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NATIONAL AGRICULTURAL LABORATORIES

DETAILED SOIL SURVEY OF NGAO IRRIGATION SCHEME
(SOUTH TANA DIVISION– TANA RIVER DISTRICT)

by

P.J.K. Kanake

TAILED SOIL SURVEY REPORT NO. D18, 1980

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KENYA SOIL SURVEY

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TABLE OF CONTENTS

1. INTRODUCTION

According to the priority programme of the Minor Irrigation Development Committee and the Minor Irrigation Proposals 1975-1978 of the Provincial Director of Agriculture (P.D.A.) Coast Province, a detailed soil survey was carried out at Ngao, covering the already existing Ngao Irrigation Scheme and the proposed extension, which together comprise a total of 207.5ha.

The fieldwork was carried out between May and September 1979. Ngao Irrigation Scheme was first started in 1972 with Kenya Government providing the initial capital for development (survey, design, construction) and acquisition of a pumping unit. In 1974 "Bread for the World" (a German Church Organisation) started giving grants to Ngao, enabling the Scheme to expand rapidly and buy its own tractor.

The Scheme has been functioning fairly successfully, with rice being grown in basins (plots) of 0.4ha (1acre) each. Small amounts of bananas, pawpaw and cassava are also grown, mainly along the canal banks and on the basin bunds or dykes.

The author's acknowledgements go to the Assistant Agriculture Officer (A.A.O.) of South Tana Division, together with his staff at Garsen; the Technical Assistant (T.A.) of Ngao Irrigation Scheme Mr. Flezian Komora, and the tenants of the Scheme, for their co-operation and assistance during the fieldwork.

2. PREVIOUS WORK.

Following a request from the Tana River Development Authority (TRDA), the Kenya Soil Survey (KSS) carried out a site evaluation of the soil conditions of the Tana delta in February 1975 (Sombroek et al, 1976). This evaluation, which covers the area between Garsen and the mouth of the Tana River, was aimed at finding out whether any large scale irrigation development in this area was feasible.

In April, 1976 Dr. H. Bonarius of the German Agricultural Team (G.A.T.) made a field trip to the lower Tana and carried out site evaluations of the then existing irrigation schemes (including Ngao) to assess their suitability for irrigation.

.../2

At the request of the Small Scale Irrigation Unit (SSIU) of the Ministry of Agriculture, the KSS made a trip to the lower Tana (KSS: PROG/21/II/41) and carried out some observations, in co-operation with the National Christian Council of Kenya (NCCK), Lower Tana Project Team, on the sites of several irrigation schemes - including Ngao.

In all cases suitable soils were identified for irrigation development, but further soil studies and mapping, on semi - detailed and detailed levels, were recommended. This detailed soil survey is therefore a follow up of the studies mentioned above.

3. ENVIRONMENTAL CONDITIONS

3.1. Location and Communications

The survey area is situated in the South Tana Division of Tana River District, Coast Province. It lies at latitude 2°, 20' 8"S and longitude 40°.10' 3"E, and at an altitude of about 15m above sea level.

Road transport serves as the major means of communication. The main national trunkroad (loose surface) from Mombasa to Garsen and Garissa and Lamu by-passes Ngao village by about 13km. A secondary road links Ngao, via Tarasaa village, with the main road. Bus Services are usually available to and from Ngao, in addition to all other types of transport vehicles. However, heavy rains and flashfloods frequently disrupt the road transport communications. There is a dry-weather airstrip at Garsen (about 33km away) and an irregularly mainted one at Ngao. Telephone services are available at Garsen and Postal services are available three times a week from Malindi to Garsen and Tarasaa.

Social amenities at Ngao include a primary school, a Government Hospital and clean piped water system. A mixed Government secondary school is available at Tarasaa.

3.2. Geology and Physiography

The survey area is situated in the Tana river floodplain, which consists of Recent alluvial sands, silts and clays (Matheson, 1961).

The floodplain is generally flat and extensive and is only a few metres above sea level. The only recognisable meso-relief features are branching, abandoned river channels and their associated levees and basins (backswamps).

The survey area comprises both river levees and backswamps. The levees are slightly elevated above the general level of the backswamps.

3.3. Climate:

The survey area lies within the Dry-Sub-humid to semi-arid climatic zone (Kenya Atlas, 1970). The mean annual rainfall is 757mm and occurs in a bi-modal pattern. The rainy seasons are from April to July, with the highest peak in May, and from November to December. The average monthly (1972) are shown in Table I (observation period of 15 years):

Table I. Average monthly rainfall figures for Ngao

Jan.	Feb.	Mar.	Apr.	May.	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
22	11	58	116	113	76	38	39	77	48	95	64	757

Temperature are high, ranging from 30°-34°C. Potential evaporation is also high, ranging from 2200-2400mm per year (Eo, Penman).

Under the present climatic conditions therefore, irrigated agriculture is the most reliable way of growing food.

3.4. Vegetation:

The river levees are generally covered with tall elephant grass, with only scattered mango and palm trees. The river basins (backswamps) are covered with tall grasses of various species. The lowest areas of the river basins (backswamps) which are more frequently flooded are dominated by tall Echinocloas spp. (swampgrass), while the slightly higher lying areas are dominated by Cynodon dactylon (stargrass) interrixed with Acacia bushes and shrubs and the occassional solitary palm trees.

3.5. Present Landuse:

Due to their lighter textures, better drainage, and workability, the Levee soils are used for the cultivation of subsistence crops such as bananas, maize, cassava, sugarcane pawpaws and mango and coconut trees.

The river basins (backswamps) which are lower lying and have heavy textured (mainly clay) poorer drained soils, are extensively used for grazing, but small parts are also used for rice growing.

3.6. Hydrology and water resources

The Tana river is the only perennial stream in the area. The dry season flow rate average is 80m3/sec, but may be 30m3/sec once in 10 years. The biannual floods of the Tana, caused mainly by upcountry rains, occur usually in the April-June and November-December periods. The high floods usually disrupt communications and transport by either washing away bridges and sections of the road, or by making the roads muddy, slippery and impassable, while they may also destroy crops in the fields.

The quality of the Tana river water is good for irrigation. Its average electrical conductivity (E.C.) is 215 micromhos/cm, which corresponds to a salt content of 130ppm. Average sodium adsorption ratio (S.A.R.) is 0.6, Residual Sodium Carbonate (RSC) value is 0.4 me/litre, and Boron content is 0.07ppm (Acres/Ilaco, 1967).

4. SURVEY METHODS

A topographic map of scale 1:2500, produced by Wapimaji (Surveyors) Ltd. under contract by the Small Scale Irrigation Unit (S.S.I.U.) of the Ministry of Agriculture, was used as a basemap. All observations and provisional soil boundaries were marked on this map which was later reduced to a scale of 1:5,000 to make the final soil map.

The fieldwork was done in two phases. The first phase consisted of 82 augerhole observations. These were made following a grid system of 100 metres which had been marked in the field with small concrete beacons by the topographical surveyors. The soils were examined for depth, mottling, texture, consistence, etc. They were also analysed for pH and salinity using portable electrical equipment. All the data from each observation were recorded on the KSS "Routine augerhole description forms for detailed surveys".

After completion of the augerhole observations, provisional soil mapping units were deliniated, based mainly on soil texture, drainage pH and salinity.

During the second phase representative sites in the different units were selected, in which profile pits were made. A total of 4 profile pits were made in the survey area. The profile pits were dug to a depth of about 150cm and described in detail, according to the KSS standards, which are based on the F.A.O. Guidelines for Soil Profile Description (1977). Each soil horizon was sampled for chemical and physical analysis in the National Agricultural Laboratories.

After the receipt of the laboratory data, the soil boundaries based on field data were slightly re-adjusted where necessary.

.../5

5. SOILS

5.1. Systematics and nomenclature

As shown in the legend of the soil map, the survey area has first been subdivided into physiographic units. Within each physiographic unit, various soil mapping units have been distinguished, taking into account soil characteristics such as drainage condition, colour, texture, etc.

Each mapping unit of the soil map is identified by a mapping symbol, for which a code system is used. The symbols appearing in the code system are explained below:

A	-	Floodplain
A1	-	River levees
Ab	-	Riverbasins (backswamps)

The numerals 1,2, etc, connote different soil units within the physiographic subdivisions.

5.2. General properties of the soils:

There are two major categories of soils in the area:

- river levee soils, which are stratified, and are varying texture and consistence
- riverbasin (backswamp) soils, which have mainly a clay texture.

The river levee soils occur mainly on the levees of the present - day rivercourse and a former rivercourse. These are generally well drained to moderately well drained, extremely deep (deeper than 200cm), reddish brown (5YR 4/3) to very dark grey (10YR 3/1), stratified, firm, loamy sand to clay soils (mapping units A11 and A12).

The riverbasin soils are mainly found in the lower lying areas further away from the river. They are imperfectly drained to very poorly drained, extremely deep (deeper than 200cm), dark yellowish brown (10Y 4/4) to black (7.5YR 2.5/0) soils (mapping units Ab1 and Ab2). Their texture is predominantly firm clay, but in places, friable, silty clay loam, may be found at 80-120cm depth.

5.3. Description of the soil mapping units:

5.3.1. River Levee Soils

.../6

Mapping unit A1[1]

Extent	:	69 ha
Meso/Micro-relief	:	basin dykes and cowfotoes
Slope	:	0-2%
Vegetation	:	Tall grassland and riverine forest
Land use	:	basin irrigation of paddy rice, in addition to bananas, pawpaw, sugarcane, mangoes and coconuts (grown on the plot boundaries).
Soils	:	well drained to moderately well drained, extremely deep (deeper than 200cm), reddish brown (5YR 4/3)* to very dark grey (10YR 3/1), very friable, loamy sand to silty clay; with about 20-30cm topsoil of dark reddish brown (5YR 3/2) to very dark grey (5YR 3/1), firm clay. The structure varies from fine, weak, crumb in the topsoil, to fine and coarse, weak, angular blocky in the subsoil.
Salinity/sodicity	:	non-saline throughout, but in places slightly sodic in the subsoil.
Chemical aspects		
topsoil	:	pH-H_2O** is near neutral 6.7-7.2, pH-KCl** 5.7; CEC and base saturation are high, 62me/100g and 71% respectively.
subsoil	:	pH-H_2O** increases with depth from 7.1-8.0 (slighty alkaline to moderately alkaline) pH-KCl** also increases with depth from 5.8-6.6; C.E.C. is high enough, increasing with depth from 18-67%; base saturation is also high, varying from 71-100%.

* unless otherwise stated, the colour given is in moist state and is according to the Munsell Colour Charts.

** pH-H_2O and pH-KCl are measured in 1:2½ soil: water suspensions.

.../7

Fertility aspects : Organic matter content is low to moderate (%C 0.4-1.0) but all the other major nutrients - Phosphorus (P 53.0ppm), Potassium (K 0.67 me/100g). Calcium (Ca 12.0 me/100g) are available in sufficient quantities.

Differentiating Criteria : these soils differ from the other levee soils (mapping unit A12) by their slightly lighter textures and their colour. These soils are mainly found in the active levees of the present - day river course, whereas those of unit A12 are found in the old levees of an abandoned river course.

Limitation for furrow irrigation: topsoil of firm clay (poor workability)

Limitation for basin irrigation : well drained to moderately well drained; loamy sand to silty clay subsoil (high permeability)

Suitability for irrigation (after land improvements): moderately suitable for furrow irrigation and moderately suitable for basin irrigation (paddy rice)

Mapping Unit A12

Extent : 8 ha

Meso/microrelief : old river levees, cowfotoes

Slope : 0-2%

Vegetation : tall grassland and riverine forest

Landuse : mainly grazing, with a few banana plants intermixed with maize and cassava.

Soils : well drained to moderately well drained, extremely deep (deeper than 200cm), dark reddish brown (5YR 3/4) to very dark greyish brown (10YR 3/2), friable, silty clay, with a 20-30cm topsoil of dark greyish brown (10YR 4/2) to very dark grey (10YR 3/1), firm clay.

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

Differentiating Criteria: these soils differ from the other levee soils (Mapping Unit $A1_1$) by their slightly heavier textures and their colour variations. They are also found mainly on old levees of the abandoned rivercourse.

.../8

Limitation for Furrow irrigation - firm clay topsoil (poor workability)
Limitations for Basin irrigation - well drained to moderately well drained (high permeability)
Suitability for irrigation (after land improvement): moderately suitable for furrow irrigation and moderately suitable for basin irrigation (paddy rice).

5.3.2. River basin soils

Mapping Unit Ab1

Extent	:	27.5 ha
Meso/microrelief	:	basin dykes, cowfotoes
Slope	:	0-1%
Vegetation	:	grassland
Landuse	:	grazing and basin irrigation of paddy rice
Soils	:	imperfectly drained to poorly drained, extremely deep (deeper than 200cm) dark grey (10YR 4/1) to black (7.5YR 2.5/0), firm, clay soils. They are stratified in the deeper subsoils, with dark yellowish brown (10YR 4/4), friable, silty clay loam to silty clay at 80-120cm depth. Their structure varies from fine to medium, weak, angular blocky.
Salinity/sodicity	:	non-saline and non-sodic throughout.
Chemical aspects		
top soil	:	pH-H_2O is near neutral (6.5) and pH-KCl is 5.2, C.E.C. is high (66 me/100g) and base saturation is also high (63%)
sub soil	:	pH-H_2O near neutral (7.2) and pH-KCl increases with depth from 5.5 - 5.9, CEC is high but decreases with depth from 60-24 me/100g; base saturation is also high, and increases with depth from 66-81%.
Fertility aspects (Mehlich analysis)	:	the topsoils have sufficient organic matter content (C% 1.6). The major nutrient elements are available in sufficient quantities. Phosphorous (P) 38ppm, Potassium (K) 1.0 me/100g, Calcium (Ca) 13 me/100g and Magnesium (Mg) 10 me/100g.

.../9

Differentiating Criteria -: these soils differ from the other riverbasin soils (Mapping Unit Ab2) by a slightly better drainage condition (imperfectly drained to poorly drained) and by the occurrence of silty clay loam to silty clay at 80-120cm depth.

Limitations for furrow irrigation -: imperfectly drained to poorly drained, firm clay topsoil, (poor workability) some ponding and water-logging during the rainy seasons.

Limitations for basin irrigation -: no apparent limitations

Suitability for irrigation (after land improvement): moderately suitable for furrow irrigation and highly suitable for basin irrigation (paddy rice).

Mapping Unit Ab2

Extent : 103 ha

Meso/Microrelief : some gilgai, cowfotoes and basin dykes.

Slope : 0-1%

Vegetation : tall grassland

Landuse : grazing and basin irrigation of paddy rice.

Soils : poorly drained, extremely deep (deeper than 200cm), dark reddish brown (5YR 3/2) to black (10YR 2.5/1) firm clay soils. Their structure varies from coarse, strong, columnar in the topsoil to medium, moderate, angular blocky in the subsoil.

Salinity/Sodicity : non-saline and non-sodic throughout.

Chemical aspects topsoil : pH-H_2O is near neutral (6.7), pH-KCl is 5.3, and both C.E.C. (66 me/100g) and base saturation (64%) are high.

.../10

Subsoil	:	$pH-H_2O$ decreases with depth from 8.4-6.5, pH-KCl also decreases with depth from 6.0-5.5, C.E.C. increases with depth from 50-56 me/100g, base saturation decreases with depth from 96-81%.
Fertility aspects (Mehlich analysis)	:	Organic matter content is sufficient (%C 1.43) The major nutrients are available in sufficient quantities: Phosphorous (P) 41.0ppm, Potassium (K) 0.8 me/100g, Calcium (Ca) 13 me/100g, Magnesium (Mg) 10 me/100g.
Differentiating Criteria	:	these soils differ from the other river-basin soils (Mapping Unit Ab1) by being poorer drained (poorly drained to very poorly drained) and by having a firm clay texture throughout the profile (no stratification).
Limitations for furrow irrigation	-	poorly drained to very poorly drained, firm clay top soil (poor workability).
Limitation for basin irrigation (paddy rice)	-	no apparent limitations.
Suitability for irrigation	-	(after land improvements): moderately suitable for furrow irrigation, but for basin irrigation (paddy rice).

5.4. Soil fertility status

The appraisal of the soil fertility in the survey area is based on the chemical analysis of topsoil samples taken from representative profile pits in each of the major soil mapping units. However this appraisal should be regarded as a very general one due to the limited number of samples analysed.

The analytical data on the available nutrients are presented in table 2.

Table 2: Available nutrients (Mehlich analysis)

Field designation		Al_1	Al1	Ab_1	Ab2
Profile no.		197/94	179/95	179/96	179/93
Lab.		13050	13056	13063	13044
Depth in cm		0-23	0-22	0-16	0-17
pH		6.5	6.6	6.0	6.0
Na	m.e. /100g	0.9	0.7	0.8	0.4
Ka	"	0.7	0.5	1.0	0.8
Ca	"	12.0	10.0	13.0	13.0
Mg	"	9.0	9.0	10.0	10.0
Mn	"	0.6	0.6	0.4	0.7
P	p.p.m.	53.0	67.0	38.0	41.0
C	%	1.0	0.4	1.6	1.4

The analytical data presented above show that the soils of mapping units Ab1 and Ab2 (riverbasin soils) are slightly acid (pH 6.0) and have a high organic matter content (%C 1.4-1.6). These soils are also rich in Pottasium (K 0.8 - 1.0 m.e./100g), Phosphorous (P 38.0 - 41.0 ppm) and Calcium (Ca 13.0 m.e./100g).

The soils of mapping unit Al_1 (river levee soils) are low to moderate in organic matter content (%C 0.4-1.0), but have sufficient Potassium (K 0.5-0.7 m.e./100g) Phosphorous (P 53-67ppm) and Calcium (Ca 10-12 m.e. /100g). For optimum production of crops in these soils (mapping unit Al_1) the application of compost manure or green manure (ploughed in) mixed with Ammonium Nitrate (AN) or Diammonium Phosphate (DAP) is recommended.

6. LAND SUITABILITY FOR SURFACE IRRIGATION.

Surface irrigation specifically refers to furrow and basin irrigation methods. Basins are flat areas surrounded by low ridges or dykes. They are flooded with water and are suitable for rice growing, as rice requires a substantial amount of standing water during its growth period. Flat areas with heavy clay soils which will not take in water readily are usually recommended. Furrow irrigation is commonly used for row crops such as maize, vegetables, bananas, tree crops, etc. Irrigation water is brought in a furrow or ditch and runs in smaller furrows between the plants.

.../12

Two kinds of interpretative land classification for irrigation have been used (see also appendix 2):

(a) Current land suitability:- an appraisal of the suitability of land for a specific use (surface irrigation in this case) without significant land improvement measures which would alter the present limitations and qualities of the land.

(b) Potential land suitability:- an appraisal of the potential suitability of the land for a specific use after significant land improvement measures have been carried out, indicating the level and type of land improvement required.

Four classes of land suitability are used, and their basic definitions are given below:

Class 1: These are lands that are highly suitable for irrigation farming; being capable of producing sustained and relatively high yields of climatically adapted crops at a reasonable cost. These lands potentially have a relatively high payment capacity.

Class 2: These are lands that have a moderate suitability for irrigation. These are usually either adaptable to a narrower range of crops, more expensive to develop for irrigation, or less productive than class 1 lands. Potentially these lands have intermediate payment capacity.

Class 3: These are lands that have a marginal suitability for irrigation. They are less suitable than class 2 lands and usually have either a serious single deficiency or a combination of several moderate deficiencies in soil, topography or drainage properties.

Class 4: These are lands which are considered unsuitable for irrigation due to very severe deficiencies and limitations. Their reclamation may not be technically or economically feasible, depending on the type and level of the limitations.

The different categories of limitations considered in the survey area are:-

- Soil limitations (symbol "S"):- based on the texture of the topsoil, infiltration rate, soil depth, claypans or hardpans, topsoil stoniness and subsoil permeability.
- Drainage limitation (symbol "W"):- based on the degree, depth and colour of mottling; groundwater depth, temporary water logging and flooding.

.../13

Table 3 gives the limitations of the various mapping units:

The current land suitability, the land improvement requirements and potential suitability of each soil unit for furrow irrigation are given in table 4. The additional capital letters to the Roman figures denote the factor (s) imposing the limitations. The same information for basin irrigation is given in table 5. The potential suitability classification is arrived at by considering the cumulative effect of several persisting land limitations which will affect the productive capacity of a soil unit.

.../14

Table 3: Major limitations of the soil mapping units

Mapping Unit	Limitations	
	Furrow irrigation	Basin irrigation (paddy rice)
Al_1	Soil texture - firm clay topsoil	soil texture - loamy sand to silty clay subsoil
	- -	Drainage - well drained to moderately well drained
Ab1	soil texture - firm clay topsoil	- -
	Drainage - imperfectly drained to poorly drained	- -
	some ponding and water-logging may occur during rainy seasons	- -
Ab2	Soil texture - firm clay topsoil	- -
	Drainage - poorly drained to very poorly drained	

- means no apparent limitation

.../15

TABLE 4: Land suitability classification and land improvement requirements for furrow irrigation (row crops)

Soil Mapping Unit	Current suitability	Land improvement requirement*	Potential Suitability	Area in ha
Al_1	II SW	D	II S	69.0
Al_2	II SW	d	II S	8.0
Ab_1	II SW	D	II S	27.5
Ab_2	III SW	D	II S	103.0

* D and d = high and low artificial drainage requirements respectively; in addition to clearing, levelling and canal constructions.

Table 5: Potential land suitability classification for Basin Irrigation of paddy rice

Mapping Unit	Potential Land Suitability*	Area (ha)
Al_1	II S	69.0
Al_2	II S	8.0
Ab_1	I	27.5
Ab_2	I	103.0

* after land clearing, levelling and canal and basin constructions.

.../16

7. CONCLUSIONS AND RECOMMENDATIONS

- The survey area which covers an area of 207.5 ha is situated in the floodplain of the Tana river. The area is physiographically subdivided into the river levee land (Al) and river basinland (Ab).
- The whole area is considered to be moderately suitable for furrow irrigation after land improvement, the persistent limitation being the clayey top soil texture.
- For basin irrigation of paddy rice, a total of 130.5 ha (mapping units Ab_1 and Ab_2) are considered as highly suitable, while the other 77ha (mapping units Al_1 and Al_2) are considered as moderately suitable, after land improvements.
- In addition to the initial clearing, levelling and canal and basin construction, drainage measures should be instituted to prevent the rise of the groundwater table and to leach the salts which may accumulate with time, in all the irrigated areas.
- It would be worthwhile to develop at least a part of the survey area for furrow irrigation of rowcrops such as maize, grams, cassava, vegetables, sugarcane, bananas, etc. It is proposed that the levee soils (mapping units Al_1 and Al_2) be used for this purpose.
- Flooding from the Tana river may present some hazard, so flood protection dykes should be constructed all around the irrigated area. The dykes should be strong and high enough to stop the highest possible floods which may occur.

.../17

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.../18

SOIL ANALYTICAL DATA

KSS Profile no. 179/94

Mapping unit: A11

Lab. no./79	13049	13050	13051	13052	13053	13054	13055
Depth in cm	0-9	9-23	23-39	39-50	50-66	66-84	84-120
Sand %	14	12	10	18	46	18	12
Silt %	24	22	22	30	28	30	12
Clay %	62	66	68	52	26	52	76
Texture class	C	C	C	C	SCL	C	C
pH-H_2O 1:2½ susp.	6.7	7.2	7.1	7.9	8.1	8.0	7.8
pH-KCl 1:2½ susp.	5.7	5.7	5.8	6.3	6.6	6.6	6.4
EC (mmhos/cm) 1:2½ susp.	0.46	0.27	0.26	0.34	0.27	0.44	0.45
C %	1.31	0.89	0.65	0.30	0.15	0.24	0.30
CEC (me/100gm)	61.0	62.0	57.8	47.5	18.4	44.1	66.8
Exchangeable Cations							
Ca (me/100g)	26.0	27.0	24.0	22.0	11.6	22.0	30.0
Mg "	14.8	15.2	16.2	14.0	6.8	6.0	16.0
K "	1.0	0.9	0.5	0.3	0.2	0.4	0.4
Na "	1.5	1.5	1.6	2.0	1.9	3.0	1.9
Sum	43.3	44.6	42.3	38.3	20.4	31.4	48.4
Base sat.	71.0	72.0	73.0	81.0	100.0	71.0	73.0
E.S.P.	2.0	2.0	3.0	4.0	10.0	7.0	3.0

.../19

APPENDIX 1: DETAILED DESCRIPTION OF REPRESENTATIVE SOIL PROFILES AND ANALYTICAL DATA

Mapping Unit Al_1 — Profile no. 179/94

Geology	:	Recent alluvial deposits
Physiography	:	river levee (of the Tana floodplain)
Relief, macro	:	level
" meso/micro	:	basin walls
Vegetation/land use	:	tall grassland and riverine forest/Basin irrigation of paddy rice
Erosion	:	nil
Surface stoniness	:	nil
Rock outcrops	:	nil
Flooding	:	frequent
Slope gradient	:	0-2%
Effective soil depth	:	very deep (deeper than 120cm)
Root distribution	:	common fine roots up to 70cm
Drainage class	:	moderately well drained

0-9cm	dark brown (7.5YR 3/2) clay; fine, weak, crumb structure; friable when moist, sticky and plastic when wet; many pores; clear and smooth transition to:
9-23cm	very dark grey (10YR 3/1) clay; fine, weak crumb structure; friable when moist, sticky and plastic when wet; many pores; gradual and smooth transition to:
23-39cm	dark brown (7.5YR 3/2) clay; fine to medium, very weak, subangular blocky structure; friable when moist, sticky and plastic when wet; many pores; abrupt and smooth transition to:
39-50cm	dark greyish brown (10YR 4/2) very weak, fine to medium, subangular blocky structure; friable when moist, very sticky and very plastic when wet; many pores; abrupt and smooth transition to:
50-66cm	dark greyish brown (10YR 4/2) sandy clay loam; very weak, medium to coarse, columnar structure; friable when moist, very sticky and very plastic when wet; many pores; abrupt and smooth transition to:

.../20

66–84cm	greyish brown (10YR 5/2) clay; weak, fine to coarse, angular blocky structure; friable when moist, sticky and plastic when wet; common pores; gradual and smooth transition to:
84–120cm	grey (10YR 5/1) clay; weak, fine to coarse, angular blocky structure; friable when moist, sticky and plastic when wet; common pores.

.../21

SOIL ANALYTICAL DATA

KSS Profile no. 179/96

Mapping unit: Ab1

Lab. no./79	13063	13064	13065	13066	13067	13068
Depth in cm.	0-16	16-34	34-64	64-89	89-102	102-110+
Sand %	14	8	12	18	18	28
Silt %	8	12	8	20	40	38
Clay %	78	80	80	62	42	34
Texture class	C	C	C	C	C/SIC	CL
pH-H_2O 1:2½ susp.	6.5	6.9	7.0	7.2	7.2	7.1
pH-KCl 1:2½ "	5.2	5.5	5.7	5.6	5.9	5.9
EC (mmhos/cm) 1:2½ susp.	0.29	0.33	0.35	0.24	0.24	0.18
CEC (me/100g)	65.5	66.5	66.0	51.0	35.0	24.0
Exchangeable Cations						
Ca (me/100g)	22.0	26.0	24.0	22.0	14.4	12.0
Mg "	16.2	17.6	16.8	13.2	7.2	6.0
K "	2.3	1.0	0.4	0.4	0.2	0.2
Na "	1.0	2.1	2.1	1.3	1.1	1.0
Sum	41.5	46.7	43.3	37.0	23.0	19.3
Base sat.	63.0	70.0	66.0	72.0	66.0	81.0
E.S.P.	1.0	3.0	3.0	3.0	3.0	4.0

.../22

Mapping unit Ab1	Profile no. 179/96
Geology	: recent alluvial deposits
Physiography	: river basin
Relief, macro	: level
meso/micro	: basin walls; cowfotoes
Vegetation/land use	: tall grassland/grazing and basin irrigation of paddy rice
Erosion	: nil
Surface stoniness	: nil
Rock outcrops	: nil
Flooding	: frequent
Slope gradient	: 0-2%
Effective soil depth	: very deep (deeper than 120cm)
Drainage class	: imperfectly drained to poorly drained

0-16cm	very dark grey (7.5YR 3/1) clay; fine to medium, moderate, subangular blocky structure; very hard when dry, firm when moist, sticky and plastic when wet; few, very fine pores; clear and smooth transition to:
16-34cm	dark grey (10YR 4/1) clay; medium to coarse, weak, prismatic to angular blocky structure; hard when dry, firm when moist, sticky and plastic when wet; few, very fine pores; abrupt and smooth transition to:
34-64cm	very dark greyish brown (10YR 3/2) clay; medium to coarse, weak, prismatic to angular blocky structure; hard when dry, firm when moist, sticky and plastic when wet; few, very fine pores; abrupt and smooth transition to:
64-89cm	black (7.5YR 2.5/0) clay; medium, weak, angular blocky structure; firm when moist, sticky and plastic when wet; common, very fine pores; abrupt and smooth transition to:
89-102cm	dark brown (10YR 3/3) silty clay; medium, weak, angular blocky structure; friable when moist, sticky and plastic when wet; common, very fine pores; clear and smooth transition to:

.../23

102-120cm	dark brown (10YR 4/4) clay loam; medium, weak, subangular blocky structure; friable when moist, sticky and plastic when wet; common, very fine pores.

.../24

SOIL ANALYTICAL DATA

KSS Profile No. 179/93

Mapping unit: Ab2

Lab. no./79	13044	13045	13046	13047	13048
Depth in cm.	0-17	17-44	44-87	87-115	115-130
Sand %	14	16	10	10	12
Silt %	12	16	22	30	10
Clay %	74	68	68	60	78
Texture class	C	C	C	C	C
pH-H_2O 1:2½ susp.	6.7	7.4	7.1	6.7	6.5
pH-KCl 1:2½ "	5.3	5.9	5.9	5.6	5.5
EC (mmhos/cm) 1:2½ susp.	0.33	0.35	0.40	0.96	0.93
C %	1.43	0.40	0.42	0.50	0.60
CEC (me/100g)	65.5	50.0	50.0	54.0	55.5
Exchangeable Cations:					
Ca (me/100g)	24.0	28.0	18.0	30.0	26.0
Mg "	15.2	17.6	14.3	16.8	14.0
K "	1.5	0.9	0.3	0.4	1.7
Na "	1.2	1.5	1.5	2.7	3.3
Sum	42	48	34	50	45
Base sat.	64	96	68.0	93.0	81
E.S.P.	2.0	3.0	3.0	5.0	6.0

.../25

Mapping unit Ab_2 — Profile no. 179/93

Geology	:	recent alluvial sediments
Physiography	:	river basin
Relief, macro	:	level
" meso/micro	:	cowfotoes
Vegetation/land use	:	tall grassland/grazing and basin irrigation of paddy rice
Erosion	:	nil
Surface stoniness	:	nil
Rock outcrops	:	nil
Flooding	:	frequent
Slope gradient	:	0-1%
Effective soil depth	:	very deep (deeper than 150cm)
Root distribution	:	medium and fine roots occur in the profile up to 150cm deep
Internal drainage class	:	poorly drained

0-17cm	dark brown (7.5YR 3/2) clay; coarse to very coarse, strong, columnar structure; very hard when dry, firm when moist, sticky and plastic when wet; common, very fine to fine pores; clear and smooth transition to:
17-44cm	dark grey (10YR 4/2) clay; coarse, strong, columnar to subangular blocky structure; very hard when dry, firm when moist, sticky and plastic when wet; few, very fine pores; clear and smooth transition to:
44-87cm	dark brown (10YR 3/3) clay, coarse to very coarse, strong, angular blocky structure; very hard when dry, firm when moist, sticky and plastic when wet; few, very fine pores; gradual and smooth transition to:
87-115cm	dark brown (7.5YR 3/2) clay; medium to coarse, moderate angular blocky structure; very hard when dry, firm when moist, sticky and plastic when wet; few, very fine pores; abrupt and smooth transition to:
115-130cm	black (10YR 2.5/1) clay; fine to medium, weak, angular blocky structure; firm when moist, sticky and plastic when wet; few, very fine pores.

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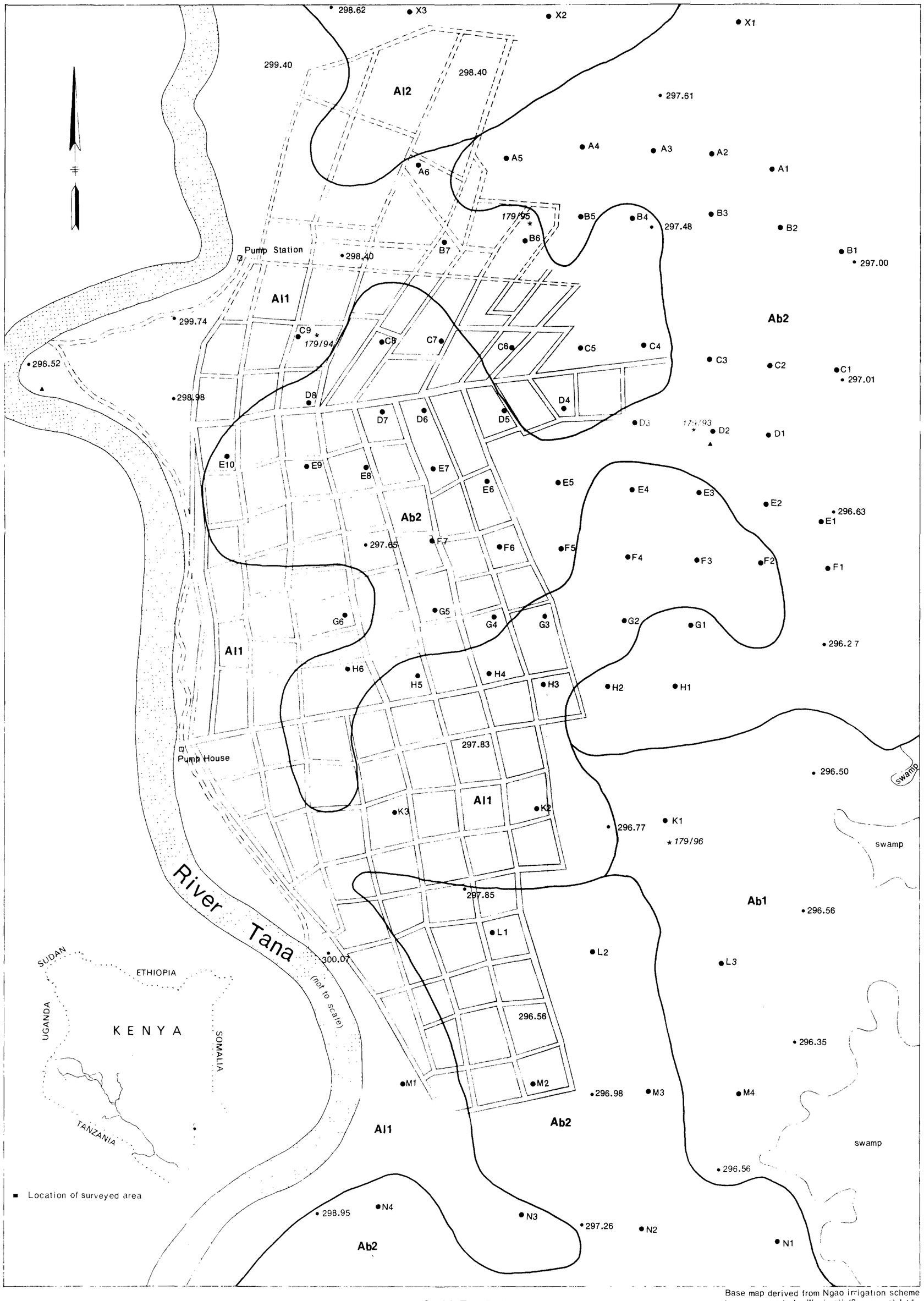
DETAILED SOIL MAP OF NGAO IRRIGATION SCHEME

Appendix 2 to report No. D 18 (South Tana Division, Tana River District)



SCALE 1:5,000

0 50 100 200 300 400 500m

Base map derived from Ngao irrigation scheme topo map made by Wapimaji (Surveyors) Ltd. Scale 1:2,500

LEGEND

A Soils developed on recent alluvial deposits of the Tana river flood plain (slopes less than 2%)

Al RIVER LEVEE SOILS

- Al1 — well drained to moderately well drained, extremely deep, reddish grey to dark brown, friable to firm, loamy sand to silty clay, with a 20–30cm topsoil of dark reddish brown to very dark grey, firm clay
- Al2 — well drained to moderately well drained, extremely deep, dark reddish brown to very dark greyish brown, friable to firm, silty clay loam to silty clay, with a 20–30cm topsoil of dark greyish brown to very dark grey, firm clay

Ab RIVER BASIN SOILS

- Ab1 — imperfectly drained to poorly drained, extremely deep, dark grey to black, firm clay, with dark brown to dark yellowish brown, friable, silty clay loam at 80–120cm depth
- Ab2 — poorly drained to very poorly drained, extremely deep, dark reddish brown to black, firm clay

LAND SUITABILITY CLASSIFICATION FOR FURROW IRRIGATION

mapping unit	current suitability	land improvement requirement *	potential suitability	area (ha)
Al1	II SW	D	II S	69.0
Al2	II SW	d	II S	8.0
Ab1	II SW	D	IIS	27.5
Ab2	III SW	D	II S	103.0

** in addition to clearing, levelling and canal construction*

POTENTIAL LAND SUITABILITY FOR PADDY RICE (BASIN IRRIGATION)

mapping unit	potential land suitability*	area (ha)
Al1	II S	69.0
Al2	II S	8.0
Ab1	I	27.5
Ab2	I	103.0

** after land clearing, levelling, canal and basin constructions*

KEY TO LAND SUITABILITY CLASSIFICATION

Suitability Classes

- I highly suitable
- II moderately suitable
- III marginally suitable
- IV unsuitable

TYPE OF LIMITATION

- S soil
- W drainage

LAND IMPROVEMENT REQUIREMENTS

type / rate	grading	artificial drainage	initial salt leaching and soil amendments
low	(g)	(d)	(e)
moderate	g	d	e
high	G	D	L
very high	**G**	**D**	**L**

KEY

- **Ab2** soil mapping symbol
- soil boundary
- ★ 179/95 sampled profile pit, with ref. number
- ● C9 augerhole with ref. number
- ●300.09 spot height
- ▲ pillar
- road
- plot boundary and irrigation canal
- proposed plot boundary and irrigation canal

1 sq cm = 0.25ha

Prepared and drawn by Kenya Soil Survey in April, 1980

Drawing No. 80023