

WOSSAC: 135  
631.4  
(676.2)

NZOIA PILOT IRRIGATION SCHEME

Bunyala

---

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

(YALA SWAMP RECLAMATION)

---

SOIL SURVEY UNIT

KENYA

NOVEMBER 1966

---



## C O N T E N T S

### INTRODUCTION.

1. Physiognomy.
2. Soil description and analytical results.
3. Quality of the Nzoia Waters.
4. Soil Management:
  - A. Permeability and Aggregation:-  
Prospects for improvement.
  - B. Drainage and Flood Control.
  - C. The Role of Fertiliser.
  - D. Proposed Cropping.

### REFERENCES.

C O N T E N T S

INTRODUCTION

1. Introduction
2. Soil description and analytical results
3. Quality of the Water
4. Soil Management
- A. Fertility and Aggravation-  
Prospects for improvement
- B. Drainage and Flood Control
- C. The Role of Fertilizer
- D. Proposed Cropping

REFERENCES

## 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.

Acknowledgements are due to Messrs. Gitau, Hinga, Muturi, Mwae and the Survey of Kenya.

REPORT OF THE

The project area lies south of the ...  
about 5 miles from the mouth of the ...  
on the north side of the ...  
This comprises 750 acres, the soils of ...  
which had previously been mapped as a ...  
level (1:50,000) by Sir A. Gibb (1950).

This survey was commissioned by the ...  
Agriculture Organization to initiate a ...  
500 acres with a view to a more extensive ...  
near along the river. This area would be served by a ...  
trapping installation to be sited on the bank of the river ...  
near to the ...

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

It is assumed that the ...  
scheme will be cotton, rice and ...  
line to well suited for experiment in the ...  
house and the results ...  
determined. It is ...  
body of the National Agricultural Laboratory.

The map accompanying this report was drawn from ...  
unclassified aerial photographs of ...  
of 1:50,000.

Acknowledgements are due to Messrs. Gibb, ...  
Murray, ... and the survey of ...

## 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 lands stream basins (Map Unit 11) are dominated by rushes (Cyperaceae).

The soils are alluvial and form part of the flood-plain 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 soil 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 size. Irregularity of level 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 "boom" and stock sheltering. The relatively recent levees (Map Unit 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 albida 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 thicket, so that this bush now constitutes a single dominant (especially on Map Unit 1, 2 and 3). A few remnant thickets are found on lighter textured soil. These essentially consist of Acacia torturosa, Coprosma sp., Cassia hispida, Grewia rotundifolia, Marrubium triquetrum, Myciurus senegalensis and Hybanthus reticulatus. Acacia albida commonly occurs on the site of very poorly drained sites (Map Units 4 & 11). Acacia polyacantha forms very local thickets on Map Unit 9. Common associates of poorly drained sites (Map Unit 1 and 2) include Mimosa zimbabwensis and Pythium lanceolatum. A preliminary inventory of the vegetation of the pilot scheme is given in the Appendix, which locally forms a dense Acacia cover. The reason for the widespread abandonment of local cultivation is primarily a result of the Government promise of an irrigation scheme in 1950, which never came to fruition.

Of the whole area of alluvium about 90% consists of poorly drained very dark brown to very dark grey clay with fine eutecite. The somewhat level land (Map Unit 1) is essentially water logged but not ponded, a measure of drainage was provided by the locally raised levees in the form of a shallow channel drainage. The slightly depressed areas (Map Unit 2) are associated with mucky formation. The ponded lands (Map Unit 11) are dominated by rushes (Cyperaceae).

SOIL FERTILITY AND IRRIGATION

(a) Methodology: Several soil samples were sampled from the topsoil horizon at intervals.

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.

Soil samples were analysed with a Perkin-Elmer 521 atomic absorption spectrophotometer for the quantities of Nitrogen, Phosphorus, Potassium, Calcium, Magnesium, Sodium, and Chlorine. Differential thermal analysis was carried out on Magnesium Oxide.

(b) Abbreviations: The abbreviations are used in the text.

- O.S. Organic substance
- NORF. Nitrogen
- C.E.C. Cation exchange capacity
- Ca. Calcium
- Mg. Magnesium
- K. Potassium
- Na. Sodium
- P.P.P. Phosphorus percentage
- S.S.P. Sulphur percentage
- pH. Potential hydrogen ion activity of the soil solution
- EC. Electrical conductivity
- p.p.m. Parts per million
- S.S.P. Sulphur percentage
- Hp. Hydrogen potential
- I. Irrigation

(c) Soil Survey Report

1. Higher Irrigation

Soils occurring in Map Units 5, 6 and 7 are generally heavy and contain alluvium of varying age.

Much of the area is subject to flooding by  
overflow from the pools and the streams which depend  
on the plain; during the flood the entire region  
was totally inundated.

The permanent ground water table is certainly  
higher than 25 feet and may occur within 5 feet of the  
soil surface close to meadows, and probably associated  
with local sandy levee deposits.

A deep channel (canal or drain?) circumvents the  
southwest part of the north of the project site  
and is now in a deteriorating state. Such an old  
development outside the overall scheme planning is to be  
discarded, 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 (<2 $\mu$ ) 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 abbreviations 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 <sub>e</sub> . 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.

SOIL DESCRIPTIONS AND ANALYTICAL METHODS

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

For soil conductivity assessment followed methods of the U.S. Dept. of Agriculture ("Diagnose 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 Nelson A. Richardson, A. Robertson W and Kopper H ("Mass Analysis Methods for Soil Fertility Evaluation" Memo, of the Soil Agricultural Lab. 1952). Mechanical analysis was performed by hydrometer. Method for determining the colloidal content of soil, "Soil Sci. Soc. Amer. Proc. 25, p. 312-31" (1931) were prepared according to Thies A.A. and Howard W.E. ("A Paste Method for Preparation of Slides for Clay Mineral Identification by X-ray Diffraction" 1953 Soil Sci. Soc. Amer. Proc. 25, p. 90-91) and were analyzed with a direct recording X-ray diffractometer. For the quantitative analysis of clay minerals, the method of Thies A.A. and Bellis B. ("Quantitative Analysis of Clay Mineral Mixtures by X-ray Diffraction" 1954, Nature 204, p. 1228-1230) was followed. Differential Thermal Analysis (D.T.A.) was also carried out on Magnesium-saturated clay.

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

Organic Matter	O.M.
Nonporosity	NONP.
Cation Exchange Capacity	C.E.C.
Clay	Ca.
Magnesium	Mg.
Potassium	K.
Sodium	Na.
Exchangeable Sodium Percentage	E.S.P.
log of the reciprocal of the concentration of the hydrogen ion	pH
Electrical Conductivity of the saturation extract	EC, sat. ext.
Parts per million	P.p.m.
Milli equivalents per cent	m.e.c.
Exchange acidity arising from negatively charged permanent cation exchange capacity sites	Hp
Prophores	P.

(c) Soil Types, Profile Description and Data

1: Higher Type levee soils

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

### 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 gleyed 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 gleeting 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.

Map Unit 5

This comprises long narrow levees on the north western side of the project area. The area is heavily eroded; it has only 50% grass cover. The soils are calcareous very dark grayish brown sandy clay loam overlying caliche and silty grayish brown light to medium gray with some very fine gravel. The surface is flat and shows abundant drainage dark blotching at 2 feet and below. The pH of the saturated extract varies from 7.4 to 8.0.

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 caliche and in which exchangeable sodium is more or less absent. The soils consist of non calcareous sandy clay loam with about 1.5% organic matter overlying dark grayish brown medium clay subsoil. Deposits of calcareous sandy material form discrete layers within the soil. Below 4 feet fluting occurs with drainage rust nodules and streaks. Treatment lime should appear in the sub surface layers but calcium concentrations are absent.

The soil would have excellent suitability for the irrigation of a wide range of crops. Their topographic position prevents the use of canals 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 generally deficient in nitrogen, phosphorus and potassium.

Map Unit 7

This comprises very local and relatively recent levees associated with stream meanders with an unrelenting 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 grayish brown medium to heavy clay subsoil. Deposits of calcareous sandy material form discrete layers within the soil.

These areas will require leveling and will consequently expose poorly drained and infertile clay subsoils. The overlying sandy material will be spread over considerable areas of adjoining units 1 and 2 soils, thereby somewhat alleviating their heaviness of texture. Owing to the very local nature of the Map Unit 7 soils, special treatment post-leveling would be both impracticable and uneconomic. On leveling these soils could be treated as adjoining Map Units 1 or 2 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 crumbly 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.

Blair's footed bat

Unit 1

This unit contains a very small area of rock  
group light to medium gray throughout the profile.  
lying on the north western side of the project area.  
The strata are thin and weakly developed.  
The overall composition shows that this unit is light  
and settling below 1 foot, unconsolidated by light.

The unit is from 1 to 2 feet and the surface has  
an average of 10% to 15% sand and silt and is  
of the fine to medium sand type. It is composed of  
quartzite in nature, with some mica and feldspar.  
The texture is somewhat coarse. The unit is light  
and is highly resistant to weathering (see log Unit  
1 above).

Unit 2

This unit represents a shale member which may  
be locally sandy in all but the northern and the  
western areas. It is a light gray to medium gray  
quartzite with some mica and feldspar. It is  
1 to 2 feet in thickness. The weathering surface is not  
rippled.

The member is relatively thin and is gray in  
color. It is 1 to 2 feet in thickness. It is  
composed of quartzite with some mica and feldspar.  
The texture is somewhat coarse. The unit is light  
and is highly resistant to weathering. Below  
30 inches there is a small concentration of mica.

If it is possible, the shale member is levelled  
and the weathering surface is not rippled.

Unit 3

This member is a sandstone with some  
siltstone. These are in the northern and the  
western areas. They have a light to medium gray color  
and a coarse to medium texture. The weathering surface  
is sandy and is highly resistant to weathering.  
within the 4 feet profile.

The oil ranges from 5 to 10% and the color is  
without trace, gray to light brown.

Because of the local nature and limited  
exposure of this unit, it is suggested that it  
should be levelled and the detailed study over  
the adjoining units.

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. Gleiting 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

FARADIC MAPPORTMENT

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 occasional of sand and very fine gravel. Gassing 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 sets 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, Faradic Mapportments. (Table 1)

PROFILE DESCRIPTION

Site 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 27 inches.
- Profile Depth : 27 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. Fine light blotches: abundant distinct fine root mottles common near blotches. Predominant blotches are dark brown, brown and

TABLE A  
MAP UNIT 2  
PARAQUIC HAPLORTHENT.

	TOP SOIL		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 <sub>2</sub> O)	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 <sub>3</sub>	0.7	0.4 - 1.0	0.7	0.5 - 1.0

TABLE A  
 MAP UNIT 2  
 PHYSICAL CHEMISTRY

	TOP SOIL		SUBSOIL	
	Mean	Range	Mean	Range
% Silic	24	18 - 30	15	10 - 18
% Clay	62	52 - 70	65	67 - 78
% O.M.	3.0	2.4 - 3.5		
H (H <sub>2</sub> O)	6.4	5.3 - 8.8	5.4	4.8 - 8.5
Im Sat. cont.	7.3	7.0 - 7.5	7.0	6.7 - 7.5
Hp	0.3	0.3 - 0.8	0.4	0 - 0.8
P. prop. m.	18	13 - 23	18	11 - 22
K m.e.v.	0.30		0.03	
Ca m.e.v.	8.8	7.0 - 10.4	7.5	5.7 - 8.8
Mg m.e.v.	6.7	6.1 - 8.3	6.2	4.8 - 8.0
C.B.C.	31.8	28.4 - 41.8	32.4	30.2 - 39.2
P.S.P.S	4.8	1.3 - 6.3	7.8	4.8 - 12.0
E.Ca.	0.5	0.4 - 0.9	0.8	0.1 - 2.5
% CaCO <sub>3</sub>	0.7	0.4 - 1.0	0.7	0.3 - 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.

dark yellowish brown (10YR 4/2-7.5R 4/4).  
Very few very fine roots. Gradual lower boundary.

30-41". Dark grey (10YR 4/1), somewhat silted.  
Very hard, light clay, with fine and medium strong  
blocky structure, and some evidence for weak  
siltstone-like developed part. 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 5/1), somewhat silted.  
Hard, sandy clay, with fine and medium  
moderately developed blocky structure. Brown  
brown (7.5R 5/3) and dark yellowish brown (10YR 5/4)  
mottles. Fine and medium black (10YR 2/1) and very  
dark grey (10YR 3/1) blotches, with prominent fine  
scales following the course of root channels.  
Common very fine concretions of calcareous material  
with a few coarse concretions. Slight block  
reaction with 10% HCl. Fine 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 <sub>2</sub> O)	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 <sub>3</sub>	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 <sub>e</sub> Sat. ext.	0.35	0.34	0.90	0.43
E.S.P.	1.9	3.6	4.8	3.8

TABLE 1.  
 PIT No. 23  
 West Unit 2

FACONING SAMPLES

Depth	0-10"	10-30"	30-41"	41"+
Sand %	18	20	42	58
Silt %	18	14	18	12
Clay %	64	66	40	30
pH (H <sub>2</sub> O)	5.3	5.3	5.1	5.0
pH (Sat. ext.)	7.9	7.3	7.8	8.3
Sp. Gr.	2.65	2.65	2.65	2.65
Available Moisture				
R	0.05	0.05	0.05	0.04
Cu	10.4	10.0	8.8	8.0
Mg	0.0	0.0	1.0	6.3
F (p.p.m.)	18	18	22	24
% CaCO <sub>3</sub>	0.4	0.4	0.0	1.1
S.R.C.	41.8	41.8	58.8	41.8
Exch. bases				
Ca	14.52	14.70	18.00	15.70
Mg	0.72	0.74	1.14	2.27
K	1.70	1.40	1.30	1.20
Na	0.70	1.20	1.30	1.30
EC Sat. ext.	0.32	0.34	0.30	0.47
S.P.P.	1.3	1.8	4.8	3.0

TABLE B  
MAP UNIT 1  
AQUIC HAPLORTHENTS.

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; fertilizing 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).

Very poorly drained level lands.

Map Unit 1.

AGRIC HAPLOTYPES.

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 with negligible permeability. The clay 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. Concentrations of calcium carbonate may occur at depths in excess of 10 feet. They are invariably deeper than the layers of gypsum deposition. Structures are very strongly developed with evidence for cracking in the dry season. Particular subsoil structures are also observed with slicken-sides and clay lenses.

The pH ranges from 5.2 to 7.0 increasing with depth. High concentrations of salt and bicarbonate 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 phosphoric fertilizers; crops may also respond to potassium. 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 2 soils. It is possible therefore that under irrigation some degree of internal drainage will be achieved. This given the construction of high ridges to provide for more extensive drainage; fertilizing and provision for pest control; it is conceivable that cotton and certain other staple crops may be successful. (see section 4B, Proposed outline)

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

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

TABLE B  
MAP UNIT 1  
AQUIC HAPLORTHENT.

	T O P S O I L		S U B S O I L	
	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 <sub>e</sub>	0.7	0.3 - 1.1	3.6	0.5 - 6.5
% CaCO <sub>3</sub>	0.7	0.6 - 1.0	0.8	0.5 - 1.3

TABLE 2  
MAP SHEET 1  
AGRICULTURAL UNIT

SUBSIDIARY	TOTALS		Range	Mean	Range
	Area	Volume			
1	14	14	10 - 18	10	2 - 18
2	28	28	15 - 30	15	10 - 30
3	5.0	5.0	2.0 - 6.0	3.0	1.0 - 6.0
4	5.0	5.0	2.0 - 6.0	3.0	1.0 - 6.0
5	7.0	7.0	3.0 - 8.1	4.3	1.0 - 8.1
6	6.0	6.0	3.0 - 6.1	4.0	1.0 - 6.1
7	12	12	10 - 14	10	10 - 14
8	0.0	0.0		0.0	
9	10.0	10.0	1.4 - 11.9	5.0	0.0 - 11.9
10	6.0	6.0	2.0 - 6.0	4.0	0.0 - 6.0
11	48.0	48.0	30.0 - 48.0	40.0	10.0 - 48.0
12	2.0	2.0	1.1 - 12.0	1.0	0.0 - 12.0
13	0.0	0.0	0.0 - 1.1	0.0	0.0 - 1.1
14	0.0	0.0	0.0 - 1.0	0.0	0.0 - 1.0

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 Pistula.  
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.

	0-4"	4-11"	11-28"	28-47"	47" +
No.	1	2	3	4	5
Mo.	0.20	0.20	0.20	0.20	0.20
Sat. ext.	0.05	0.05	0.05	0.05	0.05
H.S.P.	2.0	2.0	2.0	2.0	2.0

PROFILER DESCRIPTION

Ref 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. Slightly permeability.

Vegetation Cover : 50% Bush - Acacia acacia thicket. Ground cover of grass with a relatively high level of surface organic matter. Rooting to 5".

Profile Depth : 85"

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 root 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 (2.5Y 5/1), very hard gleyed 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 pitted, very hard heavy clay, with fine to coarse strong blocky structures. Some slickensides 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 :)

CAQUIC HAPLORTHEM.

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 <sub>2</sub> O)	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 <sub>3</sub>	0.78	0.37	0.40	0.47	0.58
C.E.C.	44.0	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
FCe 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.

E.S.P. 2.0 4.8 6.2 10.2 11.4

C.M. Comp = Clay Mineral Composition.

TABLE 2.

PLT NO. 22  
(Map Unit 1)

CLAY MINERAL COMPOSITION

Depth	0-4"	4-11"	11-28"	28-47"	47"+
Band #	14	12	14	18	10
Slit #	18	12	10	12	12
Clay A	1.2	0.2	0.4	0.3	0.3
Na	0.90	1.90	2.60	4.40	2.22
Fe (ppm)	2.3	2.0	4.2	6.3	7.7
Sat. ext.	0.80	0.32	1.60	3.70	1.92
E.S.P.	2.0	4.8	6.2	10.2	11.4
C.M. Comp = Clay Mineral Composition.	0.2	0.2	0.2	0	0
Ca	6.3	2.0			
C.M. Comp & Kaolin	100	-	22		
Montmorillonite	Trace		42		
Available nutrients	0.10	0.02	0.03	0.04	0.02
Ca	13.6	9.0	7.2	8.0	8.3
Na	7.2	6.2	6.0	7.8	9.2
F (p.p.m.)	1.28	0.2	0.4	0.3	0.3
Na	0.90	1.90	2.60	4.40	2.22
Fe (ppm)	0.18	0.31	0.40	0.47	0.58
Sat. ext.	0.80	0.32	1.60	3.70	1.92
E.S.P.	2.0	4.8	6.2	10.2	11.4
C.M. Comp = Clay Mineral Composition.	0.2	0.2	0.2	0	0
Exch. Bases	19.72	19.00	15.00	20.70	20.70
Ca	9.36	8.92	8.80	14.12	12.22
Na	1.2	0.2	0.4	0.3	0.3
Fe	0.90	1.90	2.60	4.40	2.22
Sat. ext.	0.50	0.32	1.60	3.70	1.92
E.S.P.	2.0	4.8	6.2	10.2	11.4

C.M. Comp = Clay Mineral Composition.

#### 4. Very Poorly Drained Depressed Lands

##### 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 contents. 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).

UNIT 2

ADJUSTED CHARACTERISTICS

The important features that distinguish the soils of Unit 2 from those of Unit 1 are as follows:

- (i) Higher clay content throughout the profile (average 70% clay).
- (ii) Surface organic matter is significantly higher (averages 4.1%).

(iii) It decreases with depth.

(iv) Significantly lower soil water content. Lower water content is the exception of drainage waters which have been expected to have shown an accumulation of salts in the lower-lying areas. In fact the reverse has occurred, indicating the leaching effect of the soil 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 2 saprolites cover fairly extensive low-lying areas and are often associated with an undulating water-table in the form of tussocks and hummocks.

The surface very dark brown to very dark grey very heavy clay is dominated by kaolin and has a relatively low permeability. The impermeable very dark grey, very heavy clay saprolite contains montmorillonite and kaolin in almost equal proportions. Both kaolin and dark blotching are prevalent, often to within 6 inches of the surface. Structures are strongly developed, the soil cracking widely on drying out. Well developed slickensides with clay faces are a normal feature. Common sinuosity of fissures 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, phosphorus and potassium. These saprolites may be improved for better the addition of nitrogenous and phosphatic fertilizers. The soils are not at this stage recommended for other crops (including cotton) because of their heavy texture and impermeability.

Table 3 indicates mean values and the range for the more important chemical properties of Unit 2, plus saprolites.

Soil Profile No. 19 has been chosen as representative of Unit 2 (Table 3).

TABLE C  
MAP UNIT 9  
AQUIC HAPLORTHENT.

	T O P S O I L		S U B S O I L	
	Mean	Range	Mean	Range
% Silt	11	8 - 15	10	6 - <del>15</del>
% 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. Ce	0.4	0.3 - 0.5	2.3	0.4 - 4.6
% CaCO <sub>3</sub>	0.7	0.4 - 0.9	0.9	0.7 - 1.2

TABLE 2  
WATER  
TEMPERATURE  
RECORDS

Station	Mean	Range	Mean	Range
10	10	8 - 12	11	9 - 13
70	70	68 - 72	70	68 - 72
		8.8 - 9.2	9.1	8.8 - 9.4
1.1	1.1	0.1 - 2.1	0.8	0.3 - 1.3
7.1	7.1	6.8 - 7.4	7.2	6.9 - 7.5
0.7	0.7	0.3 - 0.9	0.5	0.2 - 0.8
12	12	12 - 12	12	12 - 12
	10.0		10.0	
8.8	8.8	8.3 - 9.3	8.9	8.4 - 9.4
3.8	3.8	3.0 - 4.6	3.4	2.0 - 4.8
10.5	10.5	9.2 - 11.8	10.1	8.8 - 11.4
10.4	10.4	9.2 - 11.6	10.1	8.8 - 11.4
3.3	3.3	2.0 - 4.6	2.9	1.6 - 4.2
0.9	0.9	0.4 - 0.9	0.7	0.2 - 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. 100% - 10% Acacia Sieberiana  
10% Sphaeranthus  
Gomphrenoides.  
80% Grass.  
Rooting to 60"

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  $\frac{1}{2}$ " 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.

5. Comp - Soil Mineral Composition

PLANT SPECIES

1911

West the South West corner of the Project area; some 75 meters from the Southern boundary canal.

Micro-organisms. Micro-organisms: abundant with purple and black.

Receding - very poor. Biological activity: none.

100% Ascaris sibirica  
10% Sphaerium  
Common  
100% Grass

Location 1

1911

1911

1911

Plant Specimens

Very dark grey (10YR 2/1) to very dark greyish brown (10YR 2/2) very firm, heavy clay, with medium to coarse sand grains, and fine and medium sized pebbles. Common faint reddish-brown streaks and small black spots. The soil is very moist and has a strong alkaline reaction with abundant very fine roots. Micro-organisms: Common medium and coarse sized and very fine roots. Lower boundary clear and sandy.

Very dark grey (10YR 2/2) to black (7.5YR 2/1) very firm, heavy clay, with medium strongly developed and coarse sized pebbles. Some evidence for weak biological activity. Micro-organisms: Common and coarse sized, very fine roots. Lower boundary clear and sandy.

Very dark grey to very dark brown (10YR 2/1; 10YR 2/2) very firm, very heavy clay, with fine and medium sized pebbles and angular sand grains. Biological activity: few roots. Common fine and coarse sized pebbles. Lower boundary clear and sandy. Very few very coarse sized pebbles. Lower boundary clear and sandy.

Dark grey (10YR 4/1) very firm, very heavy clay, with medium strongly developed and coarse sized pebbles. Micro-organisms: Common fine and coarse sized pebbles. Lower boundary clear and sandy.

Very dark grey (10YR 2/1) faintly colored, very firm, very heavy clay, with fine and medium sized pebbles and angular blocky sand grains. Micro-organisms: Common fine and coarse sized pebbles. Lower boundary clear and sandy.

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(H <sub>2</sub> O)	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	0	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	-
% CaCO <sub>3</sub>	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 <sub>e</sub> Sat. Ext.	0.50	2.70	6.50	5.60	2.15

C.M. Comp = Clay Mineral Composition.



Chemical Composition of Azala Waters.

Lab No.	pH	SO <sub>4</sub>	Exch. cation m.e./100g					Ca	Mg	Cl	NO <sub>3</sub>
			Na	K	Ca	Mg	CO <sub>3</sub>				
5413	6.5	106	0.37	0.07	0.65	0.3	0.2	+	3		

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.

Map Unit 10.

These very dark brown sandy clay although low  
lying have a lighter texture than the Map Unit 9  
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  
leaf mottling and blotching occur below 2 feet  
and 4 feet 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.

Map Unit 11.

These very dark gray heavy clay (average 70%  
through profile) demonstrate tabular drainage and  
are usually found to within 1 foot of the surface.

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

### 3. Chemical Composition of Nzoia Waters.

LAB NO.	Date	pH	EC <sub>e</sub>	Exch. cation m.e./litre				SAR	HCO <sub>3</sub> ppm	CO <sub>3</sub> ppm	Cl ppm	RSC
				Na	K	Ca	Mg					
5685	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-----

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 need for improvement in the soil structure should be remembered after the first flush of organic decomposition is complete.

The Map Unit 1 and 2 soils show indications of pockets of alkali, as well as accumulation of salts with maximum concentrations at ground level 2 feet depth. With addition of organic matter and the local spreading of surface - textured deposits from adjoining Map Units 3, 6 and 7 onto these soils, texture and internal drainage will be significantly improved.

The levels of subsoil salt and alkali are not considered detrimental in development. Because the lack of permeability it is envisaged that the introduction of closely spaced drains will provide sufficient lateral flow to prevent a build-up of salinity. Some 4 units of salt is suggested by the presence of low levels of salt in the local irrigation water.

Chemical Composition of Waste Water

No.	Date	pH		Temp. (°C)		Total Solids (mg/l)		Total Suspended Solids (mg/l)		Total Dissolved Solids (mg/l)	
		min	max	min	max	min	max	min	max	min	max
1	10/15/54	6.5	7.5	15	20	100	150	50	100	50	100
2	10/20/54	6.8	7.8	18	22	120	180	60	120	60	120
3	10/25/54	7.0	8.0	20	25	150	220	80	160	70	140
4	10/30/54	7.2	8.2	22	28	180	260	100	200	80	160

This water is classified as "low salinity" - low sodium water (S.A. 1954). The carbonate concentration is also low. These waters should therefore have also for this purpose; the activity would also be beneficial in the city.

10/15/54  
 10/20/54  
 10/25/54  
 10/30/54

#### 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.

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

MAP UNIT 9.

19	Surface	432	moderately slow
19	14"	0	negligible
19	36"	0	negligible
<hr/>			
37	3"	280	moderately slow
<hr/>			

MAP UNIT 10.

25	Surface	432	moderately slow
25	45"	40	slow
<hr/>			

TABLE 1

PERCENTAGE OF

POPULATION

SEX

AGE GROUP

EDUCATION

RELIGION

Male

100

100

100

Female

100

100

100

Male

100

100

100

Female

100

100

100

TABLE 2

Male

100

100

100

Female

100

100

100

Male

100

100

100

Female

100

100

100

TABLE 3

Male

100

100

100

Female

100

100

100

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.

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

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

Paddy are water-logged for much of the year, but a gentle flow of water should be continuously maintained so that anaerobic conditions do not arise; the ground 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 desiccation. 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 the demands on soil conditions. However the addition of organic matter through green manuring between paddy seasons may be most desirable. It is important to conduct green manuring during the time of puddling so that ammonia ions are formed rather than nitrates which are susceptible to nitrification; 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 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.

Pressure and Flow Control

Flow control is provided throughout most of the system. This includes routing and selective routing of material to various parts of the system. The low air capacity of the system is maintained by the partial pressure of the air as well as that of oxygen. This is achieved by means of a flow control valve at the inlet to the system. This valve is controlled by a differential pressure switch. The valve is normally closed and will become open if the pressure on the inlet side becomes higher than the pressure on the outlet side. This valve is normally closed and will become open if the pressure on the inlet side becomes higher than the pressure on the outlet side.

The flow control valve is normally closed and will become open if the pressure on the inlet side becomes higher than the pressure on the outlet side. This valve is normally closed and will become open if the pressure on the inlet side becomes higher than the pressure on the outlet side.

The flow control valve is normally closed and will become open if the pressure on the inlet side becomes higher than the pressure on the outlet side. This valve is normally closed and will become open if the pressure on the inlet side becomes higher than the pressure on the outlet side.

The flow control valve is normally closed and will become open if the pressure on the inlet side becomes higher than the pressure on the outlet side. This valve is normally closed and will become open if the pressure on the inlet side becomes higher than the pressure on the outlet side.

The flow control valve is normally closed and will become open if the pressure on the inlet side becomes higher than the pressure on the outlet side. This valve is normally closed and will become open if the pressure on the inlet side becomes higher than the pressure on the outlet side.

The flow control valve is normally closed and will become open if the pressure on the inlet side becomes higher than the pressure on the outlet side. This valve is normally closed and will become open if the pressure on the inlet side becomes higher than the pressure on the outlet side.

The flow control valve is normally closed and will become open if the pressure on the inlet side becomes higher than the pressure on the outlet side. This valve is normally closed and will become open if the pressure on the inlet side becomes higher than the pressure on the outlet side.

TABLE 5

R A I N F A L L.

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
FORT 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.

The presence of a widespread deficiency of nitrogen phosphate and potash was evident in Section 2. Even the lowest show low levels of nutrients.

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

Although analyses indicate a significant deficiency in levels of potassium, application of potassium salts will give a worthwhile return. Nitrate of Potash (KNO<sub>3</sub>) should however be included in a treatment in the preliminary trials.

Fossils 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 (H<sub>2</sub>O). This is not a toxic level and therefore application of lime is not of the question.

Today also will respond to nitrogen whether as ammonium green manure or as inorganic fertilizer (ammonium sulphate). A combination of these treatments may be expected to give optimum results. If nitrogen is to be applied as ammonium sulphate, carefully selected trials will be necessary to determine the exact time of application as well as the field moisture to be expected. The fertilizer should be applied at several levels separately in the same way as discussed with application trials in the past. These treatments should themselves be compared with fertilizer applied both in the nursery and in the field. All these treatments should be compared with incorporation of green manure in the field.

## 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 yields 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. 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 the soil must be covered and sufficient income generated to pay back interest on capital. For these purposes a gross income of 150 an acre should be taken as the minimum acceptable level.

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 most of the area initially in paddy for the continuous cropping of paddy on almost all holdings. So as to obtain the high levels of gross income required, the growing of substitutes or winter food crops should not be considered and livestock should be kept outside the scheme.

Rice is not only one of the more remunerative crops for such a scheme, but also the best suited to the environmental conditions of the very heavy soils of the lowland areas. Rice is well suited to growing on small fields of about an acre. Yields with current fertilizing should exceed 20 bags/acre/year.

It is presumed that the rice will be irrigated from a nearby river. This is likely to give higher yields than direct broadcasting, besides facilitating a greater

Observation of the rice crop is essential in order to obtain the maximum yield from the country's resources.

The farmer's proposed plot a minimum area of 30 acres be set aside for properly conducted and tested

- (i) Detailed trials on rice culture.
- (ii) Extensive trials on cotton.
- (iii) Observations on the inter-cropping of possible "new" crops e.g. Soyabean.

These trials should be aimed as far as possible on a convenient area of land covering soil of high fertility and of the soil type of major importance.

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

2. Rice Trials

- (i) Date of Sowing Experiment.
- (ii) Fertilizer trial using several rates of nitrogenous and phosphate 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 prejudice 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 yields 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.

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

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 Greenhouse crops, which should be finished in about 2 weeks prior to transplanting the seedlings.

Possible green manure crops include:-

- Crotalaria. Juncea
- Glycine phascolia
- Vicia

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

Experimental 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 slight and short-sighted to introduce this crop extensively as has been suggested by the UNCTAD team, before it has been subjected to a wide range of trials since a soil containing 15-20% clay is not usually recommended for cotton. It would however be equally unwise to prejudice 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, it is usually fertilized and careful attention is paid to weeds and high general standards of husbandry, the crop may be better than expected. It is however questionable whether 1500 lbs. can be exceeded per acre on any class 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 yields in excess of 2000 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, Hennon 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 inoculation.

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

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 3/- a bag, but the export market pays 5/- per bag extra provided the oil content is of the requisite standard. The crop takes 4 to 5 months to mature.

Kanva 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 unastatutory soil for soybean. Varieties Bafan Congo, Hannon local and the Blyvoor types could all be tried. These varieties averaged 24.5% oil and all 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 inoculation.

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 bearing bean, should fetch 5/- per bag delivered to the store. It is worth possible to overcome the high cost of transport, than the export potential is considerable. Other likely varieties include:-

Canadian Wonder  
Michigan Pea Bean

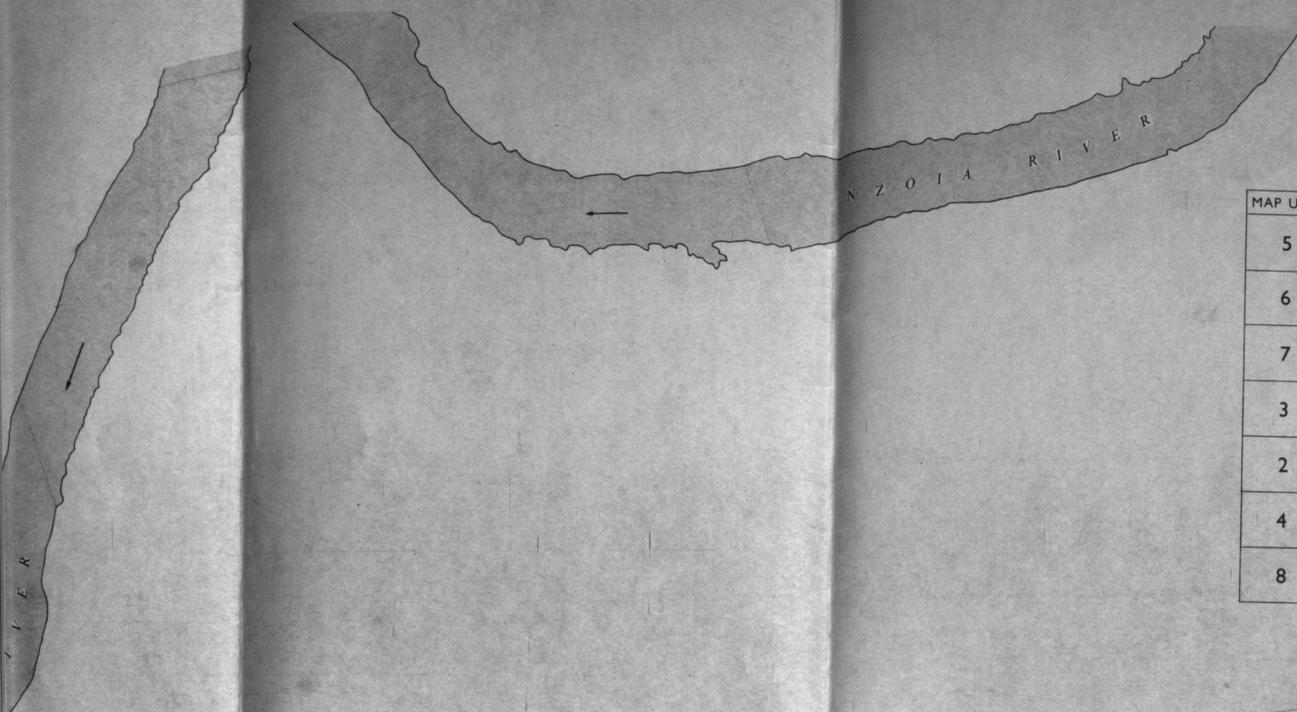
12. Observation Trial on Kernal

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

Kernal is a gross feeder of nitrogen. Variety G.A. should be used, planted on ridges as close together as possible. Provision will be required within the rows 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 a ton.

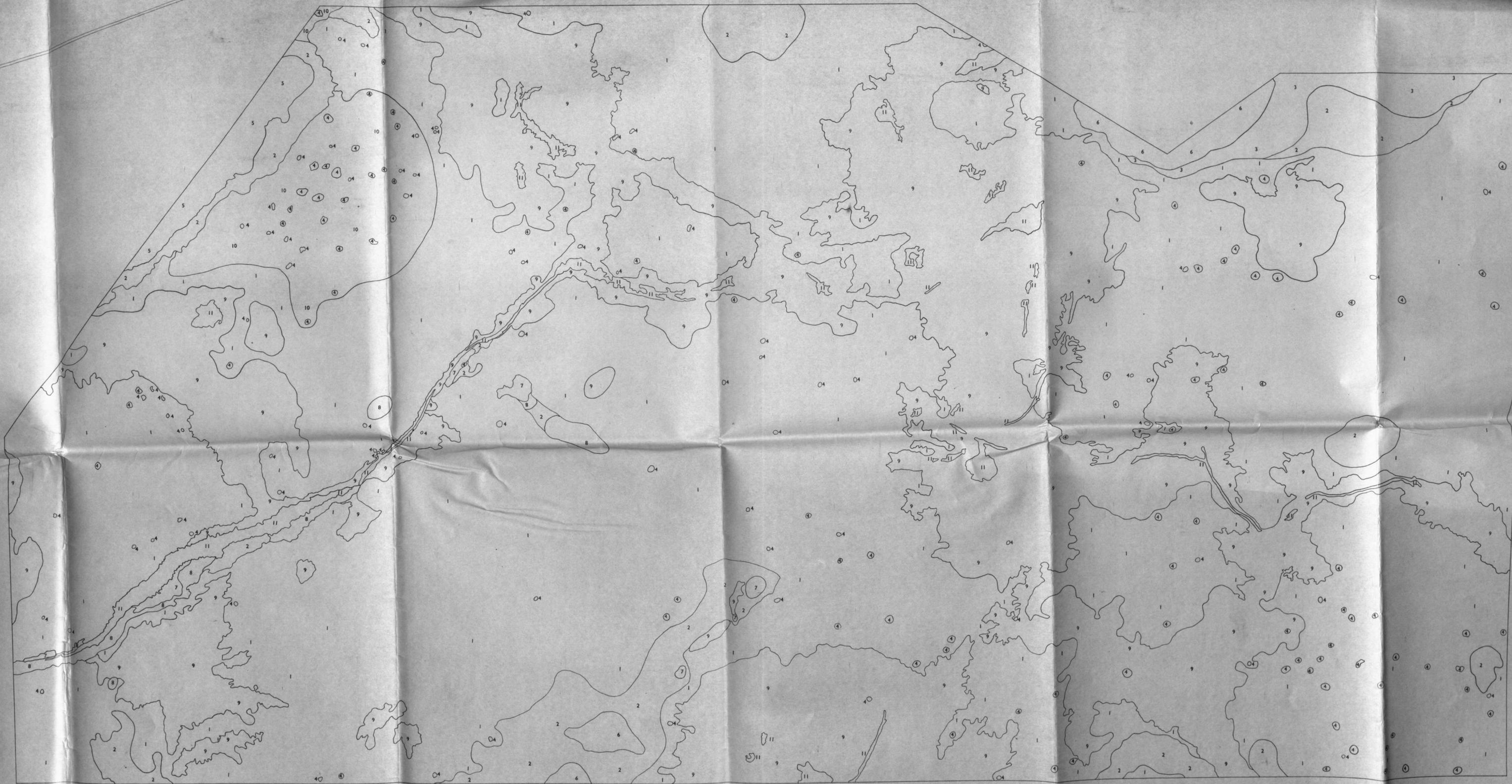
ARTHUR BIE  
VICTOR D'GONZA  
JOE HALL



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 gypsicous 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.

REFERENCES

- "Diagnosis and Improvement of Saline and Alkali Soils".  
Agricultural Handbook No. 60. U.S.D.A. 1954.
- SIR A. Gibb. 1956. "Kenya Nile Basin ; Water Resources  
Survey".  
Soil Classification; "7<sup>th</sup> Approximation."  
U.S.D.A. (1960, 1964).
- Geological Survey of Kenya. North and Central Kavirondo.  
"Report No. 5."
- "Soils of Western Samia."  
Soil Survey Unit, Kenya. 1966.
- "Ahero Pilot Irrigation Scheme."  
Soil Survey Unit, Kenya. 1966.