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TANA DELTA IRRIGATION PROJECT
(EXTENSION)

SEMI-DETAILED SOIL SURVEY

J. Stolp

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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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ANNEX
(single cover lodged with Kenya Soil Survey, Nairobi)

1.1 Soil profile description sheets (with field measured pH and EC)

1.2 Location of observations

PREFACE

A semi-detailed soil survey was carried out by the Netherlands Soil Survey Institute in the Tana Delta area, Kenya, in the period September-October 1982 at the request of Haskoning B.V. Consulting Engineers and Architects, Nijmegen.

This soil survey was done within the framework of the feasibility study of the Tana Delta Irrigation Project. Haskoning B.V. received the assignment for this project from the Tana and Athi River Development Authority. The investigation covered an area of approximately 10 000 ha, selected on the basis of the results of a reconnaissance soil survey in March 1981.

The soil survey team consisted of J. Stolp (team-leader), A. Krabbenborg, G. van der Veen and J. Vrielink. R. de Nijs, a junior agronomist employed by Haskoning, joined this team. J.J. Vleeshouwer (project leader) supported the team in the Netherlands.

The cooperation and assistance of local authorities in the area is much appreciated.

The Director,

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

SUMMARY

The area covered by the semi-detailed soil survey for the Tana Delta Irrigation Project is situated in the southern part of the Tana River District in the Coast Province of Kenya. It is located in the floodplain of the Tana river, roughly extending from Ngao irrigation scheme north-westerly, to the Orma village of Odhole south-easterly (Fig. 1.2.01). The total area presented on the soil map is approximately 10,400 ha.
The survey area is liable to seasonal flooding and a great part of the area is more or less subject to sedimentation of Tana river sediment. The physiography of the Tana Delta is presented in Fig. 1.2.02. The three major land forms are river levee land, river basin land and estuarine basin land. The first two consist of soils developed on recent fluvial sediments, the latter of soils developed on subrecent marine sediments.
The general pattern of the soils is shown on the soil map (MAP 1.01). Soils of the river levee land are generally comprised of a complex of deep, usually stratified and variable soils with textures ranging from predominantly clay to micaceous sand (1,525 ha). Four different soil units are distinguished, mainly on the basis of differences in texture and topographical position. Additional information about relief, salinity and vegetation is given. Land suitability for large-scale irrigated rice varies from unsuitable for levee soils with textural constraints to moderately suitable for fine textured levee soils.
Soils of the river basin land are usually uniform and consist of strongly cracking clay in the top metre. They are grouped according to differences in sequence of sediments within 200 cm depth:

1 deep river basin soils (3,700 ha)
2 moderately deep river basin soils over levee sediments (145 ha)
3 moderately deep river basin soils over marine sediments (2,190 ha)
4 shallow river basin soil over marine sediments (795 ha)

Each group consists of three soil units because of a distribution over three classes of drainage conditions: moderately well to imperfectly drained, imperfectly drained, poorly drained. The poorly drained area is the most important.

The first three groups are non-calcareous to 100 cm depth, have a predominantly neutral soil reaction over the same depth and are non-sodic. The degree of salinity in the top metre is low; non-saline with a few exceptions.
The fourth group is also non-calcareous, but soil reaction decreases with depth to slightly acid or acid. Exchangeable Sodium Percentage is more than 6 in the top metre (sodic). The degree of salinity in these soils varies from non-saline to moderately saline.

The land suitability for large-scale irrigated rice varies from highly suitable for the bulk of the soils in river basin land to marginally suitable for soils with mainly salinity constraints.
Soils in estuarine basin land cover an area of 1,980 ha including an area of an association of two soil types. A large part (1,645 ha) is distinguished as deep marine basin soils. An area of 335 ha consists of moderately deep marine soils over old alluvial sediments. These soils are uniform in texture, consisting of strongly cracking clay in the top metre. The topsoil is remarkable black to very dark gray, and extends to

a depth of 40/80 cm below the surface. Concerning the top metre these soils are non-calcareous, neutral to slightly acid and predominantly sodic. The degree of salinity is generally rather severe as moderately saline material occurs in many places within a depth of 70/80 cm below the surface. Deeper than 70/80 cm, an acid, partly unripened clay is present (catclay). The subsoil, consisting of old alluvial sediments has a low structure stability when wet.
Land suitability for large-scale irrigated rice varies from highly suitable for the non-saline soils, comprising roughly one third of the area via moderately saline with soils in roughly half of the area to marginally suitable. Salinity constraints and soil texture are the main limitations.
The criteria for the appraisal for large-scale irrigated rice are similar to those of a preceding investigation in an adjacent area. They are presented in Table 1.5.01 with conditions concerning irrigability, drainability and prevention of salinisation (Chapter 1.5.2).
Each soil mapping unit is appraised separately and the results are given in Table 1.5.04. Figure 1.5.01 illustrates the spatial extent of areas with its land suitability class for large-scale irrigated rice. The land suitability map (MAP 1.02) gives more detailed information. The results are summarised as follows.

Land suitability for large-scale irrigated rice

Suitability class	Description of class	Limitations	Area (ha)
1	highly suitable	none to minor	6,470
2	moderately suitable	slight to moderate	1,750
3	marginally suitable	moderate to severe	1,125
NS	unsuitable	-	990

1.1 INTRODUCTION

1.1.1 General

The Tana Delta area is usually flooded twice a year, in May/June and November/December. During these times the perennial Tana river overflows the levees or breaks through its banks. Lower lying basin lands are inundated to depths of one metre or more. Crops, including rice planted with the receding flood, are grown along the riverbanks. In total, less than one percent of the area of the floodplain is cultivated. A great deal of the water is not utilised. In view of the great need for areas that can supply large amounts of food for the increasing number of people in Kenya, the Tana Delta area is likely to be of much interest for rice production.

The Tana and Athi River Development Authority (TARDA) felt the need of an inventory of the soil resources in the Tana Delta area and requested a soil survey within the framework of the feasibility study of the Tana Delta Irrigation Project.

After a reconnaissance soil survey in the first phase of the project (Chapter 1.4.1) a semi-detailed soil survey was carried out in an area of approximately 11,000 ha. This area was selected on the basis of data collected during the reconnaissance survey. The southern boundary of this area was rather arbitrary. The total area of soils suitable for large-scale irrigated rice could easily be extended in a southern direction (Haskoning and Mwenge IAL, 1982). In September and October 1982 a soil survey team from the Soil Survey Institute of the Netherlands carried out the field work for the semi-detailed survey in a so-called "extension-area" of approximately 10,000 ha.

1.1.2 Terms of Reference

The consultants' proposal for the semi-detailed soil survey in the "extension area" was considered to follow the general norms and practices for such a survey (Siderius, W. 1980). The semi-detailed survey was to be carried out using a map scale of 1 : 25 000. The inspection density would be one observation per 15-20 hectares. Augering was to be done down to 200 cm and samples taken at five depths (20, 40, 70, 110 and 160 cm depth) for determination of pH and electrical conductivity (EC) in a 1 : 2.5 (soil: water v/v) suspension. Representative profile pits in major soil mapping units were to be dug to a depth of 2 metres and augered up to 5 metres, soil conditions permitting. Soil samples were to be taken from the representative pits and submitted to the National Agricultural Laboratories (NAL) for analysis. Permeability tests and infiltration tests were to be carried out at approximately 10 selected sites. Subsoil investigations were to be carried out up to 5 metres, if soil conditions would allow, with a density of 1 out of 20 soil survey observations. Soil profile pits with augering up to 5 metres were included in these subsoil investigations to approach this density. After completion of the survey all original field notes were to be submitted to Kenya Soil Survey (KSS).

1.1.3 Survey objectives

The objective of the semi-detailed soil survey was to collect and evaluate data on the soil conditions of the 10,000 ha and to determine the suitability for large-scale irrigated rice. The investigations resulted in a soil map and a land suitability map for large-scale irrigated rice. This report gives the information on the physical environment, methods applied and comprehensive descriptions of the soil mapping units, including physical and chemical characterization. It furthermore gives a short account of procedures and physical criteria used in the land classification.

1.2 LOCATION, GEOLOGY, HYDROLOGY AND GENERAL LAND FEATURES

1.2.1 Location and communications

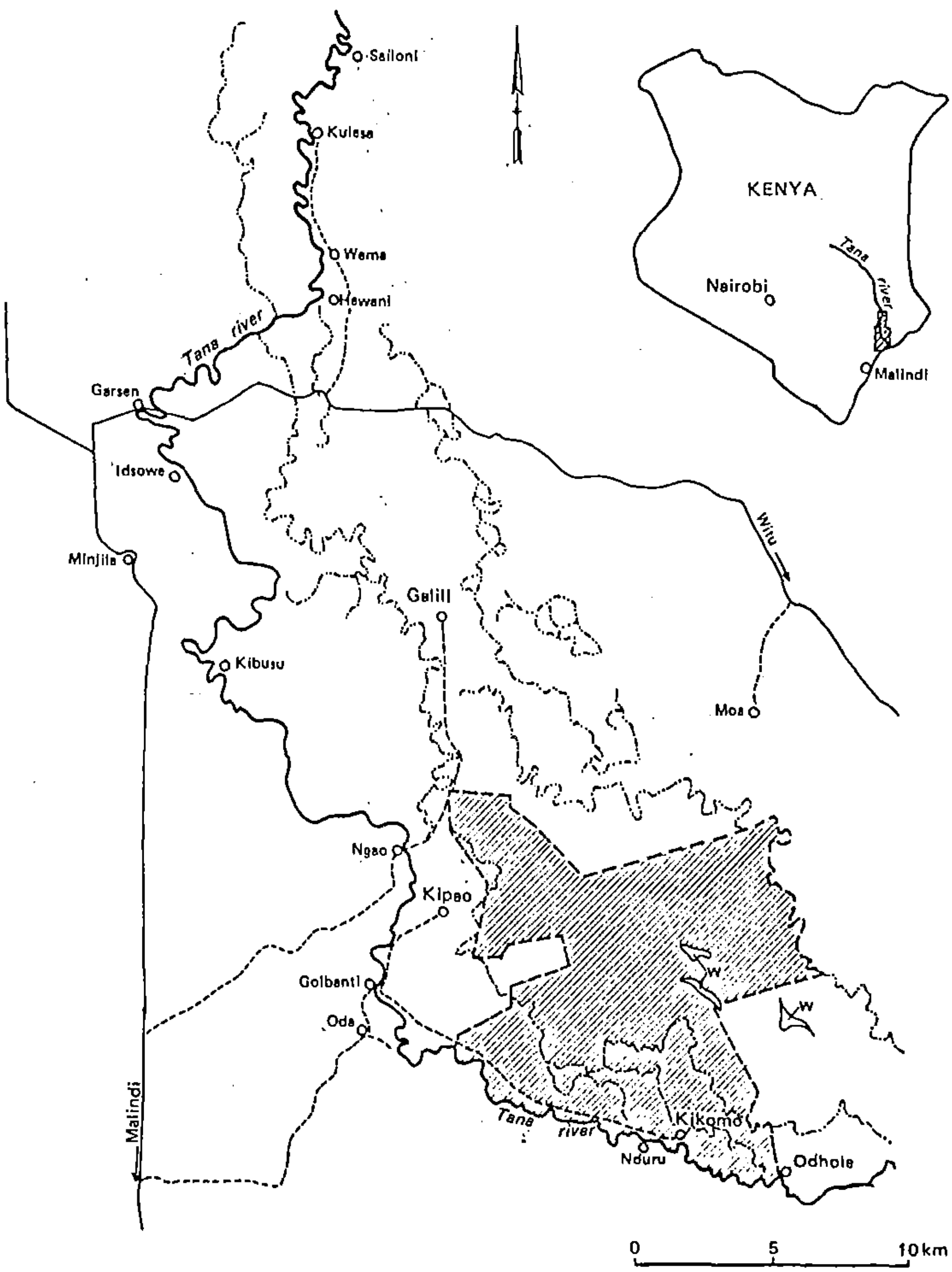
The project area is situated in the southern part of the Tana River District in Coast Province. It lies between latitude 2° 23'S and 2° 30'S, and longitude 40° 11'E and 40° 20'E.
The location of the project area is indicated in Figure 1.2.01. The area extends roughly from the Ngao irrigation scheme, north-west, to Odhole village, south-west. The Tana river is the southern boundary. The eastern boundary coincides partly with the Abarfarida, the other part does not coincide with a land feature, but is artifically drawn. The northern boundary follows very roughly a west-east line from Ngao irrigation scheme to the Abarfarida, south of Moa. The western boundary is irregular.

The total acreage of the area (including villages and swamps) is 10,400 ha. Villages occur on the Tana river bank; from west to east Handarako, Kikomo, Arithi and Odhole. These are Orma villages which are permanently inhabited. Temporary settlements occur on higher lying areas in the vast floodplain, often located near a former river course or on a small ridge. Orma men with their cattle stay here during the dry season. They also come from villages far away from the project area. One large Orma village, Kipao, should be mentioned, because the project area is grazing area for them (Fig. 1.2.04). Tracks which connect the villages are mainly footpaths. They are usually concentrated on the higher lying areas (levee land) near the Tana river or its former courses. The north-eastern part has no regular track. Between the villages of Handarako and Odhole there is arable land on the Tana river bank. People from the Pokomo villages on the south bank of the Tana river cultivate these areas.

1.2.2 Geology, hydrology and general land features

In geological reports (Matheson, 1961; Williams, 1962) the delta area of the Tana river is mapped as "recent alluvium with bands of older sand and clay ridges". The bands of older sand and clay ridges, deposited during various oceanic phases (Tertiair, Holocene) and becoming progressively younger towards the coast, border the recent alluvial floodplain. The project area is located in this alluvial plain and the sediments originate from the Tana river and from deposits of marine material in an estuarine environment. The physiography of the Tana delta is presented in Fig. 1.2.02.
The marine sediments occur in the eastern to south-eastern part of the area and are connected with those in the vast estuarine area, which has its inlet near the recent outlet of the Tana river. The deposition dates long before the sediments of the Tana river were transported to this area. The notation "subrecent" in the legend of the soil map deals with this aspect. Most marine sediments in the area are covered by fluvial sediments (Fig. 1.4.04), though vast areas are distinguished in which soils lack the clear presence of fluvial material. Particularly in the areas of the last mentioned soils the morphology of the gullies and connected land features indicate the former estuarine environment.

Vegetation in these areas is restricted to mainly grasses (Echinochloa spp.). On relatively high-lying areas acacia bush is present. In the western part the presence of fluvial sediments is supported by the landscape features of a fluviatile area; levee land and basin land. The levees are the ridges or banks which accompany the actual Tana river and the former river courses. They range from fifty to several hundred metres wide and are 0.5 to roughly one metre higher than the basin land (back-swamps). Locally, levees are silted up with basin clay and levee material is only found in the subsoil. The relative elevation of the soils of the levees and the better drainage conditions enable trees to grow. At many places the former river courses are characterized by riparian forest (Fig. 1.2.03). Besides the trees the vegetation in levee land consists of grasses (Cynodon Dactylon, Digitaria spp. and Echinochloa spp.) and shrubs (mainly acacia spp.). The basin land is characterized by its low-lying situation between the surrounding levees. An example of this situation can be found on the soil map in the area north of Handarako. Vegetation in basin land is limited to grasses (Echinochloa spp., Oryza longistaminata, Cynodon spp. and Digitaria spp.) and sedges (Cyperaceae). Small ridges (levees) of approximately fifty metres wide occur in river basin land. They are indicated on the soil map with a special feature. Their location in the field often coincides with a vegetation of acacia trees and palmtrees (mainly Doumpalms).



KEY

main road — track — Tana river — former river course — surveyed area — lake or swamp (W)

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fig: 1.2.01

title: LOCATION OF THE AREA OF THE SEMI – DETAILED SOIL SURVEY

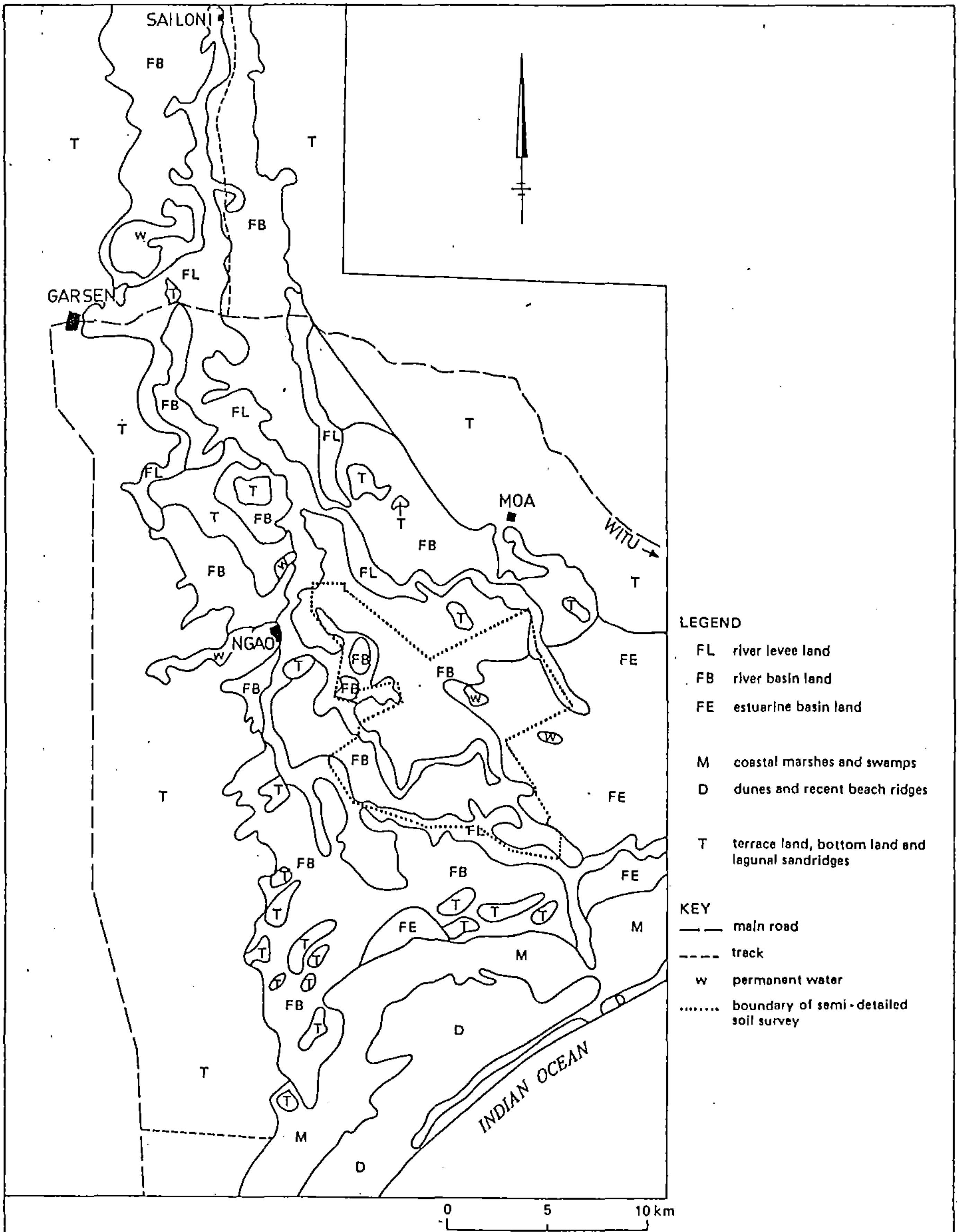

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Fig. 1.2.03 Riparian forest along a former river course

Fig. 1.2.04 Cattle track in the vicinity of Kipao

1.3 METHODS OF INVESTIGATION

1.3.1 Office methods

Reports and maps of the reconnaissance survey of the Tana Delta (Haskoning and Mwenge IAL, 1981) and of the semi-detailed survey of an area of 10,000 ha in the Tana Delta (Haskoning and Mwenge IAL, 1982) were the main source of information about soils in the project area. All data collected for that survey were used if relevant. Prior to the fieldwork, aerial photographs, scale 1 : 25,000 (Gauff, 1982) were studied and an uncontrolled photo-mosaic was composed for the preparation of the soil map. During the actual fieldwork all locations of observations and boundaries, as seen in the field and indicated on a field aerial photographical map, were transferred to this photo mosaic. A stereoscopic study of the aerial photographs was carried out periodically to support the fieldwork and to adjust the soil boundaries on the photo-mosaic. After completion of the fieldwork a draft base map was prepared, making use of the new topographic map, scale 1 : 25,000, of the project area in the Tana Delta. More specified information was outlined on this topographic map like former deep and shallow river courses and other drainage ways. The data of the soil salinity and soil acidity were incorporated in a draft soil map. Then the final soil boundaries and symbols were transferred to the revised topographic map, scale 1 : 25,000. This resulted in a final soil map, which was used to outline the areas of different suitability for large-scale irrigated rice. A map, indicating for each observation the soil salinity and the salinity of groundwater, if present within 2 metres depth, was prepared. The soil salinity is based on the electrical conductivity data of suspended soil samples from five different depths of each augerhole (see chapter 1.4.6.2). Salinity of the groundwater is presented in mS/cm (electrical conductivity) and concerns the real measured value.

1.3.2 Field methods

The actual fieldwork was carried out in September and the first week of October, 1982. The fieldwork was executed from a tented camp, stationed at Tarasaa 8 km from Ngao. The field office and the field laboratory could be set up in a nearby wooden house. The Tana river had to be crossed by boat at Ngao to reach the survey area. Cars (4WD) were stationed opposite Ngao on the eastern bank of the Tana river. The investigations were carried out by several teams, viz. soil survey, field physical tests and laboratory. Fieldwork comprised routine augering by hand to a depth of 200 cm at intervals of 300 to 400 metres in a pattern, mainly conditioned by the accessibility of the area. One out of approximately 30 augerings was augered up to a depth of five metres, soil conditions permitting. At the start of the survey the lower basin areas were still inundated and not accessible by car. Therefore, this area was surveyed after the water had either evaporated or drained away. Some parts nevertheless remained inundated and had to be surveyed on foot. Some gullies that could not be crossed by car, also necessitated such a survey.

At each augerhole soil samples were taken at specific depths, viz. 20, 40, 70, 110 and 160 cm, for screening tests in the field laboratory at Tarasaa (pH, EC and degree of dispersion).

If groundwater was encountered within a depth of 200 cm, a water sample was taken for tests in the field laboratory.

Representative sites were selected in major soil units and 150-200 cm deep profile pits were dug. The pits were subsequently augered up to a depth of five metres, soil conditions permitting. These pits were described and sampled for later chemical analysis at the National Agricultural Laboratories. Composite samples of the topsoil (usually 0-20 cm) were taken for fertility evaluation.

Land and soil properties were recorded on standard soil augerhole and soil profile pit description forms, following the standards applied by the Kenya Soil Survey which are based on the "Guidelines for soil profile description (FAO, 1977). A total of 570 augerings were made and described. Approximately 20 augerings occur just outside the boundary of the surveyed area. This was due to a revised outlining of the area to be surveyed, during fieldwork, and for correlation purposes with the semi-detailed soil map of the preceding soil survey (Haskoning and Mwenge IAL, 1982). Furthermore, data of 12 profile pits were collected. Infiltration tests and hydraulic conductivity tests were carried out at the selected sites for the major soil units where profile pits were dug. The sites were selected in locations where the soil was very moist nearby. Infiltration and hydraulic conductivity tests were thus carried out under moist to wet conditions of the soil and the results must be considered in this respect. The hydraulic conductivity tests were carried out on the layers at a depth of 50-150 cm. The methods applied, are described in Chapter 1.4.7.

Field laboratory

In the field laboratory at Tarasaa the electrical conductivity (EC) and pH of approximately 3,000 samples from augerings and profile pits were determined in a 1 : 2.5 (soil:water) suspension. These samples were taken at 20, 40, 70, 110 and 160 cm depths as a routine. Additional sampling of the profile pits occurred according to the described soil horizons. The 1 : 2.5 suspensions were prepared in standard size, small tubes with two marks, one at 2½ volume level and another one at 3½ volume level. The tubes were filled with deionized water up to the first mark giving 2½ volume water. In the field, crushed soil aggregates were added until the level of the suspension reached the 3½ mark, thus resulting in a soil : water ratio of 1 : 2.5 (volume/volume). The samples were thoroughly shaken after one day field survey. After standing overnight in the field laboratory, EC and pH were measured in the clear solution above the suspended soil. The degree of suspension was determined by measuring the height of the suspension in the tube. If no clear solution was available, another 2½ volume deionized water was added, the suspension shaken and set aside for one day to settle. The soil aggregates added to the deionized water in the field were usually moist with very little or no air enclosed. The degree of moistness (dry, moist and wet) was noted on the soil augerhole description form. A few experiments were carried out to determine the average moisture percentage of the material in the field, of the 1 : 2.5 v/v samples and of the saturated soil pastes. This resulted in a conversion factor for the electrical conductivity values (see Chapter 1.4.6.2).

1.3.3 Laboratory methods

57 soil samples and 10 fertility samples were taken from 11 representative profile pits and delivered to the National Agricultural Laboratories (NAL), Nairobi. NAL employs the following methods:

Sample preparation	: Breaking up of aggregates by careful pounding with pestle and mortar; sieving through a 2 mm sieve. The fine earth fraction (less than 2 mm) is used for further analyses.
Texture (hydrometer)	: No chemical treatments to remove cementing agents, shaking overnight with sodium hexametaphosphate/sodium carbonate in an end-over-end shaker at 40 r.p.m. Measurements of silt + clay (0-50 μ) and clay (0-2 μ) with a hydrometer ASTM 152H after 40 seconds and 2 hours respectively. Sand fraction (50-200 μ) obtained by difference (Day, 1956).
pH-H_2O and EC	: pH and EC are routinely measured in suspensions with a soil : water ratio of 1 : 2.5. Suspensions are prepared by scooping up one volume of fine earth and adding it to 2½ volumes of water. For samples with an EC greater than 0.8 mmhos/ cm a saturation extract is prepared for additional pH and ECe determination. Upon request the soluble salts in the extract are also measured.
pH-KCl	: Measurement in a suspension with a 1 : 2.5 ratio of soil: 1N KCl.
$CaCO_3$	: Gravimetric determination of loss of carbon dioxide (Richards, 1954).
$CaSO_4$	: Determination of gypsum is based on the low solubility in an aqueous solution of acetone. The separated and washed gypsum precipitate is determined quantitatively using a reference graph showing the relationship between the concentration and electrical conductivity of gypsum solutions.
Carbon	: Walkley and Black method (Black, 1965 pp. 1372/ 6).
Cation exchange capacity	: CEC is determined by successive leachings of the soil with 1 N sodium acetate of pH 8.2, 95% ethyl alcohol and 1 N ammonium acetate of pH 7.0. Determination of Na in the last leachate by EEL flamephotometer.
Exchangeable cations	: Leaching of the soil with 1 N ammonium acetate of pH 7.0. Determination of Na, K and Ca by EEL flamephotometer, with addition of lanthanum chloride for the last element. Mg is determined with an atomic absorption spectrophotometer.

"Mass Analysis" for available nutrients (on composite top-soil samples)	: Extraction of the soil by shaking for one hour at a 1 : 5 ratio with 0.1 N HCl/0.025N H_2SO_4. Determination of Ca, K soil samples) and Na by EEl flamephotometer. Mg is determined colorimetrically with Thiazol yellow reagent (Mehlicht et al., 1962). Mn is also determined colorimetrically using phosphoric acid-potassium periodate for colour development (Mehlich et al., 1962). For P, the vanadomolybdophosphoric yellow method is followed.

At 17 locations groundwater was sampled and sent to NAL for analysis of EC, pH, Ca + Mg, Na, CO3 + HCO3, Cl and SO_4.

1.4 SOILS

1.4.1 Previous work

1.4.1.1 Site evaluation

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, scale 1 : 100,000, was prepared mainly on the basis of aerial photo interpretation and supported by a limited number of field observations. The areas of river basin land, comprising about 38,000 ha, were considered "moderately well suited" for irrigation. The soils were described as "deep, non-calcareous, heavy clay soils that are usually non-saline and non-alkaline". Fig. 1.2.02 shows the generalized and in some parts revised Physiography of the Tana delta, derived from the map of the site evaluation.

1.4.1.2 Reconnaissance soil survey

A reconnaissance soil survey was carried out in the Tana Delta (Netherlands Soil Survey Institute, 1981) to investigate in more detail the river basin land for the selection of areas feasible for the development of large-scale rice cultivation (Haskoning and Mwenge IAL, 1981). The total area for the reconnaissance survey extended over approximately 63,500 ha. Three major physiographic units were distinguished for the delta area Floodplains (41,500 ha), Terrace land (18,000 ha) and Former Beach Ridges (2,300 ha). As one of the aims of the project was gravity irrigation, Terrace land and Former Beach Ridges were considered unsuitable. The soils of the Floodplains have more potential for rice production. The Floodplains consist of soils developed on recent fluvial sediments in river basin land and river levee land and soils developed on subrecent marine sediments. The latter are found near the mouth of the Tana river and extend far land-inwards (estuarine basin land).

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 deficiencies in soil and land qualities. Soils consisting of fluviatile sediment over subrecent marine sediments (5,700 ha), also have low potential due to acidity and salinity constraints. As a result of the appraisal for large-scale irrigated rice a total area of 24,200 ha highly suitable soils was established. However, some of it consists of rather small patches. One large, continuous area was found north and south of the Garsen-Witu road, extending northwards to Wema and in a southerly direction to an east-west line approximately six kilometres south of Moa. South-east of this line, soils become saline at shallow depth. The other large area is situated east and north-east of Ngao. In view of its extent and accessibility it was recommended that the 10,000 ha for the envisaged project should be selected in the area north and south of the Garsen-Witu road.

1.4.1.3 Semi-detailed soil survey

The recommended area of 10,000 ha for the Tana Delta Irrigation Project (Chapter 1.4.1.2) was the object of a semi-detailed soil survey within the framework of the feasibility study (Haskoning and Mwenge IAL, 1982). The southern boundary of this area is rather arbitrary and not confined by physical features. It was suggested that a feasibility study should also be carried out for the area south of the recommended area. The suggestion was supported by the presence of highly suitable soils as found with the reconnaissance soil survey.

1.4.2 Soil classification

The soil classification 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. This major soil group is subdivided into two subgroups; eutric and vertic Fluvisols. The latter consists of strongly cracking ("vertic") clay. Saline and sodic phases are indicated when applicable. The soils developed on subrecent marine sediments are classified in the group of the Fluvisols. They occur in an area which is liable to flooding. The addition of fresh (Tana river) sediment is generally very small. Due to the "vertic" properties of the clay, one subgroup is distinguished, vertic Fluvisols. In places, soils are found with a thick black topsoil and which consist of cracking clay. These soils may be considered to belong to the group of the Vertisols (subgroup pellic Vertisols). Saline and sodic phases are indicated when applicable.

1.4.3 Legend of the semi-detailed soil map

1.4.3.1 General

All soil mapping units are grouped in one major physiographic unit, viz. FLOODPLAIN and subsequently divided according to the parent material on which they are formed. The soils developed on recent fluvial sediments have been grouped into: river levee land, including the crevasse splays (code L), and in river basin land (code B). The soils of the river levee land are subdivided predominantly on the basis of the variation in texture (major soil units L1, L2, L3 and L4). The soils of the river basin land are firstly divided on the basis of differences in sedimentation (Table 1.4.01; major soil unit) and subsequently according to differences in drainage conditions. The last feature coincides with the topographical position. The low-lying basin soils for instance, are poorly to very poorly drained. The relationship implies that the topographical position is reflected more or less in the description of the drainage conditions. The sub-division of a major soil unit results in soil units (Table 1.4.01; codes soil units).

Table 1.4.01 Soil units in river basin land and their codes

Major soil unit	Code soil units
deep river basin soils	B1, B2, B3
moderately deep river basin soils over levee sediments	BL1, BL2, BL3
moderately deep river basin soils over marine sediments	Bm1, Bm2, Bm3
shallow river basin soils over marine sediments	BM1, BM2, BM3

The landform for the soils developed on subrecent marine sediments is estuarine basin land. According to differences in sediments two units are distinguished; deep marine basin soils (M) and moderately deep marine soils over old alluvial sediments (MT). A subdivision on the basis of different drainage conditions is also made for these soils (addition 1, 2 and 3 to M and 1 to MT). Additional features are used to describe salinity conditions, relief, vegetation type and presence of extremely acid material. Salinity conditions are indicated, using a salinity profile classification (S0, S1, S2, S3 and S4), relief conditions are noted, according to relief classes (I and II), the vegetation type is mentioned only if bushland or forest was present (b, f) and information on acidity (soil reaction) is given with an addition to the code M or m, when applicable. The criteria and corresponding codes are explained in Chapter 1.4.3.2.

1.4.3.2 Differentiating criteria

Differentiating criteria, used in the legend and the descriptions of the mapping units and representative profiles are:

- Texture, structure and other characteristics e.g. concretions and consistence are described according to the "Guidelines for soil profile description" (FAO, 1977).
- Colour of the soils is described according to the Munsell Soil Colour Charts and the Japanese "Revised Standard Soil Colour Charts".
- Soil reaction. The following classes in soil reaction and the corresponding ranges are used:

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

- Soil salinity: The following salinity classes and corresponding rates are used: (see also Chapter 1.4.6.2).

Salinity class	ECe (mS/cm)	EC (1 : 2.5 v/v)* (mS/cm)
non-saline	<4	<2
slightly saline	4-8	2-4
moderately saline	8-16	4-8
strongly saline	>16	<8

* valid for moist material with a texture of clay and which does not contain gypsum crystals

- Salinity profile. The sequence of salinity in a soil profile, measured at specific depths is classified as follows:

Code	Salinity class at specific depth (cm below surface)		
	20	40/50	70/80
S0	non-saline	non-saline	non-saline
S1	non-saline	non-saline	slightly saline
S2	non-saline	non-saline	moderately saline
or	non-saline	slightly saline	slightly saline
S3	non-saline	slightly saline	moderately saline
S4	non-saline	moderately/ strongly saline	moderately/ strongly saline

* The code S0 is not indicated on the soil map

- Soil sodicity. The following sodicity classes and corresponding rates are used: (see also Chapter 1.4.6.3)

Sodicity class	ESP*
non-sodic	0- 5
slightly sodic	6-10
moderately sodic	11-15
strongly sodic	>15

* Due to the lack of sufficient ESP data of analysed samples the description of the soil sodicity is limited often to an indication of non-sodic or sodic for the soil from 0-100 cm depth.

- Infiltration rate. The following classes in infiltration rate and the corresponding rates (I-basic) are used: (see also Chapter 1.4.7.2)

Infiltration class	rates in cm/hr
very slow	<0.05
slow	0.05-0.4
moderately slow	0.4 -1
moderately rapid	1 -2
rapid	2 -4
very rapid	>4

- Hydraulic conductivity. The following hydraulic conductivity classes and corresponding rates are used: (see also Chapter 1.4.7.3)

Hydraulic conductivity class	Rates in cm/day
very slow	<3
slow	3-10
moderately slow	10-20
moderate	20-40
moderately rapid	40-80
rapid	80-160
very rapid	>160

- Relief class. The following relief classes on the basis of meso- and microrelief features are used:

Code	Description	
I	mesorelief :	predominantly flat; few shallow depressions
	microrelief:	smooth except for gilgai and sinkholes
II	mesorelief :	flat to very gently undulating; wide network of shallow depressions
	microrelief:	smooth except for gilgai, small (sedge-) tussocks and cowfoetoes

- Vegetation type. The following vegetation types are distinguished:

Code	Description
b	bushland; shrubs less than 6 m high, covering up to 40% of the area
f	forest; woody vegetation more than 6 m high, mainly riparian forest along former river courses

- Extremely acid soil material. The presence of extremely acid soil material, starting within a depth of one metre below surface or between one metre and 1.5 metre depth is based on the measurements of the pH-H_2O at specific depths. Extremely acid material has a pH-H_2O value of 4.5 or less

Depth classes of extremely acid material

Symbol on the map	pH-H_2O at a depth of		
	40/50	70/80	110/120 cm
M	>4.5	<4.5	<4.5
M or n	>4.5	>4.5	<4.5

1.4.4 Description of the soil mapping units

1.4.4.1 River levee land and crevasse splays

The soils of river levee land and crevasse splays (Chapter 1.2.2) consist in general of a complex of deep, usually stratified, and highly variable soils. Figure 1.4.0.1 shows such stratified soils along the Tana River Bank.

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 relatively high position in the area they are well drained to imperfectly drained.

Four physiographically recognizable units are distinguished. The most important unit (L1) consists of soils belonging to the meander-belt and its adjacent levees of the recent Tana river and its former courses. Related to this unit is unit L2: the soils of the crevasse splays. The deposits of this unit have a similar variable texture though in many parts heavy clay of the former basin is found in the subsoil. The third unit (L3) consists of soils of the natural levee, predominantly fine textured, but stratification with layers of fine sand occurs. Layers of fine sand are found, mainly in small ridges. Vegetation on these ridges is more developed. The fourth unit (L4) is comprised of soils on the levee of a former river course near Kikomo. These levee soils consist of clay throughout.

Soil unit L1

Soils of this unit occur in and along the meander-belt of the Tana river and its former courses, mainly in the southern part of the area

Extent	: 925 ha
Topography	: flat to gently undulating, moderately high, in places high lying; in places very irregular due to the presence of abandoned river courses
Vegetation	: grassland, bushed grassland, woodland and patches of riparian forests
Land use	: open grazing, wild life
Drainage conditions	: well drained to imperfectly drained; not flooded or shallow flooded for short periods; groundwater level mainly deeper than 200 cm (Sept. '82)
Soils:	
general	: brown to yellowish brown, often stratified, sand to clay; rich in micas. The texture of the topsoil ranges from, in places, sand to usually clay, the subsoil is frequentl. a firm clay
calcareousness	: usually non-calcareous
soil reaction	: pH-H_2O (1 : 2.5 v/v) ranges from 6.5-8.0
salinity	: usually non-saline, in places strongly saline
sodicity	: non-sodic
infiltration	: infiltration ranges from rapid (sandy topsoil) to slow (topsoil with texture of clay)
hydraulic conductivity	: variable, from slow to rapid
Soil classification	: eutric and vertic FLUVISOLS, partly saline phase

Land suitability for large-scale irrigated rice:

Soil mapping unit*	Limitations		Land suitability	Extent
	main	minor		
L1 I SO	texture	-	NSz	225
L1 I SO b	texture, vegetation	-	NszT	240
L1 I SO f	texture, vegetation	-	NSzT	420
L1 I S2 b	texture, salinity	vegetation	NSzs	20
L1 I S2 f	texture, salinity, vegetation	-	NSzs(T)	10
L1 I S4 b	texture, salinity	-	Nszs	10

* The code SO is not indicated on the soil map

Representative profiles: profile description no. 1 (Appendix 1.1)

Soil unit L2

These are soils in the deposits of the break through a natural levee (crevasse splays). The deposits occur as fans or tongues of sand elongated away from the river. The size of the crevasse splays differs from one place to another. The village of Handarako e.g. is situated on these soils. Sinkholes are common features on these soils

Extent : 25 ha

Topography : slightly elevated levee, in places a gully (overflow channel) is still present

Vegetation : bushed grassland and grassland

Land use : habitation, open grazing

Drainage conditions : well drained to moderately well drained; usually no flooding; groundwater deeper than 200 cm (Sept.'82)

Soils:

general : complex of stratified sand and clay, rich in micas, over clay

calcareousness : non-calcareous

soil reaction : the pH-H_2O (1 : 2.5 v/v) ranges from 6.5 in the topsoil to 7.5 in the subsoil

salinity : on the basis of a few observations it appears that soils are non-saline from 0-100 cm

sodicity : non-sodic

Soil classification : eutric and vertic FLUVISOLS

Land suitability for large-scale irrigated rice:

Soil mapping unit*	Limitations		Land suitability	Extent
	main	minor		
L2 I SO	texture	-	NSz	5
L2 I SO b	texture, vegetation	-	NSzT	20

* The code SO is not indicated on the soil map

Soil unit L3

Soils of this unit occur in relatively high areas with an irregular pattern, corresponding with the presence of small ridges. Surface relief however is, on average, flat. The small ridges originate from the very small levees along shallow gullies which are predominantly silted up. The main ridges are indicated on the soil map.
The soils are predominantly fine textured and consist of heavy clay. In connection with small ridges inclusions of layers with micaceous fine sand occur. In places, sinkholes are present.

Extent : 400 ha

Topography : flat to very gently undulating

Vegetation : bushed grassland, bushland (mainly Acacia sp.) and riparian forest

Drainage conditions : moderately drained

Soils:

general : dark brown to brown, clay to clay loam, in places over stratified micaceous sand and clay. The presence of layers of sand is irregular

calcareousness : non-calcareous

soil reaction : pH-H_2O (1 : 2.5 v/v) varies from 6.5-8.0 (neutral to moderately alkaline)

salinity :
- soils that are non-saline to at least 100 cm have salinity profile S0
- salinity profile S4 is found in a small area where strongly saline material occurs at shallow depth

sodicity : predominantly non-sodic, in places sodic in subsoil

Soil classification : vertic FLUVISOLS, partly saline phase

Land suitability for large-scale irrigated rice:

Soil mapping unit*	Limitations		Land suitability	Extent
	main	minor		
L3 I S0 b	texture	vegetation	3Z(T)	360
L3 I S0 f	texture, vegetation	-	NSzT	30
L3 I S4 b	salinity	-	NSs	10

* The code S0 is not indicated on the soil map

Soil unit L4

The soils of this unit occur on the levees of a former river course in the vicinity of Kikomo and on the transition to the river basinland

Extent : 175 ha

Topography : predominantly flat

Vegetation : bushed grassland, bushland

Drainage conditions : open grazing

Soils:

general : dark brown to brown clay, over grayish brown clay

structure : the topsoil has a weak to moderate, coarse prismatic structure, breaking into weak, fine subangular and angular blocks. The subsoil has mainly moderate, medium angular blocks; medium to thick slickensides occur

calcareousness : non-calcareous

soil reaction : pH-H_2O (1 : 2.5 v/v) varies from 6.5-8.5 (neutral to moderately alkaline), near Kikomo in the subsoil slightly acid

salinity : predominantly non-saline to at least 100 cm (salinity profile S0), but in places (25 ha) non-saline from 0-50/80 cm over slightly saline (salinity profile S1). Deeper than approx. 100 cm usually moderately saline

sodicity : usually non-sodic (0-100 cm)

Soil classification : vertic FLUVISOLS, partly saline phase

Land suitability for large-scale irrigated rice:

Soil mapping unit*	Limitations		Land suitability	Extent
	main	minor		
L4 I S0	-	-	1	25
L4 I S0 b	vegetation	-	2T	110
L4 I S1 b	vegetation	-	2T	25
L4 II S0	topography	-	2t(z)	15

* The code S0 is not indicated on the soil map

1.4.4.2 Soils of the river basin land

These soils are subdivided according to differences in sedimentation (Table 1.4.01). They consist mainly of heavy to very heavy clay to at least 80/100 cm depth.

The soils have a strongly developed blocky or prismatic structure when the soil is dry. The blocky and/or prismatic structure is moderate to weak when the soil is moist to wet. Very often, polished and grooved surfaces ("slickensides") are present on the structure elements (Fig. 1.4.02).
Wide and deep cracks develop in the dry season. This feature and the presence of slickensides indicate the "vertic" characteristics of these soils. Soils have a high content of 2 : 1 lattice clays and hence a high cation exchange capacity. Base saturation is high.
Usually the soils are non-calcareous. In places $CaCO_3$ concretions occur in non-calcareous material. The pH is generally between 6.5 and 8.0.

In general the soils are non-saline in the top 80/100 cm. Deeper, salinity usually increases. Many areas with a non-saline subsoil occur in the western part of the project are.

The soils are usually non-sodic, but a sodic phase does occur. The exchangeable sodium increases with depth. This reflects the presence of saline groundwater and, in places, the presence of older alluvial deposits.

The physical characteristics of the river basin soils were measured in a moist condition of the soil. The basic infiltration ranges from 0.03 cm/hr in wet soils to more than 4 cm/hr in relatively dry soils. The median value is approximately 0.15 cm/hr. When saturated, these soils have a very slow infiltration rate.

The hydraulic conductivity, at 50-150 cm depth, ranges from 0.25 to 2.5 cm/day (median value of 0.35 cm/day). This slow hydraulic conductivity implies that it is very difficult to achieve proper drainage in these soils.

Deep river basin soils (B)

These soils consist of cracking ("vertic") clay of recent fluvial origin up to a depth of at least two metres. According to differences in drainage conditions three soil units are distinguished. Each soil unit is subdivided in several soil mapping units according to differences in relief, salinity profile and vegetation type.

Soil unit B1

These soils occur on the fringes of the levee land, mainly in the western part of the area and along the Tana River

Extent	: 1,585 ha
Topography	: flat, moderately high lying; weak gilgai
Vegetation	: grassland and bushed grassland; predominantly Acacia sp. and few palmtrees (doumpalms)
Land use	: extensive open grazing
Drainage conditions	: moderately well to imperfectly drained; shallow depth of floods, mainly less than 25 cm; groundwater level deeper than 2 metres (Sept. '82)
Soils:	
general	: these deep soils have a 10-20 cm thick topsoil of very dark gray clay overlying dark brown clay
structure	: the topsoil usually has a prismatic structure, breaking to fine angular and subangular blocky elements. Moderate, medium to coarse angular blocks are present in the subsoil to a depth of 100/150 cm. Usually slickensides are present
calcareousness	: usually non-calcareous, in places $CaCO_3$ concretions occur in a non-calcareous subsoil
soil reaction	: pH-H_2O (1 : 2.5 v/v) ranges from about 6.5-7.5 in the topsoil to 8.0 in the subsoil
salinity	: predominantly non-saline from 0-100 cm (salinity profile S0). The subsoil of the areas along the Tana river are also non-saline or slightly saline. A bushed area in the northern part of the central area and the adjacent non-bushed area have at 70/80 cm depth moderately saline material (salinity profile S2), that increases with depth in salinity to strongly saline, in places
sodicity	: usually non-sodic
Soil classification	: vertic FLUVISOLS, partly saline phase

Land suitability for large-scale irrigated rice:

Soil mapping unit*	Limitations		Land suitability	Extent
	main	minor		
B1 I S0	-	-	1	1320
B1 I S0 b	-	vegetation	2(T)	30
B1 I S0 f	vegetation	-	2T	5
B1 I S1	-	-	1	5
B1 I S1 b	-	vegetation	1(T)	5
B1 I S2	salinity	-	2s	160
B1 II S2 b	salinity	vegetation	2s(T)	60

* The code S0 is not indicated on the soil map

Soil unit B2

These soils occur in areas adjacent to the central parts of the river basin land with deep river basin soils

Extent	: 1,180 ha
Topography	: flat to very gently undulating because of depressions and shallow gullies; moderately low lying; weak gilgai microrelief
Vegetation	: grassland (grasses and, in places, sedges) or bushed grassland (Acacia sp.)
Land use	: extensive open grazing
Drainage conditions	: mainly imperfectly drained, locally poorly drained; depth of floods 20/40-60 cm; groundwater level deeper than two metres (Sept. '82)
Soils:	
general	: 10-20 cm thick topsoil of very dark gray clay, in places black, humic clay, over dark grayish brown, cracking clay
structure	: the topsoil has weak to moderate, very fine to fine subangular blocky structure. To approximately 50 cm depth there is a coarse prismatic structure, breaking into fine to medium subangular blocky elements. From 50 to 100/150 cm depth medium to coarse blocky elements, mainly because of the presence of medium to thick slickensides
calcareousness	: usually non-calcareous, in places CaCO3 concretions in non-calcareous material
soil reaction	: pH-H_2O (1 : 2.5 v/v) ranges from 6.0 to 7.0 in the topsoil and from 6.5 to 7.5 in the subsoil
salinity	: the soils are non-saline to 40/50 cm depth. The area in the north-eastern part of the surveyed area is slightly saline at 70/80 cm depth or moderately saline. In this area salinity increases with depth. Elsewhere the soils are non-saline at 70/80 cm depth and usually non-saline or slightly saline at greater depth (salinity profile S0)
sodicity	: usually the soils are non-sodic when the clay in the top metre is non-saline.
infiltration	: very slow when wet
hydraulic conductivity	: very slow

Soil classification : vertic FLUVISOLS, partly saline phase

Land suitability for large-scale irrigated rice:

Soil mapping unit*	Limitations		Land suitability	Extent
	main	minor		
B2 I S0	-	-	1	440
B2 I S1	-	-	1	10
B2 II S0	-	topography	1(t)	415
B2 II S1	-	topography	1(t)	200
B2 II S2	salinity	topography	2s(t)	115

* The code S0 is not indicated on the soil map

Soil unit B3

Soils of this unit occur in the central parts of the basins and in depressions

Extent	: 935 ha
Topography	: predominantly flat to very gently undulating mesorelief with a wide network of shallow depressions and gullies (relief classes I and II). Microrelief varies, but is usually uneven due to grasses and sedges on tussocks, cowfoetoes, elephant prints and weak gilgai
Vegetation	: grassland (grasses and sedges)
Land use	: extensive open grazing and wildlife grazing
Drainage conditions	: poorly drained, in places very poorly drained; the depth of the seasonal flood varies from 60 cm to more than 120 cm

Soils:

general	: a 10-20 cm thick topsoil of very dark gray, in places black, humic to peaty clay overlies dark gray, cracking clay. The latter changes with depth into dark grayish brown, cracking clay
structure	: the topsoil has a very fine to fine subangular blocky structure. The subsoil has a prismatic macrostructure breaking into angular blocks or has an angular blocky structure throughout. Size of the blocks varies from fine to coarse. The coarse angular blocky structure usaully occurs at greater depth and coincides with the presence of common to abundant slickensides. Usually slickensides start at a depth of 20 to 60 cm below the surface and extend to greater depth
calcareousness	: usually non-calcareous throughout
soil reaction	: pH-H_2O (1 : 2.5 v/v) varies from 6.0 to 7.0 in the topsoil and from 6.5 to 8.0 in the subsoil
salinity	: predominantly non-saline from 0 to 100 cm (salinity profile S0). Deeper than 100 cm generally non-saline or slightly saline, in places moderately saline
sodicity	: usually non-sodic in the top metre. The amount of sodium increases considerably in soil layers that are slightly to moderately saline
infiltration	: these soils have a very slow to slow infiltration. The median of the basic infiltration rate in relatively wet soils is 0.14 cm/hr (not adjusted for evaporation losses during measurement)
hydraulic conductivity	: very slow when wet; 0.15-0.50 cm/day (at 60-145 cm depth) for 5 sites on relatively wet soils

Soil classification : vertic FLUVISOLS

Land suitability for large-scale irrigated rice:

Soil mapping unit*	Limitations		Land suitability	Extent
	main	minor		
B3 I SO	-	-	1	305
B3 II SO	-	topography	1(t)	630

* The code SO is not indicated on the soil map

Representative profiles: profile descriptions nos. 2, 3 and 4 (Appendix 1.1)

Moderately deep river basin soils over levee sediments (BL)

These soils consist of cracking ("vertic") clay to a depth of at least one metre, over soil material of variable texture. The subsoil layers originate from sedimentation in the meander- belt of a former Tana river course.

Texture of the subsoil ranges from micaceous fine sand to sandy clay. The subsoil may be calcareous and stratified.

The basin clay in the top metre does not differ from the clay in the top metre of the adjacent deep river basin soils (soil unit B). The subdivision of these soils according to drainage conditions, topography, salinity and vegetation is done as for deep river basin soils. A large similarity exists but for the subsoil and the presence of hardly visible silted up former river courses.

Three soil units are distinguished.

Soil unit BL1

These soils occur in the south-western part of the area, close to the Tana river. They are connected with an area of levee soils

Extent : 75 ha

Topography : flat to very gently undulating mesorelief; shallow depressions and remnants of former river courses that largely have been silted up

Vegetation : bushed grassland (mainly Acacia spec.)

Land use : open grazing and wildlife grazing

Drainage conditions : moderately well to imperfectly drained; the depth of the seasonal flood is generally less than 25 cm

Soils:

general : 10-20 cm very dark gray clay over dark brown, cracking clay. Deeper than 100 cm the heavy, fluvial clay changes into micaceous, usually stratified soil material with a texture of sand to clay

structure : similar to soil unit B1 except for the "levee" subsoil which has an angular blocky structure when the texture is clay, but has a single grain structure when sand prevails

calcareousness : usually non-calcareous, in phases slightly calcareous subsoil or $CaCO_3$-concretions in a non-calcareous matrix

soil reaction : pH-H_2O (1 : 2.5 v/v) varies from 6.5-7.5 in the topsoil and from 7.0-8.0 in the subsoil

salinity : non-saline, also deeper than one metre (salinity profile SO)

sodicity : non-sodic

infiltration : very slow when wet; measured value high due to cracks

hydraulic conductivity : rapid in stratified, sandy subsoil

Soil classification : vertic FLUVISOLS

Land suitability for large-scale irrigated rice:

Soil mapping unit*	Limitations		Land suitability	Extent
	main	minor		
BL 1 I SO	-	subsoil	1(z)	5
BL 1 I SO b	-	subsoil, vegetation	2(zT)	10
BL1 II SO	topography	subsoil	2t(z)	60

* The code SO is not indicated on the soil map

Representative profiles: profile description no. 5

Soil unit BL2

These soils are found north-east of the Ngao irrigation scheme on both sides of a former, silted up river course

Extent	: 50 ha
Topography	: flat, except for the former river course
Vegetation	: grassland (grasses and reeds)
Land use	: open grazing
Drainage conditions	: imperfectly drained, in places poorly drained; depth of the floods varies from 30/40-60 cm

Soils:

general	: 10-20 cm very dark gray, in places black, humic clay over dark grayish brown, cracking clay. Deeper than 100 cm the basin clay changes into micaceous, usually stratified soil material with a texture of sand to clay
structure	: the topsoil has a moderate, very fine subangular blocky structure, changing into a coarse prismatic structure breaking to moderate fine to very fine angular blocks. Slickensides are usually present. The "levee" subsoil material has little or no structure
calcareousness	: non-calcareous
soil reaction	: pH-H_2O (1 : 2.5 v/v) ranges from 6.5-7.5 throughout
salinity	: non-saline throughout
sodicity	: non-sodic
infiltration/ hydraulic conductivity	: not measured but probably slow when wet

Soil classification : vertic FLUVISOLS

Land suitability for large-scale irrigated rice:

Soil mapping unit*	Limitations		Land suitability	Extent
	main	minor		
BL2 I SO	-	subsoil	1(z)	50

* The code SO is not indicated on the soil map

Soil unit BL3

Soils of this unit occur in the relatively lowest parts of a silted up meanderbelt area of a former river coarse. More than 100 cm river basin clay overlies micaceous, stratified "levee" material with a texture of sand to clay. These soils are largely similar to soil unit B3 of the deep river basin soils

Extent : 20 ha

Topography : flat to very gently undulating mesorelief; flat microrelief

Vegetation : grassland

Land use : extensive open grazing

Drainage conditions : poorly drained; depth of seasonal floods 40-60 cm

Soils:

general : 10-20 cm very dark gray, in places black, humic to peaty clay over dark gray to grayish brown, cracking clay, deeper than 100 cm changing into micareous, usually stratified, sand to clay

structure : similar to soil unit B3 except for the "levee" subsoil which has angular blocky structure when texture is clay but is single grain when sand prevails

calcareousness : non-calcareous

soil reaction : pH-H_2O (1 : 2.5 %) varies from 6.5 to 7.5

salinity : non-saline throughout in the top metre

sodicity : non-sodic

Soil classification : vertic FLUVISOLS

Land suitability for large-scale irrigated rice:

Soil mapping unit*	Limitations		Land suitability	Extent
	main	minor		
BL3 I SO	-	subsoil	1(z)	5
BL3 II SO	topography	subsoil	2t(z)	15

* The code SO is not indicated on the soil map

Representative profiles: profile description no. 6 (Appendix 1.1)

Moderately deep river basin soils over marine sediments (Bm)

Before the sedimentation of fluvial (basin) clay from the Tana river floods an estuarine environment with marine sediments was present. Adjacent to the river basin land with deep river basin soils, the moderately deep river basin soils are distinguished, having more than one metre fluvial clay, deposited on the marine sediments.

The soils consist of cracking ("vertic"), fluvial clay to a depth of at least one metre, over clay of marine origin. The transition of the fluvial clay to the marine clay is marked by a dark gray horizon, the so-called buried topsoil of the marine sediments.

Soils are non-calcareous throughout. The soil reaction in the top metre is neutral to moderately alkaline. The marine sediments in the subsoil are usually slightly acid and contain small to large gypsum crystals. In the lower part of the horizon with gypsum crystals, red and yellow mottles are present in places. Deeper, only yellow mottles occur and soil reaction decreases to values of pH 4.5 or even less.

Soil unit Bm1

These soils occur adjacent to a former river course, north of Kikomo, which enters the estuarine area and adjacent to the Abarfarida, a former river course in the north-eastern part of the area

Extent	: 655 ha
Topography	: flat to very gently undulating mesorelief. Small ridges are present; usually 20 to 40 metres wide and with the highest parts 0.5 to 1 m above the average level of the adjacent flat area. They are indicated on the soil map. Moderately gilgai microrelief
Vegetation	: grassland and bushed grassland. Small areas are bushland or forest
Land use	: extensive open grazing
Drainage conditions	: moderately well to imperfectly drained; the depth of the seasonal floods varies from 10-30 cm
Soils:	
general	: 10-20 cm very dark gray clay over dark brown, cracking, fluvial clay, deeper than 80/100 cm changing into dark gray, marine clay with gypsum crystals in varied size and amount
structure	: the topsoil usually has a prismatic structure, breaking into fine angular and subangular blocks. Moderately developed, medium to coarse angular blocks are present below to a depth of 100 to 150 cm. Slickensides, polished and grooved surfaces, produced by one soil mass sliding past another are common features, in particular in the fluvial top soil and to a lesser extent in the marine subsoil.
calcareousness	: non-calcareous
soil reaction	: pH-H_2O (1 : 2.5 v/v) varies from 6.5-7.5 in the fluvial topsoil and decreases to values less than 6.5 in the subsoil. In places the pH-H_2O is less than 4.5 in the subsoil (deeper than 100 cm). This is indicated on the soil map by underlining the m of the soil mapping code
salinity	: half of the area is non-saline in the top metre (salinity profile S0). The bulk of these non-saline soils are also non-saline in the subsoil. The soils with salinity profile S2 are non-saline from 0-40/50 cm depth, but deeper moderately saline

sodicity : soils with salinity profile S0 are non-sodic and soils with salinity profiles S2 and S3 have exchangeable sodium percentages of more than 6 within 100 cm depth and are classified as sodic

infiltration/ hydraulic conductivity : not measured but probably slow to very slow when wet

Soil classification : vertic FLUVISOLS, partly saline-sodic phase

Land suitability for large-scale irrigated rice:

Soil mapping unit*	Limitations		Land suitability	Extent
	main	minor		
Bm1 I S0	-	-	1	130
Bm1 I S0 b	_	vegetation	1(T)	55
Bm1 I S2	salinity	-	2s	230
Bm1 I S2 f	salinity, vegetation	-	3sT	35
Bm1 I S3	salinity	-	3s	45
Bm1 I S3 b	salinity	vegetation	3s(T)	10
Bm1 I S3 b	salinity	vegetation	3s(T)	20
Bm1 II S0	-	topography	1(t)	130

* The code S0 is not indicated on the soil map

Soil unit Bm2

These soils occur north and east of Kikomo in an intermediate situation between the lowest parts of the basins and the higher areas along the former river courses

Extent	: 620 ha
Topography	: flat to very gently undulating mesorelief, small ridges are present; usually 20-40 metres wide and approximately 50-100 cm above the surroundings. Those ridges, with a gully in their centre, are indicated on the soil map. Weak gilgai microrelief
Vegetation	: grasses and in places, sedges
Land use	: extensive open grazing
Drainage conditions	: imperfectly drained, in places poorly drained. Depth of seasonal floods: 20-50 cm
Soils:	
general	: 10-20 cm very dark gray, in places black, humic clay over dark grayish brown, cracking, fluvial clay; deeper than 80/100 cm changing into dark gray, marine clay with gypsum crystals in varied size and amount
structure	: the topsoil has a moderate, fine subangular blocky structure. A weak, coarse prismatic structure is present from 20-60 cm, breaking into fine to medium subangular and angular blocks. Deeper than 60 cm medium to coarse blocks are present, mainly because of the presence of slickensides
calcareousness	: non-calcareous
soil reaction	: pH-H_2O (1 : 2.5 v/v) ranges from 6.5-7.5. Deeper than 80/100 cm 5.6-6.5. In a small area the pH-H_2O drops to less than 4.5 at this depth. This is indicated on the soil map with an underlined m in the code of the mapping unit
salinity	: except for the small area with an extremely acid subsoil, these soils are non-saline in the top metre
sodicity	: predominantly non-sodic
infiltration/ hydraulic conductivity	: not measured, but probably slow to very slow

Soil classification : vertic FLUVISOLS, partly saline phase

Land suitability for large-scale irrigated rice:

Soil mapping unit*	Limitations		Land suitability	Extent
	main	minor		
Bm2 I S0	-	-	1	345
Bm2 I S2	salinity	-	2s	35
Bm2 II S0	-	topography	1(t)	240

* The code S0 is not indicated on the soil map

Soil unit Bm3

Soils of this unit occur in the central parts of the basins and depressions

Extent : 915 ha

Topography : similar to soil unit B3

Vegetation : similar to soil unit B3

Land use : similar to soil unit B3

Drainage conditions : similar to soil unit B3

Soils:

general : 10-20 cm very dark gray, in places black, humic to peaty clay over dark grayish brown, cracking, fluvial clay, deeper than 80/100 cm changing into dark gray, marine clay with gypsum crystals in varied size and amount

structure : see soil unit B3

calcareousness : non-calcareous

soil reaction : pH-H_2O (1 : 2.5 v/v) varies from 6.5 to 7.5 from 0-80/100 cm depth. Deeper than 80/100 cm pH-H_2O is less than 6.5

salinity : predominantly non-saline in the top metre (salinity profile S0). In the area close to the Abarfarida slightly saline at 70/80 cm depth and usually moderately saline at greater depth (salinity profile S1)

sodicity : predominantly non-sodic

infiltration : very slow

Soil classification : vertic FLUVISOLS, partly saline phase

Land suitability for large-scale irrigated rice:

Soil mapping unit*	Limitations		Land suitability	Extent
	main	minor		
Bm3 I S0	-	-	1	670
Bm3 II S0	-	topography	1(t)	30
Bm3 II S1	-	topography	1(t)	180
Bm3 II S2	salinity	topography	2s(t)	35

* The code S0 is not indicated on the soil map

Representative profiles: profile descriptions nos. 7, 8, 9, 10 (Appendix 1.1)

Shallow river basin soils over marine sediments (BM)

These soils occur in areas with decreasing features of fluvial sedimentation over marine sediments in former estuarine land. Shallow river basin soils have less than 80/100 cm fluvial clay over marine clay. They consist of cracking ("vertic") clay to a certain depth. The transition of the fluvial clay to the marine clay is marked, as in soils of unit Bm, by a dark gray horizon of 10-40 cm thickness, the so-called buried topsoil of the soil on marine sediments. Layers with gypsum crystals occur in the marine sediments at a depth of roughly 90-160 cm below the surface. Most soils are soft at a greater depth than 100 cm. This consistence of the clay is described as "partly unripened". In the lower part of the horizon with gypsum crystals red and yellow mottles are usually present. They represent the former presence of jarosite (cat-clay). At greater depth only yellow mottles with a brighter colour are present. Soil reaction shows pH-H_2O values of less than 4.5, in some places even less than 3.5.

Soil unit BM1

These soils occur north of Kikomo, on the eastern side of a former river course, extending into the nearly estuarine basin land. The total extent of these soils is only 30 ha. As these soils are largely comparable to the soils of soil unit Bm1, one is referred to the description of that soil unit except for:

- salinity; soil unit BM1 has salinity profile S2 and S3. This implies saline material at rather shallow depth

Soil classification : vertic FLUVISOLS, saline-sodic phase

Land suitability for large-scale irrigated rice:

Soil mapping unit*	Limitations		Land suitability	Extent
	main	minor		
BM1 I S2	salinity	-	2s	5
BM1 I S3 b	salinity	vegetation	3s(T)	20
BM1 I S3	salinity	-	3s	5

* The code SO is not indicated on the soil map

Soil unit BM2

These soils occur in areas near the low lying central parts of the estuarine basin land and the higher lying areas along the former river courses

Extent	: 230 ha
Topography	: flat to very gently undulating; some small ridges occur as described in soil unit BM2. Weak gilgai microrelief
Vegetation	: grasses
Land use	: extensive open grazing
Drainage conditions	: mainly imperfectly drained, in places poorly drained; flooding to a depth of 20-60 cm
Soils:	
general	: 10-20 cm very dark gray, in places black, humic clay over dark grayish brown, cracking, fluvial clay less than 80/100 cm deep changing into gray to dark gray, soft (partly unripened) marine clay
structure	: the topsoil has a weak to moderate, fine subangular blocky structure. From 20-60 cm depth coarse prismatic structure, breaking into subangular and angular blocks and deeper than 60 cm medium to coarse blocks, mainly because of the presence of slickensides
calcareousness	: non-calcareous
soil reaction	: pH-H_2O (1 : 2.5 v/v) ranges from 6.5-7.5, within 100 cm depth changing into 5.6 to 6.5. In a small area the pH-H_2O drops to less than 4.5. This is indicated on the soil map with an underlined M in the code of the mapping unit
salinity	: these soils are usually slightly to moderately saline at 70/80 cm depth (salinity profile S2. A small area has soils which are non-saline in the top metre
sodicity	: predominantly sodic
infiltration	: measured values are high, class rapid due to cracks, probably slow to very slow when wet
hydraulic conductivity	: very slow
Soil classification	: vertic FLUVISOLS, partly saline-sodic phase

Land suitability for large-scale irrigated rice:

Soil mapping unit*	Limitations		Land suitability	Extent
	main	minor		
BM2 I S0	-	-	1	45
BM2 I S2	salinity	-	2s	5
B<u>M</u>2 I S2	salinity	-	2s	10
Bm2 I S3	salinity	-	3s	170

* The code S0 is not indicated on the soil map

Representative profiles: profile description no. 11 (Appendix 1.1)

Soil unit BM3

These soils occur on the transition of deep river basins soils to the deep marine basin soils

Extent	: 535 ha
Topography	: predominantly flat to very gently undulating mesorelief with a wide network of shallow depressions or gullies (reliefclass I and II). Small ridges, which are usually 20-40 metres wide and approximately 50-100 cm above the surroundings occur to a small extent in this mapping unit. Flat microrelief
Vegetation	: grassland
Land use	: extensive open grazing
Drainage conditions	: poorly drained, in places very poorly drained; the depth of the seasonal floods varies from 60/80 cm to more than 120 cm
Soils:	
general	: 10-20 cm very dark gray, in places black, humic to peaty clay over dark grayish brown, cracking, fluvial clay, less than 80/100 cm deep changing into gray to dark gray, usually soft (partly unripened) marine clay
structure	: the topsoils has a very fine subangular and angular blocky structure. The subsoil has either a complex structure, consisting of a prismatic structure breaking to angular and subangular blocks or has an angular blocky structure throughout. Size of the blocks varies from very fine to medium. The presence of common to abundant slickensides occurs below the topsoil
calcareousness	: non-calcareous throughout
soil reaction	: pH-H_2O (1 : 2.5 v/v) varies from 6.0-7.0 in the topsoil and in the subsoil. At greater depth, the subsoil is, in places, extremely acid (pH-H_2O <4.5)
salinity	: predominantly non-saline from 0-70/80 cm depth. In some places non-saline in the topsoil and changing from slightly saline to moderately saline in the subsoil
sodicity	: predominantly non-sodic. In some places the ESP is high enough to characterize the soil as sodic phase
infiltration/ hydraulic conductivity	: not measured but probably slow to very slow when wet

<u>Soil classification</u> : vertic FLUVISOLS, partly saline-sodic phase

<u>Land suitability for large-scale irrigated rice:</u>

Soil mapping unit*	Limitations		Land suitability	Extent
	main	minor		
BM3 I S0	-	-	1	265
BM3 I S1	-	-	1(s)	70
BM3 I S2	salinity	-	2s	55
BM3 I S2	salinity	-	2s	25
BM3 I S3	salinity	-	3s	5
BM3 II S0	-	topography	1(t)	100
BM3 II S2	salinity	topography	2s(t)	15

* The code S0 is not indicated on the soil map

1.4.4.3 Soils of the estuarine basin land

Soils of the estuarine basin land are developed on subrecent marine sediments (Chapter 2). They consist mainly of heavy to very heavy clay to at least two metres depth. Recent deposition of fresh sediment is very small though the area is seasonally flooded with water from the Tana river and run-off water from the higher lying surrounding area (terraces). Due to this small addition and the "vertic" properties of the clay, indicated by slickenside features, a dark gray to black topsoil of 20-80 cm thickness has developed in these soils. Wide and deep cracks develop in the dry season and a moderately to strongly developed blocky or prismatic structure can be distinguished. A gilgai microrelief is usually present. Structure is less developed when the soils are moist or wet.

In relation to the origin from marine back swamps, catclay phenomena are present in the subsoil in many places. This implies the presence of yellow mottles of jarosite and a strongly to extremely acid soil reaction in the deeper subsoil. As it concerns subrecent marine sediments, part of the jarosite has disintegrated. On top of the horizon with yellow mottling usually a horizon with red and dark yellow mottling occurs in which the soil reaction is less acid. Gypsum crystals are also found in this horizon and in the gray clay above. Roughly, gypsum crystals occur from 80/100 to 150/160 cm depth. Another phenomenum of these soils is the soft (unripened) subsoil, the presence largely depending upon the topographical situation (drainage conditions). Poorly drained areas for instance have soils with a soft (partly unripened) subsoil starting roughly from one metre depth. Softness increases with depth.
The soils are non-calcareous.
The bulk of the soils in estuarine basin land are more or less saline within one metre depth. This presence of salinity at relatively shallow depth can probably be attributed to marine groundwater, which has not been drained in spite of a long period of seasonal flooding. Because of the presence of saline (marine) groundwater most soils have more than six percent exchangeable sodium within one metre depth. Therefore, a sodic phase is commonly indicated in the description of the soil units.

Deep marine basin soils (M)

These soils consist of cracking ("vertic") clay of subrecent marine origin, which extends to a depth of two metres or more. According to differences in drainage conditions three soil units are distinguished. Each soil unit is subdivided in several soil mapping units on the basis of differences in relief, salinity profile and vegetation type.

Soil unit M1

Extent	: 185 ha
Topography	: flat; moderate gilgai microrelief
Vegetation	: grasses
Land use	: extensive open grazing
Drainage conditions	: moderately well to imperfectly drained; depth of seasonal floods usually less than 25 cm
Soils:	
general	: 10-20 cm black, humic clay over very dark gray to black, cracking clay. Between 40-70 cm changing into dark gray clay, at greater depth into gray clay with, in places, yellow mottles (catclay). Gypsum crystals are frequently present untill the horizon with yellow mottles is reached
structure	: prismatic structure in topsoil, breaking to angular and subangular blocks. Medium to coarse angular blocks in subsoil
calcareousness	: non-calcareous
soil reaction	: pH-H_2O (1 : 2.5 v/v) ranges from 6.5 to 7.5. Deeper than 150 cm pH-values of 4.5 to 5.5
salinity	: non-saline in the topsoil (0-20 cm); slightly to moderately saline below the topsoil (salinity profile S2 and S3)
sodicity	: sodic
infiltration/ hydraulic conductivity	: not measured, but probably slow to very slow when wet
Soil classification	: vertic FLUVISOLS, in places pellic VERTISOLS, saline-sodic phase

Land suitability for large-scale irrigated rice:

Soil mapping unit*	Limitations		Land suitability	Extent
	main	minor		
M1 I S2	salinity	-	2s	110
M1 I S3	salinity	-	3s	75

Soil unit M2

These soils occur in the eastern part of the project area. Relatively higher parts in this area of estuarine basin land with these soils are surrounded by the lower lying areas with gullies

Extent	: 365 ha
Topography	: flat to very gently undulating because of depressions and shallow gullies; weak gilgai microrelief
Vegetation	: grasses
Land use	: extensive open grazing
Drainage conditions	: imperfectly drained, in places poorly drained; depth of seasonal floods 25 to 40/50 cm
Soils:	
general	: 10-20 cm black, humic clay over very dark gray to black, cracking clay. Between 50-80 cm changing into dark gray clay, at greater depth into gray, usually soft (partly unripened) clay with yellow mottles (catclay). Gypsum crystals are usually present between 70/80 and 120/130 cm depth
structure	: topsoil with fine angular and subangular blocky structure. Medium to coarse angular blocks below topsoil. Slickensides
calcareousness	: non-calcareous
soil reaction	: pH-H_2O (1 : 2.5 v/v) series from 6.0-7.5 from 0-70/100 cm depth. At greater depth pH-H_2O decreases to values lower than 4.5, in places
salinity	: the bulk of the soils has salinity profile S2; non-saline from 0-70/80 cm and moderately saline from 70/80 cm onwards
sodicity	: predominantly sodic, due to a moderately saline subsoil, starting within one metre depth
infiltration/ hydraulic conductivity	: not measured, but probably slow to very slow
Soil classification	: vertic FLUVISOLS, in places pellic VERTISOLS, saline-sodic phase

Land suitability for large-scale irrigated rice:

Soil mapping unit*	Limitations		Land suitability	Extent
	main	minor		
M2 I S1	-	-	1	90
M21 I S2	salinity	-	2s	70
M2 I S2	salinity	-	2s	70
M2 I S2	salinity, acidity	-	3sa	15
M2 I S3	salinity, acidity	-	3sa	5
M2 II S2	salinity	topography	2s(t)	35
M2 II S2	salinity	topography	2s(t)	55
M2 II S2	salinity, acidity	topography	3sa(t)	25

Soil unit M3

Soils of this unit occur in the central part of the project area which is dominated by the presence of a small lake and an elongated swampy depression. This area and the areas in the south-eastern part of the project area are part of the vast estuarine land south-east of the surveyed area.

Extent	: 985 ha
Topography	: predominantly flat, to a small extent very gently undulating mesorelief. A wide network of shallow depressions and relatively deep gullies are present. Usually flat microrelief, except for temporary cowfoetoes
Vegetation	: grasses and, in a few places, small sedges
Land use	: extensive open grazing
Drainage conditions	: poorly drained, in places very poorly drained
Soils:	
general	: approximately 10 cm black, humic to peaty clay over black, cracking clay. Between 40-80 cm changing into dark gray clay, at greater depth (120/150 cm) into gray, usually very soft (half ripened) clay with yellow mottles (catclay). Gypsym crystals occur usually from 70/80 to 120 cm depth
structure	: fine subangular and angular blocky structure from 0-70 cm depth. From 70 cm fine to medium angular blocks. Abundant slickensides, starting from 15 cm depth. Structure in the catclay subsoil is usually weakly developed or absent
calcareousness	: non-calcareous
soil reaction	: pH-H_2O (1 : 2.5 v/v) varies from 6.0 to 7.5 from 0-70/100 cm depth. In many places pH-H_2O values decrease to 4.5 or less.
salinity	: the greater part of the soils are non-saline in the top metre, but salinity increases usually to moderately saline from 100 metre depth onwards in these soils. The other part of the soils usually have moderately saline material starting at a depth of 70/80 cm or less.
sodicity	: related to the salinity profile the soils are non-sodic (S0) or sodic (S1 and S2)
infiltration	: very slow
Soil classification	: vertic FLUVISOLS, in places pellic VERTISOLS, partly saline-sodic phase

Land suitability for large-scale irrigated rice:

Soil mapping unit*	Limitations		Land suitability	Extent
	main	minor		
M3 I S0	-	-	1	90
M3 I S0	-	-	1	300
M3 I S1	acidity	-	2a	70
M3 I S2	salinity	-	2s	350
M3 II S0	-	topography	1(t)	175

* The code S0 is not indicated on the soil map

Representative profiles: profile description no. 12 (Appendix 1.1)

Moderately deep marine basin soils over old alluvial sediments (MT)

The soils of this unit consist of cracking ("vertic") clay of subrecent marine origin. Deeper than approximately one metre the clay is very sticky and may be classified as old alluvial sediment, deposited long before the subrecent marine clay. One soil unit is distinguished.

Soil unit MT1

Extent	: 335 ha
Topography	: flat; moderate gilgai microrelief
Vegetation	: grasses, in places acacia trees
Land use	: extensive open grazing, at some high lying locations temporary settlements are present
Drainage conditions	: moderately well to imperfectly drained; depth of seasonal floods predominantly less than 20 cm
Soils:	
general	: 0-10 cm black, humic clay over black, cracking clay. Between 40/70 cm changing into gray, cracking clay, deeper than 100 cm changing into dark gray or olive gray, very sticky clay (old alluvial) sediments). Gypsum crystals are frequently present from 70 to 120 cm depth. The old alluvial sediments contain, in places many coarse (5-10 mm) $CaCO_3$-concretions
structure	: prismatic structure in topsoil, breaking to angular and subangular blocks. Medium to coarse angular blocks in subsoil due to slickensides. Presumably no structure in the old alluvial sediments
calcareousness	: non-calcareous in subrecent marine clay; many CaCO3 concretions in the old alluvial sediments
soil reaction	: pH-H_2O (1 : 2.5 v/v) varies from 6.5 to 7.5. The subsoil of old alluvial sediments has pH-values from 7.0 to 8.0
salinity	: non-saline in topsoil (0-20/30 cm), slightly saline at about 40/50 cm and moderately saline at 70/80 cm and deeper
sodicity	: sodic, due to the high salinity
infiltration/ hydraulic conductivity	: not measured, but very slow when wet
Soil classification	: vertic FLUVISOLS, in places pellic VERTISOLS, saline-sodic phase

Land suitability for large-scale irrigated rice:

Soil mapping unit*	Limitations		Land suitability	Extent
	main	minor		
Mt1 I S3	salinity, sodicity	-	3sd	335

Soil samples: profile no. 13 (Appendix 1.1)

1.4.4.4 Association (M2/M3)

One area consists of soils of mapping unit M2 II S1 and M3 II S1. The extent is 110 ha. For detailed information one is referred to the description of soil unit M2 and soil unit M3.

1.4.5 Subsoil investigations

Information about the subsoil was collected from 30 augerings to a depth of five metres below the surface. Augerings from the bottom of soil profile pits are included. In several places, soil conditions prevented augering to five metres depth, because of, for instance, sand flowing into the auger hole.
The data from the subsoil material include texture, pH-H_2O and electrical conductivity (EC mS/cm) of (1 : 2.5 v/v) soil samples and pH-H_2O and EC of the groundwater.
Some general conclusions are summarized below and generally concern data of soils in river basin land.

1.4.5.1 Texture

Deeper than two metres below the surface the soils in river basin land consist predominantly of marine clay. In several places however micaceous, very fine sand occurs if the location of the augering was in the vicinity of a former river course. In between these courses a texture of clay prevails.

1.4.5.2 Soil reaction

The pH-H_2O (1 : 2.5 v/v) values of the samples of the deep subsoil indicate in general the presence of slightly acid or even strongly acid material. Figure 1.4.07 gives examples of the change in soil reaction with depth. Deep river basin soils have a rather constant soil reaction but if a subsoil of marine sediments is present a decrease to a strongly, or even extremely acid soil reaction occurs. Due to the presence of non-oxidized soft material in the very deep subsoil the pH-H_2O values increase again.

1.4.5.3 Salinity

The degree of salinity of the subsoil is closely related to the texture and the origin of the sediments in the subsoil. A soil consisting of heavy clay throughout has a slightly, but more commonly, moderate saline subsoil. Corresponding with these salinity conditions, electrical conductivity of the groundwater reached values of 10 to 20 mS/cm. The ratio of the EC-value of the groundwater and the EC (1 : 2.5 v/v) value of a wet soil sample varies from 3 to 5. Due to the very slow hydraulic conductivity of these heavy clay soils, refreshment of the groundwater with non-saline floodwater is of minor importance. Salinity is less severe if "levee" material is present (varying from micaceous, very fine sand to slightly stratified sandy clay). There, EC values are less than 2, both of soil samples and groundwater.
Refreshment of the groundwater occurs through infiltration of floodwater. The EC (1 : 2.5 v/v) of moist soils has a relative maximum in soil horizons between 100 en 200 cm below surface. However, in places, it is found deeper (e.g. river levee land and the area of deep river basin soils). Figure 1.4.07 gives the change of salinity with depth. Information about the salinity of the subsoil is presented on MAP 1.03. The degree of salinity (EC-values) measured at 110 cm and 160 cm depths is combined to one value and indicated on the map. The code for the salinity profile (0-100 cm depth) is also indicated and the real value of the electrical conductivity of the groundwater (if present within 200 cm depth). The degree of salinity increases considerably with depth in the soils of the eastern part of the area.

1.4.6 Soil chemical characteristics and soil fertility

1.4.6.1 Soil reaction (pH), calcium carbonate and gypsum

Soil reaction (pH), which is expressed by the negative logarithm of the hydrogen activity in a soil/water suspension or extract, is determined in the field laboratory on soil samples (see Chapter 1.3.3).
The bulk of the soils in the survey area have pH-H_2O values varying from 6.5 to 8.0. The pH-values of the topsoils are predominantly in the range of 6.5 to 7.5. This neutral soil reaction corresponds with the field experience that alkaline earth carbonates are not present. Soil testing on carbonates by adding some hydrochloric acid revealed in general no effervescence for soil samples from 0-100 cm depth.
The nature of the soil material in the subsoil largely determines the pH-H_2O. When fluvial sediments are present the pH-values continue from the topsoil in the same range or increase slightly to pH-values of 8. Marine sediments in the subsoil demonstrate a different pattern of soil reaction roughly coinciding with the feature of yellow mottles. A marine subsoil without yellow mottles decreases slightly in pH-values or continues to have the same pH-value range. When yellow mottles are present, pH-H_2O may drop to values of 3.5 or less. However, many horizons are observed with yellow mottles in combination with dark red mottles and/or iron mottles which generally have pH-H_2O values ranging from 4.0 to 5.0, occasionally higher. Soil reaction in the deeper subsoil shows an increase in pH-H_2O because of the non-oxidized state of the soil material. Fig. 1.4.07 gives the changes in soil reaction (and electrical conductivity) with depth for six representative profiles. Soils are differentiated according to the degree of acidity. The degree is expressed by means of a "depth of extremely acid material" classification. This classification, which resembles an acidity profile, is given in Chapter 1.4.3.2 under the heading "depth classes of extremely acid material".

The presence of calcium carbonate and other carbonates was quantitatively estimated by the effervescence with hydrochloric acid (HCl) on the soil material from the augerhole in the field. Usually, the soils in the river basin land and river levee land are non-calcareous in the top 100 cm. The subsoil below that depth contains only in a few areas $CaCO_3$-concretions in a non-calcareous matrix. In estuarine basin land soils are non-calcareous from the surface to any depth, except for soils over old alluvial sediments. In these sediments coarse $CaCO_3$ concretions occur in considerable amounts and are typical of this material.

Gypsum was roughly estimated in the field by visual observation of the amount of gypsum crystals. Usually they are not present within 70 cm depth. Gypsum crystals are a rare feature in deep river basin soils but common in estuarine basin soils and river basin soils over marine sediments. They usually occur at depths ranging from 70/110 to 120/140 below the surface. Occasionally gypsum crystals are present in the upper part of horizons with yellow mottles. This may imply that after sedimentation a long time passed in which jarosite formed and disintegrated.

1.4.6.2 Salinity

The electrical conductivity of all samples from augerings and profile pits was measured in a field laboratory, in a suspension based on a volume ratio of 1 : 2.5 (soil: water). Internationally applied criteria for salinity appraisal of soils refer to the electrical conductivity of the saturation extract (ECe) of a soil sample. The method involved for obtaining the extract is rather cumbersome, requiring the preparation of a saturated paste and a subsequent extraction by suction. This method is very laborious and requires readily available laboratory facilities. Therefore, the described field method (Chapter 3.3) has been used. Conversion of the results of the field method to the conditions of the saturation extracts was carried out. In the absence of ECe data for calibration the following rough procedure was followed to estimate ECe, which is based on the equation

$ECe = a. \frac{Mf}{SP} ECf$ in which "Mf" is the moisture percentage (w/w)

of the soil suspension, "SP" the moisture percentage of the saturation paste and "a" a coefficient which is usually less than one. The moisture percentage "Mf" of the soil suspensions was calculated using the average moisture percentage of the field samples and an assumed particle density of 2.5 for the clay. The moisture percentage of the augerhole soil material was roughly estimated in the field using the descriptions dry, moist and wet. Laboratory determinations revealed that the moisture percentage of a dry soil averages about 25 per cent, a moist soil about 40-45 per cent and a wet soil about 55 per cent. The corresponding moisture percentages of the 1 : 2.5 v/v suspensions of the dry, moist and wet soil material are 170, 225 and 260 per cent (on weight basis). This accounts for soil material that consists of (heavy) clay. Laboratory determinations of the moisture percentage of the saturation paste of this material equals roughly 100 per cent (range 85-115 per cent for 25 samples).

The coefficient a* was estimated between 0.8 and 0.9 for soils without gypsum crystals and between 0.7 and 0.8 for soils with gypsum crystals. As a result of these considerations the following conversion factors were applied:
- dry soil material; factor 1.5 (or ECe = 1.5 ECf)
- moist soil material without gypsum crystals; factor 2
- moist soil material with gypsum crystals, factor 1.75
- wet soil material without gypsum crystals; factor 2
- wet soil material with gypsum crystals; factor 2.25.

Each ECf value was converted to the corresponding ECe-value and subsequently to the corresponding salinity class (the classes are given in Chapter 1.4.3.2). Using the converted values of the soil samples of 20, 40 and 70 cm depths a salinity profile was established for each observation (see Chapter 1.4.3.2 for the grouping of salinity classes to a salinity profile). The average salinity profile of all observations within a soil mapping area is added to the code of the soil mapping unit. The code S0 is not indicated however. Strongly deviating salinity profiles of observations are indicated separately on the soil map with a symbol.

*The coefficient a is the result of several factors, e.g. ion activity effect, increased dissolution of less soluble salts, suspension effect. In general, the over-all effect is a factor less than one.

For soil classification purposes (FAO/UNESCO, 1974), a saline phase is distinguished if some horizons within 100 cm of the surface have an electrical conductivity of the saturation extract higher than 4 mS/cm at 25°C. In additions, the subdivision of salinity into salinity profiles is connected with the salinity criteria used in the appraisal of the soils for large scale rice cultivation. Information about the salinity, by means of the salinity profile is given in Chapter 1.4.4 for each soil unit. Additional information about the salinity in the horizons deeper than 100 cm from the surface is given on MAP 1.03. The salinity profile of the soil from 0-100 cm depth is combined with a salinity profile based from 100-200 cm. The latter on the basis of the converted ECf values of the samples at 110 and 160 cm depths. One general conclusion is that in the area of river basin soils over marine sediments and in estuarine basin land the salinity increases considerably with depth even when the top metre is classified as non-saline (code SO). Fig. 1.4.07 illustrates the changes in electrical conductivity (ECf) with depth for several soil types.

1.4.6.3 Sodicity

Sodicity of a soil is described by the exchangeable sodium percentage (ESP) on the soil's exchange complex. Soils which have more than 6% saturation with exchangeable sodium in some horizons within 100 cm of the surface are marked as soils with a sodic phase (FAO-Unesco, 1974). In general, physical properties become increasingly unfavourable with increasing levels of exchangeable sodium (Chapter 1.5.3.5). Based on the available laboratory data of soil samples analysed at NAL and partly supported by the degree of dispersion observed in the samples analysed in the field laboratory a sodic phase is indicated for some of the major soil units. It is stressed here that the sodicity of soils, as mentioned in the legend and in the description of the mapping units, should be considered as a rough indication. A reliable differentiation needs laboratory determinations of the ESP-values of many more soil samples. To compensate for the lack of sufficient data of analysed samples, the degree of dispersion, the pH and EC (1 : 2.5 v/v) measured in the samples of augerings were taken into consideration as a provisional indication of sodicity. It is realized that this method is not fully reliable, but it was the best that could be done under the circumstances to trace sodic soil material. The soils of river levee land and the bulk of the soils in river basin land are characterized as non-sodic. The degree of sodicity is connected with the salinity of the soil material. Laboratory data indicate that non-saline material with a pH-H_2O less than 8.0 usually have a low ESP. Shallow river basin soils over marine sediments and soils of estuarine basin land are classified predominantly as sodic. More often than not they have saline soil material (ECe-value of four or more) in some horizon within one metre depth. The sodium percentage of the saline groundwater in these soils is high and this leads to a relatively high percentage of sodium on the exchange complex. Old alluvial soil material in the subsoil of soil unit MT1 disperses considerably in spite of the presence of coarse $CaCO_3$ concretions. This material is predominantly strongly sodic.

1.4.6.4 Cation exchange capacity and exchangeable bases

The cation exchange capacity (CEC) of the soils in the river basin land is high due to the high content of clay. It varies from 25 me per 100 gram for soil with a texture of approximately 40 per cent clay to 45 me per 100 gram for soil with a texture of approximately 70 per cent clay. On average the CEC per gram clay is 0.5-0.6 me. The CEC of topsoils is slightly higher because organic matter also contributes to the exchange complex.

The base saturation is the degree to which the exchangeable bases saturate the exchange complex of the soil. The major exchangeable bases are Ca, Mg, K and Na. The base saturation of the soils of the river basin land is at least more than 50 per cent. Slightly to strongly saline soil horizons commonly have a base saturation of 100 per cent. In these horizons, the sum of exchangeable cations analysed in the laboratory exceed the CEC. Base saturation in non-saline soil horizons varies considerably though some pattern is present. The base saturation of the topsoil ranges from 55 to 80 per cent without any relation with the pH-H_2O values. Below the topsoil the base saturation increases in general to values between 70 and 100 per cent. Soils with a high CEC and a high base saturation are potentially fertile as they may provide adequate supply of plant nutrients. The important nutrient K is always present in relatively low amounts, often not exceeding 1 me/100 gram soil. A relatively high amount of Na is present on the exchange complex. This unfavourable condition, sodicity, is dealt with in Chapter 1.4.6.3.

1.4.6.5 Soil fertility

Around most profile pits composite samples of the 0-20 cm top- soil were taken and subjected to a "Mass analysis" method for soil fertility evaluation. The results are presented in Appendix 1. Some conclusions are given here. Soil reaction is slightly acid, pH-H_2O (1 : 1 v/v) ranges from 5.4 to 6.3, on average 5.9. The organic matter content ranges from 1.2 to 2.6 per cent org. C with a median value of 1.6 per cent. This level is moderate to sufficient. Deeper than 20 cm the below surface the organic matter content decreases rapidly to values of 0.2 to 0.4 org. C. The content of N is closely related to the organic matter content; the ratio between the org. C per cent and the N per cent varies from 6 to 8. The average content of N is moderate. The figures for available phosphorus (P) indicate a sufficient level. The average level is 36 ppm P. The critical level below which P may be deficient is 20 ppm. The available Ca varies roughly between 13 and 19 (me/100 g) and available Mg between 7.5 and 9.5 (me/100 g). These values can be considered as high to very high as the critical level is 2.0 for Ca and 1.0 for Mg.

Potassium figures indicate in general a level that can be considered as sufficient. There are no samples with K-values below the critical level of 0.2-0.4 me/100 gram. Sodium content (in me/100 gram) is sufficiently below the critical level of 2.

1.4.7 Soil physical characteristics

1.4.7.1 Introduction

The water retention and transmitting properties, the workability and structure stability are important for assessing the irrigation suitability. Chemical characteristics, particularly sodicity and its interaction with salinity, influence and possibly determine the physical characteristics of the soil.

1.4.7.2 Infiltration

Infiltration is the entry of water into the topsoil. Measurements of the infiltration rate were carried out in the field close to the profile pits. The conditions for the infiltration measurements were in general those of a "wet run" infiltration. The moisture content of the topsoil was very close to the saturation percentage. At some locations, particularly in the relatively high basin areas, the topsoil was already starting to dry out and a few, shallow and narrow cracks had developed. Infiltration is largely influenced by the moisture content. Dry soils have cracks that facilitate the entry of water, resulting in a high and often variable infiltration rate. Even a wet run measurement on these initially dry soils results in relatively high values. Clay soils that have been inundated for a long period are swollen and the cracks have disappeared. Infiltration in these soils is slow as long as the soils are wet from the surface. The infiltration rates were measured with two or three single rings (diameter 20 cm) and one double ring set-up (diameter 30 cm and 53 cm (Fig. 1.4.05)). The rings were driven carefully to a depth of 15-20 cm into the soil at each site, and filled up to about 10 cm with water. Refilling took place when the water level had dropped by about 5 cm. The water level was recorded after 1, 2, 3, 4, 5, 10, 20, 30, 40, 50, 60, 75, 90, 105, 120, 135, 150, 165, 180, 210 and 240 minutes.

The infiltration rate was calculated using the formula

$$I\ cum = cT^{m}.$$ In which:

I cum = accumulated intake (cm)
T = elapsed time for each accumulated intake (hr)
c, m = constants;
c and m were calculated using double logarithmic paper. The final or basic infiltration rate (I-bas) is a relatively constant rate which occurs after several hours. "Relatively constant" means that I-bas is achieved when the change per hour is less than 10 per cent. The time T (in hrs) for the calculation of I-bas is given by the formula $T = 10\ (1 - m)$ hrs. I-bas values range from 0.03 cm/hr on wet soils to more than 4.5 cm/hr on relatively dry soils with cracks that had started to develop. The very low value of 0.03 cm/hr roughly equals the order of the evaporation during the measurement. Table 1.4.02 gives a division according to the value of the basic infiltration (I-bas.)

Table 1.4.02 Basic infiltration rates (cm/hr) in moist to wet basin soils

	basic infiltration rate (cm/hr)					
range	0-0.1	0.1-0.25	0.25-0.5	0.5-1.0	1.0-2.0	>2.0
number	9	10	1	0	4	10

The majority of the infiltration rates must be classified as very slow. Particularly the poorly drained basin soils have very low values. Table 1.4.03 gives the basic infiltration rates and formula constants c and m for sites near profile pits. From this table it can be seen that the high values are related to soils with better drainage (e.g. BL1 I S0, BM2 1 S3). Cracks, more or less developed, are present in these soils. One exception is profile no. 9, where rather high infiltration rates were measured, though the soil was classified as poorly drained. Large cracks were observed in this soil, causing a rapid infiltration. This example and the list of figures may confirm the statement already made that:

1 infiltration in these clay soils largely depends on the moisture condition (and related presence of cracks) of the soil;
2 after long saturation infiltration drops almost to zero.

Table 1.4.03 The basic infiltration and formula constants c and m for sites near profile pits

Profile description no.	Soil mapping unit	Ring* no.	Formula constants c	m	Basic infiltration rate (cm/hr)
1	L1 I S0	1	0.21	0.83	4.75
		2	0.15	0.80	2.75
		3	0.25	0.65	1.50
2	B3 I S0	1	0.08	0.33	0.03
		2	0.12	0.82	2.55
		3	0.04	0.59	0.15
		4	0.22	0.30	0.06
3	B3 I S0	1	0.16	0.41	0.12
		2	0.02	0.69	0.14
		3	0.01	0.75	0.18
		4	0.43	0.33	0.15
5	BL1 I S0	1	0.53	0.44	0.55
		2	1.70	0.46	2.05
		3	3.00	0.49	4.75
6	BL3 II S0	1	0.07	0.46	0.08
		2	0.13	0.44	0.13
		3	0.15	0.43	0.14
		4	0.15	0.42	0.13
7	Bm3 I S0	1	1.25	0.23	0.15
		2	0.30	0.19	0.02
		3	0.04	0.45	0.04
		4	1.30	0.27	0.24
9	Bm3 I S0	1	2.60	0.49	4.15
		2	0.46	0.65	2.75
		3	1.50	0.47	2.00
		4	3.80	0.35	1.65
11	BM2 I S3	1	4.00	0.39	2.55
		2	0.12	0.78	1.85
		3	3.30	0.41	2.55
		4	4.30	0.40	3.00
12	M3 I S0	1	0.12	0.40	0.09
		2	0.05	0.46	0.06
		3	0.15	0.37	0.08
		4	0.12	0.29	0.03

* The highest number is the double ring

1.4.7.3 Hydraulic conductivity

The permeability of the subsoil was measured with the augerhole pour-in method (inversed augerhole method). Three augerholes of approximately 1.5 metre depth were filled with water to a depth of about 50/70 cm below the surface and the drop of the water level with time was recorded (fig. 1.4.06). Hydraulic conductivity (k) was calculated with the equation given by ILRI (1974, Vol. III, p. 292). The results are presented in Table 4.04. K-values are given for the period 2-4 hours after start. Start is the moment that water is poured into the augerholes. This period is relevant for the calculation with the equation because the data from the 0-2 hrs period after start do not fit the straight line which is required for the use of the equation. The very slow hydraulic conductivities imply that internal drainage is very difficult to achieve when the soil is wet.

Table 1.4.04 Hydraulic conductivity values according to the inversed augerhole method

Profile description no.	Soil mapping unit	Horizon of measurement cm below surface	Hydraulic conductivity (cm/day)			
			no. replicate			average
			1	2	3	
1	L1 I S0	50-150	failed	4.0	14.0	9.0
2	B3 I S0	60-100	0.35	0.15	-	0.25
3	B3 I S0	50-145	0.35	0.50	0.30	0.40
5	BL1 I S0	70-145	5.5	9.6	10.7	8.6
		60-95	2.2	2.8	-	2.5
6	BL3 II S0	20-90	0.30	0.30	0.30	0.30
7	Bm3 I S0	50-150	0.35	0.35	0.40	0.35
8	Bm3 I S0	/0-150	0.25	-	-	0.25
9	BM3 I S0	50-145	0.70	0.50	0.95	0.70
11	BM2 I S3	60-150	0.70	0.75	0.45	0.60

The poorly drained soils (B3 etc.) have low values. The median of the hydraulic conductivity in these soils is 0.35 cm/day which marks these soils as very slow regarding hydraulic conductivity.

1.4.8 Chemical analysis results of groundwater samples

The field laboratory measurements of the electrical conductivity of groundwater samples resulted in values from 0.2 mS/cm to 30 mS/cm. Consequently, the degree of salinity varies considerably. Groundwater, therefore, cannot be considered as a source for irrigation water. Table 1.4.05 gives the chemical characteristic of groundwater, sampled at scattered locations. The chemical composition of the groundwater largely determines the nature and balance of exchangeable cations. Because of its impact, particular reference is made to the exchangeable sodium percentage (ESP) of soil horizons within groundwater range. The ESP-value can be estimated from the Sodium Adsorption Ratio (SAR) of the groundwater (Handbook No. 60, USDA). The data in Table 1.4.05 indicate that high ESP values are present in horizons with an acid soil reaction and a high degree of salinity. It concerns marine sediments in which probably the originally present saline groundwater of marine origin has been more or less leached. Low ESP values coincide with a low degree of salinity and occur in horizons with an alkaline soil reaction. Groundwater here is most likely from fluvial origin.

Table 1.4.05 Chemical data of groundwater samples

	Location of groundwater sample (profile pit or auger hole)														
	11	P1	P3	P4	123	P5	132	135	217	420	439	P7	P11	P12	551
pH	8.2	7.4	8.2	3.6	8.6	8.6	8.6	7.6	4.1	3.6	8.6	3.2	8.2	8.5	7.9
Elec.cond. mS/cm	7.0	9.5	19.3	10.4	0.36	0.92	1.85	0.25	26.9	26.0	0.45	4.5	6.0	0.95	1.75
Sodium (me/litre)	35.7	43.6	85.5	43.5	2.08	6.90	6.48	1.74	173.9	167.9	2.60	12.2	38.7	3.50	13.6
Potassium "	0.26	0.26	0.26	1.54	0.02	0.26	0.26	0.16	0.26	4.87	0.05	0.77	1.03	0.02	0.50
Calcium "	14.0	18.0	16.0	14.0	0.70	1.40	10.0	0.34	52.0	42.0	0.12	12.0	3.32	2.76	0.66
Magnesium "	19.0	30.0	16.0	38.0	0.44	1.90	2.0	0.28	48.0	46.0	0.26	20.0	16.9	3.67	1.58
Carbonates "	0.72	NIL	0.20	NIL	0.20	1.00	0.64	NIL	NIL	NIL	0.20	NIL	2.40	0.20	0.64
Bicarbonates "	2.80	3.74	1.72	30.0	2.54	3.06	3.70	1.60	0.50	20.0	2.0	10.0	8.08	1.60	10.60
Chlorides "	61.0	90.30	120.0	60.0	0.62	4.38	24.0	0.71	249.5	210.0	2.0	30.0	39.0	4.20	4.50
Sulphate "	8.90	2.81	0.94	14.53	0.29	1.64	0.94	0.05	16.41	30.0	0.27	5.90	8.91	3.38	3.38
SAR "	8.8	8.9	21.4	8.5	2.8	5.4	2.6	3.1	24.6	25.3	6.0	3.05	12.2	2.0	12.9
ESP "	10.4	10.5	23.5	10.0	3.0	6.0	2.9	3.5	27.0	27.5	7.0	3.5	14.2	2.1	14.5

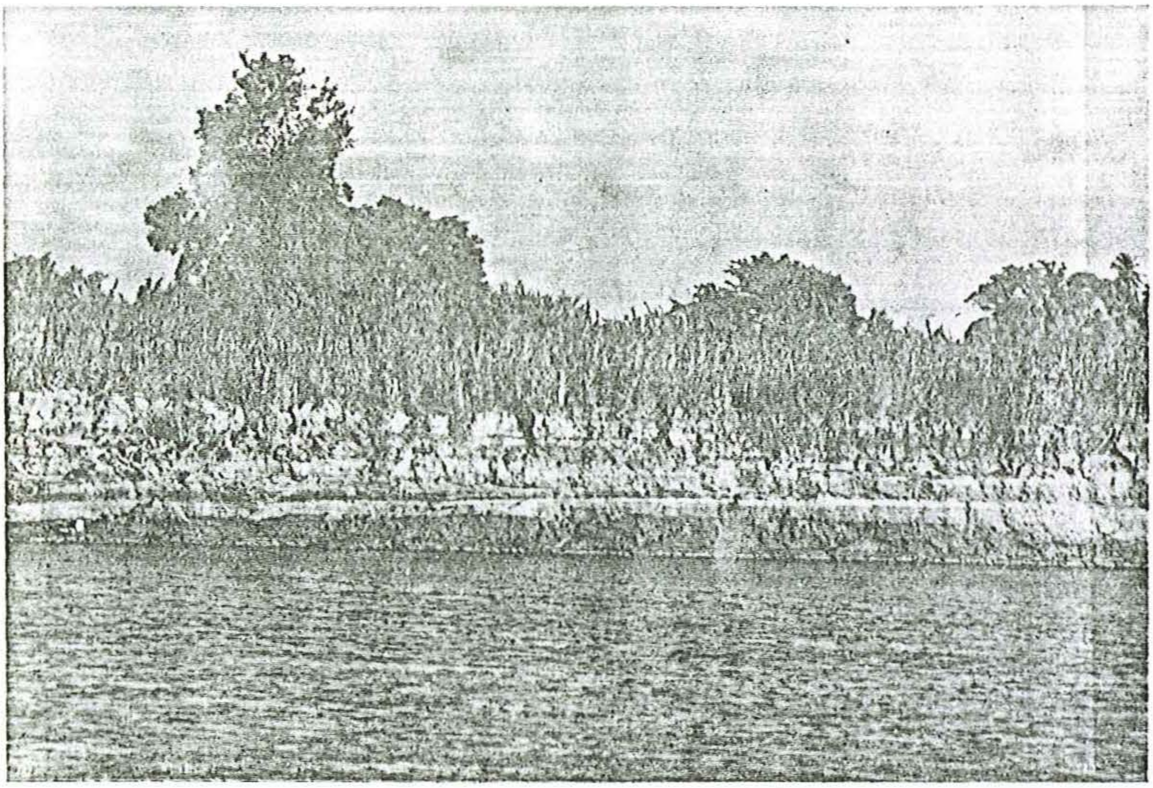


Fig. 1.4.01 Stratified levee soils along the Tana River *)

Fig. 1.4.02 Slickensides, polished and grooved surfaces produced by one soil mass sliding past another, are common features in the swelling river basin clay soils. Photograph from 60-80 cm depth *)

*) These figures are identical to the figures 4.01 and 4.02 of the report on Project I

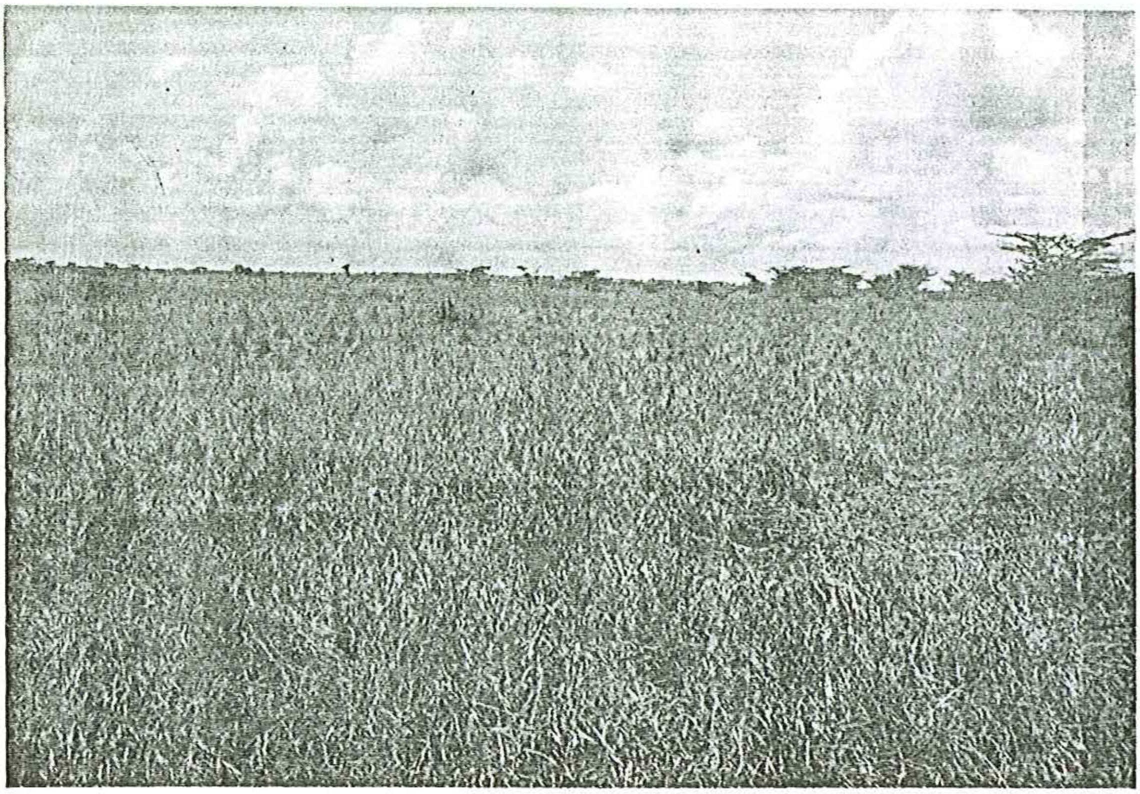


Fig. 1.4.03 Bushed grassland on deep river basin soils in moderately high lying river basin land

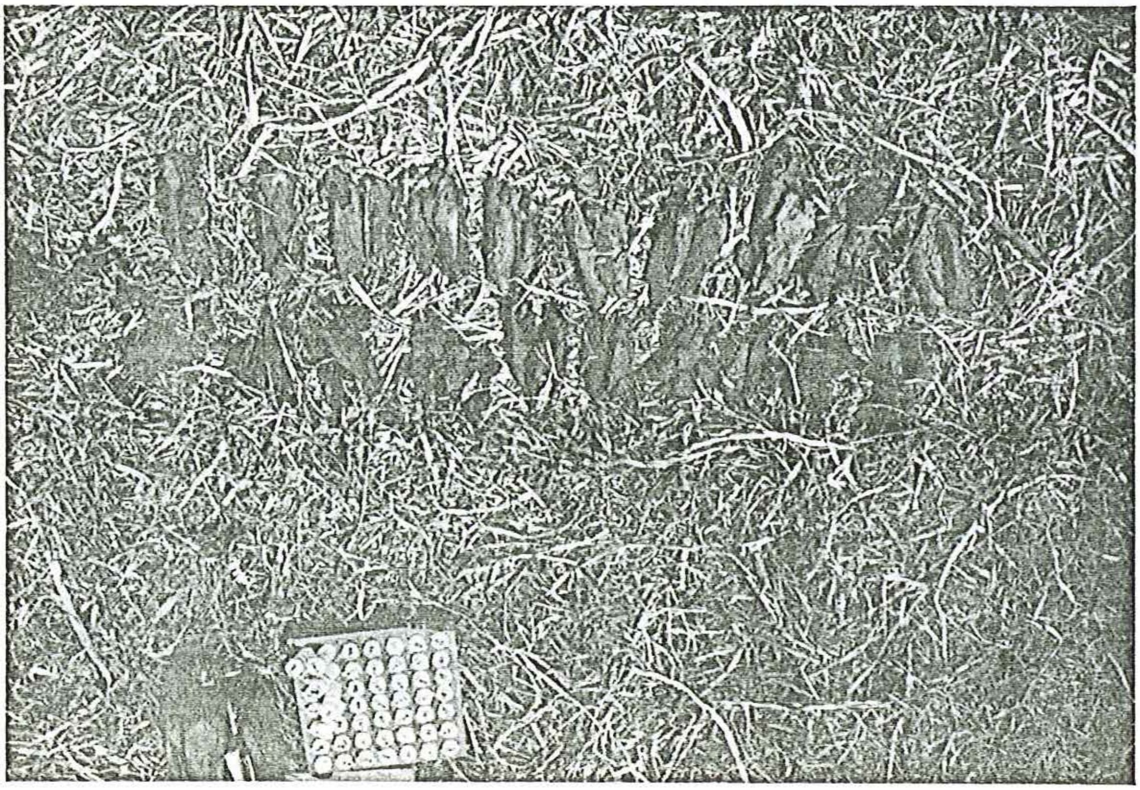


Fig. 1.4.04 Soil material from an augerhole in a moderately deep river basin soil over marine sediments; dark (brown) fluvial clay in the upper file, light (gray) marine clay in the lower file

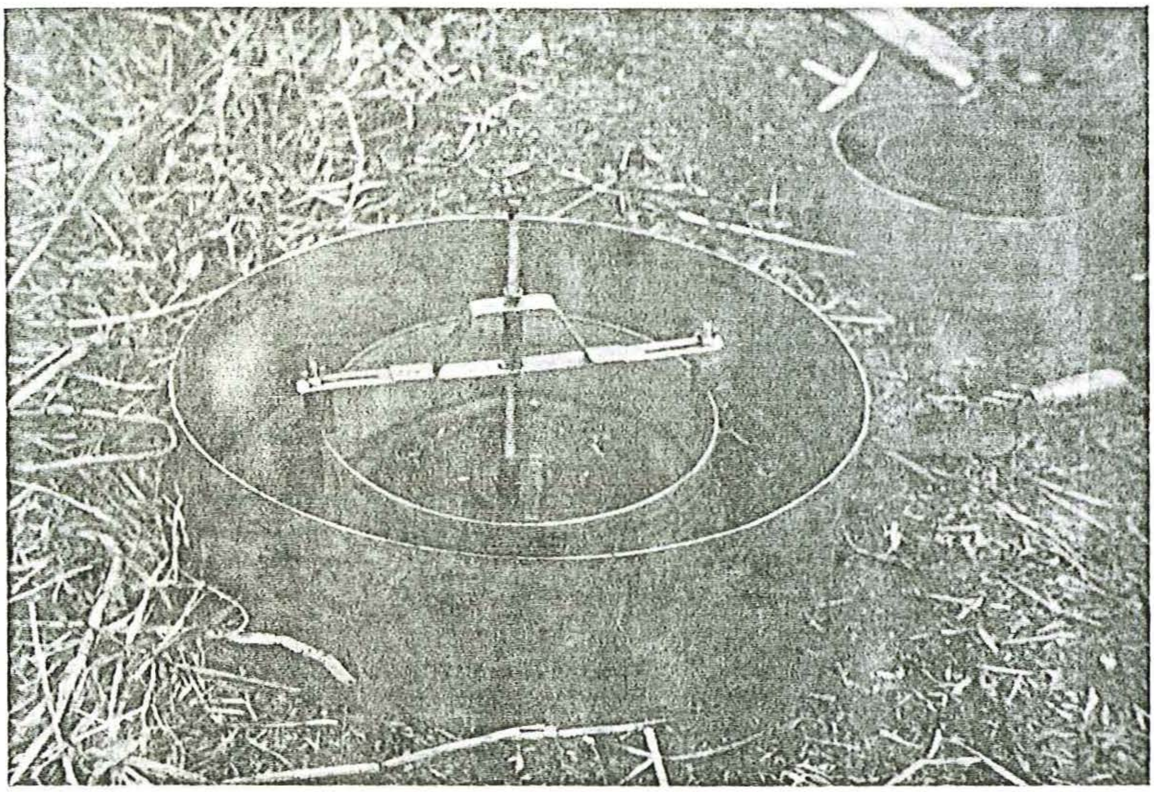


Fig. 1.4.05 Set-up of the infiltration measurement with the double ring method

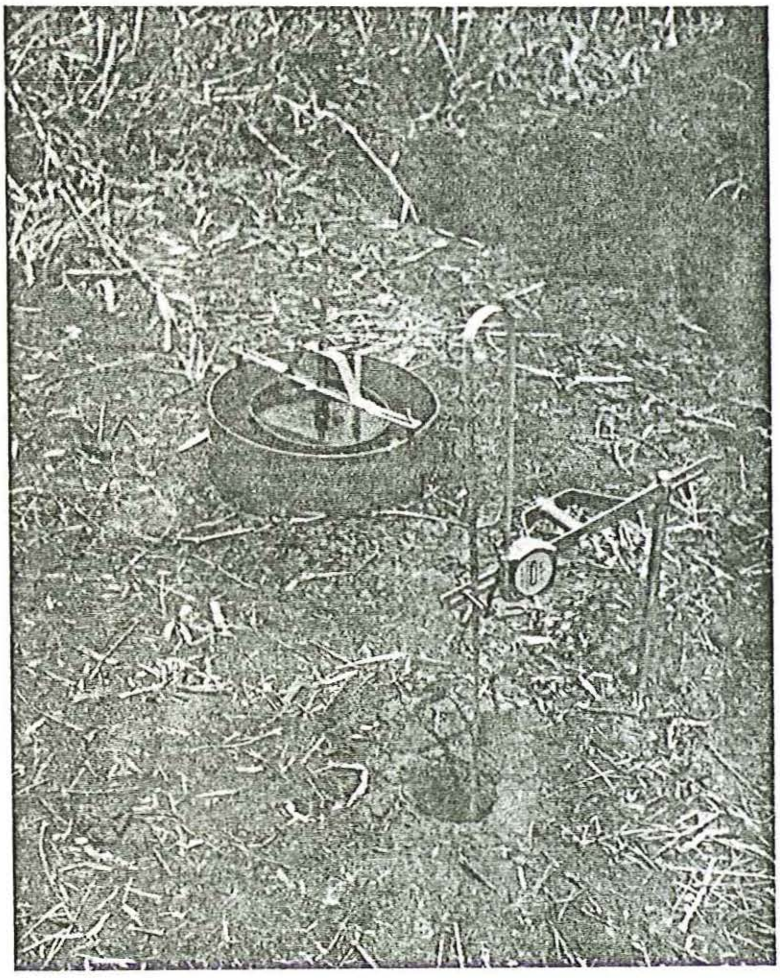
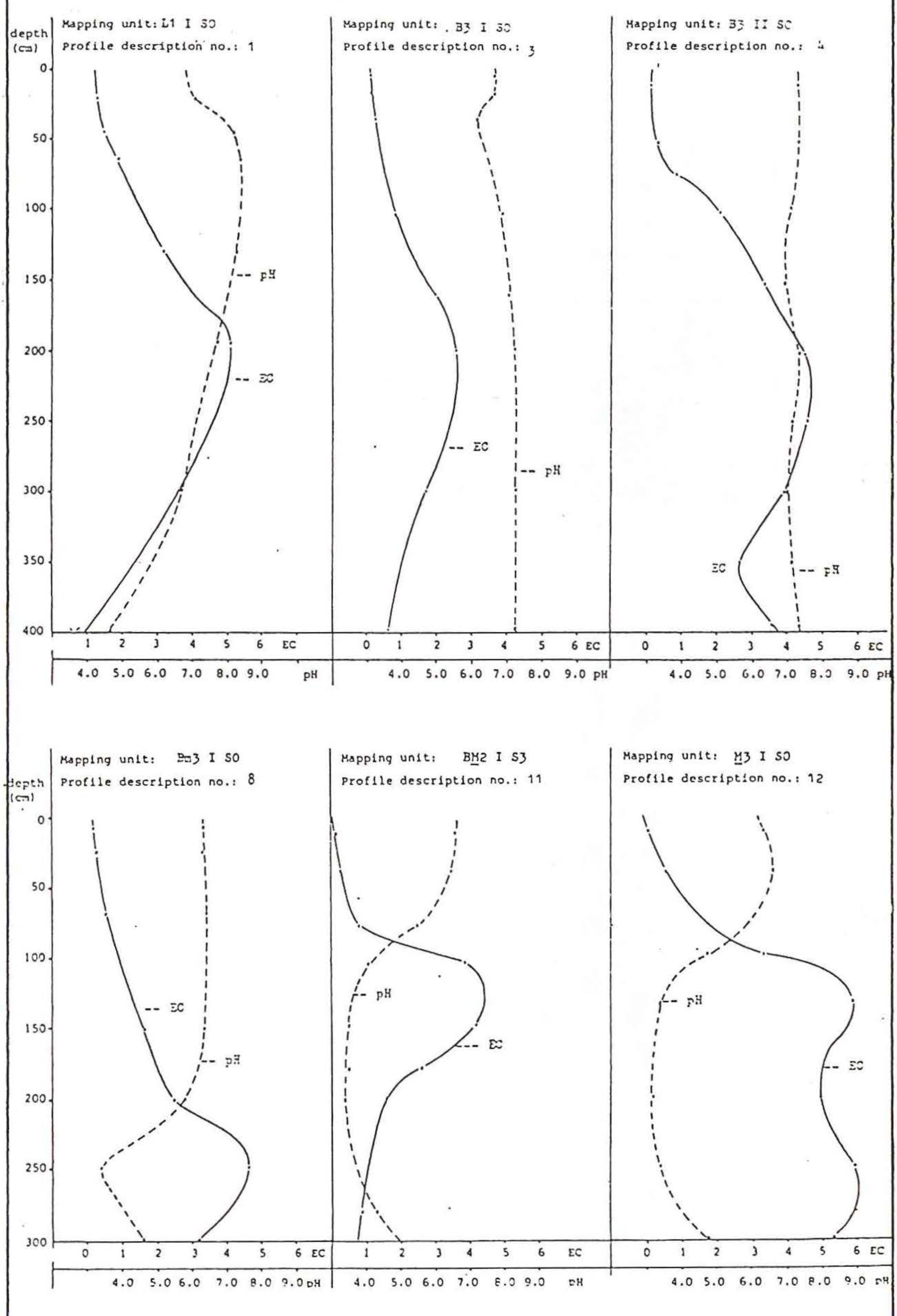


Fig. 1.4.06 Set-up of the measurement of the hydraulic conductivity (foreground). In the background the double ring for the infiltration measurement



HASKONING BV

Mwenge International Associated Limited

fig : 1.4.07

title: Salinity EC (1 : 2.5 v/v) mS/cm and pH-H_2O (1 : 2.5 v/v) in 6 representative soil profiles

1.5 LAND SUITABILITY FOR LARGE-SCALE IRRIGATED RICE

1.5.1 Classification

The land classification 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, 1981). Their proposed criteria for land suitability classification for irrigation are used in principal for this study. Modifications are made to allow for soil conditions in the project area. The suitability criteria are the same as those of the semi-detailed survey in the adjacent area of the Tana Delta Irrigation Project (Haskoning and Mwenge IAL, 1982). One addition applies to acidity of the soil reaction.
The land suitability classes are based on the physical and chemical constraints of the area. To determine the suitability of the various soil mapping units, first the limitations in soil and land qualities are evaluated and subseqeuently compared with the minimum criteria of the various suitability classes (Table 1.5.01).

1.5.2 Land suitability classes

The appraisal of the suitability is carried out, assuming that:
- flood control works are constructed, in order to protect the area from both flooding and erosion
- sufficient irrigation water of good quality is transported to the areas 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 are distinguished (Table 1.5.02). Classes 2, 3 and NS (unsuitable) are subdivided according to the main limiting factor(s). A main limiting factor which represents only a minor limitation and which does not determine the suitability class, is indicated in brackets. This is particularly relevant for suitability class 1. The factors and their codes are given in Chapter 1.5.3 and in Table 1.5.02. It should be kept in mind that the suitability presented is only valid for irrigated rice.

1.5.3 Land qualities and specific criteria

1.5.3.1 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. Requirements are:
- 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 is of particular importance when large-scale cultivation is planned
- no salinity in the rooting zone, to a depth of approximately 20-40 cm. Rice is known to grow on soils with a saline sub- soil at shallow depths, 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.

The following land qualities, which determine the suitability of land for large-scale irrigated rice, were considered:

soil texture
soil depth
hydraulic conductivity
soil reaction
soil salinity
soil sodicity
topography
vegetation

In the next paragraphs the above mentioned land qualities are dealt with in further detail.

1.5.3.2 Soil texture, soil depth and hydraulic conductivity (soil texture indicated in the suitability class with code "z")

These qualities are dealt with here together, because in the project area they are very much related.

Rice is grown on soils that are slowly permeable or that can be made slowly permeable. Soils that consist of clay to a certain depth respond in general to this condition. The hydraulic conductivity of the soils in the river basin land and estuarine basin land is slow (Chapter 1.4.7.3) if the clay is moist or wet. The soils of the river levee land largely consist of stratified sand and clay. The hydraulic conductivity of these soils is higher due to the rapid permeability of the sandy layers. Control of the irrigation water is more difficult to achieve and seepage may occur. To prevent these unfavourable conditions the soil has to respond to soil texture criteria. The texture criteria deal with the particle size fraction and thickness (Table 1.5.01). Also, the texture of the deeper subsoil is considered as the presence of stratified sand and clay may increase the costs of the development; for instance, the lining of some parts of the irrigation canals to prevent seepage. The texture of the subsoil is a quality acting as a minor limiting factor, therefore indicated in brackets (Table 1.5.02). In addition, for large-scale cultivation of irrigated rice, the hydraulic conductivity has to be slow (Table 1.5.01). Soil depths meet the criteria, mentioned in Table 1.5.01; all soils in the project area are very deep (depths greater than 1.20 m).

1.5.3.3 Soil reaction (limiting factor indicated in the suitability classes with code "a")

Values of pH 5.5 to 6.5 in the rooting zone of soils for rice are most common. These values become higher under flooded conditions. Rice can be grown on soils with a pH of eight or more, however, with moderate success. Production is considerably reduced in soils with pH values less than four. In the project area the pH of the rooting zone is in general between 5.5 and 7.5. Higher values occur only in a few places. However, in vast areas the deeper subsoil is strongly acid to extremely acid with pH-H_2O values less than 3.5, in places. The depth of occurrence of extremely acid soil material is used to define acidity criteria (Table 1.5.01). A shallow depth of this material is considered limiting because of contamination of the rooting zone with this acid material during levelling. The minimum requirements are mentioned in Table 1.5.01.

1.5.3.4 Soil salinity (limiting factor indicated in the suitability classes with code "s")

Soil salinity is an important characteristic for the evaluation of the suitability of the land. The yield of rice decreases with increasing salinity of the rooting zone; an ECe-value of 5 mS/cm gives a decrease of 10 per cent, ECe-value of 6 mS/cm a decrease of 25 per cent and an ECe-value of 8 even 50 per cent (ILRI, 1974).

Much attention is therefore given to the EC-values of the soils (see also Chapter 1.4.3.2 and 1.4.6.2).

The minimum salinity criteria, given in Table 1.5.01, largely correspond with those given by KSS (Muchena, 1981), but are adapted to the salinity conditions prevailing in the project area.

1.5.3.5 Soil sodicity (limiting factor indicated in the suitability class with code "d")

Sodic material has an adverse effect on the chemical and physical condition of a soil. The relatively high sodium content on the exchange complex adversely influences the nutrition status of the soil. More important however is the easy dispersion of the clay because of the high sodium content on the exchange complex. Structure stability of this soil material is low and difficulties may be expected in the construction of canals and drains when present at shallow depths. The minimum criteria are mentioned in Table 1.5.01. The estimation of the sodicity is complicated. The approach is discussed in Chapter 1.4.6.3.

1.5.3.6 Topography (limiting factor indicated in the suitability classes with code "t")

Limiting topographic factors are derived from the macro topography (slope) and meso- and microrelief.

Slope deals with differences in topography over larger distances, mainly expressed by the length and steepness of the slope. Within the project area, slope is not a limiting factor in the land appraisal. The basin land is flat. In the river levee land 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.

Mesorelief concerns medium sized differences in topography over rather short distances. It takes into account the surface features occurring within the general macrorelief. In the project area they are related to sedimentation processes; river levees, channels, depressions, gullies. The presence of a fine network of shallow gullies and depressions in the almost flat areas is generally a limitation of minor importance in the project area as the necessary levelling for large-scale rice irrigation development has to be carried out anyhow and is slightly more expensive in areas with topographical limitations (relief class II on the soil map). Microrelief is characterized by relief irregularities and undulations found within short distances, such as gilgai, cowfoetoes and tussocks. These minor undulations are not considered to be a limitation. As for the gilgai, this microrelief feature is present almost everywhere because of the swelling and shrinking property of the clay that is present in the majority of the soils. This may imply that some levelling is required annually. The criteria for the factor topography are given in Table 1.5.01.

1.5.3.7 Vegetation (limiting factor indicated in the suitability classes with code "T")

The density and type of vegetation on the land indicates the degree of clearing needed for reclamation. Vegetative cover varies from non-restrictive (grasslands) to severely restrictive (riparian forest). Riparian forest is a main limiting factor in various areas of river levee land, though less important than the textural constraints. This factor is of minor importance in the areas that are covered with bush (e.g. acacia shrub) in relation to the costs of clearing. Table 1.5.01 gives the minimum requirements for the suitability classes.

1.5.4 Results of the land suitability classification

The main results of the appraisal of the soils for large- scale irrigated rice are presented in Table 1.5.03. This table summarizes the results of the appraisal of each soil mapping unit in Table 1.5.04.

The spatial extent of the land suitability classes is indicated in Figure 1.5.01. This figure is derived from the land suitability map (MAP 1.02).

Table 1.5.03 Land suitability for large-scale irrigated rice

Suitability class	Description of class	Limitations	Extent (ha)
1	highly suitable	none to minor	6,470
2	moderately suitable	slight to moderate	1,750
3	marginally suitable	moderate to severe	1,125
NS	unsuitable	-	990

Class 1 consists of land that is highly suitable for irrigated rice production. Minimum costs are expected for development and management associated with the land. Class 1 comprises soils of river basin land and estuarine basin land which are non-saline throughout or slightly saline in the subsoil when considering the soil from the surface to one metre depth. The areas of these soils with a flat relief and few shallow depressions comprise about 4,040 ha. Areas with the same types of soils, but which have more relief due to a wide network of shallow depressions and gullies, include 2,210 ha. An area of 220 ha with these non-saline soils have minor limitations due to stratified sand and clay, mainly deeper than one metre, due to vegetation hindrance or to salinity.

Class 2 consists of land of moderate productivity due to slight to moderate limitations in soil qualities or moderate costs for development. This class includes river basin soils and estuarine basin soils which are non-saline in the topsoil but slightly saline from 40 cm onwards or moderately saline from 70/80 cm onwards (1,125 ha). An area of 255 ha of these soils has a slightly irregular relief (relief class II). The remnant area of this class, 370 ha, comprises various soil types; river levee soils, consisting predominantly of clay with vegetation hindrance (140 ha), estuarine basin soils with a limitation because of acidity at shallow depth (70 ha), river basin soils over levee sediments with textural constraints (90 ha) and basin soils with vegetation hindrance (70 ha).

Class 3 consists of land with a restricted productivity for irrigated rice due to moderate to severe limitations in soil qualities. Relatively high costs for development (i.e. levelling and clearing) are associated with this class. Class 3 (1,125 ha) comprises mainly shallow river basin soils over marine sediments and estuarine basin soils with a limitation due to saline soil material at shallow depths. Some of the estuarine soils are also acid at shallow depth. Furthermore, river levee soils, consisting of clay to clay loam over, in places, stratified sandy micaceous sand and clay (unit L3) and which have a dense bush vegetation cover, are appraised as marginally suitable. The main limitation for these soils is the presence of sand layers at variable depth and occurrence. A relatively high lying area, east of the elongated depression in the central part of the project area, has saline soil material at shallow depth and, predominantly deeper than one metre easily dispersing soil material (old alluvial deposits). Due to the low stability of the structure of this soil material, difficulties may arise in construction of canals and drains if this soil material has to be removed.

Class NS includes land that does not meet the minimum requirements for the other land suitability classes. The main limitation for most of the soils in river levee land and crevasse splays (990 ha) is the irregular pattern of stratified sand material. This implies an unfavourable and often unexpected drainage pattern. In addition, the topography would require expensive levelling. An area of 50 ha with river levee soils also has salinity limitation because of moderately to strongly saline soil material, starting at shallow depth.

Table 1.5.01 LAND CLASSIFICATION CRITERIA FOR LARGE-SCALE IRRIGATED RICE, NOT CONSIDERING IRRIGABILITY AND DRAINABILITY
Specification for Tana Delta Irrigation Project (Extension)

Land characteristics	Land classification criteria			
	suitability class			
	1	2	3	NS
Soil texture (z)	clay to clay loam over clay (within 50 cm)	clay to clay loam over clay (within 50 cm)	clay to clay loam over clay loam (within 50 cm)	Class NS includes land that does not meet the minimum requirements for the other land classes
Soil depth	90 cm plus	90 cm plus	90 cm plus	
Hydraulic conductivity	slow	slow	slow	
Soil reaction (a) (<100 cm depth)	pH-H_2O <8.5 to at least 80/100 cm depth	pH-H_2O <8.5 to at least 80/100 cm depth	pH-H_2O <8.5 to at least 50 cm depth	
	pH-H_2O >4.5 to at least 80/100 cm depth	pH-H_2O >4.5 to 40/70 cm depth; deeper pH-H_2O >3.5	pH-H_2O >4.5 to 20/40 cm depth, pH-H_2O >3.5 to 40/70 cm depth, deeper pH-H_2O 3.5 or less	
Soil salinity (s) (<100 cm depth)	0 - 40/70 cm non-saline 40/70 - 100 cm non-saline or slightly saline	- 0 - 40/70 cm non-saline 40/70 - 100 cm moderately saline - 0 - 20/40 cm non-saline or slightly saline 20/40 - 100 cm slightly saline	0 - 20/40 cm non-saline 20/40 - 40/70 cm slightly saline 40/70 - 100 cm moderately saline	
Soil sodicity (d) (<100 cm depth)	0 - 40/50 cm non-sodic 40/50 - 80/100 cm non-sodic to moderately sodic (ESP <15%)	0 - 40/50 cm non-sodic 40/50 - 80/100 cm non-sodic to moderately sodic (ESP <15%)	0 - 40/50 cm non to slightly sodic >40/50 cm moderately to strongly sodic	
Topography (t) — slope	<1%	<1%	<2%	
Topography (t) — meso and micro relief	smooth, except for gilgai and minor undulations	somewhat irregular (<5 dm); smooth, except for gilgai and minor undulations	slightly irregular (<1 m) but no major gullies or dissections	
Vegetation (T)	grassland up to moderate bush; woody cover less than 20%	up to moderate to thick bush; woody cover less than 40%	up to dense bush and thicket, but excluding continuous high woodland/ forest; woody cover less than 80%	

Table 1.5.02 Suitability classes; general description and indication of main limiting factor(s)

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	1 1(t) 1(T) 1(z) 1(s)	
2	Moderately suitable		
	Land of moderate productivity; slight to moderate limitations in soil qualities or requiring moderate costs for development	2a 2s 2s(t) 2s(T)	 2T 2t(z) 2z(T)
3	Marginally suitable Land of restricted productivity for irrigated rice; moderate to severe limitations in soil qualities and - in addition - requiring relatively high costs of development (i.e. levelling) or requiring relatively high costs for levelling and clearing	3s 3s(T) 3sT 3sa	 3sa(t) 3z(t) 3sd
NS	Unsuitable Land which is unsuited to sustained irrigated rice production; severe limitations in soils, topography and/or vegetation cover	NSz Nszs Nszt NSs NSzs(T)	

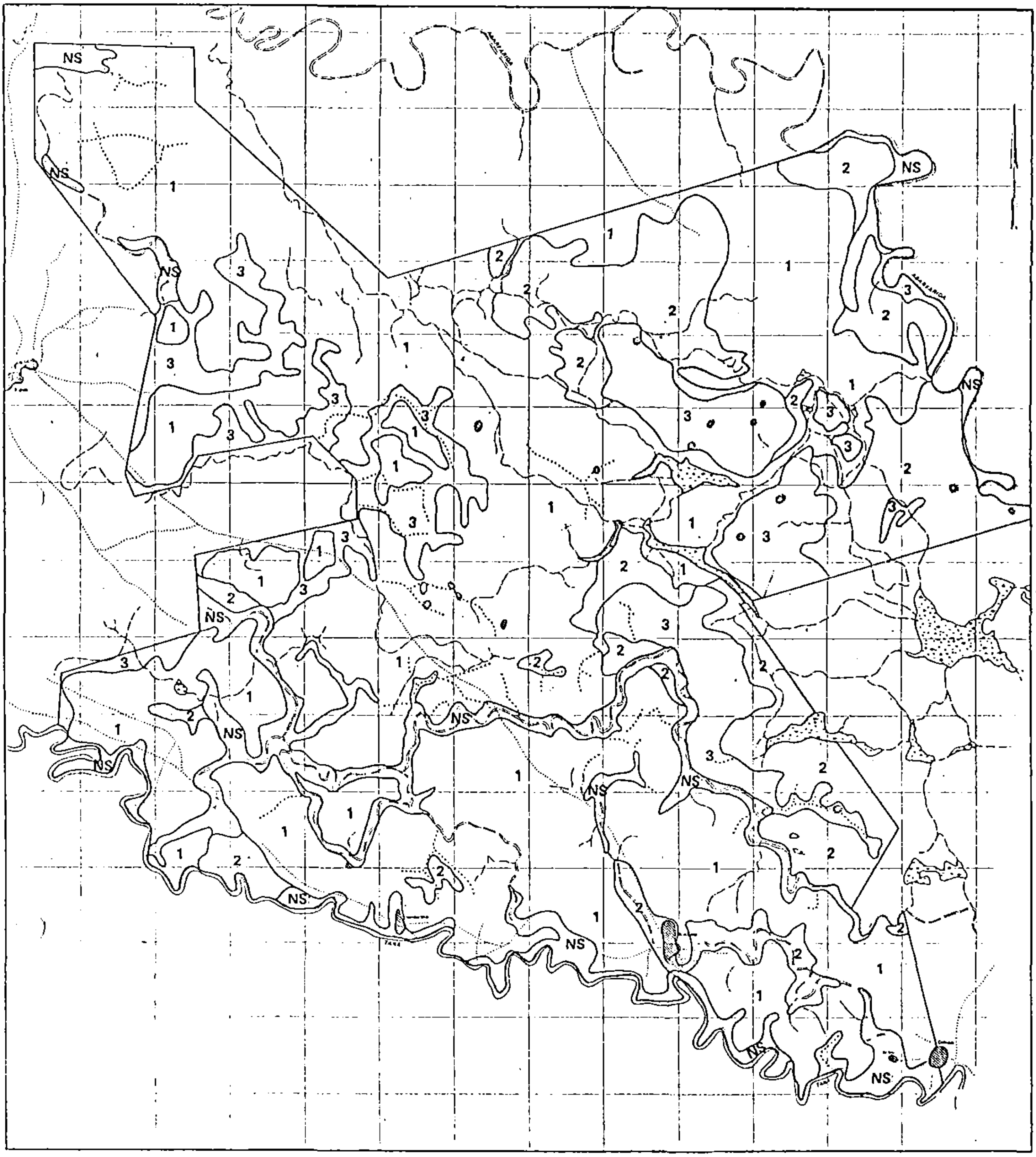
Key of codes for main limiting factors*

a soil reaction
d soil sodicity
s soil salinity
t topography
T vegetation
z soil texture

* A main limiting factor which represents only a minor limitation and which does not determine the suitability class is indicated in brackets.

Table 1.5.04 Soil mapping units and land suitability for large-scale irrigated rice

Soil mapping unit	Suitability class	Extent ha	Extent %
	1 HIGHLY SUITABLE		
L4 I S0, B1 I S0, B1 I S1, B2 I S0, B2 I S1, B3 I S0, Bm1 I S0, Bm2 I S0, Bm3 I S0, BM2 I S0, BM3 I S0, M2 I S1, M3 I S0, M3 I S0	1	4,040	39.0
B2 II S0, B2 II S1, B3 II S0, Bm1 II S0, Bm2 II S0, Bm3 II S0, Bm3 II S1, BM3 II S0, M3 II S0, M2/M3 II S1	1(t)	2,210	21.4
B1 I S0 b, B1 I S1 b, Bm I S0 b	1(T)	90	0.9
BL1 I S0, BL2 I S0, BL3 I S0	1(z)	60	0.6
BM3 I S1	1(s)	70	0.7
Total class 1		6,470	62.6
	2 MODERATELY SUITABLE		
B1 I S2, Bm1 I S2, Bm2 I S2, BM1 I S2, BM2 I S2, BM2 I S2, BM3 I S2, BM3 I S2, M1 I S2, M2 I S2, M2 I S2, M3 I S2	2s	1,125	10.[illegible]
B2 II S2, Bm3 II S2, BM3 II S2, M2 II S2, M2 II S2	2s(t)	255	2.4
B1 II S2 b	2s(T)	60	0.6
L4 I S0 b, L4 I S1 b, B1 I S0 f	2T	140	1.4
M3 I S1	2a	70	0.7
L4 II S0, BL1 II S0, BL3 II S0	2t(z)	90	0.9
BL1 I S0 b	2z(T)	10	0.1
Total class 2		1,750	16.9
	3 MARGINALLY SUITABLE		
Bm1 I S3, BM1 I S3, BM2 I S3, BM3 I S3, M1 I S3	3s	300	2.9
Bm1 I S3 b, Bm1 I S3 b, BM1 I S3 b	3s(T)	50	0.5
Bm1 I S2 f	3sT	35	0.3
L3 I S0 b	3z(T)	360	3.[illegible]
M2 I S2, M2 I S3	3sa	20	0.2
M2 II S2	3sa(t)	25	0.2
MT1 I S3	3sd	335	3.3
Total class 3		1,125	10.9
	NS UNSUITABLE		
L1 I S0 b, L1 I S0 f, L2 I S0 b, L3 I So f	NSzT	710	6.9
L1 I S0, L2 I S0	NSz	230	2.2
L1 I S2 b, L1 I S4 b	NSzs	30	0.3
L3 I S4 b	NSs	10	0.1
L1 I S2 f	NSzsT	10	0.1
Total class NS		990	9.6



LEGEND

code	Suitability class
1	Highly suitable
2	Moderately suitable
3	Marginally suitable
NS	Unsuitable

KEY

- Village
- Temporary settlement
- Footpath or track
- Tana River
- Former river course, deep
- Former river course, shallow
- Gully
- Secondary gully
- Swamp, intermittent lake
- Small ridge
- Boundary of semi-detailed Soil survey area

HASKONING BV
Mwenge International Associated Limited

title:

GENERALIZED LAND SUITABILITY MAP

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APPENDIX A

LABORATORY DATA OF PROFILE DESCRIPTION NO.: 1

Observation no.: P10 Soil classification: vertic FLUVISOL

Mapping unit: L1 I SO

Horizon	A1	C1	C2	C3	C4
Depth of sample (cm)	10-30	30-50	60-70	120-140	190-200
TEXTURE					
Sand % 2.0 - 0.05 mm	20	18	26	12	12
Silt % 0.05 - 0.002 mm	20	20	32	16	12
Clay % 0.002 - 0 mm	60	62	42	72	76
Texture class	C	C	C	C	C
CHEMICAL DATA					
pH-H_2O (1 : 2.5 v/v)	6.7	7.3	7.7	7.7	6.7
pH-KCl "	5.6	6.3	6.6	6.5	5.5
EC (mS/cm) "	0.29	0.40	0.55	1.30	0.29
$CaCO_3$ (%)	0.16	0.13	0.35	0.74	0.10
$CaSO_4$ (%)	0.06	-	0.06	-	0.03
C (%)	0.91	0.09	0.03	0.06	0.06
N (%)					
C/N					
CEC (me/100 g), pH 8.2	36.0	35.0	26.0	36.0	32.0
Exch. Ca (me/100 g)	10.9	13.7	8.5	18.0	18.0
" Mg "	9.2	9.7	7.0	11.7	12.2
" K "	1.1	1.0	0.6	0.6	0.8
" Na "	1.0	1.3	1.4	4.2	4.9
Sum of cations	22.2	25.7	17.5	34.5	35.9
Base sat. %, pH 8.2	62	73	67	96	>100
ESP at pH 8.2	3	4	5	12	15
Saturation extract:					
Moisture %					
pH-paste					
ECe (mS/cm)					

FERTILITY ASPECTS:

(depth in cm)	0-20 cm
Ca (me/100 g)	16.0
Mg "	7.2
K "	0.66
Na "	0.86
P (ppm)	44.0
Mn (me/100 g)	0.10
Exch. acidity (me/100 g)	
pH-H_2O (1 : 1 v/v)	5.9
C (%)	1.42
N (%)	0.19

FIELD LABORATORY DATA

Horizon	Depth (cm)	1 : 2.5 soil-water v/v	
		pH	EC (mS/cm)
A1	10-30	6.1	0.28
C1	30-50	7.2	0.5
C2	60-70	7.4	0.9
	120-140	7.3	2.2
	190-200	6.5	4.2
	300	5.7	2.7
	400	4.7	1.0
	500	6.4	0.42
gr.w.	500	6.8	1.2

Profile description no. 1

Observation/date : P10; coordinates E.637650/N.9726050; 21/9/'82

Mapping unit : L1 1 SO

Physiography : Floodplain; River levee land

Topography : flat; weak gilgai microrelief with sinkholes

Vegetation : grasses; some palmtrees and herbs

Salinity/sodicity : slightly saline and moderately sodic from 120 cm onwards

Drainage conditions : well to imperfectly drained; depth of seasonal floods: 0-10 cm; groundwater at 5.0 m depth

Profile description:

A1	0-30 cm	very dark gray (N3 dry) humic clay; strong, coarse prismatic structure breaking to weak to moderate, medium angular and subangular blocks; many, very fine pores; very hard when dry, very firm when moist, sticky and plastic when wet; few, fine, faint iron mottles; common, fine roots; gradual, wavy transition to
C1	30-50 cm	brown to dark brown (10YR 4/3 dry) clay; strong, coarse prismatic structure breaking to weak to moderate medium, angular and subangular blocks; few, thin slickensides; many, very fine pores; very hard when dry, very firm when moist, sticky and plastic when wet; few, fine, faint iron mottles; common, fine roots; gradual, wavy transition to
C2	50-80 cm	yellowish brown (10YR 5/4 dry) sandy clay loam; moderate to strong, medium, subangular blocky structure; many, fine pores; hard when dry, friable when moist, very sticky and slightly plastic when wet; common, fine,distinct iron mottles; common, fine roots; many micas; clear, smooth transition to
C3	80-170 cm	dusky red (7.5YR 3/2 dry) clay; strong, coarse angular blocky structure; abundant, thick slickensides; common, very fine pores; very hard when dry, very firm when moist, very sticky and very plastic when wet; common, medium, distinct iron mottles; common to few, very fine roots up to 110 cm; few carbonate (2 mm) and manganese (2 mm) concretions; gradual, smooth transition to
C4	170-250 cm	dark gray (10YR 4/1 dry) clay; strong, coarse angular blocky structure; abundant, thick slickensides; very hard when dry, very firm when moist, very sticky and very plastic when wet; common, coarse, prominent iron mottles; type of transition not observed because of augering from 200 cm onwards
A1b1	250-260 cm	black (N2 dry) clay, buried topsoil
C5	260-300 cm	dark grayish brown (10YR 4/2 dry) clay; very hard when dry, very firm when moist, very sticky and very plastic when wet; common, coarse, prominent iron mottles
A1b2	300-310 cm	black (N2 dry) clay; buried topsoil
C6	310-360 cm	very dark gray (N3 moist) clay; very firm when moist, sticky and plastic when wet; common, medium, distinct iron mottles
C7	360-440 cm	dark grayish brown (10YR 4/2 moist) clay; very firm when moist, very sticky and very plastic when wet; many, coarse, prominent, red and yellow mottles; many gypsum (2 mm) concretions
C8	440-500 cm	very dark gray (N3 wet) clay; very sticky and very plastic when wet; many micas

Remarks: From 0-10 cm high amount of organic matter.

LABORATORY DATA OF PROFILE DESCRIPTION NO.: 2

Observation no.: P1 — Soil classification: vertic FLUVISOL

Mapping unit: B3 I SO

Horizon	A1	C1	C2	C3	C4
Depth of sample (cm)	0-12	15-25	50-70	110-130	160-180
TEXTURE					
Sand % 2.0 - 0.05 mm	14	12	14	40	46
Silt % 0.05 - 0.002 mm	16	10	10	20	14
Clay % 0.002 - 0 mm	70	78	76	40	40
Texture class	C	C	C	C	SC
CHEMICAL DATA					
pH-H_2O (1 : 2.5 v/v)	5.8	6.3	7.6	7.7	7.7
pH-KCl "	4.7	5.2	6.6	6.6	6.5
EC (mS/cm) "	0.40	0.60	0.60	1.35	1.85
$CaCO_3$ (%)	0.16	0.16	0.15	0.26	0.31
$CaSO_4$ (%)	-	-	0.06	0.06	0.06
C (%)	1.85	0.98	0.46	0.35	0.06
N (%)					
C/N					
CEC (me/100 g), pH 8.2	36.0	36.0	33.0	28.0	26.0
Exch. Ca (me/100 g)	13.7	14.5	12.0	18.0	8.8
" Mg "	9.2	14.0	11.7	17.2	10.5
" K "	1.2	1.2	0.9	0.6	0.3
" Na "	0.8	1.2	1.8	3.8	2.3
Sum of cations	24.9	30.9	26.4	39.6	21.9
Base sat. %, pH 8.2	69	86	80	>100	84
ESP at pH 8.2	2	3	5	14	9
Saturation extract:					
Moisture %					
pH-paste					
ECe (mS/cm)					

FERTILITY ASPECTS:

(depth in cm)	0-20
Ca (me/100 g)	19.0
Mg "	8.2
K "	0.82
Na "	0.79
P (ppm)	30.0
Mn (me/100 g)	0.41
Exch. acidity (me/100 g)	
pH-H_2O (1 : 1 v/v)	5.4
C (%)	2.19
N (%)	0.26

FIELD LABORATORY DATA

Horizon	Depth (cm)	1 : 2.5 soil-water v/v pH	EC (mS/cm)
A1	0-12	6.5	0.19
C1	15-25	6.4	0.31
C2	50-70	6.4	0.45
C3	110-130	6.6	1.7
C4	160-180	6.6	3.0
C5	200	6.7	2.5
C5	300	7.0	2.6
C6	400	7.0	2.2
C7	500	7.0	1.9
gr.w.	165	6.7	9.0

Profile description no. 2

Observation/date : P1; coordinates E.635900/N.9734500; 5/10/'82

Mapping unit : B3 I S0

Physiography : Floodplain; River basin land

Topography : flat; gilgai microrelief

Vegetation : grasses and some herbs

Salinity/sodicity : deeper than 100 cm slightly to moderately saline and sodic

Drainage conditions : very poorly drained; depth of seasonal floods up to 100 cm; groundwater level at 1.6 m

Profile description:

A1	0-12 cm	black (N2 moist) humic clay; moderate, medium subangular and angular blocky structure; common, fine pores; very firm when moist, sticky and plastic when wet; many, medium, prominent iron mottles; common, fine roots; clear, wavy transition to
C1	12-28 cm	gray (10YR 5/1 moist) clay; moderate, medium subangular and angular blocky structure; few, thin slickensides; few, fine pores; very firm when moist, very sticky and very plastic when wet; many, medium, distinct iron mottles; few, fine roots; clear, wavy transition to
A1b1	28-34 cm	black (N2 moist) humic clay; buried topsoil
C2	34-106 cm	dark gray (10YR 4/1 moist) clay; moderate, medium angular blocky structure; common, medium slickensides; few, fine pores; very firm when moist, very sticky and very plastic when wet; few, fine, faint iron mottles; very few, very fine roots; gradual, wavy transition to
C3	106-142 cm	brown to dark brown (10 YR 4/3 moist) clay; moderate, medium angular blocky structure; common, medium slickensides; consistency as above; few, fine, faint iron mottles; few micas; clear, smooth transition to
A1b2	142-153 cm	very dark gray (N3 moist) humic clay; buried topsoil
C4	153-170 cm	dark gray (10YR 4/1 moist) sandy clay; strong, very fine subangular and angular blocky structure; few, thin slickensides; firm when moist, very sticky and slightly plastic when wet; many, medium, distinct iron mottles; few carbonate (4 mm) concretions; common micas; augering from 170 cm onwards
C5	170-330 cm	dark gray (10YR 4/1 moist) sandy clay; consistency as above; many, medium, distinct iron mottles, few carbonate (4 mm) concretions; few micas
C6	330-400 cm	dark gray (10YR 4/1 moist) sandy clay loam; firm when moist, sticky and non-plastic when wet; mottling as above; few carbonate (4 mm) concretions and a few micas
C7	400-500 cm	dark gray (10YR 4/1 moist) clay; firm when moist, very sticky and very plastic when wet; many, common, distinct iron mottles; few carbonate (4 mm) concretions; few micas

LABORATORY DATA OF PROFILE DESCRIPTION NO.: 3

Observation no.: P5 — Soil classification: vertic FLUVISOL

Mapping unit: B3 I S0

Horizon	A1	C1	A1b1	C2	C3
Depth of sample (cm)	5-10	10-20	30-40	100-110	150-170
TEXTURE					
Sand % 2.0 - 0.05 mm	16	12	14	10	12
Silt % 0.05 - 0.002 mm	10	8	16	10	12
Clay % 0.002 - 0 mm	74	80	70	80	76
Texture class	C	C	C	C	C
CHEMICAL DATA					
pH-H_2O (1 : 2.5 v/v)	5.5	5.7	5.3	6.9	7.8
pH-KCl "	4.4	4.6	4.2	5.8	6.3
EC (mS/cm) "	0.40	0.27	0.30	0.70	0.15
$CaCO_3$ (%)	0.07	0.11	0.08	0.12	0.78
$CaSO_4$ (%)	-	0.01	0.02	0.06	-
C (%)	0.31	0.34	0.88	0.31	0.03
N (%)					
C/N					
CEC (me/100 g), pH 8.2	43.0	48.0	47.0	43.0	42.0
Exch. Ca (me/100 g)	11.3	12.0	16.0	12.6	12.6
" Mg "	12.5	13.7	16.0	16.5	17.2
" K "	3.0	2.2	0.9	1.0	1.1
" Na "	1.8	1.8	1.8	4.0	5.0
Sum of cations	28.6	29.7	34.7	34.1	35.9
Base sat. %, pH 8.2	67	62	74	79	85
ESP at pH 8.2	4	4	4	9	12
Saturation extract:					
Moisture %					
pH-paste					
ECe (mS/cm)					

FERTILITY ASPECTS:

(depth in cm)	0-20
Ca (me/100 g)	13.2
Mg "	8.6
K "	1.14
Na "	1.18
P (ppm)	36.0
Mn (me/100 g)	0.13
Exch. acidity (me/100 g)	
pH-H_2O (1 : 1 v/v)	5.9
C (%)	1.2
N (%)	0.19

FIELD LABORATORY DATA

Horizon	Depth (cm)	1 : 2.5 soil-water v/v pH	EC (mS/cm)
A1	5-10	6.7	0.17
C1	10-20	6.7	0.17
A1b1	30-40	6.2	0.23
C2	100-110	6.9	0.8
C3	150-170	7.1	2.0
C4	200	7.3	2.6
C5	300	7.3	1.7
C7	400	7.3	0.6

Profile description no. 3

Observation/date : P5; coordinates E.637150/N.9731050; 20/9/'82

Mapping unit : B3 I SO

Physiography : Floodplain; River basin land

Topography : flat; weak gilgai to flat microrelief

Vegetation : grasses and some sedges

Salinity/sodicity : non-saline throughout; sodic from 100 cm onwards

Drainage conditions : very poorly drained; depth of floods up to 70 cm; groundwater at 2.20 m depth

Profile description:

A1	0-10 cm	very dark gray (10YR 3/1 moist) humic clay; weak, fine prismatic structure breaking to weak, coarse angular and sub-angular blocks; common, very fine pores; very hard when dry, very firm when moist, sticky and plastic when wet; few, fine roots; gradual, smooth transition to
C1	10-27 cm	dark gray (10YR 4/1 moist) clay; weak, fine prismatic structure breaking to weak, coarse, angular and subangular blocks; common, very fine pores; very hard when dry, very firm when moist, very sticky and very plastic when wet; many, medium, prominent iron mottles; few, fine roots; clear, smooth transition to
A1b1	27-40 cm	black (N2 moist) clay; buried topsoil
C2	40-120 cm	dark gray (10YR 4/1 moist) clay; moderate medium, angular blocky structure; common, medium slickensides; few, fine pores; very firm when moist, very sticky and very plastic when wet; few, fine, faint iron mottles; few, manganese (2 mm) concretions; few, very fine roots, clear, smooth transition to
A1b2	120-133 cm	black (N2 moist) clay; buried topsoil
C3	133-200 cm	dark grayish brown (10YR 4/2 moist) clay; moderate fine, angular blocky structure; abundant, thick slickensides; very firm when moist, very sticky and very plastic when wet; common, medium, distinct iron mottles; few carbonate (2 mm) concretions; augering from 200 cm onwards
C4	200-300 cm	dark grayish brown (10YR 4/2 moist) clay; very firm when moist, very sticky and very plastic when wet; common, medium, distinct iron mottles; few carbonate (2 mm) concretions
C5	300-340 cm	dark gray (10YR 4/1) clay; very firm when moist, very sticky and very plastic when wet; many, medium, prominent iron mottles; few carbonate (2 mm) concretions
C6	340-380 cm	dark gray (5Y 4/1 moist) clay; very sticky and very plastic when wet; many, medium, prominent iron mottles; few carbonate (2 mm) concretions; few micas
C7	380-400 cm	sand; end of augering because of sand flowing into augerhole

LABORATORY DATA OF PROFILE DESCRIPTION NO.: 4

Observation no.: P3 — Soil classification: vertic FLUVISOL, sodic phase

Mapping unit: B3 II SO

Horizon	A1	AC	C1	C2
Depth of sample (cm)	10-20	40-60	90-110	140-160
TEXTURE				
Sand % 2.0 - 0.05 mm	12	10	12	16
Silt % 0.05 - 0.002 mm	22	12	6	20
Clay % 0.002 - 0 mm	66	78	82	64
Texture class	C	C	C	C
CHEMICAL DATA				
pH-H_2O (1 : 2.5 v/v)	6.3	7.3	7.8	7.5
pH-KCl "	4.8	6.2	6.7	6.3
EC (mS/cm) "	0.45	0.18	1.60	3.50
$CaCO_3$ (%)	0.12	0.12	0.14	0.26
$CaSO_4$ (%)	-	0.06	0.06	-
C (%)	1.56	1.20	0.49	0.17
N (%)				
C/N				
CEC (me/100 g), pH 8.2	44.0	43.0	48.0	36.0
Exch. Ca (me/100 g)	25.0	13.3	17.8	16.5
" Mg "	17.7	14.8	20.7	16.5
" K "	0.8	0.8	1.1	1.0
" Na "	4.0	4.0	11.0	9.3
Sum of cations	47.5	32.9	50.6	43.3
Base sat. %, pH 8.2	>100	77	>100	>100
ESP at pH 8.2	9	9	23	26.
Saturation extract:				
Moisture %				
pH-paste				
ECe (mS/cm)				

FERTILITY ASPECTS:

(depth in cm)	0-20
Ca (me/100 g)	18.3
Mg "	8.8
K "	0.56
Na "	1.24
P (ppm)	32.0
Mn (me/100 g)	0.18
Exch. acidity (me/100 g)	
pH-H_2O (1 : 1 v/v)	5.5
C (%)	1.71
N (%)	0.24

FIELD LABORATORY DATA

Horizon	Depth (cm)	1 : 2.5 soil-water v/v pH	EC (mS/cm)
A1	10-20	7.3	0.21
AC	40-60	7.3	0.43
C1	90-110	7.1	2.2
C2	140-160	7.0	3.4
C3	200	7.4	4.6
C3	250	7.2	4.6
C3	300	7.1	4.0
C4	350	7.2	2.7
C5	390	7.4	3.6

Profile description no. 4

Observation/date : P3; coordinates E.640800/N.9731850; 29/9/'82

Mapping unit : B3 II SO

Physiography : Floodplain; River basin land

Topography : flat; flat microrelief

Vegetation : grasses

Salinity/sodicity : from 100 cm depth slightly saline; sodic throughout

Drainage conditions : poorly drained; depth of seasonal floods up to 70 cm; groundwater at 1.10 m depth

Profile description:

A1	0-40 cm	very dark gray (N3 moist) humic clay; weak, very coarse prismatic structure breaking to weak, very fine subangular and angular blocks; common, medium slickensides; common, very fine pores; very firm when moist, sticky and very plastic when wet; few, very fine roots; distinct, smooth transition to
A/C	40-60 cm	grayish brown (10YR 5/2 moist) clay; weak, very fine angular blocky structure; common, medium slickensides; common, very fine pores; very firm when moist, sticky and very plastic when wet; few, very fine roots; gradual, irregular transition to
C1	60-140 cm	gray to grayish brown (2.5Y 5/1 moist) clay; moderate, fine angular blocky structure; abundant, thick slickensides; very firm when moist, sticky and very plastic when wet; gradual smooth transition to
C2	140-190 cm	gray to grayish brown (2.5Y 5/1 moist) clay; structureless; abundant, thick slickensides; firm when moist, sticky and plastic when wet; common, medium, distinct iron mottles; few micas; type of transition not observed because of augering from 190 cm onwards
C3	190-320 cm	gray (5Y 5/1 moist) clay; firm when moist, sticky and plastic when wet; common, mediumn, distinct iron mottles; few carbonate (2 mm) concretions up to 250 cm; few micas
C4	320-370 cm	dark gray (5Y 4/1 moist) clay with sand in nests; firm when moist, sticky and plastic when wet; few, fine distinct iron mottles; common micas
C5	370-400 cm	very dark gray to black (5Y 2.5/1 moist) sandy clay; friable when moist, sticky and slightly plastic when wet; common micas; end of augering because of sand flowing into augerhole

LABORATORY DATA OF PROFILE DESCRIPTION NO.: 5

Observation no.: P9 — Soil classification: vertic FLUVISOL, sodic phase

Mapping unit: BL1 I SO

Horizon	A1	AC	C1	C2	C3	C4
Depth of sample (cm)	5-15	30-45	70-100	110-130	130-150	150-170
TEXTURE						
Sand % 2.0 - 0.05 mm	14	12	10	14	42	16
Silt % 0.05 - 0.002 mm	10	8	12	12	32	26
Clay % 0.002 - 0 mm	76	80	78	74	26	58
Texture class	C	C	C	C	L	C
CHEMICAL DATA						
pH-H_2O (1 : 2.5 v/v)	5.6	6.6	6.9	6.8	7.0	6.8
pH-KCl "	4.6	5.5	5.9	5.7	5.9	5.7
EC (mS/cm) "	0.29	0.35	1.00	1.60	1.20	1.60
$CaCO_3$ (%)	0.01	0.01	0.17	0.07	0.09	0.12
$CaSO_4$ (%)	0.01	0.06	-	-	-	0.01
C (%)	1.03	0.03	0.03	1.14	0.03	0.40
N (%)						
C/N						
CEC (me/100 g), pH 8.2	37.0	32.0	32.0	37.0	19.2	34.0
Exch. Ca (me/100 g)	14.0	13.7	15.4	16.3	8.0	13.3
" Mg "	13.2	14.3	14.5	13.2	7.0	11.6
" K "	1.2	0.9	0.7	0.8	0.4	0.7
" Na "	1.5	2.5	5.3	7.3	4.9	7.8
Sum of cations	29.9	31.4	35.9	37.6	20.3	33.4
Base sat. %, pH 8.2	81	98	>100	>100	>100	98
ESP at pH 8.2	4	8	16	20	26	23
Saturation extract:						
Moisture %						
pH-paste						
ECe (mS/cm)						

FERTILITY ASPECTS:

(depth in cm)	0-20
Ca (me/100 g)	14.4
Mg "	8.2
K "	0.44
Na "	1.46
P (ppm)	36.0
Mn (me/100 g)	0.16
Exch. acidity (me/100 g)	
pH-H_2O (1 : 1 v/v)	6.3
C (%)	1.14
N (%)	0.15

FIELD LABORATORY DATA

Horizon	Depth (cm)	1 : 2.5 soil-water v/v pH	EC (mS/cm)
A11	5-15	6.5	0.2
A12	30-45	6.9	0.28
C1	70-100	7.1	1.3
C2	110-130	7.0	2.4
C3	130-150	7.0	2.4
C4	150-170	7.0	3.0
C5	200	7.0	2.8
A1b2	230	7.1	2.7
C6	300	6.8	4.0
C8	400	6.8	4.0
C9	480	7.3	5.0
gr.w.	370	6.5	18

Profile description no. 5

Observation/date : P9; coordinates E.638100/N.9726950; 12/9/'82

Mapping unit : BL1 l SO

Physiography : Floodplain; River basin land

Topography : flat, some gullies; weak gilgai microrelief

Vegetation : grasses

Salinity/sodicity : from 0-200 cm non-saline; sodic

Drainage conditions : imperfectly drained; depth of floods up to 20 cm; groundwater at 3.70 m depth

Profile description:

A11	0-20 cm	very dark gray (10YR 3/1 dry) humic clay; coarse prismatic structure breaking to moderate, fine angular and subangular blocks; few, fine pores; very hard when dry, very firm when moist, sticky and plastic when wet; common, fine roots; gradual, wavy transition to
A12	20-50 cm	dark gray (10YR 4/1 dry) humic clay; strong, coarse prismatic structure breaking to weak, medium angular blocks; common, medium slickensides; few, fine pores; very hard when dry, very firm when moist, sticky and very plastic when wet; few, fine, faint iron mottles; few, fine roots; gradual, wavy transition to
C1	50-105 cm	dusky red (7.5YR 3/2 dry) clay; moderate, medium prismatic structure and weak, coarse angular blocky structure; abundant, thick slickensides; few, fine pores; very hard when dry, very firm when moist, sticky and very plastic when wet; common, fine, distinct iron mottles; very few, very fine roots; clear, smooth transition to
A1b1	105-110 cm	very dark grayish brown (10YR 3/2 moist) clay, buried topsoil; clear, smooth transition to
C2	110-130 cm	dark brown (10YR 3/3 moist) clay; moderate, coarse angular blocky structure; abundant, thick slickensides; common, very fine pores; very hard when dry, very firm when moist, sticky and very plastic when wet; few, fine, faint iron mottles; many micas; abrupt, smooth transition to
C3	130-150 cm	light brownish gray (2.5Y 6/2 moist) sandy clay loam;structureless; few, very fine pores; slightly hard when dry, friable when moist, sticky and slightly plastic when wet; common, medium, distinct iron mottles; few micas; clear, smooth transition to
C4	150-190 cm	dark brown (10YR 3/3 moist) clay; weak, very fine, angular blocky structure; few, very fine pores; very hard when dry, very firm when moist, sticky and very plastic when wet; type of transition not observed because of augering from 190 cm onwards
C5	190-220 cm	dark brown (10YR 3/3 moist) clay; very hard when dry, very firm when moist, sticky and very plastic when wet
A1b2	220-240 cm	black (N2 moist) clay; buried topsoil
C6	240-310 cm	dark grayish brown (10YR 4/2 wet) clay; sticky and very plastic when wet; common, medium, distinct iron mottles; many micas
C7	310-330 cm	dark gray (5Y 4/1 wet) sandy clay; very sticky and very plastic when wet; many, medium, distinct iron mottles; many micas
C8	330-400 cm	dark gray (5Y 4/1 wet) sandy clay loam; very sticky and very plastic when wet; many, medium, distinct iron mottles; many micas
C9	400-500 cm	dark greenish gray (5G 4/1 wet) clay; very sticky and very plastic when wet; many, coarse, prominent yellow mottles (jarosite)

LABORATORY DATA OF PROFILE DESCRIPTION NO.: 6

Observation no.: P12 — Soil classification: vertic FLUVISOL

Mapping unit: BL3 II SO

Horizon	A1	C1	A1b1	C2	A1b2	C3
Depth of sample (cm)	0-10	20-40	46-55	60-80	100-120	130-150
TEXTURE						
Sand % 2.0 - 0.05 mm	12	10	16	10	24	30
Silt % 0.05 - 0.002 mm	16	6	18	16	26	36
Clay % 0.002 - 0 mm	72	84	66	74	50	34
Texture class	C	C	C	C	C	CL
CHEMICAL DATA						
pH-H_2O (1 : 2.5 v/v)	6.7	6.9	6.8	6.9	7.1	7.4
pH-KCl "	5.5	5.8	5.8	5.8	6.0	6.3
EC (mS/cm) "	0.29	0.35	0.30	0.50	0.30	0.35
$CaCO_3$ (%)	0.07	0.10	0.09	0.10	0.09	0.11
$CaSO_4$ (%)	0.03	0.06	0.06	0.06	0.06	0.06
C (%)	0.08	0.03	1.13	0.03	0.03	0.03
N (%)						
C/N						
CEC (me/100 g), pH 8.2	44.0	43.0	49.0	43.0	32.0	21.0
Exch. Ca (me/100 g)	11.2	13.1	13.2	12.6	6.9	6.3
" Mg "	12.7	17.5	17.0	17.2	10.5	8.0
" K "	1.7	0.9	0.6	0.6	0.3	0.4
" Na "	0.3	1.2	1.4	1.7	0.9	1.2
Sum of cations	25.9	32.7	32.2	32.1	18.6	15.9
Base sat. %, pH 8.2	59	76	66	75	58	76
ESP at pH 8.2	1	3	3	4	3	6
Saturation extract:						
Moisture %						
pH-paste						
ECe (mS/cm)						

FERTILITY ASPECTS:

(depth in cm)	0-20
Ca (me/100 g)	15.0
Mg "	9.2
K "	0.96
Na "	0.73
P (ppm)	38.0
Mn (me/100 g)	0.34
Exch. acidity (me/100 g)	
pH-H_2O (1 : 1 v/v)	6.1
C (%)	1.48
N (%)	0.19

FIELD LABORATORY DATA

Horizon	Depth (cm)	1 : 2.5 soil-water v/v pH	1 : 2.5 soil-water v/v EC (mS/cm)
A1	0-10	7.1	0.27
C1	20-40	6.9	0.32
A1b1	46-55	6.9	0.40
C2	60-80	6.9	0.43
A1b2	100-120	6.4	0.43
C3	130-150	7.3	0.49
C4	200	7.2	0.5
C5	300	6.8	0.6
C6	360	6.0	1.6

Profile description no. 6

Observation/date : P12; coordinte E.640450/N.9724850; 21/9/'82

Mapping unit : BL3 II S0

Physiography : Floodplain; River basin land

Topography : flat; flat microrelief

Vegetation : grasses and some herbs

Salinity/sodicity : non-saline and non-sodic throughout

Drainage conditions : very poorly drained; depth of seasonal floods 40-60 cm; groundwater at 0.60 m depth

Profile description:

A1	0-10 cm	very dark gray (10YR 3/1 moist) humic clay; weak, medium prismatic structure breaking to weak, medium angular and subangular blocks; common, fine pores; very hard when dry, very firm when moist, sticky and plastic when wet; few, fine, faint iron mottles; common, fine roots; gradual, smooth transition to
C1	10-46 cm	dark gray (10YR 4/1 moist) clay; weak to moderate, medium angular and subangular blocky structure; common, medium slickensides; common, fine pores; very hard when dry, very firm when moist, very sticky and very plastic when wet; common, coarse, distinct iron mottles; common, fine roots; clear, smooth transition to
A1b1	46-55 cm	black (N2 moist) humic clay; buried topsoil
C2	55-90 cm	dark gray (10YR 4/1 moist) clay; moderate, fine angular blocky structure; abundant, thick slickensides; few, very fine pores; very firm when moist, very sticky and very plastic when wet; many, coarse, prominent iron mottles; common, very fine roots; clear, wavy transition to
A1b2	90-120 cm	black (N2 moist) humic clay; weak, fine angular blocky structure; abundant, thick slickensides; few, very fine pores; very firm when moist, sticky and plastic when wet; very few, very fine roots; clear, smooth transition to
C3	120-190 cm	very dark gray (10YR 3/1 moist) sandy clay loam; structureless; common, micro pores; friable when moist, very sticky and slightly plastic when wet; many, medium, prominent iron mottles; many micas; clear, smooth transition to
C4	190-220 cm	very dark gray (10YR 3/1 moist) clay; very sticky and very plastic when wet; many, coarse, prominent iron mottles; many micas; type of transition not observed because of augering from 200 cm onwards
C5	220-300 cm	very dark gray (N3 wet) sand; non-sticky and non-plastic; many, medium, iron mottles; many micas
C6	300-360 cm	black, unripened clay; very sticky and very plastic; end of augering because of water prohibiting the augering of the soil material

LABORATORY DATA OF PROFILE DESCRIPTION NO.: 7

Observation no.: P8

Soil classification: vertic FLUVISOL

Mapping unit: Bm3 I SO

Horizon	A1	C1	C2	C3
Depth of sample (cm)	5-15	35-45	65-75	125-140
TEXTURE				
Sand % 2.0 - 0.05 mm	18	12	12	10
Silt % 0.05 - 0.002 mm	18	8	6	10
Clay % 0.002 - 0 mm	64	80	82	80
Texture class	C	C	C	C
CHEMICAL DATA				
pH-H_2O (1 : 2.5 v/v)	5.2	6.0	6.0	6.3
pH-KCl "	4.1	4.9	4.9	5.2
EC (mS/cm) "	0.35	0.40	0.60	0.70
$CaCO_3$ (%)	0.11	0.08	0.07	0.08
$CaSO_4$ (%)	-	-	-	-
C (%)	1.83	0.97	0.31	0.23
N (%)				
C/N				
CEC (me/100 g), pH 8.2	39.0	37.0	36.0	37.0
Exch. Ca (me/100 g)	10.5	14.0	13.5	14.2
" Mg "	9.2	11.0	13.2	11.0
" K "	1.6	1.7	1.1	1.4
" Na "	0.5	1.0	1.5	1.8
Sum of cations	21.8	27.7	29.3	28.4
Base sat. %, pH 8.2	56	75	81	77
ESP at pH 8.2	1	3	4	5
Saturation extract:				
Moisture %				
pH-paste				
ECe (mS/cm)				

FERTILITY ASPECTS: (depth in cm)	0-20
Ca (me/100 g)	15.0
Mg "	7.2
K "	0.66
Na "	0.64
P (ppm)	32.0
Mn (me/100 g)	0.20
Exch. acidity (me/100 g)	
pH-H_2O (1 : 1 v/v)	5.4
C (%)	1.65
N (%)	0.24

FIELD LABORATORY DATA

Horizon	Depth (cm)	1 : 2.5 soil-water v/v	
		pH	EC (mS/cm)
A1	5-15	6.4	0.18
C1	35-45	6.4	0.34
C2	65-75	6.4	0.45
C3	125-140	6.4	0.6
C4	200	6.3	1.2
C6	300	3.7	2.3
C7	400	5.6	0.8
gr.w.	270	3.9	3.5

Profile description no. 7

Observation/date : P8; coordinates E.639350/N.9727800; 14/9/'82

Mapping unit : Bm3 I SO

Physiography : Floodplain; River basin land

Topography : flat; weak gilgai microrelief

Vegetation : grasses and some sedges

Salinity/sodicity : non-saline and non-sodic throughout

Drainage conditions : very poorly drained; depth of floods up to 80 cm; groundwater at 2.70 m depth

Profile description:

A1	0-25 cm	very dark gray (N3 moist) humic clay; weak, fine angular and subangular blocky structure; common, fine pores; very hard when dry, very firm when moist, sticky and plastic when wet; few, fine, faint iron mottles; frequent, fine roots; gradual, wavy transition to
C1	25-50 cm	dark gray (N4 moist) clay; weak, coarse angular blocky structure; few, thin slickensides; common, fine pores; very firm when moist, sticky and very plastic when wet; common, medium, distinct iron mottles; few, manganese (3 mm) concretions; few, fine roots; gradual, wavy transition to
C2	50-80 cm	dark grayish brown (10YR 4/2 moist) clay; moderate, coarse angular blocky structure; common, medium slickensides; many, medium pores; very firm when moist, very sticky and very plastic when wet; many, coarse, distinct iron mottles; very few, very fine roots; few manganese (1 mm) concretions; clear, wavy transition to
A1b	80-85 cm	very dark gray (N3) clay; buried topsoil; clear, wavy transition to
C3	85-200 cm	dark gray (N4 moist) clay; moderate, coarse angular blocky structure; abundant, thick slickensides; few, very fine pores; very firm when moist, very sticky and very plastic when wet; few, fine, faint iron mottles; very few, very fine roots up to 160 cm; few manganese (1 mm) concretions; augering from 220 cm onwards
C4	200-230 cm	dark gray (N4 moist) clay; very sticky and very plastic when wet; common, medium, distinct iron mottles and prominent yellow mottling
C5	230-280 cm	dark gray (N4 moist) sandy clay; very sticky and plastic when wet; mottling as above
C6	280-310 cm	dark gray (N4 wet) loamy sand; very sticky and non-plastic; many, coarse, prominent iron mottles
C7	310-400 cm	very dark gray (N3 wet) sand; end of augering because of sand flowing into augerhole

LABORATORY DATA OF PROFILE DESCRIPTION NO.: 8

Observation no.: P11 — Soil classification: vertic FLUVISOL

Mapping unit: Bm3 I SO

Horizon	A1	C1	C2	C3
Depth of sample (cm)	0-15	20-30	60-80	140-160
TEXTURE				
Sand % 2.0 - 0.05 mm	14	12	12	14
Silt % 0.05 - 0.002 mm	16	8	12	14
Clay % 0.002 - 0 mm	70	80	76	72
Texture class	C	C	C	C
CHEMICAL DATA				
pH-H_2O (1 : 2.5 v/v)	5.7	6.6	6.5	6.4
pH-KCl "	4.4	5.1	5.0	4.9
EC (mS/cm) "	0.55	0.55	0.70	1.50
$CaCO_3$ (%)	0.15	0.15	0.15	0.13
$CaSO_4$ (%)	0.01	-	-	0.01
C (%)	1.93	0.64	0.55	0.09
N (%)				
C/N				
CEC (me/100 g), pH 8.2	48.0	39.0	39.0	32.0
Exch. Ca (me/100 g)	20.5	10.5	9.6	15.4
" Mg "	14.0	12.7	12.2	17.2
" K "	1.5	0.9	0.8	1.4
" Na "	1.2	1.3	1.4	1.2
Sum of cations	37.2	25.4	24.0	35.2
Base sat. %, pH 8.2	78	65	62	>100
ESP at pH 8.2	3	3	4	4
Saturation extract:				
Moisture %				
pH-paste				
ECe (mS/cm)				

FERTILITY ASPECTS:

(depth in cm)	0-20
Ca (me/100 g)	18.1
Mg "	8.2
K "	0.56
Na "	1.02
P (ppm)	36.0
Mn (me/100 g)	0.18
Exch. acidity (me/100 g)	
pH-H_2O (1 : 1 v/v)	5.8
C (%)	2.56
N (%)	0.40

FIELD LABORATORY DATA

Hori-zon	Depth (cm)	1 : 2.5 soil-water v/v	
		pH	EC (mS/cm)
A1	0-15	6.4	0.22
C1	20-30	6.4	0.32
C2	60-80	6.5	0.56
C3	140-160	6.4	1.7
C4	200	5.8	2.5
C4	250	3.4	4.7
C5	300	4.6	3.2
C5	350	6.0	2.5
C5	400	7.0	2.6
C5	450	7.5	2.7
C5	500	7.6	2.1
gr.w.	60	7.5	5.0

Profile description no. 8

Observation/date	: P11; coordinates E.643400/N.9725700; 7/10/'82
Mapping unit	: Bm3 l SO
Physiography	: Floodplain; Estuarine basin land
Topography	: flat; flat microrelief
Vegetation	: grasses
Salinity/sodicity	: from 120 cm slightly saline; non-sodic up to 200 cm depth
Drainage conditions	: very poorly drained; depth of seasonal floods 50-80 cm; groundwater at 0.6 m depth

Profile description:

A1	0-15 cm	very dark gray (N3 moist) humic clay; weak, fine subangular and angular blocky structure; common, fine pores; firm when moist, sticky and plastic when wet; few, fine, faint iron mottles; common, fine roots; gradual, smooth transition to
C1	15- 35 cm	dark gray (N4 moist) clay; moderate, medium subangular and angular blocky structure; common, medium slickensides; common, fine pores; very firm when moist, sticky and very plastic when wet; common, medium, distinct iron mottles; common, fine roots; clear, smooth transition to
C2	35-120 cm	dark gray (N4 moist) clay; moderate, medium angular blocky structure; common, medium slickensides; few, very fine pores; very firm when moist, sticky and very plastic when wet; few, fine, faint iron mottles; few fine roots up to 100 cm; clear, wavy transition to
C3	120-200 cm	grayish brown (2.5Y 5/2 moist) clay; strong, fine angular blocky structure; abundant, thick slickensides; very firm when moist, very sticky and very plastic when wet; few, fine, faint iron mottles; few iron (2 mm) concretions; augering from 200 cm onwards
C4	200-290 cm	grayish brown (2.5Y 5/2 wet) clay; very sticky and very plastic when wet; common, medium, distinct iron mottles
C5	290-550 cm	dark greenish gray (5GY 4/1 wet) sandy clay; very sticky and plastic when wet; common micas; sandy loam from 550 cm onwards

LABORATORY DATA OF PROFILE DESCRIPTION NO.: 9

Observation no.: P6

Soil classification: vertic FLUVISOL, saline-sodic phase

Mapping unit: Bm3 I SO

Horizon	A1	C1	C2	C3
Depth of sample (cm)	10-20	40-50	90-100	160-170
TEXTURE				
Sand % 2.0 - 0.05 mm	22	20	14	12
Silt % 0.05 - 0.002 mm	10	22	6	20
Clay % 0.002 - 0 mm	68	58	80	68
Texture class	C	C	C	C
CHEMICAL DATA				
pH-H_2O (1 : 2.5 v/v)	6.9	7.4	6.9	7.0
pH-KCl "	6.0	6.3	6.0	6.0
EC (mS/cm) "	0.30	0.85	5.00	4.00
$CaCO_3$ (%)	0.11	0.10	0.14	0.14
$CaSO_4$ (%)	0.06	0.06	1.11	0.02
C (%)	0.65	1.17	0.11	0.17
N (%)				
C/N				
CEC (me/100 g), pH 8.2	37.0	32.0	37.0	36.0
Exch. Ca (me/100 g)	10.5	9.2	18.0	11.5
" Mg "	14.7	14.8	13.2	12.0
" K "	1.2	0.8	1.1	1.2
" Na "	2.4	4.9	12.5	11.0
Sum of cations	28.8	29.7	44.8	35.7
Base sat. %, pH 8.2	78	93	>100	99
ESP at pH 8.2	6	15	34	31
Saturation extract:				
Moisture %				
pH-paste				
ECe (mS/cm)				

FERTILITY ASPECTS:
(depth in cm)

Ca (me/100 g)

Mg "

K "

Na "

P (ppm)

Mn (me/100 g)

Exch. acidity (me/100 g)

pH-H_2O (1 : 1 v/v)

C (%)

N (%)

FIELD LABORATORY DATA

Horizon	Depth (cm)	1 : 2.5 soil-water v/v	
		pH	EC (mS/cm)
A1	10-20	6.7	0.46
C1	40-50	7.0	1.1
C2	90-100	6.3	5.0
C3	160-170	6.7	6.0
C3	200	6.8	5.0
C4	300	6.6	3.4
C5	400	6.9	3.0
gr.w.	200	6.2	20

Profile description no. 9

Observation/date : P6; coordinates E.642000/N.9728550; 24/9/'82

Mapping unit : Bm3 I SO

Physiography : Floodplain; River basin land

Topography : flat; flat microrelief

Vegetation : grasses

Salinity/sodicity : moderately saline from 80 cm onwards; sodic throughout

Drainage conditions : very poorly drained; depth of seasonal floods 40-70 cm; groundwater at 2.0 m depth

Profile description:

A1	0-27 cm	very dark gray (N2 moist) humic clay; moderate, very coarse prismatic structure breaking to moderate, coarse angular and subangular blocks; common, very fine pores; very hard when dry, very firm when moist, sticky and very plastic when wet; few, fine, faint iron mottles; frequent, very fine roots; gradual, wavy transition to
C1	27-60 cm	gray (10YR 5/1 moist) clay; moderate to weak, coarse prismatic structure breaking to weak to moderate, coarse sub-angular and angular blocks; few, thin slickensides; common, very fine pores; very hard when dry, very firm when moist, sticky and very plastic when wet; common, medium, distinct iron mottles; few, very fine roots; gradual, wavy transition to
C2	60-150 cm	gray (10YR 5/1 moist) clay; weak, medium angular blocky structure; abundant, thick slickensides; few, very fine pores; very firm when moist, sticky and very plastic when wet; few, fine, faint iron mottles; few, very fine roots up to 80 cm; gradual, wavy transition to
C3	150-275 cm	gray (10YR 6/1 moist) clay; weak, coarse angular blocky structure; abundant, thick slickensides; very firm when moist, very sticky and very plastic when wet; common, medium, distinct iron mottles; type of transition not observed because of augering from 200 cm onwards
C4	275-315 cm	dark greenish gray (5BG 4/1 moist) clay; very firm when moist, sticky and very plastic when wet; few micas
C5	315-430 cm	dark gray (N4 wet) sandy clay; friable when moist, slightly sticky and plastic when wet; end of augering because of sand flowing into augerhole

LABORATORY DATA OF PROFILE DESCRIPTION NO.: 10

Observation no.: P2 Soil classification: vertic FLUVISOL

Mapping unit: Bm3 II S1

Horizon	A11	A12	A13	C1	C2	C4
Depth of sample (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 (mS/cm) "	0.40	0.40	0.85	1.10	1.55	1.60
$CaCO_3$ (%)						
$CaSO_4$ (%)						
C (%)	2.28	1.21	0.23	0.17	0.14	1.36
N (%)						
C/N						
CEC (me/100 g), pH 8.2	51.8	55.4	45.4	32.6	41.6	34.6
Exch. Ca (me/100 g)	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:						
Moisture %			109.3	104.1	89.8	
pH-paste			7.8	7.6	8.0	
ECe (mS/cm)			1.05	2.35	4.5	

FERTILITY ASPECTS:

(depth in cm)	5-10	0-20
Ca (me/100 g)	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/100 g)	0.13	0.20
Exch. acidity (me/100 g)		
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 (cm)	1 : 2.5 soil-water v/v	
		pH	EC (mS/cm)
A11	10	5.6	0.58
A12	20	6.4	0.53
A13	40	7.6	1.0
C1	70	7.7	1.6
C1	110	6.8	3.3
C2	170	7.4	3.3
C3	200	7.4	2.9
C3	280	7.0	2.1
gr.w.	330	6.9	5.0

Profile description no. 10

Observation/date : P2; coordinated E.645450/N.9732850; 29/3/'81

Mapping unit : Bm3 II S1

Physiography : Floodplain; River basin land

Topography : flat; gilgai microrelief

Vegetation : grassland

Salinity/sodicity : non-saline and non-sodic throughout

Drainage conditions : poorly drained; depth of seasonal floods up to 100 cm; groundwater at 3.3 m depth

Profile description:

A11 0-10 cm black (N2 moist) humic clay; moderate, very fine angular blocky structure; firm when moist, slightly sticky and plastic when wet; common, fine, distinct iron mottles along root channels; many, fine roots; clear, smooth transition to

A12 10-20 cm 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

A13 20-40 cm very dark gray (10 YR 3/1 moist) and pockets of black (N2 moist) clay; strong, very fine angular blocky structure; abundant, medium slickensides; very firm when moist, very sticky and very plastic when wet; common, fine roots; few carbonate (5 mm) concretions; clear, wavy transition to

C1 40-150 cm 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, decreasing to very few, fine roots up to a depth of 80 cm; few carbonate (3-10 mm) and manganese (3 mm) concretions; clear, smooth transition to

C2 150-180 cm very dark gray (5Y 3/1 moist) clay; weak, coarse angular blocky structure; firm when moist, sticky and very plastic when wet; common, fine, distinct iron mottles; few carbonate (3 mm) and manganese (3 mm) concretions; many micas

C3 180-300 cm greenish gray (5GY 5/1 moist) sandy loam; very sticky and plastic when wet; common, coarse, prominent iron mottles

C4 300-360 cm greenish gray (5BG 5/1 moist) clay alternating with sandy loam; very sticky and slightly plastic when wet; end of augering due to unripened soil material

LABORATORY DATA OF PROFILE DESCRIPTION NO.: 11

Observation no.: P7 | Soil classification: vertic FLUVISOL

Mapping unit: BM2 I S3

Horizon	A1	C1	A1b	C2	C3	C4
Depth of sample (cm)	2-20	30-50	70-90	100-110	140-160	170-190
TEXTURE						
Sand % 2.0 - 0.05 mm	14	10	14	10	12	16
Silt % 0.05 - 0.002 mm	16	10	18	18	14	14
Clay % 0.002 - 0 mm	70	80	68	72	74	70
Texture class	C	C	C	C	C	C
CHEMICAL DATA						
pH-H_2O (1 : 2.5 v/v)	6.0	6.2	4.8	4.1	3.7	3.7
pH-KCl "	5.0	5.1	4.0	3.3	3.3	3.0
EC (mS/cm) "	0.40	0.45	0.85	2.90	3.50	2.30
$CaCO_3$ (%)	0.10	0.10	0.07	0.09	0.09	0.12
$CaSO_4$ (%)	0.06	0.06	-	0.41	0.02	0.02
C (%)	0.45	0.31	0.74	0.37	0.40	0.40
N (%)						
C/N						
CEC (me/100 g), pH 8.2	43.0	39.0	43.0	39.0	36.0	39.0
Exch. Ca (me/100 g)	12.0	11.3	13.7	14.2	10.9	10.5
" Mg "	12.7	15.2	16.0	17.3	24.0	19.5
" K "	1.2	0.9	1.1	1.2	1.5	1.7
" Na "	1.2	1.8	2.8	3.0	4.9	3.3
Sum of cations	27.1	29.2	33.6	35.7	41.3	35
Base sat. %, pH 8.2	63	75	78	92	>100	90
ESP at pH 8.2	3	5	7	8	14	8
Saturation extract:						
Moisture %						
pH-paste						
ECe (mS/cm)						

FERTILITY ASPECTS:

(depth in cm)	0-20
Ca (me/100 g)	14.6
Mg "	8.2
K "	0.82
Na "	0.96
P (ppm)	38.0
Mn (me/100 g)	0.24
Exch. acidity (me/100 g)	
pH-H_2O (1 : 1 v/v)	6.0
C (%)	1.25
N (%)	0.16

FIELD LABORATORY DATA

Horizon	Depth (cm)	1 : 2.5 soil-water v/v	
		pH	EC (mS/cm)
A1	2-20	6.6	0.24
C1	30-50	6.5	0.32
A1b	70-90	5.1	0.8
C2	100-110	4.1	3.9
C3	140-160	3.5	4.2
C4	170-190	3.5	2.6
C5	200	3.4	1.6
C6	280	4.3	0.9
gr.w.	107	3.2	5.2

Profile description no. 11

Observation/date	:	P7; coordinates E.644450/N.9728600; 25/9/'82
Mapping unit	:	BM2 I S3
Physiography	:	Floodplain; River basin land
Topography	:	flat; weak gilgai microrelief
Vegetation	:	grasses and some herbs
Salinity/sodicity	:	moderately saline from 90 cm onwards; sodic from 70 cm onwards
Drainage conditions	:	very poorly drained; depth of seasonal floods 60-80 cm; groundwater at 1.80 m depth

Profile description:

A1	0-20 cm	black (N2 moist) humic clay; moderate, coarse prismatic structure breaking to strong, very fine subangular and angular blocks; few, fine pores; very hard when dry, very firm when moist, sticky and plastic when wet; common, fine roots; gradual, wavy transition to
C1	20-70 cm	dark gray (10YR 4/1 moist) clay; moderate, coarse prismatic structure breaking to strong, very fine subangular and angular blocks; common, medium slickensides; few, very fine pores; very firm when moist, very sticky and very plastic when wet; few, fine, faint iron mottles; few, very fine roots; few manganese (2 mm) concretions; gradual, smooth transition to
A1b	70-90 cm	black (N2 moist) humic clay; strong, very fine subangular and angular blocky structure; common, medium slickensides; few, very fine pores; very firm when moist, very sticky and plastic when wet; few, fine, faint iron mottles; few, very fine roots; few manganese (2 mm) concretions; clear, smooth transition to
C2	90-120 cm	dark gray (10YR 4/1 moist) clay; weak, medium angular blocky structure; common, medium slickensides; very firm when moist, very sticky and very plastic when wet; abrupt, smooth transition to
C3	120-170 cm	gray (5Y 5/1 moist) clay; weak, medium angular blocky structure; abundant, thick slickensides; very firm when moist, very sticky and very plastic when wet; common, medium , distinct iron mottles; gypsum (5-10 mm) concretions; gradual, smooth transition to
C4	170-200 cm	gray (5Y 5/1 wet) clay; weak, medium angular blocky structure; abundant, thick slickensides; very sticky and very plastic when wet; many, coarse, prominent red mottles and common, medium, distinct yellow mottles; type of transition not observed because of augering from 200 cm onwards
C5	200-280 cm	gray (5Y 5/1 wet) clay; consistency as above; many, coarse, prominent yellow mottles and common, medium, distinct red mottles
C6	280-320 cm	dark greenish gray (5GY 4/1 wet); very sticky and slightly plastic when wet; end of augering because of sand flowing into augerhole

LABORATORY DATA OF PROFILE DESCRIPTION NO.: 12

Observation no.: P4

Soil classification: vertic FLUVISOL, sodic phase

Mapping unit: M3 I SO

Horizon	A11	S12	C1	C2
Depth of sample (cm)	5-15	30-50	90-110	130-140
TEXTURE				
Sand % 2.0 - 0.05 mm	12	12	12	16
Silt % 0.05 - 0.002 mm	18	14	20	22
Clay % 0.002 - 0 mm	70	74	68	62
Texture class	C	C	C	C
CHEMICAL DATA				
pH-H_2O (1 : 2.5 v/v)	6.3	6.7	4.7	3.9
pH-KCl "	4.7	5.2	3.9	3.4
EC (mS/cm) "	0.40	0.70	3.0	4.0
$CaCO_3$ (%)	0.13	0.11	0.07	0.08
$CaSO_4$ (%)	0.03	0.06	0.11	1.8
C (%)	0.90	0.84	0.06	0.06
N (%)				
C/N				
CEC (me/100 g), pH 8.2	39.0	35.0	39.0	32.0
Exch. Ca (me/100 g)	12.6	16.4	10.5	28.0
" Mg "	15.7	17.2	18.0	20.5
" K "	1.5	1.6	1.5	1.6
" Na "	1.5	2.7	3.8	3.3
Sum of cations	31.3	37.9	33.8	53.4
Base sat. %, pH 8.2	80	>100	87	>100
ESP at pH 8.2	4	8	10	10
Saturation extract:				
Moisture %				
pH-paste				
ECe (mS/cm)				

FERTILITY ASPECTS:

(depth in cm)	0-20
Ca (me/100 g)	15.6
Mg "	9.2
K "	0.90
Na "	1.12
P (ppm)	38.0
Mn (me/100 g)	0.24
Exch. acidity (me/100 g)	
pH-H_2O (1 : 1 v/v)	5.7
C (%)	1.74
N (%)	0.24

FIELD LABORATORY DATA

Horizon	Depth (cm)	1 : 2.5 soil-water v/v pH	EC (mS/cm)
A11	5-15	6.4	0.13
A12	30-50	6.7	0.57
C1	90-110	4.8	3.4
C2	130-140	3.4	6.0
C3	200	3.2	5.0
C4	250	3.4	6.0
C4	300	4.8	5.4
C4	350	5.4	5.0
C4	400	6.4	5.3
C4	450	5.7	3.1
C4	510	7.4	3.0

Profile description no. 12

Observation/date : P4; coordinates E.645550/N.9731600; 6/10/'82

Mapping unit : M3 I SO

Physiography : Floodplain; Basin land

Topography : flat; flat microrelief

Vegetation : grasses

Salinity/sodicity : moderately saline from 115 cm onwards; sodic

Drainage conditions : poorly drained; depth of seasonal floods 80 cm; groundwater at 0.8 m depth

Profile description:

A11	0-15 cm	black (10YR 2/1 moist) humic clay; weak, very fine subangular and angular blocky structure; common, very fine pores; firm when moist, sticky and plastic when wet; mottling along root stems; few, fine roots; clear, wavy transition to
A12	15-80 cm	black (N2 moist) humic clay; moderate, fine angular blocky structure; abundant, medium slickensides; few, very fine pores; very firm when moist, sticky and very plastic when wet; mottling along root stems; few, very fine roots; clear, wavy transition to
C1	80-115 cm	gray (N5 moist) clay; moderate, fine angular blocky structure; abundant, medium slickensides; few, very fine pores; consistency as above; many, medium, prominent red and yellow mottles; common gypsum (2 mm) concretions; gradual, wavy transition to
C2	115-180 cm	gray (N5 moist) clay; weak, fine angular blocky structure; abundant, thin slickensides; very firm when moist, sticky and very plastic when wet; many, medium, prominent yellow mottles; type of transition not observed because of augering from 180 cm onwards
C3	180-240 cm	very dark grayish brown (10YR 3/2 wet); sticky and very plastic when wet; common, coarse, prominent yellow mottles; few micas
C4	240-500 cm	dark greenish gray (5GY 4/1 wet); sticky and very plastic when wet; common, coarse, prominent yellow mottles to 270 cm depth

Remarks: From 500 cm onwards many carbonate concretions.

LABORATORY DATA OF PROFILE NO.: 13

Observation no.: S96

Mapping unit: MT1 I S3

Soil classification: vertic FLUVISOL, saline-sodic phase

Horizon	A1	C1	C2	C3
Depth of sample (cm)	0-30	30-90	90-130	130-250
TEXTURE				
Sand % 2.0 - 0.05 mm	20	20	52	56
Silt % 0.05 - 0.002 mm	8	8	10	12
Clay % 0.002 - 0 mm	72	72	38	32
Texture class	C	C	SC	SCL
CHEMICAL DATA				
$pH-H_2O$ (1 : 2.5 v/v)	7.6	7.9	7.8	8.3
pH-KCl "	6.5	7.0	7.0	7.5
EC (mS/cm) "	0.55	2.00	2.90	1.85
$CaCO_3$ (%)	0.14	0.30	0.08	1.17
$CaSO_4$ (%)	0.01	0.06	0.02	0.02
C (%)	0.58	0.38	0.06	0.03
N (%)				
C/N				
CEC (me/100 g), pH 8.2	30.0	32.0	19.0	19.0
Exch. Ca (me/100 g)	12.3	13.3	7.5	18.1
" Mg "	3.8	11.8	9.7	11.0
" K "	1.5	2.3	1.2	1.0
" Na "	1.9	3.6	3.6	7.0
Sum of cations	19.5	31.0	22.0	37.10
Base sat. %, pH 8.2	65	96	>100	>100
ESP at pH 8.2	6	11	19	37
Saturation extract:				
Moisture %				
pH-paste				
ECe (mS/cm)				

FIELD LABORATORY DATA

Horizon	Depth (cm)	1 : 2.5 soil-water v/v	
		pH	EC (mS/cm)

no data available