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# KENYA SOIL SURVEY

## DETAILED SOIL SURVEY OF KIMANA IRRIGATION SCHEME

KAJIADO DISTRICT

by

E. N. K. Mugai and P. J. K. Kanake

DETAILED SOIL SURVEY REPORT No.D 11, 1978

Kenya Soil Survey
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## TABLE OF CONTENTS

## 1. INTRODUCTION

On request from the Minor Irrigation Development Committee of the Land and Farm Management Division, Ministry of Agriculture, a detailed soil survey was conducted in the 177 ha Kimana Irrigation Scheme. Prior to the detailed soil survey which was carried out in the period between August and November 1977, a pre-survey involving 4 augerhole observations was conducted in July 1976. The purpose of this early work was to evaluate the feasibility of conducting a detailed soil survey in the Tikondo/Kimana irrigation schemes.* Kimana (which lies on the western side of the Oloitokitok road was preferred; because topographic map existed and because the soils looked more promising.

While a soil map and report are necessary prerequisites in assessing whether an irrigation scheme is worth starting at all in a given area and is needed in the design of the canal and drainage works, it is evident that this report will have limited value for the latter. This is because land is already adjudicated and demarcated into individual plots which in most cases are not compatible to a well designed canal and drainage network. Water is the major constraint and this problem (water shortage) can be alleviated only through proper canal design and efficient irrigation methods.

The co-operation of Mr. Ndolo, the AAO-Oloitokitok, and the farmers at Kimana during the survey period is greatly acknowledged by the authors. Acknowledgement is also given to the Senior Soil Chemist and staff of the the Soil Chemistry Section, National Agricultural Laboratories for analysing the soil samples.

## 2. PREVIOUS WORK

Irrigation farming at Kimana started in 1969 through the initiative of the local people. The canals were haphazardly dug till 1974 when the government, through the District Development Committee, released some funds to finance their proper construction. In July 1975, topographic survey work started; by early August 1975 the map including the main canals was completed for the Kimana area.

* In this report the area west of the Oloitokitok road is called Kimana, east of the road, Tikondo.

In July 1976, the Kenya Soil Survey (S.T.F.) visited the scheme and did a pre-survey study which consisted of four augerhole observations in both Kimana and Tikondo schemes. Loitulelei river water was also sampled for laboratory analysis. This work was reported in "Kimana and Rembo schemes - Kajiado, A pre-survey report" (mimeo).

The Ministry of Water Development, Hydrology Section, has been measuring the flowrates of Kimana and Tikondo springs from 1939 to 1965. Unfortunately no gauging stations have ever been opened on the Loitulelei river. This data is of great importance in assessing how much land can be irrigated in a well planned irrigation system.

Mention must be made of the reconnaissance soil survey (scale 1:250,000) which presently is being conducted in the Kajiado District by L. Touber of the FAO/UNDP Wildlife Management Project, Ministry of Tourism and Wildlife (at present with Kenya Soil Survey). In this survey, Kimana soils fall in unit YVb which is described as consisting of soils which are "well drained, deep to very deep, dark brown, very friable, gravelly clay [illegible] loam", conforming well with the description of the soils of units $YV_1$ and $YV_2$ in this report.

## 3. ENVIRONMENTAL CONDITIONS

### 3.1. Location and Communications:

The survey area is located in the Oloitokitok division of Kajiado District. It lies at latitude 2°48' S and longitude 37° 32'E, and at an elevation of 1260 m above sea-level. The area is served by a dry weather road from Sultan Hamud. This road is impassable when the seasonal rivers are filled with water. The area is about 15km north from Oloitokitok town.

### 3.2. Geology and physiography:

The soils of the survey area have developed on colluvium/alluvium deposits derived from the Kilimanjaro volcanic rocks. The alluvium/colluvium, which is easily recognised in the C-horizon, overlies the volcanic lava. Colluvial/alluvial lava pebbles are found varying in quantity in the soil profile; sometimes in gravel beds of varying thickness. Volcanic boulders are common in the upper part of the scheme.

The survey area is located in the piedmont plain of the Kilimanjaro mountain. The general landscape is flat to very gently undulating with slope decreasing to the North.

### 3.3. Climate, vegetation and land use.

There is no meteorological station at Kimana. The only station of close proximity to the survey area is Oloitokitok. However Oloitokitok rainfall and temperature data are on the higher and lower side resp. compared with those assumed for Kimana. Kimana is thought to have a rainfall in the order of 600 mm. With an annual evaporation in the order of 1970 mm, Kimana's rainfall/evaporation ratio is 30% which puts the area in ecological zone V (Makindu near Kibwezi for example has the same $r/E_o$ ratio of 30%). The risks of rainfed agriculture in zone V are very high.

Table I gives temperature and potential evaporation (derived from altitude) for Kimana and rainfall for Oloitokitok. Table II gives temperature, potential evaporation (derived from altitude) and rainfall recorded at Rongai area scheme (the latter one is appr. 10 km NW of Oloitokitok and 10 km SW of Kimana.

As shown in tables I and II, rainfall is concentrated in two rainy seasons viz. March to April and November to December. The November to December rainy season seems to be the most reliable.

Due to nearness to Kilimanjaro, the average temperatures might be up to 3$^{o}$ C lower than those calculated and reported in table I and II.
The water deficit, as shown by the rainfall/evaporation (r/Eo) ratio, is quite high except in November, March and April, indicating that no crop taking more than two months to mature, can be grown in the area without supplementary irrigation.

The vegetation types of the survey area vary from one spot to another. It varies from wooded bushed grassland, in the south western part through dense thicket in the northern part, to "forest" in the region where the river Loitulelei disappears into the ground. The trees consist exclusively of Acacia tortilis. However, along the river it is replaced by Acacia xantophloea. The dominant shrub species are Balanites aegytiaca, Salvadora persica and Maerua spp. To the east of Kimana area, these shrub spp. are replaced by Acacia nubica.
The most frequent grass species is Pennisetum stramineum, often accompanied by Pennisetum mezianum and Cynodon plectostachyus.

Table I Temperature and Potential Evaporation for Kimana (derived from altitude) and rainfall for Oloitokitok (M. of A. office), Station No.9237004

| Month | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | Annual Total average |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temperature °C (mean) | 22.5 | 23.2 | 23.5 | 22.8 | 21.9 | 21.0 | 20.4 | 20.6 | 21.5 | 22.2 | 22.2 | 22.0 | 22.0 |
| Rainfall (mm) 1946-1971 | 53 | 59 | 113 | 123 | 33 | 25 | 2 | 1 | 3 | 57 | 176 | 150 | 795 |
| Potential Evaporation (mm) | 197 | 177 | 197 | 158 | 158 | 138 | 138 | 138 | 158 | 177 | 158 | 177 | 1971 |
| r/Eo % | 27 | 33 | 58 | 78 | 21 | 18 | 1 | 1 | 2 | 32 | 112 | 85 | 40 |

Table II Rongai Area - Temperature and Evaporation (derived from altitude) and rainfall for 1971 and 1972, station no.9237026 (altitude 1373m).

| Month | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | Annual Total Average |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temperature °C (mean) | 21.8 | 22.4 | 22.8 | 22.1 | 21.2 | 20.3 | 19.7 | 21.1 | 20.7 | 21.5 | 21.4 | 21.3 | 21.4 |
| Potential Evaporation (mm) | 193 | 173 | 193 | 155 | 155 | 135 | 135 | 135 | 155 | 174 | 155 | 173 | 1931 |
| Rainfall (mm) 1971 | 34 | 60 | 72 | 274 | 40 | 0 | 0 | 0 | 0 | 0 | 298 | 196 | 974 |
| 1972 | 127 | 80 | 95 | 0 | 26 | 0 | 0 | 0 | 0 | 40 | 284 | 131 | 783 |

At present basin type of irrigation is being practiced and subsistance crops like maize, bananas, sugarcane etc. are grown. However, recently the Horticultural Development Authority has been encouraging the cultivation of horticulturao crops, in particular onions and cabbages, especially the former one is doing very well.

### 3.4. Hydrology and water resources

River Loitulelei which originates from Mt. Kilimanjaro is the only source of irrigation water at Kimana. The other water resources are the Tikondo and Kimana springs. However, Tikondo spring is being used to irrigate the Tikondo Scheme while Kimana spring is at present not being utilised for irrigation purposes.

There are no discharge measurements for Loitulelei stream. However, it is estimated to have less flow than Tikondo and Kimana springs. At present it is irrigating about half of the potential irrigable land at Kimana though with a lot of problems. It is not understood whether this is due to poor management or real lack of water. However, it is clear that expansion of the present irrigated land will create more water shortage problems.

The only solution for this problem would be to pump Loitulelei water upstream into a storage reservoir if all the Kimana irrigable lands are to be used.

The following are flow rates for Kimana and Tikondo springs:

Table III - Flow rates of Kimana and Tikondo springs:

| Springs | Date | $ft^3/sec$ | $m^3/sec$ |
|---|---|---|---|
| Kimana | 13-2-61 | 6.82 | 0.19 |
| | 9-3-65 | 6.99 | 0.20 |
| | 6-8-65 | 8.99 | 0.26 |
| Tikondo | 9-3-65 | 1.19 | 0.03 |

Data supplied by Ministry of Water Development.

The water of Loitulelei is suitable for irrigation. It has no salt or sodium hazard as reflected by the low electrical conductivity, sodium adsorption ratio and the adjusted SAR (see table IV). With so low sodium content of the water and the very good drainage of the soils, no increase in the ESP of the soils will be anticipated in the short run. The following is the chemical analysis of two samples; one taken from the river Loitulelei itself (at the intake point) in July, 1976 and the other taken about 100 m downstream from the intake point, in November, 1977.

Table IV - Chemical analysis of Loitulelei river water

| Analysis | Lab.No.4872/76 (intake) July, 1976. | Lab.No.8899/77 (from canal) 13/11/77 |
|---|---|---|
| pH | 7.0 | 8.6 |
| EC, (micromhos/cm) | 275 | 264 |
| Sodium (me /1) | 0.96 | 1.90 |
| Potassium " | 0.21 | 0.21 |
| Calcium " | 0.79 | 0.48 |
| Magnesium " | 1.27 | 0.70 |
| Carbonates " | NIL | 0.54 |
| Bicarbonates " | 3.06 | 2.46 |
| Chlorides " | 0.60 | 0.30 |
| Sulphates " | TRACE | NIL |
| Sodium Adsorption Ratio (SAR) | 0.95 | 2.5 |
| Adjusted SAR* | 1.62 | 3.75 |

The groundwater is deeper than 2m in the whole of the survey area. However, the soils are moist in the area where the Loitulelei river disappears into the ground. The tall trees growing at the site are attributed to the moist conditions prevailing in the soil throughout the year.

* In the presence of CO2 and/or HCO3, the Ca and Mg in irrigation water (or groundwater) may precipitate resulting in a higher Na/Ca+Mg ratio- so in a higher SAR value. The adjusted SAR value takes this process into account (FAO, 1976).

## 4. SURVEY METHODS.

A topographic map scale 1:5,000, produced by the Farm mapping unit of the Ministry of Agriculture was used as field base map. All the observations and field boundaries were marked on this map.

The survey work was done in two phases. The first phase consisted of augerhole observations. These were made following a grid system of 100m except where ground surface features necessitated an increase in observations. The depth of observations was 2.0m except in cases where stones, gravel or hard pans did not allow deeper augering. The soils were described for colour, depth, mottling, texture, consistance, stoniness etc. and analysed for pH and salinity in 1:5 suspension using portable electrical equipment.

After completion of the augerhole observations, provisional soil units based mainly on depth, texture, stoniness and pH, were drawn.

Representative sites in the different units were selected in which profile pits and infiltration tests were located. The profile pits were dug to a minimum depth of 1.5m. They were described in detail. Each horizon was sampled for chemical and physical analysis in the N.A.L. laboratory. Composite samples for chemical fertility properties were taken from the topsoil.

Infiltration tests were conducted according to the Double Ring-Infiltrometer method. The readings were recorded at hourly intervals till a near constant figure was reached.

After the receipt of laboratory data, the soil boundaries based on field data were slightly readjusted if needed.

## 5. SOILS.

### 5.1. Systematics and nomenclature

The whole of the survey area has the same physiography and geology and therefore all the mapping units bear the same symbols for physiography and geology. The soil profile characteristics which affect the management and use of the land, such as degree and depth of stoniness, the presence and depth of a duripan and the texture of the soil, have been used in separating the soil mapping units. The presence and depth of the duripan has been indicated by symbols used in the code. Other differences in soil profile characteristics which do not have a direct significance in the use and management of the soils have only been indicated by numerical figures.

The symbols in the code are explained below:

Y - Piedmont plain (physiography)
V - Soils developed on alluvium/colluvium deposits derived from undifferentiated igneous rocks
$\underline{M}$ - Very shallow soil depth over hardpan
$\overline{M}$ - Shallow soil depth over hardpan
m - Moderately deep soil over hardpan
$\underline{m}$ - Deep soil over hardpan

## 5.2. General properties of the soils

There are two major categories of soils in the survey area:

- those soils overlying a duripan and having severe surface and subsurface stoniness
- soils only gravelly below 100 - 150 cm.

The first category of soils consists of mapping units YV$\underline{M}$, YVM and YV$\underline{m}$, and are found in an area with slopes of more than 0.5%. They are characterised by a lot of surface and subsurface stones and gravels and a duripan (hardpan) at a depth of 20-120cm. The duripan is usually the limiting layer.

The second category covering about 96% of the total area, is found in the rather flat lower areas which have slopes of less than 0.5%. These soils are extremely deep and without any significant surface gravel in most of the area. Gravelly layers are common from about 100 cm.

All the soils of the survey area have very friable to friable (moist) and soft to slightly hard (dry) consistencies. The topsoil structure is usually crumby to weak subangular blocky. Generally the texture varies from clay loam to loam. In places the soils are calcareous. Chemical soil fertility assessed on basis of CEC, carbon percentage and available nutrients is rated as high (appendix 3)

One notable characteristic of the Kimana soils is their high porosity and good structure which accounts for their high infiltration rates and good rooting.

Infiltration rates (appendix 1) are high, classified as moderate to rapid (13.3; 5.7; 15.8; 13.8; 6.3 cm/h). This is attributed to the very porous nature and the good structure of the soils.

Besides the soil limitations of units YVM YVM and YVm, the area in which they are located is not irrigable due to water conveyance difficulties arising from the higher elevation of the area in relation to the present intake point.
The duripan occurs on varying depths, being shallow in the southern part and non-existent or extremely deep in the northern part of the scheme. This duripan is both saline and sodic (see analytical data of profile 182/3-100(B1).

Salinity was also recorded in a few scatered places though not mappable (see analytical data for X5 and F1.

A duripan is a subsurface horizon that is cemented by silica. They vary in the degree of cementation by silica and, in addition, they commonly contain accessory cements, chiefly iron oxides and calcium carbonate. As a consequence, duripans vary in appearance but all of them have very firm to extremely firm consistences. The parent materials of soil that have a duripan normally contain only a small amount of calcium. If calcium is abundant, a calcic horizon tends to supplant the duripan. The most strongly expressed cementation is commonly in soils that contain an appreciable amount of glass in the overlying horizons, which suggests the importance of soluble silica to the genesis. Geographically, duripans are restricted largely to areas of volcanism. Soils may be in sediments derived from regions that are rich in pyroclastic materials such as tuffs. Duripans are virtually impenetrable to roots of many plants. Under irrigation, such horizons are slowly permeable to water. (USDA, 1975).

From soil classification point, the soils can be classified as eutric Cambisols in the FAO/UNESCO system used in the preparation of the Soil Map of the World. In places the soils are less developed and show clearly stratification, they are then classified as eutric Fluvisols.

Soil units YVm, YVM and YVM have been classified as eutric Cambisols, duripan phase as the upper level of the duripan occurs within 100 cm of the surface.

## 5.3. DESCRIPTION OF THE SOIL MAPPING UNITS

## - GRAVELLY SOILS WITH A DURIPAN:

### 5.3.1. Mapping Unit YVM

The soils of this unit are well drained, very shallow to shallow (20-50cm) over duripan (hardpan) and dark reddish brown (5YR 3/3*) to dark yellowish brown (10YR 3/4 - 3/6) in colour. The structure of the topsoil is crumby. The "subsoil" has weak crumby to porous massive structure. Consistence when moist is very friable, to friable. In places and in some horizons, the soils are moderately to strongly calcareous. Textures vary from very gravelly clay loam to very gravelly loam. Gravels occur all through the profile.

Extent: 2.3 ha
Meso - and micro relief: None
Slope: about 0.5% - 0.8%
Vegetation/land use: Bushland to wooded bushed grassland/grazing

### 5.3.2. Mapping Unit YVM

Most characteristics of the soils of this unit except depth are like those of unit YVM. The depth of these soils ranges from shallow to moderately deep (30-85 cm over a hardpan (duripan). The duripan is the limiting factor to depth.

Extent: 1.9 ha
Meso - and micro relief: None
Slope: about 0.7%
Vegetation /land use: Bushed grassland/grazing

### 5.3.3. Mapping unit YVm

The soils of this unit are also like those of unit YVM except that they are generally deep (80-130 cm over a hardpan (duripan).

* all colours in moist condition unless otherwise stated.

Additional remarks on Units YVM, YVM and YVm

The roadcut profile (B1; 182/3-100) revealed that the duripan overlies a friable, finer textured soil (IIB1 horizon) which in turn overlies another duripan. The occurrence of this alternate layering of friable soil and duripan in Unit YVM is also evident at the river-bank in units YVM and YV1.

The duripan is saline and sodic (ECe: 35 mmhos/cm; ESP: 25). It is sandy loam in texture (laboratory).
For laboratory data on duripan see Appendix 2, profile 182/3-100.

- Other Soils

5.3.4. Mapping Unit YV1

These soils are well drained and dark-reddish brown (5YR 3/3-3/4). They are extremely deep (   180 cm); gravelly layers may be found from about 100 cm depth. However, these gravels are not regarded as "limitation to depth" as roots can easily penetrate through them. The topsoil structure is mainly crumby to weak subangular blocky. The structure of the subsoil is porous massive in general. Consistence is very friable to friable (when moist), soft (when dry). Calcareousness of varying degree is found in some places and horizons. Texture is mainly clay loam to loam. For representative profile see appendix 2: 182/3-101.

Extent: 3.8 ha
Meso and micro-relief: None
Slope: about 0.6%
Vegetation/land use: Wooded bushland with trees along the river/grazing.

5.3.5. Mapping Unit YV2

This unit forms about 94% of the survey area. The soils are like those found in unit YV1 in most of the characteristics. However, there are some differences in colour, structure, consistence, calcareousness and depth. Colour varies from dark reddish brown (5YR 3/3-3/4) to dark brown (7.5YR 3/2-3/3). Some horizons may be dark yellowish brown (10YR 3/4). The structure, especially in the north western part may be angular blocky with hard (when dry) and friable (when moist) consistence.

The soils of this unit are calcareous only in few places and horizons within the profiles. They are extremely deep ( 180 cm). Salinity was found in one place only (X5).

For representative profiles see appendix 2.

Extent: 166.5 ha
Meso and micro-relief: Termite mounds (common)
Slope: less than 0.5%
Vegetation/land use: Varying from bushland to woodland/basin irrigation of onions and other crops; grazing in the uncultivated area.

## 5.4. Land suitability for surface irrigation

Surface irrigation specifically refers to basin and furrow irrigation methods. The former is the type of irrigation in which water is allowed to flow into prior prepared basins. Basins are areas surrounded by low ridges or dykes. Furrow method is a type of irrigation in which water is brought in a furrow and runs in smaller furrows between the crops.

At Kimana, the present method of irrigation is in fact a combination of the above two, especially where onions are grown. In the basins themselves, ridges are made (the size depending on the inter-row spacing of onions) inbetween where water is run through.

Overhead irrigation and trickle types of irrigation are uneconomic in most minor irrigation schemes since "low value" crops are grown. These types of irrigation methods are only recommended where topography and soils do not allow surface irrigation. The crops grown must have high economic returns to be able to repay the capital investment involved.

The <u>current</u> land suitability classification is defined as follows: an appraisal of the suitability of the land for a specific use (surface irrigation of annual crops, other than rice in this case) in the present conditions or with "modest" or "normal" improvements.

Major land improvements which distinguish current and potential suitability (which is not considered here and requires major capital inputs) are such as <u>land grading</u>, <u>clearing</u>, <u>leaching</u>, <u>drainage</u>

of saline and/or alkali and poorly drained soils, breaking of hard pans, etc. Clearing and levelling are here not considered as major land improvements.

Four classes of land suitability are used and their definitions are given below. Land suitability classes reflect degrees of suitability. The classification is qualitative rather than quantitative.

CLASS I: Highly suitable

The land is without apparent hazards and/or limitations of soil, topography, salinity/ sodicity and/or drainage in case of current suitability.

CLASS II: Moderately suitable

The land shows slight hazards and/or limitations of soils, topography, salinity/ sodicity and/or drainage under present conditions (in case of current suitability).

CLASS III: Marginally suitable

The land has moderate to severe hazard and/or limitations under present conditions (in case of current suitability) under present economic and technological levels.

CLASS IV: Unsuitable

The land shows severe hazards and/or limitations for any type of irrigation farming under present conditions (in case of current suitability).

The topography (T) limitations/hazards are rated in general depending on the general slope pattern, the meso-and micro relief and the erosion hazard. At Kimana, topography limitation refers in this case to the elevation of the land, relative to the present intake point of the irrigation water, as these soils (units: YVM and YVm) are not irrigable unless the water intake point is located more upstream.

The salinity and sodicity (A) limitations are rated according to the salt content (ECe) and the exchangeable sodium percentage (ESP) and the depths at which they are found in the soil profile. At Kimana, salinity and sodicity are only concentrated in the duripan. The effect of salinity/sodicity to the overlying soils will depend on the solubility of the salts in the duripan, in the irrigation water, and the drainage conditions.

The drainage (W) limitations are rated according to the degree of interacting of individual characteristics such as groundwater depth, temporary waterlogging and flooding hazard. At Kimana, the current drainage condition is good but is bound to deteriorate if the areas with duripans at shallow to moderate depths are irrigated without proper drainage measures.

Most of the so called soil (S) limitations cannot be corrected. For example soil limitations such as soil texture ( cf. infiltration rate), "soil" depth and to a certain degree the general slope. In cases where the depth limitation is a hardpan, the depth can only be increased by breaking the hardpan, if this is feasible. The limitations at Kimana are "soil" ones and are therefore "uncorrectable". Hence, only current suitability classification is considered.

Table V gives the limitations of the various mapping units.
Table VI gives the current land suitability classes of the respective mapping units, taking into account these limitations.

Table V: Major limitations of the soil mapping units

| unit: | limitations: |
|---|---|
| YVm | Saline and sodic hardpan at 80-120cm depth, gravelly soils |
| YVM | Saline and sodic hardpan at 50-80cm depth, gravelly soils |
| YVM | Saline and sodic hardpan at 25-50cm depth, gravelly soils |
| YV1 | - |
| YV2 | In places: high infiltration rates |

* units YVm, YVM and YVM: elevation of these units is higher than the present water intake point.

Table VI: Land suitability classification for irrigation

| Mapping unit | Current land suitability class | area (in ha) |
|---|---|---|
| YV$\underline{m}$ | IIST | 2.7 |
| YV$\overline{M}$ | IIIST | 1.9 |
| YV$\underline{M}$ | IV | 2.3 |
| YV$\overline{1}$ | I | 3.8 |
| YV2 | I | 166.5 |
| | Total: | 177.2 |

## 6. CONCLUSIONS AND RECOMMENDATIONS

- The soil survey area - total about 177 ha - consists of soils developed on alluvial and colluvial deposits of volcanic origin. The slope decreases from the south (0.5 to 1%) to the north (0.5%). The soils change likewise; the ones in the more flat areas being deeper and less gravelly than those in the more sloping areas.

- Essentially, the soils fall into two categories:

  a) those soils overlying a duripan (hardpan) at less than 100cm depth and having moderate to severe surface and subsurface stoniness (gravels).

  b) soils without surface stoniness and lacking a duripan at depth of less than 200 cm. However gravelly layers are common below 100 cm depth.

The first category of soils comprises mapping units YVM, YVM and YVm. The latter consists of mapping units YV1 and YV2.

- The soils of the whole survey area consist in general of very friable clay loam to loam. In units YVM, YVM and YVm, they are gravelly throughout while in units YV1 and YV2 gravelly layers are found only at depth of more than 100 cm.

- Soil chemical fertility is rated as high in all units, except for nitrogen (N) in the units YVM and YVM.

- Mapping units YVM, YVM and YVm are resp. unsuitable, marginally and moderately suitable for irrigation, depending on the depth of the hardpan (duripan). The hardpan is saline and sodic, and virtually impenetrable for roots. It may also affect drainage. These soils are also moderately to strongly gravelly.

- Mapping units YV1 and YV2 constitute the largest part of the survey area (93%). They are classified as highly suitable for irrigation. However, the infiltration rates are on the high side.

- In mapping unit YV2 (166 ha) salinity was found in two "isolated" places. The occurrence of this salinity was not mappable.

- Loitulelei river water is of good quality for irrigation.

- Drainage measures though not of immediate importance should constitute a part of the irrigation system to avoid any increase of salts in the long run.

## 7. REFERENCES


| | |
|---|---|
| E.A.M.D., 1972 | "Summary of rainfall in Kenya for the years 1946-1972" E.A. Meteorological Dept., Nairobi. |
| FAO, 1967 | Guidelines for soil description, FAO, Rome. |
| FAO/Unesco 1974 | Irrigation and drainage of arid lands: FAO/Unesco, Rome/Paris. |
| FAO, 1976 | Water quality for Irrigation, Irrigation and drainage paper No.29, Rome. |
| Ministry of Agriculture, Agricultural Office, Oloitokitok, 1975 | Kimana Irrigation Scheme progress report, (Re:LTK: IRRIG/PROJ/33/1/24) |
| Munsell Colour Co. 1959 | Munsell Soil Colour Charts |
| Richards, L.A.(ed.), 1954 | Diagnosis and improvement of saline and alkali soils. Agriculture Handbook 60, U.S.D.A. |
| Soil Institute of Iran, 1970 | Mannual of land classification for irrigation publ. No.205, Ministry of Agriculture, Iran. |
| Survey of Kenya, 1970 | National Atlas of Kenya, 3rd ed. Nairobi. |
| Touber, L. in prep. | Soils of the Amboseli-Kibwezi area, with soil map on scale 1:250.000 Kenya Soil Survey, Nairobi/FAO of the United Nations |
| USDA - Soil Survey Staff 1975 | Soil Taxonomy, Agricultural Handbook No.436 |

Appendix I: Soil Physical Properties.

INFILTRATION RATES (cm/hr)

| Mapping Unit | YVM | $YV_1$ | $YV_2$ | | | |
|---|---|---|---|---|---|---|
| Location - Field ref.no. | A5/B5 | C5 | L4 | S6 | Y2 | Y8 |
| Basic (near constant) | 13.3 | 5.7 | 5.7 | 15.8 | 13.8 | 6.3 |
| Class | R | M | M | R | R | M |

Key to infiltration classes*

| cm/h | Descriptive term* |
|---|---|
| 0.1 ........................................ | very slow (VS) |
| 0.1 - 0.5 ........................................ | slow (S) |
| 0.5 - 2.0 ........................................ | moderately slow (MS) |
| 2.0 - 6.5 ........................................ | moderate (M) |
| 6.5 -12.5 ........................................ | moderately rapid (MR) |
| 12.5 -25.5 ........................................ | rapid (R) |
| > 25.5 ........................................ | very rapid (VR) |

* according to U.S. Soil Conservation Service

Appendix I (cont.)

## MOISTURE CHARACTERISTICS

| Field Ref. No. | Profile No. | Depth (cm.) | Mapping Unit | % Water (V/V) $pF_{2.3}$ | $pF_{2.7}$ | $pF_{3.7}$ | $pF_{4.2}$ | Available $H_2O$ $pF_{2.3} - pF_{4.2}$ | Bulk Density | Texture |
|---|---|---|---|---|---|---|---|---|---|---|
| Y8 | 182/3-107 | Surface | YV2 | 34.0 | 31.0 | 22.3 | 17.4 | 16.6 | 0.9 | Loam |
| Y2 | 182/3-106 | Surface | YV2 | 37.2 | 32.5 | 22.7 | 14.2 | 23.0 | 0.9 | Loam |
| S6 | 182/3-104 | 70 | YV2 | 26.5 | 21.6 | 27.9 | 19.4 | 7.1 | 1.2 | Sandy clay loam |

SOIL ANALYTICAL DATA

Field Ref.: Kimana $B_1$
KSS Profile No. 182/3-100
Mapping Unit YVm

| Laboratory No.77/ | 9396 | 9397 | 9398 | 9399 |
|---|---|---|---|---|
| Depth in cm | 0-21 | 21-45 | 45-80 | 80-117 |
| Sand % | 56 | 34 | 72 | 24 |
| Silt % | 18 | 34 | 16 | 36 |
| Clay % | 26 | 32 | 12 | 40 |
| Texture class | SCL | CL | SL | C |
| pH-$H_2O$ (1:2½ suspension) | 7.4 | 7.4 | 7.1 | 7.1 |
| pH-KCl " | 6.4 | 6.2 | 6.5 | 6.1 |
| EC (mmhos/cm) " | 0.14 | 0.65 | 5.0 | 0.1 |
| $CaCO_3$ | 0 | 0 | 0.2 | 0.7 |
| C% | 0.95 | 0.75 | | |
| N% | 0.10 | 0.08 | | |
| Saturation % | | | 51.2 | |
| ECe (mmhos/cm) | | | 35.0 | |
| pH-paste | | | 6.9 | |
| CEC (me/100g soil) | 18.6 | 26.6 | 73.0 | 24.4 |
| **Exchangeable cations:** | | | | |
| Ca (me/100g soil) | 7.9 | 9.3 | 26.0 | 15.0 |
| Mg " | 4.2 | 10.2 | 11.5 | 12.7 |
| K " | 2.7 | 3.4 | 1.5 | 4.4 |
| Na " | 0.6 | 0.8 | 17.0 | 8.2 |
| Base sat.% | 82.9 | 89.1 | 76.7 | 100 + |
| ESP | | | 23 | 33 |
| Qualitative $CaCO_3$ | 0 | 0 | 0 | ++ |

Appendix 2: Detailed descriptions of the representative soil profiles and analytical data.

| Mapping Unit YVm | Profile No. 182/3-100 (Road cut) |
|---|---|
| Geology: | "Kilimanjaro volcanics" alluvium |
| Physiography: | Piedmont plain |
| Relief: macro: | Flat |
| " meso/micro: | Slightly irregular; termite mounds |
| Vegetation/Landuse: | Bushed grassland/grazing |
| Erosion | None |
| Rock outcrops: | None |
| Flooding: | Nil |
| Surface stoniness: | Gravel on surface |
| Slope gradient: | About 0.7% |
| Effective soil depth: | 45cm |
| Drainage class: | Well drained |

| | | |
|---|---|---|
| (A) | 0-21cm: | Reddish brown (5YR 4/3 moist) gravelly sandy clay loam; fine, weak crumb structure; soft when dry, very friable when moist, sticky and plastic when wet; many very fine to fine pores; many fine and medium roots; gradual and smooth transition to: |
| (B) | 21-45cm: | Dark reddish brown (5YR 3/3 moist) gravelly clay loam; fine, weak crumb to granular structure; soft when dry, very friable when moist, sticky and plastic when wet; many, very fine and fine pores; many fine roots; clear and wavy transition to: |
| Csi | 45-80cm: | Brown (5YR 4/4 moist) gravelly sandy loam duripan with some thin pockets of soil through which roots penetrate |
| IIB1 | 80-117cm: | Brown (5YR 4/4 moist) gravelly clay; fine, weak sub-angular blocky structure; hard when dry, friable when moist, very sticky, very plastic when wet; slightly cemented (by silica) few, very fine and fine pores; few fine roots; clear and wavy transition to: |
| IICsi | 117+cm | Brown (5YR 4/4 moist) gravelly duripan |

SOIL ANALYTICAL DATA

Field Ref. Kimana C5
KSS Profile No.182/3 - 101
Mapping Unit YV1

| Laboratory No.77/ | 9400 | 9401 | 9402 | 9403 | 9404 |
|---|---|---|---|---|---|
| Depth in cm | 0-18 | 18-52 | 52-96 | 96-145 | 145+ |
| Sand % | 40 | 58 | 40 | 32 | 28 |
| Silt % | 18 | 14 | 44 | 52 | 48 |
| Clay % | 42 | 28 | 16 | 16 | 24 |
| Texture class | C | SCL | L | L | L |
| pH-$H_2O$ (1:2½ suspension) | 9.5 | 7.4 | 8.4 | 8.3 | 8.3 |
| pH-KCl " | 8.2 | 6.7 | 6.5 | 6.4 | 6.3 |
| EC (mmhos/cm) " | 0.85 | 0.125 | 0.105 | 0.11 | 0.09 |
| C% | 0.87 | 1.01 | | | |
| N% | 0.08 | 0.07 | | | |
| CEC (me/100g soil) | 21 | 21.8 | 23.4 | 23.4 | 23.4 |
| Exchangeable cations: | | | | | |
| Ca (me /100g soil) | 12.0 | 12.2 | 9.7 | 11.0 | 11.0 |
| Mg " | 3.5 | 5.1 | 6.9 | 9.0 | 0.8 |
| K " | 3.4 | 2.3 | 1.2 | 1.7 | 2.3 |
| Na " | 0.8 | 1.9 | 1.7 | 1.9 | 1.5 |
| Base Sat. % | 93.8 | 98.3 | 83.3 | 100+ | 66.7 |
| Qualitative CaCO3 | 0 | 0 | 0 | 0 | 0 |

| Mapping Unit YV1 | Profile No. 182/3-101 |
|---|---|
| Geology: | "Kilimanjaro volcanics" alluvium |
| Physiography: | Piedmont plain |
| Relief: macro: | Flat |
| " meso/micro: | None |
| Vegetation/Landuse: | Shrubs and trees growing along the river banks, 50% bare ground/Grazing |
| Erosion: | None |
| Rock outcrops: | None |
| Flooding: | Annual/seasonal during heavy storms on the mountain slopes |
| Surface stoniness: | None |
| Slope gradient: | 0.6% |
| Effective soil depth: | 145+cm |
| Drainage class: | Well drained |

| | | |
|---|---|---|
| A1 | 0- 18 cm: | Reddish brown (5YR 4/4 moist); clay;medium, weak, sub-angular blocky structure; slightly hard when dry, friable when moist, slightly sticky, plastic when wet; many fine and few coarse pores; many medium and fine roots; diffuse and smooth transition to: |
| $A_3$ | 18- 52 cm: | Dark reddish brown (5YR 3/3 moist) sandy clay loam; porous massive structure; soft when dry, very friable when moist, slightly sticky and slightly plastic when wet; many fine pores; many fine and medium roots; diffuse and smooth transition to: |
| $C_1$ | 52- 96 cm: | Dark reddish brown (5YR 3/4 moist), loam; porous massive structure; soft when dry, very friable when moist, slightly sticky, slightly plastic when wet; many fine pores; many fine roots; diffuse and smooth transition to: |
| $C_2$ | 96-145 cm+ | Dark reddish brown (5YR 3/3 moist), slightly gravelly loam; porous massive structure; very friable when moist, many fine pores; common fine roots. |
| $C_3$ | 145+cm | Gravel layer with some loam soil |

## SOIL ANALYTICAL DATA

Field Ref.: Kimana S6
KSS Profile No.182/3 - 104
Mapping Unit YV2

| Laboratory No. 77/ | 9440 | 9441 | 9442 | 9443 | 9444 | 9445 |
|---|---|---|---|---|---|---|
| Depth in cm | 0-24 | 24-52 | 52-70 | 70-110 | 110-136 | 136-154 |
| Sand % | 60 | 28 | 52 | 58 | 60 | 68 |
| Silt % | 18 | 38 | 24 | 20 | 20 | 20 |
| Clay % | 22 | 36 | 24 | 22 | 20 | 12 |
| Texture class | SL | CL | SCL | SCL | SCL | SL |
| $pH\text{-}H_2O$ (1:2½ suspension) | 8.0 | 7.8 | 7.8 | 8.5 | 8.7 | 8.7 |
| pH-KCl " | 7.2 | 6.5 | 6.2 | 7.3 | 7.3 | 7.3 |
| EC (mmhos/cm) " | 0.4 | 0.1 | 0.2 | 1.0 | 1.1 | 0.9 |
| $CaCO_3$% | 0.8 | 0.1 | 0.2 | 1.0 | 1.1 | 0.9 |
| C% | 3.03 | | | | | |
| N% | 0.29 | | | | | |
| CEC (me/100g soil; pH 8.2) | 27.0 | 21.0 | 27.0 | 29.6 | 28.0 | 32.0 |
| **Exchangeable cations** | | | | | | |
| Ca (me/100g soil) | 29.0 | 11.2 | 10.7 | 26.0 | 31.0 | 22.2 |
| Mg " | 1.4 | 4.9 | 6.2 | 5.2 | 5.7 | 6.5 |
| K " | 5.8 | 4.6 | 3.5 | 3.4 | 3.3 | 4.4 |
| Na " | 0.6 | 0.6 | 0.6 | 1.9 | 2.2 | 2.0 |
| Base sat. % | 100+ | 100+ | 77.0 | 100+ | 100+ | 100+ |
| Qualitative CaCO3 | 0 | 0 | 0 | +++ | +++ | +++ |

| Mapping Unit $YV_2$ | Profile No. 182/3-104 |
|---|---|
| Geology: | "Kilimanjaro volcanics" alluvium |
| Physiography: | Piedmont plain |
| Relief: macro: | Flat |
| " meso/micro: | None |
| Vegetation/landuse: | Secondary growth of castor oil plants and Acacia spp. on fallow land |
| Erosion: | None |
| Rock outcrops: | None |
| Flooding: | Seasonal during heavy rain storms |
| Surface stoniness: | None |
| Slope gradient: | < 0.5% |
| Effective soil depth: | > 200cm |
| Drainage class: | well drained |

| | |
|---|---|
| A 0- 24cm | Brown to dark brown (7.5YR 4/4 moist); sandy loam;fine to medium, weak crumb structure; soft when dry, very friable when moist, sticky and plastic when wet; many, very fine to medium pores; many fine to coarse roots; clear and smooth transition to: |
| $(B_{21})$ 24-52cm | Brown to dark brown (7.5YR 4/4 moist); clay loam; coarse, moderate sub-angular blocky structure; slightly hard when dry, very friable when moist, sticky and plastic when wet; many, very fine to medium pores, many fine roots; gradual and smooth transition to: |
| $(B_{22})$ 52-70cm | Brown to dark brown (10YR 4/3 moist); sandy clay loam; medium, weak sub-angular blocky structure; soft when dry, very friable when moist, sticky and plastic when wet; many, very fine and fine pores; common, fine roots; clear and smooth transition to: |
| $C_1$ 70-110cm | Dark brown (10YR 3/3 moist), fine sandy clay loam; porous massive structure, slightly hard when dry, very friable when moist, slightly sticky and slightly plastic when wet; many very fine and fine pores; common, fine roots; diffuse and smooth transition to: |

| | |
|---|---|
| $C_2$ 110 - 136cm: | Dark brown (10YR 3/3 moist), fine sandy clay loam; porous massive to medium weak angular blocky structure; slightly hard when dry, very friable when moist, slightly sticky and slightly plastic when wet; many, very fine and fine pores; few, fine roots; diffuse and smooth transition to: |
| $C_3$ 136 - 154cm: | Dark yellowish brown (10YR 4/4 moist); medium sandy loam; porous massive to medium, weak angular blocky structure; slightly hard when dry, very friable when moist, slightly sticky and slightly plastic when wet; many, very fine and fine pores; gradual and smooth transition to: |
| $C_4$ 154 - 208+cm | Dark yellowish brown (10YR 4/4 moist); clay loam; massive to coarse moderate angular blocky structure; soft when dry, very friable when moist, slightly sticky and slightly plastic when wet; many very fine and fine pores |

Remark: 1. Very well rooted; - many coarse roots 0-25 cm and many fine roots 25-110 cm

2. Very fine gravel. throughout

## SOIL ANALYTICAL DATA

Field Ref.: Kimana Y2
KSS Profile No. 182/3 - 106
Mapping Unit $YV_2$

| Laboratory No.77/ | 9392 | 9393 | 9394 | 9395 |
|---|---|---|---|---|
| Depth in cm | 0-15 | 15-42 | 42-100 | 100-192 |
| Sand % | 32 | 38 | 31 | 40 |
| Silt % | 44 | 42 | 42 | 40 |
| Clay % | 24 | 20 | 22 | 20 |
| Texture class | L | L | L | L |
| pH-$H_2O$ (1:2½ suspension) | 8.1 | 8.3 | 7.1 | 7.4 |
| pH-KC " | 6.9 | 7.5 | 7.7 | 7.8 |
| EC (mnhos/cm) " | 0.2 | 0.15 | 0.2 | 0.5 |
| $CaCO_3$% | 0.2 | 1.9 | 0.6 | 1.0 |
| C% | 2.28 | 1.04 | | |
| N% | 0.24 | 0.12 | | |
| CEC (me/100g soil; pH 8.2) | 44.0 | 47.0 | 44 | 42 |

**Exchangeable cations**

| | | | | |
|---|---|---|---|---|
| Ca (me /100g soil) | 25.0 | 44.5 | 25.0 | 25.0 |
| Mg " | 8.5 | 9.7 | 13.0 | 4.0 |
| K " | 8.5 | 9.0 | 16.8 | 25.0 |
| Na " | 0.6 | 1.2 | 0.9 | 2.0 |
| Base Sat. % | 96.0 | 100+ | 100+ | 100+ |
| Qualitative $CaCO_3$ | 0 | +++ | ++ | +++ |

Mapping Unit: $YV_2$

Profile No. 182/3 - 106

| | |
|---|---|
| Geology: | "Kilimanjaro volcanics" alluvium |
| Physiography: | Piedmont plain |
| Relief: macro: | Flat |
| " meso/micro: | None |
| Vegetation/Landuse: | Bushed grassland/grazing |
| Erosion: | None |
| Rock outcrops: | None |
| Flooding: | Nil |
| Surface stoniness: | None |
| Slope gradient: | $<$ 0.5% |
| Effective soil depth: | $>$ 190cm |
| Drainage class: | Well drained |

| | | |
|---|---|---|
| A | 0- 15cm | Brown to dark brown (7.5YR 4/4 moist); slightly gravelly loam; fine, moderate crumb structure; soft when dry, very friable when moist, sticky and plastic when wet; many, very fine to fine pores; dense "mat" of fine to medium roots, gradual and smooth transition to: |
| (B) | 15- 42cm | Brown to dark brown (7.5YR 4/4 moist); slightly gravelly loam; medium, weak crumb structure; soft when dry, very friable when moist, sticky and plastic when wet; many, very fine medium pores; many, fine to medium roots; slightly to strongly calcareous; gradual, smooth transition to: |
| $C_1$ | 42-100cm | Brown to dark brown (7.5YR 4/4 moist); slightly gravelly loam, massive to coarse, weak crumb structure; soft when dry, very friable when moist, sticky and plastic when wet; many very fine and medium pores; common fine and medium roots; slightly to strongly calcareous; distinct, wavy transition to: |
| $C_2$ | 100-192cm | Brown to dark brown (7.5YR 4/4 moist); slightly gravelly loam, massive to fine, weak subangular blocky structure; soft when dry, very friable when moist, sticky and plastic when wet; many very fine and fine pores, calcium carbonate powdery pockets; common, fine roots. |

SOIL ANALYTICAL DATA

Field Ref.: Kimana Y8
KSS Profile No. 182/3 - 107
Mapping Unit YV2

| Laboratory No.77/ | 9412 | 9413 | 9414 | 9415 |
|---|---|---|---|---|
| Depth in cm | 0-13 | 13-65 | 65-105 | 105-160 |
| Sand % | 18 | 24 | 22 | 20 |
| Silt % | 54 | 44 | 50 | 44 |
| Clay % | 28 | 32 | 28 | 36 |
| Texture class | SiCL | CL | CL | CL |
| $pH-H_2O$ (1:2½ suspension) | 7.4 | 7.3 | 7.1 | 7.3 |
| pH-KCl " | 6.4 | 6.1 | 5.8 | 5.8 |
| EC (mmhos/cm) " | 0.22 | 0.14 | 0.16 | 0.11 |
| $CaCO_3$% | 0.1 | 0.2 | 0.1 | 0.2 |
| C% | 2.57 | | | |
| N% | 0.26 | | | |
| CEC (me /100g soil; pH 8.2) | 44.0 | 28.6 | 26.4 | 25.4 |

Exchangeable cations

| | | | | |
|---|---|---|---|---|
| Ca (me./100g soil) | 22.0 | 12.5 | 11.4 | 18.6 |
| Mg " | 11.1 | 9.0 | 5.9 | 1.2 |
| K " | 0.7 | 1.7 | 1.2 | 2.1 |
| Na 2 | 0.4 | 1.5 | 1.1 | 2.3 |
| Base Sat. % | 77.7 | 86.4 | 74.2 | 95.3 |
| ESP | - | - | - | 9 |
| Qualitative $CaCO_3$ | 0 | + | 0 | + |

Mapping Unit $YV_2$ | Profile No. 182/3-107

| | |
|---|---|
| Geology: | "Kilimanjaro volcanics" alluvium |
| Physiography: | Piedmont plain |
| Relief: macro: | Flat |
| " meso/micro: | None |
| Vegetation/Landuse: | Bushed grassland/grazing |
| Erosion: | None |
| Rock outcrops: | None |
| Surface runoff: | Slow |
| Slope gradient: | $< 0.5\%$ |
| Effective soil depth: | $> 150$ cm |
| Drainage class: | moderately well drained |

| | | |
|---|---|---|
| A | 0 - 13cm | Dark reddish brown (5YR 3/4 moist); silty clay loam, fine, weak crumb structure; hard when dry, very friable when moist, sticky and plastic when wet, many fine to coarse pores; dense "mat" of medium and fine roots; clear and smooth transition to: |
| $B_{21}$ | 13 - 65cm | Dark reddish brown (5YR 4/4 moist), many, fine to medium, prominent, yellowish red mottles; clay loam; strong, fine angular blocky structure; hard when dry, firm when moist, sticky and plastic when wet; many very fine to fine pores; dense "mat" of medium to fine roots (up to 40 cm), clear and wavy transition to: |
| $B_{22}$ | 65 -105cm | Reddish brown (5YR 4/4 moist); clay loam; moderate, fine, angular blocky structure; slightly hard when dry, friable when moist, sticky and plastic when wet; many, very fine to fine pores; many, medium to fine roots; gradual and wavy transition to: |
| $C_1$ | 105 -160cm | Reddish brown (5YR 4/4 moist); clay loam; fine, weak sub-angular blocky structure; slightly hard when dry, very friable when moist, sticky and plastic when wet; many, very fine to coarse pores; few, fine roots |

SOIL ANALYTICAL DATA

Field Ref.: Kimana J4
KSS Profile No. 182/3-103
Mapping Unit $YV_2$

| Laboratory No.77/ | 9429 | 9430 | 9431 | 9432 | 9433 |
|---|---|---|---|---|---|
| Depth in cm | 0-13 | 13-30 | 30-80 | 80-140 | 140-173 |
| Sand % | 28 | 34 | 44 | 56 | 24 |
| Silt % | 44 | 42 | 32 | 24 | 36 |
| Clay % | 28 | 24 | 24 | 20 | 40 |
| Texture class | CL | L | L | SCL | C |
| $pH-H_2O$ (1:2½ suspension) | 7.3 | 7.5 | 7.9 | 7.9 | 7.7 |
| pH-KCl " | 6.9 | 6.2 | 6.4 | 6.5 | 6.3 |
| EC (mmhos/cm) " | 0.35 | 0.14 | 0.13 | 0.11 | 0.13 |
| $CaCO_3$ | 0 | 0 | 0 | 0 | 0 |
| C% | 1.18 | 1.17 | | | |
| N% | 0.12 | 0.12 | | | |
| CEC (me./100g soil; pH 8.2) | 23.6 | 27.4 | 20.0 | 35.0 | 22.6 |
| **Exchangeable cations** | | | | | |
| Ca (me /100g soil) | 12.2 | 11.8 | 12.2 | 14.3 | 11.0 |
| Mg " | 6.0 | 2.9 | 8.5 | 8.0 | 33.2 |
| K " | 3.5 | 0.8 | 1.4 | 0.9 | 2.8 |
| Na " | 0.9 | 0.8 | 1.4 | 1.0 | 1.6 |
| Base Sat.% | 95.0 | 59.5 | 100+ | 69.1 | 100+ |
| Qualitative $CaCO_3$ | 0 | 0 | 0 | 0 | 0 |

Mapping Unit $YV_2$ — Profile No. 182/3 - 103

| | |
|---|---|
| Geology: | "Kilimanjaro volcanics" alluvium |
| Physiography: | Piedmont plain |
| Relief: macro: | Flat |
| " meso/micro: | Irrigation furrows |
| Vegetation/Landuse: | Cultivation (bananas, onions) |
| Erosion: | None |
| Rock outcrops: | None |
| Slope gradient: | $<$ 0.5% |
| Effective soil depth: | $>$ 170 cm |
| Drainage class: | Well drained |

| | | |
|---|---|---|
| Ap | 0- 13 cm | Dark reddish brown (5YR 3/3 moist); clay loam; medium, weak sub-angular blocky structure; hard when dry, friable when moist, sticky and plastic when wet; many, coarse pores; clear and smooth transition to: |
| $B_1$ | 13- 30 cm | Dark reddish brown (5YR 3/3 moist); loam; medium, moderate sub-angular blocky structure; hard when dry, friable when moist, sticky and plastic when wet; many fine pores; clear and wavy transition to: |
| $B_{21}$ | 30- 80 cm | Dark reddish brown (5YR 3/3 moist); loam; fine, moderate sub-angular blocky structure; slightly hard when dry, friable when moist, slightly sticky and plastic when wet; many fine and coarse pores; clear and smooth transition to: |
| $C_1$ | 80-140 cm | Dark reddish brown (5YR 3/3 moist); sandy clay loam; porous massive structure; slightly hard when dry, friable when moist, sticky and plastic when wet; common medium and coarse pores; abrupt and smooth transition to: |
| $C_2$ | 140-173 cm | Dark yellowish brown (10YR 4/4 moist); gravelly clay; massive structure; slightly hard when dry, friable when moist, sticky and plastic when wet; compact; common medium to coarse pores. |

SOIL ANALYTICAL DATA

Field Ref.: Kimana $F_1$
KSS Profile No. 182/3 - 102
Mapping Unit $YV_2$

| Laboratory No.77/ | 9405 | 9406 | 9407 | 9408 | 9409 | 9410 | 9411 |
|---|---|---|---|---|---|---|---|
| Depth in cm | 0-15 | 15-29 | 29-85 | 85-99 | 99-111 | 111-143 | 143-158 |
| Sand % | 46 | 46 | 46 | 72 | 48 | 48 | 62 |
| Silt % | 18 | 18 | 34 | 12 | 36 | 36 | 18 |
| Clay % | 36 | 36 | 20 | 16 | 16 | 16 | 20 |
| Texturel class | SC | SC | SCL | SL | L | SCL | L |
| $pH-H_2O$ (1:2 suspension) | 8.2 | 7.8 | 8.7 | 8.1 | 7.5 | 7.6 | 7.6 |
| pH-KCl " | 6.4 | 7.6 | 7.6 | 7.1 | 6.9 | 6.3 | 6.7 |
| EC (mnhos) " | 0.12 | 0.16 | 3.5 | 1.05 | 1.25 | 0.35 | 0.3 |
| $CaCO_3$% | - | 0.5 | 1.2 | 0.1 | 0.1 | 0.1 | 0.1 |
| C% | 1.0 | 1.65 | | | | | |
| N% | 0.11 | 0.15 | | | | | |
| Saturation % | | | 43.2 | 45.6 | 44.2 | | |
| ECe (mmhos/cm) | | | 15.0 | 7.0 | 6.5 | | |
| pH paste | | | 7.4 | 7.3 | 7.2 | | |
| CEC (me /100g soil pH 8.2) | 24:4 | 31.0 | 20.2 | 15.6 | 19.2 | 17.0 | 43.5 |
| **Exchangeable cations** | | | | | | | |
| Ca (me /100g soil | 12.2 | 22.2 | 26.0 | 10.6 | 15.0 | 6.6 | 28.0 |
| Mg " | 5.6 | 11.5 | 6.5 | 2.9 | 4.7 | 4.5 | 7.6 |
| K " | 4.2 | 0.7 | 5.3 | 5.6 | 3.8 | 1.6 | 0.1 |
| Na " | 0.5 | 0.7 | 2.0 | 1.5 | 1.3 | 1.7 | 0.3 |
| Base saturation % | 91.4 | 100+ | 100+ | 100+ | 100+ | 84.7 | 82.8 |
| E.S.P. | | | 9.5 | 9.7 | 6.7 | 10 | - |

Mapping Unit $YV_2$ Profile No. 182/3 - 102

| | |
|---|---|
| Geology: | "Kilimanjaro volcanics" alluvium |
| Physiography: | Piedmont plain |
| Relief: macro: | Flat |
| " meso/micro: | None |
| Vegetation/Landuse: | Bushed grassland/cultivation in places - bananas, onions etc. |
| Erosion: | None |
| Rock outcrops: | None |
| Surface stoniness: | None |
| Effective soil depth: | 100 cm |
| Drainage class: | Moderately well drained |

| | | |
|---|---|---|
| A11 | 0 - 15cm | Brown to dark brown (10YR 4/4 dry, 10YR 4/3 moist); sandy clay; moderate, medium crumby structure; slightly hard when dry and very friable when moist, sticky and plastic when wet; many fine to coarse pores; clear and smooth transition to: |
| A12 | 15 - 29cm | Dark brown (10YR 4/4, dry, 10YR 3/3 moist); sandy clay; weak, fine crumby structure; slightly hard to soft when dry and very friable when moist, sticky and plastic when wet; many, medium to coarse pores; moderately calcareous; clear and smooth transition to: |
| B | 29 - 85 cm | Brown to dark brown (7.5YR 4/4 both dry and moist); gravelly sandy clay loam; weak, fine crumby to weak, medium subangular blocky structure; soft to slightly hard when dry and very friable when moist, sticky and plastic when wet; many, medium to coarse pores; strongly calcareous, abrupt and smooth transition to: |
| C1 | 85 - 99 cm | Dark reddish brown (5YR 4/3 dry, 5YR 3/4 moist); strongly gravelly sandy loam; common, prominent, coarse mottles; abrupt and smooth transition to: |
| C2m | 99 -111 cm | Dark reddish brown (5YR 4/3 dry, 5YR 3/4 moist); loam, massive to weak, coarse angular blocky structure; extremely hard when dry, very firm when moist, sticky and plastic when wet; common, very fine and few, medium pores; prominent coarse mottles, locally strongly calcareous; abrupt and smooth transition to: |

| | | |
|---|---|---|
| C3 | 111-143 cm | Dark reddish brown (5YR 4/3 dry, 5YR 3/4 moist); sandy clay loam; porous massive; soft when dry, very friable when moist, slightly sticky and plastic when wet; many, medium to coarse pores; clear and smooth transition to: |
| C4 | 143-158 cm | Dark yellowish brown (10YR 5/6 dry, 10YR 4/4 moist); loam; moderate, coarse, subangular blocky structure; slightly hard when dry and very friable when moist, sticky and plastic when wet; many, fine to coarse pores; common, prominent, coarse mottles; slightly to moderately calcareous |

Other remarks:

1. Rooting to 85 cm depth; none below 85 cm.

SOIL ANALYTICAL DATA

Field Ref. Kimana X5
Mapping Unit $YV_2$ Auger observation

| Laboratory No.77/ | 9421 | 9422 | 9423 | 9424 |
|---|---|---|---|---|
| Depth in cm. | 0-10 | 10-70 | 70-130 | 130-200 |
| Sand % | 48 | 40 | 38 | 40 |
| Silt % | 28 | 32 | 28 | 36 |
| Clay % | 24 | 28 | 24 | 24 |
| Texture class | SCL | CL | L | L |
| pH-$H_2O$ (1:2½ suspension) | 8.0 | 8.3 | 7.2 | 6.7 |
| C% | 2.8 | | | |
| N% | 0.31 | | | |
| Saturation % | | 49.8 | 36.7 | 56.8 |
| ECe (mmhos/cm) | | 16.5 | 22.0 | 5.0 |
| pHe | | 6.3 | 7.6 | 8.1 |

Appendix 3

AVAILABLE NUTRIENTS

| Field Designation Profile Pit No. | Y2 182/3-106 | | B1 182/3-100 | | C5 182/3-101 | | F1 182/3-102 | | Y8 182/3-107 | X5 182/3-109 | X11 182/3-110 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Lab No. 77/ | 9392 | 9393 | 9396 | 9397 | 9400 | 9401 | 9405 | 9406 | 9412 | 9421 | 9425 |
| Depth in cm | 0-15 | 15-42 | 0-21 | 21-45 | 0-18 | 18-52 | 0-15 | 15-29 | 0-13 | 0-10 | 0-30 |
| pH | 7.7 | 8.6 | 7.1 | 6.8 | 7.1 | 8.2 | 7.6 | 8.5 | 7.4 | 7.9 | 6.6 |
| Na (me/100g soil) | 0.49 | 0.52 | 0.24 | 0.42 | 0.58 | 1.58 | 0.54 | 0.60 | 0.34 | 0.52 | 0.31 |
| K " | 3.60 | 2.4 | 2.0 | 2.15 | 2.00 | 1.46 | 3.60 | 4.6 | 3.20 | 6.0 | 2.15 |
| Ca " | 30.0 | 37.0 | 5.6 | 7.2 | 7.2 | 7.2 | 11.2 | 36.0 | 22.0 | 32.0 | 15.2 |
| Mg " | 6.6 | 7.8 | 4.4 | 9.0 | 3.8 | 4.4 | 5.1 | 9.4 | 7.8 | 8.4 | 6.8 |
| Mn " | 0.54 | 0.1 | 0.7 | 0.59 | 1.34 | 1.14 | 1.10 | 0.48 | 0.72 | 0.43 | 0.57 |
| P (ppm) | 228 | 8.8 | 111 | 40 | 138 | 62 | 212 | 12 | 118 | 252 | 142 |
| N% | 0.24 | 0.12 | 0.1 | 0.08 | 0.08 | 0.07 | 0.11 | 0.15 | 0.26 | 0.31 | 0.2 |
| C% | 2.28 | 1.04 | 0.95 | 0.75 | 0.87 | 1.01 | 1.1 | 1.65 | 2.57 | 2.83 | 2.28 |
| Hp (me/100g soil) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Appendix 3 (cont.)

AVAILABLE NUTRIENTS

| Field Designation | J4 182/3-103 | | Z12 182/3-113 | S6 182/3-104 | T6 182/3-112 | |
|---|---|---|---|---|---|---|
| Lab. No.77/ | 9429 | 9430 | 9434 | 9440 | 9416 | 9417 |
| Depth in cm | 0-13 | 13-30 | 0-20 | 0-24 | 0-10 | 10-50 |
| pH | 7.2 | 7.4 | 6.6 | 7.9 | 6.6 | 6.7 |
| Na (me/100g soil) | 0.79 | 0.56 | 0.34 | 0.78 | 0.82 | 1.9 |
| K " | 2.7 | 2.00 | 4.00 | 3.6 | 2.00 | 0.92 |
| Ca " | 10.8 | 11.2 | 24.0 | 30.0 | 9.4 | 36.0 |
| Mg " | 5.6 | 6.2 | 5.4 | 9.8 | 6.2 | 4.8 |
| Mn " | 1.08 | 0.84 | 0.88 | 0.43 | 1.6 | 1.02 |
| P (ppm.) | 92 | 84 | 183 | 58 | 62 | 70 |
| N% | 0.12 | 0.12 | 0.21 | 0.29 | 0.24 | 0.14 |
| C% | 1.18 | 1.17 | 2.33 | 3.03 | 2.68 | 1.29 |
| Hp(me/100g soil) | 0 | 0 | 0 | 0 | 0 | 0 |

Ql48a KE 1978.02

# DETAILED SOIL MAP OF KIMANA IRRIGATION SCHEME

## KAJIADO DISTRICT

Appendix 4

### LEGEND

GRAVELLY SOILS WITH DURIPAN*

| | |
|---|---|
| YVm | well drained, deep, dark brown to dark yellowish brown, very friable to friable, gravelly and stony, loam to clay loam over duripan; in places moderately to strongly calcareous; rapid infiltration |
| YVM | like YVm, but shallow to moderately deep over duripan |
| YVM | like YVm, but very shallow to shallow over duripan |

OTHER SOILS

| | |
|---|---|
| YV1 | well drained, very deep to extremely deep, dark reddish brown, very friable, loam to clay loam; in places calcareous; very gravelly from about 100 cm; moderate infiltration |
| YV2 | well drained, extremely deep, dark reddish brown to dark brown, very friable to friable, loam to clay loam; gravelly from about 100 cm; moderate to rapid infiltration |

* *duripan: a subsurface horizon cemented by silica*

LAND SUITABILITY CLASSIFICATION FOR IRRIGATION

| mapping unit | current land suitability class | area (in ha) |
|---|---|---|
| YVm | IIST | 2.7 |
| YVM | IIIST | 1.9 |
| YVM | IV | 2.3 |
| YV1 | I | 3.8 |
| YV2 | I | 166.5 |
| | | total: 177.2 |

KEY TO LAND SUITABILITY CLASSIFICATION

SUITABILITY CLASSES

| | |
|---|---|
| I | highly suitable |
| II | moderately suitable |
| III | marginally suitable |
| IV | unsuitable |

TYPE OF LIMITATION

| | |
|---|---|
| S | soil |
| T | topography and/or erosion |
| A | salinity and/or sodicity |
| W | drainage |

KEY TO INFILTRATION CLASSES*

| rate (cm/hr) | descriptive term |
|---|---|
| < 0.1 | very slow |
| 0.1 – 0.5 | slow |
| 0.5 – 2.0 | moderately slow |
| 2.0 – 6.5 | moderate |
| 6.5 – 12.5 | moderately rapid |
| 12.5 – 25 | rapid |
| >25 | very rapid |

*according to US Soil Conservation Service

KEY TO DEPTH CLASSES

| thickness soil in cm | symbol | name |
|---|---|---|
| 0 – 25 | M | very shallow |
| 25 – 50 | M | shallow |
| 50 – 80 | | moderately deep |
| 80 – 120 | m | deep |
| 120 – 180 | | very deep |
| > 180 | | extremely deep |

Location of surveyed area

### KEY

YV2 .........soil mapping symbol

soil boundary

augerhole observation or pit without sampling

augerhole with sampling

augerhole observation and infiltration test

pit with sampling

pit with sampling and infiltration test

182/3–102 number of profile

1 cm² 1 ha

road

boundary of surveyed area

river

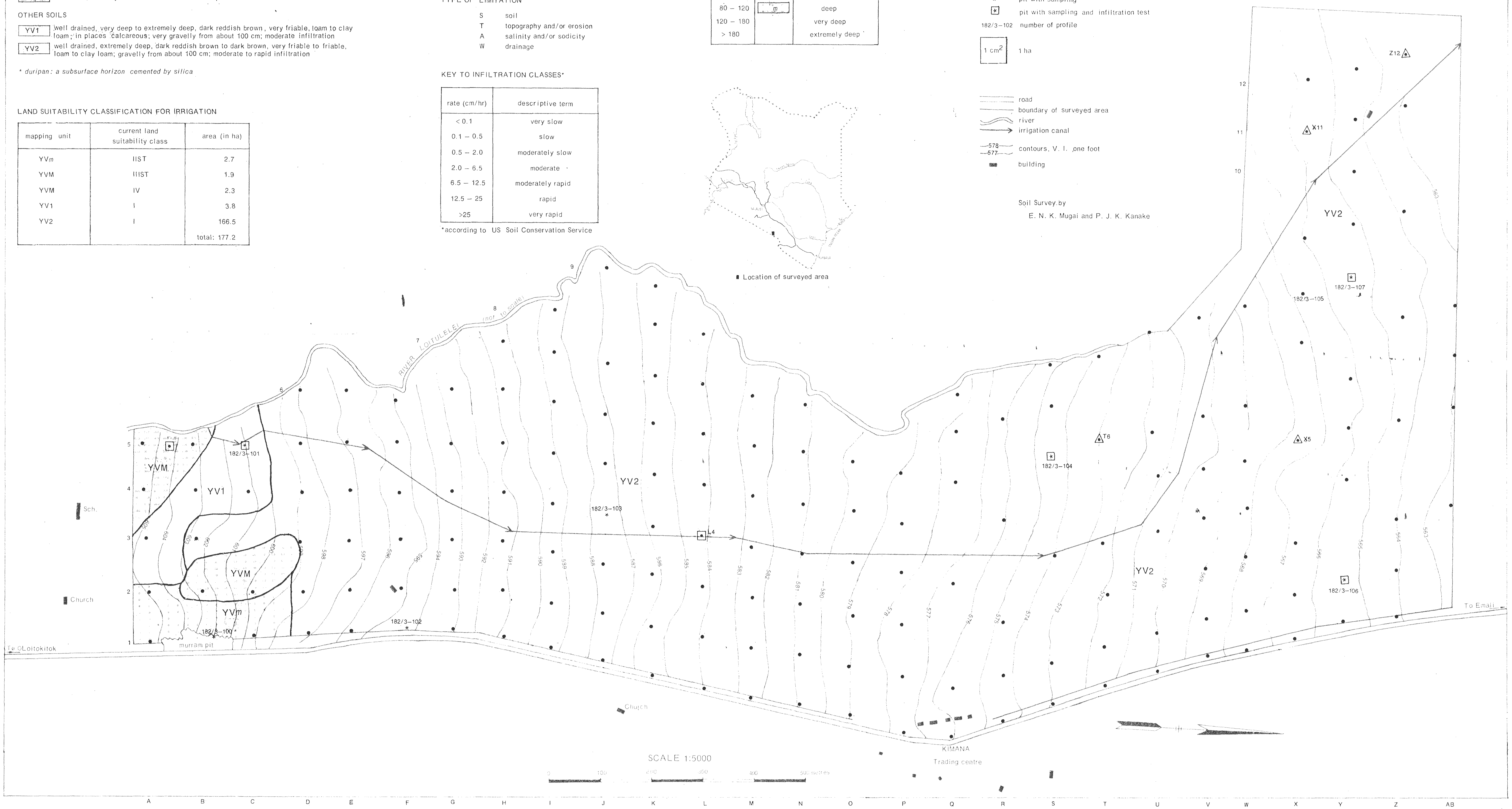
irrigation canal

578 577 contours, V. I. one foot

building

Soil Survey by

E. N. K. Mugai and P. J. K. Kanake




Base map supplied by Farm Mapping Unit, Nakuru

Soil map drawn and prepared by Kenya Soil Survey, in April 1978

Detailed Soil Survey D11, appendix 4. Drawing No. 78022