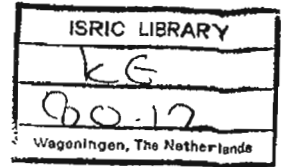


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DETAILED SOIL SURVEY OF ODA IRRIGATION SCHEME
SOUTH TANA DIVISION - TANA RIVER DISTRICT

by

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DETAILED SOIL SURVEY REPORT No. D17, 1980

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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 (PDA) Coast Province, a detailed soil survey was carried out at Oda.

The field work which started in March 1979 was delayed until August 1979 due to very heavy floods in the lower Tana caused by prolonged heavy rains around the Mt. Kenya area.

This survey covers the existing Oda Irrigation Scheme and its proposed extension, together comprising a total of 94.0ha. (approx.). The existing scheme of about 28ha was started in 1968 with Government grants, and ministries providing the technical inputs required, viz. survey, design, construction and pump units. Rice has been cultivated in basins of 0.4ha (1 acre) each, together with small amounts of maize, green grams and cotton. The new extension and relocation of Oda Irrigation Scheme/~~implemented~~ was in accordance with joint proposals of the Small Scale Irrigation Unit (SSIU) of the Ministry of Agriculture and the NCCK's Lower Tana Project team.

2. PREVIOUS WORK

In February 1975, following a request from the Tana River Development Authority (TRDA), the Kenya Soil Survey (KSS) carried out a site evaluation of the soil conditions in the Tana delta (Sombroek et al, 1976), covering the area between Garsen and the mouth of the river Tana. The aim of the study was to find out whether any large-scale irrigation development in this area was feasible.

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

At the request of the Small Scale Irrigation Unit (SSIU) the KSS made a field trip to Oda Irrigation Scheme and carried out in co-operation with the National Cristian Council of Kenya (NCCK) Lower Tana Project Team, feasibility studies to select a suitable site for the extension of the scheme. In all cases, suitable soils were identified for irrigation development but further soil studies and mapping on semi-detailed levels were recommended. This detailed soil survey is therefore a follow up of the studies mentioned above.

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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 and longitude $2^{\circ} 25' . 6''S$ and $40^{\circ} . 10' . 3''E$ respectively and at an elevation of approximately 12m above sea level.

A secondary road links Tarassa trading centre with the national Mombasa-Garsen trunkroad. From Tarassa a motorable track goes on to Oda via Golbanti Village, but is impassable for a good deal of the year. Bus services are frequent between Tarassa and the main road but less frequent from Golbanti. Only four-wheel drive vehicles and light pick-ups can travel to Oda even when the track is passable.

There is a dry-weather airstrip at Garsen (about 36km away) and an irregularly maintained one at Ngao (8km). Telephone services are also available at Garsen.

The river Tana is extensively used by the local inhabitants for transport of people and cargo by canoe. Motor-engined dhows are also sometimes used for transporting people and goods between Lamu/Kipini and Ngao, especially during the rainy seasons when road transport between Garsen and Lamu (mainland) is usually cut off by floods.

Social amenities at Oda include a primary school and a dispensary. A government secondary school and district hospital are available at Tarassa and Ngao respectively.

3.2. Geology and Physiography

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

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

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

3.3. Climate

According to the National Atlas (Survey of Kenya, 1970), the survey area lies within the Dry Sub-Humid to Semi-Arid climatic zone. The mean annual rainfall is 757mm (EAMD, 1970). It occurs in a bimodal pattern, with rainy seasons from April to July, with the highest peak in May, and from November to December. The monthly rainfall averages for the Ngao (Station 92.400.04), which is about 8km to the North-West of Oda, are given in table 1.

Table 1. Average monthly rainfall (in mm) for Ngao (average of 6 yrs.)

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	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 prevailing climatic conditions, irrigated agriculture is the most reliable means of growing food.

3.4. Vegetation

The area next to the river (river levee) is generally covered with tall elephant grass (*Pennisetum purpureum*) with solitary mango and palm trees scattered here and there. The river basin areas are covered with tall grasses of various species. The lower areas which are more frequently flooded are dominated by tall *Echinochloa* spp. (swamp grass), while the slightly higher lying areas are dominated by *Cynodon dactylon* (stargrass), intermixed with various species of *Acacia* bushes and shrubs and the occasional solitary palm trees.

3.5. Present land use

The floodplain is generally used for extensive grazing. Subsistence farming is mainly practised on the levee soils due to their better drainage, lighter textures and hence better workability. Parts of the backswamps are used for rice growing. The main annual crops include rice, sugarcane, maize, green grams, beans, cassava, sweet potatoes and pumpkins. The biannual/perennial crops include bananas, pawpaw and mangoes.

3.6 Hydrology and water resources

Water for the irrigation scheme will be pumped from the Tana River which is the only perennial stream in the area. The dry season flow rate average is $80\text{m}^3/\text{sec}$, with a flow of $30\text{m}^3/\text{sec}$ once in 10 years. The biannual flooding of the Tana, caused mainly by upcountry rains, occur usually in April-June and November-December respectively. The floods, usually disrupt communications and transport by either washing away bridges and sections of the roads, or by making the roads muddy, slippery and impassable; while they may also destroy field crops.

The quality of the Tana river water is good for irrigation. The river water's average electrical conductivity (E.C) is 3215 micromhos/cm, which corresponds to a salt content of 130ppm. Average Sodium Adsorption and Boron content is 0.07ppm (Acres/Ilaco, 1967).

The ground water level fluctuates with seasons - it occurs below 120cm in the wet season. Gleying was observed to occur very commonly from a depth of 100cm, downwards.

4. SURVEY METHODS

A topographic map of scale 1:2,500 was produced by Mapimaji (Surveyors) Ltd., under contract by the Small Scale Irrigation Unit (SSIU) of the Ministry of Agriculture. This map shows the location of the small concrete beacons made by the toposurveyors in a 100m grid and was therefore used as a basemap. All observations and provisional soil boundaries were plotted on it.

The fieldwork was done in two phases. The first phase consisted of 102 augerhole observations, made in a grid system of 100 following the concrete beacons. The depth of observation was 2m and the soils were described for colour, depth, mottling, texture, consistence, etc. They were also analysed for pH and salinity using portable electrical equipment. All data were recorded on the standard KSS forms for routine augerhole observations.

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

Survey methods cont'd.

During the second phase of the fieldwork, four representative sites were selected in which profile pits were made. 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 FAO Guidelines for Soil Profile Description (1977). Each soil horizon was sampled for chemical and physical analyses in the National Agricultural Laboratories.

After the receipt of the laboratory data, the soil boundaries based on field data were readjusted where necessary.

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 conditions, colour, texture, salinity/sodicity, 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
- Al - river levees
- Ab - river basins (backswamps)
- Sa - saline/sodic

The numerals 1, 2, etc, connote different 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 moderately well drained, stratified and of varying texture and consistence;
- river basin (backswamp) soils, which are poorly drained and mainly have a clay texture.

The river levee soils are mainly found on the levees of the present day river course and a former river course. They are generally well drained to imperfectly drained, extremely deep, yellowish red (5YR 4/6) to dark grey (10YR 4/1) stratified soils varying from loose sand to firm clay.

...../6.

5.2. cont'd

They comprise the mapping units A11, A12, A13, A13sa and A14sa, the last two being sodic from 100cm and 50cm depths respectively (see chapter 5.3.1.).

The river basin soils are mainly found on the lower lying backswamps, further away from the river banks. These are imperfectly drained to very poorly drained, extremely deep, dark brown (7.5YR 3/2) to very dark grey (10YR 3/1), clay soils. Gleying occurs quite commonly from a depth of about 90 cm. These soils are found in mapping units Ab1 and Ab2 (see chapter 5.3.2.).

5.3. Description of the soil mapping units

5.3.1. Mapping levee soils

Mapping unit A11

Extent	:	4.5 ha
Meso/micro relief	:	some gilgai.
Slope	:	0-2%
Vegetation	:	tall grass
Land use	:	grazing and cultivation of paddy rice, green grams, maize, pawpaw and bananas.
Soils	:	well drained to moderately well drained, extremely deep (deeper than 200cm), yellowish red (5YR 4/6) * to red (2.5YR 4/6), friable, sandy loam to sandy clay, with 40cm topsoil of dark brown (7.5YR 3/2), firm clay. The structure varies from massive in the topsoil.
Salinity/sodicity	:	non saline but in places strongly sodic in the subsoil.
Chemical aspects	:	
topsoil	:	pH-H ₂ O ** is near neutral (7.2), pH-KCl *** is 5.6; CEC and base saturation are high, 43 me/100g and 79% respectively.

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

** pH-H₂O and pH-KCl are measured in 1:2½ soil: water suspensions.

Mapping unit A11 cont'd

- subsoil : pH-H₂O increases with depth from 7.1 to 8.0 (neutral to strongly sodic), pH-KCl also increases with depth from 5.8 to 7.6; CEC decreases with depth from high to low (50-11.0 me/100g) but base saturation is high, increasing with depth from 89-100%.
- Fertility aspects (Mehlich analysis) : soils are slightly acid (pH 6.3) and are low in organic matter content (%C 0.74), but other available nutrients-phosphorous (P 65ppm), potassium (K 0.57me/100g), calcium (Ca 12.0 me/100g) and magnesium (Mg 9.0 me/100g) are sufficient.
- Differentiating criteria : these soils differ from the other levee soils by their better drainage and their reddish colour.
- Limitation for furrow irrigation : topsoil of firm clay (poor workability).
- Limitation for basin irrigation : well drained to moderately well drained, friable, sandy loam to sandy clay (high permeability).
- Suitability for irrigation (after land improvements) : highly suitable for furrow irrigation and moderately suitable for basin irrigation (paddy rice).

For the description of a representative profile see appendix 1 profile no. 179-89.

Mapping unit A12

- Extent : 25 ha
- meso/micro relief : cowfatoes
- Slope : 0-2%
- Vegetation : tall grass
- Land use : grazing
- Soils : moderately well drained, extremely deep (deeper than 200cm) dark brown (7.5YR 3/2) to very dark greyish brown (10YR 3/2), stratified, friable, sandy loam to silty clay, with dark brown (10YR 3/3) firm clay in the deeper subsoil (150cm depth).

Mapping unit A12 cont'd.

- Soils : The structure varies from strong, medium, angular blocky in the topsoil to weak, fine, subangular blocky in the subsoil.
- Salinity/sodicity : non saline and non sodic throughout.
- Chemical aspects
- topsoil : pH-H₂O is slightly alkaline (7.5), pH-KCl is 5.9; CEC and base saturation are high, 49me/100g and 82% respectively.
- subsoil : pH-H₂O increases with depth from 7.4 to 8.2 (near neutral to moderately alkaline), pH-KCl also increases with depth from 6.0 to 6.4; CEC is high and increases with depth from 21.0 to 35.0; base saturation is very high and increases with depth from 76% to 100%.
- Fertility aspects : the soils are near neutral (pH 6.6) and they are low (Mehlich analysis) in organic matter content (0.53). Other major nutrients - Phosphorous (P 65ppm), potassium (K 0.5me/100g), calcium (Ca 11.9me/100g) and magnesium (Mg 8.0me/100g) are sufficient.
- Differentiating criteria : these soils differ from those of mapping unit A11 by their dark brown to dark greyish brown colour, their drainage and their firm clay texture in the deeper subsoil.
- Limitation for furrow irrigation : moderately well drained, with firm clay in the deeper subsoil (150cm).
- Limitation for basin irrigation : stratified, loose to friable, sandy loam to sandy clay soils (high permeability).
- Suitability for irrigation(after land improvement) : highly suitable for furrow irrigation and moderately suitable for basin irrigation (paddy rice).

Mapping unit A13

- Extent : 12 ha
- Meso/micro relief : nil.
- Slope : 0-2%
- Vegetation : grassland
- Land use : grazing.

Mapping unit A13 cont'd.

- Soils : moderately well drained to imperfectly drained, extremely deep (deeper than 200cm), dark brown (10YR 3/3) to dark grey (10YR 4/1), stratified, friable, sandy loam to sandy clay; with 200cm topsoil of dark brown (10YR 3/3), friable to firm, silty clay to clay.
- Salinity/sodicity : non saline and non sodic throughout.
- Chemical aspects : as for A12
- Fertility aspects : as for A12
- Differentiating criteria : these soils differ from those of the previous unit (A12) by their drainage and topsoil texture.
- Limitation for furrow irrigation : no apparent limitation
- Limitation for basin irrigation : moderately well drained to imperfectly drained, friable, sandy loam to sandy clay soils (high permeability).
- Suitability for irrigation(after land improvements) : highly suitable for furrow irrigation and moderately suitable for basin irrigation (paddy rice).

Mapping unit A13sa

- Extent : 16ha
- meso/micro relief : old river levees and lagoonal sand ridges.
- Slope : 2%
- Vegetation : grassland
- Land use : grazing.
- Soils : these soils are like those of mapping unit A13, except for their salinity and sodicity. The structure varies from single grain (in sand layers) and massive to weak, medium, subangular blocky.
- Salinity/sodicity : slightly saline and moderately to strongly sodic from about 100cm depth.

Mapping unit A13sa cont'd.

Chemical aspects

topsoil : pH-H₂O is moderately acid (5.7) and pH-KCl is 4.7
CEC and base saturation are high - 31.0 me/100g and 60%
respectively.

subsoil : pH-H₂O increases with depth from slightly alkaline to
strongly alkaline or sodic (7.7-9.8), pH-KCl also
increases with depth from 6.0 to 8.6; CEC is moderate,
varying with depth from 14 to 18, but base saturation is
very high, increasing with depth from 81% to 100%.

Fertility aspects : the soils are moderately acid (pH 5.3) and are rich in
organic matter (%C 1.77). The other major nutrients -
phosphorous (P 32ppm), potassium (K 0.6me/100g),
calcium (Ca 7.0me/100g) and magnesium (Mg 5.0me/100g)
are moderately available.

Differentiating criteria : these soils differ from those of the previous ones
(mapping unit A13) by their salinity and sodicity.

Limitation for furrow irrigation : slightly saline and moderately to strongly sodic
from about 100cm depth.

Limitation for basin irrigation : as for A13, and in addition slightly saline and
moderately to strongly sodic from about 100cm depth.

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

Mapping unit A14sa

Extent : 6 ha

Meso/micro relief : old river levees and lagoonal sand ridges

Slope : 1-2%

Vegetation : grassland

Land use : grazing

Soils : moderately well drained to imperfectly drained,
extremely deep (deeper than 200cm), red (2.5YR 4/6)
to dark brown (7.5 YR 4/4), sandy loam to sandy clay; with
about 30cm topsoil of dark brown (7.5YR 3/2), firm clay.

Mapping unit A14sa cont'd.

- Salinity/sodicity : strongly sodic from 50cm and slightly saline from 100cm depth.
- Chemical aspects : as for A13sa
- Fertility aspects : as for A13sa
- Differentiating criteria : these soils differ from the previous ones (mapping unit A13sa) by their colour, firm clay topsoil texture and sodicity from 50cm depth.
- Limitation for furrow irrigation : strongly sodic from 50cm and slightly saline from 100cm depth.
- Limitation for basin irrigation : as for furrow irrigation, in addition to stratified, friable sandy loam to sandy clay soils.
- Suitability for irrigation(after land improvement) : moderately suitable for furrow irrigation and marginally suitable for basin irrigation (paddy rice).

5.3.2. River basin soils

Mapping unit Ab1

- Extent : 27ha
- Meso/micro relief : nil.
- Slope : 0-2%
- Vegetation : tall grassland with few acacia trees
- Land use : grazing and irrigated paddy rice.
- Soils : imperfectly drained to poorly drained, extremely deep (deeper than 200cm) dark brown (7.5YR 3/2), firm clay, with dark grey (10YR 4/1), mottled, firm, sandy clay from 100cm depth. The structure is weak to moderate, fine to medium, subangular blocky.
- Salinity/sodicity : non saline and non sodic throughout.
- Chemical aspects
topsoil : pH-H₂O is near neutral (6.9), pH-KCl is 5.6; both CEC and base saturation are high, viz. 38.5me/100g and 70% respectively.

River basin soils cont'd.

subsoil : pH-H₂O varies with depth from slightly alkaline (7.9) to moderately alkaline (8.4), pH-KCl also varies with depth from 6.3 to 6.8; CEC is high but decreases with depth from 58.0 me/100g to 31.0 me/100g and base saturation is very high, varying from 51 to 98%.

Fertility aspects : the soils are slightly acid, and are low in organic matter content (%C 0.74). The major nutrients phosphorus (P 48ppm), potassium (K 0.5me/100g), calcium (Ca 11.0 me/100g) and magnesium (Mg 7.4 me/100g) are sufficiently available.

Limitation for furrow irrigation : imperfectly drained to poorly drained, firm clay (poor workability, low permeability).

Limitation for basin irrigation : no apparent limitation

Suitability for irrigation(after land improvements) : moderately suitable for furrow irrigation but highly suitable for basin irrigation.

Mapping unit Ab2

Extent : 3.5 ha.

Meso/micro relief : slight depression.

Slope : 0-1%

Vegetation : swamp grass (Echinochloas spp.).

Soils : poorly drained to very poorly drained, extremely deep (deeper than 200cm), dark brown (10YR 3/3) to very dark grey (10YR 3/1), firm clay.

Salinity/sodicity : non saline and non sodic throughout.

Chemical aspects : as for AM

Fertility aspects : as for Ab1

Limitation for furrow irrigation : poorly drained to very poorly drained, firm clay, swampy and waterlogged (poor workability).

Limitation for basin irrigation : no apparent limitation

Suitability for irrigation(after land improvement). : moderately suitable for furrow irrigation and highly suitable 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 non-composite 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	A11	A12	A13sa	Ab1
Profile No.	179/89	179/90	179/92	179/91
Lab. No.	11626	11619	11631	11638
Depth in cm.	0-30	0-17	0-10	0-15
pH	6.3	6.6	5.3	6.3
Na me/100g	0.84	0.66	1.58	0.48
K "	0.57	0.50	0.60	0.52
Ca "	11.9	11.2	7.0	10.8
Mg "	9.1	8.0	5.0	7.4
Mn "	0.98	0.93	0.45	0.91
P ppm	65.0	65.0	32.0	48.0
C %	0.74	0.53	1.77	0.74
Hp m.e%	-	-	0.4	-

The soils are moderately acid to slightly acid (pH 5.3-6.6) and the availability of the major nutrients (P, K, Ca and Mg) is sufficient. However, they are low in organic matter (C%), except for mapping unit A13sa which has a moderate level of organic matter (C% = 1.77).

The Cation Exchange Capacity (C.E.C) values which may also be used as a measure of the potential productivity in terms of the capacity of the soil to retain and supply plant nutrients, are quite high for these soils (see Appendix 1 - Soil Analytical data).

For optimum production of crops however, nitrogenous fertilizers (viz. Ammonium Nitrate, Calcium Ammonium Nitrate, Urea, etc.) and Farm Yard Manure (FYM) should be applied.

6. LAND SUITABILITY FOR SURFACE IRRIGATION

Surface irrigation refers specifically to basin and furrow 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" 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 run in smaller furrows between the crops.

Two kinds of interpretative land classification for irrigation have been used:

- 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 potentialities of the land units, indicating the level and type of land improvement required on the one hand, and the suitability for irrigation after land improvements on the other hand.

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

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

Class II: 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. Potentially these lands have intermediate payment capacity.

Class III: 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.

6 cont'd.

Class IV: 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 are:

- Soil limitations (symbol "S")--: based on the texture of the topsoil, infiltration rate, soil depth, clay pans or hardpans, topsoil stoniness and subsoil permeability.
- Salinity and sodicity limitations (symbol "A")--: based on the total salt content and the sodium percentage occurring in the profile.
- Drainage limitations (symbol "W")--: based on the degree, depth and colour of mottling; groundwater depth and temporary waterlogging.

Table 3 gives the limitations of the various mapping units for basin and furrow irrigation.

The current land suitability, the main limitations and the extent of each soil unit are given in table 4. The additional capital letters to the Roman figures denote the factor (s) imposing the limitations. The key to the land improvement requirements and the definitions of the land improvement levels are also shown in table 4 and in appendix 2.

The potential suitability classification is arrived at by considering the cumulative effect of several persisting land limitations which will affect its ^{productive} capacity. The potential suitability classification for basin irrigation of paddy rice is given in table 5.

Table 3: Major limitations of the soil mapping units

Mapping unit	Limitations	
	Furrow irrigation	Basin irrigation
A1	topsoil of firm clay (poor workability)	well drained to moderately well drained, friable, sandy loam to sandy clay (high permeability)
A12	moderately well drained, soils with firm clay in the deeper subsoil (150cm depth)	stratified, loose to friable, sandy loam to sandy clay soils (high permeability)
A13	no apparent limitation	moderately well drained to imperfectly drained, friable, sandy loam to sandy clay soils (high permeability)
ABsa	slightly saline and moderately to strongly sodic from 100cm depth	as for A13, and in addition slightly saline and moderately to strongly sodic from about 100cm depth
A14sa	strongly sodic from 50cm and slightly saline from 100cm depth	as for furrow irrigation, in addition to stratified, friable, sandy loam to sandy clay soils (high permeability)
Ab1	imperfectly drained to poorly drained, firm clay (poor workability and low permeability)	no apparent limitation
Ab2	poorly drained to very poorly drained, firm clay, swampy and waterlogged (poor workability)	no apparent limitation

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

Soil Mapping Unit	Current Suitability (Surface Irrigation)	Land Improvement requirements	Potential Suitability (Surface Irrigation)	Extent (in ha)
A11	IIW	d	I	4.5
A12	IIW	d	I	25.0
A13	IIW	d	I	12.0
A13sa	IIW A	D1	IIA	16.0
A14sa	IVWA	<u>DL</u>	IIA	6.0
Ab1	IVWS	D	IIS	27.0
Ab2	IVWS	<u>D</u>	IIS	3.5

Key to land improvement requirements

<u>rate</u>	<u>artificial drainage</u>	<u>initial salt leaching and soil amendments</u>
low	(d)	(1)
moderate	d	1
high	D	L
very high	<u>D</u>	<u>L</u>

Table 5: Potential land suitability classification for basin irrigation of paddy rice.

Mapping Unit	Potential land suitability	Extent (in ha)
A ₁	II S	4.5
A ₂	II S	25.0
A ₃	II S	12.0
A _{3sa}	III SA	16.0
A _{4sa}	III SA	6.0
Ab ₁	I	27.0
Ab ₂	I	3.5

7. CONCLUSIONS AND RECOMMENDATIONS

- The soils of Oda Irrigation Scheme were investigated in detail, covering a total of 94.0 ha comprising the existing scheme and the proposed extension.
- Mapping units A₁, A₂ and A₃ are considered as highly suitable for surface irrigation after land development, while the other units (A_{3sa}, A_{4sa}, Ab₁ and Ab₂) are considered as moderately suitable for furrow irrigation after land development due to various limitations (see Table 3).
- Virtually all the river basin (backswamp) soils, comprising of mapping units Ab₁ and Ab₂, are considered to be highly suitable for basin irrigation of paddy rice after land development. These soils, which mainly fall within the river levees are considered to be moderately suitable to marginally suitable for basin irrigation of paddy rice after land development (see Table 5).
- Most of the old scheme has been developed for basin irrigation. It is however proposed that about one half of the total area should be developed for furrow irrigation of row crops. This area should be located in the levee soils of mapping units A₁, A₂, A₃, A_{3sa} and A_{4sa}. The other half of the area should be developed for basin irrigation of paddy rice. This would be located in the river basin soils of mapping units Ab₁ and Ab₂.

- Proper drainage improvement measures should be given a high priority in the development and long term planning of the scheme.
- Mapping unit A13sa is moderately to strongly sodic and slightly saline from about 100cm while mapping unit A14sa is strongly sodic from 50cm and slightly saline from 100cm. Irrigation and drainage should therefore be given special attention in these two units. Application of gypsum would have a positive effect by keeping the ESP values down and also improving the soil structure.
- For rice cultivation, it is recommended to grow only one crop in a year to allow for proper drainage of the soils for a certain period of the year.
- Flooding by the Tana river presents a major hazard, which, if uncontrolled will disrupt or destroy crop growing in the fields. Flood protection dykes should therefore be constructed all around the irrigated areas. The dykes should be strong and high enough to stop the highest possible floods.

...../20.

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SOIL ANALYTICAL DATA

KSS. Profile No. 179-89

Mapping Unit A11

Lab No./79	11626	11627	11628	11629	11630
Depth in cm	0-30	30-56	56-70	70-90	90-110+
Sand %	22	12	24	72	70
Silt%	26	22	12	12	6
Clay%	52	66	64	16	24
Texture class	C	C	C	SL	SCL
pH-H ₂ O 1:2 $\frac{1}{2}$ suspension	7.2	7.1	7.1	9.0	8.8
pH-KCl 1:2 $\frac{1}{2}$ "	5.6	5.8	6.0	6.8	7.6
EC(mmhos/cm) 1:2 $\frac{1}{2}$ susp.	0.12	0.85	0.90	0.25	0.70
C %	0.74	0.50	0.56	0.09	0.09
CEC(me/100g)	43	50	49	5.8	10.9
EXCHANGEABLE CATIONS:					
Ca (me/100g)	20	26	24	2.8	4.2
Mg "	12	14.8	14.3	3.04	3.76
K "	1.03	0.36	0.39	0.15	0.19
Na "	0.95	3.55	6.85	3.55	7.05
Sum	33.98	44.71	45.54	9.54	15.20
Base saturation	79	89	93	100	100
E.S.P.	2	7	14	61	67

...../22.

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

<u>Mapping Unit A2</u>	<u>Profile No. 179-89</u>
Geology	: recent alluvial deposits
Physiography	: river levee (of the Tana floodplain)
Relief, macro	: level
" , meso/micro	: none
Vegetation/land use	: tall grass (star grass spp.); paddy rice, green grams, maize and pawpaws are cultivated.
Erosion	: nil
Surface stoniness	: nil
Rock outcrops	: none
Flooding	: frequent
Slope gradient	: 0-2%
Effective soil depth	: extremely deep (200cm+)
Internal drainage class	: moderately well drained to well drained.
0-30cm	very dark grey (5YR 3/1) clay; massive structure; firm when moist, sticky and plastic when wet; few, very fine to fine pores; gradual and wavy transition to:
30-56cm	dark reddish brown (5YR 3/2) clay; weak, medium to coarse, subangular blocky structure; firm when moist, sticky and plastic when wet; few, very fine to fine pores; gradual and wavy transition to:
56-70cm	dark reddish grey (5YR 4/2) clay; weak, fine to medium subangular blocky structure; firm when moist, sticky and plastic when wet; few, very fine to fine pores; abrupt and smooth transition to:
70-90 cm	reddish brown (5YR 5/4) sandy loam; weak, coarse, angular blocky structure; very friable when moist, slightly sticky and slightly plastic when wet; many, fine and coarse pores; gradual and smooth transition to:
90-110cm+	reddish brown (2.5YR 4/4) sandy clay loam; weak, coarse, angular blocky structure; very friable when moist, slightly sticky and slightly plastic when wet; many fine and coarse pores.

KSS. Profile No. 179 - 90

Mapping Unit A 12

Lab. No/79	11619	11620	11621	11622	11623	11624	11625
Depth in cm	0-17	17-35	35-43	43-62	62-73	73-97	97-110+
Sand %	22	34	28	42	20	28	20
Silt %	26	32	22	34	36	44	36
Clay %	52	34	50	24	44	28	44
Texture class	C	CL	C	L	C	CL	C
pH-H ₂ O 1:2 $\frac{1}{2}$ suspension	7.5	7.4	6.9	7.9	7.9	8.2	8.0
pH-KCl 1:2 $\frac{1}{2}$ "	5.9	6.2	6.0	6.3	6.2	6.3	6.4
EC(mmhos/cm)1:2 $\frac{1}{2}$ susp.	0.19	0.10	0.10	0.06	0.09	0.14	0.08
C %	0.53	0.59	0.29	0.12	0.29	0.09	0.24
CEC (me/100g)	49	20.8	45.5	18.4	34	20.8	34.6
Ca "	24.0	11.9	20.0	10.8	20.8	16.0	18.0
Mg "	13.6	6.56	12.4	5.48	10.0	7.24	10.4
K "	0.98	0.42	1.13	0.17	0.28	0.17	0.22
Na "	1.33	0.51	1.05	0.55	1.13	1.05	1.51
Sum	39.91	19.39	34.58	17.0	32.21	24.46	30.13
Base saturation	82	93	76	92	95	100	87
E.S.P.	3	3	2	3	3	5	4

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Mapping unit A₁₂

Profile No. 179-90

Geology : recent alluvial deposits
Physiography : river levee (of Tana floodplain)
Relief, macro : level
" , meso/micro : cowfatoes
Vegetation/land use : bushed grassland (tall riverine grasses);
mainly grazing but patches of bananas are
cultivated.

Erosion : nil
Surface stoniness : nil
Rock outcrops : none
Flooding : frequent
Slope gradient : 0.2%
Effective soil depth : very deep (over 120cm)
Internal drainage class : moderately well drained.

0-17 cm dark brown (7.5YR 3/2) clay; strong, medium,
blocky structure; firm when moist, sticky
and plastic when wet; few, very fine and fine
pores; abrupt and smooth transition to:

17-35 cm dark brown (10YR 3/3) clay loam; weak, fine to
medium, subangular blocky structure; firm when
moist, sticky and plastic when wet; common,
fine and medium pores; clear and smooth
transition to:

35-43 cm dark brown (7.5YR 3/2) clay; weak, fine,
subangular blocky structure; firm when moist,
sticky and plastic when wet; common, fine
and medium pores; clear and smooth transition to:

43-62 cm very dark greyish brown (10YR 3/2) loam;
weak, fine, subangular blocky structure;
friable when moist, sticky and plastic when
wet; many fine and medium pores; abrupt and
smooth transition to:

100 100 100 100

62-73 cm

very dark greyish brown (10YR 3/2) clay; weak, fine, subangular blocky structure; firm when moist, sticky and plastic when wet; many, fine and medium pores; clear and smooth transition to:

73-97 cm

dark brown (10YR 3/3) clay-loam; weak, fine, subangular blocky structure; friable when moist, sticky and plastic when wet; many, fine, medium and coarse pores abrupt and smooth transition to:

97-110 cm

very dark greyish brown (10YR 3/2) clay; weak, fine, subangular blocky structure; firm when moist, sticky and plastic when wet, common fine and medium pores.

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KSS. Profile No. 179 -- 92

Mapping Unit A33sa

Lab. No./79	11638	11639	11640	11641	11642	11643
Depth in cm	0-10	10-16	16-35	35-53	53-82	82-110+
Sand %	54	94	66	60	58	56
Silt %	6	0	8	10	10	10
Clay %	40	6	26	30	32	34
Texture class	SC	S	SCL	SCL	SCL	SCL
pH-H ₂ O 1:2½ susp.	5.7	6.6	7.7	8.3	9.2	9.8
pH-KCl 1:2½ "	4.7	5.7	6.0	6.5	7.4	8.6
EC (mmhos/cm) 1:2½ susp.	0.35	0.15	0.15	0.35	1.4	1.3
C %	1.77	0.52	0.52	0.52	0.46	0.46
CEC (me/100g)	30.6	3.8	14.4	17.6	15.2	18.4
EXCHANGEABLE CATIONS:						
Ca (me/100g)	10.4	1.6	6.4	6.0	7.6	13.6
Mg "	4.88	0.64	2.8	2.96	2.56	3.36
K "	0.93	0.06	0.39	0.42	0.44	1.48
Na "	2.01	0.51	2.01	5.65	13.35	20.85
Sum	18.22	2.81	11.6	15.03	23.95	39.29
Base saturation	60	74	81	85	100	100
E.S.P.	7	13	14	32	88	100

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<u>Mapping unit A13sa</u>	<u>Profile No. 179-92</u>
Geology	: recent alluvial deposits
Physiography	: river levee (of the Tana floodplain)
Relief, macro	: level
" , meso/micro	: nil
Vegetation/land use	: grassland (star grasses and swamp grass spp); grazing.
Erosion	: nil
Surface stoniness	: nil
Rock outcrops	: none
Flooding	: frequent
Slope gradient	: 0-2%
Effective soil depth	: very deep (deeper than 120cm)
Internal drainage class	: moderately well drained to imperfectly drained.
0-10cm	very dark grey (5YR 3/1) sandy clay; weak, medium, subangular blocky structure; friable when moist, sticky and plastic when wet; common, fine and medium pores; abrupt and smooth transition to:
10-16 cm	light reddish brown (5YR 6/4) medium sand; single grain structure; loose when moist, non sticky and non plastic when wet; many fine, medium and coarse pores; abrupt and smooth transition to:
16-35 cm	dark brown (10YR 4/3); many, coarse, distinct, dark red mottles; sandy clay loam; massive structure; friable when moist, slightly sticky and plastic when wet; many fine and medium pores; gradual and wavy transition to:
35-53 cm	brown (10YR 5/3), many, coarse, distinct, dark red mottles; sandy clay loam; weak, fine to medium, subangular blocky structure; friable when moist, slightly sticky and plastic when wet; common fine and medium pores; gradual and wavy transition to:

53-82 cm

brown (7.5YR 5/4), many, coarse, distinct, dark red mottles; sandy clay loam; weak, fine to medium, subangular blocky structure; friable when moist, slightly sticky and plastic when wet; common fine and medium pores; gradual and wavy transition to:

82-110cm

yellowish brown (10YR 5/4), many coarse, distinct, reddish yellow mottles; sandy clay loam; weak, fine to medium, subangular blocky structure; friable when moist, slightly sticky and plastic when wet; common, fine and medium pores.

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KSS. Profile No. 179-91

Mapping unit Ab1

Lab No/79	11631	11632	11633	11634	11635	11636	11637
Depth in cm	0-15	15-36	36-80	80-105	105-117	117-137	137-160
Sand %	28	20	10	10	12	26	48
Silt %	28	18	14	18	6	8	10
Clay %	44	62	76	72	82	66	42
Texture class	C	C	C	C	C	C	SC
pH-H ₂ O 1:2½ susp.	6.7	7.9	8.0	7.5	6.8	6.8	8.4
pH-KCl 1:2½ susp.	5.6	6.3	6.5	6.3	5.6	5.7	6.8
EC(mmhos/cm) 1:2½ susp.	0.12	0.20	0.30	0.4	0.5	0.51	0.36
C %	0.7	0.73	0.61	0.61	0.58	0.52	0.32
CEC(me/100g)	38.5	57.8	57.8	65.8	76.8	59.5	30.6
EXCHANGEABLE CATIONS:							
Ca (me/100g)	18.0	28.0	30.0	30.0	24.0	20.0	20.0
Mg "	7.6	12.4	14.0	15.2	13.2	11.2	7.44
K "	0.53	0.44	0.44	0.43	0.31	0.26	0.21
Na "	0.69	1.05	1.41	1.79	1.95	2.11	2.21
Sum	26.82	41.89	45.85	47.42	39.46	33.57	29.86
Base saturation	70	73	80	72	51	57	98
E.S.P.	2	2	2	3	3	4	7

...../30.

<u>Mapping unit Ab1</u>	<u>Profile No. 179-91</u>
Geology	: recent alluvial deposits
Physiography	: River Tana floodplain (backswamps)
Relief, macro	: level
" , meso/micro	: nil
Vegetation/land use	: bushed grassland (star grass and swamp grass); mainly grazing
Erosion	: nil
Surface stoniness	: nil
Rock outcrops	: nil
Flooding	: frequent
Slope gradient	: 0-2%
Effective soil depth	: very deep (deeper than 150cm)
Internal drainage class	: poorly drained.
0-15cm	dark brown (7.5YR 3/2); many, medium to coarse, prominent, red mottles; clay; strong, coarse, subangular blocky structure; very firm when moist, sticky and plastic when wet; few, very fine and fine pores; gradual and wavy transition to:
15-36 cm	dark reddish brown (5YR 3/3); many, fine to medium, faint, reddish brown mottles; clay; weak, fine, subangular blocky structure; firm when moist, sticky and plastic when wet; few, very fine and fine pores; gradual and wavy transition to:
36-80 cm	dark reddish grey (5YR 4/2); common, fine, faint, brownish red mottles; clay; weak, fine, subangular blocky structure; firm when moist, sticky and plastic when wet; few, fine pores; gradual and wavy transition to:
80-105 cm	dark brown (7.5 YR 3/2); common, medium to coarse, distinct mottles; clay; moderate, fine to medium, subangular blocky structure; firm when moist, sticky and plastic when wet; few, very fine and fine pores, gradual and wavy transition to:

~~105-117 cm~~

dark reddish brown (5YR 3/3); medium and coarse, distinct, dark red mottles; clay; moderate, fine to medium, subangular blocky structure; firm when moist, sticky and plastic when wet; few, very fine and fine pores; clear and smooth transition to:

117-137 cm

very dark grey (5YR 3/1); many medium and coarse, prominent, dark red mottles; clay; weak, fine to medium, subangular blocky structure; firm when moist, sticky and plastic when wet; few, very fine and fine pores; clear and smooth transition to:

137-160 cm

dark grey (5YR 4/1); common, fine and medium, prominent, reddish yellow mottles; sandy clay; weak, fine to medium, subangular blocky structure; friable when moist, sticky and plastic when wet; common fine pores; calcareous.

