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KENYA SOIL SURVEY

PRELIMINARY EVALUATION OF THE SOIL CONDITIONS OF THE TANA DELTA FOR IRRIGATION DEVELOPMENT

By

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A preliminary Evaluation of the Irrigation Suitability of the Tana Delta

INTRODUCTION

At the request of the Tana River Development Authority, a site evaluation of the soil conditions of the Tana Delta was carried out. This area lies on the east and western bank of the Tana River and stretches from Garsen to the mouth of the river. The field work was done on 14-18th January and 3rd - 8th Feb. 1975.

Like the pre-delta area (cf KSS site evaluation report no. 15) there are a few minor irrigation schemes under operation in the Tana delta zone (Oda, Ngao) while at the mouth of the river (Kau village) paddy rice cultivation on the high tidal-floods is being practised without government support. The present study should enable the Tana River Development Authority to determine whether any large-scale irrigation development in the Tana delta is feasible, and also assess it in relation to irrigation development upstream (Bura-west and Bura-east). A partially irrigated commercial estate, bounded by dikes (Bellazoni or Sadani estate) was in operation from 1912 to 1931. The accompanying map indicates the location of Bellazoni estate (about 10,000 acres). The estate was used for growing cotton, perak rubber, coconut, maize, cassava and rice. Rice was grown rainfed but augmented by floods. Rice as well as other crops were said to be doing well. Cattle was raised at small scale but they were virtually wiped out by east coast fever and rinderpest. The estate was said to be abandoned mainly because of the 1931 slump which rendered the estate uneconomic. (cf. Palmer 1951; Anon. 1953). A detailed soil and topographical survey of the estate was carried out in 1953, but the resulting maps cannot be traced. Bellis' lab data (1953) on the samples however suggest that at least two-thirds of the area (the southern part) is unsuitable for cultivation because of high salinity.

Also from Beckley's report (1934) and our own investigations in the surrounding areas it becomes apparent that at least a part of the soils are saline and are acidified on drying, besides showing irreversible shrinking. Moreover, the dykes that were constructed reduced the regular flooding which resulted in reduction of silt deposition within the estate. The enclosed area settled and in the course of time it became relatively lower than the surrounding land. In the event of the breaking of water through the dykes, the enclosed area became more vulnerable to damage by the floods.

In preparation for the fieldwork, aerial photos 1:50,000 of R.A.F. 1969 were used for preparing a physiographic photo-interpretation map of the whole area. This map was then used to locate observation points. It must be pointed out that the area under study covers many thousands of hectares and is also extremely inaccessible, even by Landrovers. This situation necessitated the use of a helicopter which could easily hop around and land on predetermined observation points. The Tana River Development Authority therefore kindly arranged for the use of a Police helicopter for two days. Under such circumstances, the relatively few observations (35 augerings) gave an adequate first insight. Beckley's data of 1934 could also be used to a degree although they are located mainly on higher ground along the river course. A few water samples were also collected for laboratory analysis.

This report and the accompanying map is only a very preliminary invesigation of the Tana delta. Before any large scale irrigation scheme could be embarked on, it will be necessary to carry out a semi-detailed soil survey of the area as well as studies on hydraulic and topographical aspects. Soil physical properties will also have to be investigated, both in the field and the laboratory. The cooperation of Mr. Classen of Ministry of Water Development and Mr. Trump of the TRDA in procuring former soils and crop data is gratefully acknowledged.

2. ENVIRONMENTAL CONDITIONS

2.1. Location and Communications:

The area under investigation consists of about 211,700 ha and forms part of Tana River district and a small part of Lamu District. The area lies approximately within the longitudes 40° 05' and 40° 30'E and latitudes 2° 17' and 2° 40'S. The larger shopping centres namely Garsen, Witu and Kipini are found at the edges of the survey area. Garsen is important in that the crossing point over the Tana by a ferry (Ministry of Works manual ferry) on the main Malindi-Lamu road is located at the town. The town is also a fueling point along the Malindi-Garissa road. Other smaller villages such as Ngao, Oda, Samikaro Idsowe are located on the high lying parts of the Tana River levees.

The main road from Malindi via Garsen and Witu to Lamu is the only all-weather road in the area. It is to be noted that during excessive floods some parts of this road are damaged and consequently communication by road is completely cut off. On the western bank of the Tana, the only villages that have feeder roads to the main Malindi-Garsen road are Karawa and Ngao. On the Eastern bank, Dida Weredi has a feeder road from the Garsen-Kipini road, crossing the floodplain.

River Tana is extensively used by the inhabitants for transport of people and cargo such as fish by canoe. The extended floodplain is virtually inaccessible by any motor vehicles.

. 2.2. Geology, Geomorphology and Drainage:

A small southern part of this area is covered by the geological report No. 52 (Geology of the Hadu-Fundilsa area North of Malindi by L.A.J. Williams). The rest of area is covered by a draft geological reconnaissance of the Lamu-Galole area (unpublished maps and reports of Matheson 1961).
The floodplain consists of recent alluvial sands, silts and clays of the Tana river. Further silting continues at the present time as a result of the biannual flooding. Other recent deposits include marine sands, muds and coastal dunes. The terraces (T) consists of Pleistocene marine sands and clays while the ridges (L) are composed of Pleistocene sands.

The floodplain is generally flat and extensive and is only a few metres above sea-level. The only recognizable mesorelief features are the branching, abandoned river streams, their levees and backswamps. The terraces rise from the floodplain through gentle slopes to an elevation of about 5 m. The ridges rise from the terraces through more abrupt slopes than the former to heights of about 15 m above sea-level. Most of these ridges are elongated and have a curved south-west to north-east direction. The Holocene coastal sand dunes appear as parallel ridges of about 20m high. Their continuity along the coast is broken up by former and present mouths of the Tana river.

The Tana is the only permanent river in the area flowing southwards in a series of meanders turning eastwards to its present mouth at Kipini. The course of the river has changed its course in the course of time leaving behind two abandoned river courses namely Mto Tana in the centre and Mto Kilifi towards the western margin of the alluvium. This change of course was aided by the construction of the "Bellazoni canal" by the Sultan of Witu in 1865, connecting the original Tana with the short river Osi near Kipini. Flooding takes place twice a year in May - June and November - December to an average depth of 30 - 60 cm. Extra supply of water comes from shallow wells in the Holocene sand dunes. Quantity of water from such wells is small but it is fresh.

2.3. Climate:

The bulk of the area under investigation lies within the semi-arid climatic zone. Mean annual rainfall decreases from the coast towards the inland.

Kipini, Witu, Ngao and Garsen have mean annual rainfall of about 1070 mm. 1095mm, 760mm and 570mm respectively. For Bellazoni Estate nearly complete monthly rainfall records are available from 1921 to 1953.

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The rainfall has a bi-modal pattern that is April to July with maximum rain in May, and November to December (Table 1).

Virtually the whole of this area lies in a zone of 20 - 30% probability of obtaining less than 750 mm rainfall.

Though the temperatures are high throughout the year, the area can be divided into two zones.

A small area along the coast has temperatures ranging from 26 - 30°C while the rest of the area has temperatures ranging from 30 - 34°C.

Potential evaporation is also high ranging from 2200 to 2400 mm per year.

With the prevailing climatic conditions, rainfed arable farming is hardly possible. But with available water from the Tana, extensive irrigation development would be possible provided that the soils are suitable and flooding can be controlled.

Table 1.

Average monthly distribution in mm.

...n Reg. ...o.	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual	No. of yrs for average
...pini ...400.00	27	8	42	141	340	134	75	41	54	54	70	85	1070	48
...tu ...400.03	26	9	36	129	291	150	82	52	65	58	96	99	1090	36
...no ...400.04	22	11	58	116	113	76	38	39	77	48	95	64	760	6
...da ...39000	17	14	44	124	164	93	67	63	58	79	139	72	930	9
...llazoni ...4002	23	7	32	108	253	148	76	54	47	59	38	83	930	22

2.4 Vegetation, Land use and Population

The vegetation of the area can be divided into four main zones. In the zone covering the floodplain on both sides of Tana, the vegetation is composed of predominantly tall elephant grass and other species of grasses. A second zone which is found on both sides of the Malindi-Garsen road has bushland vegetation cover. Various species of Acacia are found in this zone. On both sides of the Garsen-Witu road, the vegetation is predominantly woodland. Isolated patches of forest are also found in this zone.

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Mangrove swamps exist extending from the coast along past and present mouths of the Tana river.

Virtually the whole of the floodplain is used for grazing in dry periods. During the flooding period, families together with their herds move to the high lying and dry land on the terraces, ridges and levees. Subsistence farming takes place on a small scale especially on the western bank of the Tana. Cultivation is concentrated on the levees but parts of the backswamp are used for growing rice. The main annual crops include rice, sugarcane, maize, beans, cassava, sweet potatoes and pumpkins. The biannual/ perennial crops include pawpaw and mangoes. The terraces and ridges are primarily used for grazing. Around Ngao settlement, the sandy ridges are used for growing tree crops such as mangoes.

The Tana river contains fish which forms part of the staple food for the local population. Some of the fish are exported to larger towns such as Mombasa and Malindi. The Tana supports herds of hippos which at times are a menace to farmers. Other wild game existing in the area include waterbucks, various species of monkeys, and a few elephants. This wildlife is particularly common in the stretch of coastal marshes beyond the dunes.

The inhabitants of the area are the Pokomos but Somalis have of late migrated from the North East of the area in search of good grass for their animals on the eastern-bank floodplain. The population density as per 1962 census was low, 1 - 10 persons per sq. km. The prevailing climatic and flooding conditions do not favour a large population. In future however major agricultural developments could lead to migration of population from other areas.

3. The soils

3.1. Introduction

The provisional mapping of the soils was done on physiographic basis, relying very much on photo-interpretation and a limited number (35) of field observations. Extra data (19 Observations) on soils were obtained from earlier investigations carried out in the same area by Mr. Ootes and analysed by Mr. V.A. Beckley in 1933/34 (re-numbered as observation numbers 179-40 to 50 and 187-10 to 16). No field tests were performed due to shortage of time and lack of means of transporting the necessary equipment to the observation sites. The exact location of some of the observation sites could not always be established accurately owing to the smoothness of the terrain and lack of any easily identifiable ground marks.

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There are however extensive stretches of homogenous areas, therefore slight misplacement of a few observation sites do not seriously affect the soil boundaries. Little study was carried out on vegetation, consequently the descriptions given in this report is very generalised.

3.2. Floodplain:

The floodplain consists of two main land units, each of them is again sub-divided into two. The first unit, of floodplain proper, is subdivided into: river basinland (Pb1) and estuarine basinland (Pb2). The second unit, levee land (that is just above present day normal flooding), is subdivided into: river levee land (Fl1) and estuarine levee land (Fl2).

Unit Pb 1 comprising of 38,455 ha is extensively flat, without any appreciable meso and micro-relief. The land is flooded twice a year till a depth of 30-50 cm. The soils consists of heavy clay till 2-3 m depth or more, underlain by stratified sandy sediments.

The topsoil (20-60) consists of very dark gray (10YR 3/1) heavy clay which is hard when dry and also cracks rather strongly. The organic matter content is fairly high (varying between 2 and 3%C). The topsoil is non-calcareous, non-saline and non-alkali. Transition from topsoil to subsoil is gradual.

The subsoil is predominantly grayish brown (10YR 4/2) and slightly mottled (yellowish and reddish mottles) heavy clay with firm to very firm consistence, but not a hardpan. The bulk of these soils are non-calcareous, nonsaline and non-alkali. In places however, the soils are slightly saline and slightly to moderately alkali (EC 7-14 mmhos/cm; ESP 16-30%: Mollic Gleysol.). The salinity and alkalinity characteristics appear normally below 100 cm depth. This unit however is the most suitable area for irrigation development, especially for paddy rice. The hydraulic conductivity of the soil is very low (1 cm/ day, cf. site evaluation No. 15) thus deep drainage would be considerably hindered.

The unit is largely covered with a dense mat of tall grasses. At the moment extensive grazing is the main use of the land during the dry periods.

Unit Pb2 comprising of 13,815 ha. is extensively flat with microrelief of gilgai and cowfoetoes. Like unit Pb1, this unit is flooded twice a year. The soils consist of heavy clay till about 100 cm. depth and therebelow the soils vary in texture from sandy clay to sandy clay loam, the clay content decreasing with increase in depth.

The topsoil (20 - 40 cm) consists of very dark gray to dark gray (10YR 3/1 - 10YR 4/1)light clay or heavy clay, which is very hard when

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dry and cracks strongly on drying. The organic matter content is only fair (about 2%C). The topsoil is non calcareous, non-saline and non-alkali. Transition from topsoil to subsoil is gradual.

The subsoil is generally poorly drained, predominantly half ripe, in places unripe+), very dark gray to dark gray (10YR 3/1 - 10YR 4/1) heavy clay with a firm consistence. In most places, at depths below 50 cm, the pH drops to below 4.5. (to pH 3.6). Clusters of gypsum crystals are found as from depths of 40 cm but in places they increase with depths. These phenomenona, and the presence of half-ripe or unripe clay indicates possible development of catclays after the drying up of the soils. The soils are generally non-calcareous, moderately saline and alkali (EC 6-18 mmho/cm; ESP 15 - 80%): Mollic Gleysol. The salinity and alkaliness of these soils, poor drainage and possible catclay development make this unit non-suitable for irrigation development. At the moment the drier parts of this unit are used for grazing.

Unit F11 comprising of 11,960 ha, is generally flat with irregular mesorelief a.o. due to the presence of abandoned river beds and former splay and pointbar features. With very careful control of the water level paddy rice may be grown locally. The soils consists of fine sands to loam to a depth of few metres, in places however the soils are heavier. The topsoil is dark brown sandy loam to sandy clay loam with fair organic matter content (2%C). The subsoil, mainly dark yellowish brown and with reddish yellow mottles still maintains a distinct sedimentary stratification. The soils are non-calcareous, non-saline and non-alkali till a depth of at least 2m depth (Eutric Fluvisol) / Tillage of these soils would be easy but the infiltration rates would be rather high. These characteristic and the irregular mesorelief make the unit be classified as only marginally suitable for large-scale irrigation. Minor irrigation development, with pumping from the river channel, may locally be a feasible proposition. (cf. Oda and Ngao).

At the moment, cultivation at small scale is practiced within this area-whereby crops such as maize, and local fruits like bananas and mangoes are grown. The levee lands contain the villages as well. The original vegetation, presently occurring only in patches, consists of rather high riverine forest, of varied composition.

Unit F12 comprising of 1,600 ha, is generally flat but it is slightly elevated (0.5 - 1.0m) above the floodplain. Up to a depth of about 100 cm, the soils consists of ripe or half-ripe clays but there below exists stratified sandy loams which are generally waterlogged.

The topsoil is gray clay which has yellowish red mottles. The subsoil is poorly drained yellowish mottled nearly ripe or half-ripe dark gray (10YR 4/1) heavy clay. This subsoil is moderate to strongly saline and strongly alkali (EC 7-30 mmho/cm; ESP 70 - 90%) and pH drops below 4.5, (to pH 2.5) indicating a catclay hazard: Thionic Fluvisol.

At the moment, the area is intensively cultivated for small-scale paddy rice growing, utilizing natural flooding by fresh riverwater (pushed back by periodic high tides). The raised banks around the rice fields are used for growing bananas and sugarcane. At the time of the investigations, the rice crop was not doing well. The only remnants of the natural vegetation is low forest with dense undergrowth.

3.3. Coastal Marshes and Swamps

The coastal marshes and swamps consits of two units namely coastal marsh land (M1) and coastal swamplland (M2).

Unit M1 comprising of 11,620 ha, is flat with a mesorelief of tidal creeks. This land is flooded twice a year like the floodplains, but in addition has the influence of sea-water especially during the high tides.

The topsoil and subsoil consists of very dark gray (10YR 3/1 - 10YR 4/1) yellowish and reddish mottled, half-ripe heavy clays. The topsoil is non-calcareous, non-saline and non-alkali while the subsoil is saline (in places very saline) and non-alkali (EC 15 - 50 mmho/cm; ESP 15%): Eutric Gleysol/ saline phase The subsoil acidifies on drying (pH 4.5). The physical conditions of this unit is very unfavourable for human habitation therefore there is hardly any people living in this area. Vegetation consists mainly of grasses and marsh/plants. The unit is unsuitable for irrigation, unless elaborate and costly reclamation measures are applied.

Unit M2 comprising of 1,245 ha, is flat with many tidal creeks. Very little investigations were done on this unit. By extrapolation however, it could be inferred that soils here are very poorly drained, mottled and possibly unripened clays which are very saline and acidify on drying: Thionic Gleysol. This unit is much more influenced by the sea water than M1. During the high tides, most of the area is under water. The vegetation is predominantly mangrove forest. Mangrove trees are used locally for building and some of the wood is exported. The soils are unsuitable for irrigation development.

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3.4. Dunes and Recent Beach Ridges:

Unit D comprising of 13,530 ha, is undulating to rolling and located predominantly along the coast. The soils consists of excessively drained deep yellowish (10YR 7/1) sands. Cambic Arenosols. The vegetation is predominantly bushland thicket. At the moment this area is only inhabited by wild animals. Evidently, irrigation development is excluded.

3.5. Bottomlands:

Unit B comprising of 7,765 ha, consists of flat to very gently undulating depression areas within non-flooded terrain. The soils are clayey, probably strongly alkali. The vegetation varies from grassland to bushland or marsh vegetation. In places, open water prevails (especially during wet season).

3.6. Terraces

The terraces are subdivided into two units namely higher (T2) and lower (T1) terraces.

Unit T2 comprising 56,180 ha consists of flat to gently undulating terrain with a mesorelief of sub-circular depressional parts ("mud-wallows", diam. 10-200m), which appear light coloured on aerial photos. The higher terrace is about 5m above the floodplain and it occurs on both eastern and western banks of the Tana delta. The soils are well drained to imperfectly drained. The topsoil is gray to very dark grayish brown (10YR 3/6 - 10YR 3/2) sandy loam to sandy clay, slightly calcareous, non-saline and non-alkali. Like unit L1, there is a clear transition to a subsoil of which the upper part forms a pan which is extremely hard when dry. The subsoil consists of pale brown to dark gray (10YR 4/3 - 10YR 4/1), sandy clay to clay, in places calcareous, moderately saline, moderate to strongly alkali (EC 12.5 - 16 mmho/cm; ESP 17 - 50%). Salinity and alkaliness increase with depth: Solodised Solonetz.

Vegetation is mainly bushland. The presence of a hardpan and the saline-alkali condition of the soils render the unit non-suitable for irrigation development.

Unit T1 comprising 27,455 ha consists of flat to very gently undulating terrain. This lower terrace is about 2-3m above the floodplain and it occurs on both the eastern and western banks of the Tana delta. The soils are imperfectly drained. The top soil (20 - 40 cm) consists of dark gray to gray (10YR 5/2 - 5YR 4/1) calcareous non-saline and non-alkali clays. The transition to the subsoil is not as pronounced as in the T2 soils but the top of the subsoil is very hard when dry.

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It consists of predominantly gray (10YR 5/1) clay, calcareous, moderately saline and moderately to strongly alkali (EC 9.0 - 13.5 mmhos/cm; ESP 22 - 71%). Salinity and alkaliness increase with depth: Orthic Solonetz.

Vegetation is predominantly bushland and sparse grass coverage. The structural development of the soils and their salinity/alkaliness make them non-suitable for irrigated cropping.

3.7. Lagoonal Sand Ridges:

The ridges are subdivided into two units namely L2 and L1, the former being relatively higher than the latter.

Unit L2 comprising 1,250 ha. consists of gently undulating terrain. Topographic wise the ridges rise 10-15m above the floodplain. They are normally elongated and lie approximately in a North-east to South-west direction. The soils are excessively to well drained. A topsoil of yellowish brown (10YR 4/4) loamy sand which is non-calcareous, non-saline and non-alkali, grades gently into a sub-soil consisting of predominantly reddish brown (5YR 4/4) sandy loam, that is equally non-calcareous, non-saline and non-alkali; ferralic Arenosol.

The vegetation is predominantly woodland with a few Acacia species and sparse grass cover. The unit is classified as non-suitable for any irrigation development due to its unfavourable topographical position. Also, the soils are very sandy and therefore excessively permeable.

Unit L1 comprising 22,630 ha consists of flat to gently undulating land with mesorelief of slight depressions and slightly raised parts (often forming dark and lighter ripple-patterns respectively on the aerial photographs). Unlike the elongated L2 ridges, the L1 ridges are occasionally extensive.
The soils in this unit are generally well drained. They consist of a top soil of 15-40 cm fairly permeable dark yellowish brown to light gray (10YR 3/4 - 10YR 7/1) loamy sand to sandy loam, non-calcareous, non-saline and non-alkali. There is a clear transition to a subsoil of which the upper part (about 30 - 40 cm) forms a pan which is extremely hard when dry. This subsoil consists of brown to reddish brown (7.5YR 4/4 - 5YR 4/4) predominantly sandy clay loam. Generally the subsoil is non calcareous but saline and alkali (EC 15 - 20 mmho/cm; ESP 35-50%), the higher figures occuring in the deeper subsoil : Solodized Solonetz. In places however the subsoil is non-calcareous, non-saline and non alkali.

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Thevegetation varries from wooded bushland to open grassland. Considering the topography (meso-relief in particular) and the soil conditions (hardpan, salinity, alkaliness) it can be inferred that this unit is non-suitable for irrigation development.

3.8. Uplands of Magarini Sands

The uplands were little studied because of their occurrence outside the main zone of interest. The uplands are generally undulating and rise about 10m or more above the higher terraces. Unlike the more or less narrow and elongated lagoonal sand ridges, the uplands are more extensive. The soils are possibly well drained, deep, but varying in textures. The vegetation cover is predominantly dense wooded bushland. This unit, covering 940 ha, is definitely non suitable for irrigation development because of its topographical position.

4. IRRIGATION SUITABILITY

As described in chapter 3, only two units (Fb1, F11) are worth considering for any irrigation development. The other units have either topographical or soil physical or chemical limitation; or both.

The floodplain proper (Unit Fb 1) seems moderately well suited for large-scale irrigation. The extensive floodplain consists of stable (ripe) heavy clay soils that tend to have no appreciable salinity/ alkaliness and no exceptionally low pH.

These lands have the advantage that they occur in large acreages and they are very flat thus levelling would be minimal. The soils will however be difficult to manage because of the heaviness of the clay (difficult tillage). The thickness of the clay layer (2-3 m or more) could hamper deep drainage, which is essential in view of the likely salinity of the substratum (salinization hazard).

Annual cropping but not for perennial crops.

Gravity irrigation with furrows or basins would be most suitable for these lands. The growing of paddy rice seems to be a favourable proposition, also field crops like cotton, maize and sugar cane have a good chance of doing well. The floodplain could also be used for production of fodder or hay, with or without irrigation.

The acreage of the floodplain that could be considered for extensive irrigation project(s) is about 25,000 ha. This area lies in the north-eastern part of the delta, starting 7 km East of Garsen on the Garsen-Lamu road, follows the eastbank of the old Tana course in the Garsen-Ngao stretch and the eastbank of the present Tana in the Ngao-Samikaro stretch; and from there it follows a hypothetical line due NNE ("Biyadi" development area).

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The levee land (Unit Fl1) is marginally suitable for irrigated agriculture. The light texture of the soils would hamper basin irrigation due to the rapid infiltration of the soils. The unit has a disadvantage that it occurs as narrow elongated band. The presence of mesorelief would necessitate levelling which would be detrimental to the soil physical conditions. This unit has the advantage of being slightly above flooding level.
Two small irrigations schemes on this unit (at Ngao and Oda) are at the moment operational and there seems to be scope for the development of more of such minor irrigation schemes. Crops such as bananas, maize and vegetables are doing fairly well. Fruit trees crops (e.g. mangoes) would do well on these soils.

5. FLOOD PROTECTION AND DRAINAGE REQUIREMENTS

The area which is well suited for large-scale irrigation development is flooded twice a year (chapter 2.2) and therefore drainage requirements have to be considered seriously. With the construction of more and larger dams in the Tana upstream, it could be possible to control the floods to a certain extent. Without such flood control, it would be essential to protect the floodplain by low dikes (empoldering). The section of the present Garsen-Lamu road that crosses the floodplain would form the obvious northern part of such system of dikes. On the western, southern and south-eastern sides of the suggested "Biyadi" development area, however, a dike construction of at least 40 km will be required. If such protection is not possible then arrangements have to be made in a manner that the floodwater is drained off twice a year as soon as possible to allow proper land management.

Drainage is however essential to avoid ultimate salinization and/ or alkalisation of the rooting zone which would render soils unsuitable for crop growth. The Tana river surface water is of excellent quality for irrigation but the ground water may contain harmful concentration of salts in general and of sodium and bicarbonate in particular.

For the floodplain proper, where the present day dry season ground water level is only 3-4m., measures should be taken to avoid any substantial rise of the groundwater level which would result in contact between this poor-quality water and the moisture of the rooting zone. Under irrigation, there will always be excess water (over-irrigation, seepage from canals, flooding or heavy showers) which would induce such a rise unless drainage is effected.

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A major drainage canal on the western and southern side of the suggested development area may be constructed in conjuction with the dikes.

Runoff (from heavy showers) from high lying lands on the eastern part of the floodplain would have to be controlled by constructing a deep interception ditch (drainage canal) somewhere along the edge of the floodplain (on the eastern bank) to drain away such water.

6. CONCLUSION AND RECOMMENDATIONS

1. Three main physiographic units that could be considered for irrigation exists in the area of the Tana delta, namely the terraces (T_1, T_2) and the floodplain proper (Fb1). The first two units are, topographically and soil texture wise, suitable for irrigation but they have problem of salinity and alkaliness. The floodplain proper (Fb1) has heavy clays which are only slightly saline and alkali. This unit is moderately well suited for irrigation. It comprises 38400 ha in total of which 25,000 ha exist in a nearly homogeneous block to the northeast of the main river channel.

2. In any irrigation project of substantial acreage, great attention will have to be paid to deep drainage because of the necessity to keep the level of the brackish ground water sufficiently deep below the rooting zone.

3. Any major irrigation development in the floodplain should be preceded by proper semi-detailed soil survey, which should include the mapping of the chemical and hydrological properties of the deep subsoil and substratum.

4. The area enclosed by the Indian Ocean, the lowest part of the present river course and Mto Kilifi (abandoned river course in the south-western part of the delta proper) is recommended for a game park or game reserve.

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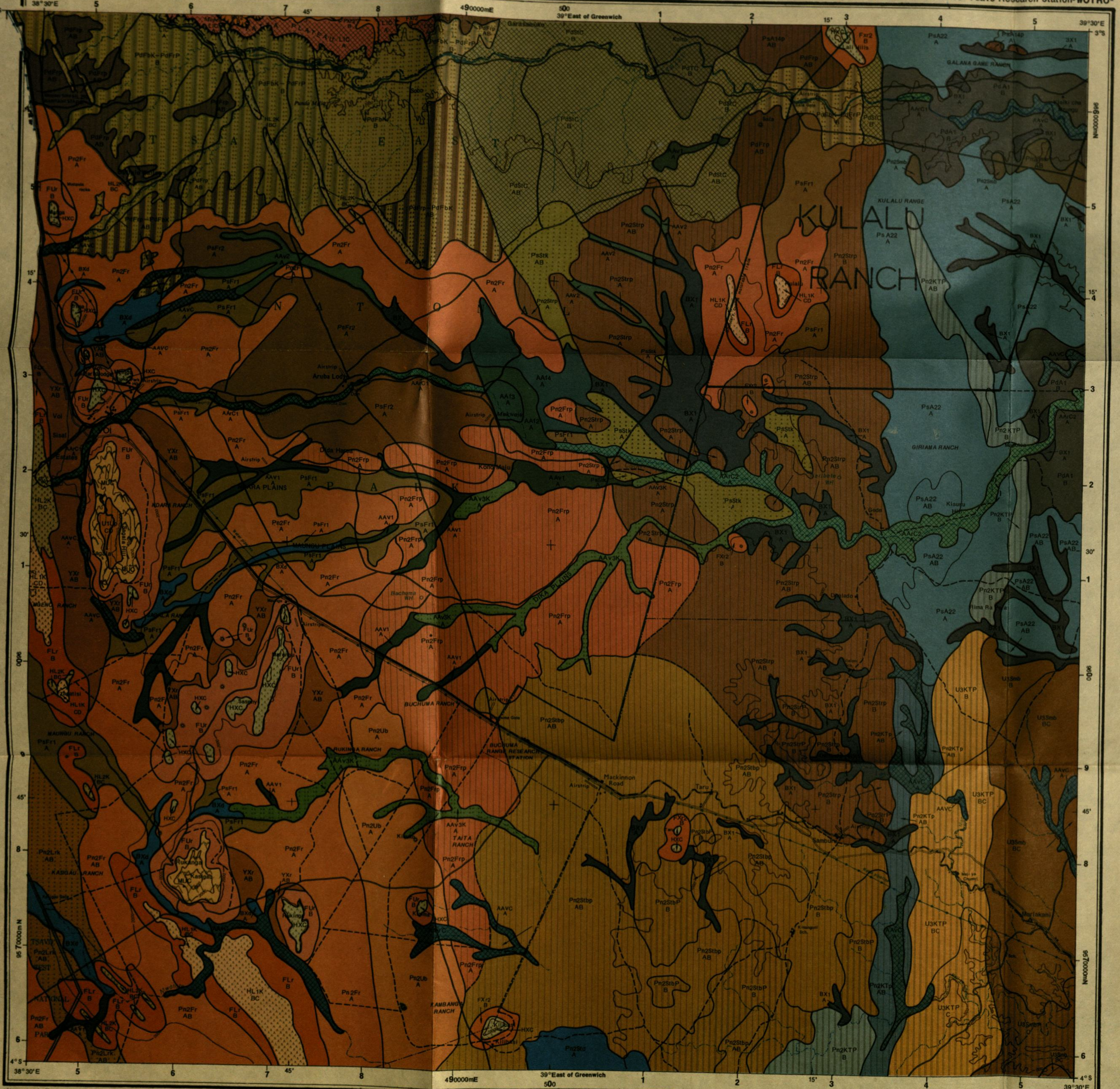
MAP SHEETS 190, 191, 196 and 197
Appendix 1b to Report No. 7 "Soils and Vegetation of the Tsavo Area"

RECONNAISSANCE SOIL MAP OF THE VOI AREA

Ministry of Agriculture-Kenya Soil Survey and
Ministry of Tourism and Wildlife-Tsavo Research Station-WOTRO*



*Netherlands Foundation for the Advancement of Tropical Research

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Scale 1:250,000

KILOMETRES 5 4 3 2 1 0 5 10 15 20 25 30 35 40 45 KILOMETRES

Base map compiled and simplified from parts of Survey of Kenya topographical map sheets SA-37-14 and SA-37-15 scale 1:250,000

LEGEND*

MOUNTAINS (relief intensity 300–1200m, slopes over 16%)

MU Soils developed on various gneisses

MUC — complex of somewhat excessively drained, shallow to moderately deep, reddish brown to light red, rocky and stony soils of varying texture; in places with humic topsoil (eutric REGOSOLS, lithic phase and humic CAMBISOLS)

HILLS, MINOR SCARPS AND LOW RIDGES (relief intensity 10–300m, slopes from 5% to over 16%)

HL Soils developed on crystalline limestone

HL1K — well drained, shallow, black, gravelly loam, over petrocalcic material or rock (orthic RENDZINAS)

HL2K — well drained, shallow to moderately deep, dark greyish brown to dark yellowish brown, calcareous, very stony, gravelly sandy clay loam, over petrocalcic material (calcic CAMBISOLS, petrocalcic phase)

HX Soils developed on various parent materials

HXC — complex of somewhat excessively drained, shallow, reddish brown to greyish brown, rocky and stony soils of varying texture (eutric and dystric REGOSOLS, lithic and stony phase)

FOOTSLOPES (at the foot of mountains and hills, slopes 2–6%)

FU Soils developed on colluvium derived from various gneisses

FUr — well drained, very deep, dark red, friable, sandy clay loam to sandy clay (rhodic FERRALSOLS and FERRAL*- chromic LUVISOLS)

FX Soils developed on colluvium derived from various parent materials

FXr2 — well drained, deep to very deep, dark red to reddish brown, friable to firm, sandy clay loam to sandy clay (chromic LUVISOLS)

FL Soils developed on colluvium derived from crystalline limestone

FLr — well drained, deep to very deep, dark red to dark reddish brown, friable to firm, sandy clay (chromic LUVISOLS)

PLATEAUS (slopes less than 2%)

LI Soils developed on phonolite (Tertiary volcanics)

LIC — complex of:
– well drained, moderately deep to very deep, dark red, friable clay; in places bouldery (rhodic FERRALSOLS)
– well drained, shallow to moderately deep, dark red, friable, rocky and bouldery clay (ferralic CAMBISOLS, lithic and stony phase)

PIEDMONT PLAINS (long slopes, 1–3%)

YX Soils developed on alluvium derived from undifferentiated gneisses and crystalline limestone

YXr — well drained, very deep, dark red, friable, sandy clay to clay (FERRAL*- chromic LUVISOLS)

UPLANDS (major rivers deeply incised)

SAGALA LEVEL (altitude approximately 1300m, slopes 5–16%)

U1U Soils developed on undifferentiated gneisses

U1Up — well drained, moderately deep to very deep, dark red to dark reddish brown, firm clay (chromic*ACRISOLS)

NYIKA LEVEL (altitude 150-250m, slopes 2-8%)

U3KT Soils developed on siltstones and shales (Maji-ya-Chumvi beds)

U3KTP — well drained, shallow, dark reddish brown to very dark brown, sandy clay loam (eutric CAMBISOLS, lithic phase)

U3Sm Soils developed on fine - grained sandstones (Mariakani sandstone)

U3Smb — well drained, deep to very deep, dark brown to yellowish brown, firm, sandy clay loam to clay, with topsoil of sandy loam (orthic LUVISOLS)

U3SmbP — like U3Smb, but shallow to moderately deep, fairly rocky and fairly stony

PLAINS

NON-DISSECTED EROSIONAL PLAINS

NYIKA LEVEL (altitude 200-600m, slopes less than 2%)

Pn2F Soils developed on gneisses rich in ferromagnesian minerals

Pn2Fr — well drained, deep to very deep, dark red to dusky red, friable sandy clay (rhodic FERRALSOLS)

Pn2Frp — like Pn2Fr, but moderately deep over quartz gravel (rhodic FERRALSOLS, petric phase)

Pn2U Soils developed on undifferentiated gneisses

Pn2Ub — well drained, deep to very deep, yellowish red, very friable, sandy clay to clay (orthic FERRALSOLS)

Pn2L Soils developed on crystalline limestone

Pn2Lrk — well drained, moderately deep to very deep, dark red to dark reddish brown, firm, sandy clay to clay, over petrocalcic material (calcic and chromic LUVISOLS, petrocalcic phase)

Pn2St Soils developed on fine to coarse - grained sandstones and arkoses (Taru grits)

Pn2Strp — well drained, moderately deep to deep, red to dark red, friable sandy clay, over quartz gravel (chromic LUVISOLS, petric phase)

Pn2StrP — like Pn2Strp, but shallow to moderately deep

Pn2Stbp — well drained, moderately deep to deep, dark reddish brown to dark brown, firm, sandy clay to clay, over quartz gravel or pisoferric material (orthic and chromic* ACRISOLS, petric or pisoferric phase)

Pn2StbP — like Pn2Stbp, but shallow to moderately deep

Pn2Std — poorly drained, very deep, black, very firm, calcareous, cracking clay, with saline and sodic deeper subsoil (pellic VERTISOLS, saline-sodic phase)

Pn2KT Soils developed on siltstones and shales (Maji-ya-Chumvi beds)

Pn2KTP — well drained, shallow, dark reddish brown to very dark brown, sandy clay loam to clay (eutric CAMBISOLS, lithic phase)

Pn2KTp — imperfectly drained, moderately deep to deep, dark greyish brown, very firm, cracking, sandy clay to clay, with calcareous and sodic deeper subsoil (vertic* PHAEOZEMS, sodic phase)

Pn2Sm Soils developed on fine - grained sandstones (Mariakani sandstone)

Pn2Smb — well drained, very deep, brown, friable to firm, sandy clay loam to sandy clay, with sodic deeper subsoil (orthic LUVISOLS, sodic phase)

SEDIMENTARY PLAINS (Nyika level: altitude 200–500m, slopes less than 2%)

PsF Soils developed on material derived from gneisses rich in ferromagnesian minerals

PsFr1 — well drained, deep to very deep, red to dark red, friable to firm, sandy clay to clay (ferric LUVISOLS)

PsFr2 — well drained, very deep, dark red to dark reddish brown, friable to firm, sandy clay (chromic LUVISOLS)

PsSt Soils developed on material derived from fine to coarse - grained sandstones and arkoses (Taru grits)

PsSk — well drained, moderately deep to deep, dark reddish brown, firm, sandy clay to clay, over pisocalcic material (calcic LUVISOLS, petric phase)

PsA1 Soils developed on unconsolidated sandy sediments (Quaternary superficial deposits)

PsA14p — well drained, moderately deep to deep, dark red, friable, sandy loam to sandy clay, over quartz gravel (rhodic FERRALSOLS, petric phase)

PsA2 Soils developed on unconsolidated clayey sediments (Plio-Pleistocene bay deposits)

PsA22 — poorly drained, very deep, dark greyish brown to black, very firm, calcareous, sodic clay; in places saline and/or cracking (orthic and vertic* SOLONETZ, partly saline phase)

DISSECTED EROSIONAL/SEDIMENTARY PLAINS (Nyika level: altitude 200–600m, slopes 1–5%)

PdF Soils developed on gneisses rich in ferromagnesian minerals

PdFrp — well drained, moderately deep, dark red, friable to firm, sandy clay loam to sandy clay, over quartz gravel (chromic LUVISOLS, petric phase)

PdFbK — well drained, shallow, yellowish brown, calcareous, gravelly sandy clay loam, over petrocalcic material (calcic CAMBISOLS, petrocalcic phase)

PdFrp–PdFbK — complex of soils of units PdFrp and PdFbK

PdFbK–PdFrP — complex of:
– soils of unit PdFbK
– well drained, shallow, dark reddish brown to dark red, stony and gravelly sandy clay loam, over quartz gravel (ferralic CAMBISOLS and chromic LUVISOLS, paralithic or petric phase)

PdSt Soils developed on fine to coarse - grained sandstones and arkoses (Taru grits)

PdStC — complex of:
– well drained, shallow, dark reddish brown, stony, gravelly sandy clay loam (chromic CAMBISOLS and chromic LUVISOLS, paralithic phase)
– well drained, shallow, yellowish brown, calcareous, stony and gravelly sandy clay loam, over petrocalcic material (calcic CAMBISOLS, petrocalcic phase)

PdT Soils developed on carbonaceous shales (Maji-ya- Chumvi beds)

PdTC — complex of:
– well drained, shallow, strong brown, slightly stony, sandy clay (orthic LUVISOLS, lithic phase)
– well drained, shallow, yellowish brown, calcareous, gravelly loam, over petrocalcic material (calcic CAMBISOLS, petrocalcic phase)

PdA Soils developed on unconsolidated clayey sediments (Plio-Pleistocene bay deposits)

PdA1 — imperfectly drained, very deep, strong brown to greyish brown, firm to very firm, sodic, sandy clay to clay; in places saline (orthic SOLONETZ, partly saline phase)

FLOODPLAINS AND ALLUVIAL VALLEYS (slopes less than 2%)

AAf Soils developed on alluvial fan deposits

AAf2 — moderately well drained, very deep, dark brown, firm sandy clay, with sodic deeper subsoil (orthic LUVISOLS, sodic phase)

AAf3 — imperfectly drained, very deep, dark brown, very firm, sandy clay to clay, with saline deeper subsoil (orthic LUVISOLS, saline phase)

AAf4 — poorly drained, very deep, dark greyish brown, very firm, calcareous, saline and sodic clay (orthic SOLONETZ, saline phase)

AAr Soils developed on subrecent to recent river deposits

AArC1 — complex of very deep, brown to very dark brown, stratified soils of varying drainage condition, consistence and texture (eutric and vertic* FLUVISOLS)

AArC2 — complex of very deep, brown to very dark brown soils of varying drainage condition, consistence and texture; in places saline and sodic

AAv Soils developed on subrecent deposits in broad alluvial valleys

well drained, deep, red to dark reddish brown, friable to firm, sandy clay to clay, over petrocalcic material (chromic LUVISOLS, petrocalcic phase)

moderately well drained, very deep, dark brown, friable, calcareous, sandy clay to clay (calcic CAMBISOLS)

moderately well drained, shallow, calcareous, sandy clay to clay loam, over petrocalcic material (calcic CAMBISOLS, petrocalcic phase)

complex of moderately well drained to poorly drained, very deep, dark reddish brown to dark brown, firm to very firm, sandy clay to clay; in places calcareous, saline and/or sodic (orthic LUVISOLS, sodic phase and orthic SOLONETZ, saline phase)

BOTTOMLANDS (slopes less than 2%)

BX Soils developed on various parent materials

very poorly drained, very deep, dark greyish brown to black, very firm, calcareous, cracking clay, with saline and sodic deeper subsoil (chromic and pellic VERTISOLS, saline-sodic phase)

very poorly drained, very deep, dark brown to dark grey, firm to very firm, sodic clay, with calcareous and saline deeper subsoil (orthic SOLONETZ, saline phase)

*For the Mtito Andei and Voi sheets one combined legend was prepared. The legend of this sheet however describes only the mapping units occurring on this sheet.

The descriptions denote the characteristics of the subsoil (usually the B–horizon). Where the topsoil differs from this subsoil by two or more textural classes, it is also described.

All gneisses and crystalline limestone mentioned in the legend belong to the Basement System rocks.

The names between brackets reflect the soil classification according to the 1974 FAO/UNESCO legend for their "Soil Map of The World". Prefixes marked with * are tentative terms awaiting international agreement on nomenclature.

KEY

U3SmbP — soil mapping symbol, depth class symbol
BC — slope class symbol

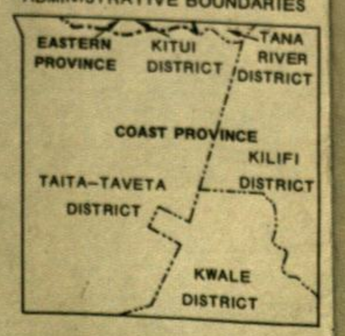
- soil boundary
- soil boundary (uncertain)
- slope class boundary

1 Sq. cm — 625 ha

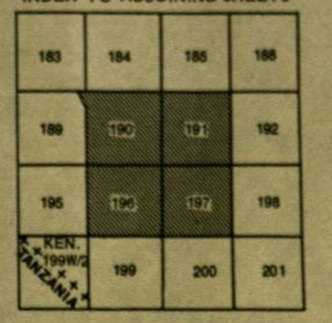
- all weather road
- track
- railway
- railway station
- international boundary
- provincial boundary
- district boundary
- building
- school
- bridge
- river
- pipeline
- contours V.I. 1000 ft.
- hill top
- scarp
- park boundary

NB. Most of the roads and tracks are in approximate alignment.

ADMINISTRATIVE BOUNDARIES



INDEX TO ADJOINING SHEETS



KEY TO SLOPE CLASSES

slope %	slope class symbol+	name of the macrorelief
0-2	A	flat to very gently undulating
2-5	B	gently undulating
5-8	C	undulating
8-16	D	rolling
16-30	E	hilly

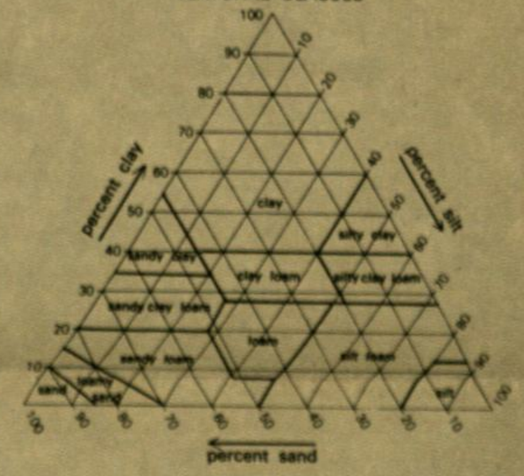
+ *not indicated for mountains, hills and minor scarps*

KEY TO DEPTH CLASSES

thickness soil in cm	symbol+ over rock or quartz gravel	symbol+ over petrocalcic/ pisocalcic material	name
0-50	P	K	shallow
50-80	p	k	moderately deep
80-120			deep
more than 120			very deep

+ *if a complex of depth classes occurs within one unit, only the symbol of the shallowest depth class is indicated*

TEXTURAL CLASSES



SOIL SURVEY AND MAP PREPARATION

soil survey (1975–1978)	W. van Wijngaarden [1], W.G. Sombroek [2], H.C.K. Kinyanjui [2]
soil correlation	W.G. Sombroek [2]
map compilation	W. van Wijngaarden [1]
map correlation	B.J.A. van der Pouw [2]
cartography	P.M.Maingi [2]

1) Tsavo Research Station-WOTRO
2) Kenya Soil Survey

PHOTO INTERPRETATION MAP OF THE PHYSIOGRAPHY OF THE TANA DELTA