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KENYA SOIL SURVEY

SEMI-DETAILED SOIL SURVEY OF THE PROPOSED WEI-WEI IRRIGATION SCHEME

(WEST POKOT DISTRICT)

by

H. C. K. Kinyanjui and J. K. Kanake

SEMI-DETAILED SOIL SURVEY REPORT No. S13, 1986

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1 INTRODUCTION

A request to carry out a soil survey of the Wei-Wei Irrigation Scheme was received from the Provincial Irrigation Engineer, Rift Valley Province (Nakuru). The purpose of the survey was to study and evaluate the soil and water resources, together with the agricultural potential of the area, with an aim of rehabilitating, modernising and expanding the existing irrigation scheme.

The scheme was established many generations ago (exact date unknown) by the local inhabitants (the Pokots), who tap water from the gorge of the Wei-Wei river and lead it through contour canals, to irrigate their fields on the alluvial fanland. Inevitably, the irrigation efficiency is comparatively very low due to lack of a properly planned irrigation canal layout and poor water management in general.

The field studies were conducted in the months of March and April 1982, covering a total area of approximately 660ha. In addition, a number of observations were carried out in the recently opened Kerio Valley Development Authority's farm, just adjacent to the Wei-Wei Irrigation Scheme. The soils of the KVDA farm are described in a separate unpublished report.

The authors are grateful to the District Officer of Sigor for his assistance, and to all others who cooperated with and assisted the survey team comprising also Messrs B.G. Mwangi and D. Ng'ethe; during the course of the fieldwork.

2 ENVIRONMENTAL CONDITIONS

2.1 Location and communications

The survey area is situated near Sigor township in West Pokot District, Rift Valley Province. It is intersected by latitude and longitude 1°29'N and 35°28'E respectively, and lies at an elevation of between 1,000 metres above sea level in the extreme south, and 700 metres above sea level in the extreme north-east.

The new all-weather (tarmacked) Kitale-Kapenguria-Lodwar road by-passes the survey area by about 7km, but a junction from this major road gives access to Sigor, via Makutano.

2.2 Geology and physiography

According to the geological survey report which covers the whole of the Cherangani Hills area (Miller, 1956), the Wei-Wei river valley is composed of recent alluvial sediments, while the adjacent plains and footslopes consist primarily of Basement System rocks, namely fine grained hornblende gneisses and biotite-hornblende gneisses (viz.: rocks rich in ferromagnesian minerals).

The physiography of the area is closely related to the geology. It comprises the footslopes (of the Cherangani Hills), the piedmont plain (or coalescing alluvial fanlands), the alluvial valley of the Wei-Wei river, and minor valleys with recent alluvial fans.

2.3 Climate

Sigor - D.O.'s Office rainfall station (89.35029) has been taken as representative for the survey area. The station lies within the northern part of the survey area at an altitude of 1067m. The station has rainfall data of 15 years (1959-1973).

2.3.1 Average annual and seasonal rainfall

The mean annual rainfall of Sigor is 842mm. The rainy period (April-August) has a seasonal average rainfall of 517mm (see table 1).

Table 1. The mean monthly rainfall of Sigor - D.O.'s Office (89.35029)

Month	J	F	M	A	M	J	J	A	S	O	N	D	Year
Rainfall (mm)	25	28	61	152	122	62	102	79	49	63	69	30	842

From table 1, it can be seen that about 60% of the total annual rainfall is received in the April-August period.

2.3.2 Mean temperatures

The mean annual temperature of the survey area is 23°C. This is as calculated with the equation T°C = 30.2 - 0.00650h where h is altitude in metres (EAMD, 1970). With similar equations the mean maximum and the mean minimum temperatures are estimated as 29°C and 17°C respectively.

2.3.3 Evaporation, evapotranspiration and agro-climatic zonation

The calculated mean annual potential evaporation (Eo) of the survey area is 2040mm. This is based on Woodhead's (1968) equation for the potential evaporation in Kenya which he expressed as Eo = 2422 - 0.358h, where Eo is in mm and h is the station's altitude in metres. The mean annual potential evapotranspiration (Et) of the area is 1360mm, which is estimated as 2/3 of the potential evaporation (Eo).

The ratio of the mean annual rainfall to mean annual potential evaporation (r/Eo) in the study area is 41%. This places the area in agro-climatic zone IV. According to Braun (1977a) and Sombroek et al. (1982) this zone is semi-humid to semi-arid. Therefore it has a medium potential for rainfed agriculture with a low risk (10-25%) of failure for an adapted maize crop assuming that soil conditions are not limiting.

The monthly evaporation (Eo) data as calculated from Braun (in prep.) are given in table 2, together with the monthly evapotranspiration (Et).

Table 2. Calculated potential monthly evaporation and evapotranspiration estimates in mm for Wei-Wei (after Braun, in prep.)

	J	F	M	A	M	J	J	A	S	O	N	D	Year
Eo	204	204	204	143	163	163	143	163	184	163	143	163	2040
Et	136	136	136	95	109	109	95	109	123	109	95	109	1360

2.3.4 Seasonal rainfall probabilities

With the estimated crop water requirements and the average rainfall data as in table 2, the probabilities of seasonal rainfall was determined using Braun's (1977b) tables. In table 3, R represents the average rainfall over the shown period while Et represents the average crop water requirement. P(R>Et) is the probability (expressed as a percentage) that the rainfall will exceed the average crop water requirements over the indicated period.

Table 3. The probability of the seasonal rainfall

		R(mm)	Et(mm)		P(R>Et)
April-June	(3 months)	336	313	May-July	56%
April-July	(4 months)	438	422	May-August	49%
April-August	(5 months)	517	545	May-September	35%

The above calculated probabilities mean that during the growing period, there is enough rainfall for a three, four and five months' crop on average in 56%, 49% and 35% of the years respectively.

2.4 Vegetation

The vegetation is composed mostly of shrubs and bushes of Commiphora, Acacia, and allied genera. Perennial grasses such as Cenchrus ciliaris and Chloris roxburghiana are dominant but disappear readily by harsh management conditions such as overgrazing. However, the soil moisture conditions due to irrigation, and seepage from the adjacent highlands have locally influenced the vegetation in the survey area. The alluvial fanland is covered by mixed Acacia bushland, while the valleys are covered by dry Acacia thicket, with Capparidaceae and Acacia tortilis woodland, with Balanites orbicularis and Indigofera spinosa as the dominant ground vegetation.

2.5 Present land use

As mentioned earlier, the survey area is inhabited by the Pokots - a sub-tribe of the Kalenjin group. The Pokots are partly pastoralists and partly agriculturalists. The agriculturalists show a considerable degree of ingenuity in their methods of irrigation. They tap water from the streams and rivers by contour canals, running along the spurs of the mountain side to the alluvial fans where they grow millet, maize, sorghum, bananas and sugarcane.

The pastoralists are found in the plains and on the adjacent plateau where they graze their cattle, sheep and goats.

2.6 Hydrology

The survey area lies in the catchment of the Wei-Wei river which is fed by several tributaries, with their headwaters from the Cherangani Hills. The main tributary is the Samakitok river which has a seasonal flow.

The minimum discharge of the Wei-Wei river at Sigor is about $1 m^3/sec$ and the water is chemically well suited for irrigation as the results from laboratory tests, shown below in table 4, carried out at the National Agricultural Laboratories, indicate.

The sediment load of the Wei-Wei river up to the confluence with the Samakitok is relatively low, even after heavy rainstorms in its catchment area. However, many of the other tributaries transport a lot of erosion material during the rainy season mainly as a result of the very rapid run-off.

Table 4. Chemical analysis results of the Wei-Wei river water

Lab. No.	3229/82
pH	6.9
Conductivity (micromhos/cm)	95
Sodium (me/litre)	0.26
Potassium "	0.06
Calcium "	0.14
Magnesium "	0.42
Carbonates "	nil
Bicarbonates "	0.77
Chlorides "	0.18
Sulphates "	0.02
Nitrates "	-
Fluorides "	-
Sodium Adsorption Ratio (S.A.R.)	0.81

3 SURVEY METHODS

3.1 Office methods

A topographical map for the survey area was supplied by the Provincial Irrigation Engineer, Nakuru. This map was reduced from the original scale of 1:5,000 to a smaller scale of 1:10,000 for the field basemap and finally to the 1:20,000 published soil map.

3.2 Field methods

Soil augerings were made to a depth of 2m (soil depth permitting), following a grid system of approximately 300m by 500m. where it was impossible to make systematic observations on a straight line due to thick bush or other obstacles, the observations were made along bush paths, tracks or roads, traversing the survey area. A total of 39 augerhole observations were made.

The soils were examined for depth, colour, texture, consistence, internal drainage, salinity (by EC meter), sodicity (by pH meter), calcareousness (by HCl reaction), etc. All the observations were systematically numbered and 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 (12 in total) were described in detail following the Kenya Soil Survey methods, which are based on the FAO "Guidelines for Soil Profile Description" (FAO, 1977). The soil colour was determined using the "Munsell Soil Color Charts" (Munsell Color Co., 1971). Colour descriptions are for moist conditions only, unless the soil was very dry, in which case the dry soil colour is given.

At each profile, all natural horizons were sampled. A composite topsoil sample for fertility analysis was taken from the area surrounding 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 of the Kenya Soil Survey for fine drawing.

3.3 Laboratory methods

Standard methods

All laboratory methods are described in short below. For more details see Hinga et al. (1980).

Preparation : Breaking up of aggregates by careful pounding with pestle and mortar, and sieving through a 2 mm sieve.

Texture : No chemical treatment to remove cementing agents; shaking overnight with sodium hexa-metaphosphate/sodium carbonate; measurement for silt (0.002-0.05mm) and clay (0-0.002mm) fractions with a hydrometer after 40 sec. and 2 hrs respectively; silt fraction (0.002-0.05mm) obtained by difference; sand is the rest factor.

pH and EC : In a 1:2½ soil-water suspension.

pH-KCl : In a 1:2½ soil-1N KCl suspension.

Organic C% : Walkley-Black method.

Cation Exchange Capacity (CEC): Leaching of the soil with 1N-sodium acetate (NaOAc) at pH 8.2. After a washing step with 96% ethyl-alcohol and N-ammonium acetate at pH 7.0, Na is determined in the last leachate by flamephotometer. After a further washing step with 96% ethyl-alcohol and leaching with acidified NaCl, NH_4 is determined by steam distillation and titration.

Exchangeable cations : Leaching of the soil with N-ammonium acetate of pH 7.0. Determination of Na and K by flame-photometer, Ca and Mg by atomic absorption spectrophotometer.

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. For Mg the same procedure as for exchangeable Mg. For P the Olsen method is used. Mn is measured colorimetrically using phospheric acid - potassium periodate for colour development.

4 SOILS

4.1 Previous work

No detailed soil studies have been done previously, but in 1975 the German Agricultural Team (GAT) carried out a preliminary evaluation of the soil and water resources along the Wei-Wei river valley to determine their suitability for irrigation development (Bonarius, 1975). According to this study, the survey area is a piedmont plain comprising coalescing alluvial fans, extending from the footslopes of the Cherangani Hills. Several soil types were identified, varying from gravelly, well drained, moderately deep, dark reddish brown to brown sandy loam, to imperfectly drained, very deep, dark brown to very greyish brown, sandy clay to heavy clay.

The 'Land Systems Atlas of Western Kenya' (Scott et al., 1971) gives some soil information in its description of land systems and land facets.

In 1976 the KSS completed a reconnaissance soil survey report on the 'Soils of the Kapenguria Area' (Gelens et al., 1976). In this report, three soil mapping units were distinguished in the survey area, viz.:

- FGby : well drained, deep, dark reddish brown to brown, friable loamy sand to clay; in places stratified (eutric CAMBISOLS) on the footslopes
- YGbcl : well drained, deep, dark brown to dark reddish brown, friable to firm (compact), sandy clay to clay (VERTI*-chromic LUVISOLS) in the piedmont plain
- AC : complex of stratified and non-stratified soils of various textures, colours and drainage conditions; on floodplains and terraces of various levels (eutric FLUVISOLS) along the Wei-Wei river.

The exploratory soil map and agro-climatic zone map of Kenya (Sombroek et al., 1982) covers the area too, but not at a reasonable detail.

4.2 General properties of the soils

The pattern of the soils is largely determined by parent material and physiography. The soils of the footslopes are very shallow to shallow with a texture of gravelly sandy loam. Severe rainsplash and rill erosion has washed away the topsoil leaving stones and in places boulders on the surface. The soils have a low organic matter content (0.4 to 0.5 %C) and a low CEC (5-8 me/100g soil).

The soils occuring in the coalescing fanland (mapping units YF1p, YF2, YF3) are somewhat excessively drained to well drained, deep to very deep, friable, with textures ranging from sandy loam to sandy clay loam. Organic carbon in the topsoil ranges from 0.8 to 1.0%. The pH ranges from 6.6 to about 8.0. In the areas bordering mapping unit YF4 the deep subsoil is slightly to moderately sodic. The CEC is in general moderate (less than 16 me/100g soil) except in mapping unit YF3 where it

is high (20 to 25 me/100g soil). These are the best soils in the irrigation scheme.

The soils of the piedmont plain proper (mapping unit YF4) are moderately well drained, very deep, with a clay texture and are generally difficult to work on. They form a crust on the surface and are firm when moist, sticky and plastic when wet. Organic carbon content is rather high in the topsoil (1.3%) and varies from 0.2 to 0.7% in the subsoil. The CEC is high (21 to 29 me/100g soil). The pH ranges from 8.1 in the topsoil to 9.8 in the subsoil. At 85cm the ESP is about 17.5, at 130cm the ESP is 24 which indicates a moderate sodicity.

The soils of the alluvial river valley occur along the Wei-Wei river. These are well drained, stratified, extremely deep, moderately calcareous with varying textures, generally sand to sandy loam. The pH of the first 100cm ranges between 8.0 to 8.3 decreasing with depth. In the deeper horizons the pH ranges from 8.6 to 9.0 without any sequence. The CEC ranges from 1.8 to 12.4 me/100g soil and varies from horizon to horizon. In some seasons the river floods the alluvial plain.

The soils of the minor valleys and recent alluvial fans are well drained to moderately well drained, very deep with sandy loam textures. The streams which are perpendicular to the Wei-Wei river are perennial and start from springs that emerge just below the footslopes. Areas next to the streams and around where the springs are located are moderately well drained. The recent alluvial fans have well drained soils. Organic carbon in the topsoil is 1.3%, in the subsoil it varies from 0.2 to 0.5% without any horizon sequence. The pH ranges from 7.5 to 8.1, CEC ranges from 16.0 me/100g soil in the topsoil to 5.0 me/100g soil in the subsoil (decreasing with depth).

4.3 Description of the soil mapping units

4.3.1 Systematic and nomenclature

Every mapping unit in the soil map is identified by a code for which a code system is used. The first letter in the code denotes physiography, the second letter geology, and the last letter or numerical figure denotes the various soil characteristics. The letter(s) appearing below the code indicate(s) the slope class.

The following codes are used:

Physiography

F - Footslopes
Y - Piedmont plain/coalescing alluvial fanland
A - Alluvial river valleys
V - Minor valleys and alluvial fans.

Geology (Parent material)

F - Gneisses rich in ferromagnesian minerals (Basement System rocks)
A - Alluvial/colluvial material.

Soils

1, 2, - Various soil characteristics

P, p - Depth class annotations. For explanation see 'Key to depth classes' of appendix 2.

Slope classes

A	0	-	2%
B	2	-	5%
C	5	-	8%

The soils are classified according to the 1974 FAO/UNESCO legend for their "Soil map of the world".

4.3.2 Soils of the footslopes

Mapping unit FFP

Extent	:	56 ha.
Parent material	:	Gneisses rich in ferromagnesian minerals (Basement System rocks).
Macro-relief	:	Gently undulating to undulating, slopes 3-6%.
Erosion	:	Severe rainsplash and rillwash erosion.
Rockiness/stoniness	:	Rocky/stony.
Vegetation	:	Bushland.
Land use	:	Grazing - mainly goats, some cattle and sheep were also kept.
Soils, general	:	This mapping unit has somewhat excessively drained very shallow to shallow, dark reddish brown, gravelly sandy loam soils over rock, with an A(B)R profile, in places AR profile, and gradual and wavy transition between the horizons.
colour	:	Dark reddish brown (5YR 3/3).
texture	:	Sandy loam.
structure	:	Porous massive.
consistence	:	Friable when moist, slightly sticky and non-plastic when wet.
Chemical properties		
A-horizon	:	Organic carbon is 0.4%, pH-H_2O is 6.8 and pH-KCl 6.1. The CEC is 8.0 me/100g soil. Base saturation is 73%.
B-horizon	:	Organic carbon is 0.37%, pH-H_2O is 8.2 and pH-KCl 7.0. The CEC is 4.6 me/100g soil. Base saturation is 73%.
Salinity/sodicity	:	Non saline/non sodic.

Diagnostic criteria : Ochric A-horizon with or without cambic B-horizon and coherent hard rock within 45cm.

Classification : eutric CAMBISOLS, lithic and stony phase and LITHOSOLS.

For the description of a representative profile with analytical data see appendix 1, profile No. 1 (observation no. 75/2-658).

4.3.3 Soils of the piedmont plains/coalescing alluvial fanlands

Mapping unit YF1p

Extent : 65 ha.

Parent material : Alluvium/colluvium derived from gneisses rich in ferromagnesian minerals (Basement System rocks).

Macro-relief : Gently undulating, slopes 2-3%.

Erosion : Nil.

Vegetation : Bushland.

Land use : Grazing - mainly goats; cattle and sheep were also kept. Cultivation - maize, cassava, bananas under irrigation.

Soils, general : Somewhat excessively drained, deep to very deep, reddish brown to dark reddish grey, friable sandy loam soils with a stone line between 60 and 70cm. The soils have an AC profile with clear and smooth transitions in the topsoil and abrupt to gradual and wavy transitions in subsoil.

colour : Reddish brown (5YR 4/3) to dark reddish grey (5YR 4/2) throughout.

texture : Sandy loam throughout.

structure : A-horizon: massive.

C-horizon: massive, developing into very weak, medium to coarse, subangular blocky.

consistence : Slightly hard to hard when dry, friable when moist, sticky and plastic when wet.

Chemical properties

A-horizon : Organic carbon is 0.99%. pH-H_2O is 6.8 and pH-KCl 5.0. The CEC is 13.0 me/100g soil. Base saturation is 69%.

C-horizon : Organic carbon content ranges from 0.26 to 0.34%. pH-H_2O increases with depth from 6.6 to 7.9 and pH-KCl from 5.2 to 7.0. The CEC ranges between 8.0 and 11.6 me/100g soil. The base saturation increases with depth from 66 to 100%.

Salinity/sodicity : Non-saline/non-sodic.

Diagnostic criteria : Ochric A-horizon, base saturation over 50%.

Classification : eutric REGOSOLS.

For the description of a representative profile with analytical data see appendix 1, profile no.2 (observation no. 75/2-657).

Mapping unit YF2

Extent : 165 ha.

Parent material : Alluvium/colluvium derived from gneisses rich in ferromagnesian minerals (Basement System rocks).

Macro-relief : Gently undulating, slopes 2-3%.

Erosion : Nil.

Vegetation : Bushed grassland.

Land use : Cultivation under furrow irrigation - maize, cassava and bananas are grown.

Soils, general : This unit consists of well drained, very deep, reddish brown to dark brown, friable sandy clay loam soils. They have ABC profiles with clear and smooth transitions in the topsoil and with gradual to diffuse and smooth to wavy transitions in the lower horizons.

colour : A-horizon: dark brown (7.5YR 3/2).

B-horizon: (dark) reddish brown (5YR 4/3-4/4).

texture : Sandy clay loam throughout.

structure : A-horizon: porous, massive to weak, medium subangular blocky.

B-horizon: moderate, fine to medium, subangular and angular blocky.

consistence : Hard when dry, friable when moist, sticky and plastic when wet.

Chemical properties

A-horizon : Organic carbon content ranges between 0.56% and 0.87%. pH-H_2O ranges between 7.1 and 8.3 and pH-KCl between 5.9 and 7.6. The CEC ranges between 9.4 and 14.6 me/100g soil. The base saturation ranges between 57 and 65%.

B-horizon : Organic carbon content is 0.67% decreasing with depth to 0.17%. pH-H_2O ranges between 7.3 and 8.0 and pH-KCl between 5.5 and 6.6. The CEC ranges between 6.2 and 16.0 me/100g soil. The base saturation ranges between 56 and 94%.

Salinity/sodicity : Non-saline/non-sodic.

Diagnostic criteria : Ochric A-horizon and cambic B-horizon with base saturation of over 50%.

Classification : eutric CAMBISOLS.

For the description of a representative profile and analytical data see appendix 1, profile no.3 (observation no. 75/2-656).

Mapping unit YF3

Extent	:	196 ha.
Parent material	:	Alluvium/colluvium derived from gneisses rich in ferromagnesian minerals (Basement System rocks).
Macro-relief	:	Flat to gently undulating, slopes less than 3%.
Erosion	:	In places gully development.
Vegetation	:	Bushland.
Land use	:	Grazing - cattle, goats and sheep. The area was under irrigation before it was abandoned after the supply canal was destroyed by a wide gully.
Soils, general	:	This unit consists of well drained, very deep, reddish brown to dark reddish grey, very friable to friable sandy clay loam to clay soils. They have ABC profile with gradual to clear and wavy transitions between the horizons.
colour	:	A-horizon: dark brown (7.5YR 3/2) B-horizon: ranges from reddish brown (5YR 4/3) to dark reddish grey (5YR 4/2).
texture	:	Sandy clay loam throughout.
structure	:	A-horizon: porous massive. B-horizon: weak to moderate, fine to medium angular blocky.
consistence	:	Friable when moist, sticky and plastic when wet.

Chemical properties

A-horizon	:	Organic carbon content ranges between 0.83% and 1.90%. pH-H_2O ranges between 7.5 and 8.3, and pH-KCl between 6.1 and 7.6. The CEC ranges between 15.0 and 19.2 me/100g soil. The base saturation ranges from 62 to 81%.
B-horizon	:	Organic carbon content ranges between 0.17% and 0.65%. pH-H_2O ranges between 7.3 and 8.0 and pH-KCl between 5.4 and 7.6. The CEC ranges between 8.8 and 18.8 me/100g soil. The base saturation ranges between 62 and 81%.
Salinity/sodicity	:	non-saline/non-sodic.
Diagnostic criteria	:	cambic B-horizon.
Classification	:	eutric CAMBISOLS.

For the description of a representative profile and analytical data see appendix 1, profile no. 4 (observation no. 75/2-665).

Mapping unit YF4

Extent : 50 ha.

Parent material : Alluvium/colluvium derived from gneisses rich in ferromagnesian minerals (Basement System rocks).

Macro-relief : Flat to very gently undulating, slopes 1-2%.

Erosion : None.

Vegetation : Bushland.

Land use : Grazing of cattle (sheep and goats are only herded in the areas close to homes which are in this case at the footslopes or up on the slopes of Cherangani hills); abandoned cultivation (under irrigation) disrupted through the blocking of the supply canal by a wide gully.

Soils, general : This unit consists of moderately well drained, very deep, dark brown to very dark greyish brown, friable to very firm, calcareous, moderately sodic, clay soils. They have an ABC profile; many, moderate to strong slickensides; clear and wavy to diffuse and smooth transitions between the horizons.

colour : A-horizon: very dark greyish brown (10YR 3/2).

B-horizon: dark brown (10YR 3/3).

texture : Clay throughout.

structure : A-horizon: moderate, fine to medium subangular blocky.

B-horizon: moderate to strong, coarse to very coarse columnar (Bu horizon) and angular blocky.

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

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

Chemical properties

A-horizon : Organic carbon content is 1.31%. pH-H_2O is 8.1 and pH-KCl is 7.8. The CEC is 24.6 me/100g soil. The base saturation is 75%.

B-horizon : Organic carbon ranges between 0.29% and 0.71%. pH-H_2O ranges between 8.3 and 9.8 and pH-KCl 6.6 and 7.5. The CEC ranges between 21.4 to 28.5 me/100g soil. The base saturation ranges between 65 and 100%. The soil is calcareous and slightly to strongly sodic with an ESP of 18 at 100cm depth.

Salinity/sodicity : Non-saline/non-sodic to slightly sodic, (ESP 6.7, pH 9.1) to a depth of 85cm. Deeper than 85cm the soil is strongly sodic (ESP 17 to 24%, pH 9.5 to 9.8).

Diagnostic criteria : Ochric A, a cambic B and vertic properties.

Classification : vertic CAMBISOLS, sodic phase.

For the description of a representative profile with analytical data, see appendix 1, profile no. 5 (observation no. 75/2-661).

4.3.4 Soils of the alluvial river valleys

Mapping unit AA1

Extent : 57 ha.

Parent material : Recent and subrecent alluvial deposits of the Wei-Wei river.

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

Erosion : In places gully erosion.

Vegetation : Bushland.

Land use : Mainly grazing, in places maize, cassava and sugarcane.

Soils, general : This unit consists of somewhat excessively drained, extremely deep, dark brown to black, stratified, friable, moderately calcareous, sand to sandy loam soils. These soils have no or very little development with only an AC horizon sequence. The horizon boundaries are abrupt and smooth to wavy.

- colour : Ranges from dark brown (10YR 3/3) to black (10YR 2.5/1) without any sequence.
- texture : Sand to sandy loam without any depth sequence.
- structure : Massive and single grained.
- consistence : Friable when moist, slightly plastic and slightly sticky when wet for the horizons with sandy loam texture, loose when moist, non-sticky and non-plastic when wet for the horizons whose texture is sand.

Chemical properties : Organic carbon varies irregularly between 0.26 and 1.20%. pH-H_2O ranges from 8.0 to 8.7 and pH-KCl from 6.8 to 7.8. The CEC ranges between 1.8 and 12.4 me/100g soil depending on the texture. The base saturation ranges from 47 to over 100%. The soil is moderately calcareous. All the chemical data have no sequence in relation to depth.

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

Diagnostic criteria : Stratification, organic matter decreases irregularly with depth and is still at a high level at 1.25m depth; base saturation over 50%.

Classification : eutric FLUVISOLS.

For the description of a representative profile with analytical data see appendix 1, profile no. 6 (observation no. 75/2-660).

4.3.5 Soils of the minor valleys and alluvial fans

Mapping unit VA1

Extent : 71 ha.

Parent material : Recent and subrecent alluvial deposits.

Macro-relief : Flat to very gently undulating with slopes less than 2%.

Erosion : Nil.

Vegetation : Bushland.

Land use : Cultivation of bananas, cassava and sugarcane.

Soils, general : This unit consists of well to moderately well drained (due to the effects of the springs), very deep, dark brown to very dark grey, stratified, very friable to friable sandy loam soils. They have an AC profile with clear to abrupt and wavy transitions between the horizons.

- colour : Ranges from dark brown (10YR 4/3) to very dark grey (10YR 3/1).
- texture : Sandy loam is dominant with sand and sandy clay loam lower down the profile.
- structure : Ranges from weak to moderate, medium to coarse subangular and angular blocky to porous massive throughout.
- consistence : Slightly hard when dry, very friable when moist, slightly sticky and slightly plastic when wet.

Chemical properties

- A-horizon : Organic carbon content is 1.33%. pH-H_2O is 7.5 and pH-KCl 5.8. CEC is 16.0 me/100g soil. The base saturation is 55%.
- C-horizon : Organic carbon content decreases irregularly with depth to a minimum of 0.20%. pH-H_2O ranges between 7.8 and 8.1 and pH-KCl between 6.0 and 6.2, both vary with horizons without any proper sequence. CEC ranges between 5.0 and 7.4 me/100g soil decreasing with depth. The base saturation varies irregularly between 35% and 74%.

Salinity/sodicity : Non-saline/non-sodic.

Diagnostic criteria : Stratification, organic matter content decreases irregularly with depth and is still at a high level at 1.25m depth; base saturation between 20 and 50cm depth is over 50%.

Classification : eutric FLUVISOLS.

For the description of a representative profile with analytical data see appendix 1, profile no. 7 (observation no. 75/2-663).

4.4 Soil fertility status

The appraisal of the soil fertility in the survey area is based on the chemical analysis of composite topsoil samples taken from the area surrounding each representative profile pit in each of the soil mapping units. This appraisal can only be regarded as very general one due to the complexity of the area. The samples were taken from the top 30cm of the soil and only the available nutrients shown in the analytical data (see table 5 below) have been taken into consideration for fertility appraisal. The rating of the fertility is based on Mehlich et al. (1964).

According to the analytical data shown in table 5, all the soils have a near-neutral pH (6.7-7.2). They are adequately supplied with most of the basic nutrients, viz.: K, P, Ca and Mg. However, N, which is extremely important for the vegetative growth in all plants, is deficient in all soils. In view of this, it is strongly recommended to apply Nitrogenous fertilizers (e.g. S.A., C.A.N., A.N.), or to add Farm Yard Manure (FYM) or Compost manure to the soils to improve their N status.

Table 5. Available nutrients (0-30cm)

Mapping unit	FFP	YF1p	YF2	YF3	YF4	AA1	VA1
Observation No.	75/2-658	75/2-657	75/2-656	75/2-664	75/2-661	75/2-660	75/2-663
Lab No. /82	5635	5634	5633	5641	5638	5637	5640
pH	6.7	6.7	6.7	6.9	6.8	7.2	6.9
Na (me/100g)	0.06	0.06	0.06	0.08	0.14	0.04	0.08
K "	0.8	0.6	0.5	0.4	0.9	0.5	0.4
Ca "	3.8	3.2	5.2	4.2	8.1	4.4	4.2
Mg "	3.6	4.1	3.8	2.8	6.0	2.8	2.8
Mn "	0.6	0.6	0.8	0.5	0.5	0.4	0.5
P (ppm)	54	77	33	52	58	250	52
N (%)	0.15	0.1	0.13	0.1	0.13	0.1	0.1
C (%)	0.92	0.63	1.03	0.84	0.4	0.8	0.84
EC (mmhos/cm)	-	-	-	-	-	0.13	-

5 LAND EVALUATION

5.1 Procedure

The land evaluation in this report follows closely the "Framework for Land Evaluation" (FAO, 1976). It is based on the assumption that land evaluation can only be done correctly for a well defined land utilisation type (LUT) if the land qualities are properly specified and rated. Proposals for the rating of land qualities have been compiled by Braun and van de Weg (1977). These land qualities are used to establish specifications for each land suitability class for a specific LUT in this case smallholder irrigation under furrow irrigation method. The crops grown are bananas, maize, beans, cassava, sugarcane and sweet potatoes. These are all grown at subsistence level with low to medium technology. Only hand tools are used in all the activities involved in the preparation of the land.

The land suitability classes have been defined as follows: (after FAO, 1976 modified)

Class S1.1: Highly suitable

Land having no significant limitations to sustained application of a given use, or only minor limitations that will not significantly reduce productivity or benefits and will not raise inputs above an acceptable level.

Class S1.2: Moderately suitable

Land having limitations which in aggregate are moderately severe for sustained application of a given use; the limitations will reduce productivity or benefits and increase required inputs to the extent that the overall advantage to be gained from the use, although still attractive, will appreciably be inferior to that expected on class S1.1 land.

Class S1.3: Marginally suitable

Land having limitations which on aggregate are severe for sustained application of a given use and will so reduce productivity or benefits, or increase required inputs that this expenditure will be only marginally justified.

Class NS: Unsuitable

Land which has qualities that appear to preclude sustained use of the kind under consideration.

5.2 Land evaluation for smallholder irrigation

5.2.1 Land qualities

A land quality is an attribute of the land that acts in a distinct matter on the suitability of the land for the use under consideration.

Each land quality may be a combination of single land characteristics. For every mapping unit a rating of the relevant land qualities is made. The following land qualities are used:

1. slope
2. soil moisture storage capacity
3. drainage condition/availability of oxygen
4. soil fertility
5. sodicity
6. workability of the soil/possibility for the use of agricultural implements.

Slope

Slope is a very important land quality. As the slope increase the suitability for surface irrigation use decreases. The slopes are rated as follows:

slope %	rating
0 - 2	1
2 - 3	2
more than 3	3

SMSC Soil Moisture Storage Capacity

The soil depth is a very important characteristic in evaluating this land quality in that it determines the amount of moisture that can be stored in the soil. Deeper soils also allow deep penetration of roots thereby increasing the area over which nutrients and water can be extracted.

The texture of the soil influences the amount of pores which in turn determine the moisture that can be held in the soil. A coarse textured soil e.g. loamy sand, sandy loam or sandy clay may hold less moisture due to the presence of dominantly large pores, than a fine textured soil like clay which may hold more moisture due to the nature of pores.

The soil moisture storage capacity is estimated using graphical correlations between water and clay content and equations derived from these graphs (Braun and van de Weg, 1977).

Estimated easily available moisture per 10cm of soil for various textures

texture	LS	SL	SCL	SC	SiC	C
e.e.a.m. (mm)	3.2	4	5.5	8	10.5	11.2

Soil moisture storage capacity is considered as the total productive available moisture which is a function of depth and texture. The ratings are as follows:

SMSC in mm for 100cm depth	ratings
more than 100	1
70-100	2
40-70	3
less than 40	4

Ox Drainage condition/Availability of oxygen

The soil drainage condition refers to the rate at which water is internally removed from the soil. The characteristic is observed in the field. Mottles and dark grey colours in the subsoil are indicators of poor drainage and are here regarded qualitatively as the basis for rating the drainage condition of a soil. Well drained soils have a good aeration while poorly drained soils are badly aerated. Shallow soils may have a superficial water table close to the rooting zone. The problems affect the performance of plants as the poor drainage deprives roots of oxygen. The following classes are used:

Drainage class	Rating
Well drained/somewhat excessively drained	1
Moderately well drained	2
Imperfectly drained	3
Poorly drained	4

Fert Soil Fertility

The rating of this characteristic is based on samples of the topsoil collected in the profile pit and the surrounding areas. The analytical data used to rate the soil fertility are the CEC and the available nutrients. The following sub-ratings are used:

Sub-rating	CEC in me/100g
1	more than 16
2	12-16
3	6-12
4	2-6
5	0-2

Available nutrients are rated as follows:

Sub-rating	Available P (ppm)	Available K (me/100g)	Available Ca (me/100g)	Available Mg (me/100g)
1	more than 200	more than 3.5	more than 20	more than 12
2	80-200	2.0-3.5	10-20	6-12
3	20-80	1.0-2.0	6-10	3-6
4	0-20	0.3-1.0	2-6	1-3
5		less than 0.3	less than 2	less than 1

The final rating for fertility is arrived at by adding up the two subratings and then rating them as follows:

rating	sum of the two sub-ratings
1	2
2	3-4
3	5-6
4	7-8
5	9-10

Sod Sodicity of the soil

Sodicity causes problems in the uptake of plant nutrients from the soil. Sodium may be present in the soil in high amounts or it may be found in the irrigation water. Sodicity problems may also increase due to poor drainage of excess water from the soils.

Since root systems of the commonly grown crops develop mainly in the upper 30cm of the soil, the topsoil and subsoil are rated separately so that the topsoil is given more weight. The ratings are as follows:

Rating	ESP (0-30cm)	ESP (30-100cm)
1	less than 6	less than 6
2	6-10	6-15
3	10-15	15-40
4	15-40	more than 40
5	more than 40	more than 40

Impl Workability of the soil/possibilities for use of agricultural implements

The workability of the soil is rated mainly on the basis of dry and moist consistence. Some soils are very hard to extremely hard when dry and may be firm when moist which makes such soils difficult to work on. The workability of a soil is down-graded one class if consistence is sticky and plastic when wet. The very sticky and very plastic soils are down-graded another class.

Sub-rating	Consistence (when dry)	Consistence (when moist)
1	loose	loose
2	soft	very friable
3	slightly hard	friable/friable to firm
4	hard	firm
5	very hard	very firm/extremely firm

The sum of the two subratings gives the final ratings.

Sum of sub-ratings	final rating
2-3	1
4-5	2
6-7	3
8-10	4

The land qualities, as described above, are rated for all mapping units. The results of this exercise are shown in table 7.

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

Soil mapping unit	Land qualities					
	Slope	SMSC	Ox	Fert	Sod	Impl
FFP	3	3	1	4	1	1
YF1p	1-2	3	1	3-4	1	1
YF2	1-2	3	1	3-4	1	1
YF3	1-2	3	1	3	1	1
YF4	1	1	2	3	3	4
AA1	1	3-4	1	4-5	1	1
VA1	1-2	3	1-2	4	1	1

5.2.2 Suitability class - defining criteria

The most crucial step in the land evaluation process is the establishment of suitability class-defining criteria. In drawing the conversion tables, the Kenya Soil Survey "Internal Communication No. 23" (Muchena, 1981) has been used as well as conversion tables from other surveys (van de Weg, 1978).

Table 7. Suitability class - defining criteria for the land utilization type, small-holder, furrow irrigation for commonly grown crops

Suitability class	Slope	SMSC	Ox	Fert	Sod	Impl
S1.1	1	3	2	2	1	2
S1.2	2	4	3	3	2	3
S1.3	2	4	4	4	3	4
NS	3	4	4	4	3	4

5.2.3 Land suitability for smallholder irrigation

The results of the land evaluation exercise are shown in table 8. Mapping unit YF3 covering 196ha (see attached map) is considered to be highly suitable to moderately suitable since it does not show any major limitation except some slopes slightly steeper than 2%.

Mapping units YF1p and YF2 covering 230ha are considered to be moderately suitable due to various land limitations, the major one being low soil fertility.

Mapping units YF4, AA1 and VA1 covering 178ha are considered to be marginally suitable due to various major limitations. The major constraint in mapping unit YF4 is poor workability, availability of oxygen and slight to strong sodicity in the subsoil. Mapping units AA1 and VA1 are limited by very low soil fertility.

Mapping unit FFP (56ha) is considered to be unsuitable for furrow irrigation due to the undulating topography and due to the fact that the soils are shallow and stony.

Table 8. Potential land suitability classification for smallholder furrow irrigation of commonly grown crops e.g. maize, sorghum, peanuts, cassava, etc.

Suitability class	mapping unit	Area in ha
S1.1 - S1.2	YF3	196
S1.2	YF1p	65
	YF2	165
S1.3	YF4	50
	AA1	57
	VA1	71
NS	FFP	56

6 CONCLUSIONS AND RECOMMENDATIONS

The soils of Wei-Wei Irrigation Scheme are categorised according to the physiography they fall in. Mapping unit FFP which falls in the footslopes of the Cherangani hills is very shallow to shallow and is characterised by the washing away of most of the soil leaving boulders and stones exposed. This mapping unit is unsuitable for irrigation and it is recommended to leave it under protective vegetation.

The soils of the mapping units YF1p, YF2, YF3 and YF4 which fall in the piedmont plains/coalescing fanland are characterised by respectively lighter textured soils on the upper slopes bordering the footslopes and heavier textured soils on the almost level lower slopes. Mapping unit YF3 is highly suitable to moderately suitable since it has no major limitations except for some slopes which are steeper than 2%. Mapping units YF1p and YF2 are moderately suitable due to their low fertility. Mapping unit YF4 is marginally suitable due to its poor workability, poor availability of oxygen and the presence of a slightly to strongly sodic subsoil.

Mapping units AA1 and VA1 which fall in the minor valleys and alluvial fans are marginally suitable due to their very low soil fertility.

In addition to the initial clearing, levelling and canal constructions, drainage measures should be instituted to prevent the rise of ground water table and to leach away the salts which may accumulate with time in all irrigated areas.

As revealed from the soil analysis, almost all the soils are low in available nitrogen. This can be corrected by adding nitrogenous fertilizers. The use of manure which is available cheaply from bomas should be encouraged.

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APPENDIX 1. DETAILED DESCRIPTIONS AND ANALYTICAL DATA OF REPRESENTATIVE PROFILES.

LABORATORY DATA OF PROFILE DESCRIPTION No. 1

Observation no: 75/2 - 658 Mapping unit: FFP Soil classification: eutric CAMBISOL lithic phase

Laboratory no. /82	5580	5581				
Horizon	Ah	Bu				
Depth (cm)	0 - 20	20 - 45				
pH-H_2O (1: 2½ v/v)	6.8	8.2				
pH-KCl "	6.1	7.0				
EC (mmho/cm) "	0.03	0.28				
$CaCO_3$ (%)						
$CaSO_4$ (%)						
C (%)	0.49	0.37				
N (%)						
C/N						
CEC (me/100g), pH 8.2	8.0	4.6				
CEC " " pH 7.0						
Exch. Ca (me/100g)	2.8	1.8				
" Mg "	1.7	1.5				
" K "	0.4	0.2				
" Na "	Tr	Tr				
Sum of cations	4.9	3.5				
Base sat. %, pH 8.2						
" " %, pH 7.0						
ESP at pH 8.2						
Texture (limited pretreatment)						
Gravel % (>2.0mm)						
Sand % (2.0-0.05mm)	76	80				
Silt % (0.05-0.002mm)	10	12				
Clay % (0.002-0mm)	14	8				
Texture class	SL	LS				

Fertility aspects 0 - 30cm Laboratory no. 5635/82

General		Available nutrients			
pH-H_2O (1:2.5 v/v)	6.7	Na/me/100g)	0.06	Mn (me/100g)	0.58
Exch. acidity (me/100g)		K "	0.76	P (ppm)	54
C %	0.92	Ca "	3.8	P-Olsen (ppm)	
N %	0.15	Mg "	3.6		

Remarks:

PROFILE DESCRIPTION NO.1

General site information

Mapping unit	:	FFP
Soil classification	:	eutric CAMBISOL, lithic phase
Observation no./date	:	75/2-658
Parent material	:	gneisses rich in Fe-Mg minerals
Physiography	:	footslopes
Relief, macro	:	gently undulating to undulating, slope 4-7%
Slope at site/position	:	4%/middle
Vegetation and land use	:	bushland of Acacia senegal and Balanites spp, grazing
Erosion - water	:	sheet erosion
wind	:	nil to slight
Rockiness	:	very rocky, covers 10-25% of the surface
Effective soil depth	:	40 cm
Drainage class	:	somewhat excessively drained

Profile description

Ah	0-20 cm	dark reddish brown (5YR 3/4); sandy loam; porous massive structure; friable when moist, slightly sticky, non plastic when wet; many very fine and fine, few medium pores; many very fine and fine, common medium and coarse roots; gradual and wavy transition to:
Bu	20-45 cm	dark reddish brown (5YR 3/3); loamy sand; massive structure; friable when moist, slightly sticky, non plastic when wet; common very fine and fine, few medium pores; common very fine and fine, few medium and coarse roots; smooth and wavy transition to:
R	45 cm+	gneiss.

LABORATORY DATA OF PROFILE DESCRIPTION No. 2

Observation no: 75/2 - 657 Mapping unit: YFIP Soil classification: eutric REGOSOL

Laboratory no. /82	5574	5575	5576	5577	5578	
Horizon	Ah	Cu1	Cu2	Cu3	Cu4	
Depth(cm)	0 - 17	17 - 59	59 - 75	75-114	114-150	
pH-H_2O(1: 2½ v/v)	6.8	6.7	6.6	7.2	7.9	
pH-KCl "	5.0	5.2	5.3	5.9	7.0	
EC(mmho/cm) "	0.04	0.05	0.05	0.05	0.10	
$CaCO_3$(%)						
$CaSO_4$(%)						
C (%)	0.99	0.26	0.34	0.26	0.34	
N (%)						
C/N						
CEC(me/100g), pH 8.2	13.0	11.6	8.0	9.0	8.0	
CEC " " pH 7.0						
Exch.Ca(me/100g)	4.9	3.6	3.0	4.1	4.1	
" Mg "	3.6	3.8	2.6	3.6	4.0	
" K "	0.6	0.2	0.1	0.1	0.2	
" Na "	0.0	0.1	0.1	0.1	0.1	
Sum of cations	9.1	7.7	5.8	7.9	8.4	
Base sat. %, pH 8.2	69	66	72	88	100+	
" " %, pH 7.0						
ESP at pH 8.2						
Texture (limited pretreatment)						
Gravel % (>2.0mm)						
Sand % (2.0-0.05mm)	72	74	76	74	72	
Silt % (0.05-0.002mm)	16	8	10	10	10	
Clay % (0.002-0mm)	12	18	14	16	18	
Texture class	SL	SL	SL	SL	SL	

Fertility aspects 0 - 30 cm Laboratory no. 5634 /82

General		Available nutrients			
pH-H_2O (1: 2.5 v/v)	6.7	Na/me/100g)	0.06	Mn(me/100g)	0.63
Exch. acidity (me/100g)		K "	0.58	P (ppm)	77
C %	0.63	Ca "	3.2	P-Olsen(ppm)	
N %	0.10	Mg "	4.1		

Remarks:

PROFILE DESCRIPTION NO.2

General site information

Mapping unit	:	YF1p
Soil classification	:	eutric REGOSOL
Observation no.	:	75/2-657
Parent material	:	alluvium/colluvium derived from gneisses rich in Fe-Mg minerals
Physiography	:	piedmont plain/coalescing alluvial fans
Relief, macro	:	gently undulating, slopes 2-4%
Slope at site/position	:	2%/upper
Vegetation and land use	:	bushland, grazing
Erosion - water	:	nil
wind	:	only on bare surface
Effective soil depth	:	over 170 cm
Drainage class	:	somewhat excessively drained

Profile description

Ah 0-17 cm reddish brown (5YR 4/3); sandy loam; porous massive structure; slightly hard when dry, friable when moist, slightly sticky and non plastic when wet; many very fine and fine, common very fine, fine, medium and coarse roots; clear and smooth transition to:

Cu1 17-59 cm dark reddish brown (5YR 3/4); sandy loam; porous massive structure; slightly hard when dry, friable when moist, slightly sticky and slightly plastic when wet; many very fine, fine and medium pores; common very fine, fine, medium and coarse roots; abrupt and wavy transition to:

Cu2 59-75 cm reddish brown (5YR 4/3); sandy loam; porous massive structure; hard when dry, friable when moist, slightly sticky and slightly plastic when wet; many very fine and fine pores; common very fine, fine, medium and coarse roots; abrupt and wavy transition to:

Cu3 75-114 cm dark reddish grey (5YR 4/2); sandy loam; massive with tendency to weak, medium to coarse, subangular blocky structure; hard when dry, friable when moist, slightly sticky and slightly plastic when wet; many very fine and fine, common medium pores; common very fine and fine, few medium and coarse roots; gradual and smooth transition to:

Cu4 114-150 cm dark reddish grey (5YR 4/2); sandy loam; massive with tendency to weak medium to coarse subangular blocky structure; hard when dry; friable when moist, slightly sticky and slightly plastic when wet; many very fine and fine, common coarse pores; common very fine and fine, few medium and coarse roots; gradual and wavy transition to:

Cu5 150-170 cm : reddish brown (5YR 4/3); sandy loam; massive with tendency to weak, medium to coarse angular blocky structure; hard when dry, friable when moist, slightly sticky and slightly plastic when wet; many very fine and fine, common medium pores.

LABORATORY DATA OF PROFILE DESCRIPTION No. 3

Observation no: 75/2 - 656 Mapping unit: YF2 Soil classification: eutric CAMBISOL

Laboratory no. / 82	5569	5570	5571	5572	5573	
Horizon						
Depth (cm)	0 - 17	17 - 37	37 - 65	65-100	100-150+	
pH-H_2O (1: 2½ v/v)	7.1	7.3	7.4	7.3	7.5	
pH-KCl "	5.9	6.1	6.3	6.2	6.2	
EC (mmho/cm) "	0.09	0.06	0.07	0.05	0.06	
$CaCO_3$ (%)						
$CaSO_4$ (%)						
C (%)	0.87	0.67	0.40	0.49	0.17	
N (%)						
C/N						
CEC (me/100g), pH 8.2	14.6	16.0	10.0	9.4	12.4	
CEC " " pH 7.0						
Exch. Ca (me/100g)	5.7	5.7	5.3	4.9	5.3	
" Mg "	3.0	3.6	3.9	3.7	4.1	
" K "	0.8	0.3	0.2	0.2	0.2	
" Na "	0.1	0.1	0.1	0.1	0.2	
Sum of cations	9.6	9.7	9.5	8.9	9.8	
Base sat. %, pH 8.2	65	60	94	94	79	
" " %, pH 7.0						
ESP at pH 8.2						
Texture (limited pretreatment)						
Gravel % (>2.0mm)						
Sand % (2.0-0.05mm)	60	60	58	58	54	
Silt % (0.05-0.002mm)	18	10	10	10	12	
Clay % (0.002-0mm)	22	30	32	32	34	
Texture class	SCL	SCL	SCL	SCL	SCL	

Fertility aspects 0 - 30 cm Laboratory no. 5633 / 82

General		Available nutrients			
pH-H_2O (1: 2.5 v/v)		Na/me/100g)	0.06	Mn (me/100g)	0.76
Exch. acidity (me/100g)		K "	0.48	P (ppm)	33
C %	1.03	Ca "	5.2	P-Olsen (ppm)	
N %	1.03	Mg "	3.8		

Remarks:

PROFILE DESCRIPTION NO.3

General site information

Mapping unit	:	YF2
Soil classification	:	eutric CAMBISOL
Observation no.	:	75/2-656
Parent material	:	Alluvium/colluvium derived from gneisses rich in Fe-Mg minerals
Physiography	:	Piedmont plain/coalescing alluvial fans
Relief, macro	:	Flat to very gently undulating, slopes 1-2%
Slope at site/position	:	2%/plain
Vegetation and land use	:	Bushed grassland, cultivated - maize, bananas and cassava
Effective soil depth	:	150 cm
Drainage class	:	Well drained

Profile description

Ap	0-17 cm	dark brown (7.5YR 3/2); sandy clay loam; weak, fine subangular blocky structure; hard when dry, friable when moist, sticky and plastic when wet; many very fine, common medium and coarse pores; many very fine and fine roots; clear and smooth transition to:
AB	17-37 cm	dark reddish brown (5YR 3/3); sandy clay loam; weak, medium to coarse subangular blocky structure; hard when dry, friable when moist, sticky and plastic when wet; many very fine and fine, common medium and coarse pores; common very fine and fine roots; gradual and smooth transition to;
Bu1	37-65 cm	dark reddish brown (5YR 3/4); sandy clay loam; moderate, medium to coarse subangular blocky structure; hard when dry, friable when moist, sticky and plastic when wet; many very fine, fine and medium pores; common very fine and fine roots; diffuse and smooth transition to:
Bu2	65-100 cm	reddish brown (5YR 4/3); sandy clay loam; moderate, fine and medium, angular plus subangular blocky structure; hard when dry, friable when moist, sticky and plastic when wet; common, thick humus cutans; many very fine and fine, common medium pores; common very fine roots; gradual and wavy transition to:
Bu3	100-150^{+} cm	reddish brown (5YR 4/4); sandy clay loam; moderate, fine to medium, angular plus subangular blocky structure; hard when dry, friable when moist, sticky and plastic when wet; few, moderate humus cutans, many very fine, fine and medium pores; few very fine roots.

LABORATORY DATA OF PROFILE DESCRIPTION No. 4

Observation no: 75/2 - 665 Mapping unit: YF3 Soil classification: eutric CAMBISOL

Laboratory no. /82	5611	5612	5613	5614	5615	
Horizon						
Depth (cm)	0 - 20	20 - 54	54 - 95	95-145	145-180	
pH-H_2O (1: 2½ v/v)	7.5	7.4	7.6	7.7	8.0	
pH-KCl "	6.1	5.6	5.5	5.7	5.4	
EC (mmho/cm) "	0.06	0.10	0.14	0.16	0.13	
$CaCO_3$ (%)						
$CaSO_4$ (%)						
C (%)	0.83	0.41	0.35	0.33	0.17	
N (%)						
C/N						
CEC (me/100g), pH 8.2	15.0	18.0	16.0	18.8	18.6	
CEC " " pH 7.0	4.9	5.7	5.7	6.5	7.0	
Exch. Ca (me/100g)	3.4	4.9	5.7	6.0	5.8	
" Mg "	1.3	0.4	0.4	0.5	0.6	
" K "	Tr	0.14	0.2	0.3	0.2	
" Na "	9.6	11.1	12.0	13.3	13.6	
Sum of cations	64	62	75	70	73	
Base sat. %, pH 8.2						
" " %, pH 7.0						
ESP at pH 8.2						
Texture (limited pretreatment)						
Gravel % (>2.0mm)						
Sand % (2.0-0.05mm)	56	46	44	44	42	
Silt % (0.05-0.002mm)	14	10	10	10	12	
Clay % (0.002-0mm)	30	44	46	46	46	
Texture class	SCL	SC	C	C	C	

Fertility aspects	0 - 30 cm			Laboratory no. 5641 /82	
General		Available nutrients			
pH-H_2O (1: 2.5v/v)	6.9	Na/me/100g)	0.06	Mn (me/100g)	0.52
Exch. acidity (me/100g)		K "	1.08	P (ppm)	46
C %	0.90	Ca "	3.8	P-Olsen (ppm)	
N %	0.12	Mg "	3.8		

Remarks:

PROFILE DESCRIPTION NO.4

General site information

Mapping unit	:	YF3
Soil classification	:	eutric CAMBISOL
Observation no.	:	75/2-665
Parent material	:	alluvium/colluvium derived from gneisses rich in Fe-Mg minerals
Physiography	:	piedmont plain/coalescing fans
Relief, macro	:	flat to very gnently undulating, slopes 0-2%
Slope at site/position	:	2%/level
Vegetation and land use	:	dense bushland, grazing
Erosion - water	:	nil; in places gully development was observed
Effective soil depth	:	over 160 cm
Drainage class	:	well drained

Profile description

Au1 0-16 cm dark brown (7.5YR 3/2); sandy clay loam; porous massive with tendency to weak, fine to medium subangular blocky structure; very friable when moist, sticky and plastic when wet; many very fine and fine, common medium, few coarse pores; many very fine, fine and medium, common coarse roots; gradual and wavy transition to:

Au2 16-35 cm dark brown (7.5YR 3/2); sandy clay loam; weak, medium, subangular blocky structure; friable when moist, sticky and plastic when wet; many very fine and fine, common medium, few coarse pores; many very fine, fine and medium, common coarse roots; clear and wavy transition to:

Bu 35-57 cm dark reddish brown (5YR 3/3); sandy loam; weak, coarse, subangular blocky structure; friable when moist, sticky and plastic when wet; many very fine and fine, common medium, few coarse pores; many very fine, fine and medium, common coarse roots; clear and smooth transition to:

Bu2 57-95 cm reddish brown (5YR 4/3); sandy clay loam; weak, medium to coarse, angular blocky structure; hard when dry, friable when moist, sticky and plastic when wet; many very fine and fine, common medium, few coarse pores; common very fine and fine, few medium and coarse roots; gradual and wavy transition to:

BC 95-118 cm dark reddish brown (5YR 3/2); sandy clay loam; moderate, fine to coarse angular blocky structure; hard when dry, friable when moist, sticky and plastic when wet; many very fine and fine, common medium, few coarse pores; common very fine, few fine and medium roots; clear and wavy transition to:

C_1 118-160 cm dark reddish grey (10YR 4/2); sandy clay loam; moderate, very fine to medium, angular blocky structure; hard when dry, friable when moist, sticky and plastic when wet; many very fine and fine, common medium, few coarse pores; common very fine, few fine and medium roots.

LABORATORY DATA OF PROFILE DESCRIPTION No. 5

Observation no: 75/2 - 661 Mapping unit: YF4 Soil classification: vertic CAMBISOL, sodic phase

Laboratory no. /82	5594	5595	5596	5597	5598	
Horizon						
Depth (cm)	0 - 24	24 - 49	49 - 85	85 - 130	130 -	
pH-H_2O (1: 2½ v/v)	8.1	8.3	9.1	9.5	9.8	
pH-KCl "	7.8	6.6	6.6	7.2	7.5	
EC (mmho/cm) "	0.21	0.35	0.29	0.5	0.5	
$CaCO_3$ (%)						
$CaSO_4$ (%)						
C (%)	1.31	0.50	0.71	0.20	0.29	
N (%)						
C/N						
CEC (me/100g), pH 8.2	24.6	28.5	24.6	21.8	21.4	
CEC " " pH 7.0						
Exch. Ca (me/100g)	9.2	10.7	11.5	13.8	12.1	
" Mg "	7.0	6.8	10.4	13.1	12.1	
" K "	2.2	0.6	0.7	0.6	0.6	
" Na "	0.2	0.4	1.7	3.9	5.1	
Sum of cations	18.6	18.5	24.3	31.4	30.6	
Base sat. %, pH 8.2	75	65	98	100+	100+	
" " %, pH 7.0	-	-	6.7	17.8	24.0	
ESP at pH 8.2						

Texture (limited pretreatment)						
Gravel % (>2.0mm)						
Sand % (2.0-0.05mm)	40	36	32	32	32	
Silt % (0.05-0.002mm)	18	16	18	18	18	
Clay % (0.002-0mm)	42	48	50	50	50	
Texture class	C	C	C	C	C	

Fertility aspects 0 - 30 cm Laboratory no. 5638 /82

General		Available nutrients			
pH-H_2O (1: 2.5 v/v)	6.8	Na/me/100g)	0.14	Mn (me/100g)	0.54
Exch. acidity (me/100g)		K "	0.92	P (ppm)	58
C %	0.40	Ca "	8.1	P-Olsen (ppm)	
N %	0.13	Mg "	6.0		

Remarks:

PROFILE DESCRIPTION NO.5

General site information

Mapping unit	:	YF4
Soil classification	:	vertic CAMBISOL, sodic phase
Observation no.	:	75/2-661
Parent material	:	alluvium/colluvium derived from gneisses rich in Fe-Mg minerals
Physiography	:	piedmont plain/coalescing alluvial fans
Relief, macro	:	flat to very gently undulating, slopes 1-2%
Slope at site/position	:	2%/plain
Vegetation and land use	:	bushland, formerly cultivated - sorghum
Effective soil depth	:	160 cm
Drainage class	:	moderately well drained

Profile description

A	0-24 cm	very dark greyish brown (10YR 3/2); clay; moderate, fine to medium, subangular blocky structure; hard when dry, friable when moist, very sticky and very plastic when wet; many very fine and fine, few medium pores; many very fine and fine, common medium and coarse roots; clear and wavy transition to:
Bu1	24-49 cm	very dark greyish brown (10YR 3/2); clay; moderate to strong, coarse to very coarse columnar structure; hard when dry, friable when moist, very sticky and very plastic when wet; many thin slickensides; common very fine and fine, few medium pores; many very fine and fine, common medium and coarse roots; gradual and wavy transition to:
Bu2	49-85 cm	dark brown (10YR 3/3); clay, strong, coarse angular blocky structure; very hard when dry, firm when moist, very sticky and very plastic when wet; 2% calcium carbonate concretions; many, moderate slickensides; few very fine and fine pores; common very fine and fine, few medium roots; diffuse and smooth transition to:
Bu3	85-130 cm	dark greyish brown (10YR 4/2); clay; strong, medium to coarse angular blocky structure; very hard when dry, very firm when moist, very sticky and very plastic when wet; 4% $CaCO_3$ concretions; many thick slickensides; few very fine, fine and medium pores; few very fine and fine roots; gradual and smooth transition to:
Bu4	130-168 cm	dark yellowish brown (10YR 4/4); clay; moderate, coarse to very coarse, subangular blocky structure; very hard when dry, very firm when moist, very sticky and very plastic when wet; 5% $CaCO_3$ concretions; common, moderate slickensides; few very fine and fine pores; few very fine and fine roots.

LABORATORY DATA OF PROFILE DESCRIPTION No. 6

Observation no: 75/2 - 660 Mapping unit: AA1 Soil classification: eutric FLUVISOL

Laboratory no. /82	5587	5588	5589	5590	5591	
Horizon						
Depth(cm)	0 - 15	15 - 48	48 - 75	75 - 113	113-127	
pH-H_2O(1: 2.5v/v)	8.3	8.3	8.0	8.0	8.7	
pH-KCl "	7.2	7.0	6.8	7.2	7.8	
EC(mmho/cm) "	0.07	0.02	0.1	0.09	0.2	
$CaCO_3$(%)						
$CaSO_4$(%)						
C (%)	0.74	0.59	1.20	0.26	0.56	
N (%)						
C/N						
CEC(me/100g), pH 8.2	6.8	1.8	12.4	4.6	9.8	
CEC " " pH 7.0						
Exch.Ca(me/100g)	2.8	0.6	6.1	2.0	8.4	
" Mg "	0.8	0.2	2.9	0.4	2.6	
" K "	0.4	0.1	0.3	0.1	0.3	
" Na "	Tr	Tr	0.2	0.3	0.2	
Sum of cations	4.0	0.9	9.5	2.8	11.5	
Base sat. %, pH 8.2	58	47(1)	76	58	100+	
" " %, pH 7.0						
ESP at pH 8.2			2	7	2	

Texture (limited pretreatment)						
Gravel % (>2.0mm)						
Sand % (2.0-0.05mm)	82	92	72	92 90	72	
Silt % (0.05-0.002mm)	12	6	18	4 8	18	
Clay % (0.002-0mm)	6	2	10	4 2	10	
Texture class	LS	S	SL	S S	SL	

Fertility aspects 0 - 30 cm Laboratory no. 5637 /82

General		Available nutrients			
pH-H_2O (1: 2.5 v/v)	7.2	Na/me/100g)	0.04	Mn(me/100g)	0.38
Exch. acidity (me/100g)		K "	0.52	P (ppm)	250
C %	0.80	Ca "	4.4	P-Olsen(ppm)	34
N %	0.10	Mg "	2.8		

Remarks:

1) Probably the base saturation is too low.

PROFILE DESCRIPTION NO.(

General site information

Mapping unit	:	AA1
Soil classification	:	eutric FLUVISOL
Observation no.	:	75/2-660
Parent material	:	recent and sub-recent alluvial material
Physiography	:	alluvial river valley
Relief, macro	:	flat to very gently undulating, slopes 0-2%
Slope at site/position	:	2%/level
Vegetation and land use	:	bushland, grazing, in places cultivation
Erosion - water	:	in places gullies
Flooding	:	occasionally
Effective soil depth	:	over 180 cm
Drainage class	:	somewhat excessively drained

Profile description

A	0-15 cm	very dark greyish brown (10YR 3/2); loamy sand; porous massive structure; very friable when moist, slightly sticky and non plastic; many very fine and fine, few medium pores; many very fine and fine, common medium and coarse roots; clear and wavy transition to:
Cu1	15-48 cm	dark brown (10YR 3/3); sand; porous massive to single grain structure; loose when moist, non sticky and non plastic when wet; many very fine and fine, few medium pores; many very fine and fine, common medium and coarse roots; abrupt and smooth transition to:
Cu2	48-75 cm	black (10YR 2.5/1); sandy loam; porous massive structure; friable when moist, slightly sticky and slightly plastic when wet; many very fine and fine, few medium and coarse roots; abrupt and wavy transition to:
Cu3	75-113 cm	dark brown (10YR 3/3); sand; massive to single grain structure; loose when moist, non sticky and non plastic when wet; many very fine and fine, few medium pores; common very fine and fine, few medium and coarse roots; abrupt and smooth transition to:
Cu4	113-127 cm	very dark grey (10YR 3/1); sandy loam; porous massive with tendency to angular blocky structure; friable when moist, slightly sticky and slightly plastic when wet; calcareous; many very fine and fine, common medium pores; common very fine and fine, few medium roots; abrupt and wavy transition to:
Cu5	127-173 cm	dark yellowish brown (10YR 4/4); loamy sand; porous massive structure; loose when moist, non sticky and non plastic when wet; many very fine and fine, few medium pores; common very fine and fine, few medium roots; abrupt and smooth transition to:
Cu6	137-210 cm+	very dark greyish brown (10YR 3/2); sandy loam; porous massive with tendency to angular blocky structure; friable when moist, slightly sticky and slightly plastic when wet; many very fine and fine few medium pores; common very fine and fine, few medium roots.

LABORATORY DATA OF PROFILE DESCRIPTION No. 7

Observation no: 75/2 - 663 Mapping unit: VA1 Soil classification:

Laboratory no. /82	5604	5605	5606	5607	5608	
Horizon						
Depth (cm)	0 - 20	20 - 53	53 - 69	69 - 100	100 - 126	
pH-H_2O (1: 2½ v/v)	7.5	8.1	8.1	7.9	7.8	
pH-KCl "	5.8	6.0	6.2	6.1	6.0	
EC (mmho/cm) "	0.06	0.05	0.04	0.04	0.03	
$CaCO_3$ (%)						
$CaSO_4$ (%)						
C (%)	1.33	0.50	0.33	0.53	0.20	
N (%)						
C/N						
CEC (me/100g), pH 8.2	16.0	7.4	7.4	6.8	5.0	
CEC " " pH 7.0						
Exch. Ca (me/100g)	5.7	3.6	2.8	3.6	1.1	
" Mg "	2.7	1.6	1.4	1.3	0.6	
" K "	0.6	0.3	0.3	0.2	0.1	
" Na "	Tr	Tr	Tr	Tr	Tr	
Sum of cations	9.0	5.5	4.5	5.1	1.8	
Base sat. %, pH 8.2	55	70	59	74	35	
" " %, pH 7.0						
ESP at pH 8.2						
Texture (limited pretreatment)						
Gravel % (>2.0mm)						
Sand % (2.0-0.05mm)	58	72	74	76	90	
Silt % (0.05-0.002mm)	24	12	12	10	6	
Clay % (0.002-0mm)	18	16	14	14	4	
Texture class	SL	SL	SL	SL	S	

Fertility aspects 0 - 30 cm Laboratory no. 5640 /82

General		Available nutrients			
pH-H_2O (1: 2.5v/v)	6.9	Na/me/100g)	0.08	Mn (me/100g)	0.46
Exch. acidity (me/100g)		K "	0.44	P (ppm)	52
C %	0.84	Ca "	4.2	P-Olsen (ppm)	
N %	0.10	Mg "	2.8		

Remarks:

PROFILE DESCRIPTION NO.7

General site information

Mapping unit	:	VA1
Soil classification	:	eutric FLUVISOL
Observation no.	:	75/2-663
Parent material	:	subrecent and recent alluvial material
Physiography	:	minor river valleys and recent alluvial fans
Relief, macro	:	flat to very gently undulating, slopes 0-2%
Slope at site/position	:	2%/level
Vegetation and land use	:	bushland, cultivation - cassava, bananas and sugarcane
Effective soil depth	:	over 180 cm
Drainage class	:	well drained to moderately well drained

Profile description

Ap 0-20 cm very dark grey (10YR 3/1); sandy loam; moderate, fine subangular blocky structure; slightly hard when dry, very friable when moist, sticky and plastic when wet; many very fine and fine, few medium pores; many fine and medium, few coarse roots; gradual and smooth transition to:

AC 20-53 cm dark brown (10YR 3/3); sandy loam; weak, medium, subangular blocky structure; slightly hard when dry, very friable when moist, sticky and plastic when wet; many very fine and fine, common medium pores; many fine and medium, few coarse roots; clear and wavy transition to:

Cu1 53-69 cm brown to dark brown (10YR 4/3); sandy loam; porous massive structure; slightly hard when dry, very friable when moist, slightly sticky and slightly plastic when wet; many very fine and fine pores; common fine, few medium roots; clear and wavy transition to:

Cu2 69-100 cm dark brown (10YR 3/3); sandy loam; weak, medium to coarse, angular and subangular blocky structure; slightly hard when dry, very friable when moist, slightly sticky and slightly plastic when wet; many very fine and fine pores; common fine, few medium roots; abrupt and wavy transition to:

Cu3 100-126 cm dark yellowish brown (10YR 4/4); sand; porous massive structure; soft when dry, loose when moist, non sticky and non plastic when wet; many very fine and fine pores; common fine, few medium roots;

Cu4 126-157 cm dark brown (10YR 4/3); sandy clay loam/sandy loam; moderate, medium to coarse subangular and angular blocky structure; slightly hard when dry, very friable when moist, slightly sticky and slightly plastic when wet; many very fine and fine, common medium pores; few fine roots; abrupt and wavy transition to:

Cu5 157-180 cm dark yellowish brown (10YR 4/4); loamy sand; porous massive structure; soft when dry, loose when moist, non sticky and non plastic when wet; many very fine and fine pores.

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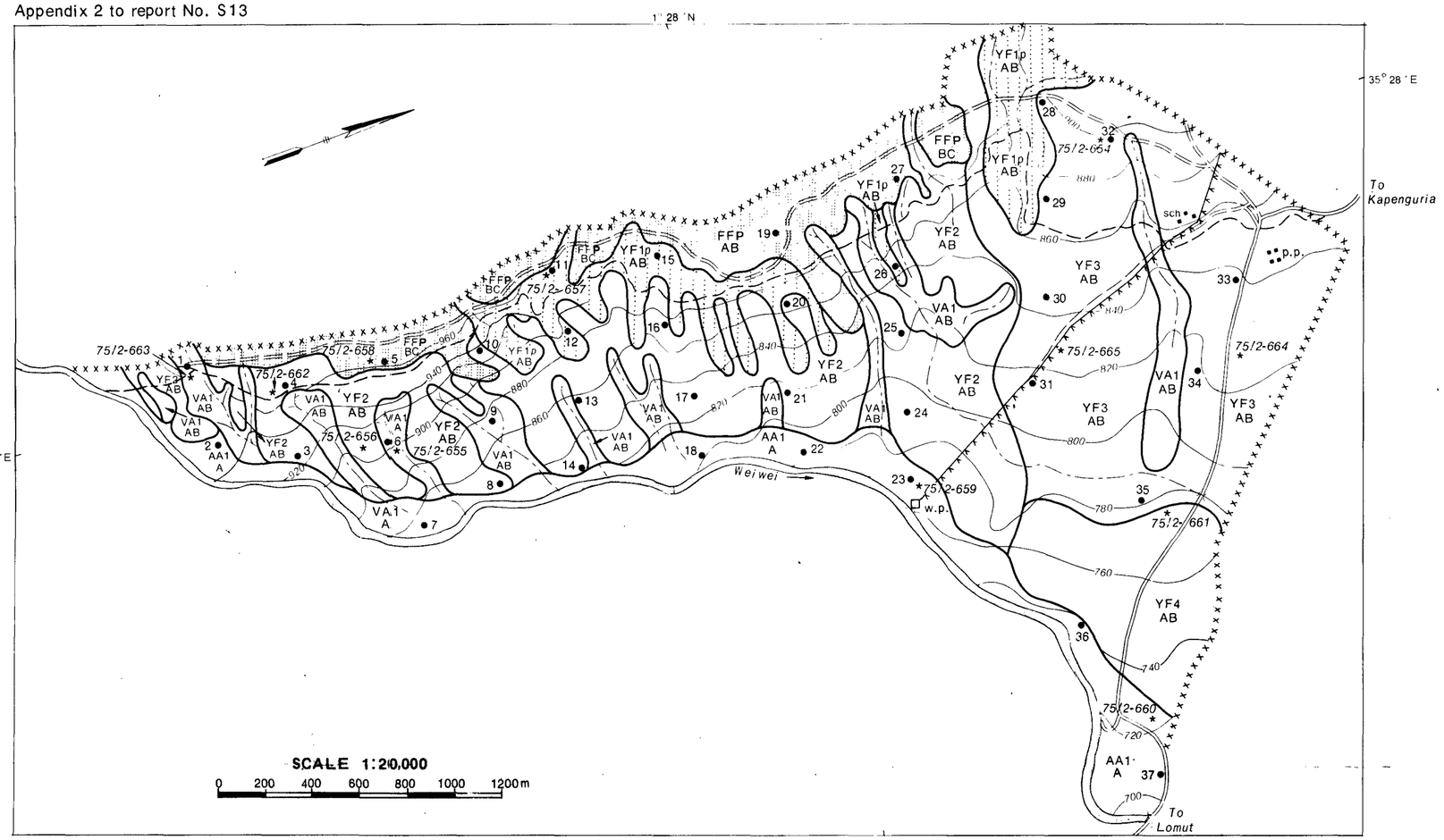
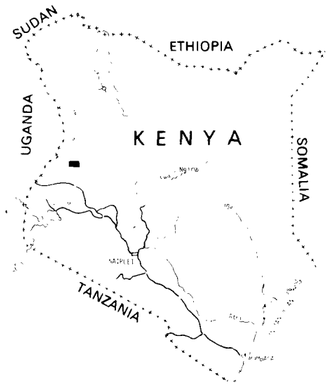
SEMI-DETAILED SOIL MAP OF THE PROPOSED WEI-WEI IRRIGATION SCHEME

Appendix 2 to report No. S13





▬ Location of surveyed area

KEY

- soil mapping code
- YF1p — depth class code
- AB — slope class code
- soil boundary
- ●7 — augerhole observation, with reference number
- ★ 75/2-659 — profile pit observation, with reference number
- 1cm2 — 4 ha
- road
- track
- river
- bridge, culvert
- other drainage way
- canal
- pipe line
- ▪▪ sch. — school
- ▪▪ p.p. — police post
- □ w.p — water pump
- survey area boundary
- 780 / 760 — contours, V.I. 20ft.

LEGEND

F FOOTSLOPES (at the foot of the mountain, slopes 3–6%)

FF Soils developed on gneisses rich in ferromagnesian minerals

- FFP — somewhat excessively drained, very shallow to shallow, dark reddish brown, friable, gravelly sandy loam, over rock (eutric CAMBISOLS, lithic and stony phase and LITHOSOLS)

Y PIEDMONT PLAIN AND COALESCING ALLUVIAL FAN-LAND (slopes 1–3%)

YF Soils developed on alluvium and colluvium, derived from gneisses rich in ferromagnesian minerals

- YF1p — somewhat excessively drained, deep to very deep, reddish brown to dark reddish grey, friable sandy loam, with a stoneline between 60cm and 70cm (eutric REGOSOLS)
- YF2 — well drained, very deep, reddish brown to dark brown, friable sandy clay loam (eutric CAMBISOLS)
- YF3 — well drained, very deep, dark reddish brown to dark reddish grey, very friable to friable, sandy clay loam to clay (eutric CAMBISOLS)
- YF4 — moderately well drained, very deep, dark brown to very dark greyish brown, friable to very firm, calcareous, moderately sodic clay (vertic CAMBISOLS, sodic phase)

A ALLUVIAL RIVER VALLEY (slopes less than 2%)

AA Soils developed on recent and sub-recent alluvial deposits

- AA1 — some what excessively drained, extremely deep, dark brown to black, stratified, friable, moderately calcareous, sand to sandy loam (eutric FLUVISOLS)

V MINOR VALLEYS AND ALLUVIAL FANS (slopes 1-3%)

VA Soils developed on recent and sub-recent alluvial deposits

- VA1 — well drained to moderately well drained, very deep, dark brown to very dark grey, stratified, very friable to friable, sandy loam (eutric FLUVISOLS)

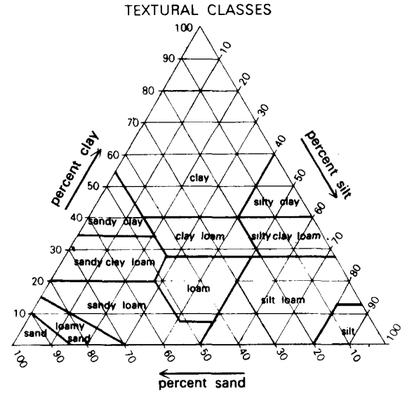
KEY TO SLOPE CLASSES

slope %	slope class code+	name of the macrorelief
0-2	A	flat to very gently undulating
2-5	B	gently undulating
5-8	C	undulating

KEY TO DEPTH CLASSES

thickness soil in cm	code over rock	name
0- 25	P	very shallow
25-50		shallow
50-80		moderately deep
80-120	p	deep
more than 120		very deep

TEXTURAL CLASSES



Base map prepared from the Farm Management Unit maps Nakuru, Scale 1:5,000

SOIL SURVEY AND MAP PREPARATION (1984,1985)

- soil survey — H.C.K.Kinyanjui J.K.Kanake, B.G.Mwangi and D.N.Gathui
- map compilation — J.K.Kanake, and H.C.K.Kinyanjui
- map correlation — J.R.Rachilo and P.T.Gicheru
- cartography — L.H.Mikisi

Drawing No. 85021