STICHTING VOOR BODEMKARTERING
WAGENINGEN

TANA DELTA IRRIGATION PROJECT

Reconnaissance report

SOILS

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Netherlands Soil Survey Institute
Staringgebouw
Wageningen

Report nr. 1609

TANA DELTA IRRIGATION PROJECT

Reconnaissance report

SOILS

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Wageningen, July 1981

TANA DELTA IRRIGATION PROJECT

De Stichting voor Bodemkartering heeft een drietal bodemkarteringen uitgevoerd in het deltagebied van de Tana rivier in Kenya. Dit bodemkundig onderzoek vond plaats in opdracht van het Ingenieursbureau HASKONING BV te Nijmegen, die een feasibility studie verrichtte voor de Tana and Athi Rivers Development Authority (TARDA) naar de verbouw op grote schaal van geirrigeerde rijst.
De resultaten van het bodemkundig onderzoek zijn als afzonderlijke deelrapporten in deze studie opgenomen. Door de Stichting voor Bodemkartering zijn aan het Ingenieursbureau de volgende rapporten uitgebracht.

1. Stolp, J. and J.J. Vleeshouwer. 1981. Tana Delta Irrigation Project. Reconnaissance Soil Survey, Soil Survey Institute, Wageningen. Report no. 1609.

   Dit rapport is verwerkt in het Interim Report dat door de opdrachtgever aan TARDA is uitgebracht. De kaartbijlagen bij dit rapport zijn alleen aanwezig in de bibliotheek van de Hoofdafdeling Karteringen bij de Stichting voor Bodemkartering.

2. Stolp, J. 1982. Tana Delta Irrigation Project. Semi-detailed Soil Survey. Soil Survey Institute, Wageningen. Report no. 1627.

   Dit rapport + kaartbijlagen is opgenomen als Annex 1 in Volume II van de Feasibility Study TANA DELTA IRRIGATION PROJECT, door Haskoning BV en Mwenge IALtd uitgebracht in oktober 1982 aan de Tana and Athi Rivers Development Authority, Republic of Kenya. De kaarten zijn door de Stichting voor Bodemkartering in concept aan de opdrachtgever afgeleverd, die voor verdere afwerking heeft zorggedragen.

3. Stolp, J. 1983. Tana Delta Irrigation Project. Semi-detailed Soil Survey (Extension). Soil Survey Institute, Wageningen. Report no. 1700.

   Dit rapport is opgenomen in Chapter 1 (Soil Survey) in Volume I van de Feasibility Study - TANA DELTA IRRIGATION PROJECT (EXTENSION) dat door de bij rapport nr. 1627 genoemde Consultants in augustus 1983 aan TARDA is verstrekt. Een exemplaar van deze Feasibility Study ligt ter inzage bij de afdeling Ontwikkelingssamenwerking van de Stichting voor Bodemkartering.

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PREFACE

A reconnaissance soil survey was carried out by the Netherlands Soil Survey Institute in the Tana Delta area, Kenya, in March 1981 at the request of Haskoning B.V. Consulting Engineers and Architects, Nijmegen.
This soil survey is part of an overall feasibility study for the cultivation of irrigated rice in the Tana Delta. Haskoning B.V. received the assignment for this project from the Tana River Development Authority. The reconnaissance soil survey team consisted of J. Stolp (teamleader), J. Mulder, H. Rosing, G. van der Veen and J.J. Vleeshouwer (aerial photo-interpretation and supervision).
The cooperation and assistance of the Kenya Soil Survey and of local authorities in the area is much appreciated. Special acknowledgement is due to F.N. Muchena (Head of Kenya Soil Survey), B.J.A. van der Pouw (Soil Survey Specialist of the Kenya Soil Survey) and M. Ali (extension officer Tana River District).

The Director

R.P.H.P. van der Schans.

SUMMARY

The project area is situated in the southern part of Tana River District and for a small part in Lamu District, both in Coast Province. The area delineated on the soil map of the reconnaissance survey extends over approximately 63 500 ha (fig. 1.1).

Three major physiographic units are distinguished in the survey area: Floodplains (41 500 ha), Terrace land (18 000 ha) and Former Beach Ridges (2 300 ha). The Tana river has eroded part of the Terrace land and has subsequently deposited recent fluvial sediments in the present delta; Floodplains. In the vicinity of the present outlet of the Tana river however these fluvial sediments overlie subrecent marine sediments, laid down in an estuarine environment.
Areas with a total extent of approximately 1500 ha and consisting of both recent fluvial and old alluvial sediments (Terrace material) are indicated separately on the soil map as Complex Areas.

The soils of the Terrace land are highly sodic and frequently saline. Soils of the Former Beach Ridges are coarse textured and often excessively drained. These soil qualities in Terrace land and Former Beach Ridges and, in addition, the location on relatively high lying areas are strong limitations for (gravity) irrigation of large-scale cultivated rice.
The soils of the Floodplains have more potential for rice production. Particularly the soils in river basin land (25 500 ha) which usually consist of heavy clay throughout, have high potential. Soils in river levee land (10 300 ha) have limitations because of deficiences in soil and land qualities. Also the soils, consisting of fluviatile sediment over subrecent marine sediments (5 700 ha), have potential, though low due to acidity constraints.

All soil mapping units are evaluated in behalf of the land suitability for large-scale irrigated rice. This evaluation implies an appraisal of soil and land qualities and subsequently the ranking of the mapping units in four suitability classes according to the severity of their limitations.
The appraisal is carried out with the assumption that

- flood control works will be constructed to prevent the area from flooding;
- sufficient irrigation water of good quality will be made available to crop areas;
- adequate measures will be taken to drain excess rainfall and irrigation water (depending upon the crop calendar and related water duty);
- adequate measures will be taken to prevent salinization of soils during cultivation.

The main results are summarized as follows:

Class	Suitability for large-scale rice irrigation	Limitations	Area (ha)
1	highly suitable	few or none	24 200
2	moderately suitable	slight to moderate	1 500
3	marginally suitable	moderate to severe	3 200
NS	unsuitable	severe	34 600

The total area of class 1 soils is 24 200 ha.
However a part of it consists of rather small patches. One large, continuous area is found north and south of the Garsen-Witu road, extending northwards to Wema and in a southerly direction to an east-west line approximately 6 km south of Moa. South-east of this line, soils become saline at more shallow depth. The other large area is situated east and north-east of Ngao.
In vieuw of its extent and accessibility it is recommended that the 10 000 ha for the envisaged project will be selected in the area north and south of the Garsen-Witu road (fig. 1.1).

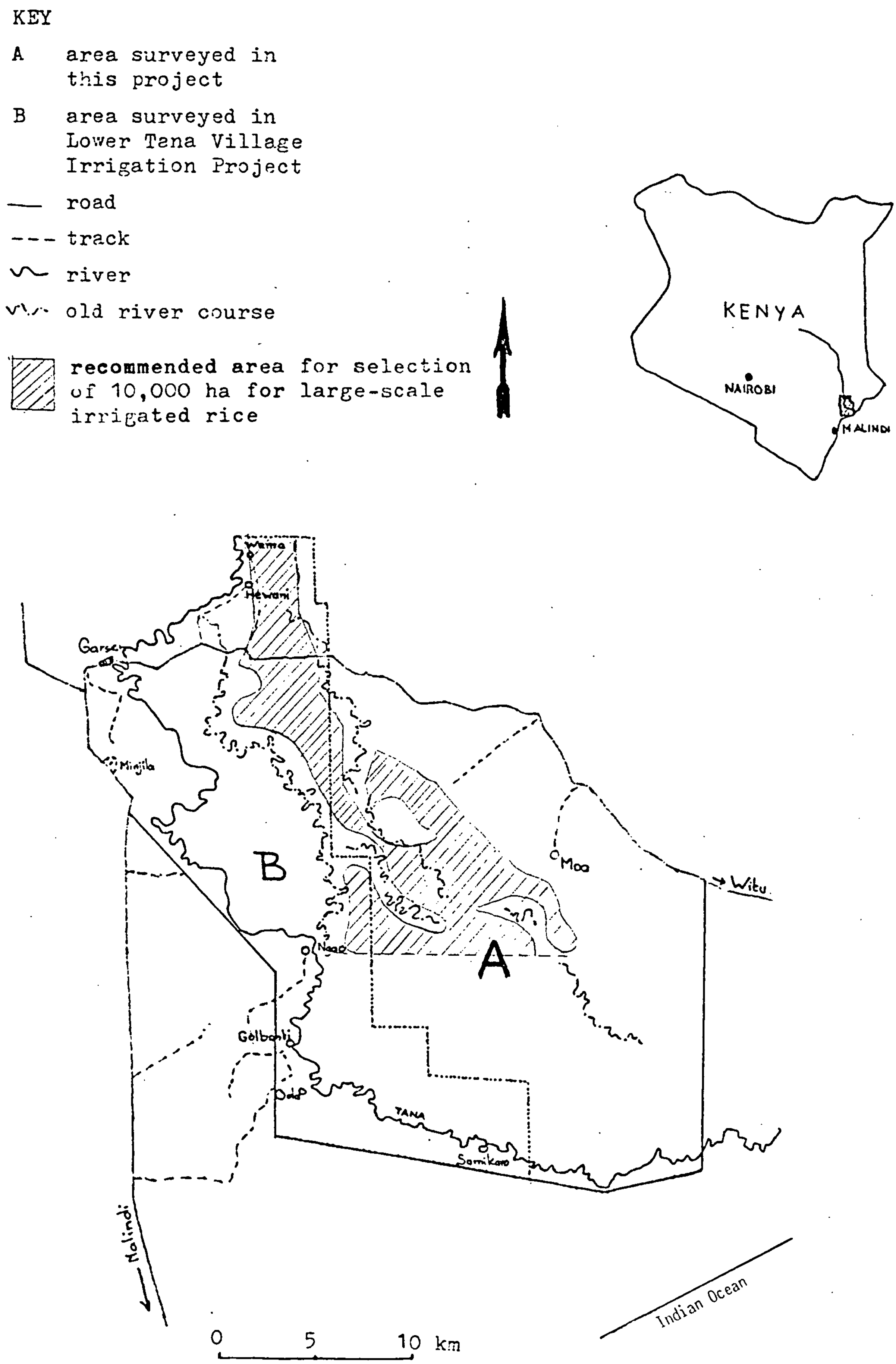


Figure 1.1 Location of the project area.

1 LOCATION, GEOLOGY AND PHYSIOGRAPHY

1.1 Location

The project area is situated in the southern part of the Tana River Division of the Tana River District and for a small part in the Lamu District, Coast Provincie.
It lies between latitude 2° 14' S and 2° 32' S, and longitude 40° 06' E and 40° 23' E.
The area extends from the road Malindi - Garsen eastwards to a south-north line about 6 km west of Witu and from Wema in the north to approximately 1 to 3 km south of the Tana river (Fig. 1.1).
The total area is 63 500 ha. It comprises 35 000 ha surveyed in this project (area A in Fig. 1.1) and 28 500 ha surveyed in the Lower Tana Village Irrigation Programme (area B in Fig. 1.1).

1.2 Geology and physiography

The delta area of the Tana River is geologically mapped as recent alluvium with bands of older sand and clay ridges. Recent deposits in the area consist of sands, muds and silt deposited during the biannual flooding of the Tana river. These deposits are less pronounced and consist mainly of heavy clay in areas at a distance from the present river course or from former courses.
The area of sedimentation, indicated as the physiographic unit Floodplains, can be divided in River Leveeland, River Basinland and Estuarine Basinland (see Fig. 3.0). Higher terraces occur adjacent to the Floodplains. In the eastern part a broad transition zone is, in places, present. In the western part of the project area terraces rise abruptly away from the floodplain.Bottomland occurs in the terrace area too.
Terrace land is the physiographic unit and comprises both landforms. Soils on Terrace land are developed on old alluvial sediments, probably from marine origin.
A number of coarse textured ridges occur within the terrace area. They are distinguished as Former Beach Ridges for the legend of the soil map.
A schematic cross-section through the Tana Delta and the relation between physiography and soil mapping units is shown in Fig. 3.1.

2 WORKING METHODS

2.1 Introduction

Part of the project area was already covered by a detailed reconnaissance soil survey of the Lower Tana Village Irrigation Program (area B in Fig. 1.1). The information of that survey is included in the results of the investigations presented here. The legends of both soil maps are very similar, but some modifications were necessary and some extra mapping units were introduced because of the presence of soils not occurring in the detailed reconnaissance survey.
The soil survey work, carried out in the frame work of the Tana Delta Irrigation Project was mainly concentrated on area A (see Fig. 1.1).
The soil classification of the mapping units is according to the "FAO-Unesco Soil map of the World" system (FAO, 1974). Modifications introduced by Kenya Soil Survey (KSS) were applied when relevant (Siderius and Van der Pouw, 1980).
The soil and land suitability maps are presented on 1 : 50 000 scale although, in view of the density of observations, a scale of 1 : 100 000 would be more appropriate. However a publication scale of 1 : 50 000 was chosen in order to show some intricate soil patterns.

2.2 Office methods

The 1 : 50 000 topographical maps of the Survey of Kenya (1971, 1974) has been used for the preparation of a base map outlining the roads, tracks, villages, the Tana River and other topographical features. Information gathered from the aerial photographs and in field were added to this base map. The map comprises also the area of the LTVIP (Lower Tana Village Irrigation Programme). The course of the Tana River on the LTVIP maps differs from the one on this base map.
A preliminary aerial photo-interpretation was carried out at the beginning of the project on the available 1 : 60 000 aerial photographs of poor quality (JICA, 1977-1979). Before the photo-interpretation was finished aerial photographs at scale 1 : 45 000 of much better quality (Geosurvey, 1980) were made available and a second photo-interpretation was done. Meanwhile the field survey was started because of the increasing risk of flooding of the area.
The photo-interpretation boundaries on the aerial photographs 1 : 60 000 and 1 : 45 000 were transferred to the base map. Based on data collected during the fieldwork, some photo-interpretation boundaries were deleted, others added or adjusted.
The majority of the soil boundaries of the detailed reconnaissance soil survey of the LTVIP-area were copied.
Office work also dealt with the collection of various publications (KSS publications pertaining to the project area, the report of the detailed reconnaissance survey of the LTVIP-area and other basic information), study of data and the writing and drafting of the information gathered.

The final soil map is based on information of:
- LTVIP soil maps and reports (see also Chapter 3.1)
- aerial photo-interpretation
- augerings and field observations on micro-, meso- and macro-relief, vegetation, etc.
- measurements in the field laboratory on soil samples of 5 depths in all soil augerings.

2.3 Field methods

At the start of the fieldwork, only aerial photographs scale 1 : 60 000 were available. Boundaries of the photo-interpretation were plotted on the aerial photographs which were taken into the field for checking and for location of the augerings. The quality of the photographs was poor and therefore orientation in the field was difficult and time consuming. The accessibility of the area was good considering the fact that often and for long periods of the year access by vehicle is impossible. Field information was collected on aerial photographs 1 : 60 000, because the 1 : 45 000 aerial photographs became available at a too late stage.
Augerings were made to a depth of 2 meters and described according to the "Guidelines for Soil Description" as used by the KSS. The standard KSS field sheets for augerings were used. In the area surveyed in this project (area A in Fig. 1.1) a total number of 160 observations mainly located in the Basinlands (Fig. 3.0), were carried out. Basin lands in area A (fig. 3.0 and fig. 1.1) comprise roughly 24 000 ha. The average observation density in these areas is one per 150 ha.
Soil pits were dug at representative sites in the major soil units. At these sites detailed soil description to 2 meters depth were made on the soil description sheets of the Kenya Soil Survey. The subsoil to 5 meters depth was described from augering in the bottom of the pits, unless the flow of saturated sand into the auger-hole or the presence of an unripened subsoil prevented the continuation of the augering. Approximately 5 percent of the observations are soil pits and are described to a greater depth than two meters.

2.4 Laboratory methods

2.4.1 Field laboratory

At the base camp (Minjila Hill) a field laboratory was established to measure the pH and electrical conductivity (EC) of samples from all the observation sites. As a routine samples were taken at 20, 40, 70, 110 and 170 cm depth below the surface, unless the evidence of special material gave rise to change this routine. Using the

procedure of KSS a 1 : 2.5 v/v sample was prepared by filling a water containing tube with soil material up to the desired level to attain the ratio 1 : 2.5. The consequence of this method is that an 1 : 1 ratio is achieved on weight base (approximately). Usually the soil was dry and groundwater was not encountered within a depth of 2 meters.
In many cases it was possible to measure directly in the clear solution above the swollen and often dispersed soil material, using a micro-electrical conductivity cell and a medium sized glass electrode (pH). Soil samples with no free water because of strong dispersion were diluted to 1 : 5 v/v and measured. A rough experiment to estimate the average percentage water in the saturation paste of the clay-material in the soils of the river basinland indicated that in general a ratio of 3 : 2 exists between the water content of the 1 : 1 weight (or 1: 2.5 v/v) samples and the water content of the saturation paste.

2.4.2 National Agricultural Laboratories (NAL)

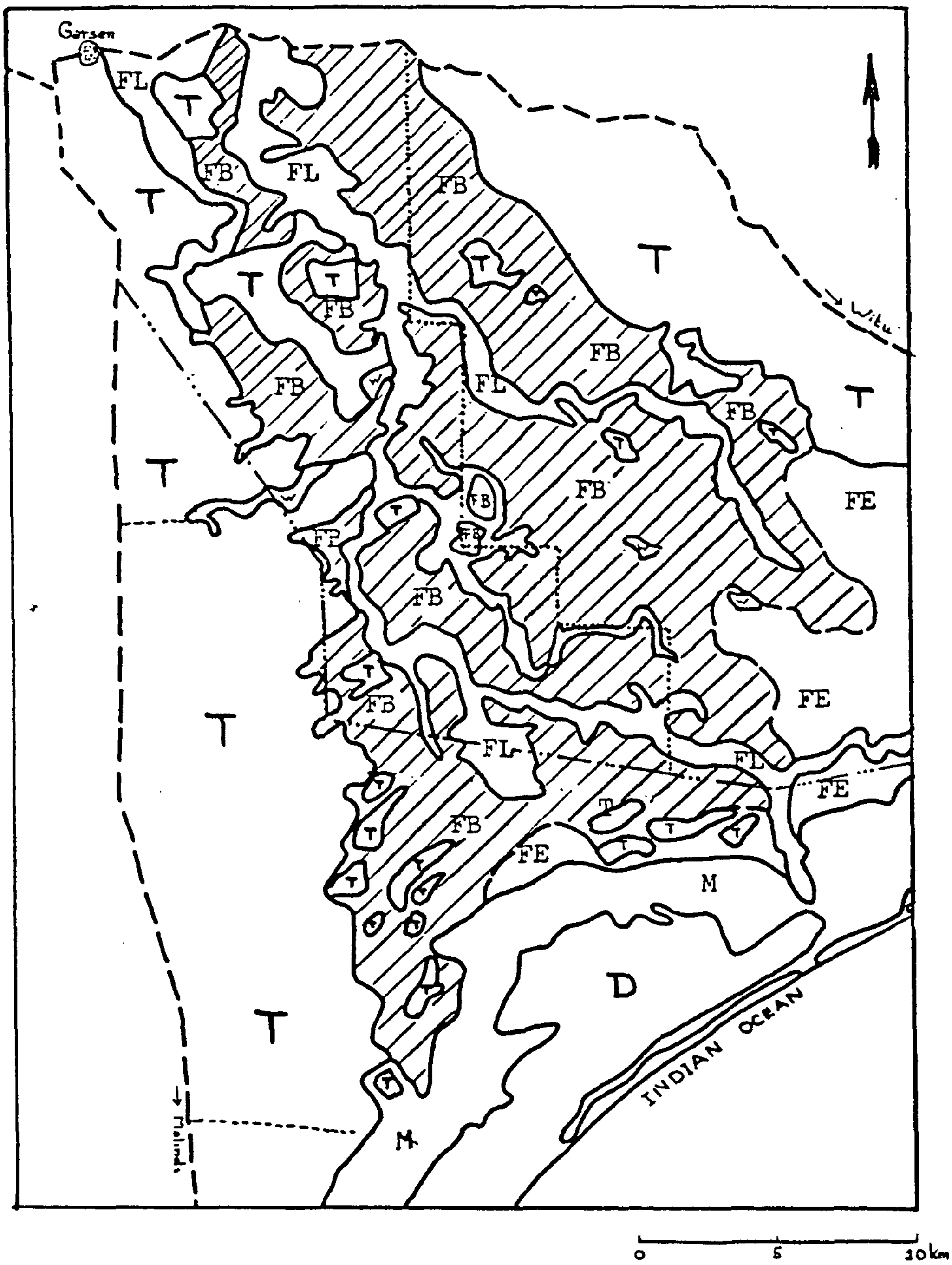
Soil samples were taken from representative soil pits and delivered to NAL Nairobi for chemical analyses. The following chemical measurements were carried out by NAL using the methods described by Legger (1978).

Fertility analyses (on topsoil samples only)

pH - 1: 1 soil water suspension
Na, K, Ca, Mg, Mn and P extracted in 0.1 N HCl and 0.025 N H_2SO_4 (first three read on flame photometer while the latter three are determined colorimetrically)
N - Kjeldahl method
C - Walkley Black (uncorrected values)
Hp- Exchangeable acidity determined on samples with pH <5.5 by leaching with $BaCl_2$.

Standard survey analyses

Texture - hydrometer method
pH - in H_2O and in KCl with soil: water ratio 1: 2.5.
pH and electrical conductivity of the saturation extract when EC (1: 2.5) is greater than 0.8 mS/cm
$CaCO_3$ equivalent - gravimetric determination of loss of CO_2
C% - on surface horizon only
CEC - at pH 8.2 (sodium acetate)
Exchangeable cations - pH 7.0 (ammonium acetate).



LEGEND

FL	River Leveeland	M	Coastal Marshes and Swamps
FB	River Basinland	D	Dunes and Recent Beach ridges
FE	Estuarine Basinland	T	Terraceland, Bottomland and Lagoonal Sand Ridges

KEY

— — —	main road	—·:::·—	boundary of the project area
W	permanent water	·········	area surveyed in Lower Tana Village Irrigation Project
- - - - - -	track		

Figure 3.0 Physiography of the Tana Delta
Generalized after the photo-interpretation map of the Tana Delta (Site evaluation Report No. 23 of Kenya Soil Survey, 1975).

3 SOILS

3.1 Previous work

A preliminary evaluation of the soil conditions of the Tana Delta for irrigation development was carried out by the Kenya Soil Survey (Wokabi et al., 1976). A map at scale 1 : 100 000 was prepared mainly on the bases of aerial photo interpretation and supported by a limited number of field observations. The areas of River Basinland, as indicated on the map at scale 1 : 100 000, were considered moderately well suited for irrigation. It comprises about 38 000 ha (Fig. 3.0). These soils were described in the KSS site evaluation report no. 23 as "deep, non calcareous, heavy clay soils that are usually non-saline and non alkali". They are the soils of main interest for this study.
The detailed reconnaissance survey for the Lower Tana Village Irrigation Programme (Grabowsky and Poort, 1980) covered about 12 000 ha of the river basinland. The results of the survey are appraised for this study. The data concerning the area starting at Wema and ending at the southern boundary near the Tana River are copied largely unchanged, except for the southern part, where differences in vegetation and relative height were not indicated on the LTVIP soil map. The soils of the Terrace land, Bottomlands and Former Beach Ridges (Lagoonal sand ridges), occurring outside the recent floodplain, are generalized. The description of the soil mapping units in those areas is based on the information given in the LTVIP survey report and soil maps.

3.2 General properties and characteristics

The soils in the area are located on the present floodplain of the Tana River and on the adjacent higher lying Terrace. The soils of the floodplain are mainly developed on recent fluvial sediments, but in the south eastern part on subrecent marine sediments. The latter area belonged to the estuarine land, the inlet of which probably can be located near Kipini. The fluvial soils are found in river levee land and in river basin land. The former estuarine land is mainly distinguished as basin land. Only along the present course of the Tana River in the most south eastern part of this area levee land is distinguished, consisting of a very recent fluvial levee deposit on top of estuarine sediments.
Figure 3.1 gives a schematic cross-section through the recent fluvial sediments in the Floodplains and through the old alluvial sediments of the Terrace land. The relation between physiography and the mapping units is shown.

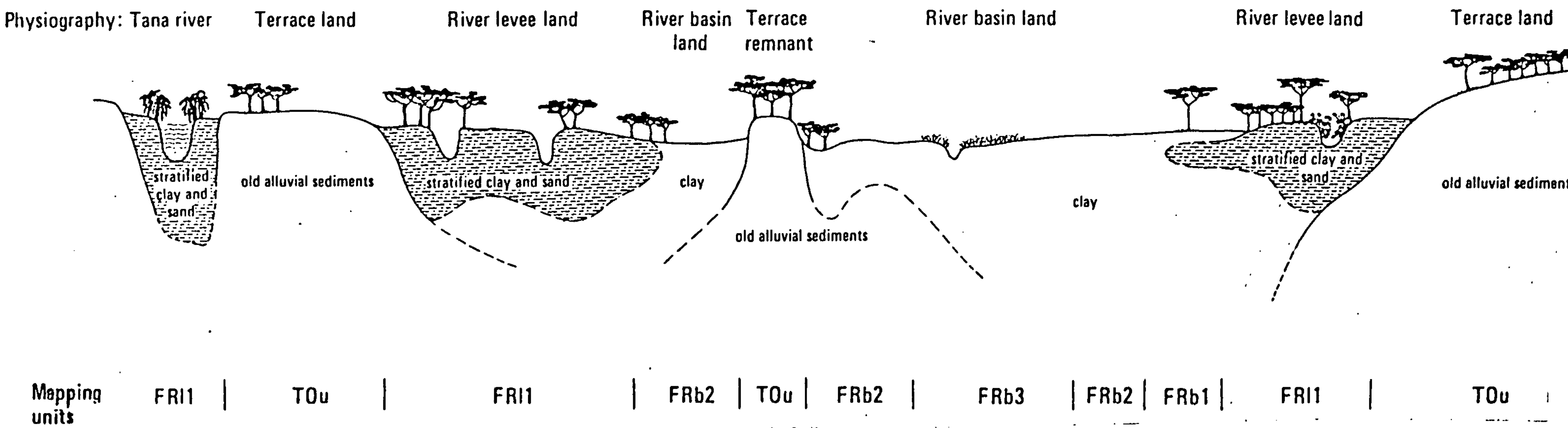


Fig. 3.1 Schematic cross-section through the Tana delta and the relation between physiography and mapping units

Figure 3.2 Borassus palms and Doumpalms are often found along former river courses

Figure 3.3 Thick bush on Terrace land is used for extensive. open grazing in the wet season

The river levee soils are variable in texture and stratified. They have predominantly fine textured layers, but medium and coarse textured layers occur in places, due to the presence of recent or old riverbeds or of overflow channels. Near and in the former estuarine area the levee soils are mainly fine textured. (Levee land with a former rivercourse in this area has often a basin sediment on the edges or is covered by this fine textured material). The vegetation on the levee land varies from grassland to riparian forest and bushland.
The river basin soils are usually uniform and consist throughout of clay to heavy clay. The soils show wide cracks after some period of drying out ("vertic" characteristics). Colour and mottling in these soils reflect their relative position in the landscape and consequently the degree of inundation during the seasonal floods. The vegetation on these soils differs with variation in relative height: grassland with sedges on tussocks in the lowest parts and bushed grassland with palms on sites with a slightly higher elevation.
The basin soils in the former estuarine area are usually uniform to a depth of 1 to 1.5 meters and consist of clay. Below that depth sandy clay to sand, probably of marine origin, may be found. This basin land is flooded and the wide shallow gullies are ponded for long periods as may be concluded from the humic and in places peaty topsoil. The vegetation type is grassland: mainly reeds on the slightly higher lying flat areas and grasses in the wide and shallow gullies. Doum palms and Borassus palms occur along former river courses (Fig. 3.2).
The soils on the old alluvial sediments of the Terrace land consist of clay, in places of medium and coarse textured material and are strongly sodic and frequently strongly saline. The Terrace land is covered with thick bush (Fig. 3.3). Within the Terrace land there are elongated bottomlands, several of them in connection with the floodplain. The soils in the bottomlands are predominantly black, cracking and fine textured. They are nearly level and grass covered.
Former Beach Ridges, within both the Terrace land and the present floodplain, consist of deep, loose, non-saline and non-sodic sands or loamy sands. These areas are usually associated with bushland or bushland thicket and have in general an undulating, in places hilly, topography.

3.3 Soil classification

The soil classification system is based on the FAO-Unesco Soil Map of the World Legend (FAO 1974). Modifications introduced by the Kenya Soil Survey (Siderius and Van der Pouw, 1980) are employed when relevant.
All soils developed on recent alluvial sediments of the Tana River are classified in the group of the Fluvisols (35 800 ha). This major soil group is subdivided in two subgroups; eutric and vertic Fluvisols. The latter consists of strongly cracking ("vertic")

clay.
The soils developed on subrecent marine sediments have also been classified as Fluvisols (5 700 ha). Apart from the two subgroups already mentioned, the subgroup thionic Fluvisols was distinguished here due to the presence of a sulfuric horizon within 125 cm of the surface. The presence of horizons, showing electricl conductivity values higher than 2.6 mS/cm (EC 1: 2.5 v/v), within 100 cm of the surface mark some subgroups with a saline phase.
The soils of the Terrace land (18 000 ha) are developed on old alluvial sediments. The two major soil groups in the Terrace land are the Solonetz and the Vertisols. Two subgroups have been identified in the Solonetz; vertic and orthic Solonetz. The Vertisols here have a very dark gray to black topsoil: pellic Vertisols.
The soils of the Former Beach Ridges (2 300 ha) are developed on sandstone and on beach deposists. They have been identified as Arenosols (subgroup ferralic Arenosols) and for a smaller part as Ferralsols (subgroup orthic Ferrasols).
The soils in Complex Areas, located in the floodplains consist of Fluvisols and Solonetz (1 500 ha)
An outline of the major groups and subgroups is given in Table 3.1.

Table 3.1 Soil classification

Parent material	Major soil group	Subgroup
Recent fluvial and subrecent marine sediments	Fluvisols	vertic Fluvisols eurtic Fluvisols thionic Fluvisols
Old alluvial sediments	Solonetz	vertic Solonetz orthic Solonetz
	Vertisols	pellic Vertisols
Sanstone and beach deposits	Arenosols	ferralic Arenosols
	Ferrasols	orthic Ferrasols

3.4 Legend of the reconnaissance soil map

The soil mapping units are grouped according to their physiographic position in the field and the parent material on which they are formed. At the highest level in the legend the following physiographic units are distinguished: Floodplains (the recent one of the Tana River), Terrace land and Former Beach Ridges. Within each unit the main parent materials are mentioned. Where possible the landform in which the sediments occur, are distinguished, e.g. river levee land, river basin land. The units for the soil map finally are based on the soil properties and characteristics. In view of the aim of this investigation, the soils of Terrace land and Former Beach Ridges are not differentiated. These soils occur outside the area

Table 3.2 . Legend of the reconnaissance soil map

F... FLOODPLAINS

FR.. Soils developed on recent fluvial sediments

FR1. River leveeland

FR11	complex of sand to clay, often stratified; excessively to imperfectly drained; usually non-calcareous and non-saline; often rich in micas (eutric and vertic FLUVISOLS)
FR12	complex of loam to clay, stratified; well to imperfectly drained; often calcareous and saline (eutric and vertic FLUVISOLS)
FR13g	dark grayish brown, cracking clay; moderately well to imperfectly drained; usually non-calcareous and non-saline; grassland (vertic FLUVISOLS)
Fr13b	like FR13g; but wooded bushland
FR13f	like FR13g; but woodland

FRb. River basinland

FRb1	10-20 cm very dark gray, humic clay over dark brown, cracking clay; moderately well to imperfectly drained; usually non-calcareous and non-saline (vertic FLUVISOLS)
FRb1f	like FRb1; but woodland
FRb2	10-20 cm very dark gray, humic clay over dark brown, cracking clay; imperfectly drained; usually non-calcareous and non-saline (vertic FLUVISOLS)
FRb2f	like FRb2; but woodland
FRb3	20 cm very dark gray, humic clay over dark grayish brown, cracking clay; poorly drained; usually non-calcareous and non-saline (vertic FLUVISOLS)
FRb3f	like FRb3; but woodland
FRb4	10-20 cm dark gray, humic clay over dark grayish brown, cracking, fluvial clay between 50-150 cm overlying marine clay or silty clay; imperfectly to very poorly drained; non-calcareous; deeper than 100 cm strongly to extremely acid (catclay); slightly to moderately saline within 100 cm; deeper than 150 cm locally unripened (vertic FLUVISOLS, saline phase)

FE.. Soils developed on subrecent marine sediments

FE1. Recent leveeland

FE11	30-100 cm grayish brown, cracking, fluvial clay over extremely acid, marine clay (catclay); imperfectly drained; non-calcareous; non-saline within 100 cm (vertic and thionic FLUVISOLS)

FEb. Basinland

FEb1	complex of: -10 cm black, humic to peaty clay over very dark gray clay, between 30-50 cm overlying extremely acid clay (catclay), locally within 150 cm changing into neutral to slightly acid sandy clay to loamy sand; poorly drained; non-calcareous; moderately saline from 30-50 cm depth onwards (thionic FLUVISOLS, saline phase) -10 cm black, peaty clay over very dark gray clay, bet 50-150 cm overlying strongly to extremely acid clay (catclay); very poorly drained; non-calcareous; moderately saline from 50-100 cm depth onwards (eutric and thionic FLUVISOLS, saline phase)
FEb2	10 cm black, humic clay over very dark gray clay, within 100 cm overlying gray clay, locally deeper than 100 cm changing into sand; imperfectly to very poorly drained; non-calcareous; slightly acid or slightly acid over extremely acid; non- to slightly saline (eutric and thionic FLUVISOLS)

T... TERRACE LAND

TO. Soils developed on old alluvial sediments

TOu	undifferentiated (orthic and vertic SOLONETZ and pellic VERTISOLS)
TOb	soils of the bottomlands, adjacent to and in connection with the floodplains; very poorly drained (pellic VERTISOLS, partly saline phase)

B. FORMER BEACH RIDGES

BQ Soils developed on sandstone and beach deposits

BQ	undifferentiated (ferralic ARENOSOLS and orthic FERRALSOLS)

C. COMPLEX AREAS

CF Soils developed on recent alluvial and old alluvial sediment[s]

CF	complex of: -mapping units FRb1, FRb2 and FRb3, often over alluvial sediments -mapping unit TOu

that had to be surveyed for large scale irrigation. Additional information about the vegetation is given for some soil mapping units.
Table 3.2 gives a review of the soil mapping units distinguished. All mapping units are described in Chapter 3.5.

3.5 Description of the soil mapping units

3.5.1 Soils developed on recent fluvial sediments

River levee land - 10 260 ha
The mapping units of the river levee land consist of a complex of deep, stratified and highly variable soils. The soils range in texture from sand to clay. On average they are medium textured, although the lower part of the profile is more commonly a firm clay. Because of their position, they are well drained to imperfectly drained. Chemically the eutric Fluvisols have a neutral to moderately alkaline reaction and are non-saline, non-sodic and non-calcareous though the finer textured soils frequently tend to be calcareous.

Mapping unit: FR11 - 7590 ha

Parent material: Tana alluvium

Topography: flat to gently undulating; locally highly dissected and uneven; relatively high position in the floodplain; adjacent to the present or former river course

Vegetation/land use: grassland, bushed grassland, woodland and patches of riparian forest; open grazing

Drainage conditions: excessively to imperfectly drained, on the average well to moderate well drained; lowest groundwater-level deeper than 2 meters; not flooded or flooded during short periods

Soils: deep, stratified and highly variable texture. The texture of the topsoil ranges from sand to clay, the subsoil is frequently a firm clay. The profile is usually non-calcareous and non-saline.

Suitability for large-scale irrigated rice: non suitable (class NSstT) because of the irregularity in the textureprofile, which can cause great losses of irrigation water (s). The presence of abandoned river courses results locally in a very irregular topography (t). The remnants of riparian forest that locally are found, indicate vegetation hindrance (T).

Mapping unit: FR12 - 520 ha

The soils of this mapping unit are found only in the Lower Tana Village Irrigation Project area. They are topographically comparable to the soils of mapping unit FR11; relatively high in the floodplain and adjacent to former river courses. The soils are deep and stratified and consist of a complex of loam to clay. They are slightly saline and calcareous. This and the other limitations mentioned for mapping unit FR11 results in suitability class NSstT.

Mapping unit: FR13g - 760 ha

These soils are found along a former Tana river course which is indicated on the soil map as Abarfarda (Fig. 3.4).

Parent material: Tana alluvium, mostly fine textured

Topography: flat, relatively high position in the floodplain; weak gilgai microrelief

Vegetation/land use: grassland (in places with reeds) and bushed grassland, locally Doum palms. Extensive, open grazing.

Drainage conditions: moderately well to imperfectly drained; soil permeability slow when wet

Soils: 10-20 cm thick topsoil of very dark gray clay over dark grayish brown, cracking clay. Sandy loam to loamy medium fine sand with micas locally starts at about 150 cm depth. Usually neutral to moderate alkaline reaction; non-calcareous, but concretions of carbonates may be present at depths of 50-150 cm below surface. Usually non-saline throughout, however in the southern area the soil is, in places moderately saline from a depth of 50 cm onwards (inclusion)

Suitability for large-scale irrigated rice: these soils can be recorded as class 1 soils, though locally the salinity of the subsoil may be a limiting factor.

For the description and the analytical data of a representative profile, see Appendix 1, profile no. I.

Mapping unit: FR13b - 1050 ha

These soils are comparable to those of mapping unit FR13g, but they are covered with wooded bushland.
They occur in the southern part of the area and comprise relatively small levees along former river courses of the Tana River.
The suitability for large-scale irrigated rice is recorded as 3tT because of the presence of the former course (unfavourable topography) and the presence of wooded bushland.

Mapping unit: FR13f - 340 ha

The soils of this mapping unit are comparable to those of FR13g, but are covered with riparian forest. These soils occur where a former river course has meandered and therefore a subsoil of loamy sand is present more frequently. These soils are unsuitable for large scale irrigated rice due to the unfavourable topography and the presence of a riparian forest (class NStT).

Figure 3.4 Heavy textured levee soils are predominantly covered with grasses and reeds (foreground: mapping unit FRl3g), but along former river courses riparian forest is locally present (background: mapping unit FRl3f)

Figure 3.5 Soils of mapping unit FRb2 are covered with grasses and reeds. In the far distance riparian forest on mapping unit FRl3f

River basin land - 25 540 ha

The soils in the river basin land consist mainly of heavy to very heavy clay up to a depth of more than 2 meters. However in the transitions to the adjacent Terrace land and the isolated patches ("islands") of Terrace land in the Floodplain, medium to coarse textured, saline and sodic terrace material is found in the subsoil. Where these soils connect with the levee land, levee material of varied texture underlies the heavy clay.
The soils have a strongly developed blocky or prismatic structure when dry. Very often, polished and grooved surfaces ("slickensides") are present on the structure elements. These slickensides and the wide and deep cracks indicate the vertic characteristics of these soils. They have a high content of 2 : 1 lattice clays and hence a high cation exchange capacity.
Available phosphorus and exchangeable potassium in the topsoil are usually low and the pH is generally between 6.0 and 8.0.
The soils are usually non-saline, non-sodic and non-calcareous.
The drainage conditions vary from poorly drained to moderately well drained, depending on the topographic position.
The hydraulic conductivity (soil permeability) depends on the moisture content of the clay. Results of hydraulic conductivity test ("K" values) as shown for these soils in the Lower Tana Village Irrigation Programme (Reconnaissance Report, 1980) show a range of 0.01 to 0.6 meters per day. The lowest values are representative for wet conditions, the higher ones indicate that water moves through cracks that have been formed during the dry season.
The infiltration rate (the movement of water through the surface layer) shows the same pattern. The considerable variation measured in these soils in the Tana River Village Irrigation Programme project, can be almost completely attributed to the presence or absence of cracks in the topsoil.

Mapping unit: FRb1 - 4900 ha

Soils of this mapping unit occur on the fringes to the levee land.

Parent material: Tana alluvium, mainly basin deposits

Topography: flat; moderately high lying; weak gilgai micro relief

Vegetation type/land use: grassland and bushed grassland, locally palmtrees (mainly Doum palms). Extensive, open grazing during the relatively long non-flood period.

Drainage conditions: moderately well to imperfectly drained; groundwater level after dry period deeper than 2 meters.

Soils: 10-20 cm thick topsoil of very dark gray clay, very fine to fine angular blocky structure, over dark brown clay, prismatic structure, falling apart into medium angular blocks, to a depth of 60-80 cm. Heavy clay throughout. In places saline and sodic, sandy clay (Terrace material) or slightly acid to moderately alkaline and non-saline, stratified, clay with micas (levee material) occurs in the subsoil. The soils ar usually non-calcareous, though lime concretions may occur in the subsoil. Soils are slightly acid to moderately alkaline in reaction and non-saline.

Figure 3.6 Sedge vegetation on soils of mapping unit FRb3 form 50 cm wide and 40 cm high tussocks, which have to be removed during reclamation

Figure 3.7 Soils of the floodplains are used for very extensive open grazing during the dry season

Suitability for large-scale irrigated rice: the land suitability class is 1. Locally the texture, salinity and alkalinity of the subsoil may be a limiting factor.

Mapping unit: FRb1f - 100 ha

The soils of this mapping unit are comparable to those of FRb1 and are found in a forested area near Wema. The suitability class is NStT; unsuitable due to irregular topography and the thick woody cover.

Mapping unit: FRb2 - 8030 ha

Soils of this mapping unit occur in the surroundings of the levee land and outcropping Terrace. Particularly north-west of Moa these soils are found as the connection to the adjacent Terrace land.

Parent material: Tana alluvium, basin deposits

Topography: flat, with small gullies; moderately low lying; gilgai microrelief.

Vegetationtype/land use: grassland (grasses and locally reeds; Fig. 3.5) and in places bushed grassland (Acacia spec.), very locally Doum palms. Extensive, open grazing.

Drainage conditions: mainly imperfectly drained, locally poorly drained where sedge grassland is present.

Soils: are very similar to the soils of FRb1 in texture and structure of the first meter; 0-20 cm topsoil of very dark gray clay, very fine to fine angular blocky structure when dry. The transition to the subsoil is very irregular because of the downwards movement of the topsoil in the cracks. Below this topsoil the clay is dark brown. It has a blocky structure or a prismatic structure falling apart in angular blocks. Slickensides are present. This soil is usually non-calcareous, though locally lime concretions from a depth of 80 cm onwards occur. The modal soil profile has a slightly acid to moderately alkaline reaction. Within 1 meter below the surface these soils are predominantly non-saline. In places the subsoil consists of slightly to moderately saline and sodic sandy clay (Terrace material). The material disperses very easily when wet.

Suitability for large-scale irrigated rice: Class 1. There are no major limiting factors. Attention has to be paid to the areas of this mapping unit where in the subsoil terrace material may occur. As this material disperses very easily it may give problems when irrigation work as digging canals, ditches are carried out.

For the description and the analytical data of representative profiles see, Appendix 1, profiles no. II, III and IV.

Mapping unit: FR2bf - 30 ha

The soils of this mapping unit are comparable to those of mapping unit FRb2. They occur east of Hewani in woodland. The suitability class is NStT; unsuitable because of topographical limitations (t) and the vegetative hindrance (T).

Mapping unit: FRb3 - 10 320 ha

Soils of this mapping unit ocur in the central parts of the basins and in depressions.

Parent material: Tana alluvium, basin deposits

Topography: flat, in the deepest parts irregular shaped gullies may occur. Microrelief is very uneven because of many sedge tussocks; gilgai microrelief.

Vegetationtype/land use: grassland; the dominant vegetation is sedges and reeds (Fig. 3.6). Very extensive, open grazing; locally wild life area.

Drainage conditions: poorly drained, in gullies very poorly drained.

Soils: a 10-20 cm thick, very dark gray topsoil of heavy clay with very fine to fine angular blocky structure overlies dark grayish brown clay, that often extends to a depth of 2 meters. Below the topsoil the structure is medium angular blocky or prismatic falling apart into angular blocks. Mottling occurs along root channels in the upper part of the soil profile. When dry, 4-6 cm wide crakcs are present up to about 60-80 cm depth. Thick slickensides are common. The soils are usually non-calcareous and non-saline in the upper meter. Deeper than 1 meter some profiles may be slightly saline or moderately saline. Soil reaction is mainly less than 7.5 (pH-water).

Suitability for large-scale irrigated rice: These soils are recorded as class 1. In places levelling may be needed in order to remove the sedge tussocks and gullies. In general it is a constraint of minor importance.

For the description and the analytical data of representative profiles, see Appendix 1, profiles no. V, VI and VII.

Mapping unit: FRb3f - 30 ha

The soils of this mapping unit are comparable to those of mapping unit FRb3. They occur in two patches of forest. The suitability class is NStT; unsuitable due to irregular topography (t) and vegetative hindrance (T).

Mapping unit: FRb4 - 2130 ha

The soils of this mapping unit are found around a lake in the south-eastern part of the area.

Parent material: Tana alluvium over marine sediments

Topography: flat; irregular mesorelief due to the presence of small, shallow gullies with a bending pattern. The difference in height between the gullies and the relatively flat areas beside the gullies varies from 0.5-1 meter. Many cowfoetoes in the gullies.

Vegetationtype/land use: reeds and herbs are found on the relatively higher areas, grasses in the gullies. Very extensive open grazing in the dry season (Fig. 3.7).

Drainage conditions: depending on the relative topographical position imperfectly to very poorly drained. The soils are probably most of the year swampy and have a slow permeability.

Soils: a 10-20 cm thick topsoil of dark gray, humic clay overlies dark grayish brown, cracking clay. To a depth of 50 up to 150 cm the clay is probably of fluvial (Tana alluvium) origin and usually non-saline. The soil reaction varies from 4.8 - 6.5 (pH-water).
It overlies a marine sediment which mainly consists of clay to silty clay, locally of silty clayloam. In places loamy fine sand with micas occurs. Usually the upper part of the marine sediment contains a variable amount of gypsum crystals. Starting at a depth of roughly 1 meter the soil reaction is strongly acid, locally extremely acid and the soil contains yellow mottles of jarosite. These soils are non-saline in the upper layers; deeper than 50 cm they are slightly to moderately saline. In the shallow gullies salinity is less severe.

Suitability for large-scale irrigated rice: this mapping unit is classified as marginally suitable (class 3st) due to the salinity of the soil (s) starting at relatively shallow depth in the areas in between the shallow gullies. The irregularity of the mesorelief due to the presence of gullies is an other limitation (t). Moreover if levelling is carried out, it increases the salinity danger of the higher areas.

3.5.2 Soils developed on subrecent marine sediments

Mapping unit: FE11 - 280 ha

The soils of this mapping unit are found along the recent Tana river, extending from Saidibabo to the eastern boundary of the area (Fig. 3.8). The course of the Tana River in this area dates from the time that the southward outlet of the Tana River was abandoned due to the digging of a connection between the Tana River near Saidibabo and the Ozi with its outlet near Kipini.

Figure 3.9 Soils of mapping unit FEb1 are strongly to extremely acid at shallow depth. This is reflected in the vegetation. Only a very open (20%) cover of very poor reeds and rushes is present

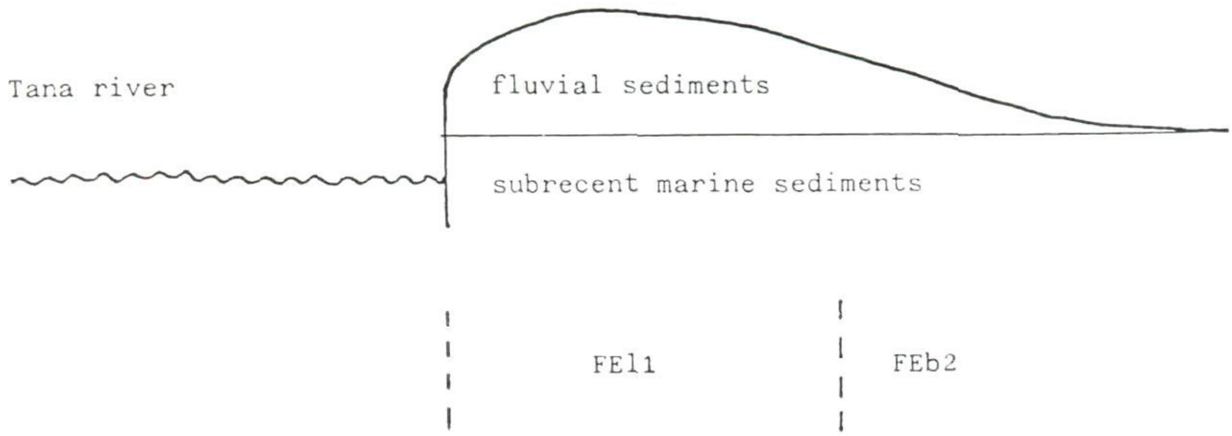


Figure 3.8 Schematic cross-section through the soils of mapping unit FEl1 and the soils of the adjacent mapping unit FEb2.

Parent material: recent Tana alluvium over marine sediments

Topography: nearly flat

Vegetationtype/land use: mainly grassland; reeds with some scattered Doum palms

Drainage conditions: imperfectly drained; flooded during short periods

Soils: 30-100 cm grayish brown, cracking, fluvial clay over extremely acid, marine clay with jarosite mottles. Locally these two sediments are separated by a 20 cm thick, very dark gray horizon (former surface horizon). These soils are non-saline within 1 meter.

Suitability for large-scale irrigated rice: the presence of an acid subsoil at moderate depth is a limiting factor and has led to a classification of moderately suitable (class 2s).

Mapping unit: FEb1 - 4260 ha

The soils of this mapping unit are developed in sediments which have been deposited in a marine (estuarine) environment. The course of a former Tana River branch indicates that the marine conditions are more or less influenced by river water and therefore also sedimentation of fluvial material may have taken place. In most places a heavy clay is found on top of marine sediments.

Parent material: Tana (basin) alluvium on marine sediments

Topography: flat with wide, shallow gullies in a reticular pattern. The areas in between the gullies have a weak gilgai relief; the gullies have a very irregular microrelief because of the presence of many cowfoetoes. In the centre of most of the gullies a natural drainage way is present.

Vegetationtype/land use: grassland, predominantly with a very poor and open vegetation of reeds and rushes on the relatively higher lying parts (Fig. 3.9) and grasses in the wide gullies and depressions. Extensive open grazing.

Drainage conditions: poorly and very poorly drained; long period of flooding.

Soils: Soils of the areas in between the gullies have a 10 cm thick topsoil of black, humic to peaty clay. It overlies a very dark gray clay to a depth of 30-50 cm. Cracks are present after some time of drying but they are not strongly developed. Usually the soil is slightly acid and non-saline to slightly saline up to 30-50 cm dept. Underneath lies a dark gray, usually extremely acid clay (pH-water values often between 3.0 and 4.0).
Gypsum crystals frequently occur to a depth of 100-120 cm. Brownish yellow mottles of jarosite start at variable depth and are locally intermixed with red mottles. In general these mottles are present within 1 meter below surface. This so called "catclay" material is usually moderately saline and extends to a depth of 150 cm. Under it marine sediments of very variable texture and consistency are present. It is predominantly extremely acid and moderately to strongly saline. Dark greenish gray, half ripened clay with jarosite mottles occurs in this deep subsoil. Where silty clay loam to loamy fine sand is found, the pH-water is less than 6.0 and jarosite mottles are not always present. The soils in the gullies and the depressions are in principle similar to the above described soils. However, due to the lower topographical position they are flooded or ponded for a longer period. Consequently a peaty topsoil of about 10 cm thickness usually occurs. In addition, the acid and saline subsoil starts at greater depth. Usually the clay is non-calcareous and very dark gray to black up to 50 cm and dark gray therebelow. Gypsum crystals and brownish yellow mottles of jarosite frequently occur. From about 1.5 meter onwards the clay is half ripened to unripened. Locally this clay overlies bluish gray, sandy material. Groundwater is strongly saline; the EC of groundwater at about 2 meters depth was 30 mS/cm.

Suitability for large-scale irrigated rice: the area of this mapping unit is considered to be unsuitable (class NSst) because of:

- extremely acid clay at shallow depth
- moderately saline at shallow depth
- irregular topography
- high risk of increasing acidity and salinity when the relatively higher areas are levelled.

For the description and the analytical data for a representative profile, see Appendix 1, profile no. VIII.

Mapping unit: FEb2 - 1170 ha

The soils of this mapping unit are located between a former branch of the Tana River and the present course. The latter one, for most of its length being the connection between the old Tana River outlet and the river Ozi, meanders through the former Ozi estuarine area. The presence of marine sediments is evident though in the western part they are found only in the subsoil below fluvial sediments.

Parent material: subrecent marine sediment with locally a thin cover of fluvial material.

Topography: flat with wide shallow gullies and depressions; cowfoetoes in gullies and depressions.

Vegetation/land use: grassland with reeds and herbs on the relatively higher areas and grasses in the gullies and depressions open grazing, east of Samicha locally crops are grown.

Drainage conditions: soils of the relatively higher areas are imperfectly drained, the gullies and depressions are poorly to very poorly drained.

Soils: a 10 cm thick topsoil of black, humic clay overlies very dark gray clay, which at a depth of 30-60 cm changes into dark gray to gray clay. Locally deeper than 1 meter gray to bluish gray sand may occur. From about 1.5 meter depth the clay is half or less ripened. The soils are slightly acid or neutral throughout. In few places strongly to extremely acid clay with jarosite mottles occurs deeper than 1 meter. Soils are usually non-saline, though salinity increases with depth. In places a slightly saline subsoil may be found deeper than 1 meter, usually combined with an acid subsoil. The electrical conductivity of the groundwater, encountered deeper than 1 m, varies from 4 to 11 mS/cm.

Suitability for large-scale irrigated rice: this mapping unit is moderately suitable because of topographical limitations (class 2t). The presence of wide shallow gullies and depressions implies levelling at moderate costs. Besides, the local occurrence of sand in the subsoil affects the soil suitability unfavourably.

3.5.3 Soils developed on old alluvial sediments

These soils occur predominantly on the Terrace land adjacent to the present floodplains but are also present within the floodplain where Terrace erosion remnants are locally found (Fig. 3.1). The soils are developed on old sediments of probably marine origin. With time they have lost their fluvic characteristics and exhibit a mature profile. Most of these soils meet the criteria for vertic Solonetz or pellic Vertisols.
The description of the mapping units is mainly based on information in the report of the detailed reconnaissance survey of the Lower

Tana Village Irrigation Project area. Only a limited number of augerings have been carried out in the eastern Terraceland during the reconnaissance soil survey of the Tana Delta Project.

Mapping unit: TOu - 17 100 ha

Parent material: old alluvial sediments

Topography: very gently undulating to flat; relatively high

Vegetationtype/land-se: bushland, bushland thicket and grassland; extensive open grazing and wildlife

Drainage conditions: well to poorly drained; soil permeability is slow, particularly when soils are saturated.

Soils: Vertic Solonetz: a 30 cm thick topsoil of loamy sand to sandy clay overlies cracking clay on the "erosion remnants". The clay is calcareous, usually sodic, slakes and disperses easily in water and is strongly alkaline in reaction, locally exceeding pH 9. The medium to coarse textured topsoil is usually non-saline, the soil below the topsoil is strongly saline especially on the very gently undulating plain and the higher lying Terrace land bordering the floodplains. A slightly to moderately saline subsoil occurs in the soils ath the edge of the present floodplains and in the floodplains.
Orthic Solonetz: soils with a topsoil of loamy sand overlying sandy loam to sandy clay loam are found on flat to undulating low ridges that extend into the present floodplains in the southwestern part of the area. These coarse to medium textured soils are alkaline, saline to strongly saline, sodic and calcareous. When wet the soil rapidly slakes. The not cracking orthic Solonetz may be found intermixed with the cracking vertic Solonetz.
Pellic Vertisols: the soils in the depressions of the Terrace land which are not connected with the recent floodplains consist of strongly cracking clay (pellic Vertisols). They are similar to the soils of mapping unit TOb.

Suitability for large-scale irrigated rice: this mapping unit is classified as unsuitable because of:
- soil limitations
- topographical limitations
- and/or vegetation hindrance

The soils of this mapping unit are located outside the area of investigation and therefore the limiting factors are not differentiated in the suitability class (class NSu).

Mapping unit: TOb - 1050 ha

The soils of this mapping unit are located in elongated depressions in the Terrace land which are in open connection with the present floodplain.

Parent material: old alluvial sediments

Topography: flat; hummocky microrelief

Vegetationtype/land use: grassland; extensive open grazing

Drainage conditions: very poorly drained

Soils: a 20-30 cm thick topsoil of black clay overlies very dark, gray clay with strongly developed cracks up to 1 meter depth when dry. From 80-100 cm onwards the clay is dark gray to gray, usually neutral in reaction and non-calcareous. These soils are usually non-saline, but in the depression south-east of Moa they are moderately to strongly saline. Near the soils of mapping unit FEb1 the soils also are strongly acid in the subsoil (catclay).

Suitability for large-scale irrigated rice: the soils of this mapping unit are partly suitable e.g. the area south of Moa, and partly unsuitable due to high salinity.

3.5.4 Soils developed on sandstone and beach deposits

The soils occur outside the area of interest for large-scale irrigated rice. Information about these soils is completely based on data given in the report of the detailed reconnaissance survey of the Lower Tana Village Irrigation Project area.

Mapping unit: BQ - 2340 ha

Parent material: sandstone and beach deposits

Topography: flat to undulating; low, elongated ridges

Vegetationtype/land use: bushland, bushland thicket; extensive, open grazing

Drainage conditions: excessively drained; rapid permeable

Soils: pale brown to reddish brown, sandy clay loam to sand, slightly to strongly acid (pH less than 6.0), non-calcareous and non-saline.

Suitability for large-scale irrigated rice: unsuitable because of topographical limitations, unfavourable drainage conditions and low water holding capacity (class NSst).

3.5.5 Soils developed on recent alluvial and old alluvial sediments

Mapping unit: CF - 1520 ha

This mapping unit is a complex of soils of mapping units FRb1, FRb2, FRb3 and TOu. However, soils of mapping unit FRb1, FRb2 and FRb3 do not consist entirely of recent alluvial clay, but often

have a subsoil of saline, sodic and alkaline, old alluvial sediment which starts at variable depth.
The areas have a flat to very gently undulating macro relief. The meso relief is irregular due to the presence of many small outcrops of mapping unit TOu. For the description of the soils of this unit see the descriptions of FRb1, FRb2, FRb3 and TOu.

Suitability for large-scale irrigated rice: the suitability classes of the components of this complex mapping unit are 1 and NSst. The overal suitability of the area is however unsuitable, because of the limiting topography and the variability in suitability over short distances.

Table 4.1 Suitability classes for large scale irrigated rice

Suitability class *	Description	Suitability class with main limiting factor(s)
1	Highly suitable Land suitable for sustained irrigated rice production; minimum costs of development and management associated with the land	-
2	Moderately suitable Land of moderate productivity; slight to moderate limitations in soil qualities or requiring moderate costs for development	 2s 2t
3	Marginally suitable Land of restricted productivity for irrigated rice; moderate to severe limitations in soil qualities and -in addition- requiring relatively high costs for development (i.c. levelling) or requiring relatively high costs for levelling and clearing	 3st 3tT
NS	Unsuitable Land which is unsuited for sustained irrigated rice production; severe limitations in soils, topography and/or vegetation cover	NSs NSst NSsT NStT NSstT NSu'

* not considering irrigability and drainability
' limiting factor(s) not differentiated

Explanation of the code:

NSstT:
- NS... - Suitability class
- ..s.. - Limitation because of deficiency in soil texture, -permeability, -reaction and/or salinity
- ...t. - Limitation because of topography (relief)
- ....T - Limitation because of vegetation hindrance

4 LAND SUITABILITY FOR LARGE-SCALE IRRIGATED RICE

4.1 Classification system used

The landclassification system of the Bureau of Reclamation of the U.S. Department of the Interior has been adopted in many countries for the classification of irrigated land.
The direct application of this system in Kenya is hampered by the lack of economic data. The Kenya Soil Survey has modified this system to allow for the conditions in Kenya (Muchena, F.N.; Internal Communication no. 23, KSS, 1981).
The proposed criteria for land suitability classification for irrigation, as written down in this publication are used in principal for this study. Modifications are made to allow for conditions in the project area and correspond with the suitability criteria, used in the soil survey for the Lower Tana Village Irrigation Programme. The land suitability classes are based on the physical and chemical constraints of the area.
To determine the suitability of the various mapping units first the limitations in soil and land qualities are evaluated and subsequently compared with the criteria of the suitability classes (table 4.2, 4.3 and 4.4).

4.2. The land suitability classes

The appraisal of the suitability is carried out, assuming that:
- floodcontrol works are constructed, in order to prevent the area from flooding
- sufficient irrigation water of good quality is transported to the area concerned. Irrigability is therefore not considered in the appraisal
- adequate measures are taken to remove drainage water and excess irrigation water. Drainability is therefore not considered in the appraisal
- adequate measures are taken to prevent soils from salinization when cultivated.

Four suitability classes, generally used for a reconnaissance survey, are distinguished (Table 4.1). Classes 2, 3 and NS (unsuitable) are subdivided according to the main limiting factor(s). These factors and their symbols are given in Chapter 4.3.2, 4.3.3 and 4.3.4 and in Table 4.1.

4.3 Soil and land qualities and specific criteria

4.3.1 General

Rice is a crop which requires a number of special conditions, which have to be considered when the suitability of the land is evaluated.

Table 4.2 Soil criteria for large-scale irrigated rice
Specifications for Tana Delta Irrigation Project

Land suitability class / Soil factor (s)		Class 1	Class 2	Class 3
Soil texture		clay to clay loam over clay (within 50 cm) non compacted	clay to clay loam over clay (within 50 cm) non compacted	clay to clay loam over clay to clay loam (within 50 cm) non compacted
Soil depth		90 cm plus	90 cm plus	90 cm plus
Soil permeability when wet		slow	slow	slow
Soil reaction	alkalinity	pH-H_2O <8.5 unless soil is non sodic and calcareous	pH-H_2O <9.0 unless soil is non sodic and calcareous	pH-H_2O <9.0 unless soil is non sodic and calcareous
	acidity	pH-H_2O >4.5 to 100 cm	pH-H_2O >4.5 to 50 cm	pH-H_2O >3.5 to 50 cm
Soil salinity (s) (EC 1 : 2.5 $^v/v$)		non saline to 100 cm (<2.6 mS/cm to 100 cm)	non saline to slightly saline to 100 cm (<5.3 mS/cm to 100 cm)	slightly saline to 50 cm over moderately saline (<5.3 mS/cm to 50 cm over >5.3 mS/cm)

Soils that fail to meet the above criteria are classified as class NS (unsuitable)

Needed is:
- a slowly permeable soil, or a soil that can be made slowly permeable because rice should be partly submerged when growing
- a level topography for uniform distribution of water. This goes specially when large scale cultivation is planned
- no salinity in the soil till at least 50 cm depth. Rice is known to grow on soils with a saline subsoil at shallow depth, but this needs special management practices and much experience. Moreover under these conditions a relatively high and continuous water supply is required and even then yields are not optimal
- no alkalinity or extreme acidity within 50 cm depth because these restrict the effective rooting depth.

4.3.2 Soil qualities (limiting factor indicated in the suitability class with symbol "s").

The following soil qualities were considered:
- soil texture
- soil depth
- soil permeability when wet
- soil reaction: alkalinity and acidity
- soil salinity.

The workability of the soil is not considered here because in this particular case soil management can be adapted to specific conditions. The soils in the river basin land however require special treatment because they are very hard when dry. In Table 4.2 the soil factors are specified for the different suitability classes.

Remarks concerning salinity criteria

The electrical conductivity values of the 1: 2.5 v/v soil samples, measured in the field laboratory, were used to determine the salinity of the soil. The EC (1: 2.5 v/v) values are related to the ECe values (electrical conductivity of the extract of a saturated paste). Referring to the description of the method used in Chapter 2.4.1 "Laboratory methods", a ratio of 3:2 is used to transfer the norm ECe values to the EC (1: 2.5 v/v) values. An ECe value of 4 mS/cm equals roughly a value of 2.6 mS/cm for the EC of the 1: 2.5 v/v sample.

4.3.3 Topography (limiting factor indicated in the suitability class with symbol "t")

Limiting topographic factors are derived from the macro-, meso- and microrelief.
Macrorelief deals with differences in topography over large distances, mainly expressed by the length and steepness of slope. Within the project area there are very few places where the slope exceeds two per cent and these are usually short, steep slopes adjacent to or into old river channels. In most of the area and

specially the basin lands, slope is not a limiting factor in the landappraisal.
Mesorelief concerns medium sized differences in topography over rather short distances. The presence of small, shallow gullies in the almost flat areas is a limitation because of the necessary levelling. Moreover, levelling in an area with an acid subsoil at shallow depth may increase unfavourable soil conditions.
The microrelief is characterized by relief irregularities and undulations found within short distance as gilgai, cowfoetoes. Meso- and microrelief indicate the degree of eveness or roughness of the landsurface and consequently the degree of levelling required to enable a uniform distribution of irrigation water. As for the microrelief, gilgai is present almost everywhere, because of the swelling and shrinking of the majority of the soils. This may imply that annually some levelling is required. The criteria for the factor topography are given in Table 4.3.

Table 4.3 Topography criteria for large-scale irrigated rice.
Specifications for Tana Delta Irrigation Project

Topography		Land suitability class		
		1	2	3
relief	macro (slope)	<1%	<1%	<2%
	meso and micro	smooth except for gilgai and minor undulations	see class 1	somewhat irregular (<1 m) but no major gullies or dissections

Land that fails to meet the above criteria is classified as class NS (unsuitable)

4.3.4 Vegetation (limiting factor indicated in the suitability class with symbol "T")

The density and type of vegetation on the land indicate the degree of clearing needed for reclamation. Vegetative cover varies from non restrictive (grasslands) to severe restrictive (riparian forest). Table 4.4 gives the specifications for the project area.

Table 4.5

Main landcharacteristics and landsuitability classes of the mapping units for large scale irrigated rice, not considering irrigability and drainability.

Group	Mapping unit	Soil texture	Soil permeability when wet	Soil reaction ($pH - H_2O$)	Soil salinity	Relief: macro; relative height	Relief: meso	Relief: micro	Vegetation type	Landsuitability classes	Acrea
RECENT FLUVIAL SEDIMENTS – RIVER LEVEELAND	FPl1*	deep, complex of sand to clay; stratified	slow to rapid	6,5 - 8,4	non-saline	flat to gently undulating; moderately high, in places high	locally very irregular, due to presence of abondoned river courses	-	grassland, bushed grassland, woodland and patches of riparian forest	NS stT (....T only locally)	7590
	FPl2*	deep, complex of loam to clay; stratified	slow to moderately rapid	6,5 - 8,4	slightly saline	flat to gently undulating; moderately high	locally very irregular, due to presence of abondoned river courses	-	riparian forest	NSstT (....T only locally)	520
	FRl3g	deep, cracking clay	slow	6,5 - 8,4	usually non-saline; locally moderately saline from 50 cm onwards	flat; moderately high	-	gilgai	grassland, bushed grassland	1	760
	FRl3b*	deep, cracking clay	slow	6,5 - 8,4	usually non-saline	flat to very gently undulating; moderately high	comprises small (levee) ridge with former river course	-	wooded bushland, bushland	3tT	1050
	FRl3f	deep, cracking clay, locally over loamy sand	slow	6,5 - 8,4	non-saline	flat to very gently undulating; moderately high	with wide former river course	-	riparian forest	NStT	340
RIVER BASINLAND	FFb1*	deep, cracking clay	slow	6,0 - 8,0	non-saline	flat; moderately high	-	gilgai	grassland, bushed grassland; locally doumpalms	1	5000
	FRb2*	deep, cracking clay	slow	6,0 - 8,0; locally in subsoil 8,5 - 9,4	non-saline; locally slightly saline from 100 cm onwards	flat; moderately low	locally depressions	gilgai, small humps in depressions	grassland, locally bushed grassland; grasses and reeds	1	8060
	FRb3*	deep, cracking clay	slow	5,8 - 7,5	non-saline; locally slightly saline from 100 cm onwards	flat; low	locally gullies	gilgai, tussocks up to 50cm height	grassland; grasses and sedges or reeds	1	10350
	FFb4	deep, cracking clay	slow	4,8 - 6,5; starting at approx. 50 cm depth 4,0-5,0 locally <4,0	non-saline; slightly to moderately saline from 50 cm onwards	flat; low and moderately low	irregular, due to presence of small, shallow gullies	gilgai on higher parts, cowfoetoes in gullies	grassland; reeds and herbs	3 st	2130
ESTUARINE LEVEELAND	FEl1	deep, clay	slow	5,0 - 7,0 deeper than 30-100 cm 3,5 - 4,5	non-saline; deeper than 100 cm moderately saline	flat; moderately low	with present Tana river bed	-	grassland; scattered doumpalms	2s	280
SUBRECENT MARINE SEDIMENTS – BASINLAND	FEb1	-deep usually clay, locally within 150 cm depth overlying sandy clay to loamy sand -deep, clay	slow slow	4,8 - 6,0; starting at 30-50cm depth usually 3,0-4,0 5,0 - 6,0 starting at 50-100cm depth usually 3,0-4,0	-non to slightly saline; usually moderately saline from 30-50 cm onwards. -moderately saline from 50-100cm onwards	flat; low	irregular, due to presence of wide, shallow gullies	weak gilgai	grassland; mainly reeds	NSst	4260
	FEb2	deep, clay, locally deeper than 100 cm changing into medium fine sand	slow	5,5 - 7,0; locally deeper than 100 cm 3,5 - 4,5	usually non-saline; locally deeper than 100 cm slightly saline	flat; low	irregular, due to presence of wide, shallow gullies and depressions	cowfoetoes in gullies and depressions	grassland; reeds and grasses	2t	1170
[illegible]	TOu*	predominantly; -topsoil of loamy sand to sandy clay over cracking clay -topsoil of loamy sand over sandy loam to sandy clay loam	slow	-usually >9,0 - >8,5	-non-saline -usually non-saline over saline to strongly saline	very gently undulating to flat; high	-	-	bushland, bushland thicket, grassland -bushland thicket	NSu	17100
	TLo	deep, cracking clay	slow	6,0 - 7,5; locally 4,0 - 5,0	usually non-saline; locally strongly saline	flat; low		gilgai, humpy	grassland	1 + NSs	1050
[illegible]	[illegible]*	deep, sandy clay loam to sand	moderate to rapid	<6,0; locally >6,0 in topsoil and >8,5 in subsoil	non-saline; locally saline in subsoil	flat to undulating	low ridges	-	bushland, bushland thicket	NSsT	2340
[illegible]	Cf	complex of: -mapping unit FRb1, FRb2, FRb3 -mapping unit TOu	slow	5,8 - 8,0; locally >8,5	non-saline; locally slightly to moderately saline from 100 cm onwards	flat to very gently undulating	irregular, due to presence of many, small outcrops of mapping unit TOu	-	grassland, bushed grassland, bushland	1 + NSst	1520

*mainly based on information in "Detailed reconnaissance soil map (sheet 2)" of the Lower Tana Village Irrigation Programme.

*small areas of the mapping units FRb1, FRb2 and FFb3 are covered with woodland or riparian forest. They are distinguished on the soil map with the symbol ....f. These areas, in total approx. 150 ha, are classified as unsuitable (class NStT) in the detailed reconnaissance survey of the LTVIP.

Table 4.4 Vegetation criteria for large-scale irrigated rice. Specifications for Tana Delta Irrigation Project

Land suitability class		
1	2	3
up to moderate bush; woody cover less than 20%	up to moderate to thick bush with high palms; woody cover less than 40%	up to dense bush and thicket, but excluding continuous high woodland/forest; woody cover less than 80%

Land that fails to meet the above criteria is classified as class NS (unsuitable)

4.4 The suitability classes of the soil mapping units

The main land characteristics of each soil mapping unit are evaluated according to the specified criteria to establish the suitability class. Here it is stressed again that irrigability en drainability are not included as limiting factors in this appraisal and flood-control works are assumed to be present.
Table 4.5 summarizes these land characteristics and suitability classes.

Class 1

Land suitable for sustained irrigated rice production; minimum costs of development and management associated with the land

The total acreage of class 1 land is 24 200 ha. This class includes soils of mapping units FRb1, FRb2 and FRb3 of the river basin land and soils of mapping unit FR13g of the river levee land. In some parts of mapping unit FRb2 and FRb3 locally levelling will be required because of the presence of some gullies. In the area between the Abarfarda and the area of complex soil mapping unit CF, locally acid and saline soils occur as inclusion.
The area of soil mapping unit FRb2 west of Moa, though classified as class 1, needs detailed investigation because of the presence of saline and alkaline old alluvial material in the subsoil near the eastern boundary.

Class 2

Land of moderate productivity; slight to moderate limitations in soil qualities or requiring moderate costs for development

1450 ha land of this class is found in the project area. 280 ha consist of soils of mapping unit FE11 and is classified as class 2s. The soil limitations of this unit are an extremely acid and/ or saline subsoil. In addition, the presence of the recent Tana river course hampers the suitability.

1170 ha belongs to soil mapping unit FEb2 and is classified as class 2t. The main limitations are the irregular topography due to wide shallow gullies and depressions and slightly elevated, small, old river levees. No major soil limitations are present, except for the local presence of medium fine sand in the subsoil and an extremely acidity and/or slightly salinity deeper than 1 meter.

Class 3

Lands that are marginally suitable because of restricted productivity and/or requiring relatively high costs for levelling and clearing

There are 3180 ha of this class in the project area. Suitability class 3 with main limiting factors t (topography) and T (vegetation) comprises 1050 ha of mapping unit FR13b. These soils are found in the southern part of the project area and consist mainly of deep cracking clay. A major limiting factor is the position on a relatively high, locally small ridge, dissected by a former river course (topography). The vegetation cover is wooded bushland or bushland, locally riparian forest. This vegetation hindrance is indicated as limiting factor T. After clearance the suitability class is 2t.
Suitability class 3st covers 2130 ha of soil mapping unit FRb4 in the river basin land. The soil consist of deep, cracking clay, but the strongly, locally extremely acid subsoil from 50 cm onwards and a slightly to moderately saline subsoil is a limitation for large-scale rice production. Moreover the irregular pattern of small shallow gullies requires levelling.

Class NS

Land which is unsuited for sustained irrigated rice production due to very severe deficiences in soils, topography and/or vegetation cover

The total acreage of this type of land is 34 600 ha. Class NSsT is associated with soil mapping units FR11 (7590 ha) and FR12 (520 ha). These soils have severe soil limitations, e.g. locally rapid permeability due to the local presence of sandy layers. The gently undulating macrorelief and the irregular mesorelief due to the presence here and there of abandoned river courses are a topographical constraint. Patches of riparian forest is in places a vegetative hindrance.
Class NSsT is associated with soil mapping unit FR13f (340 ha). Deficiencies in topography and the vegetation hindrance are the limiting factors.
Class NSst. Soil mapping unit FEb1 (4260 ha) has very severe soil limitations; in most of the area, the subsoil is extremely acid from 30-50 cm onwards and usually from that depth onwards also moderately saline. In the wide and shallow gullies the acidity and salinity starts at 50-100 cm depth. Furthermore, the irregular topography due to the presence of gullies is a major constraint, because levelling will decrease the depth at which salinity and acidity starts.

Class NSu (17 100 ha) and NSsT (2340 ha) are associated with soils developed on old alluvial deposits (soil mapping unit TOu) and with soils developed on sandy deposits (soil mapping unit BQ). These soils with major soil deficiences occur almost entirely outside the area of interest and are therefore not discussed in detail here.

Class (1 + NSs) comprises soils of mapping unit TOb (1050 ha). They are found in the bottomlands adjacent to and in connection with the floodplains. Probably small areas in the surroundings of the outlet of the bottomland are suitable, but further investigations are necessary.

Class (1 + NSst) is found in the area of mapping unit CF. The soils are developed on recent fluvial sediments and/or on old alluvial sediments. The suitability is derived from the components. The overall suitability is unsuitable because considerable differences in soil conditions occur at relatively short distances.

Small areas of the mapping units FRb1, FRb2 and FRb3 are covered with woodland or riparian forest. These areas are classified as unsuitable (class NStT) in the detailed reconnaissance survey of the LTVIP. The total area of approximately 150 ha is copied from the LTVIP maps.

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A P P E N D I X

1 Description and analytical data of representative soil profiles

LABORATORY DATA

Profile no.: I
Mapping unit: FRl3g
Soil classification: vertic Fluvisol

Horizon	A1	C1	C2	C3g	C4g	C5
Depth (cm)	0-20	60-70	120-130	230-250	430-450	450-500
Texture						
Sand % 2.0 - 0.05 mm	36	16	22	32	28	34
Silt % 0.05 - 0.002 mm	22	8	34	14	18	18
Clay % 0.002 - 0 mm	42	76	44	54	54	48
Texture class	C	C	C	C	C	C
Chemical data						
pH-H_2O (1: 2.5 v/v)	6.0	7.5	6.9	7.9	7.9	8.1
pH-KCl ,,	5.1	6.6	6.2	7.3	7.3	7.3
EC (mmho/cm) ,,	0.18	1.40	3.00	2.10	2.80	1.60
C (%)	1.47	6.38				
N (%)						
C/N						
CEC (me/100g), pH 8.2	29.2	31.8	41.7	35.6	31.6	34.2
Exch. Ca (me/100g)	8.9	12.0	9.8	32.2	16.5	33.7
,, Mg ,,	6.3	8.5	13.3	10.9	5.5	14.7
,, K ,,	0.55	trace	0.68	trace	0.47	0.55
,, Na ,,	0.32	2.82	5.42	4.14	2.95	5.92
Sum of cations	16.07	23.32	29.20	47.34	25.42	54.87
Base sat. %, pH 8.2	55	73	70	>100	80	>100
ESP at pH 8.2	1	9	13	12	9	17
Saturation extract:						
Moisture %		75.5	138.5	81.0	84.1	84.6
pH-paste		7.7	7.3	7.2	7.6	7.3
ECe (mmho/cm)		5.5	11.0	9.5	1.6	8.0

Fertility aspects: (0 - cm)	0-20 cm	
Ca (me/100g)	10.1	
Mg ,,	6.3	
K ,,	0.46	
Na ,,	0.89	
P (ppm)	29	
Mn (me/100g)	0.23	
Exch. acidity (me/100g)		
pH-H_2O (1:1 v/v)	6.0	
C%	1.47	
N%	0.13	

Field laboratory data

Horizon	Depth	1: 2.5 soil-water v/v pH	EC
A11	5	5.6	0.50
A12	20	6.4	0.60
C1	50	7.6	2.80
C2	120	7.1	4.10
C3g	180	7.1	6.00
water	450	6.5	17.00

Profile no. I (see also Fig. 3.4)

Mapping unit: FR13g

Physiography: Floodplains- river levee land; former Tana course near Moa at approx. 300 m distance

Topography: flat; weak gilgai microrelief; no visible surface cracks (after rains)

Vegetation: grasses and reeds, scattered shrubs, riparian forest along the former rivercourse at about 200 meters distance

Drainage conditions: imperfectly drained; flooded during short periods; groundwater level at 420 cm

Profile description:

A_{11}	0 - 5cm	black (10YR 2/1 moist), humic clay; moderate, very fine and fine angular blocky structure; firm when moist, sticky and plastic when wet; abundant fine roots; clear, smooth transition to
A_{12}	5 - 25cm	as above, but fine angular blocky structure and few, fine, faint iron mottles; common, fine roots; gradual, wavy transition to
C_1	25 - 100cm	dark grayish brown (10YR 4/2 moist) clay, locally alternating with sand layers; moderate, fine angular blocky structure; common, fine, distinct iron mottles; some micas; few fine roots, decreasing with depth to rare and confined to peds; gradual smooth transition to
C_2	100 - 170cm	very dark gray (10YR 3/1 moist) clay; weak, fine prismatic structure, breaking into moderate, fine angular blocks; abundant, thick slickensides; very firm when moist, very sticky and very plastic when wet; few, fine, faint iron mottles; micas; no roots; gradual, wavy transition to
C_3g	170 - 330cm	gray (5Y 5/1 moist) clay; very firm when moist, very sticky and very plastic when wet; common fine, prominent iron mottles; common (5%), small (3mm) powdery carbonates concretions;
C_4g	330 - 460cm	as above but medium and distinct iron mottles; few (3%), fine (1-10mm), soft powdery carbonates
C_5	460 - 500cm	olive gray (5Y 5/2 moist) clay; few, coarse, faint iron mottles; common (10%), fine (1-10mm) carbonate concretions.

LABORATORY DATA

Profile no.: II
Mapping unit: FRb2
Soil classification: vertic Fluvisol

Horizon	A11	A12	C1g	C2g	C3g	
Depth (cm)	1-3	5-20	60-75	100-120	160-180	
Texture						
Sand % 2.0 - 0.05 mm	16	20	20	26	34	
Silt % 0.05 - 0.002 mm	16	18	18	20	24	
Clay % 0.002 - 0 mm	68	62	62	54	42	
Texture class	C	C	C	C	C	
Chemical data						
pH-H_2O (1: 2.5 v/v)	6.0	6.5	7.6	7.7	8.2	
pH-KCl ,,	4.7	5.9	6.4	6.8	6.9	
EC (mmho/cm) ,,	0.40	0.55	2.10	1.30	0.65	
C (%)	2.83	0.92	0.43	0.20	0.20	
N (%)						
C/N						
CEC (me/100g), pH 8.2	42.6	33.4	38.6	34.2	33.6	
Exch. Ca (me/100g)	14.1	14.1	15.0	15.0	9.4	
,, Mg ,,	7.3	10.1	17.3	16.9	18.1	
,, K ,,	1.4	0.6	0.31	0.31	0.3	
,, Na ,,	1.12	3.64	0.58	0.64	1.74	
Sum of cations	23.92	28.44	33.19	32.85	29.54	
Base sat. %, pH 8.2	56	85	86	96	88	
ESP at pH 8.2	3	11	1.5	2	5	
Saturation extract: $CaCO_3$	-	+	-	+	+	
Moisture %				90.8	184.3	
pH-paste				79	7.9	
ECe (mmho/cm)				6.10	4.5	

Fertility aspects: (0 - cm)	1-3 cm	5-20 cm
Ca (me/100g)	15.2	12.1
Mg ,,	2.2	1.5
K ,,	0.04	trace
Na ,,	0.52	0.48
P (ppm)	35	7
Mn (me/100g)	trace	trace
Exch. acidity (me/100g)	0.1	
pH-H_2O (1:1 v/v).	5.4	6.3
C%	2.83	0.92
N%	0.29	0.11

Field laboratory data

Horizon	Depth	1: 2.5 soil-water v/v pH	EC
A11	2	5.6	0.5
A12	15	6.9	0.6
C1g	60	7.8	0.44
C2g	100	7.6	3.9
C3g	170	7.5	2.5
Water	350	6.6	1.6

Profile no. II

Mapping unit: FRb2

Physiography: Floodplains - river basin land; approx. 0.5 km from former river course

Topography: flat, gilgai microrelief; few cracks, 4 cm wide, 30 cm deep

Vegetation: grasses and some herbs

Drainage conditions: imperfectly to poorly drained; seasonally flooded; groundwater level at 350 cm

Profile description:

A_{11}	0 - 3cm	dark reddish brown and black (5YR 3/3 and N2 moist), humic clay; strong, very fine angular blocky structure; firm when moist, sticky and plastic when wet; abrupt, smooth transition to
A_{12}	3 - 30cm	black (N2 moist) clay; strong, fine angular blocky structure; firm when moist, sticky and plastic when wet; few, fine distinct iron mottles; many fine roots; abrupt, wavy transition to
C_1g	30 - 80cm	dark gray (10YR 4/1 moist) clay; strong, coarse prismatic structure, breaking into strong, medium, angular blocks; very firm when moist, very sticky and very plastic when wet; abundant thick slickensides; common, fine, faint iron mottles; calcareous; few fine roots, mainly along peds; gradual smooth transition to
C_2g	80 - 150cm	dark grayish brown (10YR 4/2 moist) clay; moderate, coarse prismatic structure, breaking into moderate, coarse, angular blocks; few, medium slickensides; firm when moist, sticky and plastic when wet; common, fine, faint iron mottles; strongly calcareous; few micas; clear, smooth transition to
C_3g	150 - 230cm	dark gray (10YR 4/1 moist) clay; weak, coarse angular blocky structure; few thin, slickensides; firm when moist, slightly sticky and plastic when wet; common, fine, faint iron mottles; strongly calcareous; common micas; type of transition not observed because of augering from 200 cm onwards
C_4g	230 - 280cm	dark brown (10YR 3/3 moist) sandy clay loam; firm when moist, sticky and plastic when wet; common, fine, distinct iron mottles; slightly calcareous; few (2%), small (2 mm) carbonate concretions; micas
C_5g	280 - 330cm	dark yellowish brown (10YR 4/4 moist) clay; firm when moist, sticky and plastic when wet; many, medium, distinct iron mottles; non calcareous; very few (1%), very small (1mm) carbonate concretions; micas
C_6g	330 - 400cm	dark grayish brown (10YR 4/2 moist) sandy clay; firm when moist, sticky and plastic when wet; common, medium, distinct iron mottles; micas
CG	400 - 500cm	gray (5Y 5/1 moist) sandy clay with sand layers; firm when moist, slightly sticky and slightly plastic when wet; common, coarse, distinct iron mottles; micas

LABORATORY DATA

Profile no.: III
Mapping unit: FRb2
Soil classification: vertic Fluvisol

Horizon	A11	A12	AC	C1	C3g	
Depth (cm)	0-8	20-40	60/80 - 90	90-120	240-260	
Texture						
Sand % 2.0 - 0.05 mm	24	18	16	20	18	
Silt % 0.05 - 0.002 mm	20	22	24	26	14	
Clay % 0.002 - 0 mm	56	60	60	54	68	
Texture class	C	C	C	C	C	
Chemical data						
pH-H_2O (1: 2.5 v/v)	6.0	7.0	7.1	7.2	6.5	
pH-KCl ,,	4.7	5.5	6.2	6.4	5.5	
EC (mmho/cm) ,,	0.25	0.40	2.90	2.85	2.40	
C (%)	2.66					
N (%)						
C/N						
CEC (me/100g), pH 8.2	48.6	41.2	46.6	26.1	41.2	
Exch. Ca (me/100g)	10.10	16.5	8.2	26.7	13.2	
,, Mg ,,	7.7	11.5	8.2	9.5	14.1	
,, K ,,	1.31	0.36	0.20	trace	0.36	
,, Na ,,	0.32	0.80	1.54	3.98	4.22	
Sum of cations	19.43	29.16	18.14	40.18	31.88	
Base sat. %, pH 8.2	40	71	39	7100	77	
ESP at pH 8.2	<1	2	3	15	10	
Saturation extract: $CaCO_3$	-	-	-	-	-	
Moisture %			92.1	66.2	104.6	
pH-paste			7.1	7.2	6.6	
ECe (mmho/cm)			9.0	8.0	6.0	

Fertility aspects: (0 - cm)	0-8 cm	0-20 cm
Ca (me/100g)	15.4	14.0
Mg ,,	0.6	9.2
K ,,	0.63	0.28
Na ,,	0.81	1.12
P (ppm)	31	24
Mn (me/100g)	0.35	0.40
Exch. acidity (me/100g)		
pH-H_2O (1:1 v/v)	5.9	5.9
C%	2.66	0.19
N%	0.37	1.12

Field laboratory data

Horizon	Depth	1: 2.5 soil-water v/v pH	EC
A11	5	5.5	0.60
A12	15	5.8	0.54
A13	40	6.8	0.80
AC	70	7.2	0.44
C1	110	7.1	6.0
C2g	170	6.9	5.0
C3g	240	6.6	3.9
C4g	320	6.8	1.6
gr. water	380	6.5	1.1

Profile no. III (see also Fig. 3.5)

Mapping unit: FRb2

Physiography: Floodplains - river basin land in the vicinity of river levee land

Topography: flat; moderate gilgai microrelief

Vegetation: grasses and reeds; some doumpalms at about 50 meters distance

Drainage conditions: imperfectly to poorly drained; seasonally flooded up to 1 meter; groundwater level at 380 cm

Profile description:

A_{11}	0 - 8cm	black (N2 moist), humic clay; strong, very fine angular blocky structure; firm when moist, sticky and plastic when wet; abundant fine roots; clear, smooth transition to
A_{12}	8 - 30cm	black (N2 moist), humic clay; strong, very fine and fine angular blocky structure; firm when moist, sticky and very plastic when wet; common, fine roots; clear, wavy transition to
A_{13}	30 - 60cm	very dark gray (10YR 3/1 moist) clay; moderate, very fine, angular blocky structure; few, medium slickensides; very firm when moist, sticky and very plastic when wet; common, fine, faint iron mottles, decreasing with depth to few; fine roots along peds; gradual, wavy transition to
AC	60 - 90cm	very dark gray (10YR 3/1 moist) clay; weak, medium prismatic structure, breaking into moderate, fine, angular blocks; abundant thick slickensides; very firm when moist, very sticky and very plastic when wet; few, fine, faint iron mottles; few fine roots; gradual, wavy transition to
C_1	90 - 140cm	dark gray (10YR 4/2 moist) clay with very thin layers of sand; moderate, fine, angular blocky structure; very firm when moist, sticky and plastic when wet; common, fine, distinct iron mottles; few (5%), small (2-10 mm) carbonate concretions; few micas; very fine roots along peds; clear, wavy transition to
C_2g	140 - 200cm	dark gray (10YR 4/2 moist) clay; very firm when moist, very sticky and very plastic when wet; common, medium, distinct iron mottles; gypsum crystals and micas;
C_3g	200 - 300cm	very dark gray (5Y 3/1 moist) clay; consistency as above; common, medium, distinct iron mottles; gypsum crystals
C_4g	300 - 380cm	very dark gray (5Y 3/1 moist), sandy clay; consistency as above; prominent iron mottles

LABORATORY DATA

Profile no.: IV
Mapping unit: FRb2
Soil classification: vertic Fluvisol

Horizon	A11	A12	C1	C2	C3	C4
Depth (cm)	5-10	15-20	60-70	100-110	150-160	260-270
Texture						
Sand % 2.0 - 0.05 mm	24	38	34	38	28	28
Silt % 0.05 - 0.002 mm	16	12	10	8	10	24
Clay % 0.002 - 0 mm	60	50	56	54	62	48
Texture class	C	C	C	C	C	C
Chemical data						
pH-H_2O (1: 2.5 v/v)	5.3	6.8	8.0	8.0	8.2	8.4
pH-KCl ,,	4.1	5.5	6.3	6.7	6.9	6.7
EC (mmho/cm) ,,	0.45	0.45	0.35	2.25	2.30	0.70
C (%)	1.89	0.79	0.52	0.12	0.23	0.09
N (%)						
C/N						
CEC (me/100g), pH 8.2	58.1	37.4	38.2	34.6	51.1	35.8
Exch. Ca (me/100g)	16.5	14.5	12.8	10.7	13.7	6.1
,, Mg ,,	6.5	7.3	10.9	9.5	13.7	16.1
,, K ,,	1.0	0.4	0.4	0.3	0.2	0.08
,, Na ,,	1.4	3.1	4.0	3.9	6.7	13.0
Sum of cations	25.4	25.2	28.1	24.4	34.4	35.18
Base sat. %, pH 8.2	44	67	74	71	67	98
ESP at pH 8.2	3	8	11	11	13	36
Saturation extract: $CaCO_3$						+
Moisture %					68.7	32.2
pH-paste						
ECe (mmho/cm)					4.0	12.5

Fertility aspects: (0 - cm)	0-10cm	5-10cm
Ca (me/100g)	17.6	14.7
Mg ,,	6.9	5.9
K ,,	0.69	0.46
Na ,,	1.59	1.04
P (ppm)	21	19
Mn (me/100g)	0.25	0.28
Exch. acidity (me/100g)		0.1
pH-H_2O (1:1 v/v)	5.7	5.3
C%	1.81	1.89
N%	0.38	0.39

Field laboratory data

Horizon	Depth	1: 2.5 soil-water v/v pH	EC
A11	10	5.6	0.60
A12	20	6.5	0.60
C1	70	7.9	1.00
C1	70 (repl)	8.0	1.50
C2	100	7.0	6.00
C3	160	7.8	3.70
C4	270	8.1	1.70
gr. water	410	7.3	1.60

Profile no. IV

Mapping unit: FRb2

Physiography: Floodplains - river basin land

Topography: flat; gilgai microrelief; cracks

Vegetation: grasses, some reeds

Drainage conditions: imperfectly to poorly drained; seasonally flooded up to 60 cm; groundwater level at 410 cm

Profile description:

A_{11}	0 - 10cm	black (10YR 2/1 moist), humic clay; strong, fine angular blocky structure; very hard when dry, firm when moist, sticky and very plastic when wet; few, fine, distinct iron mottles; common, fine roots; clear, smooth transition to
A_{12}	10 - 25cm	very dark gray (N3 moist) clay; strong, coarse angular blocky structure; common, thin slickensides; very firm when moist, very sticky and very plastic when wet; few, fine, faint iron mottles; very few (less than 1%), small (2 mm) carbonate concretions; common, very fine roots; clear, wavy transition to
C_1	25 - 95cm	black (5Y 2/1 moist) clay; strong, coarse prismatic structure, up to 70 cm breaking into strong, coarse angular blocks, below 70 cm into moderate, coarse, angular blocks; abundant, thick slickensides; very hard when dry, very firm when moist, very sticky and very plastic when wet; few, very fine and fine roots along peds; gradual, wavy transition to
C_2	95 - 140cm	dark gray (N4 moist) clay; structure not observed, too wet; very firm when moist, very sticky and very plastic when wet; common, thick slickensides; few, coarse, faint iron mottles; few (3%), medium (1-3 cm) carbonate concretions; gradual, smooth transition to
C_3	140 - 210cm	grayish brown (2.5Y 5/2 moist) clay; structure not observed, too wet; few, thin slickensides; firm when moist, sticky and plastic when wet; common, medium, faint iron mottles; few (3%), medium (1-2 cm) carbonate concretions; slightly calcareous; clear, smooth transition to
C_4	210 - 400cm	brown (10YR 5/3 moist) clay; firm when moist, slightly sticky and slightly plastic when wet; many, fine, faint iron mottles; micas
C_5	400 - 420cm	pale olive (5Y 6/3 moist) loamy sand; micas and black grains. End of augering due to sand flowing into the augerhole.

Remarks: -the fill-up topsoil material in the cracks was very wet and sticky, the prismas were still dry and hard

LABORATORY DATA

Profile no.: V
Mapping unit: FRb3
Soil classification: vertic Fluvisol

Horizon	A1	C1	C2
Depth (cm)	0-20	60-70	150-160
Texture			
Sand % 2.0 - 0.05 mm	20	20	42
Silt % 0.05 - 0.002 mm	6	8	18
Clay % 0.002 - 0 mm	74	72	40
Texture class	C	C	C/CL
Chemical data			
pH-H_2O (1: 2.5 v/v)	6.7	7.9	7.9
pH-KCl ,,	5.3	6.1	6.5
EC (mmho/cm) ,,	0.60	0.50	0.80
C (%)	1.07	0.49	0.17
N (%)			
C/N			
CEC (me/100g), pH 8.2	34.6	42.6	23.6
Exch. Ca (me/100g)	19.2	3.2	7.6
,, Mg ,,	12.3	17.5	4.9
,, K ,,	0.47	0.31	trace
,, Na ,,	1.12	3.76	0.50
Sum of cations	33.09	24.77	13.0
Base sat. %, pH 8.2	96	58	55
ESP at pH 8.2	3	9	2
Saturation extract: $CaCO_3$	-	-	++
Moisture %			69.7
pH-paste			8.0
ECe (mmho/cm)			2.10

Fertility aspects: (0 - cm)	0-20cm	
Ca (me/100g)	14.5	
Mg ,,	1.6	
K ,,	0.04	
Na ,,	0.55	
P (ppm)	4.	
Mn (me/100g)	trace	
Exch. acidity (me/100g)		
pH-H_2O (1:1 v/v).	6.1	
C%	1.07	
N%	0.10	

Field laboratory data

Horizon	Depth	1: 2.5 soil-water v/v pH	EC
A1	20	7.2	0.6
C1	40	7.6	0.8
C1	70	7.9	1.2
C1	110	7.6	1.8
C2	170	7.5	1.4
gr. water	220	6.7	0.7

Profile no. V

Mapping unit: FRb3

Physiography: Floodplains - river basin land

Topography: flat; gilgai microrelief

Vegetation: sedges on tussocks and some reeds

Drainage conditions: poorly drained; seasonally flooded during relatively long periods; groundwater level at 220 cm

Profile description:

A_1	0 - 35cm	very dark gray (10YR 3/1 moist) and black (N2 moist), humic clay; strong, very fine, angular blocky structure; very firm when moist, sticky and very plastic when wet; few, fine, faint iron mottles along root channels; common, fine roots; clear, wavy transition to
C_1	35 - 150cm	dark brown (10YR 4/3 moist) clay; moderate, coarse, prismatic structure; very firm when moist, sticky and very plastic when wet; abundant, thick slickensides; few (2%), small (10 mm) carbonate concretions from 80 cm onwards; few, fine roots; gradual, smooth transition to
C_2	150 - 190cm	brown (10YR 5/3 moist) clay loam to clay; moderate, fine angular blocky structure; firm when moist, sticky and plastic when wet; few, fine, faint iron mottles; few (2%), small (10 mm carbonate concretions and few (3%), small (2 mm) manganese concretions; some micas; no roots; gradual, smooth transition tc
C_3	190 - 220cm	yellowish brown (10YR 5/4 moist) fine sand; single grain; few, fine, faint iron mottles; many micas; clear, smooth transition to
C_4	220 - 260cm	yellowish brown (10YR 5/6 moist) fine sand; single grain; no mottling; many micas. End of auger observation at 260 cm due to sand moving into the augerhole.

LABORATORY DATA

Profile no.: VI
Mapping unit: FRb3
Soil classification: vertic Fluvisol

Horizon	A12	C1	C2			
Depth (cm)	15-25	60-70	160-170			
Texture						
Sand % 2.0 - 0.05 mm	18	20	22			
Silt % 0.05 - 0.002 mm	14	12	10			
Clay % 0.002 - 0 mm	68	68	68			
Texture class	C	C	C			
Chemical data						
pH-H_2O (1: 2.5 v/v)	6.2	7.3	7.1			
pH-KCl ,,	5.3	6.6	6.3			
EC (mmho/cm) ,,	0.50	0.60	1.40			
C (%)	1.21	0.35	0.32			
N (%)						
C/N						
CEC (me/100g), pH 8.2	41.2	38.6	39.8			
Exch. Ca (me/100g)	23.2	22.3	12.8			
,, Mg ,,	10.5	15.5	11.5			
,, K ,,	1.12	0.30	0.36			
,, Na ,,	0.64	2.42	2.54			
Sum of cations	35.46	40.52	27.2			
Base sat. %, pH 8.2	86	>100	68			
ESP at pH 8.2	1.5	6	6			
Saturation extract: $CaCO_3$	–	–	–			
Moisture %			105.9			
pH-paste			7.7			
ECe (mmho/cm)			4.0			

Fertility aspects: (0 - cm)	15-25cm	
Ca (me/100g)	14.0	
Mg ,,	6.4	
K ,,	0.92	
Na ,,	0.89	
P (ppm)	26	
Mn (me/100g)	0.16	
Exch. acidity (me/100g)		
pH-H_2O (1:1 v/v)	5.9	
C%	1.21	
N%	0.15	

Field laboratory data

Horizon	Depth	1: 2.5 soil-water v/v pH	EC
A11	10	5.6	0.7
A12	20	5.8	0.6
C1	40	7.6	0.8
C1	70	7.8	0.8
C1	110	7.7	2.0
C2	170	7.4	2.8
CG	470	6.8	3.8

Profile no. VI (see also Fig. 3.6)

<u>Mapping unit</u>: FRb3

<u>Physiography</u>: Floodplains - river basin land

<u>Topography</u>: flat; gilgai microrelief; many tussocks, few cracks 10 cm wide, 80 cm deep

<u>Vegetation</u>: grasses and sedges on tussocks, some reeds

<u>Drainage conditions</u>: poorly drained; seasonally flooded during relatively long periods; no groundwater within 5 meters depth

<u>Profile description</u>:

A_{11}	0 - 15cm	reddish brown (5YR 4/4 moist), humic clay; strong, fine, angular blocky structure; very firm when moist, sticky and very plastic when wet; few, fine iron mottles; clear, wavy transition t
A_{12}	15 - 30cm	black (N2 moist) clay; strong, fine, angular blocky structure; very firm when moist, sticky and plastic when wet; common, fine, distinct iron mottles; gradual, wavy transition to
C_1	30 - 150cm	dark grayish brown (2.5Y 4/2 moist) clay; moderate, medium prismatic structure breaking into moderate, fine, angular blocks; abundant, thick slickensides; very firm when moist, sticky and very plastic when wet; few, fine, faint iron mottles; few, fine roots; gradual, smooth transition to
C_2	150 - 190cm	grayish brown (2.5Y 5/2 moist) clay; moderate, fine, angular blocky structure; common, medium slickensides; few, fine, faint iron mottles; very firm when moist, sticky and very plastic when wet; few, very small manganese nodules; diffuse, smooth transition to
C_3	190 - 460cm	dark brown (10YR 4/3 moist) sandy clay; firm when moist, sticky and plastic when wet; few, fine, faint iron mottles; few, very small manganese nodules; few (1%), small (2 mm) carbonate concretions;
CG	460 - 500cm	gray (5Y 5/1 moist) sandy clay; firm when moist, sticky and plastic when wet; few, fine, faint iron mottles; few, small manganese nodules

LABORATORY DATA

Profile no.: VII
Mapping unit: FRb3
Soil classification: vertic Fluvisol

Horizon	A11	A12	AC	C1g	C2g	Cg
Depth (cm)	5-10	10-20	30-40	100-120	160-180	300-320
Texture						
Sand % 2.0 - 0.05 mm	20	22	18	16	22	34
Silt % 0.05 - 0.002 mm	10	8	10	12	24	20
Clay % 0.002 - 0 mm	70	70	72	72	54	46
Texture class	C	C	C	C	C	C
Chemical data						
pH-H_2O (1: 2.5 v/v)	6.0	6.8	7.9	7.8	7.7	7.3
pH-KCl ,,	4.9	5.4	6.6	6.6	6.6	6.5
EC (mmho/cm) ,,	0.40	0.40	0.85	1.10	1.55	1.60
C (%)	2.28	1.21	0.23	0.17	0.14	1.36
N (%)						
C/N						
CEC (me/100g), pH 8.2	51.8	55.4	45.4	32.6	41.6	34.6
Exch. Ca (me/100g)	25.2	26.7	21.2	12.8	8.3	8.2
,, Mg ,,	12.9	15.7	12.9	11.5	6.7	6.3
,, K ,,	1.35	0.90	0.76	0.63	0.55	0.91
,, Na ,,	0.78	1.34	1.34	2.06	1.14	1.12
Sum of cations	40.23	44.64	36.20	26.99	16.69	16.53
Base sat. %, pH 8.2	78	81	80	83	40	48
ESP at pH 8.2	1.5	2	3	6	3	3
Saturation extract: $CaCO_3$	–	–	+	+	+	–
Moisture %			109.3	104.1	89.8	
pH-paste			7.8	7.6	8.0	
ECe (mmho/cm)			1.05	2.35	4.5	

Fertility aspects: (0 - cm)	5-10 cm	0-20 cm
Ca (me/100g)	15.8	17.6
Mg ,,	12.6	8.6
K ,,	0.50	0.46
Na ,,	1.28	1.33
P (ppm)	26	24
Mn (me/100g)	0.13	0.20
Exch. acidity (me/100g)		
pH-H_2O (1:1 v/v)	5.8	6.0
C%	2.28	2.77
N%	0.27	0.32

Field laboratory data

Horizon	Depth	1: 2.5 soil-water v/v pH	EC
A11	10	5.6	0.58
A12	20	6.4	0.53
AC	40	7.6	1.00
C1g	70	7.7	1.60
C1g	110	6.8	3.30
C2g	170	7.4	3.30
C3g	200	7.4	2.90
C3g	280	7.0	2.10
gr. water	330	6.9	5.00

Profile no. VII

Mapping unit: FRb3

Physiography: Floodplains - river basin land south

Topography: flat; gilgai microrelief; few cracks 4 cm wide, 40 cm deep

Vegetation: grassland, mainly reeds on tussocks

Drainage conditions: poorly drained; seasonally flooded at least once a year up to 1 meter; groundwater level at 330 cm

Profile description:

A_{11}	0 - 10cm	black (N2 moist), humic clay; moderate, very fine angular blocky structure; slightly firm when moist, slightly sticky and plastic when wet; common, fine, distinct iron mottles along root channels; many fine roots (matted near surface); clear, smooth transition to
A_{12}	10 - 20cm	black (N2 moist), humic clay; moderate, very fine, angular blocky structure; firm when moist, sticky and plastic when wet; few, fine, faint iron mottles along root channels; many fine roots; gradual, wavy transition to
AC	20 - 40cm	very dark gray and pockets of black (10YR 3/1 and N2 moist) clay; strong, very fine, angular blocky structure; abundant, medium slickensides; very firm when moist, very sticky and very plastic when wet; few (1%), small (5 mm) carbonate concretions; common, fine roots; clear, wavy transition to
C_1g	40 - 150cm	dark grayish brown (10YR 4/2 moist) clay; strong decreasing to moderate, very fine and fine, angular blocky structure; abundant, thick slickensides; consistency as above; common, fine, distinct iron mottles; few (1%), small (3-10 mm) carbonate concretions; few (1%), small (3 mm) manganese concretions; few, decreasing to very few fine roots up to a depth of 80 cm; clear, smooth transition to
C_2g	150 - 180cm	very dark gray (5Y 3/1 moist) clay; weak, coarse prismatic structure; firm when moist, sticky and very plastic when wet; common, fine, distinct iron mottles; very few (<1%), small (3 mm) carbonate and manganese concretions; many micas
C_3g	180 - 300cm	greenish gray (5GY 5/1 moist) sandy loam; half ripened; very sticky and plastic when wet; common, coarse, prominent iron mottles
CG	300 - 360cm	greenish gray (5BG 5/1 moist) clay alternating with sandy loam; unripened, very sticky and slightly plastic when wet. End of augering due to unripened soil material.

LABORATORY DATA

Profile no.: VIII
Mapping unit: FEb1
Soil classification: thionic Fluvisol

Horizon	A1	C2g	CG	G1	G2	
Depth (cm)	0 - 20	60-70	150-160	250-260	350-360	
Texture						
Sand % 2.0 - 0.05 mm	14	12	16	16	54	
Silt % 0.05 - 0.002 mm	14	14	10	12	16	
Clay % 0.002 - 0 mm	72	74	76	72	30	
Texture class	C	C	C	C	SCL	
Chemical data						
pH-H_2O (1: 2.5 v/v)	5.6	4.1	3.7	4.4	7.8	
pH-KCl ,,	4.8	3.4	3.1	3.5	7.0	
EC (mmho/cm) ,,	2.50	5.50	6.00	6.00	2.85	
C (%)	1.52	0.35	1.69	2.77	0.23	
N (%)						
C/N						
CEC (me/100g), pH 8.2	38.6	40.1	37.4	37.4	19.6	
Exch. Ca (me/100g)	6.5	11.6	4.30	4.0	6.1	
,, Mg ,,	11.30	14.7	22.7	249	10.5	
,, K ,,	1.80	2.75	3.0	3.6	1.7	
,, Na ,,	4.20	6.40	14.70	18.50	6.90	
Sum of cations	23.8	35.45	44.7	51.0	25.26	
Base sat. %, pH 8.2	62	88	>100	>100	>100	
ESP at pH 8.2	11	16	39	49	35	
Saturation extract:						
Moisture %	90.7	93.9	No soil	No soil	61.3	
pH-paste	6.1	5.0			6.3	
ECe (mmho/cm)	6.0	14.5			10.0	

Fertility aspects: (0 - cm)	0-20 cm	
Ca (me/100g)	7.8	
Mg ,,	12.6	
K ,,	0.92	
Na ,,	4.5	
P (ppm)	24	
Mn (me/100g)	0.05	
Exch. acidity (me/100g)	0.1	
pH-H_2O (1:1 v/v)	5.3	
C%	1.52	
N%	0.20	

Field laboratory data

Horizon	Depth	1: 2.5 soil-water v/v pH	EC
A1	5	5.2	3.5
A1	20	5.6	3.4
C1g	40	4.5	5.6
C2g	70	4.0	7.0
C2g	110	3.8	6.0
CG	160	3.5	9.0
G1	240	3.8	11.0
G2	350	7.5	6.0
gr. water	360	6.5	26.0

Profile no. VIII (see also Fig. 3.9)

Mapping unit: FEb1

Physiography: Floodplains - basin land

Topography: flat; gently undulating microrelief; no visible surface cracks after rains

Vegetation: grasses, 20% cover

Drainage conditions: poorly drained; seasonally flooded up to 1 meter; groundwater level at 210 cm

Profile description:

A_1	0 - 30cm	black (N2 moist) clay; strong, medium, angular blocky structure; firm when moist, sticky and plastic when wet; common, fine, distinct iron mottles; common, fine roots; clear, wavy transition to
C_1g	30 - 60cm	gray (5Y 5/1 moist) clay; weak, coarse, angular blocky structure; very firm when moist, very sticky and very plastic when wet; many, red (2.5YR 4/8) iron and many, medium, reddish yellow (7.5YR 6/8), jarosite mottles; gypsum crystals; few, fine roots; diffuse, smooth transition to
C_2g	60 - 150cm	as above, but with few, fine, reddish yellow jarosite mottles; diffuse, smooth transition to
CG	150 - 190cm	dark gray (5Y 4/1 moist) clay; half ripened, very sticky and plastic when wet; diffuse, smooth transition to
G_1	190 - 320cm	dark greenish gray (5G 4/1) clay; unripened, very sticky and slightly plastic when wet
G_2	320 - 360cm	dark greenish gray (5G 4/1) clay alternating with sandy loam; unripened; slightly sticky and slightly plastic when wet; slightly calcareous; few (4%), small (3-10 mm), carbonate concretions. End of augering due to unripened material.

TANA DELTA IRRIGATION PROJECT

RECONNAISSANCE SOIL MAP

LEGEND

F... FLOODPLAINS

FR.. Soils developed on recent fluvial sediments

FRl. River levee land

FRl1	complex of sand to clay, often stratified; excessively to imperfectly drained; usually non-calcareous and non-saline; often rich in micas (eutric and vertic FLUVISOLS)
FRl2	complex of loam to clay, stratified; well to imperfectly drained; often calcareous and saline (eutric and vertic FLUVISOLS)
FRl3g	dark grayish brown, cracking clay; moderately well to imperfectly drained; usually non-calcareous and non-saline; grassland (vertic FLUVISOLS)
Frl3b	like FRl3g; but wooded bushland
FRl3f	like FRl3g; but woodland

FRb. River basin land

FRb1	10-20 cm very dark gray, humic clay over dark brown, cracking clay; moderately well to imperfectly drained; usually non-calcareous and non-saline (vertic FLUVISOLS)
FRb1f	like FRb1; but woodland
FRb2	10-20 cm very dark gray, humic clay over dark brown, cracking clay; imperfectly drained; usually non-calcareous and non-saline (vertic FLUVISOLS)

FRb2f ☐ like FRb2; but woodland

FRb3 ☐ 20 cm very dark gray, humic clay over dark grayish brown, cracking clay; poorly drained; usually non-calcareous and non-saline (vertic FLUVISOLS)

FRb3f ☐ like FRb3; but woodland

FRb4 ☐ 10-20 cm dark gray, humic clay over dark grayish brown, cracking, fluvial clay, between 50-150 cm overlying marine clay or silty clay; imperfectly to very poorly drained; non-calcareous; deeper than 100 cm strongly to extremely acid (catclay); slightly to moderately saline within 100 cm; deeper than 150 cm locally unripened (vertic FLUVISOLS, saline phase)

FE.. Soils developed on subrecent marine sediments

FE1. Recent levee land

FE11 ☐ 30-100 cm grayish brown, cracking, fluvial clay over extremely acid, marine clay (catclay); imperfectly drained; non-calcareous; non-saline within 100 cm (vertic and thionic FLUVISOLS)

FEb. Basin land

FEb1 ☐ complex of:

- 10 cm black, humic to peaty clay over very dark gray clay, between 30-50 cm overlying extremely acid clay (catclay), locally within 150 cm changing into neutral to slightly acid sandy clay to loamy sand; poorly drained; non-calcareous; moderately saline from 30-50 cm depth onwards (thionic FLUVISOLS, saline phase)
- 10 cm black, peaty clay over very dark gray clay, between 50-150 cm overlying strongly to extremely acid clay (catclay); very poorly drained; non-calcareous; moderately saline from 50-100 cm depth onwards (eutric and thionic FLUVISOLS, saline phase)

FEb2 ☐ 10 cm black, humic clay over very dark gray clay, within 100 cm overlying gray clay, locally deeper than 100 cm changing into sand; imperfectly to very poorly drained; non-calcareous; slightly acid or slightly acid over extremely acid; non to slightly saline (eutric and thionic FLUVISOLS)

T... TERRACE LAND

TO. Soils developed on old alluvial sediments

TOu ☐ undifferentiated (orthic and vertic SOLONETZ and pellic VERTISOLS)

TOb ☐ soils of the bottomlands, adjacent to and in connection with the floodplains; very poorly drained (pellic VERTISOLS, partly saline phase)

B. FORMER BEACH RIDGES

BQ Soils developed on sandstone and beach deposits

BQ ☐ undifferentiated (ferralic ARENOSOLS and orthic FERRALSOLS)

C. COMPLEX AREAS

CF Soils developed on recent alluvial and old alluvial sediments

CF ☐ complex of:
- mapping units FRb1, FRb2 and FRb3, often over old alluvial sediments
- mapping unit TOu

Key to salinity classes

ECe (mS/cm	EC (1 : 2.5v/v)* (mS/cm)	Salinity classes
0 - 4	0 - 2.6	non-saline
4 - 8	2.6 - 5.3	slightly saline
8 - 16	5.3 - 10.6	moderately saline
>16	>10.6	strongly saline

* valid for material with a texture of clay

Key to acidity classes

pH - H_2O	acidity class
<4.5	extremely acid
4.5 - 5.5	strongly acid
5.6 - 6.5	slightly acid
6.6 - 7.3	neutral
7.4 - 8.4	moderately alkaline
8.5 - 9.0	strongly alkaline
>9.0	very strongly alkaline