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KENYA SOIL SURVEY

SEMI-DETAILED SOIL SURVEY OF THE PROPOSED RURII AND SAGANA FISH CULTURE IRRIGATION SCHEMES

(MURANG'A/KIRINYAGA DISTRICT)

by

J.K.Kanake

-DETAILED SOIL SURVEY REPORT No.S11,1986

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1. INTRODUCTION

The request to carry out a soil survey of the proposed Rurii and Sagana Fish Culture Irrigation Schemes was received from the Provincial Irrigation Officer, Central Province (Nyeri). The Small Scale Irrigation Branch (SSIB) of the Ministry of Agriculture intends to develop the area for the growing of horticultural crops and rice, under irrigation.

Soil investivations were therefore carried out to identify the types of soils in the area, and to assess their suitability for surface irrigation. This would facilitate the planning and implementation of a suitable irrigation system. The fieldwork was started in May 1981 and completed in August the same year, covering a total area of approximately 653 hectares. The soils were examined at a semi-detailed level (about one observation per 9 hectares). Fieldwork was executed in collaboration with Messrs. H.C.K. Kinyanjui, B.G. Mwangi, D. Ngethe and M. Wekesa.

The author is grateful to Mr. J. Kamithi, the Provincial Surveyor, and to Mr. Opiyo, the Provincial Irrigation Officer, for their invaluable assistance; and also to all others who co-operated with, and assisted the survey team during the course of the fieldwork.

2. ENVIRONMENTAL CONDITIONS

2.1 Location and communications

The survey area is situated near Sagana Town, at the boundary of Murang'a and Kirinyaga Districts. The Rurii Scheme is found in Murang'a District, while the Sagana Fish Culture Scheme lies across Sagana River (Tana), in Kirinyaga District . The river forms the boundary between the two districts. The survey area is intersected by latitude and longitude

0^{o} 40'S and 37^{o} 11'E respectively, and lies at an elevation of approximately 1,200 metres above sea level.

The survey area, being situated between the towns of Murang'a and Sagana, which are about 8 km apart, is well served by infrastructure. Rail transport is provided by the Thika-Nyanyuki railway line which passes through both Murang'a and Sagana. The major (all weather) Nairobi-Thika-Nyeri road by-passes the area by way of the new Tana bridge, but junctions from the major road give access to the survey area through Sagana and Murang'a respectively.

2.2 Climate

In the compilation of this chapter, data from two climatic stations have been used. None of these stations is located within the survey area itself. Tana Experimental Fish Farm (90.37096) climatic station is about 1 km to the North-East of the survey area while Murang'a District Office (90.37007) climatic station is about 4.3 km to the South-West.

Table 1. Altitude, mean annual rainfall and station's particulars of stations adjoining Rurii Scheme.

Station's Name and No.	Altitude (m)	Rainfall (mm)	Years of record
Murang'a District Office (90.37007)	1280	1196	70(1904-73)
Tana Exp. Fish Farm (90.37096)	1235	1241	15(1959-73)

2.2.1 Average annual and seasonal rainfall

The average annual rainfall of the survey area was estimated by calculating the average of the above stations weighed according to their distance from the survey area. This was done for both monthly and annual totals. The average annual rainfall of the survey area is about 1230 mm. The distance between the two stations is 5.3 km.

There are two pronounced rainy seasons, namely, the long rains (March-May) and the short rains (October-December). The average seasonal rainfall of the survey are during the long rains is about 640 mm while that of the short rains is about 410 mm.

From the above average seasonal rainfall values, it has been calculated that about 52% of the average rainfall is received during the long rains while about 33% falls during the short rains.

Table 2. Estimated mean monthly rainfall of the survey area

	J	F	M	A	M	J	J	A	S	O	N	D	Year
90.37007	34	42	110	310	203	45	20	24	26	121	190	74	1196
90.37096	35	44	98	291	254	30	22	32	21	155	203	56	1241
Est. for the survey area	34	44	101	294	244	32	22	31	22	149	204	59	1236

2.2.2 Mean annual temperatures

The mean annual temperatures for the survey area as calculated with the equation $T^{o}C = 30.2 - 1.68x$ where x is altitude in thousands of feet (EAMD, 1970) is about $22^{o}C$. With similar equations, the maximum and minimum temperatures are estimated as $28^{o}C$ and $16^{o}C$ respectively.

2.2.3 Evaporation, evapotranspiration and agro-climatic zonation

The potential evaporation of the survey area is about 1990 mm. This has been estimated from Woodhead's (1968) equation for the potential evaporation (Eo) in Kenya which he expressed as follows: Eo (mm)=2422-0.358h where h is the station altitude in metres.

The potential evapotranspiration (Et) estimated as 2/3 of the potential evaporation, is about 1325 mm.

The r/Eo ratio (r=average annual rainfall and Eo=average annual potential evaporation) is about 60% which places the area in agro-climatic zone III. According to Sombroek et al. (1980), it is a semi-humid zone. It has a high to medium potential for plant growth and a low risk of failure (5-10%) for adapted crops assuming that soil conditions are not limiting.

Table 3. Climatic data for Murang'a climatic station, Tana climatic station and the survey area

Station and EAMD No.	Temperatures (^{o}C) Mean annual	Rainfall Mean annual	Eo	Et
Muranga D.O. (90.37007)	22	1196mm	1964mm	1309mm
Tana Exp. Fish Farm (90.37096)	22	1241mm	1241mm	1320mm
Estimate for the survey area	22	1233mm	1989mm	1325mm

Since the long rainy season commences in the month of March, the growing seasons will then be the April-June, April-July or April-August periods for a three, four or five months' crop respectively. Subsequently, the November-January or November-February periods will be the

growing seasons for the short rains season which commences in the month of October. During these periods, the potential evapotranspiration (Et) estimations are 278 mm, 345 mm and 424 mm for the long rains and 385 mm and 517 mm for the short rains respectively.

From the above estimates, it can be observed that the water requirement (Et) in a short rains' growing period of three months is greater than the long rains' growing period of four months.

2.2.4 Seasonal rainfall probabilities

To determine the success of crops with different water requirements per given time, Braun's (1977) probability tables have been used. Table 4a shows the short rains probabilities. In these two tables, r represents the average rainfall and Et the average water requirement. Pr>Et is the probability (expressed as a percentage) that the rainfall will exceed the water requirement. It is assumed that all rainfall will be stored in the soil. Run off or sub-surface drainage are not taken into account.

Table 4a. Rainfall probabilities for the long rains

	r(mm)	Et(mm)	Pr>Et (%)
(March-May) 3 mths	639	278 (April-June)	97
(March-June) 4 mths	671	345 (April-July)	>95
(March-July) 5 mths	693	424 (April-August)	>90

Table 4b. Rainfall probabilities for the short rains

	r(mm)	Et(mm)	Pr>Et (%)
October-December	412	385 (November-January)	45
October-January	446	517 (November-February)	25

The above calculated probabilities mean that during the long rains, there is enough for a three, four or a five months' crop on average in 9 out of 10 years (>90%), while in the short rains there is on average only enough rainfall for a three months' crop once every two years (45%).

2.3 Geology and physiography

The Rurii bottomlands which are situated south of Sagana river are formed by alluvial sandstones overlain by recent alluvial deposits of several metres thickness. These sandstones are lake deposits formed due to the daming up of the Sagana river by the Thiba basalts flow in Pleistocene to Recent times (Fairburn, 1966).

The surrounding hills consist of Precambrian biotite gneisses and granitoid gneisses. The area north of the river is developed on olivine basalts of Pleistocene to Recent age. The physiography of the area follows closely the geology. The gneisses form hills and associated footslopes of which only the latter occur in the survey area. North of the river the olivine basalts form a plain. Floodplains are found along the Sagana river. Further away from the river bottomlands with poor drainage conditions occur.

2.4 Vegetation

As mentioned earlier the survey area belongs to agro-climatic

zone III, hence, it carries a variable vegetation of either moist woodland, bushland, or savana. The bottomland areas are covered with short grasses which are dominated by Cynodon dactylon (Star grass) and various Cyperaceae sps. (Sedges). Pennisetum purpureum (Elephant grass) is found in small patches scattered along the rivers. The surrounding hill slopes and plains are covered with characteristically broad leaved trees and scattered clumps of shrubs which are dominated by Combretum spp. and Lantana camara respectively.

2.5 Present land use

The bottomlands which have poorly drained, heavy textured (clayey) soils and are seasonally flooded (by run off from the surrounding hills and overflowing of the Sagana and Ragati rivers), are used for communal grazing. The people of the surrounding areas bring in their animals to graze during the day and take them home in the evening. Due to their low-lying position, the bottomlands always provide green pastures for the animals, even during the dry seasons when there is no grass in other areas.

The floodplains, the lower footslopes, and parts of the plains (Sagana Fish Culture Scheme) are used for the cultivation of maize, beans, tobacco, vegetables, bananas and some fruit trees (mangoes and oranges). Tobacco is an important cash crop in these areas, while coffee is grown on the higher areas (soil and topography permitting). Dry season vegetables are grown in places along the rivers where the ground water table is high or where there is a high perched ground water level.

2.6 Hydrology and water resources

The survey area lies in the basin of the Tana/Sagana river and its tributaries. The two main rivers, the Sagana and the Ragati, are perenial, while small springs are commonly found along the steep hillsides. The seasonal flooding of the rivers, caused by heavy rains on the slopes of the Aberdare Mountains and Mount Kenya, may be a great hazard to road communication (especially in areas away from the major roads), and to the irrigation projects.

The quality of the Sagana/Tana river water is good for irrigation. Its average electrical conductivity (EC) is 215 micro mhos/cm, which corresponds to a salt content of 130 ppm. Average sodium adsorption ratio (SAR) is 0.6, and Boron content is 0.07 ppm (Acres/Ilaco, 1967).

The ground water fluctuates seasonally, and in the dry season, the level varies from 85 cm near the river and at the foot of the hills, to below 200 cm in other areas.

3. SURVEY METHODS

3.1 Office methods

Topographical maps for the survey area were supplied by the toposurveyor of the Provincial Irrigation Unit, Nyeri. The two maps covering the Rurii and the Sagana Fish Culture Schemes respectively, were of different scales. These maps were reduced in the office to a smaller standard scale, and joined together to make the basemap of scale 1:10,000. Field observations were plotted on this map which was finally reduced to the publication scale of 1:20,000.

3.2 Field methods

Soil augerings were made to a depth of 200 cm (soil depth permitting), following a grid system of approximately 400 m X 400 m. The soils were examined for depth, colour, texture, consistence, internal drainage, salinity (by EC meter), pH, calcareousness (by HCl reaction), etc.

All observations were marked on the map, and provisional soil boundaries were drawn, delineating the different soil mapping units, after comparing the details described above from the systematic augerings.

For every mapping unit, a representative profile pit was made. The representative profile pits were described in detail, following the Kenya Soil Survey methods which are based on the "Guidelines for Soil Profile Description" (FAO, 1977). The soil colour was determined using the "Munsell Soil Color Charts" (Munsell Color Company, 1971). Colour descriptions are for moist conditions only, unless the soil was dry, in which case the dry soil colour is given. All profile pits were sampled following the different natural horizons found in the soil. A composite topsoil sample for fertility analysis was taken in the area neighbouring each profile pit. The soil samples were taken to the National Agricultural Laboratories for standard physical and chemical analysis.

A soil map with the final soil boundaries was drawn after completing the fieldwork. The map passed through the map correlators and finally to the Cartographic Section in the Kenya Soil Survey for final drawing.

3.3 Laboratory methods

The laboratory methods are described in short below. For more details the reader is referred to Hinga et al. (1980).

Preparation	: All samples are dried, crushed and sieved through a 2 mm sieve.
Texture	: Samples are shaken over-night with sodium hexameta phosphate/sodium carbonate. The silt and clay fractions are measured with a hydrometer.
pH and Electrical Conductivity (E.C.)	: Measured in a 1:2½ soil/water suspension, and in 1-normal KCl suspension (pH only).
Organic C	: Walkley-Black method
C.E.C.	: The soil samples were first leached with 1N sodium acetate (NaOAC) at pH 8.2, then washed with 96% ethyl alcohol and N ammonium acetate at pH 7.0. Na is determined in the last leachate by flame photometer.
Exchangeable cations	: The soil is leached with 1N-ammonium acetate at pH 7 to extract the exchangeable cations. K and Na in the leachate are determined by flame photometer; and Mg and Ca are determined by atomic absorption spectrophotometer.

Exchangeable acidity (Hp) : The soil is leached with 0.6N-barium chloride (not buffered at any pH). The increase of acidity of the leacheate over that of the extracting solution is determined by tiltration with dilute sodium hydroxide.

Available nutrients : (Composite topsoil samples only) - Extraction of soil by shaking at a 1:5 ratio with 0.1N HCl/0.025N H_2SO_4. Determination of Ca, K, Na by flame photometer after an anion resin treatment for Ca. For Mg the same procedure as for exchangeable Mg. For P the sodium bicarbonate at pH 8.2 (P-Olsen) method is used. Mn is measured colorimetrically using phosphoric acid-potassium petriodate for colour development.

4. SOILS

4.1 Previous work

Prior to the present survey, some soil information on the survey area may be found on the Exploratory Soil map and agro-climatological zone map of Kenya (Sombroek et al., 1982). According to this map (scale 1:1,000,000) two major groupings of soils are recognised in the survey area, viz: soils developed on undifferentiated Basement System rocks (predominantly gneisses). These are excessively drained to well drained, shallow to moderately deep, red to brown, friable, sandy clay loam to clay; and, soils developed on Tertiary basic igneous rocks (on volcanic footridges). These are well drained, extremely deep, dusky red to dark reddish brown

friable clay soils.

An earlier soil map of Kenya of scale 1:3,000,000 by Gethin-Jones and Scott (1959), which appears in the National Atlas of Kenya (Survey of Kenya, 1970), identifies three main soil units in the survey area, namely; dark brown sandy loams (podsolic soils) derived from both sediments and basement complex rocks; black clays (grumosolic soils) derived mainly from colluvium and occurring on plains; and pinkish-red sandy loams (Latosolic soils) derived from highly dissected remnant land surfaces. Not much detailed information could be extracted from the above maps.

4.2 General properties of the soils

The soils of the area can broadly be sub-divided into four major groups based on the physiography:

(a) The soils of the footslopes:

These soils are well drained to moderately well drained and very deep. They are developed on colluvium derived from various gneisses, and range in colour and texture from yellowish brown to dark grey, loamy sand to loam. During the wet season, drainage conditions may deteriorate considerably due to seepage from the higher hillslopes. Rainsplash and rillwash erosion is severe especially under cultivation. As a result, large amounts of sand are carried down from the hills.

(b) The soils of the erosional plains:

These soils are developed from basic igneous rocks (Olivine basalts). They consist of well drained to imperfectly drained, very deep, dark reddish brown to dark grey clays. The soils are generally non-saline and non-sodic. Part of this area is seasonally flooded.

(c) The soils of the floodplains:

These soils are developed on recent alluvial deposits of the Sagana river. They consist of well drained to poorly drained, very deep, reddish brown to very dark grey, stratified, friable clay loam to firm clay. Where the floodplains extend to the base of the footslopes petroferric material occurs at depths between 50 and 100cm. Most sub-soils are slightly sodic, even as some topsoils.

(d) The soils of the bottomlands:

The soils are developed on alluvium/colluvium from various parent materials. They consist of moderately well drained to poorly drained, very deep, dark brown to very dark grey, mostly stratified clay loam to clay. They are slightly sodic and in places slightly saline. Most of the bottomlands are seasonally flooded.

4.3 Description of the Soil Mapping Units

4.3.1 Systematics and nomenclature

The first entry in the legend is the physiography and the second one the geology (parent material). Within each physiographic unit, various soil mapping units have been identified, taking into account certain soil characteristics such as texture, colour, soil depth, etc.

Each soil mapping unit is identified by a code. The symbols appearing in the code denote physiography, geology and certain soil characteristics in that order.

The following codes are used:

Physiography

F - footslopes

P - erosional plains

A - floodplains

B - bottomlands

Geology (parent material)

N - biotite gneisses

Q - granitoid gneisses

B - olivine basalts

A - alluvial deposits

X - various parent materials

Soils

m, *m* - depth class annotations (see "Key to depth classes" of appendix 2)

1,2,3, etc - subvisions based on different soil characteristics

The description in the legend (soil map) denote the characteristics of the subsoil (usually the B-horizon). Soils are classified according to the legend of the "Soil Map of the World" (FAO/Unesco, 1974).

4.3.2 Soils of the footslopes

Soil Mapping Unit FN1

Extent	: 72 ha
Parent	: biotite gneisses (Basement System rocks)
Physiography	: footslopes
Macro-relief	: gently undulating, with slope gradients of 2-5%
Erosion	: Moderate rainsplash and rillwash erosion, but may be severe if vegetation cover is removed

Vegetation : Scattered Lantana camara bushes with short grasses

Land use : extensive grazing, and cultivation of maize, beans and a few bananas and mangoes

Drainage : well drained to moderately well drained

Soils, general : this mapping unit consists of well drained to moderately well drained, very deep, dark brown to very dark grey, stratified, very friable loamy sand to sandy loam. The soils have an ABC sequence of horizons with clear and smooth transitions between the horizons. Groundwater occurs at 120cm.

colour : A-horizon: dark brown (10YR 3/3)
B-horizon: dark greyish brown (10YR 4/2) to very dark grey (7.5YR 3/0)

texture : A-horizon: loamy sand
B-horizon: loamy sand to sandy loam

structure : A-horizon: massive to very weak, medium to coarse sub-angular blocky
B-horizon: massive to very weak, medium sub-angular blocky

consistence : A-horizon: very friable when moist, slightly sticky and slightly plastic when wet
B-horizon: very friable when moist, sticky and plastic when wet.

Chemical properties

A-horizon : organic carbon 0.8%; CEC 4.5 me/100g; pH 5.4; base saturation 62%; EC is very low (0.04 mmhos/cm) and there is virtually no exchangeable sodium

B-horizon : CEC varies between 4.5 and 8.7 me/100g; pH 5.6-6.0; base saturation varies between 44% and 100%; EC 0.04 mmhos/cm; ESP is nil

Salinity/sodicity : non-saline and non-sodic

Soil Classification : cambic ARENOSOLS

For a representative profile with analytical data see appendix 1 profile No.1 (Observation No. 135/1-46)

Soil Mapping Unit FQ1

Extent : 75 ha

Parent material : granitoid gneisses(Basement System rocks)

Physiography : footslopes

Macro-relief : gently undulating, slopes 2-5%

Erosion : moderate rain splash and rillwash erosion, but may be severe if the vegetation cover is removed.

Vegetation : short to medium, bushed grassland

Land use : mainly grazing and locally sand mining (for building) near seasonal waterways.

Drainage : moderately well drained

Soils, general : this mapping unit consists of very deep,

brown to very dark grey, stratified soils of varying texture and sodicity. The soils have an ABC sequence of horizons with abrupt to gradual and smooth to wavy transitions between the horizons. Mottling is present in the B-horizon. A perched watertable occurs at depths of 30 to 70 cm.

colour : A-horizon: greyish brown (10YR 5/2) to very dark grey (10YR 3/1)
B-horizon: brown (10YR 5/3) to dark greyish brown (10YR 3/1)

texture : A-horizon: loam
B-horizon: sand to clay loam

structure : A-horizon: weak to moderate, fine sub-angular blocky
B-horizon: porous massive or loose to moderate, fine to medium angular blocky

consistence : A-horizon: friable when moist, slightly sticky and plastic when wet
B-horizon: loose to friable when moist, sticky and plastic when wet.

Chemical properties

A-horizon : organic carbon is 1.1%; the CEC follows the clay content and varies between 6 and 10 m.e./100g. The pH is about 6.6. Base saturation ranges from 35% to just over 50% in the coarse and fine textured soils

respectively. The ESP follows the same pattern: nil in the coarse textured soils to about 15 in the fine textured. The EC is below 0.1 mmhos/cm.

B-horizon : The CEC follows the clay percentage: 0.4 me/100g in coarse sand to 10.2 me/100g in sandy loams. Base saturation varies from about 35% to 100%; ESP values are very low in the sands but these go up to about 12 in the finer textures. EC is below 0.1 mmhos/cm.

Salinity/sodicity : non-saline, but in places moderately sodic.

Classification : gleyic CAMBISOLS, partly sodic phase

For a representative soil profile with analytical data see appendix 1, profile 2 (observation No. 135/1-54)

4.3.3. Soils of the volcanic plains

Soil mapping unit PB1

Extent : 24 ha

Parent material : Olivine basalts

Physiography : volcanic plain

Macro-relief : level to very gently undulating, slopes less than 1%

Erosion : none

Land use : cultivation of maize, beans, sorghum, together with a few mango and citrus trees

Drainage : well drained to moderately well drained

Soils, general : this mapping unit consists of well drained to moderately well drained, very deep, dark reddish brown to dark grey, friable to firm clay. They have an ABC sequence of horizons with clear to gradual and smooth transitions to wavy transitions between the horizons. In the deeper subsoil, Fe and Mn concretions may occur together with some moderately thick clayskins which are common

colour : A-horizon: dark reddish brown (5YR 3/4) to dark brown (7.5 YR 3/2)

B-horizon: reddish brown (5YR 4/3) to dark grey (7.5YR 4/0)

texture : clay throughout

structure : A-horizon: weak, fine to medium, crumb; to weak to moderate fine to coarse, subangular blocky

B-horizon: weak to moderate, fine to coarse, subangular blocky

consistence : A-horizon: friable when moist, sticky and plastic when wet

B-horizon: firm when moist, sticky and plastic when wet.

Chemical properties

A-horizon: : organic carbon varies between 1.4 and 1.8%; CEC varies between 25.3 and 28 me/100g; base saturation 33-41%;

EC is below 0.3 mmhos/cm

B-horizon	: CEC varies between 19.3 and 28 me/100g; base saturation increases with depth from 36% to 73%; EC increases with depth from 0.1 to 0.6; and ESP values of 8-14.5 are found in places.
Salinity/sodicity	: non-saline, but slightly sodic in places
Classification	: orthic LUVISOLS, in places sodic phase

For a representative profile with analytical data, see appendix 1, profile no. 3 (Observation No. 135/1-65)

Soil mapping unit PB2

Extent	: 56 ha
Parent material	: olivine basalts
Physiography	: volcanic plain
Macro-relief	: level to very gently undulating, slopes less than 1%
Erosion	: none
Land use	: mainly grazing
Drainage	: moderately well drained to imperfectly drained
Soils, general	: this mapping unit consists of very deep, dark brown to dark greyish brown, mottled, friable to firm, clay. The soils have an ABC sequence of horizons with gradual and smooth to wavy transitions between the horizons.

Clay cutans are present in the B-horizon
Reddish mottles are common and may develop
into hard concretions.

colour : A-horizon: dark greyish brown (10 YR 4/2)
B-horizon: dark brown (7.5YR 4/4) to greyish
brown (10 YR 5/2)

texture : A-horizon: moderate, fine subangular blocky
B-horizon: weak, fine crumby to moderate
very fine sub-angular blocky

consistence : A-horizon: hard when dry, friable when moist
sticky and plastic when wet
: B-horizon: hard when dry, friable to firm
when moist, sticky and plastic when wet.

Chemical properties :

A-horizon : organic carbon 1.8%; CEC 26 me/100g ; pH
5.7; base saturation 15%; EC 0.05 mmhos/cm

B-horizon : CEC 25.5-28.9 me/100g; pH 5.4-6.0;
base saturation increases with depth from
12-37%, EC 0.04-0.2 mmhos/cm

Salinity/sodicity : non-saline, non-sodic

Classification : gleyic ACRISOLS

For a representative profile with analytical data, see appendix 1 profile no. 4 (observation no. 135/1-60).

4.3.4 Soils of the floodplains

Soil mapping Unit AA1

Extent	: 24 ha
Parent material	: recent alluvial deposits
Physiography	: floodplains
Macro-relief	: level to very gently undulating, slopes 0-2%
Erosion	: none
Vegetation	: tall grassland
Land use	: cultivation of maize, bananas and some sugarcane
Drainage	: Well drained
Soils, general	: this mapping unit consists of extremely deep, dark reddish brown to dark brown stratified, friable clay loam to clay soils. They have an AC sequence of horizons with abrupt to clear and smooth to wavy transitions between the horizons. The deeper subsoil (below 150 cm) is moderately sodic.
colour	: A-horizon: dark reddish brown (5YR 3/2) C-horizon: dark reddish brown (5YR 3/3) to very dark greyish brown (10YR 3/2)
texture	: A-horizon: clay loam C-horizon: clay loam to clay

structure : A-horizon: weak, fine subangular blocky
C-horizon: weak to moderate, fine to coarse sub-angular blocky

consistence : A-horizon: hard when dry, friable when moist, sticky and plastic when wet
C-horizon: hard when dry, friable when moist, sticky and plastic when wet.

Chemical properties

A-horizon : organic carbon 1.7%; CEC 25 me/100g; pH 6.7; base saturation 53%; EC 0.1 mmhos/cm.

C-horizon : CEC decreases with depth and clay percentage from about 28 to 18 me/100g; pH ranges from 6.8 to 7.2;EC is 0.1 to 0.5 mmhos/cm; ESP values in the deeper sub-soil (125-198 cm) increase with depth from 7.0 to 15.8

Salinity/sodicity : non saline, but slightly to moderately sodic in the deeper subsoil

Classification : dystric-FLUVISOLS

For a representative profile with analytical data see appendix 1, profile No. 5 (observation no. 135/1-64)

Soil mapping unit AA2

Extent	: 19 ha
Parent material	: recent alluvial deposits
Physiography	: floodplains
Macro-relief	: level to very gently undulating, slopes 0-2%
Erosion	: none
Vegetation	: bushed grassland
Land use	: cultivation of maize and bananas, together with cattle grazing
Drainage	: moderately well drained
Soils general	: this unit consists of very deep, brown to very dark grey, stratified, friable to firm, slightly sodic to sodic, clay loam to clay soils. They have an AC sequence of horizons with clear to gradual and smooth to wavy transitions between the horizons. In the subsoil $CaCO_3$ concretions may occur.
colour	: A-horizon: brown (7.5YR 4/4) to dark brown (10YR 3/3) C-horizon: pale brown (10YR 6/3) to very dark grey (10 YR 3/1)
texture	: A-horizon: clay loam to clay C-horizon: clay

structure : A-horizon: weak, fine crumby to weak, fine to medium subangular blocky

C-horizon: weak to moderate, medium to coarse, angular blocky

consistence : A-horizon: hard when dry, friable when moist, sticky and plastic when wet

C-horizon: hard when dry, firm when moist sticky and plastic when wet

Chemical properties

A-horizon : the organic carbon content varies from 1.6 to 2.2%, the CEC between 25 and 30 me/100g and the base saturation between 25 and 41%. The pH is about 5.4. The EC values are below 0.2 mmhos/cm.

C-horizon : CEC ranges between 25 and 35 me/100g, and base saturation between 35 and 100%. The pH goes up in the sodic soils to 8.4. The EC increases with depth to 0.9 mmhos/cm. The ESP follows the same pattern, increasing with depth to values of 21

Salinity/sodicity : non saline but slightly sodic to sodic

Classification : eutric FLUVISOLS, sodic phase

For a representative profile with analytical data see appendix 1, profile No. 6 (observation No. 135/1-62)

Soil Mapping Unit AA3

Extent	: 58 ha
Parent material	: recent alluvial deposits
Physiography	: floodplain
Macro-relief	: level to very gently undulating, slopes 0-2%
Erosion	: nil
Land use	: maize, bananas and mango trees are cultivated, together with vegetables which are grown during the dry season on previously flooded places
Drainage	: moderately well drained
Soils, general	: this mapping unit consists of very deep dark reddish brown to dark greyish brown, stratified, friable to firm, slightly sodic clay loam to clay. They have an AC sequence of horizons with clear to gradual, and smooth to wavy transitions between the horizons.
colour	: A-horizon: dark reddish brown (5YR 3/3) C-horizon: dark brown (7.5 YR 3/2) to dark greyish brown (10 YR 4/2)
texture	: A-horizon: clay loam C-horizon: clay loam to clay
structure	: A-horizon: moderate, fine to medium crumby C-horizon: massive compact to weak, medium to coarse subangular blocky

consistence : A-horizon: hard when dry, friable when moist, sticky and plastic when wet
C-horizon: hard when dry, friable to firm when moist, sticky and plastic when wet

Chemical properties

A-horizon : organic carbon is 2.1%; CEC 29 me/100g; pH 5.5; base saturation 35%; EC 0.2 mmhos/cm

C-horizon : CEC varies from 25 to 35 me/100g; pH increases with depth from 6.3 to 7.3; base saturation varies from 40% to 59%; EC is 0.1 mmhos/cm and ESP varies from 5.1 to 6.6%

Classification : dystric FLUVISOLS, sodic phase

salinity/sodicity : non saline but slightly sodic

For a representative profile with analytical data see appendix 1, profile No. 7 (observation no. 135/1-59)

Soil mapping unit AA4m

Extent	: 46 ha
Parent material	: recent alluvial deposits
Physiography	: flood plain
Macro-relief	: level to very gently undulating, slopes 0-2%
Erosion	: nil
Land use	: livestock grazing and cultivation of maize, mangoes, bananas and beans
Drainage	: imperfectly drained to poorly drained
Soils general	: this unit consists of moderately deep, dark reddish brown to grey, stratified, friable sandy clay loam to firm clay. At medium depth a partly indurated plinthite layer (murram) is found. The soils have an ABC sequence of horizons with clear to gradual and smooth to wavy transitions between the horizons
colour	: A-horizon: dark reddish brown (5 YR 3/3) to brown (10 YR 5/3) B-horizon: dark yellowish brown (10 YR 3/4) to grey (10 YR 6/1)
texture	: A-horizon: clay loam B-horizon: sandy clay loam to clay
structure	: A-horizon: porous massive to weak, medium crumby B-horizon: compact massive to moderate, fine to medium angular blocky

consistence : A-horizon: hard when dry, friable when moist, sticky and plastic when wet
B-horizon: hard when dry, friable to firm when moist, sticky and plastic when wet

Chemical properties

A-horizon : the organic carbon content ranges from 1.4 to 2.4%; the CEC varies from about 10 to 38 me/100g depending on the clay and organic matter content. pH is between 5.0 and 6.8; base saturation varies between 25 and 91%; and EC values are below 0.25 mmhos/cm

B-horizon : CEC varies between 4 and 38 me/100g; pH between 5.2 to 7.0; base saturation varies between 20 and 100%; EC values are below 0.45 mmhos/cm

Classification : plinthic GLEYSOLS

Salinity/sodicity : non saline/ non sodic

For a representative profile with analytical data see appendix 1, profile no. 8 (observation no. 135/1-58)

4.3.5 Soils of the bottomlands

Soil mapping unit BXlm

Extent	: 60 ha
Parent material	: alluvium/colluvium derived from various parent materials
Physiography	: bottomlands
Macro-relief	: level to very gently undulating, slopes 0-1%
Erosion	: none
Vegetation	: bushed grassland
Land use	: mainly communal grazing
Drainage	: moderately well drained to imperfectly drained
Soils, general	: this unit has deep to very deep, dark brown to very dark grey stratified, sodic friable sandy loam to firm clay, over pisoferric material (murram). The soils have an ABC sequence of horizons with clear and smooth to wavy transitions between the horizons. Many distinct red mottles, sometimes hardened, are present in the B-horizons as well as some thin clay cutans.
colour	: A-horizon: dark brown (7.5YR 3/2) to very dark greyish brown (10YR 3/2) B-horizon: brown (10YR 4/3) to very dark grey (10YR 3/1)

texture : A-horizon: sandy loam to loam
B-horizon: sandy clay loam to clay

structure : A-horizon: porous massive to weak, medium to coarse sub-angular blocky
B-horizon: compact massive to moderate, medium to coarse angular blocky

consistence : A-horizon: hard when dry, friable when moist, slightly sticky and slightly plastic when wet
B-horizon: hard to very hard when dry, friable to firm when moist, sticky and plastic when wet

Chemical properties

A-horizon : organic carbon varies from 1.7 to 0.8%; CEC from 4.8 to 13 me/100g; base saturation varies from 41 to 49%; EC values are below 0.2 mmhos/cm; and ESP values are low

B-horizon : CEC varies from 2.2 to 20 me/100g; base saturation 42-100%, EC values are below 0.25 mmhos/cm; and the ESP values range from 8.2 to 35%

Salinity/sodicity : non-saline but moderately sodic to strongly sodic

Classification : plinthic ACRISOLS, sodic phase

For a representative profile with analytical data see appendix 1, profile no. 9 (observation no. 135/1-55)

Soil mapping unit BX2

Extent : 176 ha

Parent material : alluvium/colluvium derived from various parent materials

Physiography : bottomlands

Macro-relief : level to very gently undulating, slopes 0-1%

Vegetation : grassland

Land use : mainly communal grazing

Erosion : none

Drainage : poorly drained

Soils, general : this mapping unit consists of very deep, dark greyish brown to very dark grey, stratified, slightly sodic, firm heavy clay, with a topsoil of clay loam or silty clay loam. The soils have an AEBtC sequence of horizons with clear to gradual and wavy transitions between the horizons. There is an abrupt tectural change between the top-soil and the under-lying B-horizon. Mottling is present in the E and the top of the B-horizon.

colour : A-horizon: very dark greyish brown (10YR 3/2) to very dark grey (10YR 3/1)
B-horizon: dark greyish brown (10YR 4/2) to dark grey (10YR 4/1)

texture : A-horizon: silty clay loam to clay loam
B-horizon: heavy clay

structure : A-horizon: weak, medium to coarse, sub-angular blocky

B-horizon: moderate to strong, very fine to medium, angular blocky

consistence : A-horizon: hard when dry, friable to firm when moist, sticky and plastic when wet

B-horizon: very hard when dry, firm when moist, sticky and plastic when wet

Chemical properties

A-horizon : organic carbon varies from 2.2 to 1.0%, CEC is about 15 me/100g, pH varies from 5.7 to 7.0, base saturation is about 60%; EC varies from 0.08 to 0.6 mmhos/cm

B-horizon : CEC varies as the clay content increasing with depth from 15 to 38 me/100g; base saturation varies from 39 to 100%; pH varies from 5.9 to 7.2; EC decreases with depth from 0.65 to 0.06 mmhos/cm; and ESP is 6-10%

Salinity/sodicity : non-saline but slightly sodic

Classification : solodic PLANOSOLS

Inclusions : in the north-east the soils have an overwash of about 40 cm loamy sands which wedges out to the west.

For a representative profile with analytical data see appendix 1, profile no. 10 (observation no. 135/51)

Soil mapping unit BX3

Extent : 43 ha

Parent material : alluvial/colluvial, derived from various parent materials

Physiography : bottomlands

Macro-relief : level to very gently undulating; slopes less than 1%

Micro-relief : gilgai

Erosion : none

Vegetation : grassland

Land use : mainly communal grazing

Drainage : poorly drained

Soils, general : this mapping unit consists of very deep, very dark greyish brown to very dark grey, slightly saline and moderately sodic, friable to firm clay. The soils have an ABC sequence of horizons and clear to gradual and smooth transitions between the horizons. Slickensides occur from a depth of 20 cm; 3-10 cm wide cracks extend to a depth of more than 50 cm. $CaCO_3$ concretions are present in the subsoil

colour : A-horizon: very dark greyish brown (10 YR 3/2)
B-horizon: greyish brown (10 YR 5/2) to very dark grey (10 YR 3/1)

texture : clay throughout

structure : A-horizon: strong very coarse prismatic

: B-horizon: strong, coarse sub -angular blocky and weak to moderate medium to coarse angular blocky

consistence : A-horizon: very hard when dry, very firm when moist, very sticky and plastic when wet

B-horizon: very hard when dry, friable when moist, very sticky and plastic when wet

Chemical properties

A-horizon : organic carbon 0.8%, CEC 31 me/100g; pH 6.5; base saturation 94%; EC 0.3 mmhos/cm and ESP is 5.

B-horizon : CEC is 38%; pH varies between 6.5 and 7.4; base saturation is 100%; EC varies between 0.4 and 2.2 mmhos/cm; and ESP between 8 and 17.

Salinity/sodicity : slightly saline and moderately sodic

Classification : chromic VERTISOLS; sodic phase

For a representative profile with analytical data see appendix 1, profile no. 11 (observation no. 135/1-48)

4.4 Soil fertility status

The appraisal of the soil fertility in the survey area is only based on the chemical analysis of composite topsoil samples taken from the vicinity of representative profile pits in each of the soil mapping units.

Therefore, this appraisal should be regarded as a generalised one, but nevertheless, it presents a quick and useful overall picture of the soil fertility status in the survey area.

The analytical data on the available nutrients are presented in Table 5. According to this table, P is moderately supplied in mapping units AA1-AA4m, but it is low in all other units; K is low in all units except in unit PB1; Ca is low to moderate in units AA1-AA4m, PB1, BX2 and BX3, and very low in units FN1, FQ1, PB2 and BX1m. Most of the soils are low in organic C, and hence in Nitrogen.

In summary, fertility is generally low for the survey area and for optimum growth of crops,manures and/or fertilizers should be added.

Table 5. Available nutrients (0-30 cm)

Mapping unit	FN1	FQ1	AA1	AA2	AA3	AA4m	PB1	PB2	BX1m	BX2	BX3
Profile Pit no.	135/1-47	135/1-54	135/1-64	135/1-69	135/1-58	135/1-59	135/1-65	135/1-60	135/1-55	135/1-51	135/1-48
Lab. no. /81	7408	7415	8852	8850	8846	8847	8853	8848	7416	7412	7409
pH (1:1 soil/ water suspen- sion	5.8	4.3	6.0	5.7	5.4	5.0	5.4	5.0	5.4	5.5	5.3
Na me/100g	0.2	0.7	0.3	0.5	0.5	0.1	0.1	0.4	0.04	0.6	2.1
K "	0.1	0.3	0.1	0.1	0.3	0.2	0.6	0.1	0.3	0.1	0.1
Ca "	1.4	0.4	8.6	5.3	3.8	2.4	4.4	0.8	0.8	3.5	7.2
Mg "	2.3	0.6	6.0	8.0	6.0	3.0	5.5	3.0	1.0	2.9	8.2
Mn "	0.4	0.7	1.4	1.3	2.3	1.1	0.4	0.64	0.3	0.8	0.6
P(Olsen) ppm	12	10	50	35	36	16	26	22	8	14	18
N%	0.1	0.1	0.2	0.2	0.1	0.1	0.1	0.2	0.1	0.3	0.2
C%	0.8	1.2	1.4	1.4	1.9	1.5	1.5	1.9	0.8	2.3	0.9
Hp me%	-	0.6	-	-	0.1	0.5	0.3	0.6	0.3	0.4	0.2

5. LAND SUITABILITY CLASSIFICATION FOR SURFACE IRRIGATION

5.1 Methodology

The land evaluation approach as adopted by the Kenya Soil Survey closely follows the proposals of the "Framework for land evaluation" (FAO, 1976). A short summary of the basic concepts is given below:

- land evaluation is based on land qualities that can be quantified and rated
- Land qualities usually are combinations of single land characteristics
- These land qualities are used to establish suitability class specifications for each land utilization type
- For each tract of land a suitability rating is made for all land utilization types

5.2 Land utilization types

In this report land suitability evaluation has been assessed for surface irrigation which specifically refers to furrow irrigation and basin irrigation methods. Furrow irrigation is mainly used for row crops such as maize, bananas, sugarcane, vegetables, tobacco, tree crops etc. Irrigation water is brought in a furrow or ditch and run in smaller furrows between the rows of plants. 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 do not take in water readily are usually recommended for basins.

In this land classification, a high level of technology has been assumed. This level of technology in this particular survey area

implies the following:

(i) Farm power- the initial and subsequent land preparation and other operations will be carried out with the help of modern farm machinery and implements. However, some of the farm operations such as planting, weeding, spraying for pest and disease control, and harvesting may be done manually.

(ii) Technical know-how - the general level of knowledge is advanced such that the farmers are in a position to use modern agricultural practices, viz: good land preparation, application of fertilizers, using the recommended crop varieties etc.

5.3 Land qualities and characteristics

The following land characteristics/qualities were considered for land suitability classification for surface irrigation:

(a) surface and sub-surface soil texture

(b) effective soil depth

(c) degree of sodicity

(d) flooding hazard

(e) topography/slopes

(f) drainage condition (availability of oxygen)

A brief description of the land characteristics/qualities, together with their ratings is given below. The ratings have been adopted from the Kenya Soil Survey "Proposals for ratings of land qualities" (Braun and van de Weg, 1977).

(a) Soil texture

Soil texture influences the amount and size of pores and therefore the amount of water (moisture) that can occupy the spaces in the soil. A coarse textured soil, e.g., loamy sand or sandy loam may hold less moisture than a fine textured soil like clay or sandy clay. Strong textural differences (stratified horizons) may also result in water uptake difficulties by plant roots. Soil texture also influences the relative ease with which agricultural implements can be used (workability) in mechanised farm operations. The rating of soil texture is shown below:

C, SC, CL, SCL	- 1
SL, LS	- 2
S	- 3

(b) Effective soil depth

For optimum plant growth, soil depth is important as a factor in determining the amount of moisture that can be stored in the soil. It has a direct relationship to "soil moisture storage capacity". Deeper soils store more water and also allow for deeper root penetration to extract essential plant nutrients than shallower soils. The following is the rating for soil depth:

> 120 cm	- 1
120 - 80cm	- 2
80 - 50 cm	- 3
<25 - 50 cm	- 4
≤25cm	- 5

(c) Degree of sodicity

Special attention is given to sodium because it can induce marked changes in soil characteristics that directly affect plant growth. When sodium occupies about 15% of the total exchangeable cations in the soil, the structure of the soil begins to break down. Aggregates or soil crumbs break down, the soil becomes dispersed and permeability to air and water decreases markedly. Such a soil is termed as sodic soil and because of its poor physical condition, most plants cannot be economically grown on it. Sodium toxicity may also become a factor for some sodium-sensitive fruit crops such as avocadoes and citrus. The exchangeable sodium percentage (ESP) is given as a measure of the degree of soil sodicity. The rating of soil sodicity is given as follows:

ESP (0-30cm)	ESP (30-120cm)	Rating
< 6	< 6	1
6-10	6-15	2
10-15	15-40	3
15-40	>40	4
>40	>40	5

(d) Flooding hazard

The flooding of the rivers,as a result of heavy rains on the surrounding mountains and highlands may cause the rivers to overflow their natural banks, and thereby posing a great hazard to cultivated crops, irrigation structures and road communications in low lying areas. In the survey area (Rurii), the bottomlands are also flooded by runoff water from the surrounding hills.

Therefore in summary, it can be said that flooding hazards apply where a risk of temporary subversion by running waters exists. The rating of flooding hazards is based mainly on the frequency (and duration) of occurrence, as show below:

Frequency	Rating
none to every 5-10 years	1 low to very low
every 3-5 years	2 moderate
every 1-3 years	3 high
ever year	4 very high

(e) Topography/Slopes

Topography is extremely important for it influences the choice of irrigation method, the labour requirements, the irrigation efficiency, the drainage requirements, the erosion hazards, the range of possible crops, the costs of land development, the possibilities of mechanization and the possible size and shape of the fields.

Complex slopes are land deficiencies of a permanent nature. For maximum production with minimum labour requirement, irrigated fields should be large and irrigation runs should be long and straight.

The degree of slope acceptable for irrigation development depends on:

- the intended method of irrigation
- the intensity of the rainfall

- the susceptibility of the soils to erosion
- the planned cropping pattern

It is generally accepted however, that for surface irrigation, conditions are seldom favourable on slopes greater than 12%; and smooth slopes of 0.1 to 2 percent are usually regarded as ideal. With these the costs for ditches, water control structures and labour are minimal; and there is no limitation on the choice of climatically adapted crops. On steeper slopes production costs increase, erosion control structures become necessary, greater care is needed for uniform water distribution and adaptability to high value cultivated crops tends to diminish.

Extremely gentle slopes (0-0.5%) may be a source of difficulty with irrigation if the soil is slowly permeable and heavy rains are frequent. This may cause water logging which is detrimental to most crops, except for paddy rice which is grown in flooded basins. The ratings for overall slope gradient are shown below:

		Rating
A	Level to very gently sloping (0-2%)	1
B	Gently sloping (2-5%)	2

(f) Drainage condition (availability of oxygen)

Serious crop production problems arise when ground water interferes with development of an adequate rooting system except for rice (adapted crop) or contributes to the development of excessive soil salinity.

Soil permeability and depth to a drainage barrier stratum also are of great importance in appraising the internal drainage conditions and in predicting the drainability of soils. Satisfactory internal soil drainage implies a soil and immediate substratum able to transmit leaching and irrigation water through and beyond the root zone before saturation can cause injury to the growing plants.

A barrier zone is a slowly permeable stratum which restricts the downward movement of ground water, and may consist of slowly permeable clay layers, indurated or cemented hardpans . Homogenous, well structured soils are not very likely to develop these problems under irrigation, even if their texture is clayey. The presence of a drainage barrier at shallow depth, or low permeability values give obvious warnings of potential drainage problems.

In case of basin irrigation of rice, a poor internal drainage is no limitation but an asset. The rating of soil drainage limitation, which is generally based on the soil profile colour (hydromorphy) which is reflected by the presence and depth of mottling, gley or pseudo-gley horizons and groundwater, is shown below:

Drainage class	Colour mottling	Rating
Well drained	no distinct mottling within 90cm and/or reduced colours within 150cm of the surface	1
Moderately well drained soils	no distinct mottling within 50cm and/or reduced colours within 120cm	2
Imperfectly drained soils	no reduced colours or distinct mottles within 50cm	3
Poorly drained soils	partly reduced colours and distinct mottles within 50 cm	4
Very poorly drained soils	predominantly reduced colours	5

The ratings of all land qualities of each of the soil mapping units are shown in table 6.

Table 6. Ratings of the land qualities for all soil mapping units

mapping unit	soil texture	effective soil depth	sodicity	Flooding hazard	Topography slope	Drainage condition
FN1	2	1	1	1	2	2
FQ1	2	1	2	1	2	2
PB1	1	1	1	2	1	1
PB2	1	1	1	3	1	2 - 3
AA1	1	1	1	2	1	1
AA2	1	1	3	1	1	2
AA3	1	1	2	2	1	2
AA4m	1	3	1	3	1	3
BX1m	1	2	3	2	1	2 - 3
BX2	1	1	2	3	1	4
BX3	1	1	2	3	1	4

5.4 Land suitability classification

In irrigation development, it is assumed that major land improvement measures such as bush clearing, levelling, canal/furrow or basin constructions, etc.,will be initially carried out before the actual crop growing under irrigation commences; therefore, only the potential land suitability is given.

- potential land suitability classification is an appraisal of the suitability of land for a defined use after specified major improvements have been completed.

The following four classes of land suitability are used:

Class S1 Highly suitable

Lands suitable for sustained high yields of most climatically adapted crops under sustained irrigation, with minimum costs of development and management associated with the land.

Class S2 Moderately suitable

Lands of moderate productivity or requiring moderate costs for development and management because of slight to moderate limitations in land characteristics.

Class S3 Marginally suitable

Lands of restricted productivity for most crops, or lands requiring relatively high costs for development and management because of moderate to severe limitations in land characteristics.

Class NS Lands which are considered unsuitable for sustained irrigation due to excessively severe limitations in soils, topography, or drainage for a particular project setting.

5.5 Suitability class defining criteria

In this chapter the requirements of each suitability class for the land utilization type furrow irrigation for commonly grown crops

as well as for basin irrigation of rice is given. The specifications of the diagnostic criteria (= land qualities) of the suitability classes were taken from van de Weg (1978) and modified where necessary. They are presented below as "conversion tables" for furrow irrigation and basin irrigation (paddy rice). When the ratings of the land qualities of table 6 are matched with the requirements for the two LUT's under consideration (Tables 7 and 8), the land suitability for all mapping units is estabilished. The results are shown in table 9.

Table 7. Land classification criteria for furrow irrigation of commonly grown crops (maize, beans, sugarcane, tomatoes and vegetables

Land quality/Characteristic Suitability Class	Soil texture	Effective soil depth	Sodicity	Flooding hazard	Topography (overall slope)	Drainage condition
S1 Highly suitable	1	1 - 2	1	1	1	2
S2 Moderately suitable	2	3	2	2	2	3
S3 Marginally suitable	3	4	3	3	2	4
NS Not suitable	3	5	4	4	2	5

Table 8. Land classification criteria for basin irrigation of paddy rice

Land quality/characteristic Suitability class	Soil texture	Effective soil depth	Flooding hazard	Sodicity	Topography (overall slope)	Drainage condition
S1 Highly suitable	1	2	1	1	1	3
S2 Moderately suitable	1	3	2	2	1	4
S3 Marginally suitable	2	4	3	2 - 3	2	5
NS Not suitable	3	4	4	3 - 4	2	5

Table 9. Land suitability classification for furrow irrigation and basin irrigation

Mapping unit	Suitability for Furrow irrigation	Suitability for Basin Irrigation (paddy rice)	Area (ha)
FN1	S3	NS	72
FQ1	S3	NS	75
PB1	S1	S2	24
PB2	S1	S1	56
AA1	S1	S2	24
AA2	S2	S3	19
AA3	S1	S1	58
AA4m	S2	S2	46
BX1m	S1 - S2	S1 - S2	60
BX2	S1 - S2	S1 - S2	176
BX3	S1 - S2	S1 - S2	43

6. CONCLUSIONS AND RECOMMENDATIONS

- The soils of the Rurii and Sagana Fish Culture Irrigation Schemes were investigated at a semi-detailed level of soil survey covering a total area of approximately 653 hectares.
- Mapping units AA1, AA3, PB1, and PB2, which cover a total area of 162 hectares, are considered as highly suitable for furrow irrigation; while mapping units AA2, AA4m, BX1, BX2 and BX3, covering a total area of 344 hectares are considered suitable to moderately suitable for furrow irrigation. Mapping units FN1, and FQ1 (total 147 ha.) are considered as marginally suitable for furrow irrigation due to their higher sloping topography and other soil factors.

- For Basin irrigation of paddy rice, mapping units AA1, AA4m, AA3, PB1, PB2, BX1m, BX2 and BX3, comprising a total of 487 hectares are considered as highly suitable to moderately suitable, while mapping unit AA2 (19 ha) is considered as marginally suitable. Mapping units FN1 and FQ1 (total 147 ha.) are considered to be suitable for basin irrigation due to their sloping topography, and stratified sandy top soils.
- A wide range of crops may be grown on the suitable soils, but irrigated dry - season vegetables viz: cabbages, tomatoes, kale, carrots, etc., would be the best paying since there is a ready market for them in the nearby urban centres.
- Paddy rice may be introduced on a small experimental scale to a few tenants in order to find out if it is economically feasible, and whether more tenants would be attracted to it.
- The present role of the survey area as a communal grazing ground should also be given some consideration since most of the local inhabitants keep a number of cattle and goats and the bottomlands provide the only green pasture for the animals during the dry periods. The animals provide milk and meat which are vital sources of protein, as well as earning some cash. Part of the area should therefore be set aside for grazing, but the tenants should be encouraged to reduce their livestock numbers, and to change to improved animal breeds which give better yields.
- In addition to the initial clearing, levelling, canal and basin constructions, drainage and leaching measures should be taken into account to prevent the rise of the ground watertable and to leach away the salts which may accumulate with time in irrigated areas.
- Flooding which is caused by excess rainfall and runoff from the surrounding hills and by overflow of the Sagana and Ragati rivers during the rainy seasons, presents a major hazard, especially in the low lying areas. Flood control and protection dykes and spillways should be constructed around the irrigated areas.

- Mention should be made here that according to the climatic data (chapter 2.2) the rainfall probabilities indicate a good potential (above average) for rainfed agriculture.

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APPENDIX 1: DESCRIPTION OF REPRESENTATIVE PROFILES AND ANALYTICAL DATA

LABORATORY DATA OF PROFILE DESCRIPTION No. 1

Observation no: 135/1-46 **Mapping unit:** FN1 **Soil classification:** cambic ARENOSOL

Laboratory no. /81	7427	7428	7429	7430	7431	7432
Horizon	Ap	Au	Bu1	Bu2	Bu3	BC
Depth (cm)	0-23	23-34	34-47	47-63	63-83	83-130
pH-H_2O (1: 2½ v/v)	6.5	6.2	5.6	6.0	6.6	5.6
pH-KCl "	5.4	5.4	5.0	5.1	5.4	5.0
EC (mmho/cm) "	0.04	0.04	0.03	0.04	0.03	0.04
$CaCO_3$ (%)						
$CaSO_4$ (%)						
C (%)	0.8	0.4	0.7	0.5	0.7	0.4
N (%)						
C/N						
CEC (me/100g), pH 8.2	6.8	4.5	4.8	2.8	8.7	4.2
CEC " " pH 7.0						
Exch. Ca (me/100g)	3.0	2.2	2.6	2.0	2.8	2.4
" Mg "	0.9	0.9	0.8	1.0	0.7	1.0
" K "	0.3	0.3	0.3	0.2	0.3	0.2
" Na "	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.
Sum of cations	4.2	3.4	3.7	3.2	3.8	3.6
Base sat. %, pH 8.2	62	75	76	100+	44	85
" " %, pH 7.0						
ESP at pH 8.2						
Texture (limited pretreatment)						
Gravel % (>2.0mm)						
Sand % (2.0-0.05mm)	80	74	72	80	78	64
Silt % (0.05-0.002mm)	16	22	20	14	10	23
Clay % (0.002-0mm)	4	4	8	6	12	13
Texture class	LS	SL	SL	LS	SL	SL

Fertility aspects 0 - 30 cm **Laboratory no.** 7407 /81

General		Available nutrients			
pH-H_2O (1: 2½ v/v)	6.1	Na (me/100g)	0.04	Mn (me/100g)	0.5
Exch. acidity (me/100g)	-	K "	0.3	P (ppm)	46
C %	0.6	Ca "	2.0	P-Olsen (ppm)	
N %	0.06	Mg "	1.1		

Remarks: These soils are slightly acidic and have sufficient levels of all the nutrients, except N which is low. Nitrogenous fertilisers or FYM should therefore be applied to raise the level of N in the soil.

PROFILE DESCRIPTION NO. 1

General site information

Mapping unit	: FN1
Classification	: cambic ARENOSOL
Observation No./date	: 135/1-46; 24/7/81
Parent material	: Biotite gneisses (Basement System)
Physiography	: footslopes
Relief, macro	: gently undulating
Slope at site/position	: gently sloping (3-5%) convex slope
Vegetation	: short grasses, herbs and *Lantana camara* bushes
Land use	: cultivation of tobacco, mangoes and citrus
Erosion	: none apparent but rillwash and gully erosion may occur if the vegetation cover is removed
Effective soil depth	: very deep, over 130cm
Groundwater depth	: 120cm
Drainage class	: well drained to moderately well drained

Profile description

Ap	0-23 cm	: dark brown (10YR 3/3); loamy sand; massive to very weak, medium to coarse, sub-angular blocky structure; soft when dry, very friable when moist; slightly sticky and slightly plastic when wet; many very fine and fine pores; many very fine to medium roots; clear and smooth transition to: (sample no. 135/1-46a)
Au	23-34cm	: very dark greyish brown (10YR 3/2); sandy loam; massive to very weak, medium, sub-angular blocky structure; very friable when moist, slightly sticky and slightly plastic when wet; many very fine and fine pores; common very fine and fine roots; clear and smooth transition to: (sample no. 135/1-46b)
Bu1	34-47cm	: very dark brown (10YR 2/2); sandy loam; very weak, medium sub-angular blocky structure; very friable when moist; slightly sticky and slightly plastic when wet; many fine pores; common very fine and fine roots; clear and smooth transition to: (sample no. 135/1-46c)
Bu2	47-63cm	: very dark brown (10YR 2/2); loamy sand; porous massive structure; very friable when moist; slightly sticky and slightly plastic when wet; many very fine and fine pores; common, very fine and fine roots; clear and smooth transition to: (sample no. 135/1-46d)
Bu3	63-83cm	: very dark grey (10YR 3/0); sandy loam; very weak, medium, sub-angular blocky structure; very friable when moist, sticky and plastic when wet; many very fine pores; common very fine and fine roots; clear and smooth transition to: (sample no. 135/1-46e)
BC	83-105cm	: dark greyish brown (10YR 4/2); sandy loam; very weak, medium sub-angular blocky structure; very friable when moist, sticky and plastic when wet; many fine and common medium pores; common, very fine and few fine roots; clear and smooth transition to: (sample no. 135/1-46f)
C	105-130cm+	: brown to dark brown (10YR 4/3); sandy loam; weak, medium sub-angular blocky structure; very friable when moist, sticky and plastic when wet; many very fine and fine, and common medium pores

LABORATORY DATA OF PROFILE DESCRIPTION No. 3

Observation no: 135/1-65 Mapping unit: PB1 Soil classification: orthic LUVISOL

Laboratory no. /81	8894	8895	8896	8897	8898	8899
Horizon	Ap	BA	Bt1	Bt2	BC	C
Depth (cm)	0-13	13-40	40-75	75-110	110-153	153-220
pH-H_2O (1: 2½ v/v)	6.0	6.0	6.0	6.1	6.1	6.4
pH-KCl "	4.6	4.5	4.4	4.4	4.6	4.2
EC (mmho/cm) "	0.3	0.1	0.1	0.2	0.2	0.2
$CaCO_3$ (%)						
$CaSO_4$ (%)						
C (%)	1.4	0.8	0.5	0.4	0.4	0.3
N (%)						
C/N						
CEC (me/100g), pH 8.2	27.7	25.3	25.5	27.6	25.5	25.9
CEC " " pH 7.0						
Exch. Ca (me/100g)	5.6	5.6	6.7	6.7	7.0	4.5
" Mg "	5.0	4.1	4.3	5.4	4.9	3.2
" K "	0.7	0.1	0.1	0.1	0.04	0.04
" Na "	0.1	0.1	0.2	0.2	0.2	0.3
Sum of cations	11.4	10.0	11.4	12.4	12.4	8.1
Base sat. %, pH 8.2	41	39	44	45	48	31
" " %, pH 7.0						
ESP at pH 8.2						
Texture (limited pretreatment)						
Gravel % (>2.0mm)						
Sand % (2.0-0.05mm)	20	20	20	20	34	28
Silt % (0.05-0.002mm)	20	8	12	12	2	14
Clay % (0.002-0mm)	60	72	68	68	64	58
Texture class	C	C	C	C	C	C

Fertility aspects 0 - 30 cm Laboratory no. 8853 /81

General		Available nutrients			
pH-H_2O (1: 2½ v/v)	5.4	Na/me/100g)	0.08	Mn (me/100g)	0.42
Exch. acidity (me/100g)	0.3	K "	0.6	P (ppm)	-
C %	1.46	Ca "	4.4	P-Olsen (ppm)	26
N %	0.14	Mg "	5.5		

Remarks: These soils are moderately acid, and are sufficiently supplied with all the nutrients, except N, which is low.

PROFILE DESCRIPTION NO. 3

General site information

Mapping unit	: PB1
Observation no./date	: 135/1-65; 15/8/81
Classification	: orthic LUVISOL
Geology	: alluvium/colluvium, derived from basic igneous rocks (Olivine basalts)
Physiography	: level to very gently undulating
Relief, macro	: slighlty raised area above the general level of the bottomland
Slope at site/position	: very gently undulating (2%/short convex slope
Vegetation	: bushed grassland - short to medium grass between Lantana camara bushes
Land use	: cultivation of maize, beans and sorghum
Erosion,water/wind	: nil
Rock outcrops	: none
Flooding	: none at site, but may occur seasonally (after heavy rains) on other surrounding areas
Effective soil depth	: very deep, more than 150cm
Groundwater depth	: below 150cm (dry season)
Drainage class	: well drained

Profile description

Ap	0-13cm	: dark reddish brown (5YR 3/2); clay; weak, fine to medium, crumby structure; friable when moist, sticky and plastic when wet; many, very fine to fine and few medium pores; common, very fine and few, fine roots; clear and wavy transition to: (sample no. 135/1-65a)
BA	13-40cm	: dark reddish brown (5YR 3/4); clay; moderate, medium to coarse, sub-angular blocky structure; firm when moist, sticky and plastic when wet; few, thin, clay-skins; few, very fine to medium pores; few, very fine to fine roots; gradual and wavy transition to: (sample no. 135/1-65b)
Bt1	40-75cm	: dark reddish brown (5YR 3/4); clay; moderate, medium to coarse, angular blocky structure; firm when moist, sticky and plastic when wet; many, moderately thick clay-skins, common, very fine to fine pores; diffuse and smooth transition to: (sample no. 135/1-65c)
Bt2	75-110cm	: dark reddish brown (5YR 4/3); clay; moderate, fine to medium, sub-angular blocky structure; firm when moist, sticky and plastic when wet; many, thick clay-skins; common, very fine to fine pores; gradual and smooth transition to: (sample no. 135/1-65d)
BC	110-153 cm^{+}	: dark reddish grey(5YR 4/2); common, fine to medium red mottles; clay; weak, fine to medium, sub-angular blocky structure; firm when moist, sticky and plastic when wet; common, moderately thick clayskins; common, very fine to fine pores (sample no. 135/1-65e)

LABORATORY DATA OF PROFILE DESCRIPTION No. 4

Observation no: 135/1-60 Mapping unit: PB2 Soil classification: gleyic ACRISOL

Laboratory no. /81	8865	8866	8867	8868	8869	8870
Horizon	A	AB	Bul	Bts	Bt2	BC
Depth (cm)	0-20	20-34	34-52	52-74	74-90	90-100
pH-H_2O (1: 2½ v/v)	5.7	5.8	5.4	6.1	5.9	6.0
pH-KCl "	3.4	3.4	3.3	3.3	3.5	3.6
EC (mmho/cm) "	0.1	0.04	0.04	0.1	0.1	0.2
$CaCO_3$ (%)						
$CaSO_4$ (%)						
C (%)	1.8	1.3	1.2	0.6	0.5	0.5
N (%)						
C/N						
CEC (me/100g), pH 8.2	25.9	24.5	25.5	24.5	20.9	28.9
CEC " " pH 7.0						
Exch. Ca (me/100g)	2.3	1.9	1.9	1.9	2.3	4.5
" Mg "	1.1	0.5	0.3	0.5	1.2	3.6
" K "	0.1	0.1	0.04	0.04	0.04	0.1
" Na "	0.5	0.7	0.8	0.7	1.0	2.7
Sum of cations	4.0	3.2	3.1	3.1	4.5	10.8
Base sat. %, pH 8.2	15	13	12	13	22	37
" " %, pH 7.0						
ESP at pH 8.2					5	9
Texture (limited pretreatment)						
Gravel % (>2.0mm)						
Sand % (2.0-0.05mm)	28	16	16	18	18	20
Silt % (0.05-0.002mm)	28	40	32	30	32	10
Clay % (0.002-0mm)	44	44	52	52	50	70
Texture class	C	C	C	C	C	C

Fertility aspects 0 - 30 cm Laboratory no. 8848 /81

General		Available nutrients			
pH-H_2O (1: 2½ v/v)	5.0	Na/me/100g)	0.44	Mn (me/100g)	0.64
Exch. acidity (me/100g)	0.6	K "	0.06	P (ppm)	-
C %	1.94	Ca "	0.8	P-Olsen (ppm)	22
N %	0.22	Mg "	3.0		

Remarks: These soils have sufficient levels of N, P, Mg and Mn, but they are lacking K.

PROFILE DESCRIPTION NO. 4

General site information

Mapping unit	: PB2
Observation no./date	: 135/1-60, 13/8/81
Classification	: gleyic ACRISOL
Parent material	: alluvium/colluvium, derived from basic igenous rocks (Olivine basalts)
Physiography	: volcanic plain
Relief, macro	: level to very gently undulating
Slope at site/position	: 0-1%/low plain
Vegetation	: short grassland
Land use	: mainly grazing
Erosion, water/wind	: nil
Rock outcrops	: none
Flooding	: occurs seasonally after heavy rains
Effective soil depth	: very deep, 125cm
Groundwater depth	: below 125cm
Drainage class	: moderately well drained to imperfectly drained

Profile description

A	0-20cm	: dark greyish brown (10YR 4/2); many, fine, distinct, red mottles; clay; moderate, fine, sub-angular blocky structure; friable when moist, sticky and plastic when wet; few, very fine to fine pores; many fine medium roots; gradual and wavy transition to: (sample no. 135/1-60a)
AB	20-34cm	: dark brown (7.5YR 4/4); clay; weak; fine to medium, sub-angular blocky structure; friable when moist, sticky and plastic when wet; common, very fine to fine pores; common, fine and medium roots; gradual and smooth transition to: (sample no. 135/1-60b)
Bul	34-52cm	: dark greyish brown (10YR 4/2); many, fine to coarse, distinct, red mottles; clay; weak, very fine to fine, sub-angular blocky structure; friable when moist, sticky and plastic when wet; common, fine pores; common, fine and medium roots; clear and smooth transition to: (sample no. 135/1-60c)
Bts	52-74cm	: dark brown (7.5YR 4/2); common, very fine to fine, distinct, red mottles; clay; massive, to weak, fine, crumby structure; friable when moist, sticky and plastic when wet; common, thin clayskins; 2% Fe concretions which are 2-4mm thick; common fine, and few medium, pores; few, fine and medium roots; gradual and wavy transition to: (sample no. 135/1-60d)
Bt2	74-90cm	: greyish brown (10YR 5/2); many, very fine to fine, distinct, red mottles; clay; moderate, very fine, sub-angular blocky structure; friable when moist, sticky and plastic when wet; common, thin, clayskins; common, fine and few, medium pores; abrupt and smooth transition to: (sample no. 135/1-60e)
BC	90-100cm+	: dark brown (7.5YR 4/2); many, fine to medium, prominent red mottles; clay; moderate, coarse, prismatic structure; friable when moist, sticky and plastic when wet; common, thin, clayskins; common, very fine to fine pores (sample no. 135/1-60f)

LABORATORY DATA OF PROFILE DESCRIPTION No. 5

Observation no: 135/1-64 Mapping unit: AA1 Soil classification: dystric FLUVISOL

Laboratory no. /81	8887	8888	8889	8890	8891	8892
Horizon	Ap	AC	C1	C2	C3	C4
Depth (cm)	0-20	20-51	51-79	79-125	125-148	148-193
pH-H_2O (1: 2½ v/v)	6.7	7.1	7.1	6.8	7.2	7.2
pH-KCl "	5.0	5.0	5.2	5.4	5.3	6.1
EC (mmho/cm) "	0.1	0.1	0.1	0.1	0.1	0.5
$CaCO_3$ (%)						
$CaSO_4$ (%)						
C (%)	1.7	1.0	0.6	0.7	0.6	0.6
N (%)						
C/N						
CEC (me/100g), pH 8.2	25.0	33.5	28.1	24.2	27.5	17.7
CEC " " pH 7.0						
Exch. Ca (me/100g)	7.8	7.4	8.5	7.8	7.8	8.2
" Mg "	4.9	5.8	3.4	2.7	4.5	7.1
" K "	0.4	0.2	0.1	0.1	0.1	0.2
" Na "	0.2	0.5	0.5	0.7	1.9	2.8
Sum of cations	13.3	13.9	12.4	11.3	14.3	18.3
Base sat. %, pH 8.2	53	41	44	47	52	100^+
" " %, pH 7.0						
ESP at pH 8.2				3	7	16
Texture (limited pretreatment)						
Gravel % (>2.0mm)						
Sand % (2.0-0.05mm)	36	20	14	22	16	36
Silt % (0.05-0.002mm)	36	40	36	36	46	26
Clay % (0.002-0mm)	28	40	50	42	38	38
Texture class	CL	C/SICL/CL	C	C	SICC	CL

Fertility aspects 0 - 30 cm Laboratory no. 8852/81

General		Available nutrients			
pH-H_2O (1: 2½ v/v)	6.0	Na/me/100g)	0.28	Mn (me/100g)	1.44
Exch. acidity (me/100g)	-	K "	0.12	P (ppm)	-
C %	1.37	Ca "	8.6	P-Olsen (ppm)	50
N %	0.17	Mg "	6.0		

Remarks: These soils are sufficiently supplied with P, Ca, Mg and Mn; but they are deficient in N and K.

PROFILE DESCRIPTION NO.5

General site information

Mapping unit	: AA1
Observation no./date	: 135/1-64; 15/8/81
Classification	: dystric FLUVISOL
Parent material	: recent alluvial deposits
Physiography	: river alluvial plain
Relief, macro	: level to very gently undulating
Slope at site/position	: level (1%)/plain
Vegetation	: tall grassland, cleared for cultivation
Land use	: cultivation of maize, bananas and some sugarcane
Erosion water/wind	: nil
Surface stoniness	: nil
Rock outcrops	: nil
Flooding	: seasonally flooded
Effective soil depth	: very deep, over 120cm
Groundwater depth	: below 200cm
Drainage class	: well drained

Profile description

Ap	0-20cm	: dark reddish brown (5YR 3/2); clay loam; weak, very fine to fine, sub-angular blocky structure; friable when moist, sticky and plastic when wet; many, very fine to fine, and few, medium pores; many, very fine and fine roots; clear and smooth transition to: (sample no. 135/1-64a)
AC	20-51cm	: dark reddish brown (5YR 2.5/2); clay; weak, medium to coarse, subangular blocky structure; friable when moist, sticky and plastic when wet; common, very fine to fine, and few medium, pores; many, very fine and fine roots; clear and smooth transition to: (sample no. 135/1-64b)
C1	51-79cm	: dark reddish brown (5YR 3/3); clay; moderate, very fine to fine, subangular blocky structure; friable when moist, sticky and plastic when wet; common, very fine to medium pores; few, very fine and fine roots; gradual and smooth transition to: (sample no. 135/1-64c)
C2	79-125cm	: dark reddish brown (5YR 3/4); clay; weak, medium to coarse, subangular blocky structure; friable when moist, sticky and plastic when wet; many, very fine to fine and common, medium pores; few, very fine roots; clear and smooth transition to: (sample no. 135/1-64d)
C3	125-148cm	: dark brown (7.5YR 3/2); silty clay loam; weak, very fine to fine, subangular blocky structure; firm when moist, sticky and plastic when wet; many, fine to medium pores; abrupt and wavy transition to: (sample no. 135/1-64e)
C4	148-193cm+	: very dark greyish brown (10YR 3/2), clay loam; weak, fine, subangular blocky structure; firm when moist, sticky and plastic when wet; common, fine to medium pores (sample no. 135/1-64f)

LABORATORY DATA OF PROFILE DESCRIPTION No. 6

Observation no: 135/1-62 Mapping unit: AA2 Soil classification: eutric FLUVISOL sodic phase

Laboratory no. /81	8877	8878	8879	8880		
Horizon	Ap	AC	C1	C2		
Depth (cm)	0-23	23-60	60-83	83-175		
pH-H_2O (1: 2½ v/v)	5.7	6.6	8.2	8.4		
pH-KCl "	4.4	5.7	6.6	6.8		
EC (mmho/cm) "	0.2	0.3	0.9	0.8		
$CaCO_3$ (%)						
$CaSO_4$ (%)						
C (%)	1.6	1.1	0.6	0.3		
N (%)						
C/N						
CEC (me/100g), pH 8.2	30.0	26.6	34.8	32.7		
CEC " " pH 7.0						
Exch. Ca (me/100g)	5.6	6.0	5.6	7.0		
" Mg "	6.1	6.3	11.8	12.9		
" K "	0.3	0.2	0.2	0.2		
" Na "	0.3	2.6	7.4	4.5		
Sum of cations	12.4	15.0	25.0	24.6		
Base sat. %, pH 8.2	41	56	72	75		
" " %, pH 7.0						
ESP at pH 8.2		10	21	14		
Texture (limited pretreatment)						
Gravel % (>2.0mm)						
Sand % (2.0-0.05mm)	28	26	26	26		
Silt % (0.05-0.002mm)	36	34	22	26		
Clay % (0.002-0mm)	36	40	52	48		
Texture class	C	C/CL	C	C		

Fertility aspects 0 - 30 cm Laboratory no. 8850 /81

General		Available nutrients			
pH-H_2O (1: 2½ v/v)	5.7	Na/me/100g)	0.5	Mn (me/100g)	1.26
Exch. acidity (me/100g)	-	K "	0.1	P (ppm)	-
C %	1.4	Ca "	5.3	P-Olsen (ppm)	35
N %	0.16	Mg "	7.9		

Remarks: These are fertile soils which are sufficiently supplied with all the nutrients, except K.

PROFILE DESCRIPTION NO. 6

General site information

Mapping unit	: AA2
Observation no./date	: 135/1-62; 14/8/81
Classification	: eutric FLUVISOL, sodic phase
Parent material	: recent alluvial deposits
Physiography	: river alluvial plain
Relief, macro	: level to very gently undulating
Slope at site/position	: level (0-1%) plain
Vegetation	: bushed grassland
Land use	: cultivation of maize and bananas, together with cattle grazing
Erosion, water/wind	: nil
Surface stoniness	: nil
Rock outcrops	: nil
Flooding	: seasonally flooded
Effective soil depth	: extremely deep, over 175cm
Groundwater depth	: below 175cm (dry season)
Drainage class	: moderately well drained

Profile description

Ap	0-23cm	: brown (7.5YR 4/4); clay loam; weak, fine crumby structure; friable when moist, sticky and plastic when wet; many, very fine to medium pores; many, fine and medium roots; clear and wavy transition to: (sample no. 135/1-62a)
AC	23-60cm	: very dark grey (10YR 3/1); clay to clay loam; moderate, coarse to very coarse, prismatic structure; very firm when moist, sticky and plastic when wet; common, very fine to fine pores; common, fine roots; clear and wavy transition to: (sample no. 135/1-62b)
C1	60-83cm	: dark brown (7.5YR 3/2), clay; weak, medium to coarse, angular blocky to subangular blocky structure; firm when moist, sticky and plastic when wet; many, very fine to fine pores; common, very fine and few fine roots; gradual and smooth transition to: (sample no. 135/1-62c)
C2	83-175cm	: dark brown (10YR 3/3); gravelly clay; moderate, very fine to fine, subangular blocky structure; firm when moist, sticky and plastic when wet; common, $CaCO_3$ concretions; few, very fine to fine pores (sample no. 135/1-62d)

LABORATORY DATA OF PROFILE DESCRIPTION No. 7

Observation no: 135/1-59 Mapping unit: AA3 Soil classification: dystric FLUVISOL sodic phase

Laboratory no. /81	8858	8859	8860	8861	8862	8863
Horizon	Ap	AC	C1	C2	C3	C4
Depth (cm)	0-20	20-50	50-62	62-74	74-97	94-122
pH-H_2O (1: 2½ v/v)	5.5	6.3	6.3	7.0	6.8	7.3
pH-KCl "	4.1	4.6	4.8	4.8	4.9	5.9
EC (mmho/cm) "	0.2	0.2	0.1	0.1	0.1	0.04
$CaCO_3$ (%)						
$CaSO_4$ (%)						
C (%)	2.1	1.4	1.1	1.7	0.6	0.6
N (%)						
C/N						
CEC (me/100g), pH 8.2	28.7	29.1	25.0	34.5	25.9	34.3
CEC " " pH 7.0						
Exch. Ca (me/100g)	6.0	7.4	6.0	8.5	5.6	10.7
" Mg "	3.2	3.5	3.9	5.0	5.0	7.3
" K "	0.8	0.1	0.1	0.1	0.1	0.3
" Na "	0.1	0.7	0.7	0.8	2.0	2.2
Sum of cations	10.2	11.7	11.7	15.4	12.7	20.5
Base sat. %, pH 8.2	35	40	47	45	49	59
" " %, pH 7.0						
ESP at pH 8.2			3	2	8	6
Texture (limited pretreatment)						
Gravel % (>2.0mm)						
Sand % (2.0-0.05mm)	26	22	24	20	20	22
Silt % (0.05-0.002mm)	34	40	44	30	34	22
Clay % (0.002-0mm)	40	38	32	50	46	56
Texture class	C/CL	CL	CL	C	C	C

Fertility aspects 0 - 30 cm Laboratory no. 8847 /81

General		Available nutrients			
pH-H_2O (1: 2½ v/v)	5.4	Na/me/100g)	0.46	Mn (me/100g)	2.32
Exch. acidity (me/100g)	0.1	K "	0.32	P (ppm)	-
C %	1.88	Ca "	3.8	P-Olsen (ppm)	36
N %	0.24	Mg "	6.0		

Remarks: These soils are very fertile, but the levels of Mg and Mn are too high and may either cause unavailability of some of the other nutrients, or toxicity to crops.

PROFILE DESCRIPTION NO. 7

General site information

Mapping unit	: AA3
Observation no./date	: 135/1-59 ; 13/8/81
Classification	: dystric FLUVISOL, sodic phase
Parent material	: recent alluvial deposits
Physiography	: river alluvial plain
Relief, macro	: level to very gently undulating
Relief, meso/micro	: small basins for vegetable growing and associated furrows and drains
Slope at site/position	: level (0-1%)/plain
Vegetaion	: bushed grassland (cleared for vegetable growing)
Land use	: cultivation of maize, vegetables, bananas and mango trees
Erosion, water/wind	: nil
Rock outcrops	: none
Flooding	: occurs seasonally after heavy rains
Effective soil depth	: very deep (more than 150cm)
Groundwater depth	: below 150cm
Drainage class	: imperfectly drained

Profile description

Ap	0-20cm	: dark reddish brown (5YR 3/3); clay to clay loam; moderate, fine to medium crumby structure; friable when moist, sticky and plastic when wet; common, very fine to fine and few medium pores; many, fine, and medium roots; gradual and wavy transition to: (sample no. 135/1-59a)
AC	20-50cm	: dark reddish brown (5YR 3/3), clay loam; massive to weak, fine to medium, crumby structure; friable when moist, sticky and plastic when wet; common very fine to fine and few medium pores; many, fine to medium roots; abrupt and smooth transition to: (sample no. 135/1-59b)
C1	50-62cm	: dark reddish brown (5YR 3/4), clay loam; massive to weak, fine to medium, crumby structure; friable when moist, sticky and plastic when wet; common, very fine to fine and few, medium pores; common, fine and medium roots; clear and smooth transition to: (sample no. 135/1-59c)
C2	62-74cm	: dark brown (7.5YR 3/2); clay; massive structure; firm when moist, sticky and plastic when wet; few, very fine to fine pores; few, fine and medium roots; clear and wavy transition to: (sample no. 135/1-59d)
C3	74-97cm	: dark brown (7.5YR 3/3); clay; massive structure; firm when moist, sticky and plastic when wet; few, very fine to fine pores; few, fine roots; gradual and wavy transition to: (sample no. 135/1-59e)
C4	97-123cm+	: very dark greyish brown (10YR 3/2); clay; massive to weak, medium to coarse, subangular blocky structure; firm when moist, sticky and plastic when wet; few, very fine to fine pores; few, fine roots (sample no. 135/1-59f)

LABORATORY DATA OF PROFILE DESCRIPTION No. 8

Observation no: 135/1-58 Mapping unit: AA4m Soil classification: plithic GLEYSOL

Laboratory no. /81	8854	8855	8856	8857		
Horizon	Ap	AC	Clms	C2		
Depth(cm)	0-22	22-45	45-98	98-148		
pH-H_2O(1: 2½v/v)	5.0	5.0	5.7	5.7		
pH-KCl "	4.2	4.0	4.2	3.5		
EC(mmho/cm) "	0.1	0.1	0.04	0.2		
$CaCO_3$(%)						
$CaSO_4$(%)						
C (%)	1.4	1.3	0.3	0.8		
N (%)						
C/N						
CEC(me/100g), pH 8.2	19.3	15.4	3.9	27.7		
CEC " " pH 7.0						
Exch.Ca(me/100g)	3.0	2.3	1.5	6.3		
" Mg "	1.5	0.9	0.3	3.4		
" K "	0.4	0.1	0.04	0.2		
" Na "	Tr	0.1	0.1	1.5		
Sum of cations	4.9	3.3	1.9	11.4		
Base sat. %, pH 8.2	25	22	48	41		
" " %, pH 7.0						
ESP at pH 8.2				6		
Texture (limited pretreatment)						
Gravel % (>2.0mm)						
Sand % (2.0-0.05mm)	38	38	40	30		
Silt % (0.05-0.002mm)	32	32	46	20		
Clay % (0.002-0mm)	30	30	14	50		
Texture class	CL	CL	L	C		

Fertility aspects 0 - 30 cm Laboratory no. 8846 /81

General		Available nutrients			
pH-H_2O (1: 2½v/v)	5.0	Na/me/100g)	0.08	Mn(me/100g)	1.06
Exch. acidity (me/100g)	0.5	K "	0.22	P (ppm)	-
C %	1.46	Ca "	2.4	P-Olsen(ppm)	16
N %	0.14	Mg "	2.8		

Remarks: These are fertile soils which are sufficiently supplied with all the nutrients, although N is slightly low.

PROFILE DESCRIPTION NO. 8

General site information

Mapping unit	: AA4m
Observation no./date	: 135/1-58; 13/8/81
Classification	: plithic GLEYSOL
Parent material	: recent alluvial deposits
Physiography	: river alluvial plain
Relief, macro	: level to very gently undulating
Slope at site/position	: level (0-1%)/plain
Vegetation	: bushed grassland
Land use	: cultivation of maize and bananas
Erosion, water/wind	: nil
Rock outcrops	: none
Flooding	: occurs seasonally after heavy rains
Effective soil depth	: very deep, over 140cm
Groundwater depth	: 60cm (dry season)
Drainage class	: imperfectly drained

Profile description

Ap 0-22cm : dark reddish brown (5YR 3/3); clay loam; massive structure; friable when moist, sticky and plastic when wet; many, very fine to medium pores; common, fine and medium, few coarse roots; clear and smooth transition to:
(sample no. 135/1-58a)

AC 22-45cm : dark yellowish brown (10YR 3/4);clay loam; massive to weak, fine to medium, subangular blocky structure; friable when moist, sticky and plastic when wet; many, very fine to medium pores; common, fine to medium, few coarse roots; clear and wavy transition to:
(sample no. 135/1-58b)

Clms 45-98cm : grey (10YR 6/1); loam; massive, to moderate, coarse, subangular blocky structure; friable when moist, sticky and plastic when wet; 40% Fe concretions which are cemented together; common, very fine to medium pores; few, fine to medium roots; clear and wavy transition to:
(sample no. 135/1-58c)

C2 98-148cm+ : dark greyish brown (10YR 4/4); many, fine to coarse, distinct mottles; clay; massive structure; friable when moist; sticky and plastic when wet; common very fine and few fine to medium pores
(sample no. 135/1-58d)

LABORATORY DATA OF PROFILE DESCRIPTION No. 9

Observation no: 135/1-55 Mapping unit: BXlm Soil classification: plithic ACRISOL sodic phase

Laboratory no. /81	7476	7477	7478	7479	7480	7481
Horizon	Au	Au2	AB	E	Bu1	Bu2
Depth(cm)	0-24	24-40	40-56	56-70	70-84	84-110
pH-H_2O(1: 2½ v/v)	5.7	5.6	5.6	5.7	6.2	6.3
pH-KCl "	4.1	4.2	4.0	4.2	4.3	4.5
EC(mmho/cm) "	0.06	0.06	0.08	0.02	0.02	0.03
$CaCO_3$(%)						
$CaSO_4$(%)						
C (%)	0.9	0.4	0.5	0.4	0.4	0.3
N (%)						
C/N						
CEC(me/100g), pH 8.2	6.8	6.0	8.0	2.2	5.4	14.5
CEC " " pH 7.0						
Exch.Ca(me/100g)	2.2	2.6	2.6	0.7	2.6	5.8
" Mg "	0.5	0.5	0.5	0.4	0.4	0.4
" K "	0.2	Tr.	0.1	0.1	0.8	1.2
" Na "	Tr.	Tr.	0.6	Tr.	1.9	3.7
Sum of cations	2.9	3.1	3.7	1.2	5.7	11.1
Base sat. %, pH 8.2	42	52	47	56	100+	76
" " %, pH 7.0						
ESP at pH 8.2	-	-	7	-	35	26
Texture (limited pretreatment)						
Gravel % (>2.0mm)						
Sand % (2.0-0.05mm)	74	70	58	74	56	46
Silt % (0.05-0.002mm)	16	10	18	18	18	4
Clay % (0.002-0mm)	10	20	24	8	26	40
Texture class	SL	SCL/SL	SCL	SL	SCL	SC

Fertility aspects 0 - 30 cm Laboratory no. 7416 / 81

General		Available nutrients			
pH-H_2O (1: 2½ v/v)	5.7	Na/me/100g)	0.04	Mn(me/100g)	0.28
Exch. acidity (me/100g)	0.3	K "	0.32	P (ppm)	-
C %	0.83	Ca "	0.8	P-Olsen(ppm)	8
N %	0.08	Mg "	1.0		

Remarks: These are very poor soils which are deficient in almost all the nutrients, except P, K and Mg, which are marginally available.

PROFILE DESCRIPTION NO. 9

General site information

Mapping unit	: BXlm
Observation no./date	: 135/1-55; 29/7/81
Classification	: plithic ACRISOL, sodic phase
Parent material	: alluvium/colluvium from various parent materials, over pisoferric material from about 50-70cm depth
Physiography	: bottomland
Relief, macro	: level to very gently undulating
Slope at site/position	: 0-1%/level plain
Vegetation	: bushed grassland
Land use	: grazing
Erosion, water/wind	: nil
Rock outcrops	: none
Flooding	: occurs seasonally after heavy rains
Effective soil depth	: moderately deep, 80cm
Groundwater level	: below 140cm
Drainage class	: moderately well drained

Profile description

Au1	0-24cm	: dark brown (7.5YR 3/2); sandy loam; massive to weak, medium to coarse, subangular blocky structure; hard when dry, friable when moist, slightly sticky and slightly plastic when wet; many, very fine to fine and common, medium pores; many, fine roots; clear and wavy transition to: (sample no. 135/1-55a)
Au2	24-40cm	: dark brown (10YR 3/3); sandy loam; moderate, medium to coarse, angular blocky structure; friable when moist, slightly sticky and slightly plastic when wet; many, very fine to fine, and common, medium, pores; many fine roots; gradual and wavy transition to: (sample no. 135/1-55b)
Bu1	40-56cm	: brown (10YR 4/3); many, very fine to fine, faint, yellowish red mottles; gravelly sandy clay loam; massive to weak, fine to medium, subangular blocky structure; friable when moist, sticky and plastic when wet; many, very fine to fine, and common, medium pores; common, fine roots; abrupt and wavy transition to: (sample no. 135/1-55c)
Bu2	56-70cm	: yellowish brown (10YR 5/4); many, fine to medium, prominent, dark red mottles; sandy loam; massive structure; friable when moist, non-sticky and non-plastic when wet; many, very fine to fine, and common, medium pores; common, fine roots; abrupt and wavy transition to: (sample no. 135/1-55d)
Bt1	70-84cm	: greyish brown (10YR 5/2); few, fine, faint, yellowish red mottles; sandy clay loam; compact massive structure; firm when moist, sticky and plastic when wet; common, very fine to fine pores; few, fine roots; gradual and wavy transition to: (sample no. 135/1-55e)
Bt2	84-110 cm^{+}	: light yellowish brown (2.5YR 6/4); many, fine to medium, distinct, yellowish red mottles; sandy clay; compact massive structure; firm when moist, sticky and plastic when wet; few, very fine to fine pores (sample no. 135/1-55f)

LABORATORY DATA OF PROFILE DESCRIPTION No. 10

Observation no: 135/1-51 Mapping unit: BX2 Soil classification: solodic PLANOSOL

Laboratory no. /81	7455	7456	7457	7458	7459	
Horizon	A	E	Bt1	Bt2	Bt3	
Depth(cm)	0-20	20-37	37-66	66-85	85-117	
pH-H_2O(1: 2½ v/v)	6.5	7.5	7.1	6.1	6.5	
pH-KCl "	5.5	6.2	6.4	4.8	5.3	
EC(mmho/cm) "	0.6	0.7	0.4	0.1	0.1	
$CaCO_3$(%)						
$CaSO_4$(%)						
C (%)	2.2	0.7	0.8	0.4	0.4	
N (%)						
C/N						
CEC(me/100g), pH 8.2	15.2	10.8	31.8	24.2	30.8	
CEC " " pH 7.0						
Exch.Ca(me/100g)	5.8	2.8	8.5	9.2	10.6	
" Mg "	2.8	1.3	5.0	5.2	6.4	
" K "	0.1	0.1	0.1	0.1	0.1	
" Na "	0.3	Tr.	1.3	1.4	1.9	
Sum of cations	9.0	4.2	14.9	15.9	19.0	
Base sat. %, pH 8.2	59	39	47	66	62	
" " %, pH 7.0						
ESP at pH 8.2				6	6	
Texture (limited pretreatment)						
Gravel % (>2.0mm)						
Sand % (2.0-0.05mm)	22	18	12	16	18	
Silt % (0.05-0.002mm)	40	50	14	16	18	
Clay % (0.002-0mm)	38	32	74	68	64	
Texture class	CL	SICL	C	C	C	

Fertility aspects 0 - 30 cm Laboratory no. 7412 / 81

General		Available nutrients			
pH-H_2O (1: 2½v/v)	5.5	Na/me/100g)	0.64	Mn(me/100g)	0.76
Exch. acidity (me/100g)	0.4	K "	0.14	P (ppm)	-
C %	2.32	Ca "	3.5	P-Olsen(ppm)	14
N %	0.3	Mg "	2.9		

Remarks: These are fertile soils which are sufficiently supplied with all the nutrients, except K which is lacking.

PROFILE DESCRIPTION NO. 10

General site information

Mapping unit	: BX2
Observation no./date	: 135/1-51; 28/7/81
Classification	: solodic PLANOSOL
Geology	: alluvium/colluvium from various parent materials
Physiography	: bottomland
Relief, macro	: level
Slope at site/position	: less than 1%, convex bottomland
Vegetation	: short grassland, with scattered clumps of bushes
Land use	: grazing
Erosion, water/wind	: nil
Rock outcrops	: none
Flooding	: occurs seasonally after heavy rains
Effective soil depth	: very deep, more than 120cm
Groundwater depth	: below 140cm
Drainage class	: imperfectly drained

Profile description

A	0-20cm	: very dark grey (10YR 3/1); clay loam; weak, medium to coarse, subangular blocky structure; firm when moist, sticky and plastic when wet; many, very fine to fine pores; many, very fine to fine roots; clear and wavy transition to: (sample no. 135/1-51a)
E	20-37cm	: greyish brown (10YR 5/2); many, very fine to fine, distinct, yellowish red mottles; silt clay loam; massive structure; firm when moist, sticky and plastic when wet; many, very fine to medium pores; many, very fine to fine roots; clear and wavy transition to: (sample no. 135/1-51b)
Bt1	37-66cm	: dark greyish brown (10YR 4/2); many, fine to medium, distinct, dark brown, mottles; clay; strong, very fine to fine, angular blocky structure; firm when moist, sticky and plastic when wet; many, thick clayskins; common, very fine to fine pores; common, very fine to fine roots; gradual and smooth transition to: (sample no. 135/1-51c)
Bt2	66-85cm	: very dark greyish brown (10YR 3/2); clay; moderate, fine to medium, angular blocky structure; firm when moist, sticky and plastic when wet; common, thin, slickensides; few, very fine to fine pores; very few, very fine roots; gradual and smooth transition to: (sample no. 135/1-51d)
Bt3	85-117cm	: dark greyish brown (10YR 4/2); clay; moderate, fine to medium, angular blocky structure; firm when moist, sticky and plastic when wet; common, thin, slickensides; few, very fine to fine pores (sample no. 135/1-51e)

LABORATORY DATA OF PROFILE DESCRIPTION No. 11

chromic VERTISOL

Observation no: 135/1-48 Mapping unit: BX3 Soil classification: sodic phase

Laboratory no. /81	7439	7440	7441	7442	7443	
Horizon	A1	C1g	C2g	C3g	C4k	
Depth (cm)	0-20	20-42	42-71	71-95	95-120	
pH-H_2O (1: 2½ v/v)	6.5	6.7	7.0	6.5	7.4	
pH-KCl "	5.4	5.6	6.0	5.6	6.6	
EC (mmho/cm) "	0.3	0.2	2.0	0.4	2.2	
$CaCO_3$ (%)						
$CaSO_4$ (%)						
C (%)	0.8	0.7	0.9	0.7	0.3	
N (%)						
C/N						
CEC (me/100g), pH 8.2	30.8	37.0	37.0	38.0	38.0	
CEC " " pH 7.0						
Exch. Ca (me/100g)	15.4	14.4	20.9	35.3	24.2	
" Mg "	11.7	13.3	16.2	17.1	14.6	
" K "	0.3	0.1	0.1	0.1	0.2	
" Na "	1.5	3.0	2.7	6.5	2.7	
Sum of cations	28.9	30.8	39.9	59.0	41.7	
Base sat. %, pH 8.2	94	83	100+	100+	100+	
" " %, pH 7.0						
ESP at pH 8.2	5	8	7	17	7	
Texture (limited pretreatment)						
Gravel % (>2.0mm)						
Sand % (2.0-0.05mm)	18	18	18	26	14	
Silt % (0.05-0.002mm)	22	20	16	12	16	
Clay % (0.002-0mm)	60	62	66	62	70	
Texture class	C	C	C	C	C	

Fertility aspects 0 - 30 cm Laboratory no. 7409 /81

General		Available nutrients			
pH-H_2O (1: 2½ v/v)	5.3	Na/me/100g)	2.1	Mn (me/100g)	0.56
Exch. acidity (me/100g)	0.2	K "	0.1	P (ppm)	-
C %	0.94	Ca "	7.2	P-Olsen (ppm)	18
N %	0.15	Mg "	8.2		

Remarks: These soils are deficient in N and K, but they are sufficiently supplied with P, together with Ca, Mg and Na. The high levels of Mg and Na may cause toxicity to the crops.

PROFILE DESCRIPTION NO. 11

General site information

Mapping unit	: BX3
Observation no./date	: 135/1-48; 24/7/81
Classification	: chromic VERTISOL, sodic phase
Parent material	: alluvium/colluvium, derived from various parent materials
Relief, macro	: level
Physiography	: bottomland
Slope at site/position	: less than 1%, concave bottomland
Vegetation	: short to medium grassland
Land use	: grazing
Erosion, water/wind	: nil
Flooding	: occurs frequently after heavy rains
Effective soil depth	: very deep, more than 120cm
Groundwater level	: 85cm (in dry season)
Drainage class	: very poorly drained

Profile description

A1 0-20cm : very dark greyish brown (10YR 3/2); clay; strong, very coarse, columnar structure; very hard when dry, very firm when moist, sticky and plastic when wet; common, very fine and few, fine pores; common, fine roots; gradual and wavy transition to:
(sample no. 135/1-48a)

Bu1 20-42cm : very dark grey (10YR 3/1); clay; strong, coarse, subangular blocky structure; very hard when dry, friable when moist, sticky and plastic when wet; common, moderately thick cracks and common, thin slickensides; common, very fine and few, fine pores; common, fine roots; gradual and wavy transition to:
(sample no. 135/1-48b)

Bu2 42-71cm : very dark grey (7.5YR 3/0); clay; moderate, coarse, angular blocky structure; hard when dry, friable when moist, sticky and plastic when wet; common, moderately thick pressure faces and many, thick, slickenside; common, very fine and few fine pores; few, fine roots; clear and smooth transition to:
(sample no. 135/1-48c)

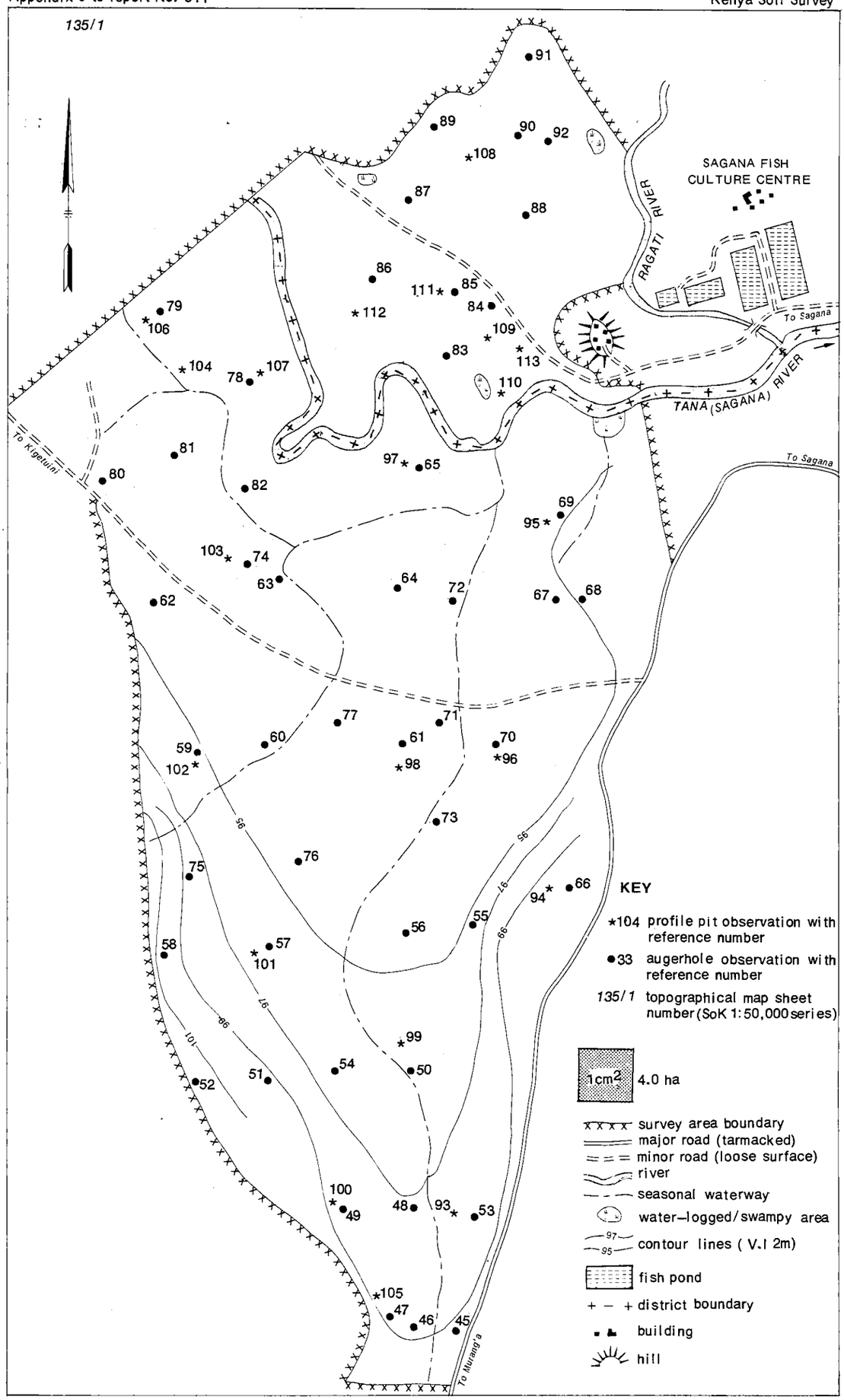
Cg 71-95cm : dark grey (10YR 4/1); clay; weak, coarse, angular blocky structure; hard when dry, friable when moist, sticky and plastic when wet; 2%, 2-10mm, $CaCO_3$ concretions, common, thick clayskins and many, moderately thick slickensides; common, very fine and few fine pores; very few, fine roots; clear and smooth transition to:
(sample no. 135/1-48d)

Ck 95-120cm^{+} : greyish brown (10YR 5/2); clay; weak, medium to coarse, angular blocky structure; hard when dry, friable when moist, sticky and plastic when wet; 5%, 3-10mm thick, $CaCO_3$ concretions; common, thick, slickensides; common, very fine and few fine pores
(sample no. 135/1-48e)

LOCATION OF OBSERVATIONS OF THE PROPOSED RURII AND SAGANA FISH CULTURE IRRIGATION SCHEMES (Murang'a/Kirinyaga Districts)

Appendix 3 to report No. S11

Ministry of Agriculture and Livestock Development.
Kenya Soil Survey



Base map derived from topographical map of the Provincial Irrigation Unit, Central Province, scale 1:2,000

SCALE 1:20,000

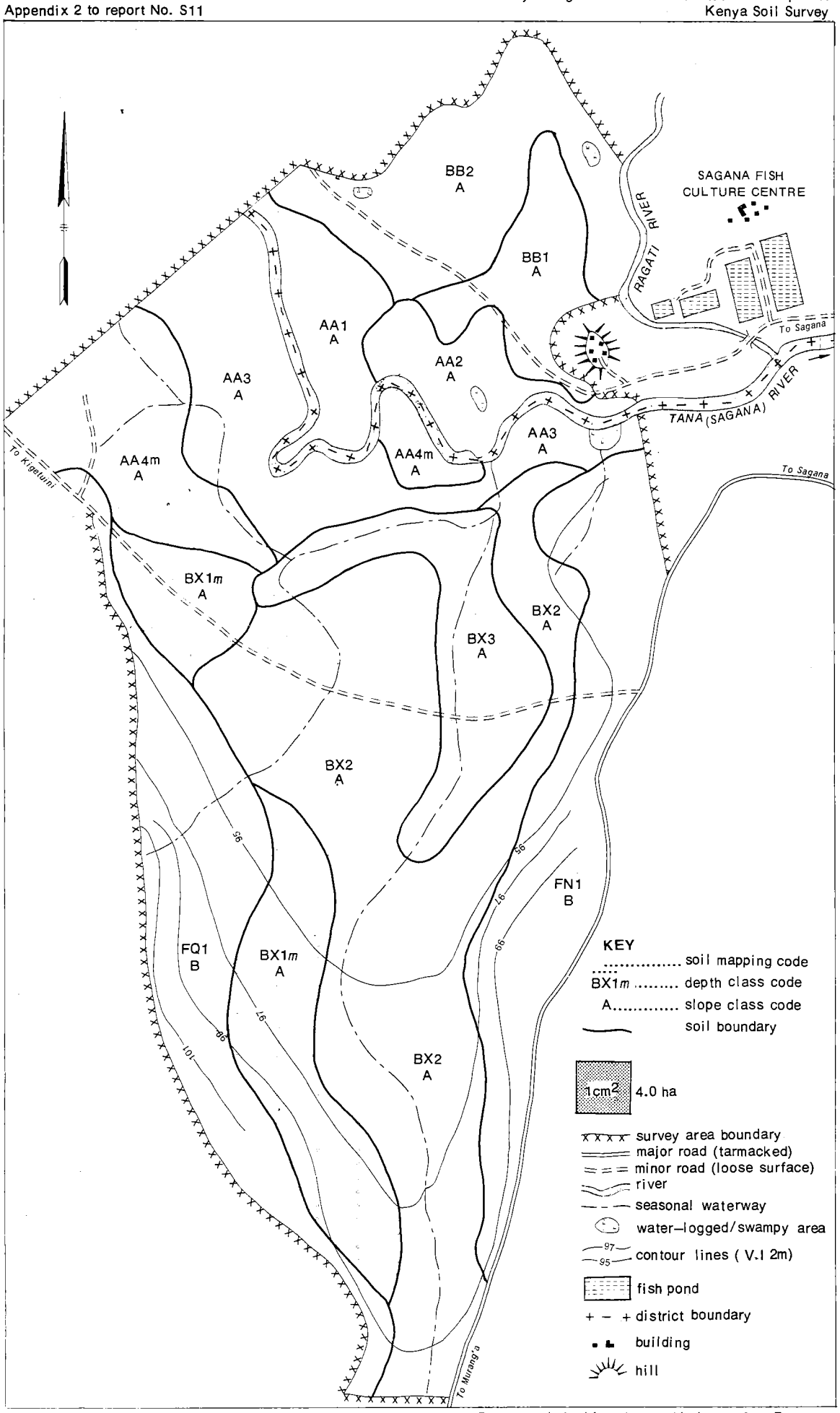
0 200 400 600 800 1000 m

Drawing No. 86030

SEMI–DETAILED SOIL MAP OF THE PROPOSED RURII AND SAGANA FISH CULTURE IRRIGATION SCHEMES (Murang'a/Kirinyaga Districts)

Appendix 2 to report No. S11

Ministry of Agriculture and Livestock Development
Kenya Soil Survey

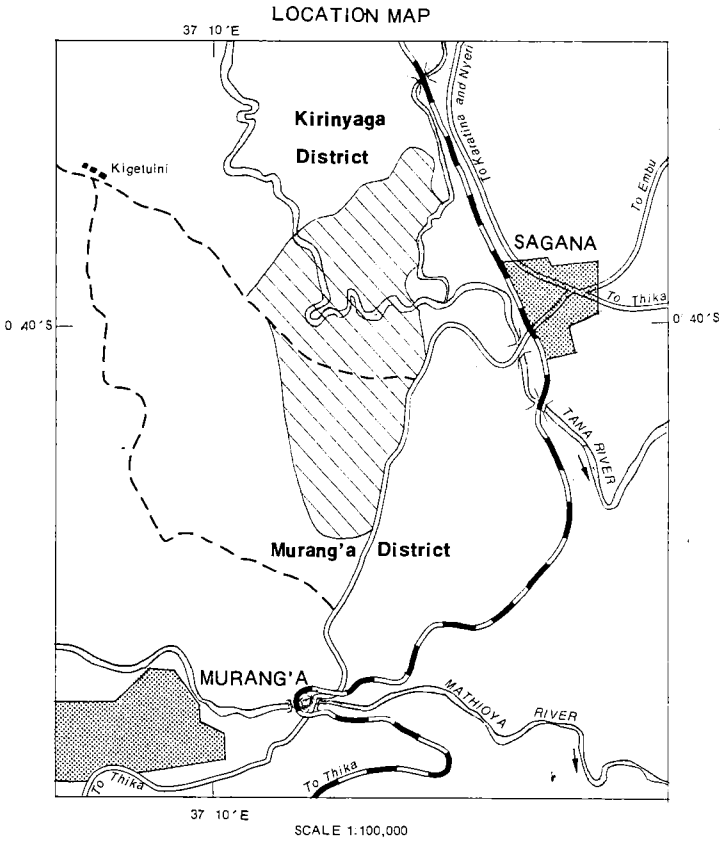


Base map derived from topographical map of the Provincial Irrigation Unit, Central Province, scale 1:2,000

SCALE 1:20,000

0 200 400 600 800 1000 m

LOCATION MAP



SCALE 1:100,000

KEY

- surveyed area
- major urban areas
- small trading centres
- major road(tarmacked)
- minor road (loose surface)
- railway
- river
- bridge

KEY TO SLOPE CLASSES

slope %	slope class code	name of the macrorelief
0-2	A	flat to very gently undulating
2-5	B	gently undulating

KEY TO DEPTH CLASSES

thickness soil in cm	code and symbol + over petroplinthite-murram	name
0-50		shallow
50-80	m	moderately deep
80-120	m	deep
120-180		very deep
more than 180		extremely deep

+ if a complex of depth classes occurs within one unit, only the code and symbol of the shallowest depth class are indicated

LEGEND

F FOOTSLOPES (slopes 2–5%)

FN Soils developed on colluvium derived from biotite gneisses

FN1 well drained to moderately well drained, very deep, dark brown to very dark grey, very friable, stratified, loamy sand to sandy loam (cambic ARENOSOLS)

FQ Soils developed on colluvium derived from granitoid gneisses

FQ1 moderately well drained, very deep, brown to very dark grey, loose to friable, slightly sodic, stratified, sand to clay loam (gleyic CAMBISOLS , partly sodic phase)

P VOLCANIC PLAINS (slopes 0–2%)

PB Soils developed on olivine basalts

PB1 well drained to moderately well drained, very deep, dark reddish brown to dark grey, friable to firm, clay (orthic LUVISOLS)

PB2 moderately well drained to imperfectly drained, very deep, dark brown to dark greyish brown, friable to firm, clay (gleyic ACRISOLS)

A FLOODPLAINS (slopes 0–2%)

AA Soils developed on recent alluvial deposits

AA1 well drained, extremely deep, dark reddish brown to dark brown, friable, stratified, clay loam to clay (dystric FLUVISOLS)

AA2 moderately well drained, very deep, brown to very dark grey, friable to firm, slightly to moderately sodic, stratified, clay loam to clay (eutric FLUVISOLS, sodic phase)

AA3 moderately well drained, very deep, dark reddish brown to dark greyish brown, friable to firm, slightly sodic, stratified, clay loam to clay (dystric FLUVISOLS, sodic phase)

AA4m imperfectly drained to poorly drained, moderately deep, dark reddish brown to grey, friable to firm, stratified, sandy clay loam to clay (plinthic GLEYSOLS)

B BOTTOMLANDS (slopes 0–1%)

BX Soils developed on alluvium/colluvium derived from various parent materials

BX1m moderately well drained to imperfectly drained, deep to very deep, dark brown to very dark grey, friable to firm, sodic, stratified, sandy loam to sandy clay, over pisoferric material (murram) (plinthic ACRISOLS, sodic phase)

BX2 poorly drained, very deep, dark greyish brown to very dark grey, friable to firm, slightly sodic, stratified, clay loam to clay (solodic PLANOSOLS)

BX3 poorly drained, very deep, very dark greyish brown to very dark grey, friable to firm, slightly saline and moderately sodic clay (chromic VERTISOLS, sodic phase)

SOIL SURVEY AND MAP PREPARATION (1982–1986)

soil survey..... J.K.Kanake, H.C.K.Kinyanjui, B.G.Mwangi, D.N.Gathui and M.Wekesa
map compilation..... J.K.Kanake
map correlation..... V.W.P.van Engelen and P.T.Gicheru
cartography..... P.M.Maingi

Drawing No. 86029