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KENYA SOIL SURVEY

SOIL CONDITIONS OF THE MARAFA-MAGARINI AREA, KILIFI DISTRICT

A preliminary assessment

by

R.F. van de Weg and W.G.Sombroek

SITE EVALUATION REPORT

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Contents:

1. INTRODUCTION.

At the request of the Ministry of Lands and Settlement, in view of a soil-conservation orientated pilot project for settlement scheme improvement, to be financed and executed in cooperation with the Australian Development Assistance Agency, a site evaluation of the area was carried out on 17th and 18th of April 1976 in the Marafa-Magarini area, N.W. of Malindi township. The data gathered should help the Ministry and the A.D.A.A. in the planning of the proposed project. No soil data of the area existed; therefore with the help of aerial photographs on scale 1:50.000, a preliminary soil map of the area was prepared. It should be stressed however that the present mapping is a provisional one, based mainly on aerial photograph interpretation and a few field observations (augerings, profile pits, roadcuts) and laboratory data. Due to the limited time available, the site evaluation concentrated on the coastal plain and the uplands; the alluvial plain of the Sabaki river was surveyed earlier (1975) by the Minor Irrigation Development Special Task Force of the Kenya Soil Survey. Use could be made of their field and analytical data on the alluvial soils. These results of their site evaluation will be published in the near future in more detail (Bonarius, in prep.) Execution of a project as envisaged should however be preceeded by a proper semi-detailed soil survey, together with a topographical survey.

2. ENVIRONMENTAL CONDITIONS

2.1. Location and Communications

The area comprises about 56.000 ha and is located north-west of Malindi town in Kilifi district, Coast Province. It stretches from the shore line of the Indian Ocean in the east till appr.39° 55' E. and from the Sabaki river in the south till the 3°S. latitude in the north. Marikebuni, Magarini, Marafa, Dagamra and Garashi are the major villages. These are connected with motorable tracks with the main road Malindi-Garsen. The area near the Sabaki river which has a more dissected topography, is not

easily accessible, especially during the rainy season. The altitude of the area is between zero and 300 ft. (90m) with a few places reaching up to 500 ft. (150m.) on the ridge just east of Magarini village.

2.2. Climate (H.M.H. Braun)

Annual rainfall in the area decreases from around 1100mm at the coast to some 900mm at 25km inland (Marafa is situated around 20km inland). There is one major rainy period from April to June. Rainfall during this period is about 600 mm on average at the coast but it decreases to about 370mm at 25km inland. The period July-August has some 160mm rainfall at the coast and 120mm at 25km inland.

"Short rains" do not really exist: the period September-November has some 200mm rainfall on average throughout or 250mm for the period September to December with 300mm for the area at 25km inland. January and February are the driest months with a total of 25mm or less at the coast and 50mm or less at 25km inland.

The average evaporation of open water estimated with the Penman method by Woodhead (1968) for Malindi is: (in mm.)

Year	J	F	M	A	M	J	J	A	S	O	N	D
2260	210	200	210	190	170	160	160	170	190	200	190	210

Summary:

rainfall		evaporation	
coast	at 25km inland		
1100mm	900mm	2260mm	Annual
600	370	520	April-June
160	120	330	July-August
200	220	580	Sept.-Nov.
250	300	790	Sept.-Dec.
25	50	410	Jan.-Febr.

As shown, evaporation exceeds precipitation almost throughout the year.

2.3. Geology and Geomorphology

The area was geologically surveyed in 1950-1951 and a report together with a map were published in 1956 (Thompson, 1956). Geologically the area is composed of unconsolidated to slightly consolidated rocks of Tertiary and Quaternary origin. The relationship between parent rock/material and soils in the area is rather clear. This warrents an elaboration of the various geological formations which occur in the area. The following is a brief account of these formations:

The oldest formation in the area are the Baratuma beds (Tm on the geol.map); they are of Miocene age. They consist of light coloured, yellow, sandy marls, marly limestone and sands with occasional light grey or dirty white sandy marls. They are considered as having been deposited mainly under littoral or neritic conditions (shallow water deposits on the continental shelf). These beds are exposed along the dissected parts of the Sabaki valley and its side valleys. During the site evaluation they were clearly observed in the strongly dissected area a few kms west of the Sabaki bridge (cf. soil unit UW1)

They are overlain by sub-aqueous deposits of late Pliocene to early Pleistocene origin (Marafa beds); these are probably of lacustrine to fluvio-lacustrine origin deposited in lagoonal conditions ("bay sediments"). They are essentially light coloured sands and clays, white to creamy white, with occasionally lenticular bands of red and purple. The sands, clays and pebble beds are cross-bedded. These Marafa beds (Tpl on the geological map) are well exposed on an erosional scarp (called: "Hell's Kitchen") north of Marafa village, from which they take their name (see photograph in Thompson, 1956,fig.1). The beds are on the whole slightly consolidated and easily erodable (see also Caswell, 1953), when exposed. Very typical for this formation is their peculiar mode of erosion with narrow "ridges" and earth pillars.

The Magarini sands (Qtl on the geological map) are wind-blown unconsolidated "sands" which accumulated as coastal dunes during the Pleistocene period, when the sea level was appr.120ft (36m)

above the present day mean sea level. They have generally a vivid red colour and take their name from Magarini hill where they are well exposed in a N-S ridge. The sands are even-grained and well sorted and the quartz grains are encrusted with a thin film of ferric oxide (Fe_2O_3), which gives them their red colour.
During the middle Pleistocene time when these coastal dunes were accumulating along the shore-line, superficial deposits of red and reddish brown sands (Qr on the geological map) were developing in the hinterland. In places these "coversands" (interpretation of the authors) may be about 6-9m thick but generally they do not exceed 1.5m. These "coversands" occur however over less extensive areas than is indicated on the geological map. They are clearly exposed in the above cited erosional scarp near Marafa village and they cover quite an area south and west of Marafa village. Like the Magarini sands these sands are frequently associated with a discontinuous ferrigenous duricrust layer and/or a thin quartz pebble bed at their base, which forms the boundary with the Marafa beds proper.

Contemporarily and shortly after the accumulation of the Magarini coastal dunes, when the sea level was about 120 ft. above the present one, sediments were accumulating on the terrace cut by the sea during this period. These sediments (Pls on the geological map) accumulated between the Magarini sands and the offshore reef which was growing further to the east. These Pleistocene sediments (called: lagoonal sands and clays or Kilindini sands) are generally light yellowish and light loamy to clayey. They occur over most of the coastal plain.
During the slow retreat of the sea from the "120ft. terrace", sandy parts locally accumulated by wind action, forming small dunes with shallow depressions in-between. They can be seen in the area between Marikebuni and Magarini village. Also the rather high dunes just north of the Sabaki bridge belong to this unit (Qt3 on the geological map).

Recent deposits are found in a stretch east of the main road Malindi-Garsen. They consist of unconsolidated marine and terrestrial

deposits (units Rm and Rt on the geological map). In places these deposits are wind-blown and have accumulated in dunes, consisting mainly of quartz sands. These sand-dunes permit practically no run-off and many successful wells, yielding fresh water, occur at their base; this often occurs within a few hundred meters of the shore-line, as can be seen near Mambrui.

Geomorphologically the area consists of the following units:

- a coastal plain stretching from the shore-line up till around 120-150ft. (36-45m); soil units: DA1, DA2, PA1, PA2, PA3; this plain is nearly flat to (very) gently undulating, the latter where low dunes have been formed.
- coastal uplands, more to the West, gently undulating to undulating, over Pleistocene and late Tertiary deposits. These uplands are more dissected towards the Sabaki river; soil units: US1.US2, US3, US4 and UW1.
- alluvial floodplain of the Sabaki river; soil units AA1 and AA2.
- the flat bottomed valleys representing in-filled valleys of tributaries to the Sabaki river; soil unit: VA1.

2.4. Drainage

The principal direction of the drainage is south-east, in the direction of the main river, the Sabaki. Apart from the Sabaki all other rivers are intermittent, flowing only during flood-time generally during the months of April to July. Several swamps, large ponds and shallow lakes occur on both sides of the river Sabaki. They have been formed by the growth of natural levees along the river and the changing bed of the river. The course of the river as indicated on the accompanying map is the one of the 1:50.000 topographical map, sheet 193-1 and 192-2, dated resp.1971 (field revision, 1970) and 1962 (field revision, 1959). Comparison with the aerial photographs of 1967 reveals however that the present course of the river differs substantially from the one on the map sheet 192-2. The course is straightened and some meanders have been cut through. Probably these changes occurred during the big floods of 1961 at which time the whole floodplain was under water (local information).

2.5. Vegetation and Land Use

The vegetation consists mainly of bushland and bushed grassland of varying density and species composition and is greatly influenced by man. In the coastal plain most of the original vegetation is cleared and the land is cultivated in particular with tree crops. In soil units US3 and US4 of the uplands, most of the area is under bush and thickets; the near absence of trees, especially in unit US4 being a striking feature.

On unit US2 an open bushland is found.

Moomaw (1960) in his study on the plant ecology of the coast region indicates that most of the area covered by the site evaluation belongs to the "lowland dry forest" dominated by Manilkara-Diospyros ("black-bark") species. A subtype of this unit dominated by Cynometra-Manilkara species is found on the Magarini" sands" (soil unit US1). The open woodland near Marafa is dominated by Brachystegia-Afzelia species, which are typical for freely draining "sands".

Land use consists mainly of treecrops: cashew, some mango and coconut beside some subsistence agriculture (maize, beans, cassava). However large stretches are still non-cultivated. Most of the cultivation is concentrated on the alluvial soils of the Sabaki floodplain. Several crops are grown here: beside some coconut mainly maize, vegetables and bananas.

Near Dagamra a small plot is irrigated, all other cropping is rainfed. However plans are underway to increase the acreage of irrigated land. Soil and topography studies have been initiated to assess the available land and water resources (Bonarius, under prep.)

2.6. Population

The Giriama are mainly concentrated along the Sabaki and inland, where-as the Swahili live along the coast. The population density is low:

Dagamra location	:	37/sq.km (Kenya Population Census, 1969)
Magarini location	:	36/sq.km
Marafa location	:	18/sq.km

3. THE SOILS

The provisional mapping of the soils was done on a physiographic basis, relying on aerial photointerpretation and a limited number of field observations. This has to be borne in mind when considering the following generalized descriptions.

3.1. The soils of the coastal uplands

Slopes range here from 2 to in general 10% but in places slopes can be up to 16%, particularly in the soil unit US1.

Unit: US1 - Soils developed on "Magarini sands": Area: 1600ha

These soils are well drained and very deep. They are dark red when dry (2.5YR 3/6) and dark reddish brown (2.5YR $\frac{3}{4}$) when moist. The texture is sandy loam in the A-horizon and sandy clay loam in the B-horizon; structure is weak, fine to medium, subangular blocky and the moist consistence is very friable. These soils have no surface sealing, are porous throughout, and are non-calcareous, non-saline and non-alkali. Subsoil pH values (H_2O) are around 4.5 with pH-KCl values slightly lower. CEC values are low: CEC soil*is 5 to 6 meq. Base saturation is around 40%. From fertility** point of view these soils are generally poor in Ca and somewhat also in Mg but not so much in K. They show P-deficiency and are also acutely N-deficient.

As shown in the data, these soils are very poor from soil chemical point of view but they have good physical properties.

The same soils are encountered in the Kwale area (Michieka, Vleeshouwer, van der Pouw, under prep.) They are classified there as Rhod-acric Ferralsols***.

Land use at present is mainly treecrops with some seasonal foodcrops like maize. This unit is suitable for treecrops, especially cashew. Major limitations for arable farming are (in places) the steep slopes, but especially the very low nutrient status of the soil.

* determined by NaAc at pH 8.2

** mixed topsoil (0-30cm) samples were analyzed for fertility assessment

*** classification according to the "Soil Map of the World", FAO/UNESCO system (UNESCO-1974)

Unit US2: Soils developed on thin unconsolidated "coversands" over Marafa beds. Area: 7500ha

At several places the Marafa beds are covered by "sheets" of probably wind blown deposits. These areas are clearly recognizable both on the aerial photographs and on the ground as their vegetation (open woodland) stands out clearly against the areas with soils of unit US4 which have only thickets and hardly any trees.

The soils of this unit were studied at Marafa where a huge erosion "niche" reveals clearly these soils and their parent materials. They are well to moderately well drained and consist of a topsoil of sandy loam over a subsoil of sandy clay to even clay at greater depth (from around 1m.) At around 2m depth a ferruginous duricrust separates these soils from the unweathered, slightly consolidated Marafa beds below.

The colour of the topsoil is dark brown (7.5YR 4/4) and of the subsoil is strong brown (7.5YR 5/6-5/8 when dry and 7.5YR 4/8-5/8 when moist). From 160cm downwards the colour is brownish yellow (10YR6/6). Mottles are common to many from 50cm downwards but faint and fine. The structure is moderate, very coarse angular blocky and clay cutans are common but weak from 50-105cm (B1+B2 horizon). The consistence is hard to very hard when dry and friable when moist.

The soils are non-calcareous except for the C-horizon (from 160cm onwards) which is slightly calcareous.

pH-H_2O of the topsoil is 4.8; the B-horizon has pH values of 3.5 to 4.0; however the pH values are higher again for the B3 horizon (105-160cm) and the C horizon (160-200cm) respectively 5.2 and 7.4 . pH-KCl values are slightly lower. The C.E.C. soil of the B-horizon is 8-9 meq. Base saturation is 45-55%.

The first 50cm are non-saline and non-alkali, however lower down ECe values are resp. 5.0,6.5,12.0 and 18.0 which indicates slight to moderate salinity. E.S.P. * values for the subsoil are resp.16, 19, 21 and 38 which indicate moderate to strong alkali hazard.

From fertility point these soils show low levels of Ca, K and Mg and an acute P and N-deficiency, it shows also a significant exchange

* E.S.P.: exchangeable sodium percentage

acidity. Surface sealing is thin but strong.
These soils may be tentatively classified as orthic Acrisols, Sodic phase. Land use at present is limited; most land is still under open wood-land but treecrops are grown (cashew) and seem to do well.
This unit seems to be less suitable both for treecrops and seasonal crops in view of the salinity and alkaliness hazard in the subsoil. It is however not unlikely that in parts where the "coversand" layer is thicker there will be no salinity/alkaliness at all or only lower down in the profile. More observations are needed to confirm this. For arable farming the major limitation is likely to be the rather low nutrient status of the soil.

Unit US3: Soils developed on Marafa beds Area: 6600ha
This unit is found in the southern part of the study area on rather irregular undulating terrain, near the Sabaki river, with short slopes ranging from 5 to 10%. The vegetation consists of thickets but these are more open than in unit US4. The soils are well drained.
The A1 horizon is 20-30cm thick and consists of a very dark greyish brown (10YR 3/2), crumby, very friable, loam to sandy clay loam; it has a clear transition to a dark greyish brown (10YR 4/2) clay subsoil (B21 horizon) with a strong, medium angular blocky structure which is firm when moist, hard when dry. The A1 and B21 horizons are non-calcareous, non-saline and non-alkali.
The B21 horizon overlies with a distinct boundary at around 40-50 cm, a B22 horizon. The latter horizon consists of a weak red (2.5YR 4/2) clay with a coarse angular blocky structure, its consistence is firm when moist and hard when dry, and many clay cutans occur. The B22 horizon grades into a B3ca horizon which has similar characteristics but having many powdery pockets of soft $CaCO_3$. These latter two horizons are moderately calcareous, are slightly to moderately saline (ECe values of 7 and 10 mmhos respectively) and are moderately to strongly alkali (E.S.P. values of 24 and 30 respectively).

C.E.C. of the A1 and B21 horizons are 15 and 17 meq./100g respectively; and the B22 and B3 horizons have C.E.C. of 27meq./100g. pH-H_2O of the A1 and B21 horizons are 7.0 and 6.2 respectively, while the B22 and B3 horizons have pH values of 7.7 and 7.8 respectively.

From fertility point of view the topsoil is to be regarded as fertile and there is no sign of any deficiency, although N% is at the low side.

Tentatively these soils were classified as luvic Phaeozems, sodic phase.

At present there is some cultivation in this unit but it is very scattered. Few treecrops and some maize are grown. These soils, although lacking a clear hardpan as in unit US4, will however pose certain restrictions to root development. The area does therefore seem little suitable for treecrops; prospects for annual crops are likely to be better, as the chemical fertility is favourable. Much depends on the structural characteristics of the subsoil over the area of the mapping unit. A more regular soil survey is needed to assess the rooting possibilities more precisely, and also the depth of the "sodic" horizon.

Unit US4: Soils developed on Marafa beds. Area: 15.500

This unit, found in the northern part of the surveyed area on slopes ranging from 2-5%, consists of imperfectly drained soils. A topsoil of sandy clay loam (of about 20cm) having a very dark greyish brown colour (10YR 3/2), and a friable consistence overlies a sandy clay B1 horizon of about 20-40cm and which is dark grey (10YR 4/1) with brown, faint mottles. Both horizons are non-calcareous, non-saline, and non-alkali. The B1horizon overlies abruptly a pronounced hardpan with a strong columnar structure. This hardpan is reddish brown (2.5YR 4/4) with common, dark grey, faint mottles; it is extremely hard when dry and shows humus-coatings, argillans (clay cutans) and slickensides; it has a fine gravelly, sandy clay to clay texture. The pan is strongly calcareous, with powdery pockets of soft lime; it is non-saline

(ECe value of 2.0) but it is moderately alkali (E.S.P. value of 20); the pH-H_2O is 8.4.
These soils can be classified as solodized solonetz.
From fertility point of view the topsoil can be regarded as fertile; only N is deficient.
Similar soils, though with less humic top, are described by Sombroek et al. (1975) in the Tana region. They are described as the soils of the "sealing loam" plain and are also developed on the geological formation Tpl, which is considered also in that area as a lacustrine, fluviatile/lagoonal deposit ("bay sediments").

Apart from grazing, the present land use is restricted to some small clearings which are or were used for maize growing. The chemical fertility of the topsoil is favourable but these soils have very low infiltration rates and the hardpan is impenetrable for roots. They are therefore unsuitable for treecrops, and seasonal crops like maize will do satisfactory only when the rains happen to be abundant and well-spread (like in 1976). The soils seem however well suitable for grazing.

Unit UW1: Soils developed on sandy marls and marly limestone.
Area: 1100ha

These soils occur in an area just West of the Sabaki bridge. The unit which is clearly recognizable on the aerial photographs, is strongly dissected. It has steep (6-10%), short, convex slopes and is interspersed with many narrow, flat bottomed valleys ("bad-lands").
Soils are shallow and moderately well to well drained and consist of a 5 to 10cm thick A-horizon (dark brown-10YR 3/3 when moist) that is subangular blocky, friable, non-calcareous, slightly gravelly sandy clay loam. The A horizon has a clear transition to a 10-30cm thick B2 horizon which is reddish brown (5YR 4/4 when moist), mottled, angular blocky, firm, gravelly sandy clay loam (moderately calcareous and having common, weak clay cutans) over the parent rock. These soils are non-saline and non-alkali. They are tentatively classified as Luvisols, lithic phase.

At present the land is under bush and no use is made of it except for some grazing. The soils are unsuitable for any kind of arable farming due to various limitations (depth, slope, dissection, erosion hazard); these limitations preclude also any substantial development for range.
Soils of this unit are perhaps also found in other places especially along the more dissected parts of unit US3 and US4. This was however not checked during the site evaluation.

3.2. Soils of the coastal plain

These soils are developed on recent and subrecent marine deposits which were deposited under lagoonal conditions. The topography is nearly flat to very gently undulating, the latter one especially in unit PA3 in which the deposits are partly wind blown giving rise to slight undulations with small depressions in-between. Most of the area is cultivated: treecrops (mainly cashew) and smallholders seasonal crops (maize, cassava, beans). Three units can be distinguished:

unit PA3: Area: 1600 ha

The soils in this unit are comparable to the ones of unit PA2 (see below); no observations were made in this unit but it seems that the colour of the soil is somewhat more red and the loamy sand to sandy loam topsoil seems to be thicker. This unit is at present mainly under treecrops with scattered smallholder maize and beans cultivation. The depressions are used for grazing.

unit PA2; Area: 7000ha

There is quite some variation in this unit especially concerning the depth of the "sandy top" layer. In general these soils are well drained and very deep. A 20-60cm thick topsoil of loamy sand to sandy loam (very dark greyish brown, 10YR 3/2) is overlying with a clear transition a subsoil of dark reddish brown to dark yellowish brown (5YR 3/4 to 10YR 4/4), subangular blocky, hard when dry, sandy clay loam. These soils are non-calcareous, non-saline and non-alkali*. pH-H_2O values range from 6.3 to 5.7. CEC-soil ranges

* E.S.P. values are around 7

from 4.6 in the topsoil to 6.8 in the subsoil. Base saturation in the subsoil is around 70%. From fertility point of view the soils are poor in Ca and somewhat also in Mg but not so much in K. N and P are both deficient.
This soil may be classified tentatively as a deep Solod. The rather hard subsoil of these soils, if this applies to the whole unit, makes them only moderately to marginally suitable for tree-crops. For the cultivation of annual crops, the poor nutrient status and the sandy texture are limiting factors.
Soils of the units PA3 and PA2 were encountered also in the Kwale area during the reconnaissance soil survey. For comparison and more details on the variations in these units, the reader is referred to this survey report (Michieka, Vleeshouwer and van der Pouw, in prep.).

Unit: PA1 Area: 1800 ha

This unit occurs on a slightly lower level of the coastal plain probably representing a younger "marine terrace".
No data were collected on these soils in this unit but some information from similar terrains north of the study area (Wokabi et al., 1975) suggests that they tend to have a rather compact subsoil that is saline and/or alkali to a degree (Solod). Their suitability for treecrop growing would therefore be very limited, and also for arable cropping they would be moderately suitable at best.

3.3. Soils of the floodplain of the Sabaki river

During the site evaluation no observations were made on the soils of the floodplain since they were already investigated during one of the site evaluations of the Kenya Soil Survey's Task Force. The results of this survey have not yet been published but use could be made of their data. Broadly two units can be distinguished:

Unit: AA1 Area: 4300ha

This unit covers the major part of the floodplain. It consists of well drained, very deep, strongly stratified soils, mainly developed

on the levees of the Sabaki river. This river has changed its bed many times which is reflected in the stratification of the alluvium. The texture ranges from silt loam to sandy clay loam; colours are mainly dark brown to yellowish brown; consistence is friable. From the laboratory data it appears that these soils are non-calcareous, non-saline and non-alkali. pH values range from 6.6. to 7.5. These soils are heavily cultivated with a wide range of crops: maize, beans, coconuts, bananas etc. As also the topography is favourable, these soils appear to be well suitable for irrigation.

Unit AA2: Area: 2000ha

Somewhat further away from the Sabaki river, in the backswamp area of the floodplain, soils of unit AA2 are found; these soils are also very deep and stratified but textures are much heavier and range from clay to sandy clayloam. They are also non-calcareous and in general non-saline and non-alkali but at a few places ECe values of 3 and 4 are found, indicating a tendency to salinity. pH values range also from 6.6 to 7.5. Drainage conditions of these soils are variable; near the uplands, drainage is poor and swampy areas occur.

These soils seem to be somewhat less suitable for irrigation as drainage may pose serious problems, and detrimental salinization may develop in the long run.

3.4. Soils of the Valley Bottoms

Unit VA2: Area: 1400ha

These valleys with flat bottoms probably represent former river valleys which at one time may have acted as estuaries. At present they are in-filled by fine textured deposits probably of fluviatile origin although marine influence should not be excluded.

Soils of this unit are very deep and poorly drained, they consist of heavy clays (clay percentage around 80%), very dark grey to very dark greyish brown (10YR 3/1 to 3/2), mottled, and of firm when moist and very hard when dry consistence. Two samples were

analyzed of which one was calcareous and the other one non-calcareous, with pH ranging from 7 to 8. They are strongly saline (ECe of 25 to 30 mmhos/cm) and have ESP values of around 20 which points to moderately alkali conditions. The salinitity and alkalinity data are based on only two augerings but the sites concerned are most probably representative for the whole unit.
The land is not cultivated at present and from the laboratory data one may assume that this unit is unsuitable for any cultivation but can be used for grazing in the dry season. In the wet season the area is swampy.

3.5. Soils of the Tidal Flats and Tidal Swamps

Unit TA1: Area: 2000ha

This unit was not surveyed during the site evaluation, the boundary was drawn from the aerial photographs.
This is a flat area with many tidal creeks. By extrapolation from other data (Wokabi et al., 1975) it could be inferred that the soils are very poorly drained, mottled (and in the swamps unripened) clays, which are very saline and may acidify on drying (Thionic Gleysols in the swamps, gleyic Solonchaks on the flats). During the high tide the swamp area is under seawater. The vegetation in the swamps is predominantly mangrove forest. Near Godoni salt is mined by evaporation of the seawater in drying pans. The soils are unsuitable for any cultivation.

3.6. Soils of the Beach Ridges and Dunes

These soils are developed on recent and subrecent marine and terrestrial deposits. The sand is partly marine, partly brought down by the Sabaki river and deposited at their mouth and brought northwardly by the along-shore currents.
Two units can be distinguished:

Unit DA1. Area: 900 ha

This unit is found on the elongated red-sand dunes stabilized just north of the Sabaki bridge. Soils are very deep, well drained and have fine sandy loam to sandy clay loam texture (ferralic

Cambisols?). These are older stabilized dunes and may have been formed in upper Pleistocene times.

Unit DA2: Area: 2700ha

This unit covers the beaches and the recently formed dunes and marine deposits. Soils are excessively drained, very deep, yellowish brown, loose sands (Arenosols). This area has many wells yielding fresh water.

In the DA1 area slopes are considerable and may range up to 10%; in the DA2 unit the area ranges from flat (around Mambrui) to undulating, due to dune formation in the north-eastern part (Ngomeni). The soils as a whole do not seem to be suitable for cultivation. Treecrops may be possible especially in unit DA1, in this unit however care has to be taken to avoid increasing accelerated erosion. At some places it was noted that due to clearing of rather steep slopes gullies were forming.

4. CONCLUSIONS AND RECOMMENDATIONS

a) The climate in the area is in general marginal for arable cropping. There is one major rainy period from April to June with rainfall ranging from about 600mm at the coast to about 370mm at 25km in-land. It seems therefore advisable to focus the attention mainly to drought-resistant crops as these can be grown without too large a risk.

b) The total area investigated comprises about 56,000ha. Out of this total, 7,200ha are at present unsuitable for any arable farming; soil units UW1, VA1, TA1 and DA2 are involved.

The soil units US1 and US2 which occupy 1,600ha and 7,500ha respectively, have good physical properties. From chemical point of view however these soils are very poor. Furthermore soil unit US2 shows moderate salinity and alkaliness in the deeper subsoil.

Soil units US3 and US4 which occupy 6,600ha and 15,500ha respectively, on the other hand, have a fertile topsoil but poor physical characteristics in the subsoil. At a depth of about 30-40cm they have a hardpan which is almost impenetrable for roots and moreover shows slight salinity and moderate alkaliness. These soils are not suitable for treecrops; suitability for arable crops depends on the variation in the structural characteristics of the subsoil. A more regular soil survey is needed to assess the average depth of the problem-free topsoil over the area.

Soil units DA1, PA3, PA2 and PA1 occupy 900ha, 1,600ha, 7,000ha and 1,800ha respectively. They seem moderately suitable for treecrops. For arable seasonal crops, however, the poor nutrient status and the sandy texture are limiting factors.

The soils of the floodplain i.e. soil units AA1 and AA2, respectively occupy 4,300ha and 2,00ha. They seem to be highly suitable for irrigation. Certain provisions will however have to be made for proper drainage measures, especially in unit AA2.

c) It should be stressed that the execution of a project as envisaged (see introduction) should be preceeded by a proper semi-detailed soil survey together with a topographical survey.

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