REPUBLIC OF KENYA

MINISTRY OF AGRICULTURE—NATIONAL AGRICULTURAL LABORATORIES

KENYA SOIL SURVEY

DETAILED SOIL SURVEY OF NEW THIGIRIE FARM (NAIROBI)

by
B.N.Ita and B.K.Waruru

ISRIC LIBRARY
KE - 1986.24
Wageningen
The Netherlands

DETAILED SOIL SURVEY REPORT No.D38,1986

Scanned from original by ISRIC – World Soil Information, as ICSU World Data Centre for Soils. The purpose is to make a safe depository for endangered documents and to make the accrued information available for consultation, following Fair Use Guidelines. Every effort is taken to respect Copyright of the materials within the archives where the identification of the Copyright holder is clear and, where feasible, to contact the originators. For questions please contact soil.isric@wur.nl indicating the item reference number concerned.

ISRIC LIBRARY
KE
86.24
Wageningen, The Netherlands

DETAILED SOIL SURVEY OF NEW THIGIRIE FARM (NAIROBI)

by

B.N. Ita and B.K. Waruru

DETAILED SOIL SURVEY REPORT NO. D38, 1986

TABLE OF CONENTES

Page

APPENDICES

LIST OF TABLES

LIST OF FIGURES

1 INTRODUCTION

At the request of the owner of the farm, a detailed soil survey of New Thigirie farm was carried out from 15th to 19th May, 1984, and in addition one week was spent in taking fertility samples of the whole farm.

The fieldwork was executed by the authors with assistance of Mr. H. Onyono.

Acknowledgements are made to the National Agricultural Laboratories, Soil Physics and Chemistry sections for analysing the samples. The report describes the soils and other ecological conditions of the New Thigirie farm in Western Division of Nairobi Province. It also assesses the land suitability for horticultural crops i.e. fruits and vegetables as well as field crops under rainfed and overhead irrigation method.

2. ENVIRONMENT

2.1 Location and communication

The farm is located about 17 km north west of Nairobi city, and is intersected by latitude $1^{\circ}13'S$ and longitude $36^{\circ}45.4'S$. Its altitude is about 1700 m above sea level.

The farm comprises about 13.6 ha and is connected to the Kihara-Ndenderu road by a dry weather road.

2.2 Climate

The survey area is located in the lower footridges of the Aberdare range. The climatic conditions of the area are described using data of Closeburn Estate Ltd (Nairobi) rainfall station (91.36104). The station has a rainfall record of 47 years (E.A.M.D., 1972) and lies 3.4 km NE of the survey area.

2.2.1 Annual and seasonal rainfall averages

The area has two rainfall seasons. The long rains occur from February to May with a peak in April, while the short rains fall from October to December having a peak in November. Total annual rainfall is 1065 mm (E.A.M.D., 1972).

Dry months are June to September and January, with July (18.2mm) as the driest month of the year (see table 1). The average seasonal rainfall for the long rains is about 583 mm (55%) and for the short rains 320 mm (30%). The dry months receive 164 mm (15%).

2.2.2 Maximum, mean and minimum temperatures

The mean annual temperature calculated using the equation $T^{o}C = 30.2 - 0.0065x$, where x is altitude in thousands of metres (EAMD, 1970), is $19^{o}C$. Mean maximum, mean minimum and absolute minimum calculated using similar formulae are $25^{o}C$, $12^{o}C$ and $5^{o}C$ respectively (see table 2).

2.2.3 Potential evaporation and evapotranspiration

Potential evaporation is estimated to be 1800 mm using Woodhead's (1968) equation {Eo (mm) = 2422 - 0.358h, where h is the station altitude in meters}. Evapotranspiration (2/3 Eo) is estimated to be 1200 mm. Both seasonal Eo calculated after Braun (in prep), and Et (2/3 Eo) are shown in table 1.

2.2.4 Simple water balance

A water balance is the difference between the amount of rainfall received at a particular place and its loss by evapotranspiration (r-Et). The Et is taken to be the crop water requirement.

Table 1. Mean, monthly and annual rainfall (r), potential evaporation (Eo), evapotranspiration Et = (2/3 Eo), Simple water balance (r-Et) and r/Eo ratio of the Closeburn Estate Ltd rainfall station

Month	J	F	M	A	M	J	J	A	S	O	N	D	Year
r (mm)	49	56	116	230	180	43	18	26	27	68	156	96	1065
Eo (mm)	198	180	180	144	126	108	90	108	162	180	144	180	1800
Et (2/3 Eo)mm	132	120	120	96	84	72	60	72	108	120	96	120	1200
r-Et (mm)	-83	-64	-4	134	96	-29	-42	-46	-81	-52	60	-24	
r/Eo (%)													

The results of a simple water balance for Closeburn Estate rainfall station are shown in Table 1. As can be seen from the table, the area has rainfall deficits in most of the year except in the months of April, May and November. That is, in these months rainfall is in excess of the crop requirements. The highest deficit is in the month of January while the lowest is in the month of March.

The rainfall probability of the area based on Braun (1977) is for long rains 69% and short ones 38%. This means that in the long rains on average in 7 out of 10 years there will be enough rainfall to meet the crop water requirements. For the short rains, it will be only in on average 4 out of 10 years.

Assuming the soil will retain the water during the long rains, both early and later maturing crops would not need any additional water. During the short rains, there is high seasonal water deficit for both early and late maturing crops and hence the need for supplementary water by irrigation. Irrigation is also needed to counter balance the low rainfall probability during that season.

Table 2. Temperatures (^{o}C)for Closeburn Estate Ltd Station

Mean annual temperature	19
Mean maximum temperature	25
Mean minimum temperature	12
Absolute minimum temperature	5

2.3 Geology and physiography

Geologically the farm is situated in the Tertiary volcanics of the "Middle Trachyte Division", namely the "Middle Upper Kerichwa Valley Tuffs" according to Saggerson (1971).

Physiographically the farm can be divided into two units viz., footridges and the minor river valley. Footridges are made up of parallel crests incised by parallel rivers on the flanks of major volcanoes. The major landform of the farm consists of a NW-SE running footridge. The ridge has convex slopes increasing from 2% at the flat-topped crest towards 30-45% at the flanks. The valley bottom is very narrow and flat,

and lies about 40 m lower than the top of the footridge. About half of the farm has slopes between 0 and 16%, while the remainder has slopes between 16 and 45%.

2.4 Vegetation and present land use

Most of the natural vegetation has been cleared to give room for crop production. Except for three fields which have been left uncultivated for grazing purpose, a small strip near the river occupied by gum trees, the homestead area and labour lines, the rest of the farm is under cultivation.

The cultivation of crops is mostly on the flat and the very gently sloping areas where the following crops are grown: cabbages, egg plants (Brinjals), carrots, bananas, capsicums, maize, napier grass, Irish potatoes, sweet potatoes, beans, tomatoes, citrus, spinach, cucurbits and pawpaws. The steep sloping area is used for cultivation of maize and cassava. The minor river valley is used for growing maize, tomatoes, cucumbers, cocoyams, lettuce and napier grass.

2.5 Hydrology and water quality

River Thigirie, a perennial stream, borders the farm on the southern side. The water from this river is used for irrigating crops on the farm.

The water quality for irrigation is determined by the degree of salinity, sodicity, and concentration of toxic elements such as Boron. Two water samples were taken from River Thigirie at an up stream and a down stream site along the farm. As can be seen in the table, the two water samples are the same in terms of dissolved ions except sulphates which vary. The up stream sample having higher amounts of sulphates than the down stream sample (see Table 3).

Suitability classification of the water for irrigation based on Richards (1954) is C2-S1 i.e., medium salinity (C2) and low sodicity (S1). Crops with moderate salt tolerance can be grown in most cases without special practices for salinity control. It can be used for irrigation on most soils with little danger of developing harmful levels of exchangeable sodium.

However, low salt tolerant crops such as oranges, lemons, beans, peas, tomatoes and avocadoes will be adversely affected unless appreciable leaching of the salts is done.

Table 3. Water sample analysis

Ref.	Thigirie River Up stream	Down stream
Lab. No./84	4605	4606
pH	7.6	7.8
Conductivity (micro mhos/cm)	350	350
Sodium (me/litre)	2.17	2.17
Potassium "	0.2	0.2
Calcium "	0.6	0.55
Magnesium "	0.55	0.6
Carbonates "	Nil	Nil
Bicarbonates "	1.72	1.70
Chlorides "	1.85	1.85
Sulphates "	0.80	0.07
Sodium adsorption ratio	2.86	2.86

3. WORKING METHODS

3.1 Soil survey methods

3.1.1 Office methods

Before commencing fieldwork any relevant data to the survey area was collected and studied viz., a map of the farm from the Land Adjucation Department, Ruiru at a scale of 1:1,250, the exploratory soil map of Kenya (Sombroek et al, 1982), the geological map of the area and the topographical map sheet No. 148/2 at a scale of 1:50,000.

3.1.2 Field methods

A topographical map from the Land Adjucation Department, Ruiru at a scale of 1:1,250 was used as the base map. Soil depth permitting, augerhole observations to a depth of 250 cm were made following a 100 by 100 m grid system. A total of 22 augerhole observations were investigated for depth, colour, texture, mottling, consistence, calcareousness (by HCl reaction) and pH determined according to the "Guidelines for soil

profile description" (FAO, 1977). These properties were recorded on the standard Kenya Soil Survey forms.

Soil colour was determined using the "Munsell Soil Color Charts" (Munsell Color Co. 1971), while soil classification was based on the legend of the "Soil map of the World" (FAO-UNESCO, 1974). Fertility samples were taken at 0-30 cm and at 30-60 cm depth. These were in addition to the fertility samples taken from the sites of the described profile pits.

Different slope aspect sites were selected and 4 profile pits dug. A profile pit in mapping unit VPgp could not be dug because it was too muddy, and therefore augerhole observations were used for its characterisation. Augerhole and profile pit observations, soil and slope class boundaries were marked on the base map. After fieldwork corrections were done, the soil map was reduced to a scale of 1:2,500 in the drawing office, where it had been forwarded together with the legend through map correlators for final drawing.

3.2 Laboratory methods

Chemical, physical and fertility analyses of the samples were carried out by the NAL/KSS laboratories. A brief breakdown of the methods is given below. For a detailed methodology, refer to Hinga et al (1980).

Prior to analysis all samples were air-dried, crushed and sieved through a 2 mm sieve.

Texture	: hydrometer method
pH H_2O/1NKCl	: in 1:2.5 soil-water/salt suspensions
Electrical conductivity (EC)	: was measured in a 1:2.5 soil/water suspension.
% Carbon	: Determined according to Walkley and Black method on A-horizon only.
% Nitrogen	: Semi-micro Kjeldahl method on A-horizon only.

Exchangeable cations

The soils were leached with 1N ammonium acetate at pH 7.0 and the exchangeable cations viz., Ca, Mg. K and Na were determined with an EEL-flame photo-meter/atomic absorption spectrophotometer.

Cation exchange capacity (CEC)

Following the leaching of the soils for exchangeable cations, the soils were successively leached with 95% ethyl alcohol, 1N sodium acetate at pH 8.2, 95% ethyl alcohol and 1N ammonium acetate at pH 7.0 solution The CEC was determined by measuring the Na concentration in the last leachates with an EEL-flame photometer.

"Mass analysis" for available nutrients (on A-horizon only)

Soils were extracted by shaking with 1:5 0.1N HCl/0.025N H_2SO_4 ratio. Then Ca, K and Na were determined by EEL-flame photometer. Mn and P were determined colorimetrically.

Bulk density

Determination of oven-dry ($105^{o}C$) weight of a soil core of known volume.

pF

Determination of moisture percentage of suctions of 0.001 and 0.2 and pressures of 15.0 atmosphere (pF 0, 2.3 and 4.2 respectively). Undisturbed ring samples for low pF values and disturbed samples for highest pF values were used.

4. THE SOILS

4.1 Previous work

According to the exploratory soil map of Kenya (Sombroek et al, 1982), the soils are described as well drained, extremely deep, dusky red to dark reddish brown, friable clay; with inclusions of well drained moderately deep, dark red to dark reddish brown, friable clay over rock, pisoferric or petroferric material (eutric NITISOLS*; with nito*-chromic CAMBISOLS and chromic* ACRISOLS, partly pisoferric or petroferric phase) occuring on the footridges of major older volcanoes.

4.2 General properties of the soils

The soils of the survey area fall under two categories of physiography viz., the footridges and the minor river valley.

The soils ofthe footridges consist of well drained, deep to extremely deep, dark red to dark reddish brown, friable clay. In places the soils are rocky and stony on the surface. They have a moderate to strong, angular and subangular blocky structure with many shiny ped surfaces.

The minor valley soils consist of imperfectly drained, deep to very deep, dark reddish brown to very dark grey, mottled, friable silty clay to clay. Generally, the soils of the survey area have a high CEC and a medium to high base saturation. The pH ranges from 5.0-6.8. Fertility is moderate with N adequately supplied but P deficiency is prevalent in the soils.

4.3 Systematics and nomenclature

The criteria used for separation of mapping units are physiography, parent material and soil characteristics such as depth, texture and colour; slopes are also indicated.

Each mapping unit is shown on the map by a code for which the following system is used.

(i) Physiography

R - volcanic footridges

V - minor valley

(ii) Geology (Parent material)

P - pyroclastic rocks (trachytic tuffs)

(iii) Soil depth classes

Depth class code	Thickness of soil (cm)	Description
-	0-25	very shallow
-	25-50	shallow
-	50-80	moderately deep
P	80-120	deep
-	120-180	very deep
-	>180	extremely deep

(iv) Slope classes

Slope class code	Slope %	Name of the micro relief
A	0-2	flat to very gently undulating
B	2-5	gently undulating
C	5-8	undulating
D	8-16	rolling
E	16-30	hilly
F	>30	mountainous

The numbers 1, 2 indicate different units within the same physiography- geology grouping. The soils are classified according to the legend of the "Soil map of the World" (FAO-UNESCO, 1974). Modifications to this system, known as Kenyan concepts are indicated with an asterisk. For a complete explanation of the Kenyan concept see Siderius and van der Pouw (1980).

4.4. Description of the soil mapping units

(a) Soils of the footridge

Mapping unit RPr1

Extent : 5.7 ha (slope class B), 2.2 ha (slope class CD), 2.2 ha (slope class E), 1.7 ha (slope class F).

Parent material : pyroclastic rocks (trachytic tuffs)

Physiography : footridge

Relief, macro : slope ranges from 2-45% at the top of crest to the flanks respectively.

Relief, micro : termite mounds

Erosion : low to high erosion hazard depending on the slopes

Land use : cultivation of maize, beans, Irish and sweet potatoes, vegetables, bananas and avocadoes under overhead irrigation, grazing of cattle and some buildings

Drainage : well drained

Soils, general : strongly weathered, extremely deep, dark red to dark reddish brown, friable clay, with shiny ped surfaces, and few to

continuous and thick clay skins in the B-horizon. The soils have an ABC sequence of horizons with clear to diffuse and smooth boundaries.

colour : A-horizon: very dusky red (2.5YR 2.5/2 moist) to dark reddish brown (5YR 3/3 to 2.5YR 3/4 moist).
B-horizon: dark reddish brown to dark red (2.5YR 2.5/4-3/6 moist).

texture : clay throughout. Silt/clay ratio varies between 0.3 and 0.5.

structure : A-horizon: moderate to strong, medium to coarse angular and subangular blocky and moderate to strong, medium crumbs.
B-horizon: weak to moderate, medium to coarse subangular blocky.

consistence : friable when moist, sticky and plastic when wet throughout

Chemical properties : A-horizon: %C ranges from 0.23 to 1.74; pH-H_2O 5.7 to 6.8; and pH-KCl varies from 4.6 to 5.6; CEC-soil ranges from 9.0 to 19.4 me/100g; while base saturation varies from 57-87%.
B-horizon: pH-H_2O ranges from 5.0 to 6.6; while pH-KCl ranges from 4.0 to 5.6; CEC-soil varies from 7.4 to 19.4 me/100g; base saturation is 44-79%.

Diagnostic properties : An ochric A-horizon, argillic B-horizon, base saturation greater than 50%.

Classification : eutric NITISOLS*

For detailed descriptions of soil profiles with analytical data see appendix 1a, profile descriptions nos. 1, 2 and 4, observation nos. (148/2-88, 148/2-89 and 148/2-91).

Mapping unit RPr2*p*

Extent	: 1.0 ha (slope class F)
Parent material	: pyroclastic rocks (trachytic tuffs)
Physiography	: footridge
Relief, macro	: mountainous, slopes >30%
Relief, micro	: nil
Erosion	: has a high erosion hazard
Land use	: cultivation of rainfed maize
Drainage	: well drained
Soils, general	: This unit has strongly weathered, deep to very deep, dark reddish brown, clay soils with common, thin to continuous moderately thick clay cutans in the B-horizon, with krotovinas and termites. The soils have an ABC sequence of horizons with clear to diffuse and smooth boundaries.
colour	: A-horizon: dark reddish brown (5YR 5/2 moist) B-horizon: dark reddish brown (2.5YR 2.5/4 moist)
texture	: clay throughout
structure	: A-horizon: moderate to strong, fine to coarse crumbs and subangular blocky. B-horizon: moderate to strong, fine to coarse angular and subangular blocky leading to weak massive in the C-horizon.
consistence	: very friable to firm when moist, sticky and plastic when wet.
Chemical properties	: A-horizon: %C is 0.11; pH-H_2O is 5.8; pH-KCl is 5.0; CEC-soil 11.6 me/100g; base saturation is 86% B-horizon: pH-H_2O ranges from 5.3 to 5.9 while pH-KCl varies from 3.5 to 4.8; CEC-soil ranges from 8.6 to 13.2 me/100g; base saturation varies from 60-81%.

Diagnostic properties	: Ochric A-horizon, argillic B-horizon, base saturation greater than 50%
Classification	: chromic LUVISOLS

For a detailed description of a soil profile with analytical data see appendix 1a, profile description no. 3 (observation no. 148/2-90).

(b) Soils of the minor valley

Mapping unit VPgp

Extent	: 0.80 ha (slope class A)
Parent material	: infils derived from trachytic tuffs
Physiography	: minor valley
Relief, macro	: flat to very gently undulating (0-2% slopes)
Relief, micro	: nil
Erosion	: low erosion hazard
Land use	: cultivation of rainfed vegetables, maize, and napier grass
Drainage	: imperfectly drained
Soils, general	: These are weakly weathered,dark reddish brown to very dark grey clays; seasonally flooded, mottled and wet with shallow ground water level.
colour	: A-horizon: dark reddish brown (5YR 2.5/2 moist)
	: B-horizon: dark reddish brown (5YR 2.5/2 moist)
texture	: clay
consistence	: friable when moist, sticky and plastic when wet throughout
Chemical properties	: A-horizon: %C is 1.36; pH-H_2O is 6.4; pH-KCl 5.5; and CEC-soil 9.8 me/100g; base saturation is 68%
	: B-horizon: pH-H_2O is 6.5, pH-KCl 5.5; CEC-soil is 13.4 me/100g; base saturation is 93%.

REMARKS: No profile pit was dug in this mapping unit, so augerhole observation no. 79 was used as a sample for analytical data.

4.5 Soil physical aspects

Availability of soil water in sufficient amounts is a major requirement for crops if they have to grow properly. A decrease in soil water beyond a critical level can cause permanent failure to crops through wilting. It is therefore necessary to know the water storage capacities of the soil in order to evaluate their capability to sustain crop growth.

Available soil water

Five core samples from each horizon of two profile pits (nos. 148/2-89 and 148/2-91) in mapping unit RPr1, were analysed at pF 2.3. Disturbed soil samples from the same horizons were similarly analysed at pF 4.2.

Available water has been assumed to be the amount of water present in the soil between these two tension levels. The results obtained are shown in tables 4 and 5.

The total available water obtained over one meter depth is 98 mm and 93 mm for profile pits 148/2-89 and 148/2-91 respectively. From this, it follows that this soil has a high water storage capacity (Braun and van de Weg, 1977).

Table 4. Water retention and bulk densities (b.d.)

Profile No.	Depth (cm)	Water retention (wt%) pF 2.3	pF 4.2	Bulk density (g/cm^3)
148/2-89	0-18	39.1	26.4	1.00
	18-70	37.3	28.2	1.00
	70-112	39.9	30.6	1.00
148/2-91	0-24	37.2	26.8	1.02
	24-39	34.6	26.3	1.01
	39-60	36.2	27.2	1.04
	60-107	36.5	27.6	1.00

Table 5. Available water (a.w.) for the depths 0-50cm and 0-100cm

	Profile no. 148/2-89		Profile no. 148/2-91	
Depth (cm)	0-50	0-100	0-50	0-100
a.w. (mm)	52	98	47	93

NB. Available water has been calculated as a product of water retention between pF 2.3 and pF 4.2, bulk density and depth.

4.6 Soil fertility aspects

Due to the different land use practices in the various plots, fertility samples were taken from 29 sampling sites covering approximately every plot. These were in addition to the fertility samples taken from and around the four described profile pits.

At every such sampling point (see figure 1 and 2 and tables in appendix 1b), a sample with subscript 'a' is of the 0-30cm depth while subscript 'b' represents the subsoil 30-60 cm depth.

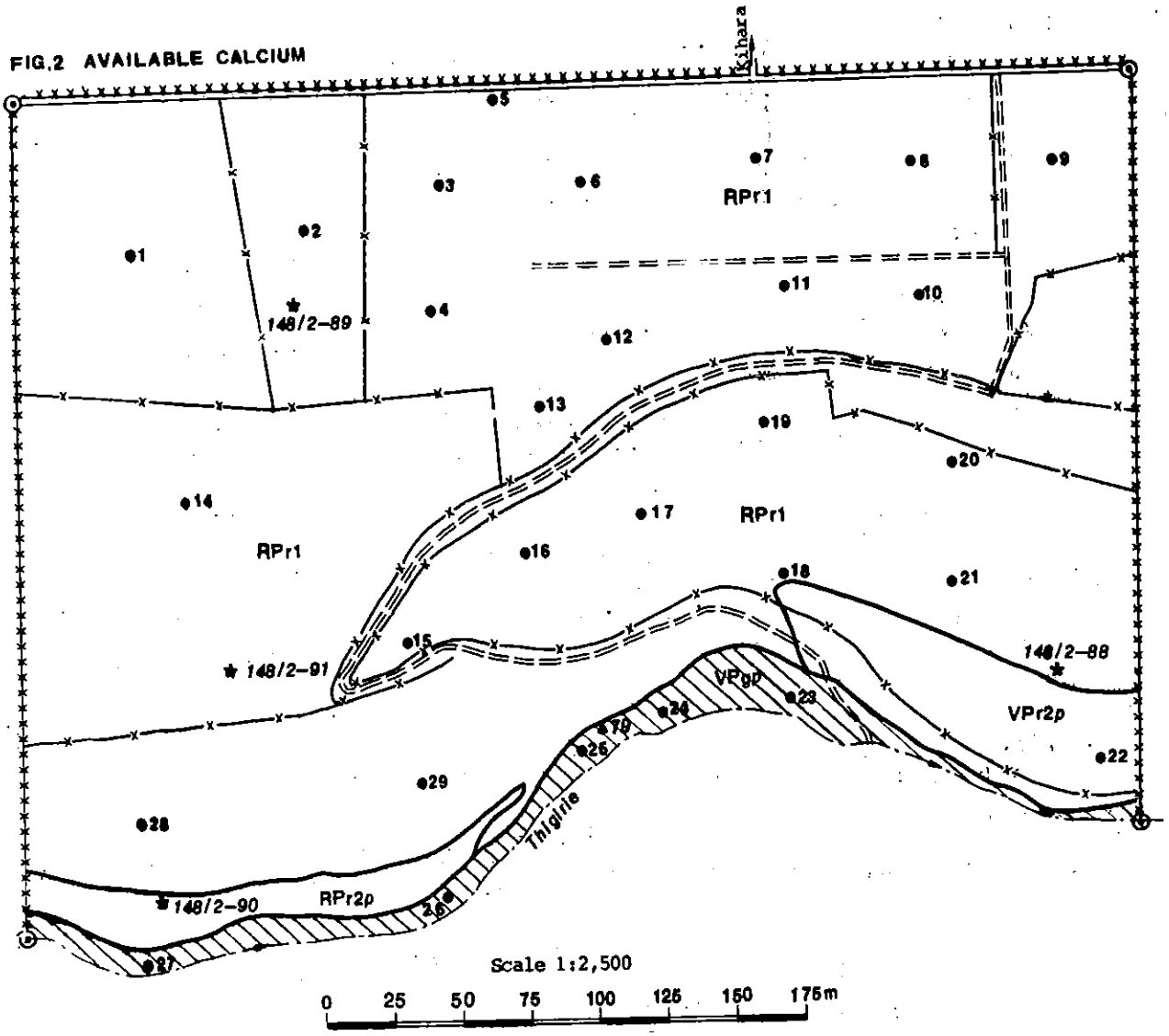
Table 6. Fertility analysis results (0-30 cm) of profile pits

Mapping unit/ slope class	RPr1 F	RPr1 B	RPr1 F	RPr1 CD	VPgp A
Profile No.	148/2-88	148/2-89	148/2-90	148/2-91	148/2-79+
Lab. no. .../84	4607	4608	4609	4610	4611
pH	6.0	6.1	6.0	5.7	6.5
Na (me/100g)	0.18	0.34	0.16	0.16	0.16
K "	1.35	1.74	1.32	1.28	0.88
Ca "	3.8	7.8	9.4	3.8	10.0
Mn "	1.55	1.46	1.60	1.55	2.0
P (ppm)	14	38	7	7	14
N %	0.24	0.30	0.33	0.29	0.28
C %	1.63	2.45	2.39	2.45	2.01

+ augerhole observation

Deficiencies underlined

FIG.2 AVAILABLE CALCIUM



LEGEND

High calcium level area (10-20 me/100g)

Medium calcium level area (6-10 me/100g)

For explanation of the codes see appendix 2

KEY

★ 148/2-88 Profile pit with fertility sampling and reference number

●16 Fertility sampling site with reference number

▲79 Augerhole observation with fertility sampling and reference number

Soil boundary

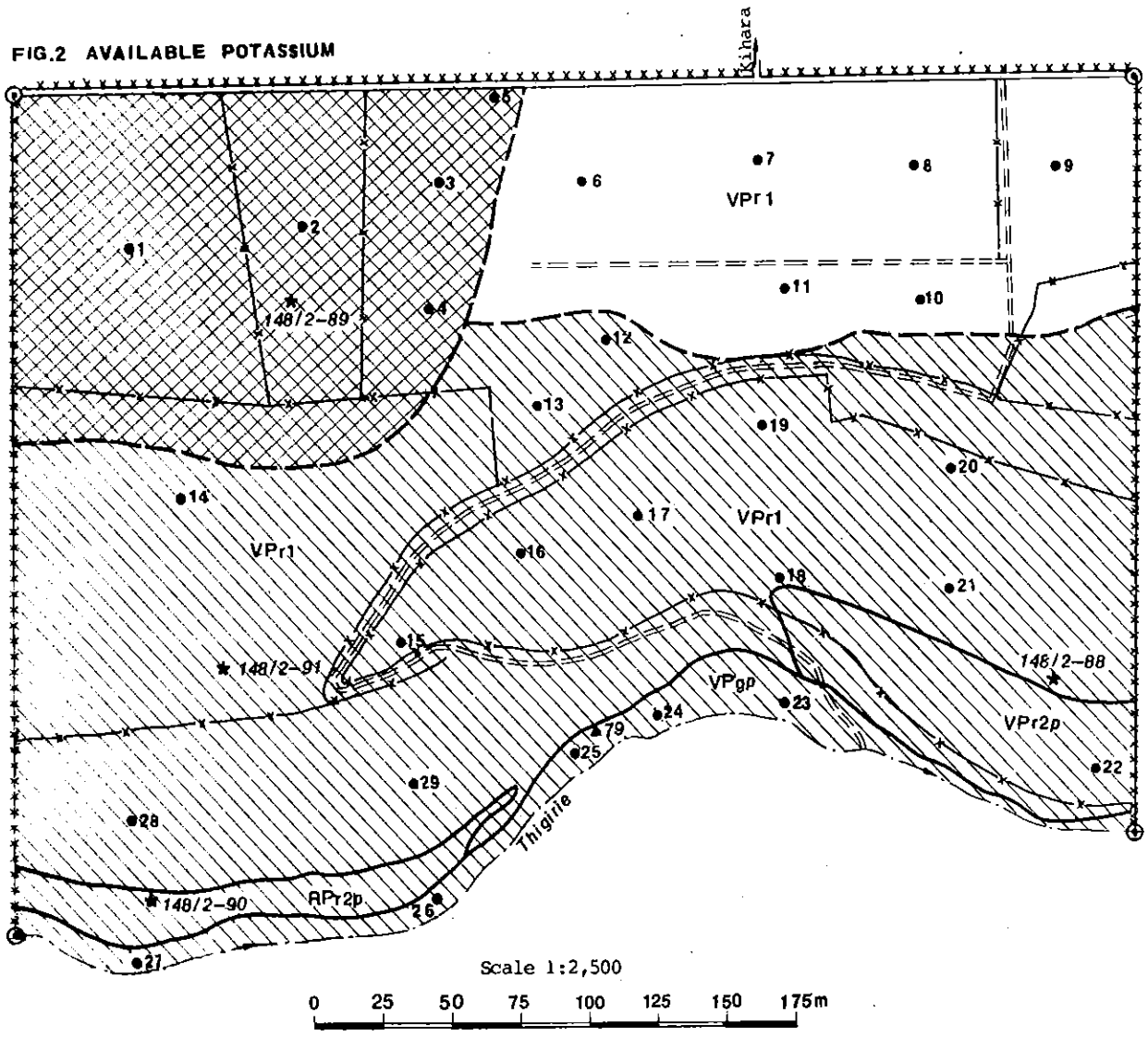
Motorable track

River

Plot boundary

survey area boundary

FIG.2 AVAILABLE POTASSIUM



LEGEND

Medium potassium level area (1.5-2.0 me/100g)

Medium to low potassium level area (0.3-2.0 me/100g)

Low potassium level area (0.3-1.0 me/100g)

For explanation of the codes see appendix 2

KEY

★ *148/2-88* Profile pit with fertility sampling and reference number

●16 Fertility sampling site with reference number

▲79 Augerhole observation with fertility sampling and reference number

Soil boundary

Motorable track

River

Plot boundary

survey area boundary

potassium level boundary

From table 6 above and tables in appendix 1b, it can be seen that the soils reaction varies from medium acid to slightly acid. The soils are adequately supplied with basic plant nutrients (viz., Ca, K and Na). Mn is sufficiently supplied to the soils.

On the other hand, most of these soils have adequate N but they are deficient in P (underlined) except in 3 samples. Cu is also deficient in all soils. There is adequate distribution of organic matter in soils except in one sample (underlined) where low C% is being observed.

In view of the above remarks, it is therefore recommended that phosphate fertilizers be applied to those soils deficient in P. Also farm yard manure and/or compost manure could be applied to these soils to improve their status and the supply of the deficient elements to the plants for better yields.

Fertility analysis results in table 6 and tables in appendix 1b were used for classification of some basic plant nutrients. Classification was based on ratings shown in table 7 below and the results shown in figures 1 and 2.

Table 7. Classification of some basic plant nutrients levels

P (ppm)	K(me/100g)	Ca(me/100g)	Interpretation
>200	> 3.5	> 20	very high
80-200	2.0-3.5	10-20	high
20-80	1.5-2.0	6-10	medium
0-20	0.3-1.0	2-6	low
0-20	<0.3	<2	very low (deficient)

5. LAND SUITABILITY FOR IRRIGATED AND RAINFED HORTICULTURAL AND FIELD CROPS

5.1 Introduction

The suitability classification was done in accordance with the "Framework for Land Evaluation" (FAO, 1976), and was solely based on physical criteria. The suitability of the New Thigirie farm was assessed for rainfed cultivation, with additional overhead irrigation of vegetables, fruits (bananas, avocadoes,citrus and pawpaw) and field crops (maize, Irish

potatoes) and sweet potato vines and napier grass.

In the process of assessment the following assumptions were made:

1. That the crops will be grown under high level of management, i.e., use of recommended cultural practices for each crop including use of improved seeds, appropriate fertilizers, chemicals for disease and pest control, proper spacing and timely farm operations like planting, weeding and chemical applications, proper soil and water conservation measures including crop-rotation, mulching, contour ploughing, strip-cropping and cut-off drains where necessary.

2. Labour is not a limiting factor.

3. Availability of irrigation water is not limiting.

4. Costs of installing the overhead irrigation system have not been considered but assumed to be repayable in time.

5.2 Land qualities and their ratings

The land qualities relevant in the area and which were subsequently used as the diagnostic criteria are:

1. Soil moisture storage capacity (SMSC)
2. Availability of nutrients
3. Possibilities of mechanisation
4. Waterlogging hazard (availability of oxygen)
5. Resistance to erosion (erosion hazard)

1. Soil moisture storage capacity

The amount of water available for plant use is very important since all physiological processes in plants take place with the help of water, and as a result water deficiency affects the growth of the plants adversely.

The amount of available moisture is determined by soil texture, porosity and depth. The available water was calculated as a difference of water retention between pF 2.3 and pF 4.2, bulk density and depth and was rated as shown in table 8 below, modified after Braun and van de Weg (1977).

Table 8. Soil moisture storage capacity (SMSC) rating

Total available moisture (TAM) in mm/100 cm depth	Rating
>100	1. very high
75-100	2. high
50-75	3. moderate
25-50	4. low
<25	5. very low

2. Availability of nutrients

The role of nutrients in plant growth and subsequent yielding capacity is vital for attainment of maximum crop output. A high CEC is a desirable characteristic of a soil as this protects a higher proportion of nutrient cations from being leached, and there is a close correlation between CEC of a soil and its productivity (Wrigley, 1981).

This land quality was assessed using cation exchange capacity (CEC) and the available cations. Soil reaction (pH) was found to be suitable and so it was not used as a diagnostic criterion. CEC and available cations were rated as shown in the table 9 below.

Table 9 Availability of nutrients ratings

(a) Sub-rating CEC of the topsoil (0-30 cm)

CEC (me/100g)	rating
>16	1. very high
12-16	2. high
6-12	3. moderate
2-6	4. low
<2	5. very low

(b) sub-rating available cations of the topsoil (0-30 cm)

Available P (ppm)	Available K (me/100g)	Available Ca (me/100g)	rating
>200	>3.5	>20	1. very high
80-200	2.0-3.5	10-20	2. high
20-80	1.0-2.0	6-10	3. moderate
<20	0.3-1.0	2-6	4. low
<20	< 3.0	<2	5. very low

(c) Final rating for availability of nutrients is derived from the sum of the sub-ratings above (a+b)

Sum of sub-ratings	Final rating
2	1. very high
3-4	2. high
5-6	3. moderate
7-8	4. low
>8	5. very low

3. Possibilities of mechanisation

The land characteristics considered under this land quality are:

- steepness of the slopes
- stoniness/rockiness/shallowness of the soil

These land characteristics affect farm operations where mechanisation is involved. They may hinder the use of machinery or reduce the efficiency of their operations. The sub-ratings and final rating of possibilities of mechanisation are shown in table 10.

Table 10. Possibilities of mechanisation ratings

(a) Sub-rating the steepness of the slope

Slope class		rating
A-B-C	(0-8%)	1
CD-D	(8-16%)	2
DE-E	(16-30%)	3
F	(30-70%)	4
G	(> 70%)	5

(b) Sub-rating the stoniness/rockiness/shallowness of the soil

rating	description
1	non-stony, non to little rocky and not shallow
2	fairly stony, fairly rocky and/or shallow
3	stony-rocky and/or shallow
4	very stony, very rocky and/or very shallow
5	exceedingly stony, and/or very rocky or very shallow

(c) Final rating of possiblities of mechanisation is arrived at by the sum of the sub-ratings a & b above

Sum of sub-ratings	final rating
2	1. very high
3	2. high
4	3. moderate
5	4. low
6	5. very low

4. Waterlogging hazard (availability of oxygen for root growth)

Plants' roots need air in the soil for proper development. With reduced aeration due to waterlogging proper root development is hindered and consequently plant growth is stunted leading to failure or poor

yielding of the plant,respectively. This land quality was rated as shown in table 11.

Table 11. Availability of oxygen rating

rating	drainage class	colour and mottling
1. very high	well drained to excessively drained soils	No distinct mottling within 90cm and reduced colours within 150 cm
1. high	moderately well drained soils	No distinct mottling within 50 cm or reduced colours within 120cm
3. moderate	imperfectly drained soils	No reduced colours or distinct mottles within 50cm
4. slight	poorly drained soils	partly reduced colours and distinct mottles within 50cm
5. No	very poorly drained soils	predominantly reduced colours

5. Resistance to erosion

Soil erosion is the removal of the top soil by the agents of erosion such as water and wind. Soil erosion by water carries large quantities of soil and also available nutrients in it, making the soil poor and reducing its capacity to hold more water and nutrients, both of which are vital for proper plant growth.

The raindrops falling on bare soil spoil the soil structure causing surface sealing which leads to reduced infiltration rate and thus increased runoff. The land characteristic considered relevant under this land quality is slope class. This land characteristic is rated as shown in table 12.

Table 12. Resistance to erosion rating (Slope class rating)

Slope class and percentage		rating
A-AB-B	(0-5%)	1
C	(5-8%)	2
D	(8-16%)	3
E	(16-30%)	4
F	(> 30%)	5

Table 13. Rating of the land qualities for all land units (soil mapping units + slope class)

	Land qualities				
Land unit (soil mapping unit/slope class)	Soil moisture storage capacity (SMSC)	Availa-bility of nutrients	Possi-bilities of mechani-sation	Availa-bilitiy of Oxygen	Resistance to Erosion
RPrl/B	1	3	1	1	2
RPrl/CD	1	4	2	1	3
RPrl/E	1	4[e]	3	1	4
RPrl/F	1	4	4	1	5
RPr2p/F	2	4	5	1	5
VPgp/A	2	4	2	3	2

e = estimated

5.3 Suitability classes and their criteria

The suitability for the land utilization types was determined using the land qualities as shown by conversion tables below and expressed by the following classes.

Class S1: Highly suitable:
Land having no significant limitations to sustained application of a given use or reduce productivity or raise inputs above unacceptable level.

Class S2: Moderately suitable:
Land having limitations which are moderately severe for sustained applica-

tion of a given use or the limitations will reduce productivity.

Class S3: Marginally suitable:
Land having limitations which are severe for sustained application of a given use and will reduce productivity or benefits.

Class NS: Not suitable
Land unsuitable for sustained production due to very severe limitations.

The requirements of each LUT are defined as minimum ratings for a certain suitability class. The requirements are shown in so called conversion tables below.

Table 14. Conversion table for maize

Suitability class	Land qualities				
	Soil moisture storage capacity (SMSC)	Availability of nutrients	Possibilities of mechanisation	Availability of oxygen	Resistance to erosion
S1	2	3	2	1	3
S2	3	4	3	2	4
S3	4	5	4	3	4
NS	5	5	5	4	5

Table 15. Conversion table for Irish potatoes

Suitability class	Land qualities				
	Soil moisture storage capacity (SMSC)	Availability of nutrients	Possibilities of mechanisation	Availability of oxygen	Resistance to erosion
S1	1	3	1	1	2
S2	2	4	2	2	3
S3	3	5	3	3	4
NS	4	5	4	4	5

Table 16. Conversion table for vegetables and moderately deep rooted fruits (bananas and pawpaws)

Suitability class	Land qualities				
	soil moisture storage capacity (SMSC)	Availability of nutrients	Possibilities of mechanisation	Availability of oxygen	Resistance to erosion
S1	1	2	3	1	2
S2	2	3	4	2	3
S3	3	4	5	3	4
NS	4	5	5	4	5

Table 17. Conversion table for deep rooted fruits (citrus and avocadoes)

Suitability class	Land qualities				
	Soil moisture storage capacity (SMSC)	Availability of nutrients	Possibilities of mechanisation	Availability of oxygen	Resistance to erosion
S1	2	3	1	1	3
S2	3	4	2	2	4
S3	4	5	3	3	5
NS	5	5	4	4	5

Table 18. Conversion table for napier grass

Suitability class	Land qualities				
	Soil moisture storage capacity (SMSC)	Availability of nutrients	Possibilities of mechanisation	Availability of oxygen	Resistance to erosion
S1	1	3	3	2	3
S2	2	4	4	3	4
S3	3	5	5	4	5
NS	4	5	5	5	5

Table 19. Conversion table for sweet potatoes

Suitability class	Land qualities				
	Soil moisture storage capacity (SMSC)	Availability of nutrients	Possibilities of mechanisation	Availability of oxygen	Resistance to erosion
S1	2	3	3	2	4
S2	3	4	4	3	4
S3	4	5	5	4	5
NS	5	5	5	5	5

5.4 Land suitability of the land units

By matching the ratings of each land quality for all land units with the requirements of the suitability classes (conversion tables) the suitability of each land unit for the various LUT is arrived at. The results of the suitability classification are shown in table 20 below.

Table 20. Land suitability classification

Land unit (soil mapping unit/slope class)	Land utilization type (LUT)						
	Maize	Irish Potatoes	Vegetables & moderately deep rooted fruits (bananas, pawpaws)	Deep rooted fruits (citrus avocadoes)	Napier grass	sweet potatoes	Area in ha
RPr1/B	S1	S1	S1	S1	S1	S1	5.7
RPr1/CD	S2	S2	S2	S2	S2	S2	2.2
RPr1/E	S2	S3	S3	S3	S3	S3	2.2
RPr1/F	NS	NS	NS	NS	S3	S3	1.7
RPr2p/F	NS	NS	NS	NS	S3	S3	1.0
VPgp/A	S3	S3	S3	S3	S2	S2	0.8

6. CONCLUSIONS OF RECOMMENDATIONS

1. Climatically all the crops grown on the farm are well adapted but land suitability for them tend to vary with different soil mapping units.

2. (a) Mapping unit RPr1/B is considered highly suitable for all the crops under consideration.

(b) Mapping unit RPr1/CD is considered moderately suitable for all the crops under consideration.

(c) Mapping unit RPr1/E is considered moderately suitable for maize, napier grass and sweet potatoes. It is marginally suitable for the rest of the crops-limitations being low possibilities of mechanisation and resistance to erosion (erosion hazard).

(d) Mapping unit RPr1/F is considered marginally suitable for napier grass and sweet potatoes, and unsuitable for the rest of the crops. The major limitations are erosion hazard and low possibilities of mechanisation.

(e) Mapping unit RPr2*p*/F is considered marginally suitable for napier grass and sweet potatoes, it is unsuitable for the rest of the crops. Limitations are low possibilities of mechanisation and erosion hazard.

(f) Mapping unit VPgp/A is considered moderately suitable for napier grass, sweet potatoes and bananas. It is marginally suitable for the rest of the crops. The major limitation is availability of oxygen (waterlogging hazard).

3. Rotation

(a) Solanacea family members viz tomatoes, Irish potatoes, capsicums, brinjals (egg plants) should be grown with rigid observance of rotation measures to prevent plant pests and pathogens build up in the soil. Their rotation cycle with other crops should cover three years.

(b) For cruciferae (Brassicas) family members viz., cabbages, kales, broccoli, brussel sprouts, rotation should be practised for the same reason as in (a) above but the cycle should cover 2 years.

NB. These rotations imply that no member of the same family should be planted in the same plot where another member of the same family has been until 3 or 2 years have elapsed respectively.

(c) Rotation should also be practised for the benefit of maintaining nutrients balance in the soil because different crops have different nutrient requirements in terms of quantity.

4. Soil and water conservation measures

(a) Steep areas having slopes of 16-30% should be used with care, otherwise failure to observe soil and water conservation measures such as bench terraces, digging of cut-off drains, use of grass strips combined with strip cropping which can minimise the potential soil erosion hazard, these areas are liable to be eroded.

(b) Steep areas having slopes of 30% and above should be left fallow, or put under napier grass which can help in reducing erosion. Alternatively a cover crop such as sweet potato can be planted to make the soil less susceptible to erosion by water while soil and water conservation measures mentioned in 4(a) above are applied in any of the cases.

7. REFERENCES

Braun, H.M.H. 1977 : Seasonal and monthly rainfall probability tables for the East-Central, North-Western and Coast region of Kenya. Miscellaneous paper no. M13, Kenya Soil Survey, Nairobi.

Braun, H.M.H. (in prep) : Evaporation and evapotranspiration in Kenya, Kenya Soil Survey, Nairobi.

Braun, H.M.H. and R.F. van de Weg; Proposals for rating of land qualities, 1977 Internal communication no. 7, Kenya Soil Survey, Nairobi.

EAMD 1970 : Temperature data for stations in East Africa, Part 1, Kenya. East African, Meteorological Department, Nairobi.

EAMD 1972 : Summary of rainfall in Kenya for the year 1972. Serial publication of the East African Meteorological Department, Nairobi.

F A O 1976 : A framework for land evaluation. Soils Bulletin no. 23, FAO, Rome.

F A O 1977 : Guidelines for soil profile description. FAO, Rome

FAO-UNESCO 1974 : Soil map of the world, Vol. 1, legend. UNESCO, Paris.

Hinga, G., F.N. Muchena and C. Njihia (eds);. Physical and chemical 1980 methods of soil analysis. Internal document, National Agricultural Laboratories, Nairobi.

Munsell Color Company; Munsell Soil Color Charts. Munsell Company Inc., 1971 Baltimore, Maryland

Richards, L.A. (ed); Diagnosis and improvement of saline and alkaline soils. 1954 Agric. Handbook no. 60. USDA, Washington.

Siderius, W., and B.J.A. van der Pouw: The application of the FAO/UNESCO 1980 terminology of the soil map of the world legend for soil classification in Kenya. Report M17, Kenya Soil Survey, Nairobi.

Sombroek, W.G., H.M.H., Braun and B.J.A. van der Pouw; Exploratory
1982 soil map and agro-climatic zone, map of Kenya, 1,000,000. Report E1, Kenya Soil Survey, Nairobi.

Woodhead, T. : Studies of potential evaporation in Kenya. EAAFRO,
1968 Nairobi.

Wrigley, G. : Tropical Agriculture. Longman, London.
1981

A P P E N D I X 1a

DESCRIPTION OF REPRESENTATIVE PROFILES WITH ANALYTICAL DATA

Observation No.	Mapping unit	Profile description No.
148/2-88	RPr1	1
148/2-89	RPr1	2
148/2-90	RPr2*p*	3
148/2-91	RPr1	4
148/2-79	VPgp	5[1)]

1) augerhole observation only

LABORATORY DATA OF PROFILE DESCRIPTION No. 1

Observation no: 148/2-88 Mapping unit: RPr1 Soil classification: eutric NITISOL*

Laboratory no. '84	4612	4613	4614	4615	4616	
Horizon	Ap	Bt1	Bt2	Bt3	Bt4	
Depth(cm)	0-15	15-35	35-62	62-104	104-270+	
pH-H_2O(1: 2.5v/v)	6.3	6.8	6.6	6.5	5.5	
pH-KCl "	5.3	5.6	5.4	5.3	4.6	
EC(mmho/cm) "	0.05	0.05	0.04	0.03	0.03	
$CaCO_3$(%)						
$CaSO_4$(%)						
C (%)	0.43	1.74	0.32	0.72	0.26	
N (%)						
C/N						
CEC(me/100g), pH 8.2	12.8	15.6	14.4	16.5	10.0	
CEC " " pH 7.0						
Exch.Ca(me/100g)	6.0	7.2	4.2	3.4	1.0	
" Mg "	1.28	2.40	2.76	2.40	0.68	
" K "	2.15	2.45	1.77	2.02	2.21	
" Na "	0.48	0.74	0.52	0.52	0.50	
Sum of cations	9.91	12.79	9.25	8.34	4.39	
Base sat. %, pH 8.2	77	82	64	50	44	
" " %, pH 7.0						
ESP at pH 8.2	3.8	4.7	3.6	3.2	5.0	
Texture (limited pretreatment)						
Gravel % (>2.0mm)						
Sand % (2.0-0.05mm)	20	16	14	14	10	
Silt % (0.05-0.002mm)	20	18	12	10	8	
Clay % (0.002-0mm)	60	66	74	76	82	
Texture class	C	C	C	C	C	

Fertility aspects	0 - 30 cm			Laboratory no. 4607/84	
General		Available nutrients			
pH-H_2O (1: 2.5 v/v)	6.0	Na/me/100g)	0.18	Mn(me/100g)	1.55
Exch. acidity (me/100g)		K "	1.35	P (ppm)	14
C %	1.63	Ca "	3.8	P-Olsen(ppm)	
N %	0.24	Mg "			

Remarks:

PROFILE DESCRIPTION NO. 1

General site information

Mapping unit	: RPr1
Soil classification	: eutric NITISOL*
Observation no./date	: 148/2-88, 22/5/84
Location/altitude	: Nairobi province, 1720m
Parent material	: pyroclastic rocks (trachytic tuffs)
Physiography	: footridge
Relief, macro	: mountainous
micro	: nil
Land use	: recently ploughed (bare)
Erosion	: no observable evidence but highly susceptible
Surface rockiness/stoniness	: nil
Groundwater level	: estimated to be very deep
Slope gradient	: 38%
Drainage class	: well drained

Profile description

Ap 0-15cm : dark reddish brown (2.5YR 2.5/4 moist); clay;moderate to strong, medium to coarse subangular blocky; friable when moist, sticky and plastic when wet; many very fine, few fine to coarse pores; worm channels; very frequent very fine to fine, common medium, roots; clear and smooth transition to:
(sample no. 148/2-88a)

Bt1 15-35cm : dark reddish brown (2.5YR 2.5/4 moist); clay; weak, medium to coarse, subangular blocky; friable when moist, sticky and plastic when wet; broken thick clay cutans; common, very fine to fine, few coarse pores; faunal nests and worm channels; many very fine to fine, few medium to coarse roots; gradual and smooth transition to:
(sample no. 148/2-88b)

Bt2 35-62cm : dark reddish brown (2.5 YR 2.5/4 moist); clay; weak to moderate, medium to coarse angular blocky; friable when moist, sticky and plastic when wet; broken thick clay cutans; many very fine, few fine and coarse pores; termite burrows, faecal material; common fine, very few medium to coarse roots; gradual and smooth transition to:
(sample no. 148/2-88c)

Bt3 62-104cm : dark red (2.5 YR 3/6, moist); clay; weak, medium to coarse, subangular blocky; friable when moist, sticky and plastic when wet; broken thick clay cutans; many very fine to fine, few medium to coarse pores; common very fine, few fine roots; ant channels, faecal material; diffuse and smooth transition to:
(sample no. 148/2-88d)

Bt4 104-270cm+ : dark red (2.5YR 3/6 moist); clay; medium to strong; coarse angular blocky; friable when moist, sticky and plastic when wet; continuous thick clay cutans; many very fine, common fine, few medium to coarse pores
(sample no. 148/2-88e)

LABORATORY DATA OF PROFILE DESCRIPTION No. 2

Observation no: 148/2-89 Mapping unit: RPrl Soil classification: eutric NITISOL*

Laboratory no. /84	4617	4618	4619	4620		
Horizon	Au	Bt1	Bt2	Bt3		
Depth (cm)	0-18	18-70	70-112	112-274+		
pH-H_2O (1: 2.5 v/v)	6.1	6.8	6.5	5.0		
pH-KCl "	5.4	5.6	5.4	4.3		
EC (mmho/cm) "	0.10	0.04	0.03	0.03		
$CaCO_3$ (%)						
$CaSO_4$ (%)						
C (%)	0.23	1.04	0.78	0.34		
N (%)						
C/N						
CEC (me/100g), pH 8.2	13.8	19.4	14.4	10.6		
CEC " " pH 7.0						
Exch. Ca (me/100g)	7.0	7.6	6.8	2.8		
" Mg "	1.80	1.28	1.98	2.40		
" K "	2.75	2.75	2.22	0.97		
" Na "	0.49	0.76	0.32	0.51		
Sum of cations	12.04	12.39	11.32	6.68		
Base sat. %, pH 8.2	87	64	79	63		
" " %, pH 7.0						
ESP at pH 8.2	3.6	3.9	2.2	4.8		
Texture (limited pretreatment)						
Gravel % (>2.0mm)						
Sand % (2.0-0.05mm)	26	18	14	12		
Silt % (0.05-0.002mm)	24	20	12	8		
Clay % (0.002-0mm)	50	62	74	80		
Texture class	C	C	C	C		

Fertility aspects	0 - 30 cm			Laboratory no. 4608/84	
General		Available nutrients			
pH-H_2O (1: 2.5 v/v)	6.1	Na/me/100g)	0.34	Mn (me/100g)	1.46
Exch. acidity (me/100g)		K "	1.74	P (ppm)	38
C %	2.45	Ca "	7.8	P-Olsen (ppm)	
N %	0.30	Mg "			

Remarks:

PROFILE DESCRIPTION NO.2

General site information

Mapping unit	: RPr1
Soil classification	: eutric NITISOL*
Observation no./date	: 148/2-89; 22/5/84
Location/altitude	: Nairobi Province, 1737m
Parent material	: pyroclastic rocks (trachytic tuffs)
Physiography	: footridge
Relief, macro	: flat to very gently undulating
micro	: termite mounds, mole borings
Land use	: grazing
Erosion	: nil
Surface stoniness/rockiness	: nil
Groundwater level	: not determined but estimated to be very deep
Slope gradient	: 2-5%
Drainage class	: well drained

Profile description

Au	0-18cm	: dark reddish brown (5YR 2.5/2, moist); clay; moderate to strong, coarse subangular blocky and medium crumbs; friable when moist, sticky and plastic when wet; many fine, common medium pores; many very fine and fine roots; clear and smooth transition to: (sample no. 148/2-89a)
Bt1	18-70cm	: dark reddish brown (2.5 YR 2.5/4, moist); clay; weak to moderate, coarse angular and subangular blocky; friable when moist, sticky and plastic when wet; continuous thick clay cutans; common very fine, fine and medium, few coarse pores; common very fine, few fine roots; clear and smooth transition to: (sample no. 148/2-89b)
Bt2	70-112cm	: dark reddish brown (2.5YR 2.5/4 moist); clay; weak to moderate, coarse angular and subangular blocky; friable when moist, sticky and plastic when wet; continuous thick clay cutans; many very fine, common fine and few medium to coarse pores; common very fine roots; diffuse and smooth transition to: (sample no. 148/2-89c)
Bt3	112-274cm+	: dark reddish brown (2.5 YR 3/4 moist); clay; moderate, medium to coarse, subangular and angular blocky; friable when moist, sticky and plastic when wet; continuous thick clay cutans; many very fine, common fine pores; few very fine roots (sample no. 148/2-89d)

LABORATORY DATA OF PROFILE DESCRIPTION No. 3

Observation no: 148/2-90 Mapping unit: RPr2p Soil classification: eutric NITISOL *

Laboratory no. /84	4621	4622	4623	4624	4625	4626	4627
Horizon	Ap	Bt1	Bt2	BCt1	BCt2	C1	C2
Depth (cm)	0-30	30-51	51-77	77-112	112-156	156-210	210-290+
pH-H_2O (1: 2.5 v/v)	5.8	5.9	5.3	5.4	5.4	5.4	5.3
pH-KCl "	5.0	4.8	4.3	4.1	4.0	3.7	3.5
EC (mmho/cm) "	0.13	0.07	0.06	0.04	0.03	0.04	0.04
$CaCO_3$ (%)							
$CaSO_4$ (%)							
C (%)	0.11	0.14	0.40	0.72	0.49	0.52	0.40
N (%)							
C/N							
CEC (me/100g), pH 8.2	11.6	13.2	11.2	12.0	9.4	9.0	8.6
CEC " " pH 7.0							
Exch. Ca (me/100g)	5.0	5.6	5.5	4.1	3.0	3.7	3.1
" Mg "	2.50	2.36	1.97	2.07	1.60	1.18	1.80
" K "	2.15	1.63	1.07	0.67	0.56	0,33	0.37
" Na "	0.35	0.44	0.52	0.55	0.53	0.54	0.55
Sum of cations	10.0	10.03	9.06	7.39	5.69	5.75	5.82
Base sat. %, pH 8.2	86	76	81	62	60	64	68
" " %, pH 7.0							
ESP at pH 8.2	3.0	3.3	4.6	4.6	5.6	9.39	6.4
Texture (limited pretreatment)							
Gravel % (>2.0mm)							
Sand % (2.0-0.05mm)	26	22	20	24	28	24	36
Silt % (0.05-0.002mm)	28	22	16	18	24	24	22
Clay % (0.002-0mm)	46	56	64	58	48	52	42
Texture class	C	C	C	C	C	C	C

Fertility aspects 0 - 30 cm Laboratory no. 4609 /84

General		Available nutrients				
pH-H_2O (1: 2.5 v/v)	6.0	Na/me/100g)	0.16	Mn (me/100g)	1.60	
Exch. acidity (me/100g)		K "	1.32	P (ppm)	7	
C %	2.39	Ca "	9.4	P-Olsen (ppm)		
N %	0.33	Mg "				

Remarks:

PROFILE DESCRIPTION NO. 3

General site information

Mapping unit	: RPr2p
Soil classification	: chromic LUVISOL
Observation no./date	: 148/2-90, 23/5/84
Location/altitude	: Nairobi Province, 1710 m
Parent material	: pyroclastic rocks (trachytic tuffs)
Pysiography	: footridge
Relief, macro	: mountainous
micro	: nil
Land use	: cultivation of maize
Erosion	: no evidence but highly susceptible
Surface stoniness/rockiness	: scattered weathering tuffs and rocks 20m away
Groundwater level	: estimated to be very deep
Slope gradient	: 34%
Drainage class	: well drained

Profile description

Ap 0-30 cm : dark reddish brown (5 YR 2.5/2 moist); clay; moderate to strong, fine to coarse crumbs and subangular blocky; very friable when moist, sticky and plastic when wet; common very fine to medium, few coarse pores; many very fine and fine roots; clear and smooth transition to:
(sample no. 148/2-90a)

Bt1 30-51 cm : dark reddish brown (2.5 YR 2.5/4 moist); clay; weak medium to coarse, angular and subangular blocky; firm when moist, sticky and plastic when wet; common thin clay cutans; many very fine, common fine to coarse pores; many very fine and fine roots; clear and smooth transition to:
(sample no. 148/2-90b)

Bt2 51-77 cm : dark reddish brown (2.5 YR 2.5/4 moist); clay; weak, fine to coarse, angular and subangular blocky; friable when moist, sticky and plastic when wet; continuous moderately thick clay cutans; many very fine, common fine to medium, few coarse pores; many very fine and fine roots; diffuse and smooth transition to:
(sample no. 148/2-90c)

BCt1 77-112 cm : dark reddish brown (2.5YR 2.5/4 moist); clay; moderate fine to coarse angular and subangular blocky; friable when moist, sticky and plastic when wet; continuous moderately thick clay cutans; common very fine, fine to coarse pores; krotovina (diameter 18 cm, depth 5cm); common very fine to fine, few medium roots; diffuse and smooth transition to:
(sample no. 148/2-90d)

BCt2 112-156 cm : dark reddish brown (2.5 YR 3/4 moist); clay; moderate, fine to coarse angular blocky; friable when moist, sticky and plastic when wet; few thin clay cutans; common very fine to coarse pores; many very fine to fine, few medium roots; diffuse and smooth transition to:
(sample no. 148/2-90e)

C1 156-210 cm : dark reddish brown (5YR 3/4 moist); clay; weak massive; firm when moist, slightly sticky and slightly plastic when wet; common very fine, few fine pores; diffuse and smooth transition to:
(sample no. 148/2-90f)

C2 210-290+cm : brown (10 YR 5/3 moist); clay; very friable when moist, slightly sticky and slightly plastic when wet
(sample no. 148/2-90g)

REMARK: The description of the soil below 210 cm depth is based on an augering.

LABORATORY DATA OF PROFILE DESCRIPTION No. 4

Observation no: 148/2-91 Mapping unit: RPr1 Soil classification: chromic* LUVISOL

Laboratory no. /84	4628	4629	4630	4631	4632	
Horizon	Au	Bt1	Bt2	Bt3	Bt4	
Depth (cm)	0-24	24-39	39-60	60-107	107-258+	
pH-H_2O (1: 2.5 v/v)	5.7	5.8	5.5	5.2	5.0	
pH-KCl "	4.8	4.6	4.2	4.0	4.0	
EC (mmho/cm) "	0.11	0.05	0.03	0.02	0.03	
$CaCO_3$ (%)						
$CaSO_4$ (%)						
C (%)	0.81	0.23	0.17	0.20	0.17	
N (%)						
C/N						
CEC (me/100g), pH 8.2	9.0	11.0	10.2	9.0	7.4	
CEC " " pH 7.0						
Exch. Ca (me/100g)	3.6	2.8	2.0	3.4	2.2	
" Mg "	0.88	0.88	1.00	0.40	0.28	
" K "	2.54	2.17	1.96	1.37	0.85	
" Na "	0.49	0.42	0.42	0.48	0.12	
Sum of cations	7.51	6.27	5.38	5.65	3.45	
Base sat. %, pH 8.2	83	57	53	63	47	
" " %, pH 7.0						
ESP at pH 8.2	5.4	3.8	4.1	5.3	1.6	

Texture (limited pretreatment)

Gravel % (>2.0mm)						
Sand % (2.0-0.05mm)	18	12	12	10	12	
Silt % (0.05-0.002mm)	24	20	14	8	12	
Clay % (0.002-0mm)	52	68	74	82	76	
Texture class	C	C	C	C	C	

Fertility aspects 0 - 30 cm Laboratory no. 4610/84

General		Available nutrients			
pH-H_2O (1: 2.5 v/v)	5.7	Na/me/100g)	0.16	Mn (me/100g)	1.55
Exch. acidity (me/100g)		K "	1.28	P (ppm)	7
C %	2.45	Ca "	3.8	P-Olsen (ppm)	
N %	0.29	Mg "			

Remarks:

PROFILE DESCRIPTION NO. 4

General site information

Mapping unit	: RPr1
Soil classification	: eutric NITISOL*
Observation no./date	: 148/2-91; 24/5/84
Location/altitude	: Nairobi Province, 1730m
Parent material	: pyroclastic rocks (trachytic tuffs)
Physiography	: footridge
Relief, macro	: rolling
micro	: termite mounds, mole borings
Land use	: grazing
Erosion	: no evidence
Surface stoniness/rockiness	: nil
Groundwater level	: estimated to be very deep
Slppe gradient	: 12%
Drainage class	: well drained

Profile description

Au	0-24cm	: dark reddish brown (5YR 3/3, moist); clay; moderate to strong, coarse crumbs, and moderate, coarse subangular blocky; friable when moist, sticky and plastic when wet; common very fine to fine, few coarse pores; termite channels; many very fine and fine, common medium and dead roots; clear and smooth transition to: (sample no. 148/2-91a)
Bt1	24-39cm	: dark reddish brown (2.5YR 3/4 moist); clay; weak to moderate, coarse angular and subangular blocky; friable when moist, sticky and slightly plastic when wet; few thin clay cutans; many very fine and common fine pores; termite channels; many fine roots; clear and smooth transition to: (sample no. 148/2-91b)
Bt2	39-60cm	: dark reddish brown (2.5YR 3/4 moist); clay; weak to moderate, coarse, angular and subangular blocky; friable when moist, slightly sticky and plastic when wet; common moderately thick clay cutans; many very fine, few fine pores; termite channels; many fine roots; diffuse and smooth transition to: (sample no. 148/2-91c)
Bt3	60-107cm	: dark red (2.5 YR 3/6 moist); clay; weak to moderate coarse angular and subangular blocky; friable when moist, slightly sticky and plastic when wet; common thick clay cutans; many very fine, few fine pores; termite channels; few very fine roots; diffuse and smooth transition to: (sample no. 148/2-91d)
Bt4	107-258+cm	: dark red (2.5YR 3/6 moist); clay; weak to moderate, coarse angular blocky with a few subangular blocky; friable when moist, slightly sticky and plastic when wet; common thick clay cutans; many very fine, common fine pores; termite channels; few very fine roots (sample no. 148/2-91e)

LABORATORY DATA OF PROFILE DESCRIPTION No. 5

Observation no: auger no.79 Mapping unit: VPgp Soil classification:

Laboratory no. '84	4633	4634				
Horizon	Ap	Bu				
Depth (cm)	0-30	30-60				
pH-H_2O (1: 2.5 v/v)	6.4	6.5				
pH-KCl "	5.5	5.5				
EC (mmho/cm) "	0.13	0.10				
$CaCO_3$ (%)						
$CaSO_4$ (%)						
C (%)	1.36	1.60				
N (%)						
C/N						
CEC (me/100g), pH 8.2	9.8	13.4				
CEC " " pH 7.0						
Exch. Ca (me/100g)	4.6	6.9				
" Mg "	0.52	2.40				
" K "	1.01	2.35				
" Na "	0.57	0.79				
Sum of cations	6.7	12.4				
Base sat. %, pH 8.2	68	93				
" " %, pH 7.0						
ESP at pH 8.2	5.8	5.9				
Texture (limited pretreatment)						
Gravel % (>2.0mm)						
Sand % (2.0-0.05mm)	20	24				
Silt % (0.05-0.002mm)	30	24				
Clay % (0.002-0mm)	50	52				
Texture class	C	C				

Fertility aspects	0 - 30 cm			Laboratory no. 4611/84	
General		Available nutrients			
pH-H_2O (1: 2.5 v/v)	6.5	Na/me/100g)	0.16	Mn (me/100g)	2.0
Exch. acidity (me/100g)		K "	0.88	P (ppm)	14
C %	2.01	Ca "	10.0	P-Olsen (ppm)	
N %	0.28	Mg "			

Remarks:

PROFILE DESCRIPTION NO. 5 (based on augerhole observation)

General site information

Mapping unit	: VPgp
Observation no./date	: auger no. 79, 17/5/84
Location/altitude	: Nairobi Province, 1700m
Parent material	: infills derived from trachytic tuffs
Physiography	: minor valley
Relief, macro	: valleybottom (flat)
micro	: nil
Land use	: cultivation of maize, napier grass
Erosion	: nil
Surface stoniness/rockiness	: upper side of the river is rocky
Flooding	: seasonal
Groundwater level	: shallow (less than 30cm)
Slope gradient	: 0-1%
Drainage class	: imperfectly drained

Auger description

Ap	0-5cm	: dark reddish brown (5YR 3/2 moist); clay; friable when moist, sticky and plastic when wet; pH 6.9; vigorous reaction with H_2O_2(3)
BA	5-25cm	: dark reddish brown (5YR 3/3 moist); clay;friable when moist, sticky and plastic when wet; pH 6.9; vigorous reaction with H_2O_2(3); common distinct (1-3mm diameter), black (2.5YR 2.5/0) mottles
Bu1	25-50cm	: dark reddish brown (2.5YR 5/4 moist); clay to silty clay; friable when moist, sticky and plastic when wet; pH 6.8; moderate reaction with H_2O_2(2); common fine and medium, distinct, (1-3mm diameter), black ^{2} (2.5YR 2.5/0) mottles
Bu2	50-100+cm	: dark reddish brown (2.5YR 2.5/4); silty clay; friable when moist, sticky and plastic when wet; pH 6.6; slight reaction with H_2O_2(1)
	REMARK	Sampling of the observation was not done per horizon due to water problem from underground. It was not possible to get a sample beyond 60cm depth.

A P P E N D I X 1b

ANALYTICAL DATA OF FERTILITY SAMPLES

ANALYTICAL DATA OF FERTILITY SAMPLES

Field Designation	a 1	b	a 2	b	a 3	b	a 4	b
Lab. No. ../84	5031	5032	5033	5034	5035	5036	5037	5038
Depth ..cm	0-30	30-60	0-30	30-60	0-30	30-60	0-30	30-60
pH	6.2	6.3	6.1	6.4	6.2	6.6	6.0	6.2
Na (me %)	0.22	0.10	0.22	0.14	0.18	0.10	0.02	0.10
K (me %)	1.64	1.32	1.26	0.88	1.68	1.04	1.37	1.16
Ca (me %)	7.6	4.8	9.6	5.7	9.8	6.3	8.6	5.0
Mn (me %)	1.95	2.32	2.50	1.70	2.80	2.36	1.85	2.76
P. (ppm)	8	6	6	6	10	6	8	6
N%	0.26		0.34		0.34		0.28	
C%	2.21	1.72	2.79	2.01	2.91	1.46	2.59	1.69
Hp (me %)	-	-	-	-	-	-	-	-
Cu (ppm)	0.9	0.6	0.8	0.8	0.8	0.8	0.8	0.6
Fe "	6.5	8.0	4.0	7.5	5.0	7.5	5.0	6.5
Zn "	17.0	13.0	19.5	11.0	23.5	12.0	18.0	14.0

Deficiencies underlined

Field Designation	a 5 b		a 6 b		a 7 b		a 8 b	
Lab. No. ../84	5039	5040	5041	5042	5043	5044	5045	5046
Depth ..cm	0-30	30-60	0-30	30-60	0-30	30-60	0-30	30-60
pH	6.0	6.0	6.0	6.1	6.3	6.4	6.6	6.5
Na (me %)	0.18	0.22	0.52	0.42	0.50	0.66	0.42	0.48
K (me %)	1.26	0.90	0.84	0.54	0.56	0.70	0.94	0.62
Ca (me %)	8.0	7.8	7.4	3.8	4.2	8.8	8.6	5.5
Mn (me %)	1.92	2.80	1.80	1.52	1.85	1.95	1.95	1.72
P (ppm)	8	6	24	16	10	18	32	14
N%	0.29		0.29		0.23		0.30	
C%	2.01	2.03	2.58	1.53	1.94	2.78	2.61	2.00
Hp (me %)	-	-	-	-	-	-	-	-
Cu (ppm)	0.6	0.6	0.4	Trace	0.1	0.2	0.2	0.4
Fe "	6.5	6.5	7.5	9.0	9.0	7.5	6.5	9.0
Zn "	20.0	19.0	19.0	6.5	13.0	21.0	17.0	10.0

Deficiencies underlined

Field Designation	a 9	b	a 10	b	a 11	b	a 12	b
Lab. No. .../84	5047	5048	5049	5050	5051	5052	5053	5054
Depth ..cm	0-30	30-60	0-30	30-60	0-30	30-60	0-30	30-60
pH	6.2	6.2	6.7	6.8	6.5	6.5	6.1	6.2
Na (me %)	0.24	0.06	0.40	0.44	0.54	0.44	0.56	0.44
K (me %)	0.80	0.52	1.84	1.56	0.74	0.46	1.74	1.16
Ca (me %)	7.8	4.8	9.8	5.0	8.6	2.0	7.2	4.8
Mn (me %)	1.85	1.58	1.55	1.74	1.85	1.60	1.70	1.90
P (ppm)	6	8	42	14	18	10	18	8
N%	0.36		0.25		0.30		0.35	
C%	2.90	2.06	2.70	1.60	2.64	1.57	2.84	1.84
Hp (me %)	-	-	-	-	-	-	-	-
Cu (ppm)	Trace	Trace	0.4	0.4	0.6	0.6	1.1	1.1
Fe "	5.5	9.0	8.0	12.0	5.5	11.5	5.5	6.5
Zn "	23.0	12.0	30.5	9.5	25.5	9.5	19.0	10.0

Deficiencies underlined

Field Designation	a 13	b	a 14	b	a 15	b	a 16	b
Lab. No. ../84	5055	5056	5057	5058	5059	5060	5061	5062
Depth ..cm	0-30	30-60	0-30	30-60	0-30	30-60	0-30	30-60
pH	6.1	6.2	6.3	6.6	5.8	5.9	6.1	6.3
Na (me %)	0.40	0.26	0.10	0.12	0.08	0.06	0.42	0.22
K (me %)	1.18	0.78	1.58	0.80	1.37	0.92	1.32	1.08
Ca (me %)	7.4	3.2	7.4	5.0	4.2	1.0	9.6	4.4
Mn (me %)	1.95	1.90	1.74	1.70	3.00	1.68	3.10	1.60
P (ppm)	16	8	8	8	6	6	8	6
N%	0.33		0.32		0.31		0.29	
C%	3.05	1.55	2.87	1.49	2.28	1.26	2.96	1.87
Hp (me %)	-	-	-	-	-	-	-	-
Cu (ppm)	1.3	1.3	1.3	0.9	0.9	0.8	0.9	0.9
Fe "	5.5	7.5	5.0	7.5	10.5	5.5	6.5	7.5
Zn "	23.0	10.0	18.0	17.0	10.5	30.5	19.5	14.5

Deficiencies underlined

Field Designation	a 17	b	a 18	b	a 19	b	a 20	b
Lab. No. ../84	5063	5064	5065	5066	5067	5068	5069	5070
Depth ..cm	0-30	30-60	0-30	30-60	0-30	30-60	0-30	30-60
pH	5.9	6.1	6.0	6.3	5.8	6.2	5.7	6.0
Na (me %)	0.29	0.14	0.14	0.10	0.14	0.13	0.16	0.10
K (me %)	1.30	0.98	1.32	1.10	1.12	0.68	1.06	0.52
Ca (me %)	7.2	4.6	9.0	3.6	7.0	3.6	6.4	4.4
Mn (me %)	2.24	1.55	1.28	0.58	0.72	0.70	0.82	0.72
P (ppm)	8	8	10	8	14	8	14	8
N%	0.30		0.29		0.24		0.23	
C%	2.81	1.84	2.34	1.08	2.34	1.31	2.43	1.23
Hp (me %)	-	-	-	-	-	-	-	-
Cu (ppm)	0.3	Trace	Trace	Trace	Trace	0.4	0.1	0.4
Fe "	7.5	5.5	7.5	7.5	9.0	6.5	8.0	9.0
Zn "	10.5	19.5	11.5	14.0	4.5	13.0	13.7	11.5

Deficiencies underlined

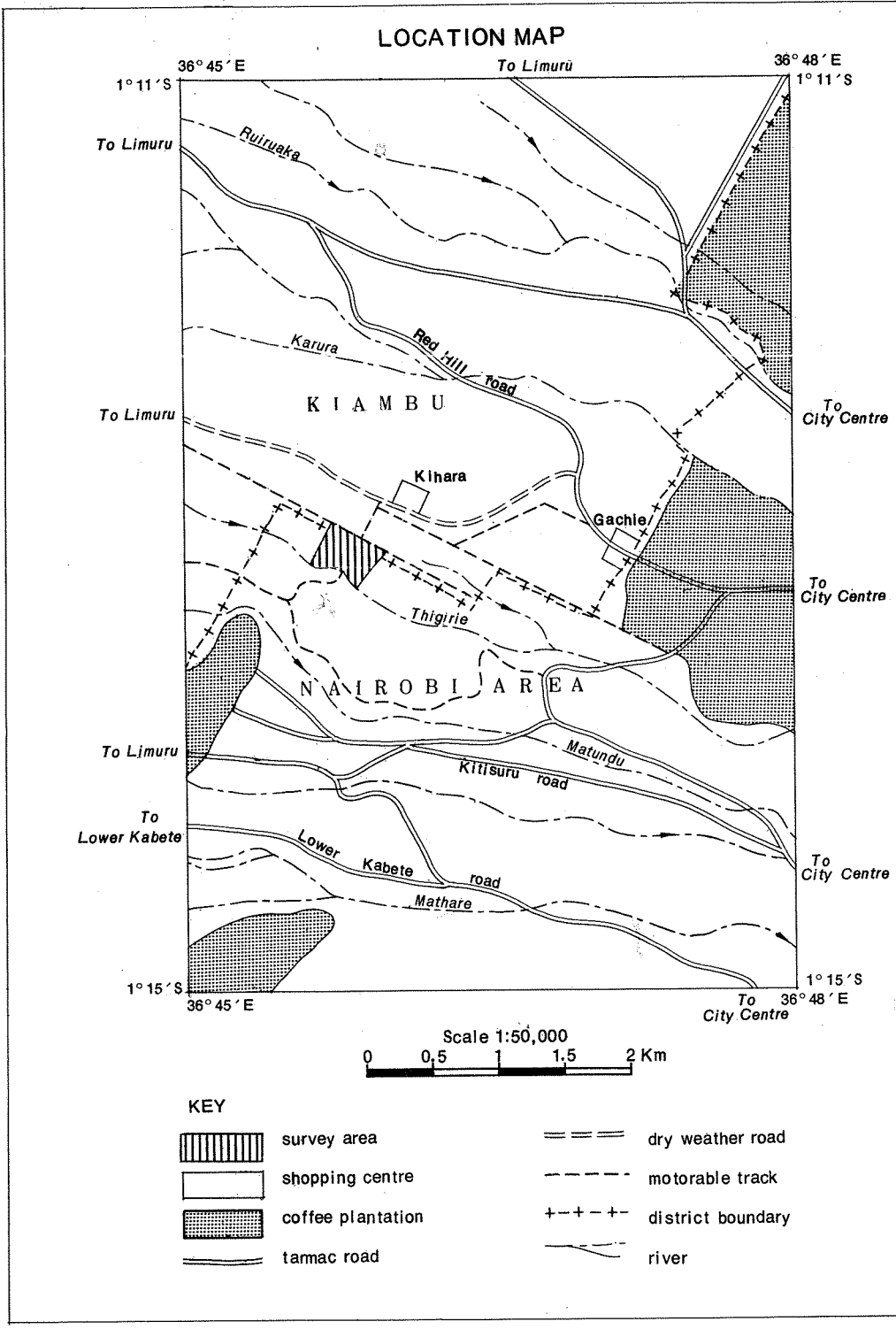
Field Designation	a 21	b	a 22	b	a 23	b	a 24	b
Lab. No. ../84	5071	5072	5073	5074	5075	5076	5077	5078
Depth ..cm	0-30	30-60	0-30	30-60	0-30	30-60	0-30	30-60
pH	6.0	5.8	6.0	5.2	6.0	6.0	6.5	6.4
Na (me %)	0.10	0.08	0.06	0.10	0.84	0.84	1.02	0.64
K (me %)	0.98	0.66	1.40	0.88	1.36	0.82	1.16	0.68
Ca (me %)	6.4	2.8	3.6	0.6	10.4	9.6	10.8	7.6
Mn (me %)	1.08	0.72	0.91	0.74	1.30	1.00	1.34	4.60
P (ppm)	6	8	8	8	14	14	16	14
N%	0.26		0.22		0.29		0.25	
C%	2.25	1.49	1.08	1.69	2.54	1.92	2.30	2.16
Hp (me %)	-	-	-	-	-	-	-	-
Cu (ppm)	0.4	0.4	0.4	0.4	1.7	1.1	0.8	0.9
Fe "	10.0	10.0	12.0	18.5	52.5	34.5	39.0	26.0
Zn "	4.5	4.0	5.0	2.5	19.5	17.0	18.0	21.0

Deficiencies underlined

Field Designation	a 25	b	a 26	b	a 27	b	a 28	b
Lab. No. ../84	5079	5080	5081	5082	5083	5084	5085	5086
Depth ..cm	0-30	30-60	0-30	30-60	0-30	30-60	0-30	30-60
pH	6.7	6.6	6.4	6.3	6.2	6.5	6.0	5.6
Na (me %)	0.84	0.82	0.76	0.60	0.62	0.64	0.10	0.04
K (me %)	0.78	0.64	1.22	0.64	1.02	0.78	1.62	1.48
Ca (me %)	11.0	9.4	9.0	5.2	7.0	6.8	4.0	0.8
Mn (me %)	1.22	1.26	1.34	4.72	1.48	1.76	1.15	0.66
P (ppm)	16	10	14	10	14	10	16	8
N%	0.23		0.24		0.24		0.25	
C%	1.95	1.69	1.75	1.66	2.09	1.54	1.98	0.99
Hp (me %)	-	-	-	-	-	-	-	-
Cu (ppm)	0.8	0.6	1.2	0.9	0.6	0.6	0.2	0.2
Fe "	25.0	47.0	39.0	54.0	31.4	51.0	10.0	17.0
Zn "	14.0	13.5	10.0	23.5	15.5	16.5	10.5	3.5

Deficiencies underlined

Appendix 2 to report No. D 38



LEGEND

R FOOTRIDGE (relief intensity 40m, slopes 2–45%)

RP **Soils developed on pyroclastic rocks** (trachytic tuffs)

RPr1 well drained, extremely deep, dark red to dark reddish brown, friable clay (**eutric NITOSOLS***)

RPr2p well drained, deep to very deep, dark reddish brown, friable clay; in places rocky and stony on the surface (**chromic LUVISOLS**)

V MINOR VALLEY (slopes 0–2%)

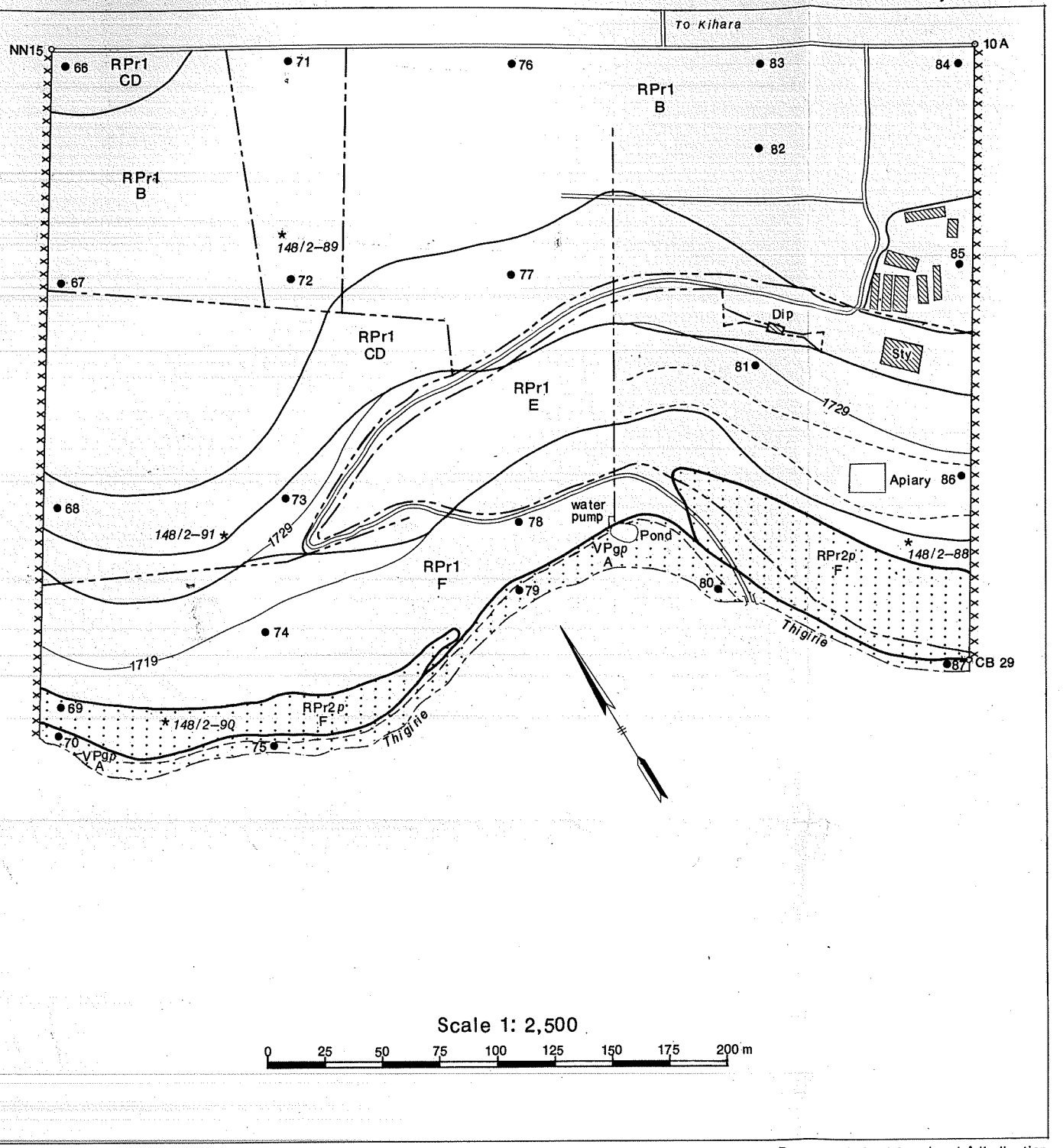
VP **Soils developed on infills derived from tuffs**

VPgp imperfectly drained, deep to very deep, dark reddish brown to very dark grey, mottled, friable, silty clay to clay

SOIL MAP OF NEW THIGIRIE FARM

(NAIROBI)

Ministry of Agriculture and Livestock Development
Kenya Soil Survey



Scale 1: 2,500

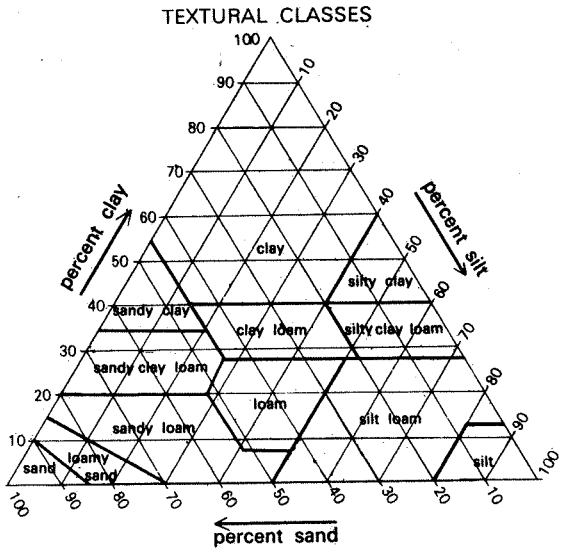
0 25 50 75 100 125 150 175 200 m

Base map derived from Land Adjudication Dept. Ruiru, Scale 1: 1,250

KEY

- soil mapping code
- UPr2p — depth class code
- AB — slope class code
- soil boundary
- slope class boundary
- ● 79 — augerhole observation, with reference number
- * 148/2–89 — profile pit observation, with reference number
- 1cm² — 0.0625 ha
- motorable track
- foot bridge
- 1729 / 1719 — contours V.I 10m
- canal
- terrace
- water way
- river
- ○ 10A — beacon, with reference number
- building
- plot boundary
- x x x x x x — survey area boundary

TEXTURAL CLASSES



KEY TO SLOPE CLASSES

slope %	slope class code	name of the macrorelief
0-2	A	flat to very gently undulating
2-5	B	gently undulating
5-8	C	undulating
8-16	D	rolling
16-30	E	hilly
>30	F	mountainous

KEY TO DEPTH CLASSES

thickness soil in cm	code and symbol* over rock	name
0–25		very shallow
25-50		shallow
50-80		moderately deep
80-120	p	deep
120–180		very deep
>180		extremely deep

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

SURVEY AND MAP PREPARATION (1984)

soil survey ..... B.K. Waruru, B. Ita and H. Onyono
map compilation ..... B.K. Waruru
map correlation ..... J.R. Rachilo and P.T. Gicheru
cartography ..... L.H. Mikisi