil
General groundwater level:	Always deep
Slope gradient:	0-2%
Surface cracking:	Some minor cracks
Drainage class:	Well drained
Effective soil depth:	Shallow
Reaction HCl:	Nil

A_1	0- 13 cm	Dark brown (10 YR $^4/4$ dry, 10 YR $^4/3$ moist); slightly gravelly clay: moderately weak medium, subangular blocky structure; very hard when dry, firm when moist, slightly sticky and slightly plastic when wet; few coarse, common medium and fine pores; few coarse, common medium and fine and many very fine roots; clear and smooth transition to:
B	13- 30 cm	Yellowish brown (10 YR $^5/6$ dry, 10 YR $^4/4$ moist); gravelly clay; few faint diffuse yellowish brown (10 YR $^5/8$) mottles; moderate medium subangular blocky structure; very hard when dry, firm when moist, slightly sticky and slightly plastic when wet, few coarse and medium, common fine pores; few medium, common fine and very fine roots; clear and wavy transition to:

C_1	30- 48 cm	Brown (10 YR $^5/3$ dry, 10 YR $^4/2$ moist); gravelly clay; few faint yellowish brown (10 YR $^5/8$) mottles; moderate coarse prismatic structure; very hard when dry; firm when moist, slightly sticky and slightly plastic when wet, common fine pores; few fine, common very fine roots; gradual wavy transition to:
Cr	48-125 cm^+	Yellowish brown (10 YR $^5/4$ dry, 10 YR $^5/3$ moist); gravelly shales, very few fine roots

Profile description 13

Observation:	198/1-6, Kilifi District, E 5.66.6, N 96.09.7; 215 m, 3/1/1980
Unit:	USs 1
Provisional soil name:	FAO: ferralic Arenosol USDA: ustoxic Quartzipsamment
Parent material:	Medium grained sands (Mariakani sandstone)
Physiography:	Coastal uplands
Relief:	Undulating, few termite mounds
Vegetation/landuse:	Brachystegia bushed woodland, bushland alternated by shifting cultivation of annual crops (maize, simsim, cowpeas), little perennial cropcultivation (cashew)
Erosion:	Moderate active, locally severe gully-erosion
Surface stoniness/rockiness:	Nil
General groundwater level:	Always very deep
Slope gradient:	0% summit
Surface sealing/crusting:	Nil
Drainage class:	Excessivelly well drained
Effective soil depth:	Shallow
Reaction: HCl:	Nil

A_1	0-14 cm	Reddish yellow 5 YR $^6/6$ dry, 5 YR $^5/6$ moist), loamy fine sand, very weak coarse subangular blocky-med. granular structure, soft when dry, very friable when moist, non sticky and non plastic when wet, very few coarse, common very fine pores, few medium, few fine, common very fine roots, diffuse smooth transition to:
C	14-130⁺ cm	Reddish yellow (3,75 YR $^7/8$ dry, 3,75 YR $^5/8$ moist), loamy fine sand, very weak subang. blocky to med. granular structure, soft when dry, very friable when moist, non sticky and non plastic when wet, few very fine pores, very few fine, few very fine roots.

Profile description 14

Observation:	198/3-9; Kilifi District; D.C. Camp Chonyi; 210 m; 14-0-1980
Unit:	USs 2
Provisional soil name;	FAO: dystric Nitosol USDA: oxic Paleustult
Parent material:	Mazeras sandstone
Physiography:	Coastal uplands
Relief:	Rolling
Vegetation/landuse:	Disturbed tropical monsoon forest; treecrops and small holder foodcrops
Erosion:	Very slight rill erosion
Surface stoniness/rockiness:	Nil
General groundwater level:	Always very deep
Slope gradient:	1%; top of small plateau
Surface sealing/cracking:	Few cracks, < 0,5 cm wide and < 50 cm deep
Drainage class:	Well drained
Effective soil depth:	Deep
Reaction HCl:	Nil

A_{11} 0- 12 cm

Reddish brown (5 YR $^{4}/3$ dry, 5 YR $^{3}/4$ moist); sandy loam; moderate medium subangular blocky structure; slightly hard when dry, friable when moist, non sticky and non plastic when wet, common large pores; frequent medium, fine and very fine roots; clear smooth transition to:

$A12_{/B1}$ 12- 25 cm

Reddish brown (5 YR $^{4}/5$ moist); sandy loam; moderate, medium angular blocky; hard when dry, friable when moist, slightly sticky and slightly plastic when wet, common fine pores; frequent medium, fine and very fine roots; clear and smooth transition to:

B_{21}	25- 47 cm	Yellowish red (5 YR 4/7 dry, 5 YR 4/6 moist); sandy clay; moderate coarse angular blocky structure; very hard when dry, firm when moist, sticky and plastic when wet, common thin clay skins; few coarse and medium pores; few coarse, medium, fine and very fine roots; clear smooth transition to:
B_{22}	47- 89 cm	Yellowish red (5 YR 5/6 dry, 5 YR 4/6 moist); sandy clay; moderate medium to coarse angular blocky structure; hard when dry, firm when moist, sticky and plastic when wet, few coarse and medium pores; very few mediun, fine and very fineroots; common thin clayskins; gradual smooth transition to:
B_{23}	89- 120 cm	Yellowish red (5YR 5/6 dry, 5 YR 4/6 moist); gravelly sandy clay; moderate medium to coarse angular blocky structure hard when dry, firm when moist, sticky and plastic when wet, common thin clay skins; few medium pores; very few medium fine and very fine roots.

Profile description 15

Observation:	198/3-12; Kilifi District; E 5.72.8 N 95. 82.8; 210 m; 18-01-1980
Unit:	USs 2
Provisional soil name:	FAO: dystric Nitosol USDA: rhodoxic Paleustult
Parent material:	Coarse grained sandstone (Mazeras Sandstone)
Physiography:	Coastal uplands
Relief:	Rolling to hilly
Vegetation/landuse:	Natural vegetation is a semidecious tropical lowland forest (see kaja forests), vegetation nowadays is a bushland. Most of the land is cultivated with mainly coconuttrees and cashewtrees.
Erosion:	Under natural conditions only slightly erodable, however under cultivation and especialy on steeper slopes erosion (sheet and rill) can be very severe
Surface stoniness/rockiness:	Nil
General groundwater level:	Deep
Surface sealing/crusting/cracking:	Few cracks, 40 cm long and 3 mm wide
Drainage class:	Well drained (4)
Human influences:	Clearings and burning
Root distribution:	In upper part of profile (first 50 cm) common roots, of all sizes, From 50 - 100 cm only few medium and fine roots.
Effective soil depth:	Very deep($\pm$ 120 cm) 5

A_1	0- 26 cm	Dark reddish brown (5 YR $^3/2$ when moist, 5 YR $^4/2$ when dry); loamy sand; fine to coarse, moderate subangular blocky and granular structure; slightly hard when dry, friable when moist, non sticky and non plastic when wet; many very fine, fine, medium and coarse pores; M sand: 420 - 600 mu; about 20% quartz particles; 0,6 mm diameter; clear and smooth transition to: (sample no 33)

B_1	26- 57 cm	Yellowish red to dark red (3.75 YR $^{3.5}/6$ when moist, 3.75 YR $^{4}/6$ when dry); sandy clay; medium to coarse, moderate to strong subangular blocky structure; slightly hard to hard when dry, friable when moist and slightly sticky and plastic when wet, few to common, thin clay skins; common very fine, fine medium and coarse pores; up to 30% quartz particles (0.6 - 1 mm in diameter); clear and smooth transition to: (sample no 34)
B_{21}	57 - 81 cm	Red (2.5 YR $^{4}/6$ when moist, 2.5 YR $^{4}/5$ when dry); sandy clay; medium, moderate subangular blocky and angular blocky structure; slightly hard when dry, friable when moist and slightly sticky and plastic when wet, few, thin clay skins; few medium and coarse pores; up to 30% quartz particles (1 -2 mm in diameter); charcoal; gradual and smooth transition to: (sample no 35)
B_{22}	81	Red (2.5 YR $^{4}/8$ when moist, 2,5 YR $^{5}/8$ when dry); sandy clay; medium, moderate angular blocky structure; slightly hard when dry, friable when moist, slightly sticky and plastic when wet, very few pores; 35% quartz particles (1 -2 mm) charcoal; (sample no 36)

Profile Description 16

Observation:	198/3-8; Kilifi District; E 5.72.0 N 95.83.9; 245 m; 8/1/1980
Unit:	USs 2
Provisional soil anme:	FAO: dystric Nitosol USDA: rhodoxic Paleustult
Parent material:	Medium-grained sands (Mazeras sandstone)
Physiography:	Coastal uplands
Relief:	Hilly; convex slopes
Vegetation/landuse:	Disturbed Brachystegia bushed woodland; shifting cultivation of annual (maize, cowpeas) and perennial (cassava) crops, partly fallow (Lantana camara)
Erosion:	Slightly active, gully and sheet erosion
Surface stoniness/rockiness:	Nil
General groundwater level:	Always very deep
Slope gradient:	0-2%; summit
Surface sealing/crusting:	Nil
Drainage class:	Well drained
Effextive soil depth:	Moderately deep
Reaction HCl:	Nil

A_1	0-25 cm	Brown (7,5 YR 5/4 dry, 7,5 YR 4/4 moist); sandy clay loam; moderately strong coarse subangular blocky structure; very hard when dry, friable when moist; slightly sticky and slightly plastic when wet, few coarse and medium, common fine and very fine pores; few medium and fine, common very fine roots; clear wavy transition to:
A_2	25-46 cm	Yellowish red (5 YR 4/6 dry; 5 YR 4/8 moist); sandy clay; moderate strong coarse subangular to angular blocky; very hard when dry, firm when moist, slightly sticky and slightly plastic when wet; few cutans: few fine and very fine pores; few medium, fine and very fine roots; gradual wavy transition to:

B_{21t}	46- 91 cm	Red (2,5 YR 5/8 dry, 2,5 YR 4/8 moist); clay moderately coarse angular blocky structure; very hard when dry, friable when moist, slightly sticky and plastic when wet, thick cutans: common small iron and manganese concretions; few fine and very fine pores; few fine and very fine roots; abrupt smooth transition to:
B_{22t}	91-150 cm	Light red (2,5 YR 6/8 dry, 2,5 YR 5/8 moist; clay, porous massive structure; very hard when dry, friable when moist, slightly sticky and plastic when wet, thick cutans: few very fine pores; few very fine roots.

Profile descrption 17

Observation:	198/1-7, Kilifi District, E 5.77.0 N 96.09.4 140 m, 9/1/1980
Unit:	USs 3
Provisional soil name:	FAO: orthic Solonchak USDA: typic Salorthid
Parent material:	Salty brown clays (Mazeras siltstone/ shales)
Physiography:	Coastal uplands
Relief:	Gently undulating, convex slopes up to 10°
Vegetation/landuse:	Brachystegia bushed woodland, grazing, few small plots with shifting cultivation of annual (maize) and perennial (cassava) crops, tree crops (bananas)
Erosion:	Nil
Surface stoniness/rockiness	Nil
General groundwater level:	Always deep
Presence of salts/alhali:	Moderately affected, no crop does well
Slope gradient:	1%, middle slope
Surface sealing/crusting:	Common vertical cracks (width: 0,5 cm, depth: 30-45 cm)
Drainage class:	Moderately well drained
Effective soil depth:	Shallow
Reaction HCl:	Nil in upper 35 cm, very strong in Bca and Cca

A_1	0- 16 cm	Dark brown (10 YR 4/3 dry, 2,5 Y 5/2 moist), clay, strong fine angular blocky structure, very hard when dry, extremely firm when moist, non sticky and plastic when wet, thin continuous intersected slickensides, few fine, common very fine pores, few medium and fine, common very fine roots, clear smooth transition to:
B_1	16- 35 cm	Yellowish brown (10 YR 5/6 dry, 2,5 Y 5/4), clay very strong, medium angular blocky structure, very hard when dry, extremely firm when moist, slightly sticky and plastic

		when wet, continuous moderately thick intersected slickensides, frequent small manganese concretions, few very fine pores, few very fine roots, gradual smooth transition to:
Bca	35–103 cm	Light olive brown (2,5 Y 5/4 dry, 2,5 Y 5/4 moist), clay, strong coarse prismatic structure,very hard when dry, extremely firm when moist, slightly sticky and plastic when wet, continuous moderately thick slickensides, frequent small manganese concretions, no pores, no roots, gradual wavy transition to:
Cca	103–130 cm	Gray (2,5 Y 5/0 2,5 Y 5/0 moist), clay, moderate very coarse prismatic structure, very hard when dry, extremely firm when moist, slightly sticky and plastic when wet, few faint brownish yellow (10 YR 6/5) mottles, reduced ped faces, frequent small manganese concretions, no pores, no roots.

Profile description 18

Observation:	198/3-5, Kilifi District, E 5.68.7 N 95.79.6, 225 m, 10/1/1980
Unit:	USK 1
Provisional soil name:	FAO: dystric Nitosol USDA: oxic Paleustult
Parent material:	Fine grained sands (Mariakani sandstone)
Physiography:	Coastal uplands
Relief:	Flat (slope class A), flat topped convex interfluves, few termite mounds
Vegetation/landuse:	Brachystegia bushed woodland, shifting cultivation of annual crops (maize), tree crops (cashew, coconut, kapok)
Erosion:	Nil
Surface stoniness/rockiness:	Nil
General groundwater level:	Always very deep
Slope gradient:	0%, interfluve
Effective soil depth:	Deep
Reaction HCl:	Nil

A_1	0-27	Brown (10 YR $^4/3$ dry, 10 YR $^3/3$ moist), fine sand, weak fine subangular blocky structure, slightly hard when dry, very friable when moist, non sticky and non plastic when wet, few fine and common very fine pores, few fine and common very fine roots, clear smooth transition to:
A_3	27-75	Yellowish brown (10 YR $^5/6$ dry, 10 YR $^4/4$ moist), fine sand, weak medium subangular blocky structure, slightly hard when dry, very friable when moist, non sticky and non plastic when wet, few fine faint mottles (10 YR $^6/6$), common very fine pores, few fine and very fine roots, gradual smooth transition to:

B_1	75-93	Yellowish brown (10 YR $^5/7$ dry, 10 YR $^4/4$ moist), loamy fine sand, weak medium subangular blocky structure, slightly hard when dry, very friable when wet, few fine faint mottles (10 YR $^6/6$), common very fine pores, few fine and very fine roots, clear smooth transiton to:
B_{2t}	$93-135^+$	Strong brown (7,5 YR $^5/6$ dry, 7,5 YR $^5/4$ moist) fine sand loam, moderate medium angular blocky to porous, massive structure, hard when dry, friable when moist, slightly sticky and slightly plastic when wet, few fine faint mottles (10 YR $^6/6$), few patchy metallic oxides, common very fine pores, no roots.

Profile description 19

Observation:	198/3-6, Kilifi District, E 5.68.3, N 95.84.8; 248 m, 10/1/1980
Unit:	USK 1
Provisional soil name:	FAO: dystric Nitosol USDA: oxic Paleustult
Parent material:	Fine grained sandstone
Physiography:	Coastal uplands
Relief:	Gently undulating (slope class B), flat topped watershed, few termite mounds.
Vegetation/landuse:	Shifting cultivation of annual crops (maize, cowpeas) and semi-annual crops (cassava), interplanted, scattered cashew pawpaw and Ricinus.
Erosion:	Nil
Surface stoniness/rockiness:	Nil
General groundwater level:	Very deep
Slope gradient:	2-3%
Surface sealing/crusting:	Nil
Drainage class:	Well drained
Effective soil depth:	Deep

A_1 (sample 5)	0- 25 cm	Dark grayish brown (10 YR 5/3 dry, 10 YR 4/2 moist), loamy sand, weak, medium, subangular blocky structure, slightly hard when dry, very friable when moist, non sticky and non plastic when wet, few coarse and fine, common very fibe pores, common very fine roots, abrupt and wavy transition to:
A_2 (sample 6)	25-62 cm	Brown(10 YR 7/4 dry, 7.5 YR 5/4 moist), loamy sand, moderate, medium, subangular blocky structure, hard when dry, very friable when moist, non sticky and non plastic when wet, few coarse and fine, common very fine pores, common very fine roots, abrupt and wavy transition to:

B_{21t} (sample 7)	62–91 cm	Yellowish red (5 YR $^{6}/5$ dry, 5 YR $^{5}/6$ moist), sandy loam, few medium, distinct, yellowish red (5 YR $^{5}/8$) mottles, strong, coarse, angular blocky structure, very hard when dry, friable when moist, slightly sticky and slightly plastic when wet, few coarse and fine, common very fine pores, few very fine roots.
B_{22t} (sample 8)	91–138 cm	see B_{21t}

Profile description 20

Observation;	198/1-3; Kilifi District, E 5.60.0; N 96.09.1; 300 m; 4/1/1980
Unit:	USK 1
Provisional soil name:	FAO: albic Arenosol USDA: ustoxic Quartzipsamment
Parent material:	Fine to very fine sands
Physiography:	Coastal uplands
Relief:	Gently undulating (slope class B); few termite mounds
Vegetation/landuse:	Bushed grassland mainly used for extensive grazing, locally maize-shambas.
Erosion:	Moderate, locally severe, active gully erosion.
Surface stoniness/rockiness:	Nil
General groundwater level:	Always very deep
Slope gradient:	0-1%
Surface sealing/crusting:	Nil
Drainage class:	Excessively drained
Effective soil depth:	Moderately deep

A 0- 14 cm (sample1)

Light yellowish brown (10 YR 7/2 dry, 10 YR 6/4 moist); porous massive structure weakly coherent; soft when dry, loose when moist, non sticky and non plastic when wet; few fine, common very fine pores; few coarse, medium and fine, common very fine roots; diffuse and smooth transition to:

C (1) 14- 50 cm (sample 2)

Brownish yellow (10 YR 7/4 dry, 10 YR 6/5 moist); sand; porous massive structree, weakly coherent; slightly hard when dry, loose when moist, non sticky and non plastic when wet; common very fine pores; very few medium, few fine and very fine roots.

$C_{(2)}$	50- 100 cm	see $C_{(1)}$	:	Sample 3
$C_{(3)}$	100-140 cm	see $C_{(1)}$	:	Sample 4

Profile description 21

Observation;	198/3-7; Kilifi District; E 5.70.6; N 95.83.4; 270 m; 3/1/1980
Unit;	USK 2
Provisional soil name:	FAO: dystric Nitosol USDA: oxic Paleustult
Parent material:	Fine to medium-grained sandstone
Physiography:	Coastal uplands
Relief;	Hilly
Vegetation/landuse:	Permanent cultivation of perennials (coconut), rotational cultivation of maize and cassava
Erosion:	Very slight, active, sheet erosion
Surface stoniness/rockiness:	Very few rock outcrops
General groundwater level:	Always very deep
Slope gradient:	1-3%
Surface sealing/crusting:	Nil
Drainage class:	Well drained
Effective soil depth:	Deep

A_{11}	0-12 cm	Dark brown (10 YR $^5/4$ dry, 10 YR $^3/3$ moist); loamy sand; weak, coarse, subangular blocky structure; soft when dry, very friable when moist, slightly sticky and slightly plastic when wet, few coarse and medium, common fine and very fine pores; few coarse and medium, common fine and very fine roots; gradual and smooth transition to:
A_{12}	12-40 cm	Dark brown (7½ YR $^4/2$ dry, 7½ YR $^3/2$ moist); loamy sand; weak, coarse, subangular blocky structure; soft when dry, very friable when moist, slightly sticky and slightly plastic when wet, few medium common fine and very fine pores; few medium, common fine and very fine roots; clear and smooth transition to:

A_2	40- 60 cm	Dark brown (7½ YR $^4/4$ dry, 7½ YR $^4/2$ moist); loamy sand; weak, coarse, subangular blocky structure; soft when dry, very friable when moist; slightly sticky and slightly plastic when wet, few medium and fine, common very fine pores; few medium, common fine and very fine roots; gradual, smooth transition to:
B_{21}	60 - 72 cm	Strong brown (7.5YR 5/6 dry, 7.5YR 5/4 moist); sandy clay loam; few fine faint strong brown (7.5YR 5/8) mottles; moderate, coarse subangular blocky structure; slightly hard when dry, friable when moist, slightly sticky and plastic when wet; few patchy clay skins; few fine and very fine pores; few medium and fine, common very fine roots; abrupt, smooth transition to:
B_{22}	72 - 135$^+$ cm	Reddish yellow (5YR 6/8 dry, 5YR 5/8 moist); sandy clay loam; few patchy clay skins; coarse subangular blocky to porous massive structure; very hard when dry, very firm when moist, sticky and plastic when wet; few very fine pores; few very fine roots

Profile description 22

Observation:	198/1-5; Kilifi District; E 5.57.7; N 96.08.2; 250 m; 10/1/1980
Unit:	PO 2
Provisional soil name:	FAO: solodic Planosol USDA: typic Natrustalf
Parent material:	Salty Pleistocene bay-sediments
Physiography:	Erosional plain
Relief:	Flat (slope class A)
Vegetation/landuse:	Scattered bushes/unproductive
Erosion:	Nil
Surface stoniness/rockiness:	Nil
General groundwater level:	Deep
Slope gradient:	0-1%
Present of salts/alkali	Moderately affected subsoil; no crop does well
Surface sealing	Moderate, 1.0 cm thick
Drainage class:	Imperfectly drained
Effective soil depth:	Shallow

A_1 sample 15	0-12 cm	Dark yellowish brown (10 YR $^5/_4$ dry, 10 YR $^3/_4$ moist); loamy sand; weak, very fine, angular blocky structure; soft when dry, very friable when moist; non sticky and non plastic when wet, common very fine pores; few coarse, medium and fine, common very fine roots; clear and smooth transition to:
A_2 sample 16	12-45 cm	Brown (10 YR $^6/_4$ dry, 10 YR $^5/_3$ moist); few fine faint, brownish yellow (10 YR $^6/_6$) mottles; loamy sand; moderate, medium, angular blocky structure; hard when dyy, very friable when moist, slightly sticky and plastic when wet, few fine and common very fine pores; few medium and fine, common very fine roots; clear and smooth transition to:

B_{21t} 45-62 cm

sample 17

Brown (10 YR $^6/3$ dry, 10 YR $^5/3$ moist); few, fine faint, brownish yellow (10 YR $^6/6$) mottles; sandy loam; moderate, medium, angular blocky structure; hard when dry, friable when moist, slightly sticky and plastic when wet, few fine and common very fine pores; few fine and very fine roots; abrupt and smooth transition to:

B_{22t} 62-110 cm$^+$

sample 18

Light brownish gray (10 YR $^6/3$ dry, 10 YR $^6/2$ moist); common fine prominent, yellowish red (5 YR $^5/8$) mottles; sandy clay loam; strong, very coarse, prismatic to massive structure; very hard when dry, very firm when moist,sticky and plastic when wet; strongly sodic; few very fine pores;no roots

Profile description 23

Observation:	198/1-4; Kilifi District; E 5.55.7; N 96.06.0; 222 m; 10/1/1980
Unit:	PO 3
Provisional soil name:	FAO: orthic Solonchak USDA: ustochreptic Calciorthid
Parent material:	Salty Pleistocene bay-sediments
Physiography:	Erosional plain
Relief:	Flat to very gently undulating (slope class A)
Vegetation/landuse:	Open bushland/unproductive
Erosion:	Nil
Surface stoniness/rockiness:	Nil
General groundwater level:	Deep
Slope gradient:	1%
Presence of salts/alkali:	Moderately to strongly affected subsoil
Surface sealing:	Moderate, 1.0 cm thick
Drainage class:	Imperfectly drained
Effective soil depth:	Very shallow to shallow

A_{11} 0- 8 cm
sample 9

Very dark gray (10 YR $^3/2$ dry, 10 YR $^3/1$ moist); sandy clay; strong, medium, platy structure; very hard when dry; very firm when moist; sticky and very plastic when wet, few fine, common very fine pores; few coarse; medium; fine and very fine roots; clear and smooth transition to:

A_{12} 8-19 cm
sample 10

Very dark gray (10 YR $^3/3$ dry, 10 YR $^3/1$ moist); sandy clay; strong, medium, angular blocky structure; very hard when dry, extremely firm when moist; sticky and very plastic when wet; few fine, common very fine pores; few coarse, medium, fine and very fine roots; clear and smooth transition to:

A_{3ca}	19-36 cm	Grayish brown (10 YR $^4/2$ dry, 10 YR $^5/2$ moist); few fine faint, brownish yellow (10 YR $^6/6$) mottles; sandy clay to clay; very strong, medium, angular blocky structure; very hard when dry, extremely firm when moist, sticky and very plastic when wet; moderately calcareous; few $CaCO_3$-concretions; 2-5 mm in size;
sample 11		

Profile description 24

Observation:	198/3-10; Kilifi District; E 5.63.7; N 95.80.4; 200 m; 14-01-1980
Unit:	PO 2
Provisional soil name:	FAO: solodic Planosol USDA: typic Natrustalf
Parent material:	Salty Pleistocene bay sediments
Physiography:	Flat to very gently undulating
Vegetation/landuse:	Grass and scattered trees; grazing, few small plots with maize, sweet potatoes
Erosion:	Very slight
Surface stoniness/rockiness:	Nil
General groundwater level:	Always deep
Slope gradient:	1%; footslope
Surface sealing/cracking:	Weak sealing, cracks 1 cm wide, 100 cm deep
Presence of salt/alkali:	Moderately to strongly affected
Drainage class:	Imperfectly drained
Effective soil depth:	Shallow
Reaction HCl:	Strongly calcareous below 40 cm

A_{11}	0- 23 cm	Dark gray (10 YR 4/1 dry, 10 YR 3/1 moist) sandy loam; moderate medium subangular blocky structure; slightly hard when dry, firm when moist, slightly sticky and slightly plastic when wet, common medium fine pores; common very fine and fine, very few medium roots; smooth clear transition to:
A_{12}	23- 39 cm	Dark grayish brown (10 YR 4/2 dry, 10 YR 4/2 moist); sandy clay loam; common fine faint yellowish brown (10 YR 5/6) mottles moderate coarse subangular to angular blocky structure; hard when dry, firm when moist, slightly sticky and plastic when wet, common medium fine pores; common very fine and fine, very few medium pores; abrupt, smooth transition to:

B_{1g}	39- 60 cm	Brownish yellow (10 YR 6/6 dry, 10 YR 6/6 moist); many fine faint dark brown (10 YR 4/3) mottles; strong very coarse angular blocky structure; extremely hard when dry; extremely firm when moist, sticky and plastic when wet, few medium pores; few fine roots; $CaCO_3$ - nodules; gradual smooth transition to:
B_{21g}	60- 85 cm	Brownish yellow (10 YR 6/6 dry, 10 YR 6/6 moist); clay; many medium faint dark brown (10 YR 4/3) and gray (10 YR 6/1) mottles; few patchy clay skins; strong; very coarse prismatic structure; extremely hard when dry, extremely firm when moist, stick and plastic when wet, few medium pores; few fine roots; many $CaCO_3$-nodules; diffuse smooth transition to:
B_{22g}	85-140 cm	Brownish yellow (10 YR 6/6 dry, 10 YR 6/6 moist); clay; many medium faint dark brown (10 YR 4/3) and gray (10 YR 6/1) mottles; few patchy clay skins; strong, very coarse prismatic structure; extremely hard when dry, extremely firm when moist, sticky and plastic when wet, few medium pores; few fine roots; few $CaCO_3$-nodules; clear wavy transition to:
B_{3g}	140^+ cm	Yellowish brown (10 YR 5/8 dry, 10 YR 5/8 moist); clay; abundant medium faint very dark grayish brown (10 YR 3/2) and gray (10 YR 6/1) mottles; moderate medium angular blocky structure; very hard when dry, very firm when moist, sticky and plastic when wet, very few medium pores; few fine roots; many medium iron and manganese concretions.

Profile description 25

Observation:	198/3-3; Kilifi District; E5.60.2 N 95.80.2;240 m.;14-10-1980
Unit:	PO 1
Provisional soil name:	FAO: ferralic Arenosol USDA: ustic Quartzipsamment
Parent material:	Sandy bay sediments
Physiography:	Dissected plain
Relief:	Undulating
Vegetation/landuse:	Bushland, extensive grazing
Erosion:	Under natural condition moderately susceptible to sheet and rill erosion, when cultivated (or over grazed) the erosion can be severe
Surface stoniness/rockiness:	Nil
General groundwater level:	Very deep
Surface sealing/crusting/cracking;	Moderate, 2-4 mm thick,no cracks
Drainage class:	Excessively drained (5)
Human influences:	Clearing and grazing
Root distribution:	Not many roots and ristricted to upper 50 cm, after 50 cm only few very fine roots
Effective soil depth:	Moderately deep

A_1	0- 52 cm	Dark brown (10 YR $^3/3$ when moist, 10 YR $^5/1$ when dry); loamy sand; fine, weak subangular blocky and granular structure; slightly hard when dry, very friable when moist and non sticky and non plastic when wet, common pores; clear and wavy transition to:
A_c	52- 75 cm	Dark brown to brown (10 YR $^4/3$ when moist, 10 YR $^5/1$ when dry); loamy sand; porous massive, weakly coherent to weak fine subangular blocky structure; slightly hard when dry, friable when moist and non sticky and non plastic when wet; few pores gradual and smooth transition to:

C	75-105 cm	Yellowish brown (10 YR $^{5}/4$ when moist; 10 YR $^{7}/2$ when dry); loamy sand; structure less, porous massive, weakly coherent to weak, fine subangular blocky; slightly hard when dry, friable when moist, non sticky and non plastic when wet, very fine pores; crotovina.

Profile description 26

Observation:	198/2-4; Kilifi District; E 5.86.3; N 96.07.6; 12 m; 9/1/1980
Unit:	A
Provisional soil name:	FAO: pellic Vertisol USDA: typic Pellustert
Parent material:	Alluvium
Physiography:	Bottomlands
Relief:	Flat valleybottom (slope class A); river levee; some gilgai
Vegetation/landuse:	Bushed grassland/grazing
Erosion:	Nil
Surface stoniness/rockiness:	Nil
Flooding:	In long-rains period
General groundwater level:	Temporarily shallow
Slope gradient:	0%
Presence of salts/alkali:	Nil
Cracking:	Vertical cracks, 10-20 cm distance, width: 1-2 cm, depth: 50-80 cm
Drainage class:	Imperfectly drained
Effective soil depth:	Shallow to moderately deep

A_1 0 3 cm

Brown to dark brown (10 YR $^4/3$ dry, 10 YR $^4/3$ moist); cracking clay; strong, fine, granular to subangular blocky structure; very hard when dry, very firm when moist, slightly sticky and plastic when wet, slightly calcareous; common fine and very fine pores; few medium, common fine and very fine roots; abrupt and smooth transition to:

(Sample 28)

AC 3-25 cm

Dark gray (10 YR $^5/4$ dry, 10 YR $^4/1$ moist); cracking clay; very strong; fine, subangular blocky structure; very hard when dry, extremely firm when moist; slightly sticky and plastic when wet; slightly calcareous; few very fine pores; few very fine roots; clear and smooth transition to:

(Sample 29)

C_1	25-56 cm	grayish brown (10 YR $^5/4$ dry, 2½ Y $^5/2$ moist); cracking clay; very strong, coarse, prismatic structure;very hard when dry, extremely firm when moist; sticky and plastic when wet; abundant, thin, intersected slickensides; few medium shells; strongly calcareous; few $CaCO_3$-concretions, 2-5 mm in size, common very fine pores; few very fine roots; gradual and smooth transition to:
		(Sample 30)
C_{2ca}	56-85 cm	Dark grayish brown (2,5 Y $^3/2$ dry, 2,5 Y $^4/2$ moist); cracking clay; very strong; coarse prismatic structure; very hard when dry, extremely firm when moist; sticky and plastic when wet; abundant thick, intersected slickensides; strongly calcareous; few $CaCO_3$- concretions 2-5mm in size; no pores; no roots; diffuse and wavy transition to:
		(Sample 31)
C_{3ca}	85-135 cm$^+$	Black (2,5 Y $^3/2$ dry, 2,5 Y $^2/0$ moist); cracking clay; very strong, medium, prismatic structure; very hard when dry, extremely firm when moist, sticky and plastic when wet, abundant thick, intersected slickensides; strongly calcareous; few $CaCO_3$-concretions, 2-5 mm in size; no pores; no roots.
		(Sample 32)

Profile description 27

Observation:	198/1-1; Kilifi District; E 5.77.8, N 95.88.9; 240 m; 27/11/1979
Unit:	UL 1
Provisional soil name:	FAO: dystric Nitosol USDA: rhodoxic Paleustult
Parent material:	Kambe limestone
Physiography:	Coastal uplands
Relief:	Gently undulating
Vegetation/landuse:	Treecrops (mango, cashew) with undergrowth of herbs and grasses
Erosion:	Nil
Surface stoniness/rockiness:	Nil
General groundwater level:	Always very deep
Slope gradient:	3% upper slope
Surface sealing/crusting:	Nil
Drainage class:	Well drained
Effective soil depth:	Very deep
Reaction HCL:	Nil

AP	0- 20 cm	Reddish brown (2,5 YR 3/6 dry, 2,5 YR 3/4 moist); fine sandy loam; moderate fine subangular blocky structure; hard when dry, friable when moist, slightly sticky and slightly plastic when wet, common fine iron concretions; few coarse, common fine and medium, few very fine pores; common medium and fine roots; clear wavy transitions to:
B_1	20- 67 cm	Reddish brown (2,5 YR 4/6 dry, 2,5 YR 3/6 moist); sandy clay; weak fine angular blo blocky structure; firm when moist, slightly sticky and plastic when wet; few patchy plastered rootchannels; common fine iron and manganese concretions; few medium, common very fine and many very fine pores common medium and fine roots; gradual smooth transitio n to:

B_{2t}	67-170 cm	Reddish brown (2,5 YR 3/6 moist); clay; weak fine to moderate subangular blocky to fine crumby structure; friable when moist, slightly sticky and plastic when wet, thin patchy cutans; common fine manganese concretions; few fine many very fine; many micro pores; few coarse, common medium and fine roots.

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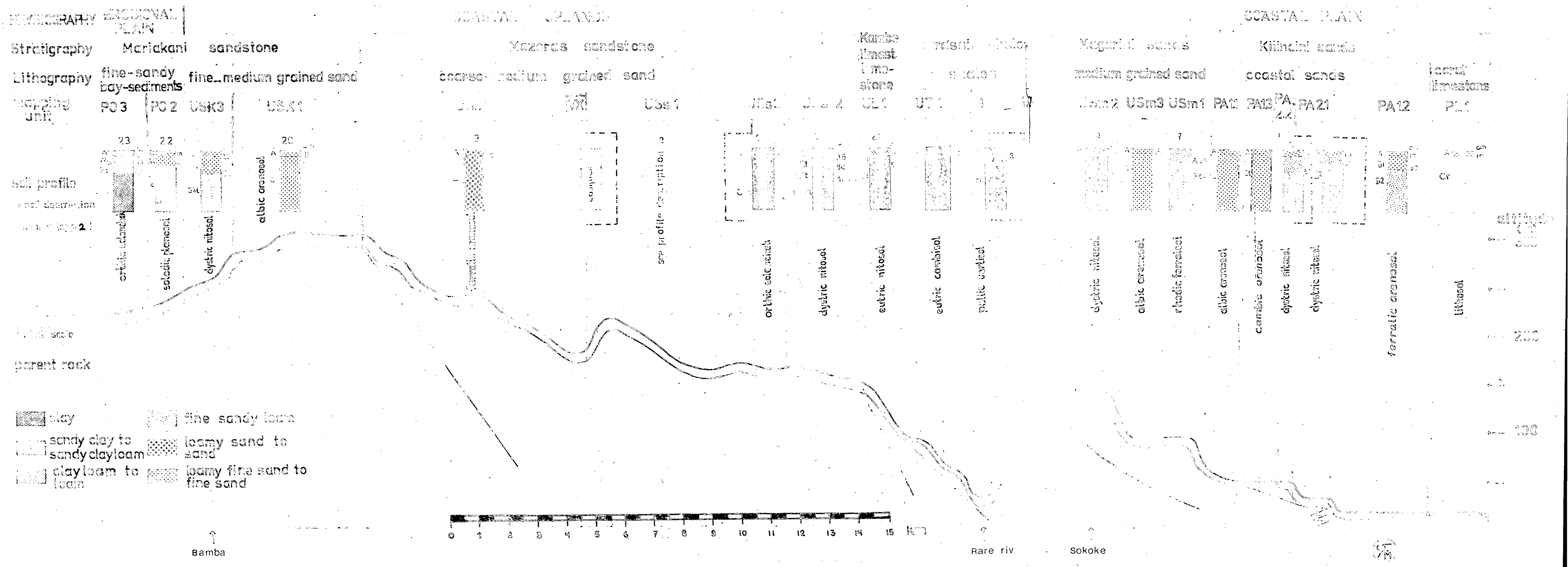
Appendix 3

schematic crossection



MAP SHEET 198 PRELIMINARY SOIL MAP OF THE KILIFI AREA

Appendix 1

6373a

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LEGEND

COASTAL PLAIN (slopes in general less than 5 %)

PL Soils developed on coral limestone with sand admixtures

PL1 well drained, shallow, yellowish red to brown, extremely rocky, loamy sand. FAO: Lithosols USDA: lithic Ustorthent

PL2 well drained, moderately deep to deep, yellowish red to dark brown, fairly rocky, friable, sandy clay loam to sandy clay, underlying 30-50 cm of sandy loam FAO: ferric Acrisol, USDA: typic Rhodustult

PA Soils developed on coastal sands (Kilindini sands)

PA11 well drained, very deep, reddish yellow to yellow, loose, sand to loamy sand. FAO: albic and luvic Arenosol, USDA: typic Quartzipsamment

PA12 excessively drained, deep to very deep, light red to yellowish red, very friable, sandy loam, underlying 30-60 cm of loamy sand. FAO: ferralic Arenosol and dystric Nitosol, USDA: ustoxic Quartzipsamment and arenic Paleustult

PA13 excessively drained to well drained, very deep, reddish yellow to dark yellowish brown, loose to very friable, sand to sandy loam. FAO: cambic Arenosol and dystric Nitosol, USDA: typic Quartzipsamment and arenic Paleustult

PA21 well drained, very deep, light red to yellowish red, friable to firm, sandy clay loam, underlying 30-60 cm of brown to dark brown loamy sand to sandy loam. FAO: dystric Nitosol, USDA: oxic Paleustult

PA22 well drained, very deep, yellowish brown to strong brown, friable to firm, sandy clay loam, underlying 30-60 cm of loamy sand to sandy loam. FAO: dystric Nitosol, USDA: typic Paleustult

PA31 well drained, very deep, yellowish red to red, friable, sandy clay loam to clay, underlying 20-50 cm of loamy sand. FAO: dystric Nitosol, USDA: rhodoxic Paleustult

PA32 well drained, very deep, yellowish red to brown, friable, sandy clay loam to clay. FAO: dystric Nitosol, USDA: oxic Paleustult

PA33 well drained to moderately well drained, very deep, yellowish brown to brownish yellow, firm, sandy clay to clay, underlying 20-60 cm of loamy sand to sandy loam. FAO: dystric Nitosol, USDA: typic Paleustult

PA34 moderately well drained to imperfectly drained, very deep yellowish brown to dark brown, firm sandy clay loam to clay. FAO: dystric Nitosol, USDA: typic Paleustult

PA35 imperfectly drained, very deep, brown to dark brown, mottled, firm to very firm, sandy clay to clay, underlying 20-60 cm of sandy loam. FAO: dystric Nitosol, USDA: aquic Paleustult

PA36 poorly drained, deep to very deep, yellowish brown to very dark gray, mottled, firm, sandy clay to clay. FAO: dystric Gleysol, USDA: tropic Fluvaquent

COASTAL UPLANDS (major rivers deeply incised, slopes in general 0-16 %)

USm Soils developed on medium-grained sands (Magarini sands)

USm1 excessively drained, very deep, red to dark red, very friable, sandy loam to sandy clay loam, underlying 20-40 cm of loamy sand. FAO: rhodic Ferralsol, USDA: typic and typic rhodic Haplustox

USm2 excessively drained, very deep, dark reddish brown to very dusky red, friable, sandy clay loam to sandy clay, underlying 20-40 cm of loamy sand to sandy loam. FAO: dystric Nitosol, USDA: rhodoxic Paleustult

USm3 well drained, very deep, light olive brown to gray brown sandy loam. FAO: albic and ferralic Arenosol, USDA: ustoxic Quartzipsamment

UT Soils developed on shales (Jurassic shales)

UT1 well drained to imperfectly drained, moderately deep to very deep, yellowish red to dark grayish brown, firm to very firm, clay; in places calcareous and/or cracking. FAO: eutric Cambisol, chromic Luvisol, chromic Vertisol, USDA: udic Ustochrept, udic Rhodustalf, typic Chromustert

UL Soils developed on limestone (Kambe limestone)

UL1 well drained, deep to very deep, yellowish red to brown, friable, silty clay to clay; in places fairly rocky. FAO: eutric Nitosol and ferric Acrisol, USDA: udic Paleustalf and typic Rhodustult

UL2 well drained, deep to very deep, weak red to red, fairly rocky, friable, sandy clay to clay; ferruginous gravel and sandstone boulders (Ø 5-15 cm) in topsoil. FAO: ferric Acrisol, USDA: typic Rhodustult

USs Soils developed on coarse-grained sandstones (Mazeras sandstone)

USs1 excessively drained, deep to very deep, reddish yellow to yellowish brown, loose, sand to loamy sand. FAO: ferralic Arenosol, USDA: ustoxic Quartzipsamment

USs2 well drained, deep to very deep, yellowish red to red, friable, sandy clay to clay; in places underlying 20-40 cm of loamy sand to sandy loam (if not truncated). FAO: dystric Nitosol, USDA: oxic Paleustult

USs3 moderately well drained, very deep, light olive brown to brown, very firm, clay; strongly saline and strongly calcareous in subsoil. FAO: orthic Solonchak, USDA: typic Natrustalf

USK Soils developed on fine-grained sandstones and siltstones (Mariakani sandstone)

USK1 association of:
- excessively drained, very deep, light red to brownish yellow, loose sand. FAO: albic Arenosol, USDA: ustoxic Quartzipsamment
- well drained, very deep, yellowish red to brown, friable sandy loam underlying 40-80 cm of sand to loamy sand. FAO: ferric Acrisol, USDA: typic Haplustult

USK2 well drained, very deep, yellowish red to brown, friable, sandy clay loam, porous massive structure, underlying 20-60 cm of loamy sand to sandy loam. FAO: dystric Nitosol, USDA: typic Paleustult

USK3 moderately well drained to imperfectly drained, very deep, olive yellow to grayish brown, mottled, firm, sandy clay loam to clay, abruply underlying 40-150 cm of sand to sandy loam. FAO: dystric Nitosol and luvic Arenosol, USDA: typic Paleustult and ustoxic Quartzipsamment

USK4 moderately well drained, shallow to moderately deep, yellowish brown to brown, sandy loam to sandy clay. FAO: dystric Cambisol and dystric Regosol, USDA: lithic Dystropept and -Quartzipsamment

EROSIONAL PLAIN (slopes in general less than 5 %)

PO Soils developed on Pleistocene "bay"-sediments

PO1 well drained to moderately well drained, very deep, yellowish brown to dark brown, very friable, sand to sandy loam. FAO: ferralic Arenosol, USDA: ustoxic Quartzipsamment

PO2 moderately well drained to imperfectly drained, very deep, light brownish gray to brown, mottled, very firm, sandy clay loam to sandy clay, abruply underlying 20-100 cm of loamy sand to sandy loam; moderately to strongly saline in subsoil FAO: solodic Planosol, USDA: typic Natrustalf

PO3 moderately well drained to imperfectly drained, deep to very deep, brown to dark grayish brown, mottled, very firm sandy clay to clay; in places strongly saline and/or excessively calcareous in subsoil. FAO: orthic Solonchak USDA: ustochreptic Calciorthid

ALLUVIAL FANS

Pf well drained, very deep, yellowish brown, friable, sand to loamy sand. FAO: dystric Cambisol, USDA: typic Ustochrept

TIDAL SWAMPS AND TIDAL FLATS

T very poorly drained, dark olive gray to black, unripened peaty and clayey soils, with sulfidic material. FAO: thionic Fluvisol and dystric Histosol, USDA: typic Sulfaquent and typic Sulfihemist

DUNES

D excessively drained, very deep, yellowish brown to brown, loose sand. FAO: cambic Arenosol, USDA: ustoxic Quartzipsamment

FLOODPLAINS

Ac complex of imperfectly drained to poorly drained, deep to very deep soils of varying colour, consistence and texture; in places calcareous and/or cracking. FAO: pellic Vertisol, USDA: typic Pellustert

MINOR VALLEYS

VX complex of deep soils of varying drainage condition, color, consistence and texture.

KEY

PL 2 soil mapping symbol
soil boundary
road
river
-100- -300- contours V.I. 200 ft.

soil survey J. Floor, R.F.M. Onck, E.M. Smaling

CARTOGRAPHY: R.F.M. ONCK

SCALE 1:100,000

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 KILOMETERS