NZOIA PILOT IRRIGATION SCHEME

Bunyala

U.N.S.F./F.A.O.

(YALA SWAMP RECLAMATION)

SOIL SURVEY UNIT
KENYA

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C O N T E N T S

INTRODUCTION.

The project area lies south of the Busonga - Lugari, dry weather road, about 6 miles from the mouth of the Nzoia river, on the north side of the Yala Swamp at about 3750 feet. This comprises 750 acres, the soils of which had previously been mapped at a reconnaissance level (1:50,000) by Sir A. Gibb (1956).

This survey was commissioned by the Food & Agriculture Organization to initiate a Pilot Scheme of 600 acres with a view to a more extensive future development along the Nzoia. This scheme would be served by a pumping installation to be sited on the bank of the river, near to the Busonga ferry.

This report outlines the major soil properties of importance for irrigation agriculture and indicates methods of soil improvement.

It is assumed that the probable crops on the scheme will be cotton, rice and kenaf. Of these crops rice is well suited to pot experiment in the green house and the results contained in this report may be supplemented, if required, by nutrition experiments on Paddy rice at the National Agricultural Laboratory.

The map accompanying the report was drawn from uncontrolled aerial photographs at an approximate scale of 1:3100.

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1. Physiognomy.

The soils are alluvial and form part of the floodplain in the lower reaches of the Nzoia. The river has meandered across its floodplain and deposited material of varying textural composition under seasonal flood conditions. The state of the area indicates the occurrence of two or more fluctuations of level within recent times by cycles of rejuvenation and aggradation. The maximum phase of rejuvenation is represented by gravels found south of this area, at depths of over 100 feet below the present surface of the Yala Swamp.

The relief is gently undulating due to the occurrence of river channels and levees of varying age. Drainage impedence is such that a local depression of only few inches is subject to seasonal water logging. The older levees (Map Units 3, 5 and 6) are raised above the general land surface and are favoured for "bomas" and stock sheltering. The relatively recent levees (Map Units 7 and 8) are very local and are generally associated with contemporary stream meanders.

According to the Vegetation Map (1:250,000) the pilot scheme lies within the zone of Acacia sieberiana and Acacia polyacantha with remnant thickets of Euphorbia etc. In fact over the past few years the area has been extensively invaded by Acacia seyal fistula, so that this bush now constitutes a single dominant (especially on Map Unit 1, 2 and 9). A few remnant thickets are found on lighter textured soil. These essentially consist of Azima tetracantha, Capparis sp., Cassia bicapsularis, Cissus rotundifolia, Maerua triphylla johannis, Maytenus senegalensis and Phyllanthus reticulatus. Acacia sieberiana commonly occurs on the edge of very poorly drained sites (Map Units 9 & 11). Acacia polyacantha forms very local thickets on Map Unit 9. Common associates of poorly drained sites (Map Units 1 and 9) include Mimosa pigra and Phyllanthus reticulatus. A preliminary invariable invader of abandoned cultivations is Sphaeranthus gomphrenoides, which locally forms a dense surface cover. The reason for the widespread abandonment of local cultivation is primarily a result of rash Government promises of an irrigation scheme in 1960, which never came to fruition.

Of the whole area of alluvium about 90% comprises poorly drained very dark brown to very dark grey Clays with glei subsoil. The somewhat level land (Map Unit 1) is seasonally water logged but not ponded; a measure of drainage was provided by the locals taking the form of shallow 6 inch drains. The slightly depressed areas (Map Unit 9) are associated with humpy formation. The ponded land stream basins (Map Unit 11) are dominated by rushes (Cyperaceae).

Much of the area is subject to flooding by overflow from the Nzoia and the streams which debouch onto the plain; during the 1961 floods the entire region was totally inundated.

The permanent ground water table is certainly higher than 35 feet and may occur within 6 feet of the soil surface close to meanders, and probably associated with local sandy levee deposits.

A deep channel (canal or drain ?) circumvents the South, West and part of the North of the project area and is now in a deteriorating state. Such an ad hoc development outside the overall scheme planning is to be deplored, but it is hoped that some use can be made of part of this system as a main drain.

2. SOIL DESCRIPTIONS AND ANALYTICAL RESULTS.

(a) Methodology: Certain characteristic soils ... were sampled according to evident morphological horizon distinctions.

pH and conductivity assessment followed methods of the U.S. Dept. of Agriculture ("Diagnosis and improvement of saline and alkaline soils" Agric. Handb. 60, U.S. Govt. Printing Office 1954). C.E.C., exchangeable cations and available nutrients were estimated by methods based on those of Mehlich A, Pinkerton A, Robertson W and Kempton R ("Mass Analysis Methods for Soil Fertility Evaluation" Memo. of the Scott Agricultural Lab. 1962). Mechanical analysis was performed by hydrometer (Buoyoucos G.J. 1927 "The Hydrometer as a new and rapid method for determining the colloidal content of soil". Soil Sci. 23, p. 319-31). Clay samples (<2μ) were prepared according to Theisen A.A. and Howard M.E., ("A paste method for preparation of slides for clay mineral identification by X-ray diffraction" 1962 Soil Sci. Soc. Amer. Proc. 25, p. 90-91) and were analysed with a direct recording X-ray diffractometer. For the quantitative analysis of clay minerals, the method of Theisen A.A. and Bellis E. ("Quantitative analysis of clay mineral mixtures by X-ray diffraction" 1964. Nature 204 p. 1228-1230) was followed. Differential Thermal Analysis (D.T.A.) was also carried out on Magnesium-saturated clays.

(b) Abbreviations: The following abbreviation are used in the text:

O.M.	Organic Matter.
MONT.	Montmorillonite.
C.E.C.	Cation Exchange Capacity.
Ca.	Calcium.
Mg.	Magnesium.
K.	Potassium.
Na.	Sodium.
E.S.P.	Exchangeable Sodium Percentage.
pH	Log. of the Reciprocal of the concentration of the hydrogen ion.
EC_e. Sat. ext.	Electrical Conductivity of the saturation extract.
p.p.m.	Parts per million.
m.e.%	Milli. equivalents per cent.
Hp	Exchange acidity arising from negatively charged permanent cation exchange capacity sites.
P.	Phosphorus.

(c) Soil types, Profile Description and data.

1. Higher lying levee soils.

Soils pertaining to Map Units 5, 6 and 7 are coarsely textured and contain alluvium of varying age.

Map Unit 5

This comprises long narrow levees on the North western side of the project area. The area is heavily grazed; it has only 50% grass cover. The soils are calcareous very dark greyish brown sandy clay loam overlying saline and alkali greyish brown light to medium clay with some very fine gravel. The subsoil is gleied and shows abundant distinct dark blotching at 2 feet and below. The pH of the saturated extract varies from 7.7 to 9.0.

Due to prevailing alkalinity and salinity this soil is unsuitable for irrigation.

Map Unit 6

These are rather acid (pH 4.7 to 5.6) sandy levees which are remarkably well endowed with calcium and in which exchangeable sodium is more or less absent. The soils consist of non calcareous sandy clay loams with about 1.5% organic matter overlying dark greyish brown medium clay subsoils. Deposits of pale coarse sandy material form discrete layers within the solum. Below 4 feet gleiing occurs with distinct rust mottles and streaks. Prominent lime spots may appear in the sub surface layers but calcium concretions are absent.

The soil would prove eminently suitable for the irrigation of a wide range of crops. Their topographic position prevents the use of furrows and sprinklers would not be justified on such a limited acreage. It is suggested that these soils be reserved for rain-grown food crops. They are presently deficient in nitrogen, phosphate and potash.

Map Unit 7

This comprises very local and relatively recent levees, associated with stream meanders; with an undulating topography and a locally high water table of up to 5 feet below the surface. The soils are brown sandy loam to sandy clay underlain by dark greyish brown medium to heavy clay subsoil. Deposits of pale and mottled sandy material form discrete layers within the solum.

These areas will require levelling and will consequently expose poorly drained and infertile clay subsoils. The overlying sandy materials will be spread over considerable areas of adjoining Units 1 and 9 soils, thereby, somewhat alleviating their heaviness of texture. Owing to the very local nature of the Map Unit 7 soils, special treatment post-levelling would be both impracticable and uneconomic. On levelling these soils could be treated as adjoining Map Units 1 or 9 soils.

2. Slightly poorly drained Slope Soils

Map Unit 3.

This unit comprises a very small area of dark brown light to medium clay throughout the profile, lying on the North Eastern edge of the project area. The structures are crumby and weakly developed. The subsoil generally shows free lime below 2 feet and mottling below 3 feet, unaccompanied by glei.

The pH ranges from 6.1 to 7.6 and the surface has an average organic matter content of about 3%. So far as fertility status is concerned, it is deficient in nitrogen, phosphate and potash. The suggestions and recommendation for Map Unit 6 soils are ideally applicable to this area (see Map Unit 6, above).

Map Unit 4.

This unit represents termite mounds, which may be locally common on all but the heaviest and ill drained areas. These termitaria can achieve considerable mass appearing as steep hillocks up to 8 feet in height. The smaller termitaria are not mapped.

The mounds are calcareous dark greyish brown, rather alkali (pH 7.0 - 7.8) light to medium clays. There is an abundance of calcium concretions though decreasing with depth. Gypsum crystals are also present but at relatively low levels. The associated phosphate is exceptionally high. Below 30 inches there is slight accumulation of salt.

It is suggested that these mounds be levelled and the deposits spread over the adjoining areas.

Map Unit 8.

This comprises meander levees with mixed alluvium. These areas are undulating and the soils have a light to medium clay surface horizon and somewhat heavier subsoil. Horizons of coarser sandy material sometimes with fine gravel occur within the 4 feet profile.

The pH ranges from 6 to 6.5; the solum is without lime, gypsum or salt deposition.

Because of the local nature and limited acreage of this Map Unit, it is suggested that it should be levelled and the deposits spread over the adjoining soils.

Map Unit 2.

PARAQUIC HAPLORTHENT

This comprises very dark brown light to medium clays with strongly developed structures but without cracking in the dry season. The surface horizon has moderate permeability and is somewhat lighter than the subsoil which may however demonstrate accretions of sand and very fine gravel. Gleiing and mottling occurs at 20 inches or below. Deposition of Gypsum and or calcium carbonate may occur at depth.

These non-saline, non-alkali soils should be suitable for a wide range of crops, given improved drainage and fertilizer (N, P and possibly K).

Table A. indicates mean values for the more important soil chemical properties, calculated from all the data of these (Map Unit 2) soils. Included in the table are also the range of values (from the lowest to the maximum). Topsoil is defined as the surface horizon and subsoil is that horizon approximately most nearly to a hypothetical horizon of 24 to 36 inches in depth.

Soil profile No. 53, has been chosen as representative of Map Unit 2, Paraquic Haplorthents. (Table 1)

PROFILE DESCRIPTION

Pit No. 53.

Location : Close to the North Western edge of the Project Area.

Relief : Plane - Microrelief: Slightly Undulating.

Drainage : Poor. Slow permeability.

Vegetation Cover : 100% - Grassland. Rooting to more than 57 inches.

Profile Depth : 57 inches.

0-10". Very dark brown (10YR 2/2) friable medium clay, with a fine moderately developed crumb and sub-angular blocky structure. Abundant fine roots. Lower boundary clear and undulating.

10-30". Very dark brown (10YR 2/2) very hard medium clay, with coarse very weak prisms, and fine to coarse moderately developed blocky microstructures. Some vertical cracking to 1" across. Faint light blotches: abundant distinct fine rust mottles: common nest blotches. Predominant blotches are dark brown, brown and

TABLE A

MAP UNIT 2

PARAQUIC HAPLORTHENT.

	TOPSOIL		SUBSOIL	
	Mean	Range	Mean	Range
% Silt	24	16 - 30	15	10 - 18
% Clay	62	52 - 70	65	57 - 76
% O.M.	3.0	2.4 - 3.5		
pH (H_2O)	5.4	5.2 - 5.6	5.4	4.8 - 6.5
pH Sat.ext.	7.2	7.0 - 7.3	7.0	6.7 - 7.5
Hp	0.6	0.3 - 0.8	0.4	0 - 0.8
P. p.p.m.	18	12 - 23	18	11 - 22
K m.e.%	0.30		0.02	
Ca m.e.%	8.8	8.0 - 10.4	7.5	5.7 - 8.8
Mg m.e.%	5.7	5.1 - 6.3	5.2	4.6 - 6.0
C.E.C.	34.2	28.4 - 41.2	33.4	30.2 - 39.2
E.S.P.8	4.2	1.9 - 8.6	7.6	4.9 - 13.6
E.Ce.	0.6	0.4 - 0.8	0.8	0.1 - 2.5
% $CaCO_3$	0.7	0.4 - 1.0	0.7	0.5 - 1.0

dark yellowish brown (10YR 4/4 ; 7.5YR 4/4). Very few very fine roots. Gradual lower boundary.

30-41". Dark grey (10YR 4/1), somewhat gleied very hard, light clay, with fine and medium strong blocky structure, and some evidence for weak slicken-side develop ment. Common medium yellowish brown (10YR 5/4) mottles: prominent coarse very dark grey (10YR 3/1) blotches. Very few very fine roots. Gradual lower boundary,

41" +. Greyish brown (10YR 5/2), somewhat gleied, hard, sandy clay loam, with fine and medium moderately developed blocky structure. Strong brown (7.5YR 5/8) and dark yellowish brown (10YR 4/4) mottles. Fine and medium black (10YR 2/1) and very dark grey (10YR 3/1) blotches, with prominent black streaks following the course of root channels. Common very fine concretions of calcium carbonate with a few coarse concretions. Slight matrix reaction with 10% HCl. Rare roots.

TABLE 1.

PIT NO. 53

Map Unit 2

PARAQUIC HAPLORTHENT.

Depth	0-10"	10-30"	30-41"	41" +
Sand %	16	20	40	56
Silt %	16	14	12	12
Clay %	68	66	48	32
pH (H_2O)	5.3	5.3	7.7	8.0
pH (Sat.ext.)	7.2	7.3	7.8	8.3
Hp	0.6	0.4	0	0
O.M. %	3.0	-	-	-
Available Nutrients				
K	0.05	0.02	0.04	0.04
Ca	10.4	10.0	7.6	8.6
Mg	6.0	5.0	7.0	6.2
P (p.p.m.)	18	18	25	24
% $CaCo_3$	0.4	0.4	0.6	1.1
C.E.C.	41.2	41.6	28.8	21.2
Exch. Bases				
Ca	14.25	16.70	15.00	12.70
Mg	6.75	7.34	7.34	5.25
K	1.70	1.40	1.20	1.20
Na	0.70	1.50	1.39	0.80
EC_e Sat. ext.	0.35	0.34	0.90	0.43
E.S.P.	1.9	3.6	4.8	3.8

3. Very poorly drained level lands.

Map Unit 1.

AQUIC HAPLORTHENTS.

These have very dark brown surface layers of very slowly permeable heavy clay.

Sub-surface layers are very dark grey to dark greyish brown and consist of heavy clay glei, with negligible permeability. The glei includes distinct mottling and blotching. A typical profile may show gypsum precipitated as visible crystals or needles generally between 2 to 5 feet below the soil surface. Concretions of calcium carbonate may occur at depth; if present, they are invariably deeper than the layers of gypsum deposition. Structures are very strongly developed with evidence for cracking in the dry season. Lenticular subsoil structures are also observed with slicken-sides and clay faces.

The pH ranges from 5.2 to 7.0 increasing with depth. High concentrations of salt and alkali are locally encountered in the subsoil below 2 feet. Low concentrations of free lime may occur but rarely.

These soils will certainly require additions of nitrogenous and phosphatic fertilizer: crops may also respond to potash. With increased fertility and the maintenance of the organic content, reasonable yields of rice can be confidently predicted. Soil textures are very much heavier than the optimum for all other crops and internal drainage is at present extremely poor. There is however evidence for leaching within the even heavier Map Unit 9 soils. It is possible therefore that under irrigation some degree of internal drainage will be achieved. Thus given the construction of high ridges to provide for more extensive drainage; confertilizing and provision for pest control; it is conceivable that cotton and certain other arable crops may be successful. (see section 4D, Proposed cropping)

Table B indicates mean values and the range for the more important chemical properties of Map Unit 1, Aquic Haplorthents.

Soil profile No. 22, has been chosen as representative of Map Unit 1. (Table 2).

TABLE B

MAP UNIT 1

AQUIC HAPLORTHENT.

	TOPSOIL		SUBSOIL	
	Mean	Range	Mean	Range
% Silt	14	10 - 18	10	6 - 14
% Clay	75	72 - 80	75	70 - 82
% O.M.	3.8	2.0 - 6.5		
pH	5.4	5.2 - 5.6	5.9	5.2 - 7.0
pH Sat.Ext.	7.5	7.0 - 8.1	7.2	6.7 - 7.7
Hp	0.3	0 - 0.4	0.2	0 - 0.5
P. p.p.m.	16	14 - 18	19	17 - 24
K m.e. %	0.04		0.02	
Ca m.e. %	10.3	7.4 - 11.8	10.3	8.0 - 12.2
Mg m.e %	6.2	5.5 - 6.8	6.5	5.5 - 7.8
C.E.C.	43.8	39.2 - 49.5	45.3	41.6 - 50.4
E.S.P.	5.9	2.1 - 12.0	12.5	3.3 - 22.0
E. C_e	0.7	0.3 - 1.1	3.6	0.5 - 6.5
% $CaCO_3$	0.7	0.6 - 1.0	0.8	0.5 - 1.3

PROFILE DESCRIPTION

Pit No. 22.

Location : 300 yards in from the North Eastern corner of the Project Area.

Relief : Plane - Microrelief: Slightly Undulating with some very shallow artificial but long abandoned drainage channels.

Drainage : Very Poor. Negligible. subsoil permeability.

Vegetation Cover: 50% Bush - Acacia Seyal Fistula.
Cover : Ground cover of grass with a relatively high level of surface organic matter.
Rooting to 51".

Profile Depth : 65"

0-4". Very dark grey (10YR 3/1) organic, hard medium clay, with a fine and medium strong blocky structure. Abundant fine and medium roots. Lower boundary clear and even.

4-11". Very dark grey (10YR 3/1) extremely hard heavy clay, with coarse moderately developed prisms, and a fine and medium strong blocky microstructure. Common distinct rust blotches, and few very fine rust mottles. Common very fine to medium roots. Lower boundary clear and undulating.

11-28". Very dark greyish brown (10YR 3/2) to dark yellowish brown (10YR 4/4), very hard heavy clay, with medium and coarse moderately developed sub-angular blocky structures. Distinct, common and coarse rust blotches: few medium rust mottles, Few fine and very fine roots. Gradual lower boundary.

28-47". Dark greyish brown (10YR 4/2) to grey (5Y 5/1), very hard gleied heavy clay, with medium and coarse moderately developed sub-angular blocky structures. Distinct medium to coarse dark blotches prominent very fine to medium rust mottles. Few clusters of gypsum crystals. Very few, fine and very fine roots. Gradual lower boundary.

47" +. Dark grey (10YR 4/1), grey (10YR 5/1) and greyish brown (10YR 5/2), faintly blotched, very hard heavy clay, with fine to coarse strong blocky structures. Some slicken-sides with clay faces. Few very fine rust mottles. Few concretions of calcium carbonate. Very few, very fine to medium roots.

TABLE 2.

PIT NO. 22.
(Map Unit 1)

AQUIC HAPLORTHENT.

Depth	0-4"	4-11"	11-28"	28-47"	47"+
Sand %	14	12	14	18	10
Silt %	18	12	10	12	12
Clay %	68	76	76	70	78
pH (H_2O)	5.3	5.0	4.2	6.6	7.3
pH (Sat. ext)	6.9	7.1	6.9	7.0	7.4
Hp	0.2	0.5	0.6	0	0
O.M. %	6.3	2.0			
C.M. Comp % Kaolin	100	-	58	--	-
% Montmorin	trace	-	42	-	-
Available Nutrients m.e. K	0.10	0.02	0.02	0.04	0.02
Ca	13.6	9.0	7.2	8.0	8.6
Mg	7.2	6.5	6.0	7.8	9.2
P (p.p.m.)	20	13	10	24	31
% $CaCao_3$	0.78	0.37	0.40	0.47	0.58
C.E.C.	44.3	41.2	41.6	42.4	45.6
Exch. Bases Ca	19.75	19.00	15.00	20.70	20.70
Mg	9.30	8.95	8.60	14.15	15.25
K	1.2	0.5	0.4	0.3	0.3
Na	0.90	1.90	2.60	4.40	5.25
ECe Sat. ext.	0.80	0.35	1.60	3.70	1.95
E.S.P.	2.0	4.6	6.2	10.5	11.4

C.M. Comp = Clay Mineral Composition.

4. <u>Very Poorly Drained Depressed Lands</u>

MAP UNIT 9

AQUIC HAPLORTHENT

The important features that distinguish the soils of Map Unit 9 from those of Unit 1 are as follows:-

(i) Higher clay content throughout the profile (average 79% clay).

(ii) Surface organic matter is significantly higher (Averages 4.1%).

(iii) pH decreases with depth.

(iv) Significantly lower salt cotents. Lands subject to the reception of drainage waters might have been expected to have shown an accumulation of salt in the lower-lying areas. In fact the reverse has occurred, indicating the leaching effect of the acid drainage water even on such heavy clay. This result provides grounds for anticipating that some leaching will take place under irrigation on all the soil types within the project area despite the very slow or negligible permeability.

These Unit 9 haplorthents cover fairly extensive low-lying areas and are often associated with an undulating micro-relief in the form of tussocks and humpies.

The surface very dark brown to very dark grey very heavy clay is dominated by kaolin and has a moderately slow permeability. The impermeable very dark grey, very heavy clay glei subsoils contain montmorin and kaolin in almost equal proportions. Rust mottling and dark blotching are prevalent, often to within 6 inches of the surface. Structures are strongly developed, the solum cracking widely on drying out. Well developed slickensides with clay faces are a normal feature. Coarse clusters of gypsum are usually encountered at depths of 30 inches and below. Occasional concretions of calcium carbonate and lime spots sometimes occur at depth.

The soils are generally deficient in nitrogen, phosphate and potassium. These haplorthents may be improved for paddy by the addition of nitrogenous and phosphatic fertilizer. The soils are not at this stage recommended for other crops (including cotton) because of their heavy texture and impermeability.

Table C indicates mean values and the range for the more important chemical properties of Map Unit 9, Aquic Haplorthents .

Soil Profile No. 19 has been chosen as representative of Map Unit 9 (Table 3).

TABLE C

MAP UNIT 9

AQUIC HAPLORTHENT.

	TOPSOIL		SUBSOIL	
	Mean	Range	Mean	Range
% Silt	11	8 - 15	10	6 - 14
% Clay	79	74 - 80	79	74 - 84
% O.M.	4.1	2.2 - 8.2		
pH	5.2	5.1 - 5.3	5.1	4.9 - 5.5
pH Sat. ext.	7.2	6.9 - 7.8	7.1	6.8 - 7.3
Hp	0.5	0.2 - 0.9	0.7	0.3 - 0.8
P. p.p.m	16	12 - 19	15	11 - 21
K m.e. %	0.04		0.01	
Ca m.e. %	9.9	8.0 - 11.2	9.6	7.6 - 11.4
Mg m.e. %	5.4	5.0 - 6.0	5.3	5.0 - 5.8
C.E.C.	40.5	47.2 - 45.6	40.5	37.6 - 44.8
E.S.P.	5.7	4.0 - 6.5	10.4	9.2 - 11.4
E. C_e	0.4	0.3 - 0.5	2.3	0.4 - 4.6
% $CaCO_3$	0.7	0.4 - 0.9	0.9	0.7 - 1.2

PROFILE DESCRIPTION

Pit No. 19.

Location	:	Near the South West corner of the Project Area; some 75 metres from the Southern boundary canal.
Relief	:	Micro-depression. Microrelief: Undulating with humpies and tussocks.
Drainage	:	Receiving - Very Poor. Negligible subsoil permeability.
Vegetation Cover. Rooting to 60"	:	100% - 10% Acacia Sieberiana 10% Sphaeranthus Gomphrenoides. 80% Grass.
Profile Depth	:	72"

0-11". Very dark grey (10YR 3/1) to very dark greyish brown (10YR 3/2) very hard heavy clay, with medium to coarse weak prisms, and fine and medium strong blocky and sub-angular blocky microstructure. Common faint to distinct rust streaks and rust mottles. (The surface ½" has a crumb structure with abundant very fine roots). Moderate permeability. Common medium and coarse; fine and very fine roots. Lower boundary clear and even.

11-29". Very dark brown (10YR 2/2) to black (7.5YR 2/1) very hard heavy clay, with medium strongly developed sub-angular blocky structures. Some evidence for weak slickenside development. Negligible permeability Common and distinct very fine rust mottles. Few fine and very fine roots. Gradual lower boundary.

29-45". Very dark grey to very dark brown (10YR 3/1; 7.5YR 3/1; 10YR 2/2), very hard, very heavy clay, with fine and medium moderately developed sub-angular blocky structure. Negligible permeability. Few rust streaks: Common faint dark brown (7.5YR 4/2) blotches. Slickensides with prominent clay faces. Few to common coarse clusters of gypsum crystals. Very few very fine roots. Clear and even lower boundary.

45-61". Dark grey (10YR 4/1) very firm, very heavy gleied clay, with medium strongly developed sub-angular blocky structure. Slickensides with clay faces. Common faint and distinct, fine and very fine rust mottles. Common coarse clusters of gypsum crystals. Rare roots. Clear and even lower boundary.

61" + . Very dark grey (10YR 3/1) faintly blotched, very firm, very heavy gleied clay, with fine and medium moderately developed sub-angular blocky structure; and evidence for slicken-sides. Rare roots.

TABLE 3

PIT NO.19
(Map Unit 9)

AQUIC HAPLORTHENT

Depth	0-11"	11"-29"	29"-45"	45"-61"	61" +
Sand %	10	16	10	10	10
Silt %	12	14	10	10	10
Clay %	78	70	80	80	80
PH(H2o)	5.1	4.6	4.9	6.1	
PH (sat.ext.)	7.2	6.8	6.7	7.0	7.4
HP m.c. %	0.9	2.5	0.7	0	0
O.M. %	3.2	-	-	-	
C.M. COMP % KAOLIN	-		60	-	-
% MONTMORIN	-	-	40	-	-
AVAILABLE NUTRIENTS m.e. K	0.04	0	6	0.02	-
" Ca	9.8	9.6	11.4	12.0	-
" Mg	5.0	5.0	5.8	7.5	-
P(p.p.m)	17	12	16	20	-
% CaCO3	0.40	0.72	0.75	0.93	0.69
C.E.C.	39.6	44.0	45.6	42.4	43.6
EXCH. BASES Ca	13.50	12.74	19.0	24.50	23.75
Mg	6.75	7.93	10.50	11.30	11.30
K	0.60	0.40	0.50	0.31	0.31
Na	2.60	3.80	6.50	7.00	7.65
E.S.P.	6.5	8.6	14.1	16.5	17.5
EC_e Sat. Ext.	0.50	2.70	6.50	5.60	2.15

C.M. Comp = Clay Mineral Composition.

Map Unit 10.

These very dark brown sandy clays although low lying have a lighter texture than the Map Unit 1 and 9 soils. Accretions of sand and fine gravel derived from the nearby levee account. for the moderately slow subsoil permeability. The sand content gradually increases with depth. Distinct rust mottling and blotching occur below 2 feet and glei under 3 feet.

Acidity ranges 5.4 to 7.4 decreasing with depth. The N, P, K levels are generally low and the organic content averages 2.7%

With extensive drainage and fertilizer, these soils will be rendered suitable for a wide range of crops.

Seasonally or permanently ponded land.

Map Unit 11.

These very dark grey heavy clays (average 76% through profile) demonstrate impeded drainage and are usually gleid to within 1 foot of the surface.

Some of this land forms meanders and stream basins. It is suggested that where appropriate main drains should pass along through these courses. Elsewhere extensive drainage will be essential prior to irrigation.

3. Chemical Composition of Nzoia Waters.

LAB NO.	Date	pH	EC_e	Exch. cation m.e/litre				SAR	HCO_3 ppm	CO_3 ppm	Cl ppm	RSC
				Na	K	Ca	Mg					
5885	4.11.55	6.9	106	0.37	0.07	0.05	0.38	0.8	+	0		
2281	4.11.55	7.0	141	0.80	0.07	0.05	0.22	2.2	–	0		
6656	5.9.66	6.4	107	0.27	0.02	0.28	0.12	0.6	1.32	0	1.56	0.92

– + denotes less than 0.2 p.p.m.

SAR = Sodium absorption ratio.

RSC = Residual sodium carbonate

This water is classed as "low salinity" - low sodium water (U.S.S.D.A. 1954). The bicarbonate concentration is also low. These waters should therefore prove safe for irrigation purposes; the acidity would also be beneficial to the crops.

-----------------oooOooo-----------------

4. Soil Management.

A. Permeability and Aggregation: Prospects for improvement.

The clay mineralogy of the predominant soils (90%) of the project area (Map Units 1, 2 and 9) reveals the presence of traces of montmorin (clay mineral similar to montmorillonite) with about 99% Kaolin in the surface horizon; but in the subsoil montmorin and kaolin are in the proportion of 50:50, with the former gradually increasing with depth. Despite the high proportion of kaolin at the surface, it appears that the soil will have a relatively high capacity for nutrient retention. However some of this capacity (see figures for C.E.C., section 2) will be lost under cultivation, unless levels of organic matter are maintained. The subsoils with their high content of montmorin are generally impermeable.

Table 4 indicates mean permeability values in millimetres per 24 hours for certain of the soil types.

Tillage aims to increase total porosity. If ploughed under moist conditions the soils being sticky and plastic would tend to adhere to machinery and puddle resulting in high cultivation costs. If ploughed in dry conditions fine pulverisation occurs, causing the soil to become impermeable on wetting. These heavy clays should therefore be cultivated within a narrow range of moisture conditions, which should be controlled by irrigation. Cultivation should take place at friable consistency. The presence of significant quantities of organic matter would make it possible to cultivate at higher moisture conditions without puddling.

The incorporation of green manure is recommended as it will not only improve the air capacity of these soils but will also raise the level of available nutrients. The aimed for improvement in the soil structure should be achieved after the first flush of organic decomposition is complete.

The Map Unit 1 and 9 soils show indications of pockets of alkali, as well as accumulation of salts with maximum concentrations at around 2 to 3 feet depth. With addition of organic matter and the local spreading of coarser - textured deposits from adjoining Map Units 7, 8 and 4 onto these soils, texture and internal drainage will be significantly improved.

The levels of subsoil salt and alkali are not considered detrimental to development. Despite the lack of permeability it is envisaged that the introduction of closely-spaced drainage will provide sufficient lateral flow to prevent a build-up of salinity. Such a supposition is supported by the presence of low levels of salts in the Nzoia irrigation water.

TABLE 4.

PERMEABILITY DATA

MAP UNIT 1.

PIT NO.	DEPTH	AVERAGE PERM. m.m./24 hours	RATING
38	Surface	484	moderately slow
38	34"	0	negligible
61	6"	812	moderate
61	36"	0	negligible

MAP UNIT 9.

19	Surface	432	moderately slow
19	14"	0	negligible
19	36"	0	negligible
37	3"	280	moderately slow

MAP UNIT 10.

25	Surface	432	moderately slow
25	45"	40	slow

The rather high level of exchangeable calcium throughout the profile should inhibit further deflocculation of the soil clays and hence prevent a deterioration in permeability. For these reasons the use of expensive soil amendments is not recommended.

The problems reviewed above refer mainly to the dry foot crops like cotton and kenaf. Clearly many of these problems would not be encountered, if the main areas of impermeable clays were used for paddy rice.

Paddys are water-logged for much of the year, but a gentle flow of water should be continually maintained so that stagnant conditions do not arise; the land should be adequately drained to allow this water to get away. Furthermore the soil's permeability should be sufficiently controlled by puddling to permit a very slow rate of percolation. The original soil structure is therefore of little or no significance for paddy; the demands of rice for controlled moisture levels are more precise than are its demands on soil conditions. However the addition of organic matter through green manuring between paddy seasons may be most successful. It is important to conduct green manuring at the time of puddling so that ammonium ions are formed rather than nitrates which are susceptible to alteration in the reduction zone to toxic nitrite and subsequent loss as gaseous nitrogen and nitrous oxide.

B. Drainage and Flood Control.

Poor drainage prevails throughout most of the area. This inhibits rooting and effective up-take of moisture and nutrients. The low air capacity of badly drained soils reduces the partial pressure of carbon dioxide as well as that of oxygen. This may effect an increase in pH and the liberation of hydroxyl and bicarbonate ions. This in turn accompanied by dilution of soil electrolyte, increases the tendency for the soil mass to become more impermeable. Good drainage on the other hand would stimulate beneficial microbial activity and an/ promote the development of/extensive rooting system.

On these generally heavy and impermeable clays a closely-spaced system of surface drainage is most appropriate. Although short furrows tend to limit the extent of cultural operations and demand more labour and supervision, relatively short furrows do enable excess waters to drain off rapidly.

Cotton and kenaf should be planted on ridges with relatively close spacing. Trials should be conducted comparing ridging with camber beds. The spacing of ridges, beds, drains etc. should be made the subject for trials on this Pilot Scheme. Impermeability is such that sub-surface drainage need not be considered.

Main drains should be constructed as far as possible along the secondary water courses and meanders.

Although the soils on the North West edge of the project area are subject to incursions of slightly saline waters from off several levees, it is not thought necessary to place an interceptor drain through this area since, following the creation of effective flood protection, the only remaining source of salinity will be one slightly saline levee along the project area boundary.

Levee construction to effect flood control from the direction of the Nzoia should take account of possible future developments along the left bank. Under conditions of exceptional rainfall, it appears that flood waters back up from the low lying areas immediately to the West and South West of the proposed project area. Consideration should be given to flood protection from this direction.

Table 5 with rainfall figures for Port Victoria and Nangina Mission is included below. It is anticipated that rainfall at Busonga would lie between the range of these 2 stations.

6. Drainage and Flood Control.

Poor drainage prevails throughout most of the area. This inhibits rooting and effective up-take of moisture and nutrients. The low air capacity of badly drained soils reduces the partial pressure of carbon dioxide as well as that of oxygen. This may effect an increase in pH and the liberation of hydrogen and hydroxide ions. This in turn accompanied by diffusion of soil electrolyte, [illegible] the tendency for the soil mass to become more impermeable. Good drainage on the other hand would stimulate beneficial microbial activity and [illegible] the development of an extensive rooting system.

On these generally heavy and impermeable clays a well-designed system of surface drainage is most [illegible]. Although short furrows tend to limit [illegible] of mechanical operations and demand more labour and supervision, relatively short furrows do [illegible] excessive water to drain off rapidly.

Cotton and kenaf should be planted on ridges with relatively close spacing. Trials should be [illegible] comparing ridging with camber beds. The spacing of ridges, beds, drains etc. should be made [illegible] on Tala Pilot Scheme. [illegible] that sub-surface drainage need not be considered.

Land grading should be constructed to [illegible] [illegible] the [illegible] water courses and [illegible].

Although the soils on the North West edge of the proposed area are subject to inundations of slightly saline waters from off several levees, it is not thought necessary to place an interceptor drain [illegible] this area [illegible] following the erection of a protective flood control dyke, the only remaining source of salinity will be the slightly saline levee along the proposed boundary.

[illegible] to effect flood control from the direction of the basin should take account of possible future developments along the left bank. Under conditions of exceptional rainfall, it appears that flood water backs up from the low lying areas immediately to the West and South West of the proposed project area. Consideration should be given to flood protection from this direction.

Table 5 with rainfall figures for Port Victoria and Bungoma Mission is included below. It is anticipated that rainfall at [illegible] would lie between the range of these 2 stations.

TABLE 5

RAINFALL.

These 2 stations illustrate the rainfall range to be anticipated in the project area.

STATION	NO. OF YEARS RECORDED	JAN.	FEB.	MAR.	APRIL	MAY	JUNE	JULY	AUG.	SEPT	OCT.	NOV.	DEC.	TOTAL
PORT VICTORIA (TO 1962)	20	2.0	2.3	5.0	7.0	5.1	2.1	1.3	2.1	1.7	2.2	3.1	1.0	34.7
NANGINA MISSION (TO 1964)	25	1.9	2.5	4.9	8.0	7.4	3.3	3.1	4.1	4.9	5.5	5.7	2.9	54.1

C. The Role of Fertiliser.

The presence of a widespread deficiency of Nitrogen, phosphate and potash was outlined in Section 2. Even the levees show low levels of nutrients.

Complex fertiliser trials are required to determine the most economic and effective fertiliser regime. Responses to phosphatic and nitrogenous fertilizers may be confidently predicted. pH levels are such that several different compounds of N and P may give significant responses: in which case the cheapest fertilizers can ultimately be selected. Single superphosphate, triple superphosphate diammonium phosphate and ammonium sulphate should all be tried.

Although analyses indicate a significant deficiency in levels of potassium, applications of potash in Kenya often fail to give a worthwhile return. Muriate of Potash (KCl) should however be included as a treatment in the preliminary trials.

Topsoils are generally acid. Whilst much of this acidity may be attributed to significant levels of variable charge hydrogen, analyses indicate the accumulation of permanent charge hydrogen (Hp). This Hp does not attain toxic levels and therefore applications of lime are out of the question.

Paddy rice will respond to nitrogen whether as leguminous green manure or as inorganic fertiliser (ammonium sulphate). A combination of these treatments may be expected to give optimum results. If nitrogen is to be applied as ammonium sulphate, carefully designed trials will be necessary so as to determine the amounts and times of application as well as the yield increases to be anticipated. The fertiliser should be applied at several levels separately in the nursery and contrasted with applications solely in the paddy. These treatments should themselves be compared with fertilizer applied both in the nursery and in the paddy. All these treatments should be compared with incorporation of green manure in the paddy.

D. PROPOSED CROPPING.

1. Introduction.

The aim should be to provide the cultivator with a reasonable cash income right from the initiation of the project. At the same time all costs must be covered and sufficient income generated to pay back interest on capital. For these purposes, a gross income of £50 an acre should be taken as the minimum acceptable level.

2. In order to facilitate supervision and management in the early years, it is recommended that cropping patterns be simplified as far as possible, preferably laying out much of the area initially to provide for the continuous cropping of paddy on almost all holdings. So as to obtain the high levels of gross income required, the growing of subsistence or staple food crops should not be considered and livestock should be kept outside the scheme.

3. Rice is not only one of the more remunerative crops for such a scheme, but also the best suited to the environmental conditions viz. very heavy poorly drained and somewhat acid impermeable clays. Furthermore the demand for rice, as a highly competitive food crop, is likely to prove elastic. Rice is well suited to growing on small fields of about an acre. Yields with correct fertilizing should exceed 20 bags/acre/crop - with 2 crops/year.

4. It is presumed that the rice will be transplanted from a nursery since this is likely to give higher yeilds than direct broadcasting, besides, facilitating irrigation.

5. Otherwise little or no precise information exists concerning rice culture in that part of the country on those particular soils.

6. It is therefore proposed that a minimum area of 30 acres be set aside for properly conducted and costed trials:-

(i) Detailed trials on rice culture.

(ii) Exploratory trials on cotton.

(iii) Observation trials for the introduction of possible "new" crops e.g. Soybeans.

These trials should be sited as far as possible on a convenient area of land covering soil of Map Units 1 and 9 i.e. the soil types of major importance.

7. The number of possible trials will of course be less than the ideal: below are listed those which should be given the highest priority.

8. Rice Trials.

(i) Date of Sowing Experiment.

(ii) Fertilizer trial using several rates of nitrogenous and phosphatic fertilizers. The time of application may well be crucial; for this reason the trial should include 3 nitrogen treatments -

1. Nitrogen applied only in the nursery.
2. Nitrogen applied only in the paddy.
3. Nitrogen applied both in the nursery and in the paddy.

Whilst ammoniacal nitrogen is proposed for the nursery, it is possible that nitrate nitrogen may prove more effective in later stages of growth.

Room should be provided for an experiment on Green Manure crops, which should be ploughed in about 2 weeks prior to transplanting the seedlings.

Possible green manure crops include:-

Crotalaria juncea

Glycine phaseolus

Vigna

Facilities should be provided for fundamental studies on soil changes under partially water-logged conditions.

9. Exploratory trials on Cotton.

Initial cotton cropping under irrigation should be confined to the 40 acres or so of Map Units 2 and 10 close to the North West corner of the project area. This could be divided up into 4 acre holdings under special supervision. Here the soils should be most suitable for cotton culture given intensive drainage.

It would be unfair and short-sighted to introduce this crop as extensively as has been suggested by the UNSF/FAO team, before it has been subjected to a wide range of trials, since a soil containing 75 - 80% clay is not usually recommended for cotton. It would however be equally unfair to prejudge this crop as there are certain grounds for optimism: The clay composition does not appear to exceed about 50% montmorillonite and alkali is only found locally and then at considerable depth. If the cotton is grown on high ridges so as to extend the rooting volume, is adequately fertilized and careful attention is paid to weeds, insects and high general standards of husbandry, the crop may do better than expected. It is however questionable whether 1500 lbs. can be exceeded per acre on any other than the trial plots.

Proposed trials:

(i) Date of Sowing.

(ii) Fertilizers, using nitrogen, phosphate and potash in different combinations.

(iii) Rotation trial with soybean.

(iv) A limited number of observation variety trials.

If experimental yeilds in excess of 2500 lbs/acre are obtained, then it would be advisable to proceed with experiments to assess optimum levels of irrigation having regard to water consumption.

10. Observation Trial on Soybean.

This may prove to be a useful rotation crop. It will however only be justified by high yields about which little is known until the crop is tried.

Present return from the internal market is 30/- a bag, but the export market pays 55/- per bag ex-farm provided the oil content is of the requisite standard. The crop takes 4 to 5 months to mature.

Kenya varieties tend to be grown at altitudes of over 5000', though certain low altitude varieties have been grown at Galole (near sea level) with varying success on somewhat unsatisfactory soil for soybean. Varieties Belgian Congo, Hernon Local and the Blyvoor types could all be tried. These varieties averaged 24.5% fats and oil in the first cropping season at Galole.

The crop will require intensive drainage and should be grown on the ridge. The seeds will probably require innoculation.

11. Observation Trial on Beans.

Given high yields some bean crops may prove attractive. They have the further advantage of a relatively low water requirement and the possibility of passing some fixed nitrogen to the subsequent crop.

Mexico 142, a good standard canning bean, should fetch 55/- per bag delivered to the store. If it were possible to overcome the high cost of transport, then the export potential is considerable. Other likely varieties include:-

Canadian Wonder
Michigan Pea Bean.

12. Observation Trials on Kenaf.

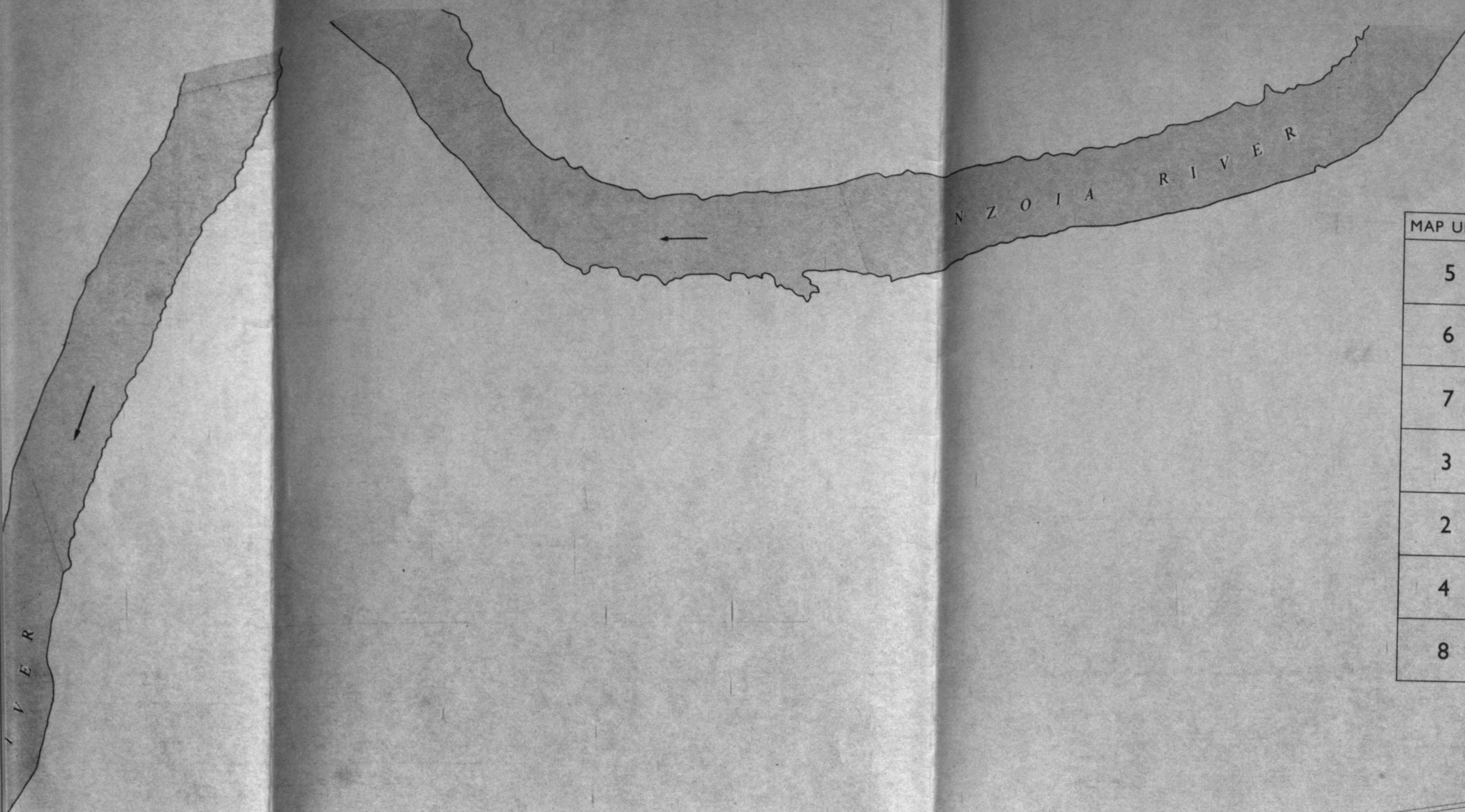
This crop is unlikely to grow its best on such heavy soils. The pH is however ideal. With high transport and labour costs kenaf should attain getting on for one ton of fibre an acre to justify itself.

Kenaf is a gross feeder of nitrogen. Variety G.4 should be used, planted on ridges as close together as possible. Provision will be required within the area of the trials for retting tanks. To prevent acidification during decomposition drainage channels will be necessary so as to ensure a slow flow of running water through the tanks. The processes of stripping and washing demand a temporary high labour requirement.

E.A. Bag and Cordage will buy fibre at £60 a ton. High quality fibre may command up to £80/ton.

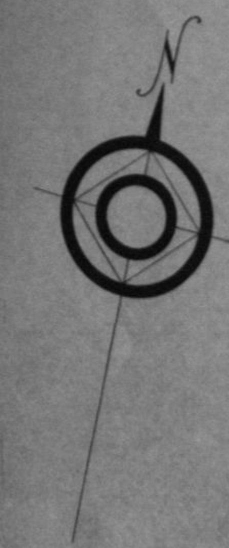
STEIN BIE
VICTOR D'COSTA
JOHN MAKIN

18, NOVEMBER 1966.



MAP UNIT	SOIL CHARACTERISTICS	DRAINAGE STATUS
5	Calcareous dark greyish-brown sandy clay loams overlying alkaline clay glei.	WELL DRAINED HIGH-LYING LEVEE SOILS.
6	Non-calcareous dark brown sandy clay loams above medium clay subsoils; with intervening layers of sand.	
7	Mottled brown sands overlying medium to heavy clay subsoils.	
3	Dark brown relatively weakly structured light clays with blotched subsoils.	SLIGHTLY POORLY DRAINED SOILS.
2	Dark brown strongly structured light or medium clays (no cracking) with glei subsoils.	
4	Larger Termitaria.	
8	Dark brown medium clays with intervening layers of coarse material.	

MAP UNIT	SOIL CHARACTERISTICS	DRAINAGE STATUS
1	Very dark brown heavy clays (cracking in draught); distinctly mottled gypsaceous glei subsoils with slickensides. Seasonally water-logged.	VERY POORLY DRAINED SOILS
9	Very dark, very heavy clays dark grey glei to within 2 feet of the surface.	VERY POORLY DRAINED DEPRESSED SOILS RECEIVING DRAINAGE.
10	Very dark, light clay ; sandy clay glei below 2 feet.	
11	Very dark grey, very heavy clay glei.	SEASONALLY OR PERMANENTLY PONDED LANDS



NZOIA PILOT IRRIGATION PROJECT

(BUNYALA)

Scale 1:3,100 Approx.

Prepared by the Soil Survey Unit 1966
For F.A.O.
Drawn by the Survey of Kenya.

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