REPUBLIC OF KENYA

MINISTRY OF AGRICULTURE—NATIONAL AGRICULTURAL LABORATORIES

KENYA SOIL SURVEY

DETAILED SOIL SURVEY OF SANDAI IRRIGATION SCHEME

(BARINGO DISTRICT)

by

H.C.K.Kinyanjui

DETAILED SOIL SURVEY·REPORT No. D19, 1982

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1. Introduction

The Soil Survey of the Sandai Irrigation Scheme was conducted at the request of the Provincial Irrigation unit, Rift Valley Province. Field work was carried out from August 1980 to March 1981. The aim of the survey was to investigate the soils and their suitability for Irrigation.

At the start of the fieldwork almost all the suitable land for cultivation was being irrigated at the initiative of the residents. This was however being practiced on shifting cultivation basis. The reasons behind the shifting is that fertilizers were not in use and therefore new areas were opened after the previous one was exhausted. Water was the main constraint in determining the area irrigated at any season.

The fieldwork was carried out by a team composed of Messrs Njeru E.B., Ekirepa A.E., Macharia P.N., Kinyanjui H.C.K., Kaneke P.J.K., Mwangi B.M., Gathui D.N., and Manyasa J.P.W. The co-operation of the Provincial Irrigation unit, Nakuru, the A.A.O. and vertirinary officer(Dr. Koech) at Marigat was greatly appreciated. Acknowledgement is also due to the soil chemistry section of National Agricultural Laboratories and the Kenya Soil Survey Laboratory for analysing the soil and water samples.

2. The Environment

2.1. Location and Communication

The survey area is located 30km south East of Marigiti the Sandai area of Baringo Distritt. It lies at latitude 0° 24'N and longitude $36^{\circ}02'$E approximately and at altitude 1000m above the sea level. The survey area is approximately 280 hectares.

The all weather road from Marigat to the lake Baringo National Park passes near the survey area. From the above road the survey area is accesible through two roads which are impassable during the wet season. One of the roads branches at the Molo river bridge while the other one branches at Loboi.

2.2. Physiography and Geology

The survey area is within the Loboi plain. The landscape is flat to very gently undulating (slopes less than 2%). In general the area slopes very gently from the waseges Range towards the Loboi swamp.

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According to McCall (1967) the area is covered by stratified deltaic silts and saline beach deposits. Observations in the field however indicate the material is alluvium in nature. Most soils were not saline and in some units no carbonates were observed. The geological unit close to the survey area which is composed of superficial deposits, volcanic soils, screes and alluvium could be the most representative. The above geological unit whose boundary is approximate might have extended further south to include the Sandai area.

2.3. Climate

Climate is one of the most important factors in determining the agricultural potential of a given area. The climatic variables given full consideration in this report are precipitation (rainfall), evaporation and temperature.

The rainfall data collected at stations adjacent to the Sandai Irrigation Scheme give a rough estimate of the average rainfall. The use of the adjacent stations was perpetuated by the fact that there are no meteorological stations in the survey area.

The average annual rainfall varies from about 650mm at Perkerra Irrigation Scheme (89.35163), 670mm at Perkerra Experimental station (89.36053) and 750mm at Maji Moto station(89.36026)(see table 1)

Table 1: Altitude and mean annual rainfall of stations around Sandai

Station name	Station no.	Altitude in m	Rainfall
Perkerra Irr. Scheme	89.35163	1000	648
Maji Moto	89.36026	1160	733
Perkerra Exp. Station	89.36053	1000	672

Source: E.A.M.D. Serial Publication for the years 1939 to 1973

Rainfall distribution is characterised by heavier falls in March-May and July - August. If considered generally, the area receives much of its rain from April to August with a short drop in June (see table 2).

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Table 2: Mean monthly Rainfall of three stations around the Sandai Survey area

Station	J	F	M	A	M	J	J	A	S	O	N	D	TOTAL
Perkerra Irr. Scheme 89.35163	39	25	58	68	80	57	74	85	37	38	46	39	648
Maji moto 89.36026	24	24	52	105	80	62	106	96	57	50	48	29	733
Perkerra Exp. station 89.36053	50	21	54	63	96	43	71	91	36	30	59	58	672

Temperature is generally not a limiting factor to crop growing in Kenya. Sandai enjoys a fairly high temperature all the year round. The computed average annual temperature at perkerra Irrigation Scheme. Maji moto and Perkerra Experimental station is 25°C, 23°C and 25°C respectively.

The average annual potential evaporation (Eo) calculated with woodhead's (1968) equation varies from about 2000mm to 2100mm (see table 3).

Table 3: Average annual Eo and r/Eo ratio

Station	Eo	r/Eo
Perkerra Irrigation Scheme	2041	36%
Maji moto	1986	32%
Perkerra Exp. station	2040	32%

The ratio r/Eo (where r is the average annual rainfall and Eo is the annual potential evaporation) gives an impression of the agroclimatic designation of the area. According to the boundary criteria for agroclimatological zones as proposed by Braun (1980), the area belongs to agroclimatological zone V (r/Eo 25-40%) which has a marginal potential for arable agriculture. The probability of receiving rainfall less than the crop water requirement (2/3 Eo) at Marigat, Maji moto and Perkerra Experimental station over the April-August period is 97%, 87% and 97% respectively. The probabilities are estimated using Braun's (1977) seasonal probability tables.

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2.4. Vegetation and land use

The survey area falls under (ecological) agroclimatological zone V (see chapter 2.3). It is characterized by dry thorn-bushland with Acacia being dominant. The grass cover is very poor due to the severe over-grazing by livestock. Most of the natural vegetation is found along drainage ways and depressions. In other areas it is found on isolated bush patches. The estimated tree cover was 2%, shrubs 15%, herbs less than 1% and grass less than 15%. Degradation of the natural vegetation is mostly by overgrazing for the grass and cutting of trees for fencing the cultivated area. In the survey area clearing was practiced while opening new cultivations.

The dominant tree and shrub species are Acacia reficiens subsp. misera, Acacia toritilis, Balanites aegyptiaca and Maerua subcordata. A denser cover of this species occurs on the northern half of the survey area where the soils are better than in the southern half which has compact clay soils. The only herbs are occurring as weeds in the abandoned cultivated areas. The dominant herbs are Cassia occidentalis, Barleria acanthoides, Solanum dubium and Solanum incanum.

The occupation of the people is mainly herding. Goats are the main livestock while cattle and sheep are only found in small numbers. The cattle seen during the field work were in very poor condition. Considering the severe overgrazing in the area, there are few chances that enough grass grows even after the rains. The same factor effects sheep. Goats are different in that they browse on the acacia and other shrubs.

Cultivation is only done within the scheme and at the bottom of the Waseges Range. The other areas are too dry for any cultivation without extra supply of water. In the scheme maize was the most important crop. Surface irrigation was being used (no activities were going on during the field work). Small basins (2m x 2m) made by constructing low dykes were flooded with water from the main canal. Water flows from one basin to the next through openings provided. All crops grown in the scheme were mainly for subsistence. The farmers were practicing shifting cultivation. At the time the survey was being carried out almost all the suitable land that could be irrigated by water from river waseges had been utilized. The practiced of shifting cultivation will therefore stop since new areas to shift to were no more available

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2.5. Hydrology and Water resources

All the rivers except the waseges flow only a short time after every storm. The waseges river is seasonal. It has a constant flow for about half a year. In view of the above, irrigation water will come from river waseges. The river flows reliably only between July and November. For the river to supply enough water for a full season including probable prolonged dry seasons, a dam has to be constructed somewhere along the river. The low river discharge limits the area that could be irrigated. The discharges in future are even likely to be lower considering the effects of farming and clearing in most catchment areas in the country.

The probability of no flow in the river expressed in percentage is shown in table 5. These probability figures indicate that in all years the river has water in August and September. The month of March is dry in almost half the period from 1948-1979. 1 year in 2, the river dries up for about 2 months or more and 1 year in 5, the river dries up for 4 months or more.

Table 4. Probability of no flow in percentage

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
33	37	47	42	24	14	12	0	1	6	4	15

The discharge data is obtained from Ministry of Water Development

3. Survey methods

3.1 Office methods

The base map was prepared from maps at a scale 1:1250, received from the Small Scale Irrigation unit, Rift Valley Province. These were then reduced in the office to a scale of 1:5000. The half a meter interval for the contours was ommited. A 200m grid system was put on the base map.

3.2. Field methods

All observations were made along the grids except the profile pits which were made in the most representative area of every mapping unit. Augerhole observations were made at a distance of 100m apart and to a depth of 2m. Profile pits were made to a depth of 1.5m except where digging to that depth was difficult due to compaction.

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The soils were examined for depth structure colour texture mottling consistency salinity sodicity calcareousness e.t.c. The different mapping units were delineated by comparing the details described above from the systematic augerings. In every mapping unit a representative profile pit was made. The representative profile pits were described in detail and the data recorded on the standard soil profile description forms. The data described from the systematic augerings were recorded in the standard Kenya Soil Survey forms for detailed surveys. All observations were described following the KSS soil survey methods which are based on the FAO "Guidelines for soil description" (FAO, 1977). The soil colour was determined using the "Munsell soil colour charts" (Munsell Colour Company, 1971). Unless otherwise stated the colour descriptions are for the moist soil conditions. All profile pits were sampled following the different natural horizons. The samples were taken to the National Agricultural Laboratories for standard physical and chemical analysis.

A soil map with final soil boundaries was drawn after completing the field work. The map passed through map collerators and altimately to the drawing room.

3.3. Laboratory methods

All soil samples were dried, crushed and sieved through a 2mm sieve.

Texture:

No pretreatment of samples to remove organic matter and cementing agents, shaking overnight with sodiumhexametaphosphate/sodium carbonate in an end-over end shaker. Measurement of silt plus clay (0-0.05mm) and clay (0-0.002mm) with a hydrometer after 40 seconds and 2 hours respectively. The silt fraction is obtained by difference (Day 1956 and Bouyoucos, 1962).

Ph-H_2O and IN KCl: pH was read with a pH-meter in a 1:2.5 soil-water/KCL suspensions.

Electrical Conductivity (Ec): was measured by conductivity meter in a 1:2.5 soil-water suspensions. For soils with an Ec of more than 1.2 mmho/cm at 25°C, the electrical conductivity was measured in the saturation extract (ECe).

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Cation exchange capacity (CEC) and exchangeable cations:

Soil samples were leached with IN NH_4OAC pH 8.2 and the determination of exchangeable cations (viz. Ca, Mg, K and Na) was carried out on EEL-flamephotometer/Atomic absorption spectrophotometer. Then the samples were leached with 95% ethyl alcohol to remove excess of ammonium acetate. The samples were leached with 1N NaoAc pH 8.2, the leachate were discarded. Subsequently, the samples were leached with 1N NH_4OAC pH 8.2 solution. The leachates were collected in a 100ml. v. flasks and the CEC was determined in the above leachates by measuring the Na-concentration in flamephotometer.

4. The soils

4.1. Systematics and Nomenclature

The whole survey area is within the same physiographic and geological unit. The soil mapping units have been distinguished by comparing the different soil characteristics such as texture, drainage conditions, salinity and/or sodicity etc.

In the soil map each mapping unit is identified by a code. The first letter denotes physiography, the second one geology, while the numerical figures indicate different soil characteristics. The following symbols are used:

Y - Piedmont Plain (Physiography)
A - Alluvial (Geology)
1,2,3,4- Different soil characteristics

4.2. General properties of the soils

The whole survey area is flat to very gently undulating with slopes of less than 2%. Three major categories of soils are recognised.

- soils that are well drained, porous and having varying textures and consistence within the same profile (unit YA_2).
- soils that have compact subsoil horizons (unit YA3)
- soils that have compact subsoil horizons and are saline and sodic (unit YA4)

The soils in the first category are: well drained, very deep, dark brown to dark yellowish brown, calcareous, stratified and have varying textures ranging from loam to silt clay loam. The pH-H_2O ranges from 7.0 to 8.0, CEC ranges from 21 to 36 me/100g soil, base

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saturation is over 100%, organic carbon ranges from 0.1% to 0.6%. These soils are non-saline and non-sodic.

The soils of the second category are: moderately well drained, very deep, very dark greyish brown to dark yellowish brown, non-calcareous, stratified and have clayey texture. The pH-H_2O ranges from 7.5 to 8.0, CEC ranges from 21 to 33 me/100g soil, base saturation is over 100%, organic carbon varies from 0.1 to 0.4%. These soils are non-saline and non sodic. This unit (YA3) is next to the Loboi swamp which may indicate that the fine material (clay) was deposited last in this case in the more flat area next to the swamp.

The soils of the last category are: moderately well drained to imperfectly drained, deep, dark greyish brown, slightly calcareous, stratified, texture is dominantly clay. The pH-H_2O ranges from 7.0 to 8.8, CEC ranges from 33 to 38 me/100g soil, base saturation is 72% to over 100%, organic carbon varies from 0.1 to 0.4%. These soils are slightly to moderately saline and sodic. They were so compact that no roots were found below 15cm from the surface. The whole unit (YA4) was in general bare.

4.3. Description of soil mapping units.

Mapping unit YA1

Extent : 100 hectares

macro-relief : flat to very gently undulating, slopes 0-2%

Land use : Maize is grown under basin irrigation. Basins about 2 x 2m are made in which the maize is grown. These are fed by several cannals passing through the area. Farming is done on shifting cultivation basis.

Soils : This unit has well drained, very deep, dark yellowish brown to dark brown, friable, moderately to strongly calcareous loam to silty clay loam soils.

The texture of both topsoil and subsoil varies from dark brown (10YR 3/3 - 4/3) to dark yellowish brown (10YR 3/4 - 4/6) without any proper sequence from the topsoil through the subsoil. The structure of the topsoil is platy (except) where disturbed by ploughing whereas that of the subsoil varies from weak to moderately developed subangular blocky.

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Salinity/sodicity : non-saline and non-sodic

Chemical properties : Topsoil:- pH-H_2O ranges from 7.7 to 9.3; pH-KCl ranges from 6.7 to 8.2. CEC is moderately high - 31 to 34 me/100g. Base saturation was over 100%. Subsoil:- pH-H_2O ranges from 7.5 to 7.8, pH-KCl ranges from 6.8 to 7.0, CEC is high 33 to 36 and the Base saturation was over 100%.

For the description of a representative profile, see appendix 1 profile No. 105/1-16

Limitation for irrigation : None

Potential suitability for irrigation : highly suitable

Mapping unit YA2.

Extent : 75 hectares

Macro-relief : flat to very gently undulating, slope 0-2%

Land use : Maize grown under basin irrigation. Basins 2 x 2m are made. The maize is grown within the basins. Water was supplied by cannals. Farming is done on shifting cultivation basis.

Soils : These are well drained, very deep, dark brown to dark yellowish brown, friable moderately to strongly calcareous silty clay to clay soils with a loamy sand to loam horizon at varying depths (between 50 and 180cm).

The texture of both topsoil and subsoil vary from silt clay to clay except for a sandy horizon which has texture varying from loamy sand to loam occuring in the subsoil. The colour varies from dark brown (7.5YR 3/2 - 4/4, 10YR 3/3 - 4/3) to dark yellowish brown (10YR 4/4) without any proper sequence. Structure is dominantly platy except the sandy horizons which are porous massive.

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Salinity/sodicity : non saline and non sodic throughout

Chemical properties : Topsoil:- pH-H_2O ranges from 7.7 to 8.0, pH-KCl ranges from 6.6 to 6.8. CEC was high (33.6 me/100g soil). Base saturation was also high (over 100%)
Subsoil:- pH-H_2O ranges from 7.6 to 8.0 decreasing with depth. pH-KCl 6.9. CEC is high (ranges from 21 to 32 me/100g soil). Base saturation is also high (96 to over 100%).

For the description of a representative profile see appendix 1 No. profile No. 105/1-14

Limitation for Irrigation : non to slight limitation for surface irrigation

Potential suitability for irrigation : highly suitable to moderately suitable.

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Mapping unit YA3

Extent : 95 hectares

Macro-relief : flat to very gently undulating, slopes 0-2%

Land use : Maize is grown under irrigation. Basins 2 x 2m are made in which the maize is planted.

Soils : These are moderately well drained, very deep, very dark greyish brown to dark yellowish brown, friable clay soils.

The texture varies from silt loam to clay except for a sandy horizon occuring at varying depths. The texture of the sandy horizon varies from loamy sand clay sandy loam. The colour varies from very dark greyish brown (10YR 3/2) to dark yellowish brown (10YR 3/4). The structure is dominantly weakly developed, medium to coarse platy developing to angular blocky in the deeper (70cm+) subsoil. The subsoil after drying gives an impression of prismatic structure. The sandy horizon was porous massive.

Salinity/sodicity : non saline throughout and non to slightly sodic in the subsoil.

Chemical properties : Topsoil - pH-H_2O ranges from 7.5 to 7.8 pH-KCl was 6.3 CEC ranges from 21 to 30 me/100g soil. Base saturation is over 100%.

Subsoil:- pH-H_2O ranges from 7.7 to 8.0 pH-KCl ranges from 6.7 to 6.9, CEC was 33 (me/100)soil. Base saturation is over 100%.

For the description of a representative profile see appendix 1 profile No. 105/1-12.

Limitations for Irrigation : The compact subsoil might not allow free drainage and root penetration.

Potential suitability for irrigation : moderately suitable for surface irrigation.

Mapping unit YA4	: 10 hectares
macro-relief	: flat to very gently undulating, slope 0-2%
Land use	: The area was bare due to over grazing.
Soils	: These are moderately well drained to imperfectly drained, deep, dark greyish brown to very dark greyish brown, friable to firm, slightly calcareous, saline and sodic soils. The texture ranges from silty loam to clay (in places gravelly clay) and loamy sand to sandy clay loam in some horizons deep (over 90cm) in the profile. Colours vary from very dark greyish brown (10YR 3/2) to dark greyish brown (10YR 4/2). Structure varies from granular in the topsoil to weakly developed angular blocky in the subsoil. The horizons occuring between 15 and 90cm are very compact (hardpan).
Salinity/sodicity	: strongly saline ECe 22.0 mmhos/cm in the topsoil, slightly to moderately saline 5.0 -14.5 mmhos/cm in the subsoil; non sodic in the topsoil, slightly to moderately sodic in the subsoil.
Chemical properties	: Topsoil: pH-H_2O ranges from 7.7 to 8.0 pH-KCl ranges from 7.1 to 7.4 CEC is high (33.0 to 38.0 me/100g) Base saturation is also high (over 100%) Subsoil: pH-H_2O ranges from 8.0 to 8.8 pH-KCl is 7.4. CEC is high (33.6 me/100g soil) Base saturation is high 72 to 95%.

For the description of a representative profile see appendix 1 profile No. 105/1-11

Limitation for Irrigation	: slight to moderate salinity, slight to moderate sodicity and hard pan between 15 and 90 cm
Potential suitability for Irrigation	: marginally suitable.

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4.5. Suitability of water for irrigation

The quality of water suitable for irrigation is determined by its potential to cause soil hazards (salinity, sodicity, and bicarbonate).

Two water samples were collected in the main canal (sample Nos. 10919 and 10920). Both samples show no salinity hazard (Ec 0.50 and 0.54 respectively). The first sample (No. 10919) shows low amounts of sodium (Na=2.15 me/1) while the second sample had higher amount of sodium (Na = 3.61 m.e./1). The calculated sodium adsorption ration (SAR) is 1.59 m.e/1 and 3.68 m.e./1 respectively. Adjusted SAR for both samples is 2.7 m.e./1 and 5.9 m.e./1. From the figures above the second sample (10920) shows slight sodicity hazard. In most cases accumulation of salinity or sodicity depends on the management of water. Proper drainage and leaching reduces any hazards. In the case of the second sample, proper management of the water would eliminate any hazard. The amount of bicarbonates in both samples are slightly high (1.90 me/1 and 1.93 me/1 respectively). Although bicarbonates are not toxic they increase sodium hazard. Calculated Residual sodium carbonate is however low (-0.78 me/1 and 0-0.02 m.e/1 respectively) which indicates the water is safe for irrigation.

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Table 5 Analytical data of two water samples

Lab. no.	10919	10920
pH	8.1	7.8
Conductivity micro mhos/cm	500	540
sodium me/l	2.15	3.61
Potassium me/l	0.13	0.16
Calcium "	0.96	1.10
Magnesium "	1.72	0.84
Carbonate "	NIL	NIL
Bicarbonate"	1.90	1.92
Chlorides "	2.48	3.40
Sulphate "	0.06	0.06
Nitrates "	-	-
Fluorides "	-	-
Sodium adsorption ratio me/l	1.59	3.68

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4.4. Land Suitability for surface irrigation

Surface irrigation may be in the form of furrow or basin. The furrow type of irrigation is where water is brought in a furrow and runs in smaller furrows between the crops. The basin type of irrigation is where water is brought in by furrows and is allowed to flow in the basins which are made of low ridges of soil. When a basin has enough water then the water is stopped from flowing in by closing the opening with the furrow.

The basin type method was being used at Sandai Irrigation Scheme. Basins of about 2x2m were made on a straight line by making low dykes. Water was being allowed in the basins at one point and allowed to flow from one basin to another through openings which were closed once the amount of water required was achieved.

Other methods of irrigation e.g. over head irrigation might not be economical considering the type of crops grown. In Sandai Irrigation Scheme only maize is grown in large scale. A few farmers grow kale and beans. No pumps are used, water flows by gravity. The cost of improving the land would be minimal since most of the area has been cleared and very little levelling will be done.

The different suitability classes are distinguished by the major land improvements such as drainage, clearing levelling reclaiming saline and/or alkaline soils e.t.c. Land suitability classes reflect the degree of suitability of the land for a specific purpose. The following are the land suitability classes used:-

CLASS 1 - Highly suitable:-
Lands without apparent hazards or limitations of soil salinity topography or drainage for irrigation farming, under present conditions.

CLASS 2 - Moderately suitable:-
Lands with slight hazards and/or limitations of soil, salinity, topography or drainage, for irrigation farming under present conditions. These lands are adapted to somewhat narrower range of crops and are expected to be more costly to prepare for irrigation e.g. drainage.

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CLASS III - Marginally suitable:-
Lands with moderate hazards and/or limitations of soil, salinity topography or drainage for irrigation farming under present conditions. These lands either have a restricted, crop adaptability or are expected to give yields lower than those of class II lands, or demand more costly improvement and management.

CLASS IV - Unsuitable
Lands with severe limitations of soil, salinity, topography or drainage for irrigation farming under present conditions except for special crops or special conditions of management which can cope with these limitations.

Topography is not a limiting factor in all the mapping units. The area is in general flat to very gently undulating (slopes less than 2%). The gentle slope allows gravitational flow of water over the whole proposed scheme area.

The salinity and sodicity limitations are rated according to the salt content (Ec), the exchangeable sodium percentage (ESP) and the depth at which they occur within the soil profile. Only one mapping unit (YA4) has salinity and sodicity hazards. The topsoil is very saline ECe 22.0 mmhos/cm while the subsoil is slightly to moderately saline- 5-14 mmhos/cm. There was slight to moderate sodicity hazard in both topsoil and subsoil.

Drainage is not expected to cause any problems in units YA1 and YA 2. The soil porosity in units YA3 and YA4 is very poor. This could cause impeded drainage. At present after a heavy shower only a few centimeters from the surface were found to be moist. the rest of the water was lost in the runoff.

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Table 6

Land suitability classification for surface Irrigation

Soil mapping unit	Current suita-bility	Land improvement	Potential suitability	Area in hectares
YA1	I	(d)(l)(g)(c)	I	100
YA2	I-IIs	(d)(l)(g)(c)	I-IIs	75
YA3	IIIsw	d l (g)(c)	IIs	95
YA4	IVsnw	D L g (c)	IIIsnw	10

Key to land improvement requirements

Rate	artificial drainage	initial salt leaching and soil amendments	grading	clearing
low	(d)	(l)	(g)	(c)
moderate	d	l	g	c
high	D	L	G	C
very high	D	L	G	C

Key to types of limitations

s soil

n salinity/sodicity

w drainage

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5. Conclusions and Recommendations

The soils of Sandai Irrigation Scheme were studied in detail. Of the 280 hectares surveyed 100 were highly suitable, 75 were highly to moderately suitable, 95 were marginally suitable and 10 were unsuitable.

The highly suitable area was composed of soil of unit YA1. The highly to moderately suitable area was composed of soils of unit YA2 (these soils are rated in both classes due to the presence of a sandy layer within the profile). The soils of both mapping units have no soil hazards and are easy to develop in that there will be minimal grading and clearing. Drainage is not a problem as long as the water management is proper. The moderately suitable area is composed of mapping unit YA3. These soils have a compact subsoil. In view of this, water management will require special attention. Grading and clearing are minimal. The unsuitable area is composed of soils of mapping unit YA4. This unit is in general difficult to develop due to the severe limitations which would be costly to correct.

It was noted that the major bottle neck was the availability of enough water. As mentioned earlier the best solution for a continous supply of adequate water will be construction of a dam on the waseges river. The present amount of water would reduce the area to be irrigated and was also not garanteed during prolonged dry seasons.

Shifting cultivation was being practiced. At the time the survey was carried out new land suitable for irrigation with water from the river waseges was running out and farmers soon or later will have no choice but to stop the practice and adopt fertilizers in their farming methods. The residents of the scheme could be encouraged to prepare manure from their livestock. This could improve the soil fertility and in addition improve the soil structure and permiability. It was noted that none of the farmers used manure. To succeed in collecting manure, bomas should be constructed for the animals at night.

The present management of water and the fields will have to be stepped-up to get higher yields. More so as the farmers will have to pay for fertilizes when the land is exhausted and no new areas available to shift to.

Since infiltrations were low the basin method which is in use is appropriate. The problem would arise if crops sensitive to water logging are grown (e.g. beans).

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Appendix 2:

Detailed description of Representative soil profiles and analytical data

Mapping unit	Observation No.	Page
YA1	105/1-16	21-23
YA2	105/1-14	24-26
YA3	105/1-12	27-29
YA4	105/1-11	30-32

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LABORATORY DATA OF PROFILE DESCRIPTION No.

Observation no: 105/1-16 Mapping unit: YAl Soil classification: eutric Fluvisols

Laboratory no. /81	4593	4594	4595	4596	4597	4598
Horizon	Ap	AC	C	2C	3C	4C
Depth (cm)	0-17	17-31	31-54	54-83	83-109	109-133
pH-H_2O (1: 2½ v/v)	9.3	7.7	7.6	7.8	7.5	7.7
pH-KCl "	8.2	6.7	7.0	6.9	6.8	6.5
EC (mmho/cm) "	1.5	0.4	0.7	0.4	0.5	0.5
$CaCO_3$ (%)						
$CaSO_4$ (%)						
C (%)	0.6	0.4	0.6	0.3	0.3	0.5
N (%)						
C/N						
CEC (me/100g), pH 8.2	31	34	37	34	34	32
CEC " " pH 7.0						
Exch. Ca (me/100g)	32	29	35	29	25	23
" Mg "	10	10	9	8	8	7
" K "	1.3	0.6	0.7	0.8	1.2	1.1
" Na "	1.0	1.0	1.2	1.1	1.0	0.9
Sum of cations	44	40	46	38	35	31
Base sat. %, pH 8.2	100+	100+	100+	100+	100+	98
" " %, pH 7.0						
ESP at pH 8.2	3	3	3	3	3	3
Texture (limited pretreatment)						
Gravel % (>2.0mm)	28	26	56	48	36	44
Sand % (2.0-0.05mm)	46	52	22	40	40	32
Silt % (0.05-0.002mm)	26	22	22	12	12	24
Clay % (0.002-0mm)	L	SiL	SCL	L	L	L
Texture class						

Fertility aspects 0 - cm Laboratory no. /

General		Available nutrients			
pH-H_2O (1: v/v)		Na/me/100g)		Mn (me/100g)	
Exch. acidity (me/100g)		K "		P (ppm)	
C %		Ca "		P-Olsen (ppm)	
N %		Mg "			

Remarks:

Mapping unit YA1

Profile No.	: 105/1-16
Geology	: Alluvium
Physiography	: Piedmont plain
Relief	: flat to very gently undulating
Land use	: Irrigation scheme (not cultivated on the spot)
Erosion	: water: sheet and gully wind: sheet
Rock outcrops	: Nil
Flooding	: Nil
Surface stoniness	: Nil
Slope gradient	: less than 2%
Effective soil depth	: over 120cm
Drainage class	: well drained

Au	0-17	Dark greyish brown (10YR 4/4 moist, 10YR 4/3 dry); loam; moderate, fine to medium platy structure; hard when dry, friable when moist, sticky and plastic when wet; common, very fine to medium pores; common fine roots; clear and smooth transition to:
AC	17-31cm	dark yellowish brown (10YR 3/6 moist 10YR 4/3 dry); silt loam; common weak distinct, yellowish brown (10YR 5/6 -5/8) mottles; weak, fine to medium subangular blocky structure; hard when dry friable when moist, sticky and plastic when wet; many very fine and fine, common medium pores; common fine roots; clear and wavy transition to:
C	31-54cm	dark yellowish brown (10YR 4/4 moist, 10YR 5/6); mottled; sand clay loam; moderate, fine to medium subangular blocky structure; very hard when dry, friable when moist, sticky and plastic when wet, many very fine and fine, common medium pores; gradual and wavy transition to:

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2C	54-83cm	dark yellowish brown (10YR 4/6 moist, 10YR 5/6 dry); loam; moderate, fine subangular blocky structure; very hard when dry, friable when moist, sticky and plastic when wet; many very fine and fine, common medium pores; diffuse and wavy transition to:
3C	83-109cm	dark yellowish brown (10YR 3/6 moist, 10YR 4/4 dry); loam; weak, very fine to fine subangular blocky structure; slightly hard when dry, friable when moist, sticky and plastic when wet; many very fine to medium pores; gradual and smooth transition to:
4C	109-133cm	dark yellowish brown (10YR 3/4 moist, 10YR 5/3 dry); loam; weak, coarse subangular blocky structure; hard when dry, friable when moist, sticky and plastic when wet; common very fine and fine, few, medium pores; abrupt and smooth transition to:
5C	133-151cm	dark brown (10YR 3/3 moist, 10YR 4/3 dry); gravelly sandy clay: weak, fine to medium subangular blocky structure; slightly hard when dry, friable when moist, sticky and plastic when wet; many very fine to medium pores; abrupt and smooth transition to:
6C	151-180cm	brown (10YR 3/4 moist, 10YR 5/4 dry); clay; weak, fine to medium subangular blocky structure; very hard when dry, friable when moist, sticky and plastic when wet; common very fine and fine, few medium pores.

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LABORATORY DATA OF PROFILE DESCRIPTION No.

Observation no: 105/1-14 Mapping unit: YA2 Soil classification: eutric Fluvisols

Laboratory no. /81	2689	2690	2691	2692	2693	2694
Horizon	Ap	CA	C	2C	3C	4C
Depth (cm)	0-19	19-44	44-60	60-81	81-103	103-162
pH-H_2O (1: v/v)	7.7	8.1	8.0	7.8	7.6	7.8
pH-KCl "	6.6	6.8	6.9	6.9	6.7	6.6
EC (mmho/cm) "	0.4	0.3	0.6	1.0	0.7	0.4
$CaCO_3$ (%)						
$CaSO_4$ (%)						
C (%)	0.2	0.2	0.3	0.2	0.1	0.2
N (%)						
C/N						
CEC (me/100g), pH 8.2	33	33	32	32	32	30
CEC " " pH 7.0						
Exch. Ca (me/100g)	26	27	29	29	24	26
" Mg "	7.0	7.0	7.0	5.2	5.2	6.3
" K "	1.3	0.5	0.4	0.4	0.4	0.5
" Na "	1.6	1.8	2.5	2.3	2.0	Tr
Sum of cations	35.3	36.5	38.9	36.9	31.1	32.3
Base sat. %, pH 8.2	100+	100+	100+	100+	96	100+
" " %, pH 7.0						
ESP at pH 8.2						
Texture (limited pretreatment)						
Gravel % (>2.0mm)						
Sand % (2.0-0.05mm)	18	26	18	38	78	26
Silt % (0.05-0.002mm)	38	34	50	38	14	46
Clay % (0.002-0mm)	44	40	32	24	8	28
Texture class	C	C/CL	SiCL	L	LS	CL

Fertility aspects	0 - cm		Laboratory no. /
General	Available nutrients		
pH-H_2O (1: v/v)	Na/me/100g)	Mn (me/100g)	
Exch. acidity (me/100g)	K "	P (ppm)	
C %	Ca "	P-Olsen (ppm)	
N %	Mg "		

Remarks:

Mapping unit YA?

Profile No.	: 106/1-14
Geology	: Alluvium
Physiography	: piedmont plain
Relief	: flat to very gently undulating
Land use	: irrigation scheme
Erosion	: water: sheet and gully
Rock outcrops	: Nil
Flooding	: Nil
Surface stoniness	: Nil
Slope gradient	: 2%
Effective soil depth	: over 120cm
Drainage class	: well drained

Ap	0-19cm	very dark greyish brown (10YR 3/2 moist, 7.5YR 4/4, dry); clay; massive to weak, coarse to very coarse subangular blocky structure; hard when dry, friable when moist, sticky and plastic when wet. common very fine and fine, few medium pores. common fine roots. gradual and wavy transition to:
CA	19-44cm	dark brown (7.5YR 3/2 moist 10YR 5/4 dry). clay/clay loam: moderate, medium to coarse platy structure. hard when dry, firm when moist sticky and plastic when wet. common very fine and fine, few coarse pores. common fine roots; clear and wavy transition to:
C	44-60cm	dark brown (7.5YR 4/4 moist, 7.5YR 5/4 dry); silty clay loam; many, distinct, strong brown (10YR 5/6) mottles; weak, fine to medium platy structure; few, thin slickensides; slightly hard when dry, friable when moist, sticky and plastic when wet; slightly calcareous; common very fine pores; few to common fine roots; clear and wavy transition to:

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2C	60-81cm	dark brown (7.5YR 4/4 moist/dry); loam; common, fine, faint mottles; weak, fine to medium, platy structure; slightly hard when dry, friable when moist, sticky and plastic when wet; slightly calcareous; common very fine pores; very few fine roots; clear and wavy transition to:
3C	81-103cm	dark brown (7.5YR 3/2 moist, 10YR 3/4 dry); loamy sand; massive; soft when dry, friable when moist non sticky and non-plastic when wet; many very fine and fine pores; very few fine roots; gradual and wavy transition to:
4C	103-162cm	very dark brown (10YR 2/2 moist, 7.5YR 5/4 dry); clay loam, massive; hard when dry friable when moist, slightly sticky and slightly plastic when wet; many very fine and fine pores.
5C	162-202cm	dark brown (7.5YR 3/2 moist, 10YR 5/4 dry); silty clay; very hard when dry, friable when moist, sticky and plastic when wet

LABORATORY DATA OF PROFILE DESCRIPTION No.

Observation no:105/1-12 Mapping unit: YA3 Soil classification: Eutric Fluvisols

Laboratory no. /81	2675	2676	2677	2678	2679	2680
Horizon	Ap	AC	C	2C	3C	4C
Depth (cm)	0-8	8-34	34-70	70-99	99-140	140-175
pH-H_2O (1: v/v)	7.8	7.5	7.7	7.7	7.7	8.0
pH-KCl "	6.3	6.2	6.7	6.9	6.9	6.9
EC (mmho/cm) "	0.5	0.5	1.2	1.3	1.4	0.8
$CaCO_3$ (%)						
$CaSO_4$ (%)						
C (%)	0.4	0.4	0.3	0.4	0.3	0.1
N (%)						
C/N						
CEC (me/100g), pH 8.2	22	30	34	34	29	33
CEC " " pH 7.0						
Exch. Ca (me/100g)	19	18	33	36	34	36
" Mg "	8.1	8.5	7.1	8.1	6.7	6.3
" K "	1.7	1.2	0.8	0.5	0.5	0.6
" Na "	2.4	2.3	1.2	1.4	1.5	1.4
Sum of cations	30.6	30.2	41.6	46.0	42.7	44.3
Base sat. %, pH 8.2	100+	100+	100+	100+	100+	100+
" " %, pH 7.0						
ESP at pH 8.2						
Texture (limited pretreatment)						
Gravel % (>2.0mm)						
Sand % (2.0-0.05mm)	20	16	18	20	26	46
Silt % (0.05-0.002mm)	54	36	30	30	26	24
Clay % (0.002-0mm)	26	48	52	50	48	30
Texture class	SiL	C	C	C	C	SCL

Fertility aspects 0 - cm Laboratory no. /

General		Available nutrients			
pH-H_2O (1: v/v)		Na/me/100g)		Mn (me/100g)	
Exch. acidity (me/100g)		K "		P (ppm)	
C %		Ca "		P-Olsen (ppm)	
N %		Mg "			

Remarks:

Mapping unit YA3

Profile No.	: 105/1-12
Geology	: Alluvium
Physiography	: piedmont plain
Relief	: flat to very gently undulating
Land use	: irrigation scheme
Erosion	: water: sheet and gullies in neighbourhood wind: sheet
Rock outcrops	: Nil
Flooding	: Nil
Surface stoniness	: Nil
Slope gradient	: 2%
Effective soil depth	: over 120cm
Drainage class	: well drained

Ap	0-8cm	dark brown (10YR 4/3 moist, 10YR 3/6 dry): silt loam: weak medium to coarse platy structure: hard when dry, firm when moist, sticky and plastic when wet: many, very fine and fine pores: common fine, few medium roots: clear and wavy transition to:
AC	8-34cm	dark yellowish brown (10YR 3/4 moist, dry); clay; weak, coarse to very coarse platy structure; hard when dry, friable when moist, sticky and plastic when wet; common, very fine and fine pores; common fine, few medium roots; clear and wavy transition to:
C	34-70cm	dark brown (7.5YR 3/2 moist, 7.5YR 4/2 dry); clay; moderate, fine to medium platy structure; many thin slickensides; hard when dry (compact) friable when moist, sticky and plastic when wet: few, very fine pores; gradual and smooth transition to:
2C	70-99cm	dark yellowish brown (10YR 3/4 moist, 10YR 4/2 dry): clay: moderate, medium to coarse, angular blocky structure: many thin slickensides: slightly calcareous: hard when dry (compact), friable when moist, sticky and plastic when wet: common, very fine to moderate pores: clear and wavy transition to:

3C	99-140cm	very dark greyish brown (10YR 3/2 moist, 10YR 4/2 dry); gravelly clay; moderate, very fine to medium angular blocky structure; many, moderate slickensides; slightly calcareous; very hard when dry (compact); friable when moist, sticky and plastic when wet; common very fine to fine pores
4C	140-175cm	yellowish brown (10YR 5/4 moist); sandy clay loam; firm when moist, sticky and plastic when wet.

LABORATORY DATA OF PROFILE DESCRIPTION No.

servation no: 105/1-11 Mapping unit: YA4 Soil classification: eutric Fluvisols-(saline and sodic phase)

aboratory no. /81	2669	2670	2671	2672	2673	2674
orizon	A	AC	C	2C	3C	4C
epth(cm)	0-15	15-32	32-58	58-73	73-90	90-104
H-H_2O(1: 2½ v/v)	8.0	7.7	8.0	8.6	8.8	8.7
H-KCl "	7.4	7.1	7.4	7.4	7.4	7.4
C(mmho/cm) "	9.5	4.0	6.0	2.5	2.0	1.9
aCO_3(%)						
aSO_4(%)						
(%)	0.3	0.4	0.3	0.3	0.1	0.1
(%)						
/N						
EC(me/100g), pH 8.2	33	38	39	34	34	34
EC " " pH 7.0						
xch.Ca(me/100g)	34	46	26	13	10	10
Mg "	7.0	3.7	6.4	5.2	3.3	3.7
K "	1.1	1.2	1.0	0.8	0.5	0.5
Na "	26	12	18	13	10	13
m of cations	68	62	50	32	24	27
se sat. %, pH 8.2	100+	100+	100+	95	72	79
" %, pH 7.0						
SP at pH 8.2						
exture (limited pretreatment)						
ravel % (>2.0mm)						
nd % (2.0-0.05mm)	24	30	18	32	52	58
lt % (0.05-0.002mm)	66	10	36	10	2	10
ay % (0.002-0mm)	10	60	46	58	46	32
exture class	SiL	C	C	C	SC	SCL

ertility aspects 0 - cm Laboratory no. /

eneral		Available nutrients			
-H_2O (1: v/v)		Na/me/100g)		Mn(me/100g)	
xch. acidity (me/100g)		K "		P (ppm)	
%		Ca "		P-Olsen(ppm)	
%		Mg "			

emarks:

Mapping unit YA4

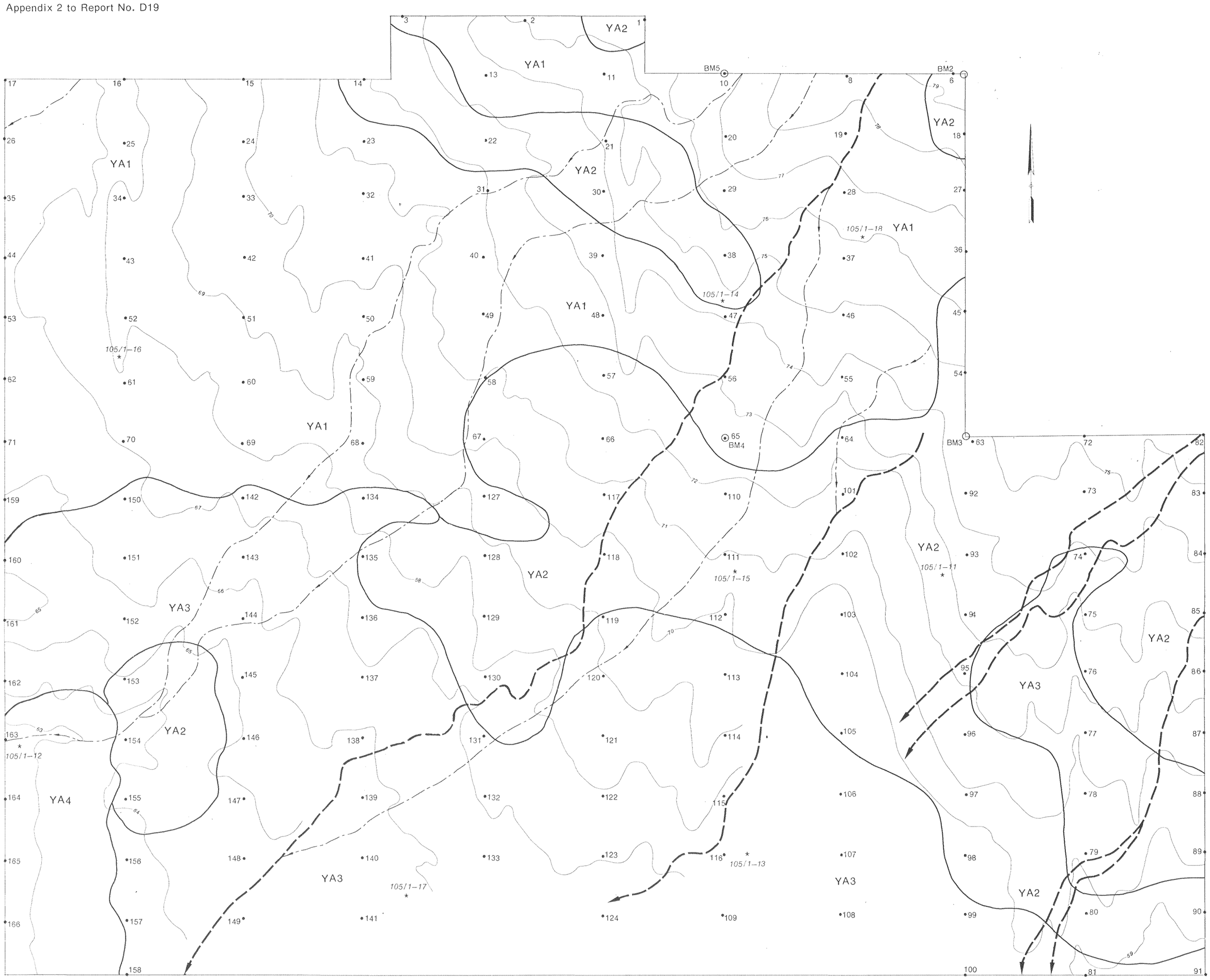
Profile No.	: 105/1-11
Geology	: Alluvium
Physiography	: piedmont plain
Relief	: flat to very gently undulating
Land use	: Extensive grazing (over grazed)
Erosion	: water: sheet and gully wind : sheet
Rock outcrops	: Nil
Flooding	; Nil
Surface stoniness	: Nil
Slope gradient	: 2%
Effective soil depth	: 50cm
Drainage	: imperfectly drained

A1	0-15cm	very dark greyish brown (10YR 3/2 moist, 10YR 4/2 dry). silt loam:moderate, very fine and fine granular structure. hard when dry, friable when moist, sticky and plastic when wet. common very fine to medium pores. few, very fine (dead) roots. clear and smooth transition to:
AC	15-32cm	brown (10YR 5/3 moist, 10YR 5/2 dry): gravelly clay. moderate, fine to medium angular blocky and subangular blocky structure: hard when dry, friable when moist, sticky and plastic when wet; hard pan: common medium pores; gradual and smooth transition to:
C	32-58cm	very dark greyish brown (10YR 3/2 moist, 10YR 5/3 dry); gravelly clay; weak, coarse to very coarse angular blocky structure; very hard when dry, firm when moist, sticky and plastic when wet; hard pan; few, very fine pores; gradual and smooth transition to:
2C	58-73cm	very dark greyish brown (10YR 3/2 moist, 10YR 4/2, dry); gravelly clay: weak, medium to coarse angular blocky structure: few, thin slickensides. extremely hard when dry, firm when moist, sticky and plastic when wet. slightly calcareous: hard pan: very few, very fine pores. clear and wavy transition to:

3C	73-90cm	dark greyish brown (10YR 4/2 moist, 10YR 4/3 dry); gravelly sandy clay; weak, fine to medium subangular blocky structure; very hard when dry, firm when moist, slightly sticky and slightly plastic when wet; slightly calcareous; hard pan; few, very fine to medium pores; clear and wavy transition to:
4C	90-104cm	dark brown (10YR 4/3 moist, 10YR 5/6 dry); sandy clay loam; massive; very hard when dry, friable when moist, non-sticky and non plastic when wet.

Appendix 2 to Report No. D19

DETAILED SOIL MAP OF SANDAI IRRIGATION SCHEME (Baringo District)



SCALE 1:5,000

0 50 100 200 300 400 500m

Base map provided by the Provincial Irrigation Engineer, Nakuru

LEGEND

Y PIEDMONT PLAINS (slopes less than 2%)

YA Soils developed on alluvial deposits

YA1 well drained, very deep, dark yellowish brown to dark brown, stratified, friable, strongly calcareous, silt loam to clay

YA2 like YA1, but with sand to sandy clay horizons between 50 and 180cm

YA3 moderately well drained, very deep, dark yellowish brown to very dark greyish brown, stratified, friable clay, with a compact clay fragipan occurring at variable depths between 30 and 140 cm

YA4 moderately well drained to imperfectly drained, deep, dark greyish brown to very dark greyish brown, friable to firm, slightly calcareous, strongly saline, slightly to moderately sodic, gravelly clay, with a hardpan from 15 to 90 cm

LAND SUITABILITY CLASSIFICATION FOR SURFACE IRRIGATION

soil unit	current suitability	required land improvement	potential suitability	area (ha)
YA1	I	(d) (l) (g) (c)	I	100
YA2	I–IIs	(d) (l) (g) (c)	I–IIs	75
YA3	IIIsw	d l (g) (c)	IIs	95
YA4	IVsaw	D L g (c)	IIIsaw	10

KEY TO LAND SUITABILITY CLASSIFICATION FOR SURFACE IRRIGATION

Limitations

s – soil
a – salinity and/or sodicity
w – drainage

Suitability classes

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

LAND IMPROVEMENT REQUIREMENTS

type / level	artificial drainage	initial leaching and/or amendment	grading	clearing
low	(d)	(l)	(g)	(c)
moderate	d	l	g	c
high	D	L	G	C
very high	D	L	G	C

KEY

YA2 ..... soil mapping unit symbol
soil boundary
•100 augerhole observation, with number
105/1–11 ★ profile pit observation, with number
1 sq cm = 0.25ha
furrow
drain
72 / 71 contours, V.I.1m

Location of surveyed area

Prepared and drawn by Kenya Soil Survey, January 1982
Drawing No. 82001