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MINISTRY OF AGRICULTURE—NATIONAL AGRICULTURAL LABORATORIES

KENYA SOIL SURVEY

DETAILED SOIL SURVEY OF NG'ANG'A'S FARM, LANGATA (NAIROBI)

by

B.K.Waruru and B.N.Ita

TAILED SOIL SURVEY REPORT No.D36,1986

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1. INTRODUCTION

At the request of the owner of the farm (Plot no. 2327/94), Kenya Soil Survey carried out a detailed soil survey with the aim of assessing the suitability for horticultural and field crops under overhead irrigation.

The fieldwork was carried out during five days in March and April 1984 by Mr. B. K. Waruru and Mr. H. Onyono.

Acknowledgement is given to Mr. Ng'ang'a, owner of the farm for the assistance given during the fieldwork; the staff of the Chemistry Section of the National Agricultural Laboratories for analysing the soil samples.

2. THE ENVIRONMENT

2.1 Location and communication

The survey area comprising of 2 ha is located in Lang'ata, Nairobi Province near Hardy Shopping Centre, about 2 km from the VoK short wave transmission station in a S.W. direction and approximately 18 km south-west of Nairobi city centre (see appendix 2 for location map).

The co-ordinates of the farm are approximately 36° 44'S and 1° 21'E. The altitude is about 1800 m above sea level. Accessibility to the farm is good through a tarmac road.

2.2 Climate

The survey area is situated in the lower areas which ascend towards the Ngong Hills. The climate of the area has been described using data of Karen Quarry Lane rainfall station (No. 91.36138). The station lies about 2 km S.W. of the survey area at 1° 23'S and 36° 44'E lines of latitude and longitude respectively. It has a rainfall record of 20 years (1972).

2.2.1 Annual and seasonal rainfall averages

The area is characterised by two rainfall seasons. The long rains lasting from March to May with their peak in April and the short rains occuring from October to January with a peak in November. Total annual rainfall is 965 mm (EAMD, 1972).

Dry months are February, June to September with July (20 mm) as the driest month of the year, (see table 1).

The average seasonal rainfall for the long rains is 475 mm (49%) and for the short rains it is 346 mm (36%), while the dry months contribute 144 mm (15%).

2.2.2 Maximum, mean and minimum temperatures

The mean annual temperatures calculated using the equation T°C = 30.2 - 0.0065x, where x is altitude in thousands of metres (EAMD, 1970) is 19°C. Mean maximum, mean minimum and absolute minimum calculated using similar formulae are 25°C, 12°C and 4°C respectively (see table 2).

2.2.3 Potential evaporation and evapotranspiration

Potential evaporation is estimated to be 1778 mm using Woodhead's (1968) equation [Eo (mm) = 2422-0.358h, where h is the station's altitude in metres]. Evapotranspiration (2/3 Eo) is estimated to be 1185 mm. Both monthly Eo calculated using 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 precipitation received at a particular place and its loss by evapotranspiration (r-Et). The Et is taken to be the crop water requirement. The results of a simple water balance for Karen Quarry Lane rainfall station are shown in table 1.

The area has a rainfall deficit in most of the year except in the months of April, May and November when there is surplus rainfall (i.e. excess in terms of crop requirements). In the rest of the months there is inadequate rainfall for crop requirements. The highest rainfall deficit is in the month of September while the lowest is in the month of December (see table 1).

The probability that rainfall is equal to or greater than the crop water requirement (Pr $\geq$ 2/3 Eo) has been calculated by Braun (1977) for various parts of the country. Data for the survey area is shown in table 3.

Table 1. Mean, monthly and annual rainfall (r), potential evaporation (Eo), evapotranspiration Et (2/3 Eo), simple water balance and r/Eo ratio of the Karen Quarry Lane rainfall station.

Month	J	F	M	A	M	J	J	A	S	O	N	D	Year
r (mm)	72	48	73	213	189	31	20	22	23	55	134	85	965
Eo (mm)	196	178	178	142	125	107	89	107	160	178	142	178	1778
Et (2/3 Eo) mm	131	119	119	95	83	71	59	71	107	119	95	119	1185
r-Et (mm)	-59	-71	-46	118	106	-40	-39	-49	-84	-64	39	-34	
r/Eo (%)													54

Table 2. Temperatures (°C) for the Karen Quarry Lane station

Mean annual temperature	19
Mean maximum temperature	25
Mean minimum temperature	12
Absolute minimum temperature	4

Table 3. Seasonal rainfall probabilities

Period	r (mm)	Et = 2/3 Eo (mm)	Pr ≥ 2/3 Eo (%)
Long rains			
April-June	433	249	86
April-July	453	308	81
April-August	475	379	70
Short rains			
November-December	274	214	64
November-January	346	345	40

It can be seen from this table that for a 3-months crop the probability for the long rains is 86%, which means that on average in 9 out of 10 years a good crop can be expected. For a 4-months crop Pr = 81%, viz. on average 8 out of 10 years have sufficient precipitation, while for a 5-months crop the probability is lowered to 70%, viz. on average 7 out 10 years will have enough rainfall. No additional moisture is needed if all precipitation is stored in the soil and no losses occur through run-off or deep percolation.

In the short rainy season the probabilities that rainfall is greater than or equal to the crop water requirement are for a 3-months crop 64% and for a 4-months crop 40% (viz. on average in 6 out of 10 and in 4 out of 10 years respectively there will be enough rainfall). The low probabilities for this season indicate the need for additional irrigation.

2.3 Geology and physiography

According to Saggerson (1971), the area is covered by Tertiary Ngong volcanics (Nairobi trachytes).

Physiographically the survey area is part of a gently undulating to rolling upland or the lower part of the volcanic footridges in which rivers like the Mbagathi are deeply incised. The relief changes over short distances (less than 10 m).

2.4 Vegetation and land use

A small relic of the Ngong forest occurs in the N.E. part of the farm. The rest of the area has a planted grass cover with exotic trees like Cyprus, Cedar, Eucalyptus and Jacaranda. 30% of the farm is cleared for cultivation of maize.

3. THE WORKING METHODS

3.1 Office methods

Since the topographical map of scale 1:50,000 didn't show enough detail, a cadastral plan at scale 1:2,500 was used as a base map. The map was enlarged to scale 1:500 and this served as a base map in the field.

After the fieldwork the base map with soils information was reduced to the final publication scale of 1:1,000.

3.2 Field methods

Using transects down the farm and visual differences in slope, 20 augerhole observations were made at an interval ranging from 10 to 60 m apart. Three profile pit observations were made, described and sampled, giving a density of 11 observations per ha.

The soils were examined for depth, texture, mottling, consistence, calcareousness (by HCl reaction) and pH according to the "Guidelines for soil profile description", (FAO, 1977). These properties were recorded on standard Kenya Soil Survey forms. Soil colour was determined using the "Munsell Soil Color Charts" (Munsell, 1971), while soil classification was done according to the legend of the soil map of the world (FAO-Unesco, 1974). Modifications to this system known as Kenyan concepts are described by Siderius and van de Pouw (1980). They are marked with an asterisk.

3.3 Laboratory methods

An outline of the methodology in chemical and physical sample analysis is given below. For a more comprehensive procedure, refer to Hinga et al. (1980).

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

Texture (Hydrometer). No chemical pretreatment was done to remove organic matter and other cementing agents.

Sand fraction 0.05-2 mm, silt 0.002-0.05 mm and clay < 0.002 mm.
pH-H_2O; 1:2.5 soil-water suspension.

pH-KCl; 1:2.5 soil - 1N KCl suspension.

Electrical conductivity (EC) in a 1:2.5 soil - water suspension.

% carbon : Walkley and Black method.

% N : semi-micro Kjeldhal method.

Exchangeable cations: The soils were leached with 1N ammonium acetate, pH 7.0 and the exchangeable cations viz. Ca^{2+}, Mg^{2+}, K^{+}, and Na^{+} determined with an EEL-flame photometer or 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 pH 8.2, 95% ethyl alcohol and 1N ammonium acetate pH 7.0 solution. The CEC was determined by measuring Na concentration in the last leachates with an EEL-flame photometer.

"Mass analysis" for available nutrients (topsoil only):

The samples were extracted with 1:5, 0.1N HCl/0.025N H_2SO_4 ratio. Ca, K and Na were determined with an EEL-flame photometer, Mn and P were determined colorimetrically.

4. THE SOILS

4.1 General properties of the soils

According to depth the soils in the survey area can be divided into three main groups. The shallow clay soils, moderately deep clays and the deep clay soils. They are all well drained and of moderate fertility. The shallow soils are gravelly, underlain by petroplinthite (indurated murram) or pisoferric material (loose murram), while the deep soils are friable with pisoferric material in places from 70 cm depth onwards.

4.2 Systematics and nomenclature

The whole of the survey area falls in one physiographic unit (uplands or lower part of volcanic foot ridges with same geology; intermediate igneous rocks - Nairobi trachytes). The separating criterion of the soil mapping units is mainly depth.

Each mapping unit is identified on the soil map by a mapping symbol for which a code system is used. The symbols in the code are as follows:

- U - uplands (physiography)
- I - soils developed on intermediate igneous rocks Nairobi trachytes (geology)
- r - red colour
- M - very shallow to shallow over petroplinthite (indurated murram)
- m - moderately deep over pisoferric material (murram)
- *m* - deep to very deep in places with pisoferric material (murram) from 70 cm and deeper.

In this survey, three depth classes were used taking into account the depth to underlying rock or petroplinthite (murram). The classes used are:

very shallow to shallow	0-50 cm
moderately deep	50-80 cm
deep	80-120 cm
very deep	>120 cm

4.3 Description of the soil mapping units

All the described profile pits fall within the mapping unit UIr*m*, thus the description of characteristics of the unit is a composite of the augerhole observations and three profile pits. Augerhole observations alone were used to characterise mapping units UIrM and UIrm. All mapping units fall into one physiographic and parent material unit (UI), for uplands and intermediate igneous rocks respectively.

Mapping unit UIr*m*

Extent	: 0.60 ha (slope class AB) 0.53 ha (slope class C) 0.48 ha (slope class CD)
Parent material	: Nairobi trachytes
Relief	: very gently undulating to rolling (slopes 2-14%)
Land use	: grazing
Susceptibility to erosion	: low to moderate
Drainage	: well drained
Soils, general	: These are strongly weathered, well drained, deep to very deep, dark red to dark reddish brown, friable clay soils with a tendency to gravelly clay in the lower horizons. They have an ABC sequence of horizons with clear to gradual and smooth boundaries. In the B-horizons are few thin clay cutans and throughout the profile are few small manganese concretions (0.1-0.3 mm).
colour	: A-horizon: dark reddish brown (5YR 3/3 to 2.5/4 moist) B-horizon: dark reddish brown to dark red (5YR 3/3 to 2.5YR 3/6 moist)
texture	: clay throughout
structure	: A-horizon: weak to moderate, medium to coarse angular and subangular blocky

: B-horizon: weak, medium to coarse prismatic breaking into angular and subangular blocky

consistence : A-horizon: friable when moist, sticky and slightly plastic when wet
B-horizon: friable when moist, slightly sticky and slightly plastic when wet

Chemical properties : A-horizon: %C ranges from 1.83 to 2.39; pH-H_2O 5.7 to 7.3 and pH-KCl from 4.2 to 5.4; CEC-soil varies between 24 and 30 me/100g, while base saturation varies from 23 to 45%.
B-horizon: pH-H_2O ranges from 4.8 to 5.8, and pH-KCl from 4.0 to 4.7; CEC-soil varies from 18 to 23 me/100g; while base saturation ranges from 21 to 44%. The ESP is below 2.

Diagnostic properties : ochric A-horizon, argillic B-horizon with a base saturation of less than 50%.

Classification : chromic ACRISOLS.

For detailed descriptions and analytical data see soil profile descriptions Nos. 1, 2 and 3 (observations Nos. 148/3-72, 148/3-73 and 148/3-74) of appendix 1.

Mapping unit UIrm

Extent : 0.03 ha (slope class C)
0.21 ha (slope class CD)

Parent material : Nairobi trachytes

Relief : gently undulating to rolling (slopes 4-14%)

Land use : grazing and partly recently ploughed for cultivation of maize and Irish potatoes.

Susceptibility to erosion : low to high

Drainage : well drained

Soils, general : they are moderately deep, dark red to dark reddish brown, clay to sandy clay loam soils. There are few (<1 mm diameter) manganese concretions in the B-horizon.

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

texture : A-horizon: clay with tendency to clay loam
B-horizon: clay.

consistence : friable when moist, slightly sticky and slightly plastic when wet.

Remarks: No profile pit was dug in this unit; a fertility sample was taken from augerhole observation no. 53 (see appendix 2 for location).

Mapping unit UIrM

Extent : 0.08 ha (slope class C)
0.17 ha (slope class CD)

Parent material : Nairobi trachytes

Relief : undulating to rolling (slopes 7-10%)

Land use : cultivation of maize, Irish potatoes (recently ploughed)

Susceptibility to erosion : moderate

Drainage : well drained

Soils, general : they are very shallow to shallow, dark reddish brown, gravelly clay, over petroplinthite or pisoferric material (murram); few manganese concretions (1-4 mm diameter).

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

texture : A-horizon: clay with tendency to gravelly clay loam
B-horizon: gravelly clay.

consistence : friable when moist, slightly sticky and slightly plastic when wet.

Remarks: No profile pit was dug in this unit and no fertility sampling was done either.

4.4 Soil fertility aspects

Table 4 below gives results of the fertility composite samples taken from the profile pits surroundings at a depth of 0-30 cm.

Table 4. Fertility analysis results (0-30 cm)

Mapping unit/ slope class	UIrm/AB	UIrm/C	UIrm/CD	UIrm/CD
Observation no.	148/3-72	148/3-73	148/3-74	Augerhole no. 53
pH	5.7	5.4	6.1	5.6
Na (me/100g)	0.16	0.40	0.14	0.16
K (me/100g)	1.06	0.94	1.22	0.98
Ca (me/100g)	3.0	2.0	9.0	3.2
Mn (me/100g)	1.18	1.34	1.14	1.75
P (ppm)	7	12	10	7
N (%)	0.20	0.22	0.26	0.15
C (%)	1.83	1.86	2.39	2.04

From table 4 above, it can be seen that the soils are of moderate acidity and sufficiently supplied with some basic plant nutrients viz. Ca^{2+}, K^{+}. All the units are low in phosphorus while unit UIrm/CD is deficient in nitrogen. Units UIrm/AB and UIrm/C have a low carbon percentage. In view of the prevailing situation, ammonium phosphate fertilizer should be applied while liming materials and farm yard manure or compost manure could be applied to improve the general soil conditions as well as supply the deficient plant nutrients.

5. LAND SUITABILITY FOR IRRIGATED HORTICULTURAL AND FIELD CROPS

5.1 Introduction

The suitability assessment of the farm was done in conformity to the principles and concepts in the "Frame work for land evaluation" (FAO, 1976), based on physical aspects only. The suitability assessment was done for both horticultural and field crops under overhead irrigation and assuming a high level of managements.

The horticultural crops for which the land was evaluated include the following vegetables viz. cabbages, tomatoes, carrots, onions, capsicums, spinach, kales, and beans, while fruits include citrus and bananas.

The field crops are maize, Irish potatoes and other similar crops with the same requirements.

The high level of management implies use of modern farming technology such as use of improved seeds, appropriate fertilizers, chemicals for diseases and pests control, proper spacing, timely farm operations (planting, weeding and chemical applications), soil and water conservation measures and crop rotation.

Thus the following assumptions were made during the assessment:

1. A high level of management will be applied
2. The inputs viz. fertilizers and/or manures, chemicals and improved seeds will be available
3. Availability of irrigation water is not limiting and the quality will be safe for crops and soils.

5.2 Land qualities and their ratings

The following land qualities were considered applicable in the survey area and used as diagnostic criteria:

1. Soil moisture storage capacity (SMSC)
2. Availability of nutrients
3. Possibilities of mechanisation
4. Availability of foothold for roots.

1. Soil moisture storage capacity (SMSC)

The amount of water the soil can retain is an important aspect for plant growth and is used as a parameter for indicating the frequency and the amount of water to apply to the crops. In turn the amount of moisture the soil can store is dependent on soil texture and depth.

The SMSC is equal to the moisture content at field capacity (pF 2.0) minus the moisture content at pF 3.7. Due to lack of pF data in the survey area the SMSC was estimated using depth and texture and rated according to Braun and van de Weg (1977) as shown in table 5.

Table 5. Soil moisture storage capacity rating

Soil moisture storage capacity 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

Nutrients play a major role in soil productivity. The ability of the soil to hold and supply plant nutrients is an important land quality which is evaluated using cation exchange capacity (CEC) and available nutrients in the topsoil (table 6). A high CEC is a desirable feature of a soil as this allows a higher proportion of nutrient cations to be stored.

Table 6. Availability of nutrients ratings

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

CEC (me/100g)	Subrating	
> 16	1	very high
12-16	2	high
6-12	3	moderate
2-6	4	low
0-2	5	very low

(b) Sub-rating available nutrients of the topsoil (0-30 cm)

Available P (ppm)	Available K (me/100g)	Available Ca (me/100g)	Sub-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
0-20	0.3-1.0	2-6	4	low
0-20	0-0.3	0-2	5	very low

The sum of the sub-ratings give the following final rating for the availability of nutrients.

(c) Final rating for availability of nutrients

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

4. Possibilities of mechanisation

The land characteristics found to be relevant in the area are

- steepness of slope
- stoniness/rockiness and shallowness of the soil.

These land characteristics are important to reckon where machinery operations are employed since they either hinder the operations or reduce the rate of their effectiveness. These land characteristics are rated in table 7.

Table 7. Possibilities of mechanisation ratings

(a) Sub-rating for slope

Slope %	rating	Description
0-8	1	flat to undulating
8-16	2	rolling
16-30	3	hilly
> 30	4	steeply dissected
> 30	5	mountainous

(b) Sub-rating for stoniness/rockiness and 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 or very shallow
5	exceedingly stony, and/or very rocky or very shallow

The sum of the sub-ratings give the following final rating for the possibilities of mechanisation.

(c) Final rating of the possibilities of mechanisation

Sum of sub-ratings	final rating	
2	1	very high
3-4	2	high
5-6	3	moderate
7-8	4	low
9-10	5	very low to none

5. Availability of foothold for roots

This land quality is useful where deep rooted crops are planted since they require sufficient depth for anchorage in the soil. The availability of foothold for roots is rated as shown in table 8.

Table 8. Availability of foothold for roots rating

depth class	depth to bedrock (cm)	rating	
very deep	> 120	1	very high
deep	80-120	2	high
moderately deep	50-80	3	moderate
shallow	25-50	4	low
very shallow	0-25	5	very low

Table 9. Rating of the land qualities for various soil mapping units

Soil mapping units/slope class	Soil moisture storage capacity	Availability of nutrients	Possibilities of mechanisation	Availability of foothold for roots
UIrm/AB	2	3	2	1-2
UIrm/C	1	3	2	1-2
UIrm/CD	1	3	3	1-2
U1rm/C	3	nd	2	3
U1rm/CD	3	3	3	3
U1rM/C	5	nd	5	5
U1rM/CD	5	nd	6	5

nd = not determined

5.3 Suitability classes and their criteria

The suitability for the land utilization types was assessed using 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 an unacceptable level.

Class S2; moderately suitable

Land having limitations which are moderately severe for sustained application 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 or requiring very high inputs.

Table 10. Suitability class-defining criteria for maize (conversion table)

Suitability class	Land qualities			
	Soil moisture storage capacity	Availability of nutrients	Possibilities of mechanisation	Availability of foothold for roots
S1	3	2	1	1
S2	3	3	2	2
S3	4	4	3	3
NS	5	5	4	4

Table 11. Suitability class-defining criteria for Irish potatoes (conversion table)

Suitability class	Land qualities			
	Soil moisture storage capacity	Availability of nutrients	Possibilities of mechanisation	Availability of foothold for roots
S1	2	2	2	2
S2	3	3	3	3
S3	4	4	4	4
NS	5	5	5	5

Table 12. Suitability class-defining criteria for vegetables (conversion table)

Suitability class	Land qualities			
	Soil moisture storage capacity	Availability of nutrients	Possibilities of mechanisation	Availability of foothold for roots
S1	2	1	2	2
S2	3	2	3	3
S3	4	3	4	4
NS	5	4	5	5

Table 13. Suitability class-defining criteria for bananas (conversion table)

Suitability class	Land qualities			
	Soil moisture storage capacity	Availability of nutrients	Possibilities of mechanisation	Availability of foothold for roots
S1	2	2	2	2
S2	3	3	2	3
S3	4	4	3	4
NS	5	5	4	4

Table 14. Suitability class-defining criteria for citrus (conversion table)

Suitability class	Land qualities			
	Soil moisture storage capacity	Availability of nutrients	Possibilities of mechanisation	Availability of foothold for roots
S1	3	2	1	1
S2	3	3	2	2
S3	4	4	3	3
NS	5	5	4	4

5.4 Land suitability classification

The final suitability of each mapping unit was arrived at by matching the land qulity ratings and the conversion tables, where the lowest single rating of any of the land qualities determines the suitability class of a particular land unit.

The results are shown below in table 15.

Table 15. Current land suitability for various land utilization types (LUTs)

Land unit (soil mapping unit/slope class)	Area (ha)	Land utilization type				
		Maize	Irish potatoes	Vegetables	Bananas	Citrus
UIrm/AB	0.60	S2	S2	S2	S2	S2
UIrm/C	0.53	S2	S2	S2	S2	S2
UIrm/CD	0.48	S3	S3	S3	S2	S2
UIrm/C	0.03	S3	S2	S2	S2	S3
UIrm/CD	0.21	S3	S3	S3	S2	S3
UIrM/C	0.08	NS	NS	NS	NS	NS
UIrM/CD	0.17	NS	NS	NS	NS	NS

6. CONCLUSIONS AND RECOMMENDATIONS

1. (a) Mapping units UIrm/AB and UIrm/C comprising 1.13 ha are moderately suitable for all crops under consideration. Limitation being availability of nutrients.

   (b) Mapping unit UIrm/CD consisting of 0.48 ha is moderately suitable for bananas and citrus; and marginally suitable for the rest of the crops. Limitations are possibilities of mechanisation and availability of nutrients.

   (c) Units UIrm/C and UIrm/CD comprising 0.24 ha are considered moderately suitable for Irish potatoes, vegetables and bananas. They are marginally suitable for the rest of the crops. Limitations are possibilities of mechanisation and availability of nutrients for unit UIrm/CD and availability of foothold for roots applying to both units.

2. (a) Assuming an evapotranspiration of 5 mm/day, mapping units UIrm and UIrm being moderately deep to very deep respectively can retain 80-100 mm of moisture per 100 cm soil depth. They will require irrigation frequency of 80-100/5 = 16-20 days, roughly once a fortnight.

   (b) The shallow unit UIrM will retain 50 mm/100 cm moisture, assuming a 5 mm/day rate of evapotranspiration. Water application frequency will be 50/5 days = 10 days, roughly once a week.

3. Phosphorus is deficient in all soils while Nitrogen deficiency is observed in some areas of the farm. Therefore appropriate fertilizers should be applied.
   Also farm yard manure or compost manure could be applied to improve the soil physical conditions as well as supply deficient plant nutrients.

4. Since the suitability of the borehole water for irrigation has not been ascertained, it would be appropriate for it to be analysed at NAL before commencing irrigation.

5. Soil and water conservation measures should be applied, in mapping units having steep slopes as precaution against potential soil erosion hazard.

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A P P E N D I X 1

DESCRIPTIONS OF SOIL PROFILES WITH ANALYTICAL DATA

LABORATORY DATA OF PROFILE DESCRIPTION No. 1

Observation no: 148/3-72 Mapping unit: UI'm Soil classification: chromic ACRISOL

Laboratory no. /84	3151	3152	3153	3154		
Horizon	Au	Bt1	Bt2	Ccs		
Depth (cm)	0-12	12-32	32-70	70-130		
pH-H_2O (1:2.5 v/v)	7.3	6.1	5.8	5.7		
pH-KCl "	5.4	4.8	4.7	4.7		
EC (mmho/cm) "	0.05	0.05	0.30	0.20		
$CaCO_3$ (%)						
$CaSO_4$ (%)						
C (%)	2.04	1.95	0.99	0.64		
N (%)						
C/N						
CEC (me/100g), pH 8.2	26.0	26.0	23.0	19.0		
CEC " " pH 7.0						
Exch. Ca (me/100g)	Trace	0.6	1.0	1.80		
" Mg "	0.32	1.84	2.64	2.32		
" K "	0.28	0.28	0.32	0.60		
" Na "	0.45	0.15	0.30	0.35		
Sum of cations	1.05	2.87	4.26	5.07		
Base sat. %, pH 8.2	23	25	29	39		
" " %, pH 7.0						
ESP at pH 8.2	1.7	0.6	1.3	1.8		

Texture (limited pretreatment)

Gravel % (>2.0mm)						
Sand % (2.0-0.05mm)	26	24	20	26		
Silt % (0.05-0.002mm)	24	24	14	18		
Clay % (0.002-0mm)	50	52	66	56		
Texture class	C	C	C	C		

Fertility aspects 0 - 30 cm Laboratory no. 3147 /84

General		Available nutrients			
pH-H_2O (1: 2.5 v/v)	5.7	Na/me/100g)	0.16	Mn (me/100g)	1.18
Exch. acidity (me/100g)		K "	1.06	P (ppm)	7
C %	1.83	Ca "	3.0	P-Olsen (ppm)	
N %	0.20	Mg "			

Remarks:

PROFILE DESCRIPTION NO.1

General Site information

Mapping Unit	: $U1_m$
Soil Classification	: chromic ACRISOL
Observation no/date	: 148/3-72, 3/4/84
Location/altitude	: Lang'ata (Nairobi province), 1800 m above sea level
Parent material	: Nairobi trachytes
Physiography	: Uplands
Relief, macro	: undulating
Relief, micro	: termite mounds
Slope gradient	: 8%
Land use	: grazing
Erosion	: low
Surface stoniness/rockiness	: Widely scattered weathering trachytes
Ground water	: not observed
Drainage class	: Well drained

Profile Description

Au 0-12 cm : dark reddish brown (2.5YR 2.5/4 moist); clay; moderate, medium to coarse subangular blocky; friable when moist, sticky and plastic when wet; many very fine to fine pores; few small (1-3mm diameter) ferro-manganese concretions; abundant very fine to fine roots; gradual and smooth transition to:

(Sample no. 148/3-72a)

Bt1 12-32 cm : dark reddish brown (2.5YR 2.5/4 moist); clay; weak, medium to coarse subangular blocky; friable when moist, slightly sticky and slightly plastic when wet; few thin clay cutans; many very fine, few fine to medium pores; frequent small (3 mm diameter) manganese concretions; abundant very fine, few fine roots; clear and smooth transition to:

(Sample no.148/3-72b)

Bt2 32-70 cm : dark reddish brown (2.5YR 3/4 moist); clay to clay loam; weak, medium to coarse prismatic, breaking into angular blocky; friable when moist, slightly sticky and slightly plastic when wet; few thin clay cutans; many very fine, few fine to medium pores; frequent small (2-4 mm diameter) manganese concretions; frequent very fine, few fine roots; abrupt and irregular transition to:

(Sample no. 148/3-72c)

Ccs 70-130 cm : dark reddish brown (2.5YR 3/4 moist); very gravelly clay; moderate to strong, medium to coarse granular and crumbs; loose when moist, slightly sticky and non plastic when wet; many very fine, few fine to medium, very few coarse pores; distinct small (1-5 mm diameter) manganese and iron oxide concretions; abrupt and irregular transition to petroplinthite layer.

(Sample no. 148/3-72d)

LABORATORY DATA OF PROFILE DESCRIPTION No. 2

Observation no: 148/3-73 Mapping unit: UIrm Soil classification: chromic ACRISOL

Laboratory no. /84	3155	3156	3157			
Horizon	Au	AB	Bt			
Depth (cm)	0-10	10-32	32-75			
pH-H_2O (1:2.5 v/v)	6.2	6.1	4.8			
pH-KCl "	5.1	4.2	4.2			
EC (mmho/cm) "	0.05	0.18	0.02			
$CaCO_3$ (%)						
$CaSO_4$ (%)						
C (%)	2.07	1.51	0.67			
N (%)						
C/N						
CEC (me/100g), pH 8.2	27.0	27.0	22.0			
CEC " " pH 7.0						
Exch. Ca (me/100g)	4.4	0.4	0.6			
" Mg "	3.36	0.48	0.56			
" K "	1.28	0.38	0.74			
" Na "	0.30	0.50	0.20			
Sum of cations	9.34	1.76	2.10			
Base sat. %, pH 8.2	42.0	25.0	21.0			
" " %, pH 7.0						
ESP at pH 8.2	1.11	1.85	0.90			
Texture (limited pretreatment)						
Gravel % (>2.0mm)						
Sand % (2.0-0.05mm)	28	22	18			
Silt % (0.05-0.002mm)	20	18	14			
Clay % (0.002-0mm)	52	60	68			
Texture class	C	C	C			

Fertility aspects 0 - 30 cm Laboratory no. 3148 /84

General		Available nutrients			
pH-H_2O (1:2.5 v/v)	5.4	Na/me/100g)	0.40	Mn (me/100g)	1.34
Exch. acidity (me/100g)		K "	0.94	P (ppm)	12
C %	1.86	Ca "	2.0	P-Olsen (ppm)	
N %	0.22	Mg "		Hp	0.1

Remarks:

PROFILE DESCRIPTION NO. 2

General site information

Mapping unit	: Ulrm
Soil classification	: chromic ACRISOL
Observation no/date	: 148/3-73, 3/4/84
Location/altitude	: Lang'ata (Nairobi province), 1800 m
Parent material	: Nairobi trachytes
Physiography	: Uplands
Relief, macro	: undulating
Relief micro	: nil
Slope gradient	: 8%
Land use	: idle land
Erosion	: no evidence
Surface stoniness/rockiness	: rock outcrops 4 m away from the observation
Ground water	: not observed
Surface sealing	: nil
Surface craking	: nil
Drainage class	: well drained

Profile description

Au 0-10 cm : dark reddish brown (2.5YR 2.5/4 moist); clay; moderate, very fine to fine subangular blocky; friable when moist, sticky and plastic when wet; many very fine, very few fine to medium pores; few small (1-3 mm diameter) ferro-manganese concretions; many very fine, common fine, few medium to coarse roots; gradual and smooth transition to:

(Sample no. 148/3-73a)

AB 10-32 cm : dark reddish brown (2.5YR 2.5/4 moist); clay; weak, medium to coarse angular and subangular blocky; friable when moist; slightly sticky and slightly plastic when wet; many very fine, few fine to medium pores; very frequent small (1-2 mm diameter) manganese concretions; common very fine and fine, few coarse roots; clear and smooth transition to:

(Sample no. 148/3-73b)

Bt 32-75 cm : dark red (2.5YR 3/6 moist); clay; weak to moderate, medium to coarse angular and subangular blocky; friable when moist; slightly sticky and slightly plastic when wet; few thin clay cutans; frequent small (1-3mm diameter) manganese concretions; many very fine, common fine, few medium roots; abrupt and irregular transition to:

(Sample no. 148/3-73c)

C 75-114 cm : dark red (2.5YR 3/4 moist); gravelly clay; loose when moist; slightly sticky and non-plastic when wet; very frequent small (2-3 mm diameter) manganese concretions; diffuse and irregular transition to murram plus weathering rock.

LABORATORY DATA OF PROFILE DESCRIPTION No. 3

Observation no: 148/3-74 Mapping unit: UIrm Soil classification: chromic ACRISOL

Laboratory no. /84	3158	3159	3160	3161	3162	
Horizon	Au	BA	Bt1	Bt2	Btcs	
Depth (cm)	0-10	10-29	29-70	70-112	112-150	
pH-H_2O (1: 2.5 v/v)	5.7	6.0	5.4	5.4	6.1	
pH-KCl "	5.0	4.2	4.0	4.2	4.6	
EC (mmho/cm) "	0.07	0.03	0.02	0.02	0.02	
$CaCO_3$ (%)						
$CaSO_4$ (%)						
C (%)	2.33	1.31	0.58	0.50	0.38	
N (%)						
C/N						
CEC (me/100g), pH 8.2	30.0	24.0	23.0	23.0	18.0	
CEC " " pH 7.0						
Exch. Ca (me/100g)	2.0	3.0	1.2	0.8	1.8	
" Mg "	1.12	2.72	0.96	0.64	1.36	
" K "	1.60	0.48	0.44	1.10	1.56	
" Na "	0.30	0.45	0.40	0.35	0.40	
Sum of cations	5.02	6.65	3.0	2.89	5.12	
Base sat. %, pH 8.2	45	23.0	22.0	29.0	44	
" " %, pH 7.0						
ESP at pH 8.2	1.00	1.86	1.74	1.52	2.22	
Texture (limited pretreatment)						
Gravel % (>2.0mm)						
Sand % (2.0-0.05mm)	18	22	18	16	16	
Silt % (0.05-0.002mm)	32	18	12	12	12	
Clay % (0.002-0mm)	50	60	70	72	72	
Texture class	C	C	C	C	C	

Fertility aspects 0 - 30 cm Laboratory no. 3149 /84

General		Available nutrients			
pH-H_2O (1:2.5 v/v)	6.1	Na/me/100g)	0.14	Mn (me/100g)	1.18
Exch. acidity (me/100g)		K "	1.22	P (ppm)	10
C %	2.39	Ca "	9.0	P-Olsen (ppm)	
N %	0.26	Mg "			

Remarks:

PROFILE DESCRIPTION NO. 3

General site information

Mapping unit	: Ulrm
Soil classification	: chromic ACRISOL
Observation no./date	: 148/3-74, 4/4/84
Location/altitude	: Lang'ata (Nairobi province), 1800 m
Parent material	: Nairobi trachytes
Physiography	: Uplands
Relief, macro	: rolling
Relief, micro	: nil
Slope gradient	: 12%
Land use	: grazing
Erosion	: no evidence
Surface stoniness/rockiness	: nil
Ground water	: not observed
Drainage class	: well drained

Profile Description

Au 0-10 cm : dark reddish brown (5YR 3/3 moist); clay;strong very fine to medium subangular blocky; friable when moist, slightly sticky and slightly plastic when wet; common very fine pores; many very fine to fine, common medium roots; clear and smooth transition to:

(Sample no. 148/3-74a)

BA 10-29 cm : dark reddish brown (2.5YR 3/4 moist); clay; moderate, medium to coarse subangular blocky; friable when moist, sticky and slightly plastic when wet; few thin clay cutans; common very fine, few fine pores; common very fine to fine, few medium and coarse roots; clear and smooth transition to:

(Sample no. 148/3-74b)

Bt1 29-70 cm : dark reddish brown (2.5YR 3/4 moist); clay; moderate, medium to coarse angular blocky; friable when moist, slightly sticky and slightly plastic when wet; common thin clay cutans; common very fine, few fine pores; few fine, medium and coarse roots; gradual and smooth transition to:

(Sample no. 148/3-74c)

Bt2 70-112 cm : dark reddish brown (2.5YR 3/4 moist); clay; weak, medium to coarse, porous massive, breaking into weak, medium to coarse angular blocky; friable when moist, slightly sticky and slightly plastic when wet; few thin clay cutans; few very fine and fine pores; few very fine,common fine and few medium roots; gradual and wavy transition to:

(Sample no. 148/3-74d)

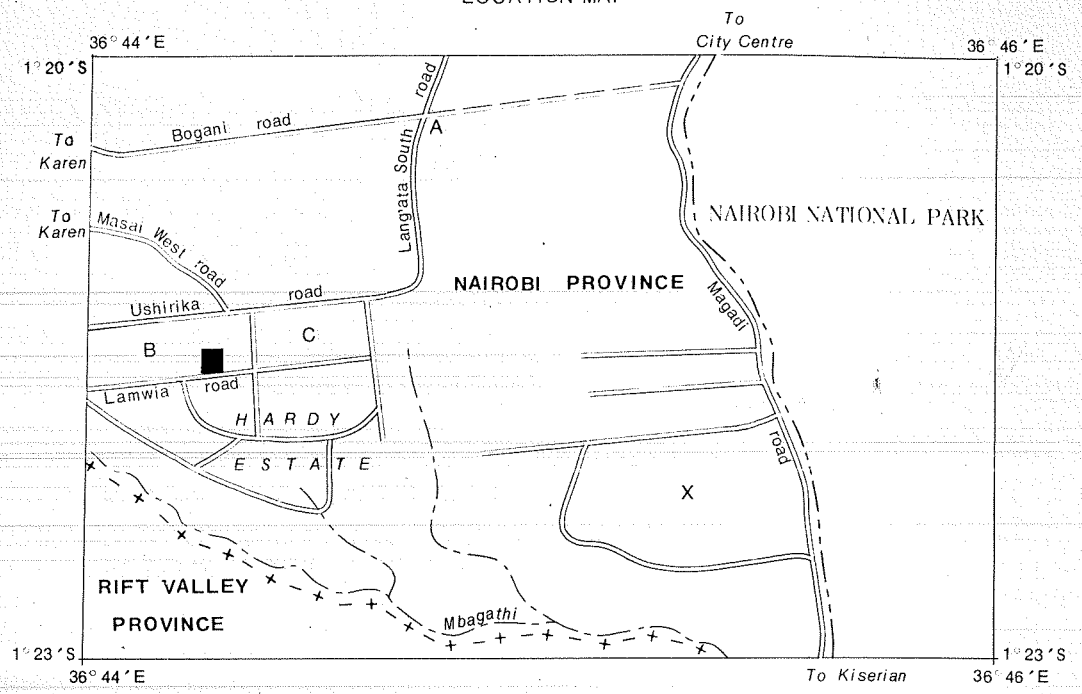
Btcs 112-150+ cm : dark red (2.5YR 3/6 moist); clay; weak, medium to coarse angular blocky; friable when moist, slightly sticky and slightly plastic when wet; few very fine pores; few very fine, fine and medium roots.

(Sample no. 148/3-74e)

DETAILED SOIL MAP OF NG'ANG'A's FARM, L.R. No. 2327/94, LANG'ATA (NAIROBI)

Appendix 2 to report No. D36

LOCATION MAP

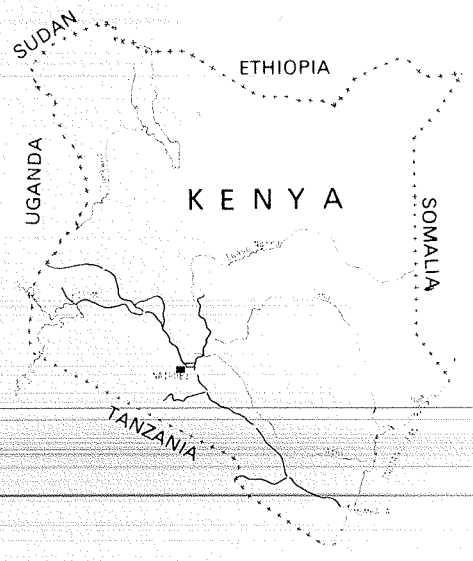


SCALE 1:50,000

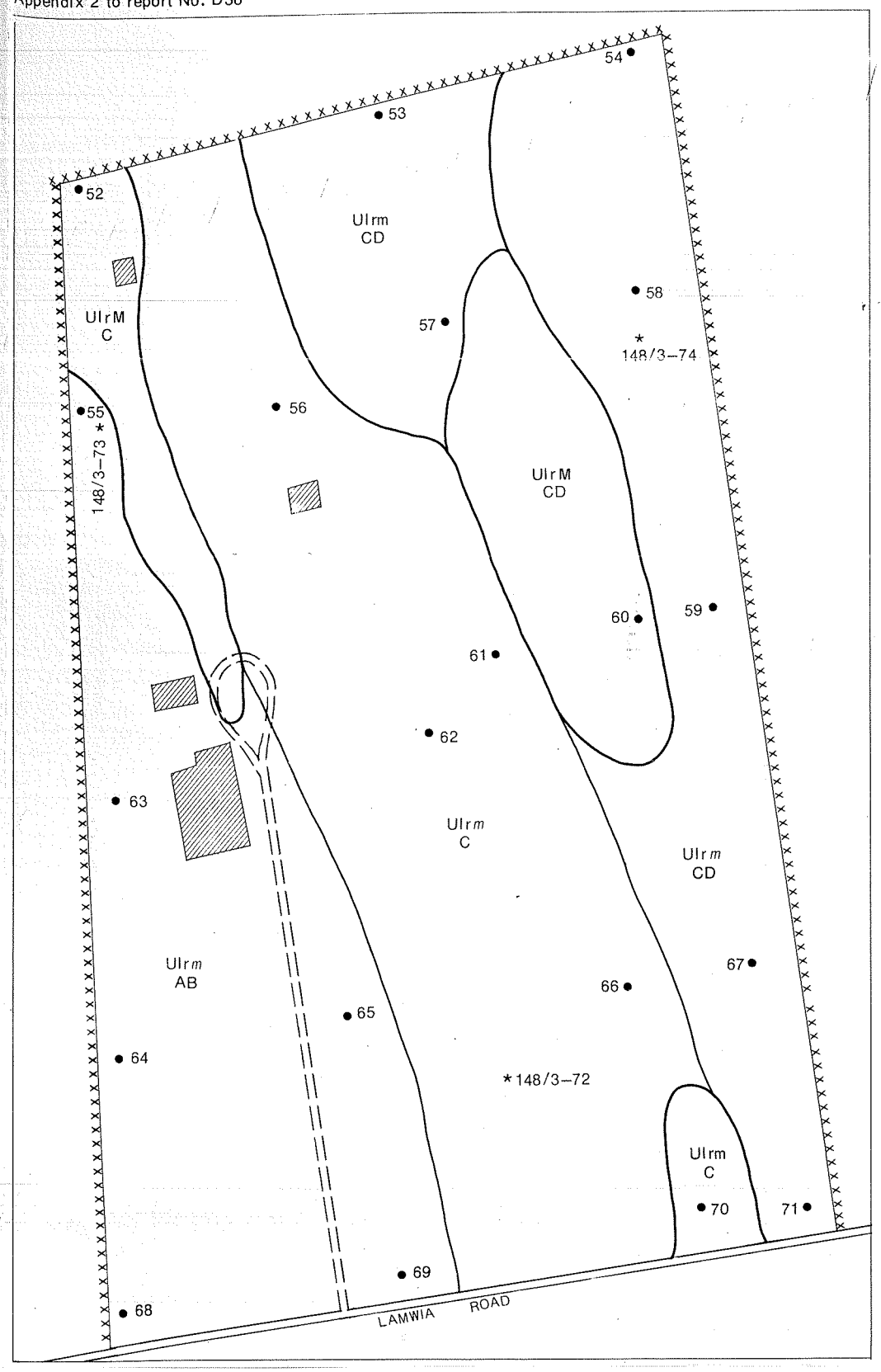
0 0·5 1 1·5 2 Km

KEY

■	survey area	tarmac road
A	Voice of Kenya transmission station	dry weather road
B	The Co-operative College	National Park boundary
C	Hardy shopping centre	Provincial boundary
X	Kenya Post and Telecommunications, Mbagathi	river



■ Location of surveyed area



SCALE 1:1,000

0 10 20 30 40 50m

LEGEND

U UPLANDS (slopes 2–12%)

Ul Soils developed on intermediate igneous rocks (Nairobi trachytes)

- Ulrm — well drained, deep to very deep, dark red to dark reddish brown, friable clay; in places with pisoferric material (murram) from 70cm (chromic ACRISOLS)
- Ulrm — well drained, moderately deep, dark red to dark reddish brown, friable clay, over pisoferric material (murram)/rock
- UlrM — well drained, very shallow to shallow, dark reddish brown, gravelly clay, over petroplinthite or pisoferric material (murram)/rock

KEY TO SLOPE CLASSES

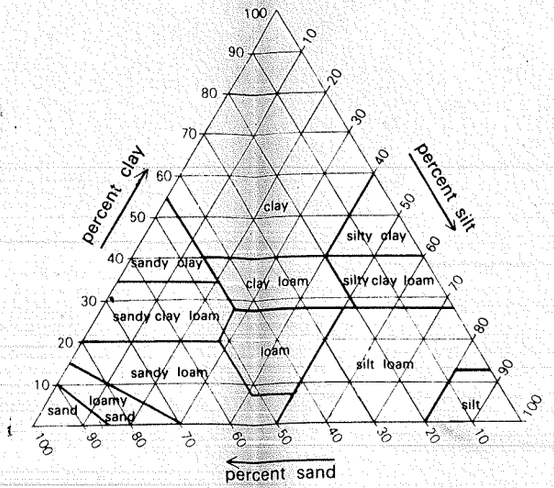
slope %	slope class code +	name of the macrorelief
0-2	A	flat to very gently undulating
2-5	B	gently undulating
5-8	C	undulating
8-16	D	rolling

KEY TO DEPTH CLASSES

thickness soil in cm	code and symbol + over rock	code and symbol + over murram	name
0 - 25	M		very shallow
25- 50			shallow
50-80	m		moderately deep
80-120	m		deep
more than 120			very deep

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

TEXTURAL CLASSES



SOIL SURVEY AND MAP PREPARATION (1984–1985)

soil survey ..... B.K.Waruru, H.Onyono

map compilation ..... B.K.Waruru

map correlation ..... J.R. Rachilo and P.T. Gicheru

cartography ..... L.H. Mikisi

KEY

- soil mapping code
- Ulrm — depth class code
- AB — slope class code
- soil boundary
- slope class boundary
- • 57 — auger hole observation, with reference number
- *148/3–52 — profile pit observation, with reference number
- 1cm² — 0.01 ha
- tarmac road
- motorable road
- building
- xxxxxx — survey area/farm boundary

Drawing No. 84097