THE SOILS OF THE MWEA EXTENSION

KARABA

SOIL SURVEY UNIT

KENYA

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1. INTRODUCTION

The Project area, comprising about 3,860 acres, lies to the North and North West of the low ridge upon which the village of Karaba is situated (referred to hereafter as the "Karaba Ridge"). The area is bounded to the North by the line of the Thiba River, the new development in Block 4 and a minor escarpment which serves to divide the Project area from the paddies of Block 2A; and bounded to the West by a minor swamp. The East of the Project Area is indeterminate, but a low ridge running North-South from the vicinity of the Karaba Ridge was presumed to be "out of command". The Project Area is based on the projected Mwea Blocks 5 and 6.

The soils of this area had previously been mapped by Bellis (1958) at a scale of 1:10,000. That survey was clearly performed in some haste, resulting in a superficial definition of the soil types.

The present survey was commissioned by the Development Planning Division of the Ministry of Agriculture in conjunction with the National Irrigation Board, and on behalf of Kreditanstalt fur Wiederaufbau, Frankfurt am Main, West Germany.

The terms of reference laid down for the Project were twofold:

1. To assess the soil status on the existing irrigation with a view of determining any deterioration.

2. To describe and estimate the acreage of the several soil types on the proposed extension area in the light of development to Rice Padi. This survey to involve the inspection of at least 20 soil profiles sited on the complete range of significant pedological situations.

   For this reason it was not necessary to plot the pit sites onto maps; nor was any form of soil map required.

Since no accurate large scale map of the area exists and since the topographical survey had not been completed at the time of writing, the acreage estimates of the soils and indeed of the entire project area should be received with caution and revised in the light of the results of the survey. All areas (acreages) stated in this report are estimated from aerial photographs (at an approximate scale of 1:60,000) by means of an Area Computer.

The Soil Survey Unit wishes to acknowledge the cooperation of the Staff on the Mwea-Tebere Irrigation Scheme and especially that of the Manager, J.J. Veen, Esq.; also the assistance of Messrs Hinga, Leyder and Muturi.

2. ABBREVIATIONS

The following technical abbreviations are used in this report:

O.M.	Organic Matter
Mont.	Montmorillonite
C.E.C.	Cation Exchange Capacity (m.e. %)
E.S.P.	Exchangeable Sodium Percentage
m.e. %	Milli equivalents per cent
p.p.m.	Parts per million
C	Carbon
Ca	Calcium
K	Potassium

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Mn	Manganese
Mg	Magnesium
P	Phosphorus
pH	Log of the Reciprocal of the Concentration of the hydrogen ion

3. METHODOLOGY

On the Extension Area, 38 soil inspection pits were dug to 6 feet: these were sited on the basis of apparent variations in natural phenomena likely to make a significant impression upon the direction of soil development. The factor of greatest importance in this respect was found to be that of topography. These soil investigations were supplemented by ground inspection on foot and by extensive augering. The approach followed on the Irrigation Scheme is described in Section 4, below.

Twenty one of these soil pits were sampled according to evident distinctions in soil morphology. Additionally, some topsoil and auger samples were analysed. % C was determined by the Walkley-Black method.

pH and conductivity assessment followed methods of the U.S. Department 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 Laboratories 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.

4. SOIL CONDITIONS ON THE EXISTING IRRIGATION SCHEMES

The Mwea Plains should be viewed as a series of clay basins underlain by Olivine Basalt. The basins form a series of steps, descending towards the East and each step is marked by a minor escarpment formed of basaltic boulders. Lateral drainage is from West to East. Necessarily those higher lying basins receiving alluvium and drainage from "the Highlands" are composed of acid material, mostly halloysite with a tendency towards ground water laterisation. Such soils under padi exhibit intense mottling in the surface layers with gleisation in the sub-surface reduction zone. Occasional iron concretions may be found.

There is a net removal of bases from such soils and these bases, if not directly carried away in the drainage, tend to accumulate in the lower lying clay basins, especially in situations where the soils are both deep and impermeable. Sodium is an ion which is especially mobile in this respect. So it is that the lower-lying clay basins (i.e. those farther East) have a higher concentration of bases and tend towards an alkaline reaction. Furthermore, since much of the coarser alluvial material is laid down in the upper basins to form light clays with significant proportions of silt, so the lower basins are composed almost entirely of a very fine textured (heavy) clay. Under long continued conditions of impeded drainage in a base-rich medium, these heavy clays have developed into montmorillonite. The Project Area comprises just such a low-lying clay basin.

It is, therefore, not possible to predict the likely course of soil development on the projected extension from consideration of the contemporary soil status on the irrigation scheme, since the vague term

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TABLE 1

LOCATION: MWEA IRRIGATION SCHEME UNIT 6: HOLDING 1963 LAB. NO. 383 - 385 : 1967

INCHES Depth	% C	% Sand	% Silt	% Clay	C.E.C.	Exchangeable Ca	Mg	bases K	m.e.% Na	E.S.P.
0-12	2.04	17	16	67	42	18	11.0	1.9	0.6	1.4
18-24		9	8	83	48	21	13.2	1.8	1.0	2.1
36-42		7	8	85	48	23	15.8	1.8	1.4	2.9

INCHES Depth	pH 1:5 H_2O	pH Sat. Ext.	% $CaCO_3$	EC_e Sat. ext.	m.e. % Available K	Ca	Nutrients Mg	P ppm.	m.e.% Mn
0-12	6.5	7.3	0	0.2	0.03	9.6	8.8	23	0.18
18-24	5.8	7.3	0	0.1	0.03	7.6	8.0	21	0.03
36-42	7.3	7.5	0	0.2	0.02	6.4	8.0	30	0.04

TABLE 2

LOCATION: TEBIRE IRRIGATION SCHEME. BLOCK 11 LAB. NO. 413 - 414 : 1967

INCHES Depth	% C	% Sand	% Silt	% Clay	C.E.C.	Exchangeable Ca	Mg	bases K	m.e.% Na	E.S.P.
0-12	1.84	13	10	77	75	41	21.3	2.6	0.8	1.1
18-24		13	14	73	74	47	23.4	2.5	0.7	1.0

INCHES Depth	pH 1:5 H_2O	pH Sat. Ext.	% $CaCO_3$	ECe Sat. ext.	m.e.% Available Nutrients K	Ca	Mg	P ppm.	m.e.% Mn
0-12	6.6	7.7	0.1	0.3	0.13	18.6	10.0	33	0.60
18-24	7.9	7.8	0.6	0.4	0.08	18.0	9.6	38	0.16

"Black Cotton Soil" in fact embraces a wide range of differing soil types, some of which may be expected to react to irrigation along dissimilar lines.

It is probable, nevertheless, that the soil development at Mwea/Tebere can provide some clues to the likely course of soil evolution on the Project Area. The aim was to compare paddies of different ages but, due to lack of irrigation records, this was not possible. Instead, resort was had to other comparative methods.

Data is provided in Table 1 and 2 of two quite separate soil types which are presently growing padi. Table 1 represents a padi on Unit 6 Mwea, derived from the drainage of the Nguka Swamp and sited on the highest-lying clay basin. The Nguka Swamp was originally described in a report of 1955 as a "moderately rich organic acid soil". The holding number 1963 was probably brought into production in 1956 and is situated half way down the feeder canal, growing a typically good crop of rice. The very dark organic topsoil only extended to 4-5 inches. The holding had received 1 cwt. of superphosphate every year since 1959; but without nitrogen. Table 2 represents a soil from a lower-lying clay basin (Block 11 at Tebere) which was developed for padi about 1959. This is a relatively shallow, very dark grey heavy clay with locally abundant basaltic rubble and boulders below 22 inches.

All of the soils under padi show obvious signs of chemical reduction. This reduction starts through the metabolism of anaerobic bacteria and results in anaerobic decomposition of organic matter, high concentrations of ammonia and carbonic acid, migration of reduced compounds of iron and manganese, production of sulphide, destruction of nitrate, increase in pH and increased solubility of silica. These profound chemical changes tend to alter the character of the soil type.

The following is a summary of the more important findings of the comparative studies:

1. Compared with the soils of the projected extension, the soils of the Irrigation scheme have a lighter topsoil texture, are more strongly gleied and are significantly more acid: they comprise about 40 to 50% montmorillonite (remainder of the clay fraction is halloysite) compared with almost pure montmorillonite in the Project Area.

2. Comparison of the composition of irrigation and drainage waters on the scheme indicates net removal of significant quantities of salt, sodium, calcium and bicarbonate. The mean conductivity of the irrigation waters is 73 micro. mhos. (and pH 7.6) that of the drains is 272 micro mhos. (pH 7.7).

3. Comparison of paddies at varying distances from the canal inlets failed to reveal any significant differences in sodium content or in pH; neither did applications of ammonium sulphate affect these properties.

4. Comparison of virgin soil with that in neighbouring paddies also failed to demonstrate any crucial differences. The expected slight increase in pH was, in fact, indicated in the data (mean pH of virgin soil = 5.8; that of the paddies = 6.0). This pH level is, incidentally, ideal for padi. The higher levels of bicarbonate in the paddies probably accounts for all of the rise in pH.

The surface salt content (already low in virgin soil) is reduced by half under irrigation; subsoil salt is lowered about 50%. Evidence for changes in the surface content of sodium is inconclusive, though some of the paddies demonstrated an insignificant increase in E.S.P. above that recorded in neighbouring virgin land. Subsoil sodium is reduced under padi.

The anaerobic decomposition of organic matter does not appear to be proceeding at a speed anticipated for paddies, presumably because the prevailing temperatures at Mwea are lower than is usual for rice production. There is generally a small decrease in organic content on the scheme, but the data were not consistent and surface organic matter comprises between 3 and 5% of the soil; in paddies originating from the Nguka Swamp, organic content still exceeds 6%.

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The paddies show enhanced levels of available manganese; nowhere does this element attain toxic proportions.

The average level of potassium (already apparently deficient in the virgin soil) is approximately halved under padi and is probably becoming a factor limiting yields of padi on the scheme. The low level of potassium may well account for the lodging which has been experienced with only comparatively small applications of nitrogen.

5. Toxic concentrations of alkali are invariably associated with lines of lateral seepage which seem to occur where there is a change in slope (convex). Here the surface E.S.P. is in the range of 7-14 and the subsurface E.S.P. is far in excess of 15 (average 29). There is visual evidence for the dispersion of the surface organic material and precipitation on the ped faces of the iron and manganese compounds translocated laterally by the seepage. At depth there is an abundance of precipitated calcium. Circumstantial evidence (especially that obtained from the condition of the natural vegetation) indicates that toxic seepage occurred prior to scheme initiation; a more detailed soil survey would have demarcated such areas. Where rice manages to survive on these seepage lines, the straw is considerably shortened and tillering is inhibited. There is absolutely no evidence to suggest that the area affected by alkali is expanding.

5. PHYSIOGNOMY OF THE PROJECT AREA

1. Geology

The Karaba ridge is composed of Simbara basaltic agglomerate. The remainder of the area is underlain by Thiba olivine basalt, boulders of which can be seen out-cropping in the North Western extremity of the Project Area. The dark greyish brown olivine basalt, erupted from Mount Kenya, is normally fine-grained and non-porphyritic with a slightly speckled appearance. Coarse ovoid vesicles are common: phenocrysts are generally scarce or absent.

The basalt is covered (unconformably) by a very fine-textured montmorillonitic alluvial clay which accumulated to a varying depth on the basaltic floor to form a heavy clay basin. This clay is not in any part derived from the underlying basalt. However, around the North Western and the South Eastern edges of the Project Area, where the alluvial clay laps up against basaltic ridges, there have been colluvial incursions of a coarser-textured brown soil material of volcanic origin.

The clay basin is now in places suffering minor erosion due to the deepening (? rejuvenation) of the course of the Thiba River and its associated tributaries. On the resulting slopes the clay cover is relatively thin and contains basaltic rubble and boulders.

2. Physiography and Drainage

The clay basin is not in any part absolutely flat. A slight trough runs through the heart of the Project Area from South West to North East. At its South Western extremity, it opens out to form a rather extensive area of swamp. To the North East it becomes a shallow rejuvenating gully which joins the Thiba River in the corner of the Project Area. This trough tends to accumulate much of the area drainage and its base broadly coincides with a line of tall Acacia woodland. To the East of the trough, the country rises very slightly to form a low whale-backed mound; but to the South East and South, a shallow trough runs below the Karaba ridge and into the swamp (referred to hereafter as the "Karaba Trough"). Within ¼ mile of the Thiba River, the surface forms a distinct convex slope (average about ¾°) down to the (minor) flood zone of the Thiba.

A few lesser gullies occur below the Karaba ridge.

3. Natural Vegetation

The area vegetation could be described generally as an open grassland of Chloris, Setaria and Themeda triandra, accompanied by scattered stunted specimens of the "Whistling Thorn" (Acacia drepanolobium): this Acacia accounts for up to 10% of the ground cover, though forming a low thicket in the South West. Occasional bush associates include:

Acacia polyacantha campylacantha, Balanites aegyptiaca and Harrisonia abyssinica. Whistling thorns become fewer up against the Karaba ridge where the vegetation merges into a dry Combretum savannah.

Minor and very local depressions receiving drainage within the clay plateau normally remain uncultivated due to seasonal waterlogging. Such areas are normally dominated by Chloris with subsidiary Pennisetum mezianum. A 10 to 20% low cover of Euclea divinorum keniensis is characteristic.

Descending towards the shallow central trough, the Whistling thorns gradually become taller and denser. This might either be a function of the soil moisture status (more moisture available for longer periods) or it may merely be that these thorns at lower levels have been established over a longer period, i.e. they are invading previously cultivated lands further upslope. Here the ground cover comprises 90-100% Chloris, with occasional clumps of Sphaeranthus and increasing sedge towards the lowest lying areas. In the base of the central trough is an open woodland of up to 50% Acacia seyal seyal with a herbaceous cover dominated by Chloris.

Both the bouldery escarpment and the (alkaline) slopes down to the Thiba River are characterised by abundant clumps of Pennisetum mezianum.

In the Karaba trough, there is a very open scrub of 20% Acacia drepanolobium with a meagre cover of stunted herbs and grasses. About 30% of the ground is bare, especially in areas of relatively intense soil cracking.

With the exception of the Pennisetum, it is concluded that, where the vegetation is edaphically significant, it is indicative of variations in surface drainage and in the degree of seasonal water-logging.

4. Cropping

Approximately one half of the project area is cultivated. Most fields grow maize intercropped with chick-pea. A significant proportion of the acreage is down to coriander which provides a high return in years of small supply.

6. SUMMARY OF SOIL TYPES

1. Clays containing basaltic boulders, overlying rock or rubbly debris at a depth of less than 3 feet. These shallow clays associated with rejuvenation cover some 500 acres. There are, however, grounds for optimism regarding their utilization:

(i) Good crops of padi are obtained on the existing scheme with as little as 18 inches of soil.

(ii) Prison labour can be used to clear the boulders.

(iii) Boulders are required for scheme structures. It is estimated that only 115 acres will be unavailable due to rock.

2. Clays on the slight slopes above the Thiba River. These are subject to incursions of lateral alkali seepage; and are generally too alkaline for rice. After scheme initiation it is thought probable that seepage, and hence alkalinity, will increase. In places there is a combination of shallow soil with alkaline seepage. In all, these unsuitable areas cover 275 acres.

3. The cracking alkaline clay of the Karaba trough. This clay accumulates alkaline run-off from the Karaba ridge and has been rendered unsuitable for rice. This trough comprises 425 acres.

4. A minor area is affected by intense alkaline subsoil seepage in certain situations beneath the North Western escarpment and covers 55 acres.

5. The remainder of the Project Area, mostly comprising a very dark grey and impermeable, poorly drained, very heavy montmorillonitic clay, is considered suitable for padi. The area involved is 2,990 acres, of which about 100 acres may be lost due to problems involved in designing the scheme to avoid sites which are pedologically unsuited to padi; i.e. 2,890 acres available.

All the above soil types are described in greater detail in Section 7 below.

7. SOIL DESCRIPTIONS AND ANALYTICAL DATA.

"Topsoil" is here defined as the surface horizon; "subsoil" is that horizon approximating most nearly to a hypothetical layer 24 to 36 inches in depth.

(a) Shallow clays with basaltic boulders

These are heavy, very dark grey clays containing basaltic boulders and/or gravel to the surface. Rocks are normally encountered within the top 3 feet. Calcium may be precipitated as free lime associated with lines of stony rubble. Apart from the stoniness, these soils exhibit many of the characteristics of the deeper clay basin soils to be described below; it is not thought necessary therefore to present a more detailed description.

Where the soil is less than 2 feet deep, there will probably be seepage from plot to plot. This flow will tend to raise water consumption and leach the more soluble nutrients. On the other hand, this lateral movement should help to inhibit adverse soil reduction.

(b) Sloping Clays above the Thiba River

These heavy, very dark grey clays are sited on slopes of 20' to 1° above the Thiba levee. They are calcareous and to a greater or lesser extent alkaline, often with intensely alkaline subsoils. There is sometimes a slight organic accumulation on these slopes.

A clear correlation was found between the presence of coarse yet soft lime spots and intense subsoil alkalinity. This observation may well be of value for the demarcation in the field of alkali-affected areas. Many of the soils investigated had basaltic stones in the profile. The mean depth of the soil above continuous boulders = 34 inches.

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TABLE 3

LOCATION: KARABA EXTENSION
PIT 14

LAB. NO. 749 - 751 : 1967

INCHES Depth	%C	% Sand	% Silt	% Clay	C.E.C.	Exchangeable bases m.e.% Ca	Mg	K	Na	E.S.P.
0-8	1.66	11	18	71	102	74	22.0	1.0	1.9	1.9
8-18		25	6	69	82	45	29.6	0.8	15.0	18.2
18-45		21	4	75	86	42	34.0	0.9	21.5	25.0

INCHES Depth	pH 1:5 H_2O	pH Sat. Ext.	% $CaCO_3$	EC_e Sat. ext.	Available Nutrients m.e.% K	Ca	Mg	P ppm.
0-8	8.2	8.5	10.1	0.4	0.07	21.0	8.5	74
8-18	8.9	7.6	9.1	0.7	0.04	16.4	9.4	26
18-45	9.0	8.1		0.9	0.04	9.8	10.0	28

The table below indicates mean values for the more important soil properties, calculated from data obtained from 6 soil profiles.

	% Silt	% Clay	%$CaCO_3$	pH Sat. Ext.	E.S.P.
TOPSOIL - Means	14	73	5.4	8.4	7.6
SUBSOIL - Means	10	74	7.6	8.3	25.3

Soil profile No. 14 has been selected as representative of these soils:

Pit No. 14 — **Profile Description**

Soil Depth: 45 inches; overlying near-continuous basaltic boulders and gravels.

Slope: 1° — Aspect: North

Microrelief: Strongly undulating

Drainage: Receiving from the South East and South West.

Vegetation: 80% Pennisetum mezianum
10% Chloris and Setaria

Minor bare areas associated with surface cracking.

0-8" Very dark grey (10YR 3/1) to Black (2.5Y 2/1) very hard heavy clay, with fine and medium strongly developed blocky structures. Surface one inch has a very fine blocky to granular structure. Slight vertical cracking. Few fine and very fine calcium concretions, locally common and increasing with depth. Common fine and very fine roots. Lower boundary clear and undulating.

8-18" Very dark grey (2.5Y3/1) extremely hard medium clay, with fine to coarse strongly developed blocky structures. Very slight matrix reaction with 10% HCl. Common fine and medium calcium concretions, locally abundant. Few fine and very fine roots. Gradual lower boundary.

18-45" Very dark grey (10YR3/0; 3/1) to dark grey(10 YR4/1) and somewhat gleied, very hard heavy clay, with lenticular orientation and evidence for slipping between structural units. Very slight matrix reaction with 10%HCl. Some basaltic gravel below 33 inches. Faint and distinct streaks and blotching. Few vertical lime streaks. Locally common and slightly hard coarse lime spots. Abundant very fine to fine calcium concretions. Lower boundary clear and undulating.

Data for Profile 14 is provided in Table 3.

(c) Thiba Levee.

These brown light alluvial clays extend on average only 50 yards South of the Thiba and are therefore of no areal significance. They are subject to **flooding** during periods of high river flow.

(d) Alkaline clays close to the North Western Escarpment

Alkaline seepage from off the clay basin above the minor escarpment locally affects the clays along the North West of the Project Area. These soils tend to be between 3 and 4 feet deep overlying basaltic boulders and are of the same type as (b) above, being calcareous and alkaline and equally unsuitable for rice.

A deep interceptor drain will be necessary along the base of this escarpment to prevent any further soil deterioration along this side of the Project Area.

(e) Alkaline clays of the Karaba Trough

These moderately cracking, very dark grey and very heavy alkaline clays are quite distinctive; they have been regarded as unsuitable for padi due to their sub-surface alkalinity.

Soil Profile No. 21 has been selected as representative of these soils:

Pit No. 21 Profile Description

Profile Depth: 45 inches

Slope: 10' Aspect: South West.

Relief: Base of trough. Microrelief: Undulating

Drainage: Receiving down the trough; very poor

Vegetation: 20% Scrub Acacia drepanolobium
50% Low herbs
30% Bare ground

Rooting below 45 inches

0-6" Very dark grey(10YR3/0) extremely hard, heavy clay, with coarse and medium strongly developed blocky structures. Vertical cracking to 1½ inches. Surface ½ inch has granular and very fine and fine strong blocky structure. Few fine rust mottles. Very slight matrix reaction with 10% HCl. Few fine and medium calcium concretions. Common fine and very fine roots. Gradual lower boundary.

6-28" Very dark grey (10YR3/0) extremely hard very heavy clay, with fine to coarse strongly developed blocky and lenticular structures. Slickensides with clay faces. Slight matrix reaction with 10% HCl. Few fine to medium calcium concretions, increasing with depth and becoming locally common. Few fine and very fine roots. Diffuse lower boundary.

28"+ Very dark grey (N4/1) extremely hard heavy clay with coarse moderately developed blocky structure. Slight matrix reaction with 10%HCl. Abundant fine and medium calcium concretions, locally in clusters. Few to common coarse lime spots. Few very fine roots.

Data for Profile 21 is provided in Table 4.

(f) Mixed Colluvial Clays close to the Karaba Ridge

Soils of the clay basin are locally overlain with colluvial surface-wash from off the slopes of the Karaba Ridge. This material, being derived from basaltic agglomerate is very dark brown (10YR2/2) or very dark greyish brown (10YR3/2): it is somewhat coarser textured than the underlying base level clay. The subsoils tend to be affected by alkaline seepage from off the Karaba Ridge. For this reason, it will

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TABLE 4

LOCATION: KARABA EXTENSION PIT 21

LAB. NO. 769 - 771 : 1967

INCHES Depth	%C	% Sand	% Silt	% Clay	C.E.C.	Exchangeable bases m.e.% Ca	Mg	K	Na	E.S.P.
0-6	1.18	13	4	83	80	50	27.9	0.2	2.4	3.0
6-28		9	10	81	72	46	30.4	0.2	6.9	9.6
28+		15	6	79	70	44	36.0	0.3	15.0	25.0

INCHES Depth	pH 1:5 H_2O	pH Sat. Ext.	% $CaCO_3$	EC_e Sat. ext.	Available Nutrients m.e.% K	Ca	Mg	P ppm.
0-6	7.6	8.3	0	0.2	0.04	15.6	10.0+	34
6-28	8.7	8.6	0.1	0.5	0.02	12.6	10.0+	33
28+	8.9	8.7	4.6	0.6	0.02	14.0	10.0+	28

TABLE 5

LOCATION: KARABA EXTENSION. PIT 24 — LAB. NO. 778 – 780: 1967

INCHES Depth	%C	% Sand	% Silt	% Clay	C.E.C.	Exchangeable bases m.e. % Ca	Mg	K	Na	E.S.P.
0-10	1.40	7	12	81	80	52	17.6	0.6	0.6	0.8
10-39		15	13	72	72	42	32.0	0.2	5.2	7.2
39+		9	8	83	68	35	37.6	0.3	10.2	15.0

INCHES Depth	pH 1.5 H_2O	pH Sat. Ext.	% $CaCO_3$	EC_e Sat. ext.	Available Nutrients m.e.% K	Ca	Mg	P ppm.
0-10	8.0	8.4	0.5	0.3	0.06	18.8	10.0^+	34
10-39	8.9	8.7	7.7	0.6	0.02	15.4	10.0^+	28
39+	8.7	8.7	5.9	0.6	0	13.6	10.0^+	26

be necessary to dig a deep interceptor drain below the length of the Karaba Ridge.

Unless further deterioration occurs, this soil is considered suitable for padi. It covers only the very fringe of the South East edge of the Project Area and, for this reason, is not described in detail.

Profile No. 24 is considered representative of these soils, data for which is presented in Table 5.

(g) Soils of the Clay Basin

These are very dark grey heavy clays which crack deeply and form a mulchy granular structure at the surface when drying (Grumustert). The solum is very hard when dry, sticky and very plastic when wet, with strongly developed blocky structures and subsoil slickensides. The clay is composed of nearly pure and well crystallized montmorillonite which is impermeable and poorly drained. Variable amounts of free lime are precipitated in the profile, mostly in the form of calcium concretions which become more numerous with depth. The topsoil is slightly alkaline, but below about 3 feet there is moderate alkalinity.

Since this soil type covers over half the Project Area, it is treated in considerable detail.

Despite the apparent uniformity of this soil type, some variation exists:

(a) In the degree of subsoil alkalinity.

(b) In the distribution of calcium concretions.

(c) In the extent of gleisation.

(d) In the proportion of surface organic matter.

Organic matter tends to accumulate in areas of seasonal water-logging; but the level is significantly reduced by surface cultivation.

A sub-type is distinguished in the lower lying areas of the Central trough. Here the clays are subject to seasonal water-logging and are distinguished by particularly heavy texture (average topsoil has 9% silt and 83% clay; subsoil has 5% silt and 84% clay), organic accumulation at the surface, common calcium concretions and gleied blotched subsoils. The distribution of this soil broadly corresponds with the area of Acacia seyal, but spreads somewhat beyond this woodland.

Soil Profile No. 18 has been selected as representative of this sub-type:

Profile Description

Pit No. 18

Profile Depth: 57 inches

Slope: 10' — Aspect: East

Relief: Near base of trough: Microrelief: Undulating

Drainage: Receiving. Seasonally ponded.

Vegetation: Bush; 20% Acacia drepanolobium
10% Acacia seyal
Euclea divinorum

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Ground cover; 90% Chloris
Cyperaceae
Themeda triandra
Sesbania sp.
Sphaeranthus sp.

Rooting below 57 inches.

<u>0-9</u>" Very dark grey (10YR3/1) very hard, very heavy clay, with very fine strongly developed blocky structures. Occasional vertical cracks. Few very fine to medium calcium concretions. Occasional fine and distinct rust mottles. Very slight rusting in root channels. Common fine and very fine roots, locally abundant. Gradual lower boundary.

<u>9-35</u>" Dark grey (10YR4/0) extremely hard, very heavy clay, with medium strongly developed blocky structures. Slickensides with clay faces. Slightly gleied with very faint blotching. Very slight matrix reaction with 10% HCl. Few to common fine calcium concretions. Few fine to very fine roots decreasing with depth. Diffuse lower boundary.

<u>35"+</u> Dark grey (10YR4/0; N4/1; N4/0) very hard, very heavy clay, with strongly developed blocky structures. Well-developed clay faces and slickensides. Common very fine rust mottles. Occasional faint rust blotching. Few fine calcium concretions increasing with depth; occasional coarse calcium concretions. Few coarse lime spots increasing with depth. Very few very fine roots.

Data for Profile 18 is provided in Table 6.

Since the sub-type described above was found to exhibit no crucial differences from the soils occurring elsewhere in the clay basin (in areas <u>not</u> subject to seasonal water-logging), it was determined to group all the soils of the clay basin together, regardless of drainage status, for the purpose of calculating the mean values which are set out in Table 7 below. These values have been computed from data derived from 18 soil profiles. The range in values (i.e. highest and lowest value recorded) is also indicated in Table 7.

No samples (anywhere in the Project Area) were found to be saline.

Two Soil Profiles - Numbers 12 and 17 - have been selected to represent this soil type, which covers an appreciable portion of the Project Area and which is considered suitable for padi. The profiles are, respectively, East and West of the Central trough.

<u>Pit No. 12</u> <u>Profile Description</u>

<u>Profile Depth</u>: 60"

<u>Slope</u>: 10' <u>Aspect</u>: South West

<u>Relief</u>: Plane Microrelief: Gently undulating

<u>Drainage:</u> Poor

<u>Vegetation:</u> 10% { Acacia drepanolobium
Acacia polyacantha
Balanites aegyptiaca
90% Chloris/Setaria grassland.

Rooting to 48".

<u>0-5"</u> Very dark grey (10YR3/0; 3/1) very hard, very heavy clay, with a strongly developed granular and fine blocky structure. Slight to medium vertical cracking. Few to common fine roots. Gradual lower boundary.

<u>TABLE 6</u>

LOCATION: KARABA PIT 18 LAB. NO. 761 - 763 : <u>1967</u>

EXTENSION.

INCHES Depth	%C	% Sand	% Silt	% Clay	C.E.C.	Exchangeable bases m.e. % Ca	Mg	K	Na	E.S.P.
0-9	2.25	7	8	85	81	54	26.8	0.3	1.0	1.2
9-35		9	6	85	86	50	32.8	0.1	1.5	1.7
35+		13	4	83	80	40	40.8	0.1	5.8	7.3

INCHES Depth	pH 1.5 H_2O	pH Sat. Ext.	% $CaCO_3$	ECe Sat. ext.	Available m.e. % Nutrients K	Ca	Mg	P ppm.
0-9	7.2	8.3	1.1	0.4	0.04	15.2	9.4	33
9-35	8.3	8.5	1.4	0.5	0.02	13.6	10.0	35
35+	8.9	8.4		0.5	0	10.6	10.0	36

TABLE 7

		% C	% Silt	% Clay	% $CaCO_3$ Free Lime	pH 1:5 H_2O	pH Sat. Ext	E.S.P.	Exch.K m.e.%	P ppm.
TOPSOIL	MEANS	1.5	8	81	0.7	7.2	7.9	1.3	0.7	34
	RANGE	1.[illegible]-2.2	4-12	73-87	0-4.6	6.2-8.2	7.4-8.4	0.7-3.7	0.1-2.2	28-40
SUBSOIL	MEANS		7	81	3.1	8.2	8.1	4.9		
	RANGE		2-14	71-89	0.1-11.3	6.7-9.2	7.4-8.8	1.1-6.7		

LOCATION: KARABA EXTENSION PIT 12 — TABLE 8 — LAB. NO. 406 – 408 & 748: 1967

INCHES Depth	% C	% Sand	% Silt	% Clay	C.E.C.	Exchangeable bases m.e. % Ca	Mg	K	Na	E.S.P.
0 – 5	1.40	7	8	85	96	57	25.0	2.2	1.2	1.3
5 – 39		9	6	85	96	55	26.0	1.9	3.4	3.4
39 – 50		11	6	83	96	60	27.4	1.8	5.8	5.8
50+		23	8	69	90	60	28.0	0.1	7.4	8.2

INCHES Depth	pH 1:5 H_2O	pH Sat. Ext.	% $CaCO_3$	EC Sat. ext.	m.e.% Available Nutrients K	Ca	Mg	P PPM.
0 – 5	6.5	7.7	0.1	0.2	0.06	18.8	9.2	36
5 – 39	6.7	7.7	0	0.3	0.03	16.4	9.2	34
39 – 50	8.6	8.4	1.4	0.6	0.02	17.4	9.2	34
50+	8.7	8.3	8.9	0.5	0	20.0	9.0	28

5-39" Very dark grey (10YR^3/0; ^{3}/1) extremely hard, very heavy clay, with a weakly developed prismatic structure and very strong blocky microstructures with clay faces. Slickensides increasing with depth. Very slight matrix reaction with 10% HCl. Very few fine calcium concretions. Few fine and very fine roots. Diffuse lower boundary.

39-50" Very dark grey (10YR^3/1) very hard, very heavy clay with coarse strongly developed sub-angular blocky structures. Few organic casts. Common very fine to fine calcium concretions increasing with depth. Occasional coarse lime spots. Very few fine to very fine roots. Diffuse lower boundary.

50"+ Very dark grey (10YR^3/1) to dark grey (10YR^4/1) very hard medium clay with blocky structure. Matrix gleied with abundant faint light blotching: also some distinct dark blotching. Slight matrix reaction with 10% HCl. Abundant fine calcium concretions.

Data for Profile 12 is presented in Table 8.

Pit No. 17 Profile Description

Profile Depth: 52"

Slope: 35#/ Aspect: East South East

Relief: Gentle slope down to Central Trough

Microrelief: Tussocks.

Drainage: Poor.

Vegetation: < 10% Acacia drepanolobium
90% Chloris.
10% Bare ground

Rooting below 52 inches.

0-9" Very dark grey (10YR^3/1) very hard, heavy clay with fine to coarse, moderate to strongly developed sub-angular blocky structure. Surface ½ inch of strong granular and very fine blocky structure. Vertical cracking to 1" with root tearing across cracks. Very few fine calcium concretions. Common fine and very fine roots. Gradual lower boundary.

9-34" Very dark grey (2.5Y^3/1 to N^4/1) extremely hard, heavy clay; fine and medium strongly developed blocky and lenticular structures with clay faces and slickensides. The lenticular orientation is well developed, cracking at 35 to 40° to the vertical. Few fine and medium calcium concretions. Very slight matrix reaction with 10% HCl at the horizon base. Few fine and very fine roots with a few root galleries. Occasional medium roots. Clear and undulating lower boundary.

34"+ Very dark grey (10YR^3/1) very hard, very heavy clay, with coarse and medium strongly developed blocky structures, having poorly developed clay faces. Slight matrix reaction with 10% HCl. Abundant fine and medium calcium concretions. Occasional coarse lime spots. Very few very fine roots.

Data for Profile 17 is presented in Table 9.

Out of 85 soil profiles opened up, or augered, on this soil type: 46 exceeded 4 feet in depth; 23 struck rocks between 42 and 48 inches; 11 showed soil between 36 and 42 inches deep; and 5 indicated between 24 and 36 inches of soil, i.e. it can be expected that about 94% of the land area covered by this soil type has a depth in excess of 36 inches.

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The topography indicates that these soils will have to be bunded at different levels so as to ensure an equitable distribution of water.

The soil factors likely to limit padi development on this land (leaving aside consideration of the depth and stoniness which were dealt with in the previous section) are the alkalinity and the existing balance of nutrients.

Alkalinity

The ideal pH for padi is between 5.5 and 6.5. Thorp ("Geography of the Soils of China", 1936) has related soil reaction to crop yields in China. He gives the following mean yields (in lbs. per acre): 2,678 lbs. from soils of pH below 6.5; 2,615 lbs. from neutral soil - pH 6.5 to 7.5; 2,320 lbs. from saline and alkaline soil, pH exceeding 7.5; 1,920 lbs. from non-saline and alkaline soil, pH exceeding 7.5. Thus, whilst padi is tolerant of a wide range of soil reaction, it appears to show a preference for acid soil. The alkalinity seems to be harmful to padi during the early growth stages; yet in parts of India, Australia and Peru, amongst other places, padi is reported to produce reasonable yields at pH levels around 8.

It can therefore be predicted with reasonable confidence that yields of padi on the Karaba extension will be lower than those from the existing scheme, yet not disastrously so: the difference may be from 2 to 6 bags per acre.

It should be remembered that the pH of the land under padi will not, in any case, remain static, but will vary according to soil moisture status, plant growth and season. In general, the pH can be expected to rise during flooding and fall on drainage. Long continued irrigation is likely to result in a depletion of bases, especially sodium. Furthermore, applications of ammonium sulphate will not only provide nitrogen for the crop but may, over a long period, also effect a decrease in alkalinity.

Fertility

Considerable differences exist between different soil types in the quantities of nutrients removed from the soil by padi. It is generally found, however, that rice takes up comparatively large amounts of nitrogen and potassium and low levels of phosphate. Potassium is particularly important in the early months since it promotes the set of grain, improves tillering, increases disease resistance and plays an important role in the formation of starch. In Malaya, it was found that a crop of 2,800 lbs. per acre removed in the grain and the straw, 67 lbs. of nitrogen, 10 lbs. of P_2O_5 (phosphate) and 70 lbs. K_2O (potash).

There is evidence to indicate that continuing irrigation with the Thiba water is causing loss through leaching, and ultimate impoverishment. Soil analyses presently indicate deficiencies in nitrogen and potassium. Yet no response has yet been obtained at Mwea with potassium fertilizer. This may be due to a nutrient imbalance. The analyses indicate a most unfavourably high ratio of Magnesium to Potassium. If it is this that is preventing a response, then there is nothing that can be done. On the other hand, it is well known that addition of but a single element to padi may be beneficial only within narrow limits, and may even cause a depression in yield where, as at Mwea, more than one nutrient is deficient. It is possible that enhanced yields may be obtained on the Karaba extension by the application of both nitrogen (as ammonium sulphate) and potassium.

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TABLE 9

LOCATION: KARABA EXTENSION. PIT 17.

LAB. NO. 758 - 760 1967

INCHES Depth	%	% Sand	% Silt	% Clay	C.E.C	Exchangeable bases m.e.% Ca	Mg	K	Na	E.S.P.
0-9	1.15	15	10	75	76	44	24.4	0.4	1.0	1.3
9-34		19	10	71	76	45	28.4	0.2	4.4	5.8
34+		9	4	87	77	46	30.5	0.2	5.8	7.5

INCHES Depth	pH. 1:5 H_2O	pH. SAT. EXT.	% $CaCO_3$	EC_e Sat. ext.	Available Nutrients m.e.% K	Ca	Mg	P ppm.
0-9	6.9	8.0	0	0.2	0.07	14.4	9.4	34
9-34	8.3	8.7	0	0.5	0.03	12.0	9.7	35
34+	8.5	8.5	3.4	0.6	0.03	15.0	10.0	32

8. KARABA EXTENSION; SUMMARY OF ACREAGES

	ESTIMATED ACREAGE.
(i) Unsuitable Areas	
Due to Boulders and Underlying Rock	115
Due to Alkali	
(a) Slopes down to the Thiba	275
(b) The Karaba Trough	425
(c) Beneath the North Western Escarpment	55
Due to associated design problems, say:	100
TOTAL UNSUITABLE	970 acres
(ii) Suitable Area	2,890 acres

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SOIL SURVEY UNIT

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