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THE SOIL RESOURCES OF THE
ARROR AREA KERIO VALLEY, KENYA

A RECONNAISSANCE SURVEY

SEPTEMBER 1987

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ACRONYMS

The following abbreviations have been used in this report:

BS	Base saturation
CEC	Cation exchange capacity
EC	Electrical conductivity
EAGRU	East African Geological Research Unit Bedford College, London.
E.S.P.	Exchangeable Sodium Percentage
F.A.O.	Food and Agriculture Organisation of the United Nations.
K.S.S.	Kenya Soil Survey, Ministry of Agriculture, Nairobi
K.V.D.A.	Kerio Valley Development Authority
N.A.L.	National Agricultural Laboratories, Ministry of Agriculture, Nairobi
T.E.B.	Total Exchangeable Bases
U.S.B.R.	Bureau of Reclamation, United States Department of the Interior
U.S.D.I.	United States Department of the Interior
U.S.D.A.	United States Department of Agriculture

CHAPTER 1
THE PHYSICAL ENVIRONMENT

1.1 INTRODUCTION

The Kerio Valley Development Authority (KVDA) are considering the utilisation of the Arror river to generate electricity in the central part of the Kerio Valley near the village of Arror (KVDA, 1986).

The control of the river also provides an opportunity to utilise the river water for the development of irrigation on the valley floor. A certain amount of irrigation is practised at present mainly by local farmers who irrigate small plots of banana, papaya and vegetables. The KVDA have two farms in the area, one of some 32ha is well established and the land for the second one is presently being cleared and will total about 40 hectares at full development.

The KVDA preliminary reconnaissance of the river hydrology indicate that about two cumecs of water could be made available for irrigation from the outfall of the proposed hydropower pipeline which would be situated between the villages of Arror and Chepkum.

A preliminary interpretation of the 1967 1:50,000 air photographs covering the area around Arror indicated that some 3000 hectares of land appeared to have sufficient irrigation potential to justify field investigations. Consequently new air photographs were taken to include these promising areas and a reconnaissance soil survey was carried out over a period of one month from mid May to mid June 1987.

This report describes the soils of the area, their potential for irrigation and provides recommendations for the more detailed soil investigations required to finalise those lands best suited to irrigation, taking into consideration both agronomic, engineering and economic factors.

1.2 LOCATION

The latitude and longitude coordinates for the Study Area are approximately 0°55' to 1°05'N and 35°37'E to 35°40'E. The area forms part of the Rift Valley system, and the irrigable portion is located on the valley floor of the Kerio at an altitude around 1000 1100 metres above mean sea level.

The location of the Study Area is shown in Figure 1.1. The Study Area is situated within the Administrative District of Elgeyo Marakwet in the western part of Kenya and occurs within the Tot Division (Figure 1.2). Tot Division includes the northern part of the Kerio Valley as well as the Elgeyo escarpment and is subsidived into five locations, of which the Study Area occupies parts of Mon and Arror locations. The area comprises about 6400 hectares of land generally lying to the east of the Biretwo-Tot road.

1.3 ACCESS

Access is gained via Eldoret to the top of the Elgeyo escarpment at Iten by some 32 kilometres of tarmac road. This metalled road then loops down the escarpment to Tambach, a distance of five kilometres, providing spectacular views across the Kerio valley to the Tugen Hills. Beyond Tambach the road is all weather albeit loose surfaced but is presently being upgraded. A series of torturous bends descend to the village of Biretwo over a distance of seven kilometres. This village lies at the foot of the escarpment and the total descent from Iten is about 1200 metres.

Two kilometres south east of Biretwo an all weather track, in very bad condition and clearly infrequently maintained, runs northwards along the foot of the escarpment to Arror which is reached after 21 kilometres.

There are no motorable tracks within the Study Area. Most rivers are fordable in the dry season, less so in the rainy season. Access is easiest along the line of the watersheds where the generally open Acacia savannah and flat terrain permit good progress on foot.

Figure 1.1 Location of project within Kenya

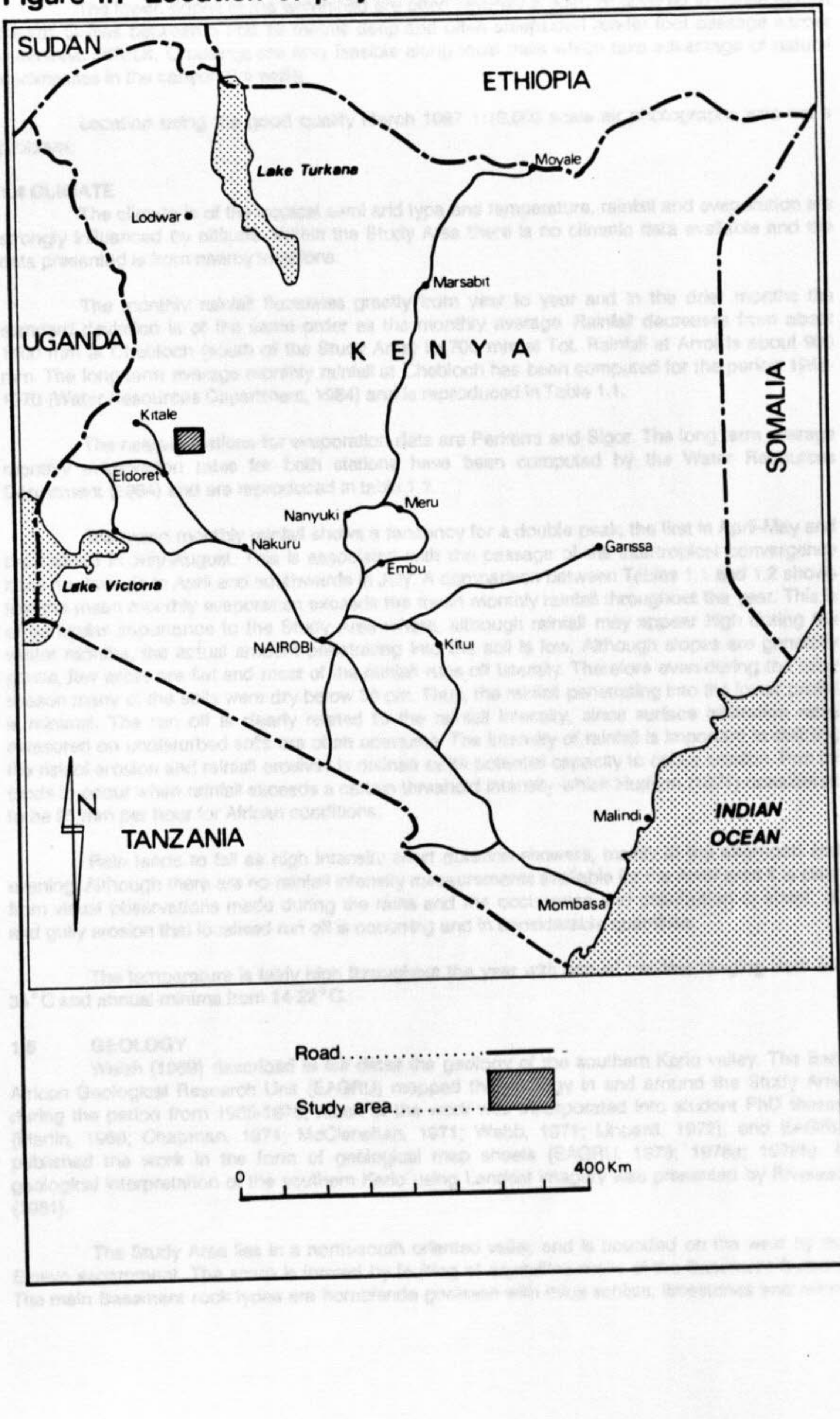


Figure 1.1 Location of project within Kenya

The lower slopes of the watershed are often severely eroded or covered in dense Acacia thicket. Gullies between 5 and 15 metres deep and often steepsided render foot passage across waterways difficult. Crossings are only feasible along local trails which take advantage of natural weaknesses in the canyon like walls.

Location using the good quality March 1987 1:10,000 scale air photographs was not a problem.

1.4 CLIMATE

The climate is of the tropical semi arid type and temperature, rainfall and evaporation are strongly influenced by altitude. Within the Study Area there is no climatic data available and the data presented is from nearby locations.

The monthly rainfall fluctuates greatly from year to year and in the drier months the standard deviation is of the same order as the monthly average. Rainfall decreases from about 1100 mm at Chebloch (south of the Study Area) to 700 mm at Tot. Rainfall at Arror is about 900 mm. The long term average monthly rainfall at Chebloch has been computed for the period 1958-1970 (Water Resources Department, 1984) and is reproduced in Table 1.1.

The nearest stations for evaporation data are Perkerra and Sigor. The long term average monthly evaporation rates for both stations have been computed by the Water Resources Department (1984) and are reproduced in table 1.2.

The mean monthly rainfall shows a tendency for a double peak, the first in April-May and the second in July-August. This is associated with the passage of the intertropical convergence zone northwards in April and southwards in July. A comparison between Tables 1.1 and 1.2 shows that the mean monthly evaporation exceeds the mean monthly rainfall throughout the year. This is of particular importance to the Study Area where, although rainfall may appear high during the wetter months, the actual amount penetrating into the soil is low. Although slopes are generally gentle, few areas are flat and most of the rainfall runs off laterally. Therefore even during the rainy season many of the soils were dry below 30 cm. Thus, the rainfall penetrating into the lower profile is minimal. The run off is clearly related to the rainfall intensity, since surface infiltration rates measured on undisturbed soils are often adequate. The intensity of rainfall is important in defining the risk of erosion and rainfall erosivity is defined as its potential capacity to cause erosion. Run off tends to occur when rainfall exceeds a certain threshold intensity which Hudson (1971) considered to be 25 mm per hour for African conditions.

Rain tends to fall as high intensity short duration showers, mainly in the afternoon and evening. Although there are no rainfall intensity measurements available for the Arror area it is clear from visual observations made during the rains and the occurrence and distribution of sheet, rill and gully erosion that localised *run off* is occurring and in considerable quantities.

The temperature is fairly high throughout the year with annual maxima ranging from 26-34°C and annual minima from 14-22°C.

1.5 GEOLOGY

Walsh (1969) described in fair detail the geology of the southern Kerio valley. The East African Geological Research Unit (EAGRU) mapped the geology in and around the Study Area during the period from 1965-1970; much of the work was incorporated into student PhD theses (Martin, 1969; Chapman, 1971; McClenahan, 1971; Webb, 1971; Lippard, 1972), and EAGRU published the work in the form of geological map sheets (EAGRU, 1973; 1978a; 1978b). A geological interpretation of the southern Kerio using Landsat imagery was presented by Rivereau (1981).

The Study Area lies in a north-south oriented valley and is bounded on the west by the Elgeyo escarpment. The scarp is formed by faulting of crystalline rocks of the Basement System. The main Basement rock types are hornblende gneisses with mica schists, limestones and minor

TABLE 1.1 LONG TERM AVERAGE MONTHLY RAINFALL (mm) 1958-1972

Location: **Chebloch** **Altitude: 1200 metres**

	J	F	M	A	M	J	J	A	S	O	N	D	Annual $\bar{x}$	Annual S
$\bar{x}$	29.8	42.5	74.9	176.2	134.6	79.3	142.6	135.7	55.1	56.6	124.7	33.5		
s	39.3	60.6	52.6	253.3	96.1	89.1	56.3	86.3	49.0	47.7	164.7	49.7	1094	371
%	2.7	3.9	6.9	16.2	12.4	7.3	13.1	12.5	5.1	5.2	11.5	3.1		

Source: Water Resources Department (1984)

Notes:

$\bar{x}$ long term monthly average

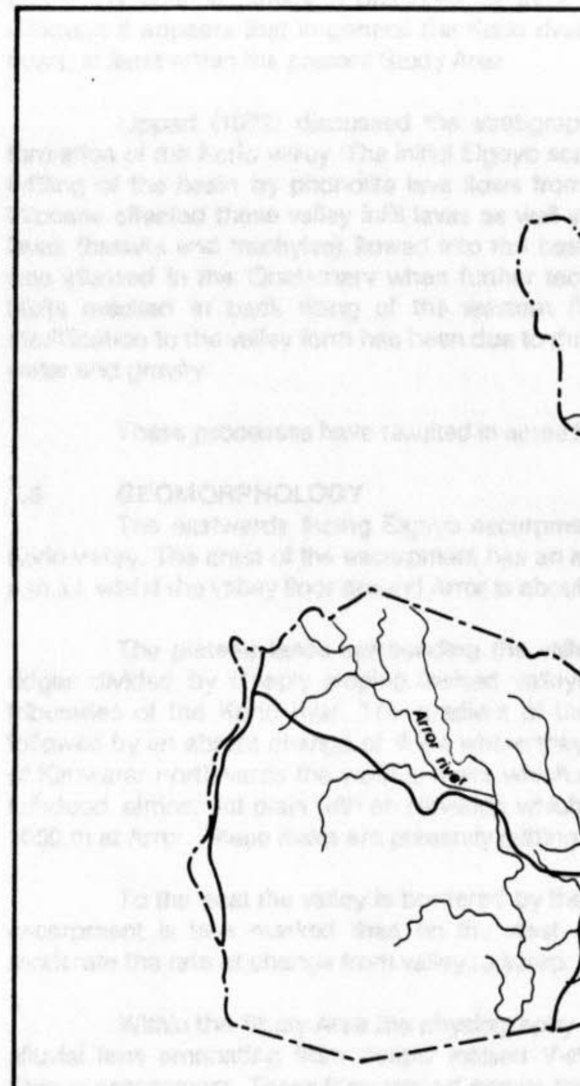
s standard deviation

TABLE 1.2 LONG TERM AVERAGE MONTHLY EVAPORATION (mm)

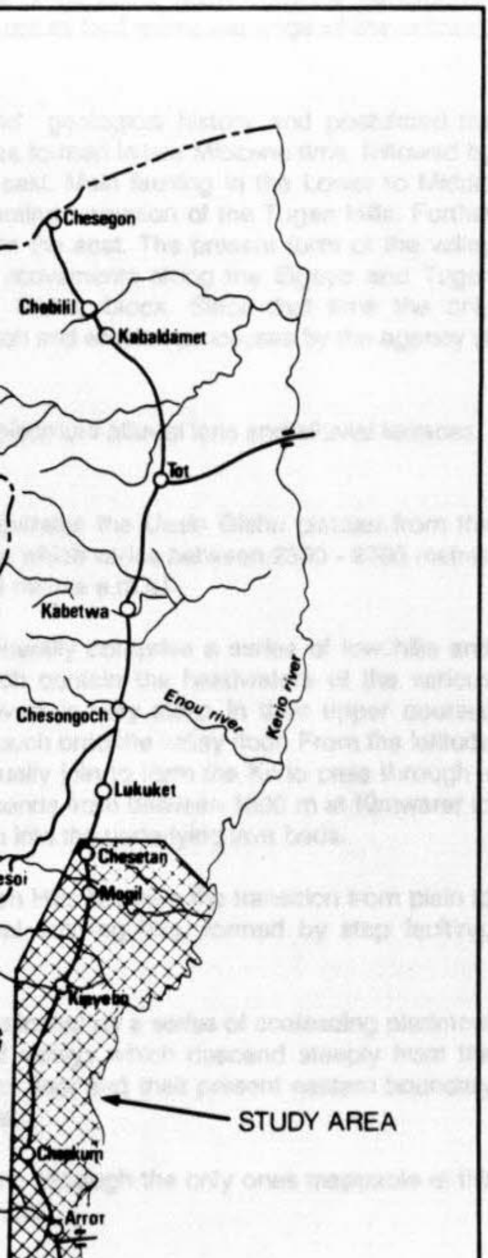
Location	**Perkerra**				**Elevation: 1050 m**			**Period: 1959 - 1982**						
	J	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	$\bar{x}$	**Annual**
$\bar{x}$	245	239	262	205	207	199	184	189	215	229	201	222	2598	186
s	24	27	36	29	36	25	26	28	26	33	33	33		
%	9.4	9.2	10.1	7.9	8.0	7.7	7.1	7.3	8.3	8.8	7.7	8.5		
Location:	**Sigor**				**Elevation: 1050m**				**Period: 1066 - 1982**					
$\bar{x}$	235	216	236	180	165	165	150	160	190	200	171	215	2285	124
S	27	37	47	30	16	21	20	23	20	18	24	33		
%	10.3	9.5	10.3	7.9	7.2	7.2	6.5	7.0	8.3	8.8	7.5	9.4		

Source: Water Resources Department (1984)

Figure 1.2 Location of project



hin Tot Division



quartzites. On the valley floor basalts and trachytes outcrop. The junction between the Basement and valley floor volcanics is obscured by thick layers of sediment wash from the escarpment although it appears that in general the Kerio river has cut its bed along the edge of the volcanic flows, at least within the present Study Area.

Lippart (1972) discussed the stratigraphy and geological history and postulated the formation of the Kerio valley. The initial Elgeyo scarp was formed in late Miocene time, followed by infilling of the basin by phonolite lava flows from the east. Main faulting in the Lower to Middle Pliocene affected these valley infill lavas as well as effecting formation of the Tugen Hills. Further lavas (basalts and trachytes) flowed into the basin from the east. The present form of the valley was attained in the Quaternary when further tectonic movements along the Elgeyo and Tugen faults resulted in back tilting of the western (Uasin Gishu) block. Since that time the only modification to the valley form has been due to deposition and erosion processes by the agency of water and gravity.

These processes have resulted in scree fans, piedmont alluvial fans and alluvial terraces.

1.6 GEOMORPHOLOGY

The eastwards facing Elgeyo escarpment separates the Uasin Gishu plateau from the Kerio valley. The crest of the escarpment has an altitude which varies between 2300 - 2700 metres a.m.s.l. whilst the valley floor around Arror is about 1100 metres a.m.s.l.

The plateau lands surrounding the valley generally comprise a series of low hills and ridges divided by steeply sloping incised valleys which contain the headwaters of the various tributaries of the Kerio river. The gradient of these rivers is very steep in their upper courses followed by an abrupt change of slope where they debouch onto the valley floor. From the latitude of Kimwarer northwards the various rivers which eventually join to form the Kerio pass through a subdued, almost flat plain with an elevation which descends from between 1300 m at Kimwarer to 1000 m at Arror. These rivers are presently cutting down into the underlying lava beds.

To the east the valley is bordered by the Tugen Hills but here the transition from plain to escarpment is less marked than on the west. Several outlying hills, formed by step faulting, moderate the rate of change from valley to scarp.

Within the Study Area the physiography is dominated by a series of coalescing piedmont alluvial fans emanating from deeply incised V-shaped valleys which descend steeply from the Elgeyo escarpment. These fans spread across the valley floor and their present eastern boundary more or less follows the present course of the Kerio river.

Minor alluvial terraces occur along all the rivers, although the only ones mappable at the scale of 1:5,000 occur along the Arror, Mon and Kerio rivers.

Three distinct geomorphic units have been recognised:

- escarpment hill slopes
- piedmont alluvial fan
- river alluvium.

1.7 DRAINAGE

The principal river, the Kerio, has its headwaters in the plateau lands north of Eldama Ravine. The Kimwarer and the Mong are perennial whereas the Mogorua and the Endo are not. These rivers drain down in a northerly direction and, after their junctions with the Kiptonoi, form the Kerio river.

Many subsidiary seasonal streams flow into the Kerio, principally from the Elgeyo escarpment. The most important are the Torch and Barweisa and, within the present Study Area, the Arror and the Mon.

The headwaters of the Arror rise in the eastern side of the Cherangani Hills where the forests of Embobut and Kipkunurr occupy the bulk of the catchment area at altitudes between 2200 - 3200 metres. the river drains in a south to south easterly direction to a point about six kilometres west of Chesoi where it turns south and runs parallel to the escarpment as far as Kapsowar village. Then it turns east and plunges over the Elgeyo escarpment, falling a distance of 1100 metres to eventually join the Kerio river in the valley bottom.

1.8 SOILS

There is a good correlation between the geomorphology and the associated soils. This correlation holds good for both the large scale regional geomorphic features and for the more localised small scale topographic features.

1.8.1 Soils of the Escarpment Hill Slopes

These are shallow, often stony soils on steep slopes, variable in texture and colour depending upon parent material which ranges from gneisses through schists to quartzites. The soils are loamy sand to sandy clay loam in texture with a slightly acid to neutral reaction. They are freely drained and colours range from reddish brown to greyish brown. Soil erosion has occurred on steeper slopes cleared for fuelwood or cropping where soil conservation measures have been neglected. Constraints of topography (steepness) and variable, often shallow, depth mean that these soils are unsuitable for irrigation.

1.8.2 Soils of the Piedmont Alluvial Fans

These soils stretch from the footslopes of the Elgeyo escarpment in an arc extending to the Kerio river. Material formed on the hillsides by the weathering of schists and gneisses has been washed down and spread across the valley floor to form coalescing alluvial fans. The sediments are very deep and natural drainage lines are commonly incised to a depth between 5 and 20 metres., Several depositional sequences of varied textured material are recognisable often separated by bands or lenses of extremely coarse textured cobbles clearly deposited under torrent flow conditions.

The principal component and presumably the youngest representative of the upper depositional layers is a dark reddish brown loam with a slightly acid to neutral reaction. Other deposits, which are believed to have formed during earlier geological times, are redder calcareous and contain more clay.

At the neck of the fans, closest to the escarpment, large boulders (1-2 metres in diameter) are embedded in the alluvium which is often of a loamy sand texture. It appears that deposition occurred in such situations by mass flow.

All piedmont alluvial soils, apart from minor areas of clays in toe-slope positions, are well drained.

Imperfectly drained grey brown calcareous clays have developed on the toeslope of the alluvium. They have been severely gullied by rainfall run off from the higher lying land and are considered to be unsuitable for irrigation due to topographic constraints.

1.8.3 Alluvial Terrace Soils

In the past the rivers have clearly been slower moving with a tendency to meander resulting in the deposition of medium textured sediment (loam and sandy loam) along their valley courses. At the present time the rivers are cutting down into the underlying rocks and the residual river terraces now occur at elevations between two and five metres above the present river level as distinct, generally flat but isolated patches of land. The soils are slightly acid to neutral in reaction, loamy with good tillage characteristics and well drained. They are well suited to irrigation development although their distribution as small, isolated patches is such that they have not been included in the final areas selected for further studies.

1.9 VEGETATION

Pratt and Gwynne (1977) identified six eco-climatic zones in East Africa. The Study Area falls within their semi-arid zone associated with marginal agricultural potential under rainfall conditions) and a natural vegetation cover of dry woodland, Acacia-Themeda associations or equivalent bush.

Sombroek et al (1982) discussed in some detail the Kenya work on the relation between climate, vegetation and agricultural potential and defined a series of agroclimatic zones.

The distribution of vegetation and overall physiognomy reflects the physiography and hence the moisture conditions at site.

The majority of the medium textured well drained soils of the Study Area support an *Acacia tortilis* woodland with *Commiphora* spp, occasional *Boscia* thicket and a variable undergrowth of grasses and herbs.

On the footslopes where clay soils become dominant and drainage is more restricted *Acacia seyal var fistula* predominates.

The Acacia tree and shrub savannah is often dense in areas of broken topography and alongside drainage channels, even when the soils are shallow. This distribution reflects the moisture status of the soils. On the interfluves and upper convex slopes and the sloping piedmont alluvial fan, sheet wash is common and water flows across, rather than into, the soils thus limiting the density of the plant species. Areas of stony or gravelly surface soils or irregular topography slow down lateral water movement and ensure that at least some water enters the profile.

CHAPTER 2

METHODS OF STUDY

2.1 AIRPHOTO INTERPRETATION

2.1.1 Existing Photography

Air photographs at 1:50,000 were taken in 1969 by Hunting Surveys Limited on behalf of the Government of Kenya.

Photographs were selected to cover both banks of the Kerio river lying between the escarpments to the west and the east and from the north. A stereoscopic examination of the photographs resulted in the delineation of several scattered areas, totalling some 3000 hectares which appeared to justify further study. Land rejected included steep, stony or eroded areas with no potential for moderate scale irrigation development. All the land deemed suitable lay between the Elgeyo escarpment and the Kerio river.

A block of land comprising some 6000 hectares lying between the Machukwa river to the south and the Mon in the north was delineated as the Study Area. This land included the 3000 hectares gross which appeared to have some potential, as judged by air photographic interpretation, for irrigation development and was included in the total area selected for new air photography at 1:10,000 scale.

2.1.2 New Photography

Aerial photography of the Study Area was acquired by PHOTOMAP of Nairobi during March 1987 at a scale of 1:10,000. This photography was examined under a Wild mirror stereoscope and land forms were delineated onto Astrafoil overlays to the prints. A draft airphoto interpretation legend was prepared. Also at this stage the opportunity was taken to select the inspection sites for field work. Sites were not selected on a rigid grid basis but located in groups to cross geomorphic units at right angles and in positions where the tone or texture of the photograph, or the land use suggested a possible change in soil type. All cultivated land was demarcated to provide information for the land use census.

2.2 FIELD METHODS

The Study Area was traversed by means of car along the limited access tracks but mainly on foot. Traverse notes were recorded continuously on a visual basis and soil sections exposed in road cuttings, erosion gullies etc were observed to complement the more specific soil inspection sites. Soil sites were inspected by excavation of soil pits or by auger. In many cases a combination of both pit and auger techniques was necessary to achieve the required depth of observation, generally to two metres. In some cases the soil depth was less than two metres and observations were stopped when non soil was encountered. Non soil encountered included bedrock or thick sequences of boulders. An average inspection density of two sites per square kilometre was achieved in those lands considered to have potential for irrigation. In total 72 pit and bore sites were excavated, described and sampled as appropriate. In addition one section was described to a depth of four metres in order to more fully appreciate the depositional sequence and the properties of the various soil layers encountered in the partly eroded lands.

The location of all inspection sites (pits, bores etc) was accurately determined on each aerial photograph by using a needle to mark through the photograph and appending the site number in ink on the reverse side.

All descriptions were recorded onto standard soil description proformas. Site descriptions included: geology, geomorphology, parent material, vegetation or land use, slope, drainage, presence of stones, gravel and rock outcrop, microrelief and degree of erosion.

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Soil descriptions included:

- depth of each horizon;
- colour;
- texture;
- structure;
- consistence,
- presence and estimation of volume of stones and gravel;
- clay skins;
- root distribution;
- details of boundary between horizons.

The Study Area covered about 6400 ha but field observations were concentrated in those areas considered to have some potential for irrigation. Nevertheless to complete the overall picture of the soil distribution an attempt has been made to categorise those soil types lying outside the potentially irrigable land.

2.3 SOIL ANALYSIS

All soil samples were submitted to the National Agricultural Laboratories Nairobi for analysis. All samples from pit sites were analysed for:

- Texture: gravel, sand, silt and clay
- pH soil-water suspension
- pH soil-potassium chloride suspension
- Electrical conductivity
- Total carbon
- Cation exchange capacity
- Exchangeable calcium, magnesium, sodium, potassium.

Samples from soil pits and routine bores were also analysed additionally for a series of analyses to evaluate the fertility status.

In total 48 samples were collected from pit sites for detailed analysis and 38 samples for fertility analysis.

Infiltration tests were carried out at each of the representative pit sites in duplicate using double ring infiltrometers.

The analytical data for all samples is presented in Appendices A.1 and A.2.

2.4 MAPPING

Soil boundaries were interpolated between inspection sites following stereoscopic examination of the 1:10,000 scale 1987 vintage air photographs. In some instances soil boundaries coincide with clear changes in geomorphology or vegetation pattern, others are less clear. Boundaries were transferred from transparent plastic overlays fixed to the air photographs onto 1:5,000 base maps using a Sketchmaster and manually adjusted where necessary. Some inaccuracies can be expected due to linear distortion but they are well within the limits of error inherent in a soil survey at this level. A similar procedure was followed in the preparation of the irrigable land capability classification and land use maps.

Ideally at the level of soil observation carried out the maps should be presented at 1:25,000. However at such a scale the detail required to delineate potential irrigable land would be missing. Consequently the final scale of 1:5,000 represents a compromise between normally accepted procedures and the practicalities needed to select land for a second stage, more detailed investigation.

The symbols and colours used for the soil mapping units accord with those recommended by FAO and the symbols and colours utilised for the irrigable land capability classification are those preferred by the USDA Bureau of Reclamation.

CHAPTER 3

SOILS

3.1 SOIL MAPPING UNITS

The Kenya Soil Survey has not adopted the soil series as a basic mapping unit. They have adopted and used the concept of the Soil Mapping Unit which is not a taxonomic unit per se. The soil mapping unit definition has been adapted from Buringh (1979) as:

'a soil or a natural body of soils, occupying a certain land area which can be delineated on a soil map, showing the geographic position of the soil units; this soil or body of soils has a set of properties which differentiate it from other soil mapping units.'

The physiographic approach which is used in Kenya for soil mapping (Siderius, 1980) enables the mapped unit to be directly related to the land evaluation unit.

3.2 PREVIOUS WORK

Land Systems of the area are described by Scott et al (1971). They distinguished various units in the Kerio-Turkwell area of which the Kerio Land System is pertinent to the present study.

This Land System is described as level to gently sloping individual or coalescing alluvial fans, dissected by drainage channels into low flat topped ridges. The fans occur most commonly on the valley slopes along the foot of the escarpment.

Siderius (1975) carried out an exploratory soil survey of the upper Kerio Valley and he categorised the soils based on physiography. Some 344,000 hectares of land were covered and a soil map prepared at 1:100,000 scale.

Mapping units described which are present in the Study Area are:

(a) Soils of the Hills and Minor Scarps (H)
The isolated hills that occur on the side of the Elgeyo escarpment are generally derived from gneisses and quartzites. Soil development is limited and soils are mainly shallow, dark reddish brown to strong brown (5YR to 7.5YR hues) sandy loam to sandy clay loam in texture. Mapping Unit HF.

(b) Soils Developed on Footslopes (F)
Red to reddish brown (5YR to 2.5YR hues) well drained sandy loam to sandy clay loam derived from colluvium on slopes between 3 to 8 per cent. Surface stones common, soils moderately deep. Mapping Unit FX.

(c) Soils on Piedmont Alluvium (Y)
Mapping Unit YF - deep dark reddish brown sandy loams grading into sandy clay loam subsoils, well drained and derived from hornblende and biotite gneiss. Included in this unit is a dark red (2.5YR 3/6) sandy clay loam over a sandy clay subsoil. Mapping Unit YFe - Unit YF but severely eroded (gullied) but remnants of the reddish brown loams are still clearly visible.

(d) Soils on the Alluvial Plain (P)
Mapping Unit PAt - deep well drained strong brown loams to sandy loams which occur on level to gently undulating terraces bordering the principal rivers.

(e) Soils Derived on Bottom Lands (B)
Mapping Unit BLa. Land in this unit comprises the lower areas between the lava flows and has a flat to gently undulating topography. The soil is mainly derived from volcanic rocks (trachytes and basalts) and is formed on colluvial material, is a well drained brown

sandy clay loam over sandy clay, calcareous and strongly alkaline (pH 8.7 - 9.0) in reaction.

Sombroek et al (1982) published the exploratory map of Kenya at a 1:1,000,000 scale. At this scale the Study Area is insignificant in extent and the soils information is too generalised to be of use.

3.3 SOIL CHARACTERISTICS

3.3.1 Chemical Characteristics

In a semi-arid environment the major chemical factors limiting irrigated agricultural land use are usually associated with the accumulation of salts in the profile. In the chemical analysis, therefore, attention is primarily focussed on the assessment of the amount of soluble salts present and the amount of exchangeable sodium associated with the soil clay. Experience from previous work in the Kerio valley (G and G, 1986) indicated that soil salinity and soil alkali hazard is generally low on these piedmont alluvial soils. Field observations during this present study confirmed the previous findings. Consequently more attention was given to the fertility status of these soils.

Detailed soil profile descriptions and related chemical data for the selected ten representative soil profiles are given in Appendix A. Chemical data from routine bore samples are given in Appendix B.

In the discussion which follows the results have been interpreted on the basis of values given in Table 3.1.

TABLE 3.1 INTERPRETATION NORMS FOR THE PRINCIPAL CHEMICAL ANALYSES (SURFACE HORIZONS)

Determination	Interpretation Class				
	1 very poor	2 poor	3 average	4 good	5 very good
Total carbon %	0.6		1.2	1.8	2.4
Total nitrogen %	0.05		0.1	0.14	0.2
Exchangeable Ca me/100g	1.0		4.0	8.0	18.0
Exchangeable Mg me/100g	0.5		1.0	2.0	5.0
Exchangeable K me/100g	0.1		0.2	0.4	0.6
Sum Bases me/100g	2.0		6.0	12.0	24.0
CEC me/100g	5.0		10.0	20.0	40.0
Base saturation %	20.0		40.0	60.0	90.0

Note: ***These figures indicate the limiting values between the five cases.***

The corresponding terms used for ranges in pH are as follows:

	pH		pH
Extremely acid	Below 4.5	Neutral	6.6 - 7.3
Very strongly acid	4.5 - 5.0	Mildly alkaline	7.4 - 7.8
Strongly acid	5.1 - 5.5	Moderately alkaline	7.9 - 8.4
Medium acid	5.6 - 6.0	Strongly alkaline	8.5 - 9.0
Slightly acid	6.1 - 6.5	Very strongly alkaline	9.1 and higher

Since only a relatively small number of profiles have been analysed the results are discussed in general terms only.

(a) pH

There is little difference in the pH soil-water suspension of the soils. Most values fall in the range from slightly acid to moderately alkaline (pH 6.1 - 8.3) with some more alkaline values up to pH 9.2 in the calcareous cracking clay soils. Subsoil pH varied from slightly acid to moderately alkaline (pH 6.2 - 8.4) with higher values up to pH 9.4 in the cracking clay soils. Subsoil pH increased down the profile.

pH values were also measured in a soil-potasium chloride suspension and these results were found to be lower than those measured in an aqueous suspension by 1.0 to 2.0 units.

(b) Exchangeable Bases

The exchangeable forms of calcium, magnesium and potassium constitute the major sources for plant nutrition. Calcium is generally the dominant cation followed by magnesium, potassium and sodium in descending order. Values are highest in the topsoil and decline somewhat in the subsoil then often increase in the deep subsoil.

Exchangeable calcium levels are average to good with little difference between the soil mapping units and the exchangeable magnesium levels are very good to good.

The values for exchangeable potassium are invariably high which agrees with the presence of mica in the soils.

The ratio of potassium to other exchangeable cations is important for plant growth. Boyer (1970) concluded that the ratio of magnesium to potassium should be less than 50 to avoid an induced potassium deficiency but greater than two to three to avoid a potassium induced magnesium deficiency in coffee.

Thus antagonisms may occur between nutrients and if the Mg/K ratio is less than two or Ca/K ratio less than five there is excessive absorption of potassium by the plant and an induced deficiency of calcium or magnesium occurs.

The Mg/K ratio exceeds two on these soils and potassium induced magnesium deficiencies should not occur.

The Ca/K ratio is greater than five and potassium induced calcium deficiencies should not occur.

(c) Cation Exchange Capacity (CEC) and Base Saturation (BS)

The CEC is extremely variable and ranges from very low values (less than 5) in sandy layers through to very high values (around 60) in the cracking clay soils. The majority of the soils are of medium texture and have good CEC values in the range from 20 to 30 milliequivalents per 100 g soil. Values are generally highest in the surface horizon and reflect the contribution made by organic matter to CEC.

Base saturation of the soils is average to good and ranges from 54 to 100 per cent. These results are in accord with the pH measurements. Thus all soils are classified (Section 3.5) as eutric (i.e. having base saturation greater than 50 per cent).

(d) Organic Carbon

Values for organic carbon range from 0.01 to 0.78 per cent and are poor to very poor. Organic matter may be obtained by multiplying the value for organic carbon by 1.72. The values obtained in these soils are however fairly typical of soils formed under semi arid conditions.

Soil organic matter is of importance to soil fertility due to its contribution to the soil exchange complex and sulphur status apart from its contribution to maintenance of soil

structure and water holding characteristics.

(e) Sulphur

Most sulphur in tropical soils is present in the topsoil in organic combination.

Studies on acid soils of eastern Australia (Barrow, 1960) showed that the presence of sulphur was closely related to the accumulation of soil nitrogen in the ratio ION : 1.25. Although analyses were not carried out for sulphur we can use the above figures to assess the possible sulphur content. A one per cent organic matter should yield about 1000 ppm of total nitrogen. Assuming a ratio of ION : 1.25 then the sulphur content would be 120 ppm. Most soils would contain lesser amounts and are regarded as having low reserves of sulphur.

The problems of sulphur deficiency appear to be associated especially with upland savannah (Greenwood, 1951) and the deficiency appears to be accentuated by drought (Dutt, 1962). Responses to sulphur applications have been achieved on many acidic soils in West Africa (Braud, 1969). Since the sulphate contents of the local rivers are low and this water would be used to irrigate crops we consider sulphates should be included in the fertiliser applications.

(f) Salinity

Salinity was not expected to be a major hazard within the Study Area, consequently it was measured using the electrical conductivity of a 1:5 soil water extract in the field laboratory and a $1{:}2^1/_2$ soil water extract in the laboratories of NAL. Most results were extremely low being less than 250 microsiemens and thus present soil salinity is not a problem for crop production. Occasionally salinity is encountered in the subsoil below 50 cm depth. The levels will reduce gradually under a sustained irrigation regime.

(g) Alkali Hazard

The alkali hazard in soils in commonly expressed in terms of exchangeable sodium percentage (ESP) of the cation exchange capacity which is occupied by exchangeable sodium. The main effect is in the dispersion of clay causing the soil to be dense and difficult to work due to reduction of permeability and infiltration rates and in general making it a poor medium for plant growth. Finely dispersed clay may be washed down the profile increasing the clay content in the deeper layers. A soil is considered alkali when the ESP exceeds 15 and this is also the generally accepted limit beyond which deterioration in the soils physical properties will affect crop performance and cultivation.

Most ESP results were low apart from those associated with the cracking clay soils. Such soils are not included in the area for development. Consequently high exchangeable sodium is not considered to be a limiting factor for crop production.

3.3.2 Soil Physical Characteristics

(a) Texture

Soil textures are varied and range from loamy sands to clays reflecting the different soil parent materials, different topographic positions and different soil forming processes which have operated.

Some soils on the piedmont alluvial fan geomorphic unit show an increase in clay content down the profile and/or the presence of clay cutans indicating clay illuviation. This increase in clay content is important to the soil classification as explained in Section 3.4.

All textural class names used in soil descriptions are based on the USDA system and accord with their soil textural diagram.

structure and water holding characteristics.

(e) Sulphur
Most sulphur in tropical soils is present in the topsoil in organic combination.

Studies on acid soils of eastern Australia (Barrow, 1969) showed that the presence of sulphur was closely related to the accumulation of soil nitrogen in the ratio (S:N) 1:25. Although analyses were not carried out for sulphur we can use the above figures to assess the possible sulphur content. A one per cent organic matter should yield about 1500 ppm of total nitrogen. Assuming a ratio of (S:N) 1:25 then the sulphur content would be 60 ppm. Most soils which contain lesser amounts and are regarded as having low reserves of sulphur.

The problems of sulphur deficiency appear to be associated especially with upland savannah (Chapman, 1985) and the deficiency appears to be accentuated by drought (Scott, 1982). Responses to sulphur applications have been achieved on many acidic soils in West Africa (Kang, 1985). Since the sulphate contents of the local rivers are low and this water would be used to irrigate crops we consider sulphates should be included in the fertilizer applications.

(f) Salinity
Salinity was not expected to be a major hazard within the Study Area, consequently it was measured using the electrical conductivity of a 1:5 soil water extract in the field laboratory and a 1:2.5 soil water extract in the laboratories of NAK. Most results were extremely low being less than 250 microsiemens and thus present soil salinity is not a problem for crop production. Occasionally salinity is encountered in the subsoil below 50 cm depth. The levels will reduce gradually under a sustained irrigation regime.

(g) Sodic Hazard
The sodic hazard in soils is commonly expressed in terms of exchangeable sodium percentage (ESP) of the cation exchange capacity which is occupied by exchangeable sodium. The main effect is in the dispersion of clay causing the soil to be dense and difficult to work due to reduction of permeability and infiltration rates and in general making it a poor medium for plant growth. Finely dispersed clay may be washed down the profile increasing the clay content in the deeper layers. A soil is considered sodic when the ESP exceeds 15 and this is also the generally accepted limit beyond which deterioration in the soils physical properties will affect crop performance and cultivation.

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All textural class names used in soil descriptions are based on the USDA system and accord with their soil textural diagram.

(b) Infiltration Tests

A total of eight infiltration tests were carried out at four representative sites.

The interpretation of the infiltration rates measured on virgin soils presents some difficulties, both because of the limitations of the double ring infiltrometer test itself, and because of possible changes in infiltration rates which may occur when land is brought under irrigated agriculture. It is often found that there is a substantial reduction in infiltration rates once irrigation and cropping start. The reasons for this include in-filling of pores by disturbed fine particles, the breakdown of organic matter, and a reduction in biotic activity. Conversely infiltration rates may increase. In the Study Area the uncultivated land has been subjected to sheet erosion and a thin dispersed surface cap has formed. This layer reduces infiltration.

Infiltration tests were conducted on soils in both the undisturbed state (non-cultivated) and after surface disturbance by hoeing. Soil cumulative infiltration data is shown in Figure 3.1 for soils in the undisturbed state (u) and after surface hoeing (p). Results showing cumulative infiltration (D) at various time intervals are given in Table 3.2 along with the basic infiltration rate. It is generally accepted that the basic infiltration rate (b) has been reached if the infiltration rate is decreasing by less than 10 per cent in an hour. The infiltration rates obtained show that the basic rate has been attained after one to three hours.

All measured infiltration rates are highly suitable for overhead irrigation (FAO, 1979), less so for surface irrigation.

For surface irrigation the optimum based rates are between 7-35 mm/hour (FAO 1979). Rates in excess of 125 mm per hour mean that such soils are not suited to surface irrigation methods.

Basic infiltration rates measured ranged from 14 to 100 mm per hour. On this basis it would seem that all the soils are suitable for surface irrigation. In practice other considerations such as topsoil texture and its stability to water, as well as soil slope, have to be considered in the final decision on irrigability.

(c) Subsoil Hydraulic Conductivities

All subsoils are well drained and at this stage it was not deemed necessary to measure subsoil hydraulic conductivity.

(d) Subsoil Structure

Root penetration of the subsoil in the Study Area will be affected by mechanical factors like compaction, lack of structural development and imperfect drainage. Compaction of subsoils was very noticeable from auger and pit observations in the dry condition. The lack of structure development as observed is largely a reflection of the prevailing soil moisture regime and structural definition could be expected to improve under the more moist regime subsequent to irrigation.

3.4 SOIL CLASSIFICATION

3.4.1 Introduction

It is important to select a soil classification which emphasises soil properties most relevant to the proposed development and which allows an easy and logical delineation of mapping units. In addition these soil units must be directly related to land classification units. The soil mapping units derived by air photo interpretation are based on geomorphology. Since the soils are related to topographic position in situations of more or less *in situ* weathering (hill slopes and piedmont fans) or on alluvial terraces then the geomorphic approach provides a firm basis for the mapping of soils.

TABLE 3.2 SOIL INFILTRATION CHARACTERISTICS

Location	Surface Condition	Soil Classification	Cumulative Infiltration (mm) after minutes 30	60	90	120	180	Basic Infiltration mm/hour
Pit 3	Undisturbed	Chromic Luvisol	15	28	40	48	62	14
	ploughed	Lo.1	20	35	50	60	80	20
Pit 4	Undisturbed	Eutric Cambisol	85	155	205	250	300	50
	hoed	Be-1	120	200	250	300	400	100
Pit 7	Undisturbed	Eutric Fluvisol	50	90	125	160	220	60
	hoed	Je.2	72	140	170	210	260	50
Pit 9	Undisturbed	Orthic Luvisol	43	82	110	130	160	30
	hoed	Lo.2	57	99	123	145	190	22

3.4.2 Soil Units

The Terms of Reference required the soils to be classified according to the Kenya System which is described by Siderius and Van der Pouw (1980). The Kenya System is based upon the FAO Soil Map of the World Legend (FAO, 1974) with modifications to suit Kenya conditions.

The system is not a true taxonomic system but it does allow soils to be grouped together on the basis of generally accepted principles of soil formation and it is sufficiently flexible to be used to formulate readily mappable units.

In order to fully categorise the soils it is necessary to consider the profile moisture as related to climate. In terms of the USDA Soil Taxonomy (1974) the soil moisture regime is classified as ustic, meaning that whereas there is limited moisture present under natural conditions it occurs at a time when other climatic conditions are conducive to plant growth.

Soils within the Study Area have been classified into Lithosols, Fluvisols, Cambisols, Luvisols and Vertisols. They are further subdivided depending upon soil profile characteristics such as clay content, base saturation, colour, weatherable minerals, presence of calcium carbonate, plinthite etc, by the identification of diagnostic horizons.

Diagnostic horizons are those soil horizons which have a set of quantitatively defined properties which are used to identify soil units. There are many diagnostic horizons and only the ones used to classify the soil units will be defined in this text.

(a) Lithosols (I)

Lithosols are soils which have a very limited depth and continuous coherent and hard rock occurs within 10 cm of the surface. Under Kenyan conditions this depth limitation is considered to be too restrictive and all soils with hard rock within 25 cm of the surface are termed Lithosols. They are further subdivided into calcaric (if calcareous) or dystric or eutric depending upon base saturation. All Lithosols are eutric (Le).

(b) Fluvisols (J)

These are soils developed on recent alluvium which are further subdivided on profile characteristics. Fluvisols encountered in this study have been classified as Eutric Fluvisols (Je) since they possess a base saturation of 50 per cent or more in the 10 - 50 cm range.

(c) Cambisols (B)

Cambisols possess a cambic B horizon.

A cambic B horizon is an altered horizon but does not have sufficient accumulation of clay or iron or other material to justify classification as other diagnostic horizons and contains significant amounts of weatherable minerals and texture of sandy loam or finer.

Eutric Cambisols (Be) were diagnosed when the base saturation between 20 and 50 cm exceeded 50 per cent and Dystric Cambisols (Bd) when base saturation was less than 50 per cent.

(d) Luvisols (L)

These soils have a diagnostic argillic B horizon and a base saturation of 50 per cent or more within 125 cm of the surface. For Chromic Luvisols the rubbed moist soil must have a hue of 5YR and a chroma more than 4 **or** a hue redder than 5YR. Both Orthic Luvisols (Lo) and chromic Luvisols (Lc) have been recognised.

(e) Vertisols (V)

These are soils which contain 30 per cent or more of clay in all horizons to a depth of at least 50 cm, which develop cracks from the surface downwards. Under natural conditions these cracks must be at least 1 cm wide and extend to a depth of 50 cm whilst

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Soils within the Study Area have been classified into Lithosols, Fluvisols, Cambisols, Luvisols and Vertisols. They are further subdivided depending upon soil profile characteristics such as clay content, base saturation, colour, weatherable minerals, presence of calcium carbonate, [illegible] etc. by the identification of diagnostic horizons.

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(b) Fluvisols (J)

These are soils developed on recent alluvium which are further subdivided on profile characteristics. Fluvisols encountered in this study have been classified as Eutric Fluvisols (Je) since they possess a base saturation of 50 per cent or more in the 20 - 50 cm range.

(c) Cambisols (B)

Cambisols possess a cambic B horizon.

A cambic B horizon is an altered horizon but does not have sufficient accumulation of clay or iron or other material to justify classification as other diagnostic horizons and contains significant amounts of weatherable minerals and texture is sandy loam or finer.

Eutric Cambisols (Be) were diagnosed when the base saturation between 20 and 50 cm exceeded 50 per cent and Dystric Cambisols (Bd) when base saturation was less than 50 per cent.

(d) Luvisols (L)

These soils have a diagnostic argillic B horizon and a base saturation of 50 per cent or more within 125 cm of the surface. For Chromic Luvisols the rubbed moist soil must have a hue of 5YR and a chroma more than 4 or a hue redder than 5YR. Both Orthic Luvisols (Lo) and chromic Luvisols (Lc) have been recognised.

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These are soils which contain 30 per cent or more of clay in all horizons to a depth of at least 50 cm, which develop cracks from the surface downwards. Under natural conditions these cracks must be at least 1 cm wide and extend to a depth of 50 cm (unless

Figure 3.1 Cumulative infiltration data

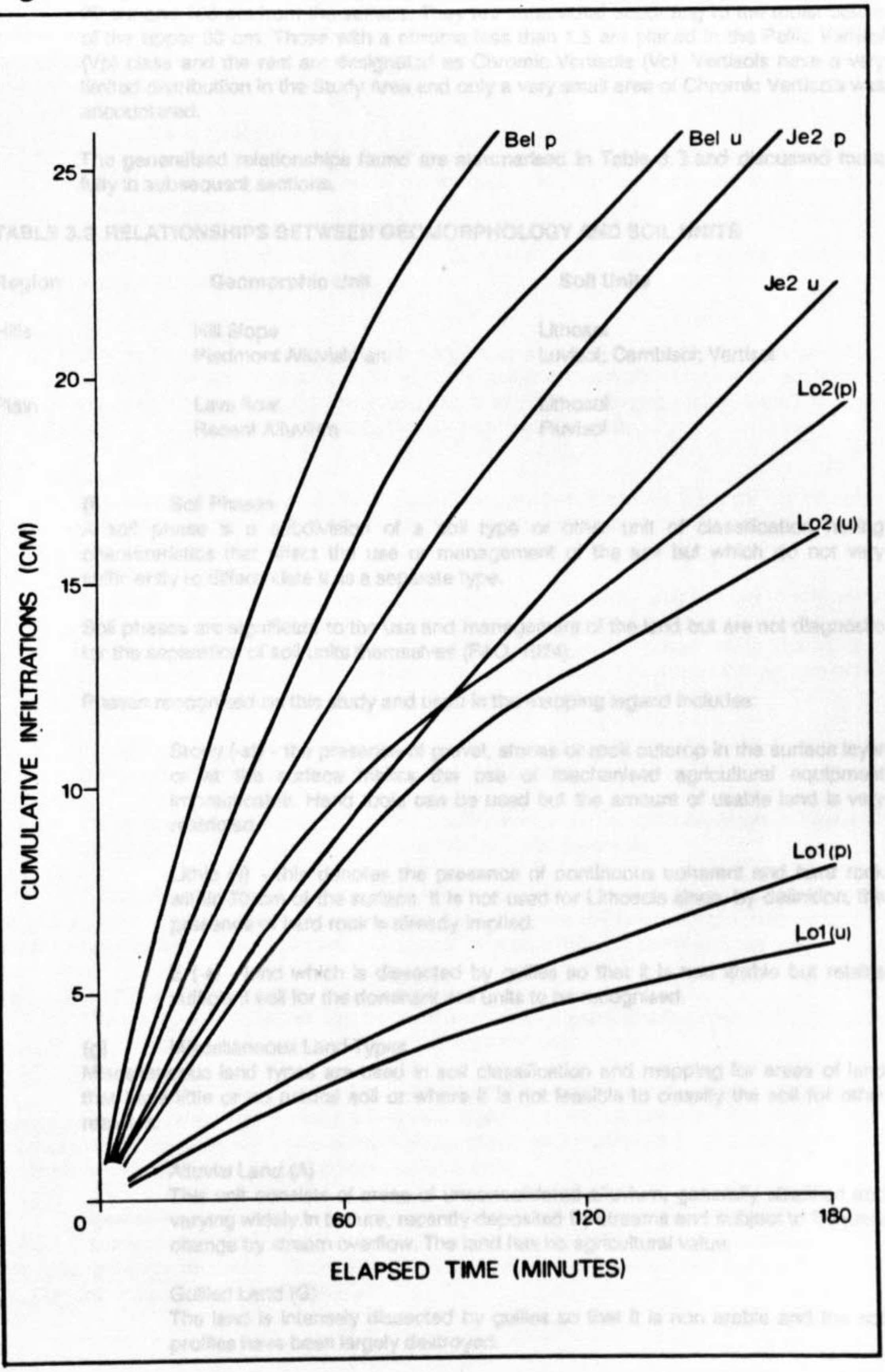


Figure 3.1 Cumulative infiltration data

exhibiting one or more of the following phenomena: gilgai microrelief, slicken-sides or wedge shaped or parallel piped (lenticular) structural aggregates at some depth between 25 cm and 100 cm from the surface. They are subdivided according to the moist colour of the upper 30 cm. Those with a chroma less than 1.5 are placed in the Pellic Vertisol (Vp) class and the rest are designated as Chromic Vertisols (Vc). Vertisols have a very limited distributiion in the Study Area and only a very small area of Chromic Vertisols was encountered.

The generalised relationships found are summarised in Table 3.3 and discussed more fully in subsequent sections.

TABLE 3.3 RELATIONSHIPS BETWEEN GEOMORPHOLOGY AND SOIL UNITS

Region	Geomorphic Unit	Soil Units
Hills	Hill Slope	Lithosol
	Piedmont Alluvial Fan	Luvisol; Cambisol; Vertisol
Plain	Lava flow	Lithosol
	Recent Alluvium	Fluvisol

(f) Soil Phases

A soil phase is a subdivision of a soil type or other unit of classification having characteristics that affect the use or management of the soil but which do not vary sufficiently to differentiate it as a separate type.

Soil phases are significant to the use and management of the land but are not diagnostic for the separation of soil units themselves (FAO, 1974).

Phases recognised on this study and used in the mapping legend includes:

Stony (-st) - the presence of gravel, stones or rock outcrop in the surface layer or at the surface makes the use of mechanised agricultural equipment impracticable. Hand tools can be used but the amount of usable land is very restricted.

Lithic (-l) - this denotes the presence of continuous coherent and hard rock within 50 cm of the surface. It is not used for Lithosols since, by definition, the presence of hard rock is already implied.

E (-e) - land which is dissected by gullies so that it is non arable but retains sufficient soil for the dominant soil units to be recognised.

(g) Miscellaneous Land Types

Miscellaneous land types are used in soil classification and mapping for areas of land that have little or no natural soil or where it is not feasible to classify the soil for other reasons.

Alluvial Land (A)

This unit consists of areas of unconsolidated alluvium, generally stratified and varying widely in texture, recently deposited by streams and subject to frequent change by stream overflow. The land has no agricultural value.

Gullied Land (G)

The land is intensely dissected by gullies so that it is non arable and the soil profiles have been largely destroyed.

3.4.3 Soil Mapping Units

The primary factors considered most relevant to proposed development include soil texture, soil depth and soil slope. Whilst other factors are often considered in soil classification, particularly in taxonomic systems, most of these other factors can be inferred or predicted from the primary factors.

(a) Soil Texture

Soil texture is probably the most important physical attribute of the soils since it determines the ease of cultivation, profile drainability, surface infiltration rate and water holding capacity.

Topsoil was used as one factor for the classification of soils into mapping units most suitable for planning purposes.

(b) Soil Depth

The depth of soil that will allow adequate root extension is an important factor to be considered when selecting land for irrigation. Adequate root development is essential for the plant to secure maximum benefit from a shallow profile since water availability may prove to be a problem particularly in the coarse textured soils.

(c) Slope Classes

The acceptable degree of slope depends upon various factors such as the intended method of irrigation, the rainfall intensity, risk of erosion and the planned cropping pattern.

Sprinkler irrigation may be practised on slopes up to 9° under arable crops whereas tree crops are commonly irrigated up to 20°. Allowance must be made for the erosive effect of intense rain storms. Land up to 8° slope could be utilised using normal soil conservation measures such as bunds and contour ridges. This slope also represents the approximate upper limit for mechanised cultivation.

By contrast gravity irrigation is restricted to much gentler slopes. Smooth slopes up to one degree (1°) are considered to be the most suitable.

The erosivity of the loamy soils of the piedmont alluvium is such that slopes in excess of two degrees (2°) should not be irrigated using surface systems.

The agriculturally most important soil criteria for reconnaissance studies are indicated on the soil map. Most of the criteria are also used to prepare the irrigable land suitability map and therefore boundaries between soil units correspond to boundaries between land class units.

3.5 MAPPING AND DISTRIBUTION OF SOILS

The mapping of soils always involves a degree of generalisation and the number of boundaries increases as the soil pattern becomes more complex.

At the present level of study it is inevitable that the actual soil distribution is somewhat more complex than shown by the map and such mapped units are not uniform. Topography of the weathered bedrock surface is very uneven in places which, whilst making little difference if the soils are deep, is a serious limiting factor on the shallower soils.

Position within the landscape is also important. The problem of distinguishing, and hence mapping, between orthic and chromic Luvisols has already been mentioned. The redder (2.5YR hue) soils appear to occupy positions where internal drainage is somewhat excessive. The areas of mapped soil units are shown in Table 3.4

(a) Fluvisols

These are the soils of the alluvial terraces and occur as small, discrete patches along all the principal rivers. Several small areas generally between one to two hectares have been mapped. The largest contiguous areas are found along the Kerio and Mon rivers. In total some 244 hectares, comprising 3.8 per cent of the total area, have been mapped. These soils, although in general mostly suitable for irrigation development, are not included in the areas selected for more detailed investigations because individual units are small, scattered and remote from the piped irrigation water supply.

(b) Lithosols

These soils are found on those parts of the escarpment walls and buttresses which intrude into the piedmont alluvial plain. The soils are shallow, stony and unsuited for irrigated cropping although some areas are used to grow shallow rooting crops utilising rainfall. The Lithosols cover 9 per cent of the Study Area.

(c) Cambisols

Cambisols have been recognised as the dominant soil unit on the piedmont alluvial plain. They are fairly young, weakly developed soils with a sandy loam to sandy clay loam texture. They are generally deep, unless eroded. Large boulders limit development in some areas, particularly on the higher parts of the pediment or alongside the larger drainage lines where torrent flow has deposited coarse detritus to form levees.

These soils constitute the stony Cambisol phase.

Elsewhere on the pediment the land is severely eroded and gullied. This comprises the eroded Cambisol phase.

Only the eutric Cambisols (758 ha) have any potential for irrigation development.

TABLE 3.4 EXTENT OF SOILS

Soil Unit FAO	Map Unit	Phase	Area (ha)	Proportion of Total Land (%)
Eutric Fluvisol	Je1	Kerio alluvium	98	1.5
	Je-2	Tributary alluvium	146	2.3
Eutric Lithosol	Ie	-	584	9.0
Eutric Cambisol	Be1	coarse	126	2.0
	Be1-e	coarse, eroded	149	2.3
	Be2	-	632	9.8
	Be2-st	stoney	40	0.6
	Be2-e	eroded	1910	29.6
Orthic Luvisol	Lo	-	686	10.6
	Lo-e	eroded	2042	31.6
Pellic Vertisol	Vp-e	eroded	not mapped	
Alluvium	A		47	0.7
			6460	**100.0**

(d) Luvisols

Some Luvisols have been mapped between piedmont alluvium fans where bedrock is close to the surface. the soils are somewhat redder than the Cambisols and show signs of clay eluviation. The soils are often stony, shallow and eroded. Only small patches of deeper soil occur and their distribution is erratic. About 686 hectares have been distinguished for further investigation. The shallow soils, where erosion is dominant, have been mapped as an eroded phase (Lo-e). Some eroded soils also occur in the lithic unit.

(f) Vertisols

Chromic Vertisols appear to be restricted to the toeslopes of the piedmont alluvium and have only a limited occurrence. None of the Vertisols are suitable for irrigation due to severe erosion. The area occupied by Vertisols is insignificant and they are not shown on the soil map.

(g) Miscellaneous Land Types

These include very variable alluvial land subject to frequent flooding or severely gullied land. They are not suitable for irrigation.

3.6 THE PIEDMONT ALLUVIUM

The soil distribution on the piedmont alluvial plain is complex and dark brown sandy loams, reddish brown sandy loams to sandy clay loams, boulder strewn loams, calcareous red clays, and brown cracking clays all occur, often in an apparently haphazard manner.

More detailed studies have shown that these soils are associated with different levels of the landscape, some of which are clearly erosion levels, formed by stripping of successive layers of alluvium.

The piedmont alluvium is often very deep, from 5 to 15 metres or more, it is stratified and ranges in texture from clay to boulder size fragments.

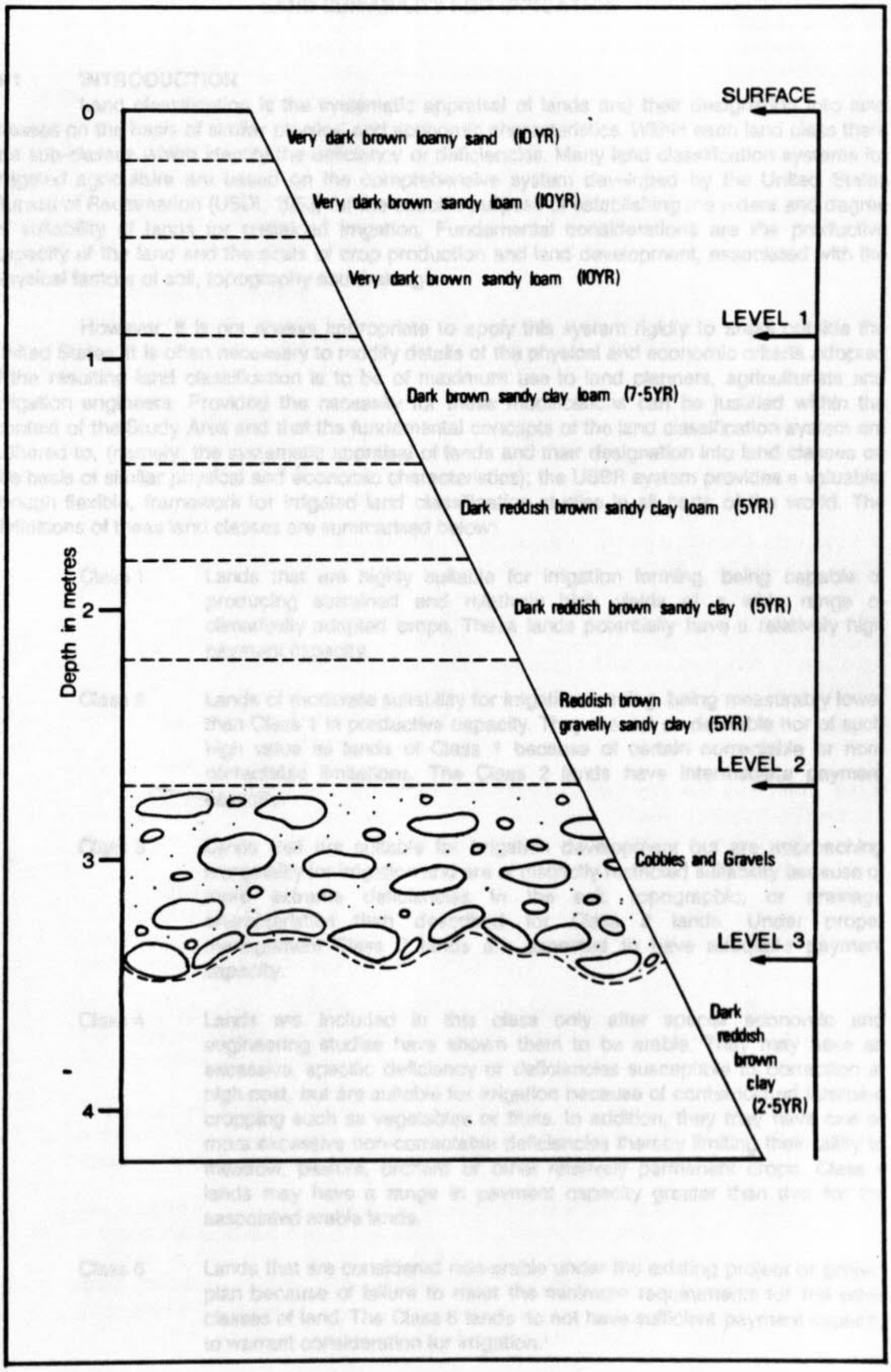
A deep section, to 5 metres, was described along the Machukwa river and the various strata identified are illustrated in Figure 3.2. This section revealed a sequence of dark brown loamy sands overlying redder sandy clay loams and calcareous layers, with interbedded layers of cobbles laid down under torrent flow conditions.

Sheet and gully erosion, operating on the piedmont alluvium, have stripped away overlying layers and various levels are exposed, particularly on the lower slopes of the fans. In such positions the calcareous red clays are exposed at the surface. In past times these clays have been cut into by the Kerio and its tributaries and bluffs between 5 to 10 metres high now stand above riverine alluvial terraces.

The red clays harden on exposure to the atmosphere to form a somewhat porous brown to reddish brown, angular structured material reminiscent of volcanic ash. This hardened layer produces a mesa like appearance to the toeslopes where it protects the land from further stripping. However due to its compact and structured character run off is channelled and gullies soon develop.

Only very detailed survey investigation could separate these various soil layers. In most cases the extent of any one soil is extremely limited. The land is severely eroded and has been mapped as an eroded phase of the dominant soil unit, principally Luvisols or Cambisols.

Figure 3.2 Section through Piedmont Alluvium



CHAPTER 4

LAND SUITABILITY FOR IRRIGATION

4.1 INTRODUCTION

Land classification is the systematic appraisal of lands and their designation into land classes on the basis of similar physical and economic characteristics. Within each land class there are sub-classes which identify the deficiency or deficiencies. Many land classification systems for irrigated agriculture are based on the comprehensive system developed by the United States Bureau of Reclamation (USDI, 1953) for the specific purpose of establishing the extent and degree of suitability of lands for sustained irrigation. Fundamental considerations are the productive capacity of the land and the costs of crop production and land development, associated with the physical factors of soil, topography and drainage.

However, it is not always appropriate to apply this system rigidly to areas outside the United States. It is often necessary to modify details of the physical and economic criteria adopted if the resulting land classification is to be of maximum use to land planners, agriculturists and irrigation engineers. Provided the necessity for these modifications can be justified within the context of the Study Area and that the fundamental concepts of the land classification system are adhered to, (namely: the systematic appraisal of lands and their designation into land classes on the basis of similar physical and economic characteristics); the USBR system provides a valuable, though flexible, framework for irrigated land classification studies in all parts of the world. The definitions of these land classes are summarised below:

Class 1 — Lands that are highly suitable for irrigation farming, being capable of producing sustained and relatively high yields of a wide range of climatically adapted crops. These lands potentially have a relatively high payment capacity.

Class 2 — Lands of moderate suitability for irrigation farming, being measurably lower than Class 1 in productive capacity. They are not so desirable nor of such high value as lands of Class 1 because of certain correctable or non-correctable limitations. The Class 2 lands have intermediate payment capacity.

Class 3 — Lands that are suitable for irrigation development but are approaching marginality for irrigation and are of distinctly restricted suitability because of more extreme deficiencies in the soil, topographic, or drainage characteristics than described for Class 2 lands. Under proper management Class 3 lands are expected to have adequate payment capacity.

Class 4 — Lands are included in this class only after special economic and engineering studies have shown them to be arable. They may have an excessive, specific deficiency or deficiencies susceptible to correction at high cost, but are suitable for irrigation because of contemplated intensive cropping such as vegetables or fruits. In addition, they may have one or more excessive non-correctable deficiencies thereby limiting their utility to meadow, pasture, orchard or other relatively permanent crops. Class 4 lands may have a range in payment capacity greater than that for the associated arable lands.

Class 6 — Lands that are considered non-arable under the existing project or project plan because of failure to meet the minimum requirements for the other classes of land. The Class 6 lands do not have sufficient payment capacity to warrant consideration for irrigation.

4.2 LAND CLASS CRITERIA

The framework of the Land Classification System is based on the system developed by the United States Bureau of Land Reclamation (1953), modified where necessary to accommodate local conditions. The general soil conditions specified by the USBR for profitable sustained irrigation are used to classify the lands in the Study Area. However, only those conditions that are considered particularly limiting in the area are isolated as primary criteria and given a coding in the sub-class legend. Soils, for example, must have an adequate supply of plant nutrients, and a favourable cation exchange capacity. The base status of the soil parent materials is adequate to maintain this nutrient supply in all the soils of the Study Area. Thus it is not considered necessary to isolate nutrient supply or inherent soil fertility as a limiting factor for irrigated agricultural development. Nevertheless it is likely that yields from all soils would be improved if dressings of nitrogen and phosphate were applied. The primary criteria used to differentiate land subclasses are shown in Table 4.1 and described below in detail.

4.2.1 Soil Physical Properties

After reviewing the physical characteristics of the soils and their immediate environment the following primary criteria for classification purposes were selected and given a letter or numerical subscript indicating the nature and degree of limitation.

Soil texture	s
Soil depth	d
Profile drainage	p

(a) Soil Texture (s)

Soil textures in the Study Area are extremely variable ranging from sand and gravel to clays. The soil texture influences the bulk density, pore space, permeability, profile drainage, structure, available moisture capacity and infiltration rate of a soil. Land is downgraded if the soil is excessively coarse or fine textured. Soils with coarse textures generally have low water holding capacities, rapid profile drainage and higher infiltration rates, features which reduce the irrigation efficiency. Fine textures tend to adversely affect aeration, profile drainage and permeability, although available moisture capacity is superior to those of coarse textured soils.

(b) Profile Drainage (p)

This factor comprises both the entry into and passage through the soil by water, and is related to soil texture, structure and clay mineralogy. Where extensive wet season flooding occurs or where high groundwater levels occur the land is downgraded.

(c) Soil Depth (d)

The depth of soil that will allow adequate root expansion is an important factor to be considered in selecting land for irrigation. Depth limitations are generally confined to piedmont soils in which depth to rock is important.

Gravelly soils, whilst not restricting root penetration, may prove unsuitable due to the high gravel content which reduces the soil volume i.e. the 'effective soil depth' is insufficient for plant growth.

Adequate rooting development is essential for the plant to secure maximum benefits from a shallow profile since water availability may prove to be a problem even on clay soils and require an increased frequency of irrigation.

A soil depth of 100 cm has been selected as the minimum for Class 1 production under average management and lesser depths have been assigned a lower rating due to a possible restriction on the range of suitable crops or lower repayment capacity. A desirable minimum depth of 50 cm has been adopted with an allowable shallower depth to 25 cm for Class 4 land.

TABLE 4.1 LAND CLASSIFICATION CRITERIA FOR IRRIGATION

Limitations	Limitation Symbol	Irrigation Method	LAND SUITABILITY CLASSES Class 1 Highly Suitable	Class 2 Moderately Suitable	Class 3 Marginally Suitable	Class 4 Special Use	Class 6 Not Suitable
Soil Factors Texture in upper 100 cm	s	O S	Sandy loam - friable clay loam	loamy sand - very permeable clay	loamy sand - permeable clay	loamy sand to permeable clay	land which fails to meet minimum requirements of other land classes.
Effective Depth (cm)	s	O S	> 100	> 75	> 50	> 25	< 25
Salinity 0-50cm	s	O S	0-1	1-2	2-4	2-4	> 4
Sodicity (S.A.R.)	s	O S	0-5	5-10	10-15	0-15	> 15
Cation exchange Capacity (0-50cm)	s	O S	> 15	> 10	> 5	> 5	< 5
pH (0-50 cm)	s	O S	6.0-8.4	4.5-8.5	4.0-8.5	4.0-9.0	< 4 > 9
Infiltration rate mm/hour	s	O S	> 10 7-25	>10 7-40	> 5 7-60	> 5 7-100	Not limiting (NL) > 100
Drainage Present profile drainage	d	O S	NL well to excessive	NL moderate	NL imperfect	NL well to imperfect	poor
Topography Slope degrees	t	O S	0-1 0-1	1-5 0-1	5-10 0-2	10-20 0-2	> 20 > 2
Erosion (run-off) hazard	t	O S	none	slight	moderate	moderate	severe
Flooding susceptibility	t	O S	none	none	occasional	occasional	frequent

Note: Irrigation method: 0 - Overhead; S - Surface

4.2.2 Soil Chemical Properties

The following criteria were selected as having the most importance for irrigation development:

- salinity
- alkali hazard
- pH
- cation exchange capacity
- percentage base saturation

(a) Salinity

The quantity, nature and distribution of soluble salts is perhaps one of the most important factors affecting irrigation development in a semi-arid area.

The analysis of soil samples has shown that natural salinity levels are low in the Study Area. Furthermore the quality of the irrigation water is good and provided sufficient water is applied to meet the leaching requirement, coupled with a well drained subsoil, then salinity buildup subsequent to irrigation should be negligible.

Class limits have been defined for each irrigable land suitability class although in practice salinity was not a critical factor in the separation of the land classes.

(b) Alkali Hazard

The alkali hazard in soils is expressed in terms of exchangeable sodium percentage (ESP) and is the percentage of the cation exchange capacity which is occupied by exchangeable sodium.

The principal effect of high ESP i.e. reduced permeability of soil is well known. Conventionally a soil is considered to have an alkali hazard when the ESP exceeds 15, although the threshold value of ESP for a decrease in permeability depends upon the type of clay mineral present.

Class limits for land classes 1, 2 and 3 were set at ESP values of 5, 10 and 15 respectively. In the final assessment all ESP values were found to be low and were not critical for the separation of land classes in the categories 1-3.

(c) pH

Soil pH measurements chiefly serve the purpose of indicating the level of soil acidity and hence predicting base saturation or the level of soil alkalinity and possibly indicating high soil ESP values. Such results need to be correlated with additional chemical data in order to establish suitable empirical relationships for diagnosis within a particular study area.

Two significant pH levels have been adopted: pH 4.5 and pH 8.5.
Below pH 4.5 aluminium often presents a problem. Above 8.5 exchangeable sodium is often significant.

(d) Cation Exchange Capacity (CEC)

CEC is a useful measure of the capacity of the soil to retain and supply plant nutrients, as well as indicating the nature of the clay minerals present.

CEC values in excess of 10 me/100 g soil over the top 25 cm of soil are necessary for sustained maximum agricultural production under irrigation whereas values less than 5 me/100 g soil are generally regarded as unsuitable for crop production.

(e) Base Saturation (BS)

Fertile, productive soils usually have an exchange capacity dominated by calcium and magnesium with lesser amounts of potassium and minor amounts of sodium. In very acid

soils a high proportion of the exchange sites are occupied by hydrogen or aluminium rather than nutrients and such soils are less productive. Differentiation according to base saturation has been made at 80 per cent, 60 per cent and 40 per cent to separate Land Classes 1, 2 and 3 and 20 per cent to distinguish between Land Class 4 and 6.

4.2.3 Site Characteristics

(a) Rocks and Stones

Rock outcrops are difficult and expensive to remove. Such land often has bedrock at or close to the surface which, within the Study Area, has been excluded from development due to shallow soil depth or steep, uneven topography.

Stones or cobbles may have to be removed from the plough layer, particularly if farming operations are mechanised. Little loss of production due to stones results in the case of orchard crops. Nevertheless removal costs must be taken into account when land classes are assigned. Such costs are reflected in the quantity of stones which have to be removed and volumes in excess of 150 m^3 per hectare are considered uneconomic to clear and such land has been excluded from development.

4.2.4 Topography

(a) Macrorelief

Land units most suited to irrigation are confined to areas of piedmont alluvium and recent alluvium.

The piedmont alluvial fan is moderately to gently sloping, with long linear slopes having an inclination between one and three degrees.

Most slopes above one degree show signs of erosion with sheet and rill erosion common. More severe gully erosion is frequent and such areas, which may have small patches of soil otherwise suitable for irrigation have been excluded due to the engineering costs which would be involved for water supply.

Land on the escarpment and its outliers, and on the small colluvial fans at the junction of the escarpment and the piedmont alluvium, is steeply sloping and generally unsuitable for any form or irrigation.

Macrorelief is such that surface irrigation is only suitable to part of the Study Area, whereas a much larger area could be accommodated if both surface and overhead systems are considered.

(b) Topography (t)

This factor refers to the slope at the investigation site. The quantitative slope classes used in Table 4.1 have been devised mainly on considerations of soil conservation methods required to maintain slope equilibrium under cultivation. The upper limit of cultivation has been set at 20°. Such steep slopes are not found in the Study Area except as very isolated occurrences on the hillslopes of the escarpment or in severely gullied land.

(c) Flood Hazard (f)

The flood hazard is most common on alluvial floodplains. No attempt has been made to quantify the degree of flooding except by frequency of occurrence. Flooding due to overflow of rivers is of restricted importance in the Study Area and is mainly due to flash floods from small torrents which originate on the escarpment.

Runoff from adjacent hillsides is commonly a problem on the land which lies at the base of the piedmont alluvial fan. Soil, stones and plant debris are moved by extensive sheet wash processes and deposited onto cultivated land. Such land is less suitable for

development since additional measures are required to prevent flooding.

(d) Erosion Hazard

The soils of the area are generally structurally fairly unstable and erosion rills and gullies were observed on many of the piedmont alluvial soils especially on the steeper slopes. Certainly slopes above 2° are prone to erosion under cultivation by rainfall and should not be developed to surface irrigation methods.

4.3 ALLOCATION OF LAND SUITABILITY CLASSES

Land suitability classes, based on the criteria discussed in Section 4.2 have been assigned to each of the soil mapping units.

Land suitability subclasses have been used and divisions are distinguished by the nature of the limitations and identified by the lower case letters s, t and d. These denote respectively soil, topography and drainage limitations. The limitations are used singly or in combination below Class 1, the basic subclasses being s, t, d, st, sd, td, and std.

This report defines the areas of arable land considered suitable for irrigation by either surface or overhead methods. The actual amount of this land deemed to be irrigable will be decided by the irrigation engineer.

4.4 MANAGEMENT PRACTICES

The Study Area soils and topography are varied and to achieve maximum areal development, both surface and overhead irrigation systems should be considered.

4.4.1 Overhead Systems

The efficiency of overhead irrigation compared to surface methods is highly dependent upon surface infiltration rates (related to soil texture) and the nature of the irrigation method used. Sprinkler irrigation tends to be much more efficient than surface methods and drip irrigation is even better.

Land constraints for sprinkler methods are rarely limiting in the Study Area, other than where soils are shallow or excessively stony or steeply sloping.

Small, frequent irrigation applications by sprinkler, coupled with small, frequent fertiliser applications would avoid undue fertiliser wastage due to leaching below the crop root zone and enable the shallower soils to be more effectively utilised.

Nitrogen and phosphorus are both limiting factors for development. Potassium may or may not be limiting; certainly, soils derived from alluvium are often well supplied with potassium. However, to achieve the higher yields required to justify the additional costs of irrigation, more intensive fertiliser inputs will be required. Higher inputs of nitrogen and phosphorus may result in a demand for supplementary potassium fertilisers.

These aspects should be considered and tested in the field during the pilot development phase.

Salinity is not a problem in the soils selected for development. Leaching requirements to ensure the removal of salts added in the irrigation water are low, due to the excellent quality of the water; normal deep percolation losses should be sufficient to maintain the desired salt balance. Subsoil salt, below normal rooting depth of 50 cm, will be gradually reduced by percolation of irrigation water through the subsoil.

4.4.2 Surface Methods

Both soil characteristics and topography limit the land suitable for surface irrigation methods. Most topsoils are either loamy sand or sandy loam texture and are very prone to erosion, thus slopes above one degree have been excluded from development. Attempts have been made

Figure 4.1 Areas with potential for irrigation

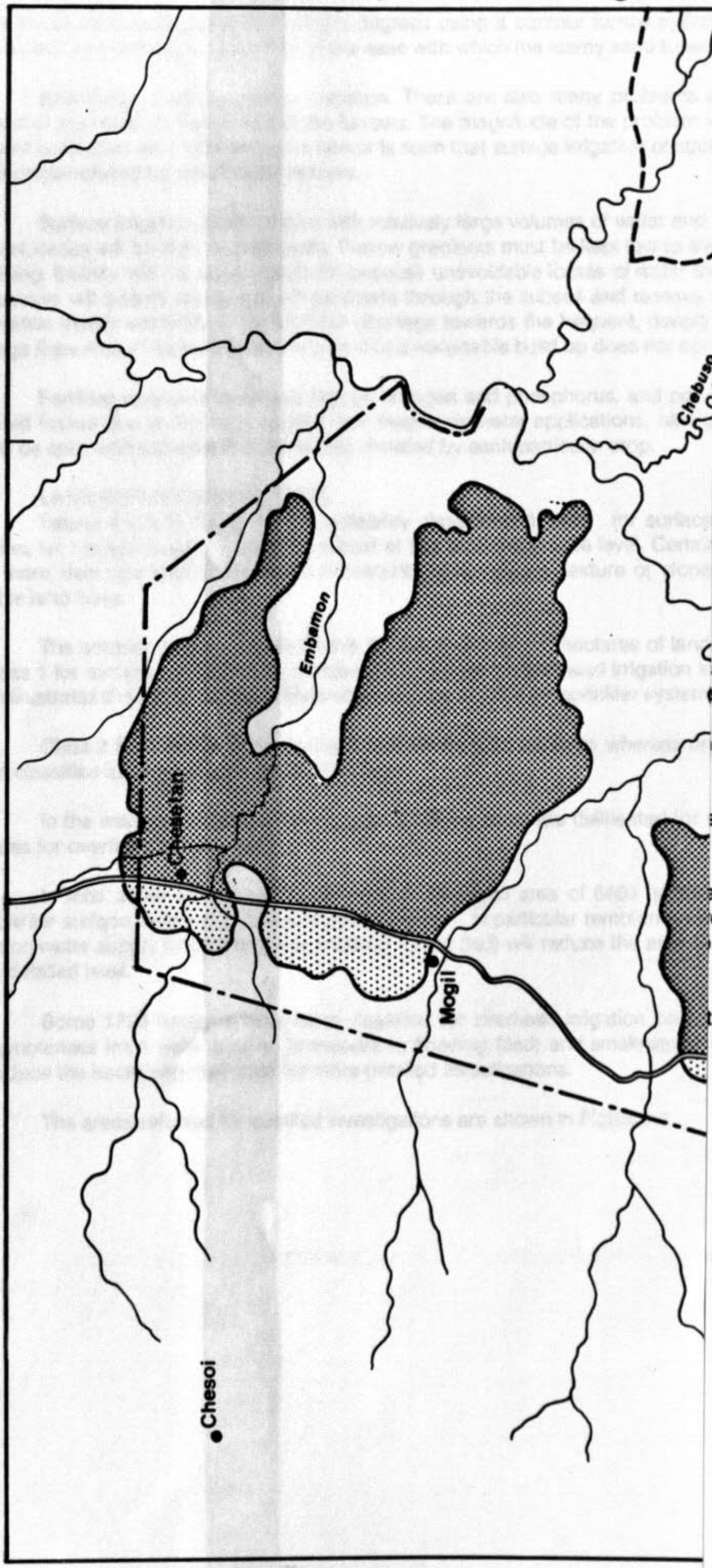


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TABLE 4.2 EXTENT OF LAND CLASS UNITS FOR SURFACE IRRIGATION

Soil Map Unit	Map Unit	Area (ha)	Proportion of Total Land (%)
Lo	1	100	1.5
Bel	2s	100	1.5
Lo; Be2; Jel	2t	924	14.3
Je2	3sd	70	1.1
Bel; Je2	3st	102	1.6
Be2-st	6s	40	0.6
Lo-e; Bel-e; Be2-e; Ie; A	6st	4719	73.2
A	6sd	15	0.2
		6460	**100.0**

TABLE 4.3 EXTENT OF LAND CLASS UNITS FOR OVERHEAD IRRIGATION

Soil Map Unit	Map Unit	Area (ha)	Proportion of Total Land (%)
Lo; Bel; Be2; Jel	1	1124	17.4
Be2	2s	392	6.1
Bel; Je2	2t	102	1.6
Be2-st	3s	40	0.6
Je2	3sd	70	1.1
A	6sd	15	0.2
Lo; Bel-e; Be2-e;	6st	4717	73.0
		6460	**100.0**

The Reconnaissance Soil Survey Map, the Irrigable Land Suitability Map and the Land Use Map are attached.

CHAPTER 5

PRESENT LAND USE

5.1 INTRODUCTION

Most cropping is based on rainfed cultivation which is rotational with land under crop on a one year in seven basis.

Many factors appear to limit cultivation. These include shallow stony soils with poor water holding capacities, lack of population due to the high incidence of malaria and difficulties encountered in the protection of crops from both domestic animals and wildlife.

Crops grown include maize, sorghum, millets, groundnuts, beans, cassava, cotton and oilseeds.

Irrigation is practised in various parts of the Study Area, principally in the vicinity of Arror and Mon rivers. An intricate network of small irrigation furrows has been constructed to convey water to small plots of land, often at a considerable distance from the river.

The majority of the water is used to irrigate tree crops of which banana, papaya and citrus are the most important.

Vegetables are also grown under irrigation and, if water is available, grain crops, cassava and cotton are given one or possibly two irrigations. Flood irrigation is traditional.

5.2 PRESENT LAND USE

The land use units were defined following field visits to the Study Area by the soil scientist and the agronomist during May and June 1987. Ten classes of land utilisation were established and they are described in more detail in Section 5.3.

Photo-interpretation of the March 1987 1:10,000 scale air photography was carried out using a stereoscope and the land unit boundaries were traced onto plastic foil overlays to the prints. The details were then transferred onto the 1:5,000 scale topographic base maps using a Plan Variograph and the individual areas measured using a planimeter.

5.3 LAND USE MAPPING UNITS

The ten units were designated by a series of letters ranging from A to J and an abbreviated form appears as the legend to the Land Use map series.

The individual units distinguished are:

A **Irrigated Farms**: Small plots of land under perennial tree crops principally bananas with some papaya and citrus. Such land is of restricted occurrence and generally occurs along or near the Arror and Mon rivers.

B **Fallow land**: This forms part of the shifting cultivation cycle and includes the more common *Acacia tortilis* savannah woodland and land clear of trees with scattered regenerating shrubs.

C **Cultivated Land**: Areas cultivated in the 1986 season. Distinguished by the signs of cultivation and the presence of the characteristic thorn fence built to keep out animals.

D1 **Regenerated Bushland**: Land which has been cleared of trees for either cultivation or fuelwood, now revegetated with a dense bush cover.

D2 **Forest**: Dense woodland, with a complete canopy cover obscuring the ground.

E **Laggam**: Scattered huts, small cultivated patches of land with associated scrub on very steep slopes of the escarpment.

F **Experimental Farm Areas**: The KVDA agricultural research farms and plant nurseries.

G **Settlement Sites**: Houses, schools etc including recreational areas.

H **Non-cultivated Scrub Land**: Steep slopes of the escarpment and badlands (severely gullied land) along streams dissecting the piedmont alluvial fan.

J **River Channel Floors**: Bare stony channel courses, subject to frequent flooding. Not cultivated.

The areas of each unit are given in Table 5.1.

TABLE 5.1 LAND USE AREAS

Unit	Ha	%
A	38	0.5
B	3664	56.7
C	643	9.9
D1	808	12.5
D2	724	11.2
E	271	4.2
F	16	0.3
G	44	0.7
H	249	3.9
J	3	0.1
Total	6460	100

CHAPTER 6

6.1. Introduction

According to the Terms of Reference the soil scientist 'should make recommendations on the most suitable site for the proposed 40 hectare irrigated agricultural pilot project'. In fact, on arrival in Kenya, it transpired that the KVDA had already selected the site based on land availability and not necessarily on soil suitability.

Clearing some 10 hectares was already well advanced in May 1987 and initial crop plantings, utilising rainfall, already in hand.

6.2. Additional Work

Following discussion with the Project Manager the Soil Scientist agreed to make sufficient observations in the proposed pilot area farm to confirm the area of land available, its general characteristics and the relevance of the soils to the soils in the larger study area.

10 auger bores (2 to 11 inclusive) and one pit (Pit 3) were made in a general area of some 40 hectares and some 14 samples were collected from depths of 0-25cm and 25-50cm for determination of soil fertility.

The approximate location of the new KVDA pilot farm is shown in Figure 6.1., along with the position of the sampling sites.

The results of the chemical analyses of all the samples are given in Appendix A.1, Profile Pit 3 and in Appendix A.2. soil fertility test results for samples P009 and P010 and in Appendix B fertility analyses of samples for C03-C016.

These results are reproduced in part in Table 6.1.

6.3. Soil Characteristics

The soils on the proposed farm site are fairly homogeneous and belong to the Orthic Luvisol mapping unit. Profile description P3 is fairly representative of the soils.

Typically the soil consists of a friable dark reddish brown sandy loam grading at 20cm to a dark reddish brown sandy clay loam, friable when moist but hard when dry. At a depth of 50-70 cm there is a gradual change to a dark reddish brown sandy clay, hard when dry.

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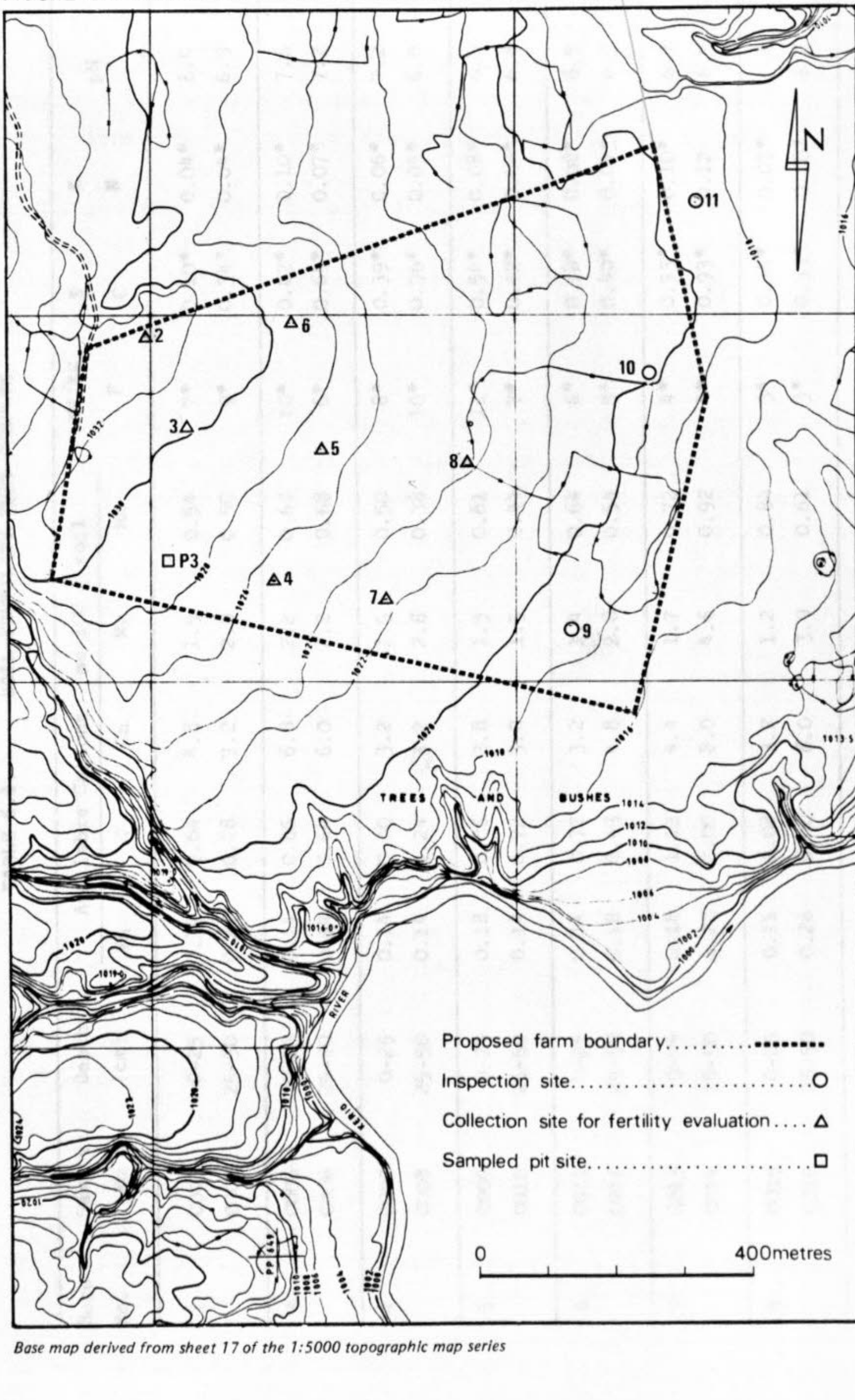
FIGURE 6·1 PROPOSED LOCATION OF KVDA PILOT FARM



Base map derived from sheet 17 of the 1:5000 topographic map series

TABLE 6.1. SOIL FERTILITY TEST RESULTS

Bore No.	Sample No	Depth (cm)	Available Cations me/100 g soil					mg/kg	%	%	pH
			Na	K	Ca	Mg	Mn	P	C	N	
2	C003	0-25	0.14	0.64	4.8	1.5	0.54	7*	0.10*	0.04*	6.9
	C004	25-50	0.22	0.28	7.2	2.8	0.50	9*	0.34*	0.04*	6.9
3	C005	0-25	0.14	0.86	6.8	2.2	0.68	10*	0.82*	0.10*	7.6
	C006	25-50	0.14	0.64	6.0	2.2	0.68	6*	0.64*	0.07*	7.2
4	C007	0-25	0.14	0.40	3.2	1.5	0.50	8*	0.39*	0.06*	7.2
	C008	25-50	0.14	1.24	3.2	2.8	0.38	10*	0.36*	0.05*	6.9
5	C009	0-25	0.18	0.86	2.8	1.5	0.61	12*	0.54*	0.08*	6.0
	C010	25-50	0.14	0.72	3.2	1.5	0.44	7*	0.42*	0.04*	6.6
6	C011	0-25	0.14	0.72	3.2	1.4	0.64	6*	0.78*	0.08*	6.5
	C012	25-50	0.18	0.43	4.8	2.8	0.54	5*	0.40*	0.04*	6.3
7	C013	0-25	0.18	1.12	4.4	1.7	0.72	4*	0.53*	0.10*	6.7
	C014	25-50	0.22	2.00	8.0	4.6	0.92	4*	0.93*	0.12	6.9
8	C015	0-25	0.11	1.08	3.2	1.2	0.84	3*	0.34*	0.07*	6.9
	C016	25-50	0.26	0.40	8.0	3.9	0.61	3*	0.53*	0.08*	6.2

* Deficiency levels

Under natural conditions the surface has a thin, moderately strong surface crust some 2 to 3 mm in thickness. This crust is derived from the dispersive impact of raindrops and is a contributory factor to surface run-off.

Rainfall therefore tends to move across the soil surface rather than to infiltrate and the depth of penetration of rainfall in the natural state is low. During field inspections, despite considerable rainfall, the soils were typically dry below depths of 20 to 30 cm. Subsoils were hard, dry and compacted.

The main variation within the farm is the texture of the upper soil layer which varies from a sandy loam to a sandy clay loam. Most of this variation is due to removal of the easily eroded sandy loam topsoil by sheet wash. Other factors do have an effect such as termite mounds, digging to remove tree stumps and of course movement of topsoil to form irrigation ditches and field bunds.

Land clearance, stumping and burning of trees, levelling of termitaria will also result in considerable variation of soil fertility.

Soil material derived from termitaria is often more fertile than surrounding soil, due to incorporation of organic material into the mound by the termites. Phosphorus levels are often enhanced.

Burning of trees results in high potash levels. Removal of topsoil results in a reduction in both the organic carbon and organic sulphur levels.

At this stage of development with considerable land clearance still to be accomplished and substantial land smoothing to be performed, only general guidance can be given on the overall fertility of the proposed KVDA farm.

6.4. Soil Fertility

The soils are well drained and have a reasonable capacity to hold soil moisture between successive irrigations. Subsoiling, as mentioned in section 6.5, will improve penetration of both water and plant roots.

Soil pH is in the slightly acid to neutral range and provides an ideal environment for most crops. Fixation of applied nutrients is also minimal in this pH range.

The macronutrient levels for calcium, magnesium, potassium and manganese are good and fertiliser applications of these nutrients are not needed.

Total nitrogen levels are poor and nitrogenous fertilisers will be required for all crops.

Total organic carbon, and hence organic matter contents, are low. Whilst the principal role of organic matter is in the maintenance of soil structural stability it is, of course, also the main supplier of sulphur to plants. The low levels of organic carbon will result in low levels of sulphur supply and sulphate containing fertilisers will be required.

Available phosphorus levels are almost universally low and phosphatic fertilisers will be required for all crops.

6.5. Management

Water penetration into the subsoil is low under present natural conditions. Consequently subsoils are hard and compacted. It is recommended that two passes are made, at right angles, using a subsoiler set to rip to a depth of 50cm to aid water penetration.

Sandy loam topsoil should be conserved wherever possible. It should not be used to construct irrigation channels because it is easily eroded and has a high infiltration rate which will result in substantial channel water losses. The reddish brown sandy clay loam subsoils are the ones which should be used for channel construction.

Existing cultivated fields are insufficiently levelled to contemplate irrigation and further land smoothing will be necessary.

Nitrogeneous and phosphatic fertilisers will be required. Since organic matter contents are low sulphur deficiencies are also expected and the fertiliser inputs should include the use of ammonium sulphate.

6.6. Applicability of Results to the Study Area

The KVDA farm is situated on orthic Luvisols (Lo) and is thus representative of about 686 hectares of potentially irrigable land.

Land has been classified according to its suitability for both surface and overhead irrigation systems.

Only 100 hectares of orthic Luvisols (Lo) have been classified as Land Class 1 for surface irrigation and the rest (586 hectares) has been downgraded to Land Class 2 due to erosion hazard resulting from slopes with gradients higher than one degree.

Should overhead irrigation methods be contemplated then all 686 hectares would fall into Class 1 land.

To put these figures into context it has been recommended that only Class 1 and Class 2 land should be irrigated by surface methods. This amounts in total to about 1124 hectares therefore the KVDA farm results are directly applicable to 686 hectares or about 60 percent of the total area selected as suitable for surface irrigation.

ACKNOWLEDGEMENTS

A study of this magnitude clearly requires the cooperation, advice and support of many individuals. It is a pleasure to record the cooperation received from the following:

Mr Tubei, Managing Director; Mr J.K. Kwambai, Deputy Managing Director; Mr Z. Kute, Irrigation Engineer and Mr F. Were, Development Planner and other members of staff of the Kerio Valley Development Authority in Eldoret.

Mr J. Cheruwon, Chief Arror Location and Mr P.C. Cheserek, Chief Mon Location.

Mr Rono, Farm Manager of the K.V.D.A. Arror demonstration farm.

Mr J.N. Qureshi, Senior Soil Chemist of the National Agricultural Laboratories, Nairobi.

* * * *

This contract has been performed with the financial assistance of the Department for Development Cooperation, Ministry of Foreign Affairs, Republic of Italy.

SUMMARY

A reconnaissance soil survey was carried out between the Machukwa and Mon rivers which are situated in the Kerio Valley in northern Kenya.

A total of some 6460 ha were surveyed at an overall density of the potentially irrigable land approximating to one site for every 50 ha. Routine inspections were made by augering and excavation of pits to a depth of two metres wherever possible. Inspection depth was often limited by rock or boulder layers deposited by torrent wash. Two samples from depths of 0-25 cm and 25-50 cm were collected from selected inspection sites and analysed for electrical conductivity, exchangeable sodium percentage and fertility. In addition a series of soil pits were excavated in representative soil types and ten of these were sampled for detailed chemical analyses. A series of infiltration tests were carried out at selected sites.

The chemical analyses showed a wide range in soil acidity, base saturation and fertility. Soils were generally deficient in nitrogen, variable in available phosphorus content but adequately supplied with potassium.

Soil boundaries were delineated onto 1:10,000 scale air photographs and the information transferred to 1:5,000 scale topographic maps.

The soils were classified according to the FAO/UNESCO system and included: Cambisols, Fluvisols, Lithosols, Luvisols and Vertisols.

An irrigable land suitability classification, based upon the concepts and principles of the United States Bureau of Reclamation, was devised and based upon easily observable physical characteristics of soil and landscape and those chemical characteristics deemed to be of practical importance to sustained agricultural production. A dual land classification, showing suitability to both surface and sprinkler methods, was presented since in many instances soil slope and textures are such that topsoil erosion is a hazard and infiltration rates are sufficiently high to render surface irrigation inefficient.

It was found that only some 1296 hectares of land were suitable for surface irrigation development, whereas if overhead irrigation is adopted the area of suitable land increases to 1728 hectares.

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APPENDIX A

SOIL PROFILE DESCRIPTIONS
AND
LABORATORY DATA

APPENDIX A.1.

SURVEY ANALYTICAL DATA

Profile Description No. P.1

Mapping Unit:	Vc-e
Soil Classification:	Chromic Vertisol
Irrigable Land Classification	6t/6t
Ecological Zone:	V
Parent Material:	Basalt
Physiography:	Lava flow
Relief - macro:	Smooth
Relief - micro:	Dissected, gullies to 2m deep
Slope Gradient:	2°
Vegetation/Land Use:	*Acacia tortilis; Boscia* spp; rough grazing
Erosion:	Severe deep gullies 2-3 m deep
Surface stoniness/rockiness:	Calcium carbonate concretions, rotting basaltic gravels
Flooding:	Nil
Surface sealing:	Nil
Salinity/alkalinity:	Slight salinity; moderately alkali
Drainage Class:	Moderately to imperfectly drained
Moisture status:	Moist to 30 cm

Sample No.	Depth (cm)	Description
P.001	0-30	Dark reddish brown moist (5 YR 3/3) clay; strong fine subangular blocky; hard dry, firm. moist, very sticky and very plastic wet; common medium pores; few coarse roots; clear smooth boundary.
P.002	30-70	Dark reddish brown moist (5 YR 3/4) clay; strong coarse prismatic breaking to strong medium angular blocky; very hard dry, firm moist, very sticky and very plastic wet; few fine pores; very few roots; abrupt smooth boundary.
P.003	70-100	Dark reddish brown moist (5 YR 4/3) clay; strong medium lenticular structure, slickensides; very hard dry, firm moist, very sticky and very plastic wet; very few pores; few small calcium carbonate concretions; gradual smooth boundary.
P.004	100-150	Dark reddish brown moist (5 YR 4/3) clay; strong coarse lenticular structure, slickensides;. very hard dry, firm moist, very sticky and very plastic wet; no pores; abundant small and medium calcium carbonate concretions.
	150-200	As above horizon with both abundance and size of calcium carbonate concretions increasing with depth.

SOIL TEST REPORT (SURVEY)

From: Eldoret
Rift Valley Province

Our ref: SOIL/2/4/XVI/119
Date Sample Received: 19th June 1987
Date Sample Reported: 27th July 1987
Sample sent by: Mr F.W. Collier, B&B, via Amedei 15, 20123 Milan, Italy.

Profile Pit No. 1

Field Ref:	P.001	P.002	P.003	P.004
Depth in cm	0-30	30-70	70-100	100-150
Lab. No./87	7017	7018	7019	7020
Gravel %	-	-	-	-
Sand %	15	15	15	15
Silt %	18	18	24	20
Clay %	67	67	61	65
Texture Class	C	C	C	C
pH-H_2O 1:2½ Suspension	7.7	7.5	7.5	7.6
PH-KC1 1:2	6.6	6.7	6.8	6.8
EC(mmhos/cm) 1:2½	0.24	1.50	1.90	2.10
C%	0.34	0.23	0.11	0.15
N%	0.04	0.02	-	-
Cat. Exch. Cap. (me/100g)	62	62	58	63
Exchangeable Cations				
Ca(me/100g)	29.4	24.8	20.2	23.9
Mg(me/100g)	9.6	8.8	7.6	9.4
K(me/100g)	0.84	0.76	0.61	0.76
Na(me/100g)	0.6	5.4	3.7	5.4
Sum Cations	40.4	39.8	32.1	39.4
Base Saturation % (BS)	65	64	55	63
ESP	1	9	6	9
Qualitative $CaCO_3$	+	++	+	++

Profile Description No. P.2

Mapping Unit:	Lo-e
Soil Classification:	Orthic Luvisol
Irrigable Land Classification	6st/6st
Ecological Zone:	V
Parent Material:	Hornblende gneiss
Physiography:	Piedmont alluvium
Relief - macro:	Undulating
Relief - micro:	Rill and gully erosion
Slope Gradient:	5°
Vegetation/Land Use:	*Acacia tortilis, Boscia;* rough grazing
Erosion:	Severe, gullies 2-3 metres deep
Surface stoniness/rockiness:	Gravel, rock outcrop
Flooding:	Nil
Surface sealing:	2-3 mm, weak
Salinity/alkalinity:	Nil
Drainage Class:	Well drained
Moisture status:	Moist to 20 cm

Sample No.	Depth (cm)	Description
P.005	0-30	Brown moist (7.5 YR 4/4) sandy loam; moderate fine subangular blocky; slightly hard dry, friable moist, non sticky and non plastic wet; many medium pores; few coarse and fine roots; gradual smooth boundary.
P.006	30-80	Reddish brown moist (5 YR 4/3) sandy clay loam; moderate medium and fine subangular blocky; hard dry, friable moist, slightly sticky and plastic wet; many fine pores; few coarse roots; few quartz gravels; occasional calcium carbonate concretions; clear smooth boundary.
P.007	80-150	Reddish brown moist (5 YR 4/3) coarse sandy clay; moderate medium subangular blocky; hard dry, friable moist, sticky and plastic wet; few fine pores; no roots; few quartz fragments; many calcium carbonate concretions; few manganese dioxide cutans; clay cutans; clear smooth boundary.
P.008	150-200	Dark reddish brown moist (5 YR 3/3) sandy clay; moderate coarse and medium subangular blocky; hard dry, firm moist, sticky and very plastic wet; few fine pores; many quartz fragments; abundant calcium carbonate concretions; few manganese dioxide cutans; well developed clay cutans; clear wavy boundary.
	200+	Rotting gneiss.

SOIL TEST REPORT (SURVEY)

From: Eldoret
Rift Valley Province

Our ref: SOIL/2/4/XVI/119
Date Sample Received: 19th June 1987
Date Sample Reported: 27th July 1987
Sample sent by: Mr F.W. Collier, B&B, via Amedei 15, 20123 Milan, Italy.

Profile Pit No. 2

Field Ref:	P.005	P.006	P.007	P.008
Depth in cm	0-30	30-80	80-150	150-200
Lab. No./87	7021	7022	7023	7024
Gravel %	-	-	-	-
Sand %	69	67	61	53
Silt %	18	8	14	18
Clay %	17	25	25	29
Texture Class	SL	SCL	SCL	SCL
pH-H_2O 1:2½ Suspension	8.4	8.6	9.1	9.4
PH-KC1 1:2	7.0	7.1	7.4	7.3
EC(mmhos/cm) 1:2½	0.15	0.14	0.22	0.26
C%	0.14	0.05	0.10	0.12
N%	0.03	0.00	-	-
Cat. Exch. Cap. (me/100g)	12	20	20	25
Exchangeable Cations				
Ca(me/100g)	22.0	12.1	15.6	12.1
Mg(me/100g)	5.1	3.2	4.4	4.0
K(me/100g)	0.28	0.22	0.24	0.28
Na(me/100g)	0.4	0.6	3.0	4.0
Sum Cations	27.8	16.1	23.2	20.4
Base Saturation % (BS)	100	80	100	82
ESP	3	3	15	16
Qualitative $CaCO_3$	+++	+++	+++	++

Profile Description No. P.3

Mapping Unit:	Lo
Soil Classification:	Orthic Luvisol
Irrigable Land Classification	1/1
Ecological Zone:	V
Parent Material:	Gneiss and/or schist
Physiography:	Piedmont alluvium
Relief - macro:	Smooth
Relief - micro:	Smooth
Slope Gradient:	1°
Vegetation/Land Use:	*Acacia tortilis, Chloris* spp; rough grazing
Erosion:	Sheet wash
Surface stoniness/rockiness:	Nil
Flooding:	Nil
Surface sealing:	2-3 mm; moderately strong
Salinity/alkalinity:	Nil
Drainage Class:	Well drained
Moisture status:	Moist to 30 cm

Sample No.	Depth (cm)	Description
P.009	0-30	Dark reddish brown moist (5 YR 3/2) sandy clay loam; moderate medium subangular blocky; hard dry, friable moist, slightly sticky and plastic wet; many fine and medium pores; abundant fine roots; clear smooth boundary.
P.010	30-70	Dark red moist (2.5 YR 3/2) sandy clay loam; moderate medium subangular blocky; hard dry, friable moist; slightly sticky and plastic wet; many fine pores; few fine roots; moderate clay cutans; gradual smooth boundary.
P.011	70-120	Dark reddish brown moist (2.5 YR 3/4) sandy clay; strong medium subangular blocky; hard dry friable moist, sticky and plastic wet; few fine pores; very few fine roots; strong clay cutans; clear smooth boundary.
P.012	120-180	Dark reddish brown moist (2.5 YR 3/4) sandy clay; strong medium and fine subangular blocky; hard dry, friable moist, sticky and plastic wet; few fine pores; no roots; strong clay cutans.

SOIL TEST REPORT (SURVEY)

From: Eldoret
Rift Valley Province

Our ref: SOIL/2/4/XVI/119
Date Sample Received: 19th June 1987
Date Sample Reported: 27th July 1987
Sample sent by: Mr F.W. Collier, B&B, via Amedei 15, 20123 Milan, Italy.

Profile Pit No. 3

Field Ref:	P.009	P.010	P.011	P.012
Depth in cm	0.30	30-70	70-120	120-180
Lab. No./87	7025	7026	7027	7028
Gravel %	-	-	-	-
Sand %	49	45	45	43
Silt %	12	14	12	12
Clay %	39	41	43	45
Texture Class	SC	SC	SC	C
pH-$H_2$0 1:2½ Suspension	8.0	7.8	7.9	8.3
PH-KC1 1:2	6.6	7.8	6.7	7.0
EC (mmhos/cm) 1:2½	0.22	0.14	0.19	0.23
C%	0.78	0.34	0.22	0.21
N%	0.07	0.02	-	-
Cat. Exch. Cap. (me/100g)	24	22	21	24
Exchangeable Cations				
Ca(me/100g)	11.4	11.6	11.7	14.7
Mg(me/100g)	1.2	0.8	0.8	2.0
K(me/100g)	0.88	1.64	2.53	2.68
Na(me/100g)	0.0	0.3	0.2	0.2
Sum Cations	13.3	14.3	15.2	19.6
Base Saturation % (BS)	55	65	72	82
ESP	0	1	1	1
Qualitative $CaCO_3$	+	+	++	+++

Profile Description Pit 4

Mapping Unit:	Be1
Soil Classification:	Eutric Cambisol
Irrigable Land Classification	3st/2t
Ecological Zone:	V
Parent Material:	Piedmont alluvium, mixed acidic rocks.
Physiography:	Piedmont fan.
Relief - macro:	Smooth
Relief - micro:	Dissected, some rills to 20 cm.
Slope gradient:	2°
Vegetation/Land Use:	*Acacia tortilis*, grazing
Erosion:	Sheet, some rill erosion
Surface stoniness/rockiness:	Occasional gravels.
Flooding:	Nil
Surface sealing:	3 mm; weak.
Salinity/alkalinity:	Nil
Drainage Class:	Well to excessively drained.
Moisture status:	Moist to 30 cm.

Sample No.	Depth (cm)	Description
P.013	0-20	Dark brown moist (7.5 YR 3/2) loamy sand; weak fine subangular blocky; slightly hard dry, friable moist, non sticky and non plastic wet; common medium pores; few roots; clear smooth boundary.
P.014	20-50	Dark brown moist (7.5 YR 3/3) loamy sand; weak fine subangular blocky; slightly hard dry, friable moist; non sticky and non plastic wet; common fine pores; few roots; abrupt smooth boundary.
P.015	50-80	Dark brown moist (7.5 YR 3/4) coarse and medium loamy sand; structureless loose; no pores; few gravels; very few roots; abrupt smooth boundary.
P.016	80-120	Dark reddish brown moist (5 YR 3/4) silt loam; moderate medium subangular blocky; hard dry, friable moist, slightly sticky and slightly plastic wet; common fine pores; no roots; clear smooth boundary.
	120-160	Dark reddish brown moist (5 YR 3/4) sandy clay loam; moderate medium subangular blocky; hard dry, firm moist, slightly sticky and slightly plastic wet; common fine pores; no roots.

SOIL TEST REPORT (SURVEY)

From: Eldoret
Rift Valley Province

Our ref: SOIL/2/4/XVI/119
Date Sample Received: 19th June 1987
Date Sample Reported: 27th July 1987
Sample sent by: Mr F.W. Collier, B&B, via Amedei 15, 20123 Milan, Italy.

Profile Pit No. 4

Field Ref:	P.013	P.014	P.015	P.016
Depth in cm	0-20	20-50	50-80	80-120
Lab. No./87	7029	7030	7031	7032
Gravel %	-	-	-	-
Sand %	65	75	31	95
Silt %	14	12	44	2
Clay %	21	13	25	3
Texture Class	SCL	SL	L	S
pH-H_2O 1:2½ Suspension	7.2	7.2	7.4	7.8
PH-KC1 1:2	5.8	6.3	6.4	6.4
EC(mmhos/cm) 1:2½	0.09	0.11	0.50	0.03
C%	0.54	0.33	0.01	0.01
N%	0.04	0.02	-	-
Cat. Exch. Cap. (me/100g)	15	9	24	1
Exchangeable Cations				
Ca(me/100g)	4.4	4.0	12.8	0.3
Mg(me/100g)	1.2	0.4	1.2	0.2
K(me/100g)	0.85	0.18	0.54	0.08
Na(me/100g)	0.3	0.3	0.3	0.1
Sum Cations	6.8	4.9	14.8	0.7
Base Saturation % (BS)	45	54	62	70
ESP	2	3	1	10
Qualitative $CaCO_3$	-	-	-	-

Profile Description Pit 5

Mapping Unit:	Je-1
Soil Classification:	Eutric Fluvisol
Irrigable Land Classification	I/I
Ecological Zone:	V
Parent Material:	Mixed alluvium from volcanic lavas and acid igneous rocks. (Kerio alluvium)
Physiography:	Alluvial Terrace
Relief - macro:	Flat
Relief - micro:	Flat
Slope gradient:	0°
Vegetation/Land Use:	*Acacia tortilis, Commiphora*
Erosion:	Nil
Surface stoniness/rockiness:	Nil
Flooding:	Nil
Surface sealing:	2-3 mm; moderate
Salinity/alkalinity:	Slight salinity
Drainage Class:	Well drained
Moisture status:	Moist to 30 cm.

Sample No.	Depth (cm)	Description
P.017	0-20	Dark brown moist (7.5 YR 3/2) very fine sandy loam; moderate fine subangular blocky; hard dry friable moist, non sticky and slightly plastic wet; medium and fine pores; mica; abundant roots; clear smooth boundary.
P.018	20-70	Dark brown to brown moist (7.5 YR 4/2) silt loam; moderate medium and fine subangular blocky; hard dry, friable moist. non sticky and slightly plastic wet; mica; few roots; clear smooth boundary.
P.019	70-120	Brown moist (7.5 YR 4/2) silt loam; moderate medium subangular blocky; hard dry, friable moist, non sticky and slightly plastic wet; mica; very few roots; clear smooth boundary.
P.020	120-180	Brown moist (7.5 YR 4/2) silty clay /loam; moderate coarse subangular blocky; hard dry, firm moist, sticky and plastic wet; mica; no roots.

SOIL TEST REPORT (SURVEY)

From: Eldoret
Rift Valley Province

Our ref: SOIL/2/4/XVI/119
Date Sample Received: 19th June 1987
Date Sample Reported: 27th July 1987
Sample sent by: Mr F.W. Collier, B&B, via Amedei 15, 20123 Milan, Italy.

Profile Pit No. 5

Field Ref:	P.017	P.018	P.019	P.020
Depth in cm	0-20	20-70	70-120	120-180
Lab. No./87	7033	7034	7035	7036
Gravel %	-	-	-	-
Sand %	21	19	13	28
Silt %	40	50	56	46
Clay %	39	31	31	26
Texture Class	CL	SiCL	SiL	L
pH-H_2O 1:2½ Suspension	7.8	8.1	7.7	7.6
PH-KC1 1:2	6.8	6.8	6.7	7.0
EC(mmhos/cm) 1:2½	0.19	0.27	2.10	2.50
C%	0.60	0.26	0.20	0.30
N%	0.04	0.02	-	-
Cat. Exch. Cap. (me/100g)	29	30	29	28
Exchangeable Cations				
Ca(me/100g)	16.5	15.8	27.5	20.1
Mg(me/100g)	6.0	5.9	6.4	5.2
K(me/100g)	1.36	0.36	1.28	0.56
Na(me/100g)	0.7	0.9	2.6	2.8
Sum Cations	24.6	23.0	37.8	28.7
Base Saturation % (BS)	85	77	100	100
ESP	2	3	9	10
Qualitative $CaCO_3$	+	++	++	+++

Our ref: SOIL/2H1X
Date sample Receive
Date Sample Reporte
Sample sent by: Mr

Profile Pit No. 5

Field Ref.
Depth in cm
Lab. No. /87
Gravel %
Sand %
Silt %
Clay %
Textural Class
pH (Paste) 1:2.5 Suspens
pH (CaCl) 1:2
ECmmhos/cm 1:2.5
C%
N%
Cat. Exch. Cap. (me/1
Exchangeable Cations
Ca (me/100g)
Mg (me/100g)
K (me/100g)
Na (me/100g)
Sum Cations
Base Saturation % (BS)
ESP
Gypsum/free $CaCO_3$

Profile Description No. P.6

Mapping Unit:	Be-2
Soil Classification:	Eutric Cambisol
Irrigable Land Classification	2s
Ecological Zone:	V
Parent Material:	mixed schists and gneisses
Physiography:	Piedmont alluvium
Relief - macro:	Smooth
Relief - micro:	Dissected, occasional rills to 20 cm.
Slope gradient:	2°
Vegetation/Land Use:	*Acacia tortilis*, fallow
Erosion:	Sheet, some rills.
Surface stoniness/rockiness:	Occasional gravels
Flooding:	Nil
Surface sealing:	2mm; weak.
Salinity/alkalinity:	Nil
Drainage Class:	Well drained
Moisture status:	Moist to 20 cm.

Sample No.	**Depth (cm)**	**Description**
P.021	0-25	Dark reddish brown moist (5 YR 3/2) coarse sandy loam; weak fine subangular blocky; slightly hard dry, friable moist, non sticky and non plastic wet; common medium pores; few roots; clear smooth boundary.
P.022	25-50	Dark reddish brown moist (5 YR 3/3) gravelly sandy loam; moderate fine subangular blocky; hard dry, friable moist, non sticky and non plastic wet; common medium pores; very few roots; gradual smooth boundary.
P.023	50-80	Dark reddish brown moist (5 YR 3/2) gravelly sandy loam; moderate medium and fine subangular blocky; hard dry, friable moist, non sticky and non plastic wet; few fine pores; no roots; clear smooth boundary.
P.024	80-140	Dark reddish brown moist (5 YR 3/2) gravelly sandy clay loam; moderate medium subangular blocky; very hard dry, friable moist, slightly sticky and slightly plastic wet; few fine pores; few cutans; no roots.

SOIL TEST REPORT (SURVEY)

From: Eldoret
Rift Valley Province

Our ref: SOIL/2/4/XVI/119
Date Sample Received: 19th June 1987
Date Sample Reported: 27th July 1987
Sample sent by: Mr F.W. Collier, B&B, via Amedei 15, 20123 Milan, Italy.

Profile Pit No. 6

Field Ref:	P.021	P.022	P.023	P.024
Depth in cm	0-25	25-50	50-80	80-140
Lab. No./87	7037	7038	7039	7040
Gravel %	-	-	-	-
Sand %	72	62	58	60
Silt %	8	8	12	10
Clay %	20	30	30	30
Texture Class	SCL	SCL	SCL	SCL
pH-H_2O 1:2½ Suspension	7.8	7.8	7.7	7.6
PH-KC1 1:2	6.4	6.2	6.1	6.0
EC(mmhos/cm) 1:2½	0.10	0.06	0.05	0.04
C%	0.72	0.22	0.22	0.19
N%	0.04	0.04	-	-
Cat. Exch. Cap. (me/100g)	16	17	20	19
Exchangeable Cations				
Ca(me/100g)	5.7	7.7	7.7	7.3
Mg(me/100g)	2.0	2.8	3.2	2.4
K(me/100g)	0.38	0.32	0.74	0.66
Na(me/100g)	0.2	0.2	0.2	0.2
Sum Cations	8.3	11.0	11.8	10.6
Base Saturation % (BS)	52	65	59	56
ESP	1	1	1	1
Qualitative $CaCO_3$	+	+	+	+

Profile Description No. P.7

Mapping Unit:	Je2
Soil Classification:	Eutric Fluvisol
Irrigable Land Classification	1/1
Ecological Zone:	V
Parent Material:	mixed schists and gneisses (tributary alluvium)
Physiography:	Alluvial terrace
Relief - macro:	Flat
Relief - micro:	Flat
Slope gradient:	0°
Vegetation/Land Use:	*Acacia tortilis, Boscia.*
Erosion:	Nil
Surface stoniness/rockiness:	Nil
Flooding:	Nil
Surface sealing:	1-2 mm; weak
Salinity/alkalinity:	Nil
Drainage Class:	Well drained
Moisture status:	Moist to 50 cm.

Sample No.	Depth (cm)	Description
P.025	0-30	Dark brown moist (10 YR 3/3) coarse sandy loam; weak fine subangular blocky; slightly hard dry, friable moist, non sticky and non plastic wet; common fine pores; mica flakes; abundant roots; clear smooth boundary.
P.026	30-50	Dark yellowish brown moist (10 YR 3/4) fine sandy loam; moderate medium and fine subangular blocky; hard dry, friable moist, slightly sticky and slightly plastic wet; few fine pores; mica flakes; common fine roots, clear smooth boundary.
P.027	50-75	Brown moist (10 YR 4/3) coarse loamy sand; weak fine granular to loose structureless; slightly hard dry, friable moist, non sticky and non plastic wet; few roots; abrupt smooth boundary.
P.028	75-90	Dark brown moist (10 YR 3/3) fine sandy loam; moderate medium and fine subangular blocky; hard dry, friable moist, slightly sticky and slightly plastic wet; no roots; abundant mica flakes; clear smooth boundary.
	90-120	Brown moist (10 YR 4/3) coarse loamy sand; weak fine granular; slightly hard dry, friable moist, non sticky and non plastic wet; no roots; abundant mica flakes; clear smooth boundary.
	120-150	Brown moist (10 YR 4/3) loamy sand; weak fine granular; slightly hard dry, friable moist, non sticky and non plastic wet; no roots; abundant mica flakes.

Profile Description No. P.8

Mapping Unit:	Be2
Soil Classification:	Eutric Cambisol
Irrigable Land Classification	1/1
Ecological Zone:	V
Parent Material:	Gneiss and/or schists
Physiography:	Piedmont alluvial fan
Relief - macro:	Smooth
Relief - micro:	Smooth
Slope gradient:	1°
Vegetation/Land Use:	*Acacia tortilis*, grazing
Erosion:	Sheet erosion; locally gullies to 1.5 metres
Surface stoniness/rockiness:	Nil
Flooding:	Nil
Surface sealing:	2-3 mm; weak
Salinity/alkalinity:	Nil
Drainage Class:	Well drained
Moisture status:	Moist to 10 cm

Sample No.	Depth (cm)	Description
P.029	0-30	Dark brown moist (7.5 YR 3/2) sandy loam; moderate fine subangular blocky; hard dry, friable moist, non sticky and non plastic wet; common medium pores; few roots; clear smooth boundary.
P.030	30-60	Dark brown moist (7.5 YR 3/2) sandy clay loam; moderate medium subangular blocky; very hard dry, friable moist, slightly sticky and slightly plastic wet; common fine pores; few gravels very few roots; clear smooth boundary.
P.031	60-90	Dark brown moist (7.5 YR 3/2) sandy clay loam; moderate medium and coarse subangular blocky; very hard dry, friable moist, slightly sticky and slightly plastic wet; few fine pores; few gravels; no roots; clear smooth boundary.
P.032	90-120	Dark brown moist (7.5 YR 3/2) sandy clay loam; moderate coarse subangular blocky; very hard dry, friable moist, slightly sticky and slightly plastic wet; thin cutans.

SOIL TEST REPORT (SURVEY)

From: Eldoret
Rift Valley Province

Our ref: SOIL/2/4/XVI/119
Date Sample Received: 19th June 1987
Date Sample Reported: 27th July 1987
Sample sent by: Mr F.W. Collier, B&B, via Amedei 15, 20123 Milan, Italy.

Profile Pit No. 8

Field Ref:	P.029	P.030	P.031	P.032
Depth in cm	0-30	30-60	60-90	90-120
Lab. No./87	7045	7046	7047	7048
Gravel %	-	-	-	-
Sand %	72	70	70	66
Silt %	12	10	8	10
Clay %	16	20	22	24
Texture Class	SL	SCL	SCL	SCL
pH-$H_2$0 1:2½ Suspension	7.9	7.6	7.7	7.7
PH-KC1 1:2	6.4	6.5	6.4	6.5
EC(mmhos/cm) 1:2½	0.11	0.24	0.14	0.21
C%	0.42	0.28	0.29	0.23
N%	0.09	0.05	-	-
Cat. Exch. Cap. (me/100g)	12	16	15	19
Exchangeable Cations				
Ca(me/100g)	4.8	5.5	5.7	7.7
Mg(me/100g)	0.4	1.2	2.4	2.4
K(me/100g)	0.34	0.58	0.57	0.30
Na(me/100g)	0.3	0.3	0.3	0.3
Sum Cations	5.8	7.6	9.0	10.7
Base Saturation % (BS)	48	48	60	56
ESP	3	2	2	2
Qualitative $CaCO_3$	+	+	-	-

Profile Description No. P.9

Mapping Unit:	Be2
Soil Classification:	Eutric Cambisol
Irrigable Land Classification	6t/2t
Ecological Zone:	V
Parent Material:	Gneiss and schist
Physiography:	Piedmont alluvial fan
Relief - macro:	Undulating
Relief - micro:	Smooth
Slope gradient:	3°
Vegetation/Land Use:	*Acacia tortilis*, fallow
Erosion:	Occasional rills
Surface stoniness/rockiness:	Nil
Flooding:	Nil
Surface sealing:	Very weak
Salinity/alkalinity:	Nil
Drainage Class:	Well drained
Moisture status:	Moist to 90 cm

Sample No.	Depth (cm)	Description
P.033	0-25	Dark reddish brown moist (5 YR 3/2) sandy loam; weak fine subangular blocky; slightly hard dry, friable moist, non sticky and non plastic wet; common medium pores; abundant roots; clear smooth boundary.
P.034	25-50	Dark reddish brown moist (5 YR 3/3) sandy clay loam; moderate medium and fine subangular blocky; hard dry, friable moist, slightly sticky and slightly plastic wet; common fine pores; plentiful roots; clear smooth boundary.
P.035	50-90	Dark reddish brown moist (5 YR 3/4) sandy clay loam; moderate medium subangular blocky; very hard dry, firm moist, slightly sticky and slightly plastic wet; common fine pores, thin cutans; few roots; gradual smooth boundary.
P.036	90-120	Reddish brown moist (5 YR 4/4) sandy clay loam; moderate coarse subangular blocky; very hard dry, firm moist, slightly sticky and slightly plastic wet; common fine pores; well developed cutans; very few roots.

SOIL TEST REPORT (SURVEY)

From: Eldoret
Rift Valley Province

Our ref: SOIL/2/4/XVI/119
Date Sample Received: 19th June 1987
Date Sample Reported: 27th July 1987
Sample sent by: Mr F.W. Collier, B&B, via Amedei 15, 20123 Milan, Italy.

Profile Pit No. 9

Field Ref:	P.033	P.034	P.035	P.036
Depth in cm	0-25	25-50	50-90	90-120
Lab. No./87	7049	7050	7051	7052
Gravel %	-	-	-	-
Sand %	76	76	64	62
Silt %	12	10	16	20
Clay %	12	14	20	18
Texture Class	SL	SL	SL	SL
pH-$H_2$0 1:2½ Suspension	8.1	8.3	7.8	8.4
PH-KC1 1:2	6.7	6.9	7.0	7.1
EC(mmhos/cm) 1:2½	0.10	0.28	0.19	0.24
C%	0.32	0.25	0.23	0.16
N%	0.04	0.02	-	-
Cat. Exch. Cap. (me/100g)	10	10	19	15
Exchangeable Cations				
Ca(me/100g)	4.8	5.1	16.5	13.2
Mg(me/100g)	0.8	0.6	1.6	2.0
K(me/100g)	0.73	0.61	0.44	0.38
Na(me/100g)	0.3	0.2	0.5	0.4
Sum Cations	6.6	6.5	19.0	16.0
Base Saturation % (BS)	66	65	100	100
ESP	3	2	3	3
Qualitative $CaCO_3$	-	-	+++	+++

Profile Description No. P.10.

Mapping Unit:	Lo
Soil Classification:	Orthic Luvisol
Irrigable Land Classification	2t/1
Ecological Zone:	V
Parent Material:	Piedmont alluvium, mixed acidic rocks
Physiography:	Piedmont fan
Relief - macro:	Smooth
Relief - micro:	Undulating
Slope gradient:	1°
Vegetation/Land Use:	*Acacia tortilis, Boscia;* rough, grazing
Erosion:	Sheet, some rills, occasional gully to 50 cm
Surface stoniness/rockiness:	Nil
Flooding:	Nil
Surface sealing:	2-3 mm; moderate
Salinity/alkalinity:	Nil
Drainage Class:	Well drained
Moisture status:	Moist to 20 cm

Sample No.	Depth (cm)	Description
P.037	0-20	Dark reddish brown moist (5 YR 3/2) coarse sandy clay loam; moderate fine subangular blocky; hard dry, friable moist, slightly sticky and slightly plastic wet; common medium pores; very few roots; few gravels; gradual smooth boundary.
P.038	20-80	Dark reddish brown moist (5 YR 3/2) sandy clay; moderate coarse subangular blocky; very hard dry, firm to friable moist, sticky and plastic wet; common fine pores; cutans; no roots; abrupt smooth boundary.
P.039	80-100	Dark reddish brown moist (5 YR 3/3) coarse sandy clay loam; moderate medium subangular blocky; hard dry, friable moist, slightly sticky and slightly plastic wet; few fine pores; abrupt smooth boundary.
P.040	100-140	Dark reddish brown moist (5 YR 3/3) fine sandy clay loam; moderate medium subangular blocky; hard dry, friable moist, slightly sticky and plastic wet.

SOIL TEST REPORT (SURVEY)

From: Eldoret
Rift Valley Province

Our ref: SOIL/2/4/XVI/119
Date Sample Received: 19th June 1987
Date Sample Reported: 27th July 1987
Sample sent by: Mr F.W. Collier, B&B, via Amedei 15, 20123 Milan, Italy.

Profile Pit No. 10

Field Ref:	P.037	P.038	P.039	P.040
Depth in cm	0-20	25-80	80-100	100-140
Lab. No./87	7053	7054	7055	7056
Gravel %	-	-	-	-
Sand %	80	40	74	42
Silt %	8	18	8	22
Clay %	12	42	18	36
Texture Class	SL	C	SL	CL
pH-H_2O 1:2½ Suspension	7.9	7.8	7.9	8.3
PH-KC1 1:2	6.1	6.3	6.5	7.0
EC(mmhos/cm) 1:2½	0.14	0.08	0.07	0.16
C%	0.31	0.27	0.18	0.28
N%	0.04	0.04	-	-
Cat. Exch. Cap. (me/100g)	12	26	13	19
Exchangeable Cations				
Ca(me/100g)	4.2	10.3	4.8	10.1
Mg(me/100g)	1.2	5.6	1.0	4.7
K(me/100g)	0.76	0.95	0.32	0.58
Na(me/100g)	0.4	0.3	0.3	0.3
Sum Cations	6.6	17.2	6.4	15.7
Base Saturation % (BS)	55	66	49	82
ESP	3	1	2	2
Qualitative $CaCO_3$	-	-	-	-

APPENDIX A.2.

SOIL FERTILITY TEST RESULTS

A.2 SOIL FERTILITY TEST RESULTS

Profile Pit No.	P1	P1	P2	P2	P3	P3	P4	P4
Field Designation	P001	P002	P005	P006	P009	P010	P013	P014
Lab No/87	7017	7018	7021	7022	7025	7026	7029	7030
Depth in cm.	0-30	30-70	0-30	30-80	0-30	30-70	0-20	20-50
Chemical Test Results								
pH	6.9	7.1	7.8	8.1	7.0	7.1	6.6	7.1
Na me%	1,04	(5.40)	0.79	0.97	0.36	0.26	0.18	0.18
K me%	0.50	0.40	**0.08**	**0.14**	1.40	0.90	0.82	**0.18**
Ca me%	28.0	18.4	42.0	34.0	9.2	7.6	4.0	3.2
Mg me%	6.2	6.8	5.0	6.5	3.1	1.5	1.2	1.3
Mn me%	0.64	0.64	0.03	0.67	0.75	0.51	0.51	0.35
P.p.p.m	**3**	**4**	**1**	**2**	**5**	**4**	24	12
N%	0.04	0.02	0.03	0.00	0.07	0.02	0.04	0.02
C%	0.34	0.23	0.14	0.05	0.78	0.34	0.54	0.33
EC (millimhos)	-	2.6	1.1	0.5	0.5	0.4	-	0.3

Remarks: (Toxicities Bracketed) Deficiencies in bold

Soil pH (1:1 soil-solution suspension) varies from neutral to moderately alkaline. Salinity is suspected in samples P_2 and P_5. Available sodium is high in sample P_2. Available potassium and magnesium vary from low to high while calcium is generally high. Available bases are measured using a double acid extraction and phosphorus by sodium bicarbonate extraction.

Profile Pit No.	P5	P5	P6	P6	P7	P7	P8	P8
Field Designation	P017	P018	P021	P022	P025	P026	P029	P030
Lab No/87	7033	7034	7037	7038	7041	7042	7045	7046
Depth in cm.	0-20	20-70	0-25	25-50	0-30	30-50	0-30	30-60
Chemical Test Results								
pH	7.4	7.8	7.3	7.6	8.2	7.0	6.5	6.9
Na me%	0.72	1.00	0.18	0.18	0.26	0.14	0.22	0.32
K me%	0.86	0.22	0.54	0.29	0.79	0.22	0.86	0.43
Ca me%	12.0	18.0	3.6	4.0	15.2	2.0	5.2	5.6
Mg me%	4.0	4.6	2.0	2.4	2.2	0.7	1.2	2.3
Mn me%	1.16	1.02	0.48	0.40	0.54	0.32	0.34	0.44
P.p.p.m	20	19	6	3	22	24	10	6
N%	0.04	0.02	0.04	0.04	0.06	0.05	0.09	0.05
C%	0.60	0.26	0.72	0.22	0.65	0.29	0.42	0.28
EC (millimhos)	0.6	0.7	0.5	0.3	0.2	0.2	-	-

Profile Pit No.	P9	P9	P10	P10
Field Designation	P033	P034	P037	P038
Lab No/87	7049	7050	7053	7054
Depth in cm.	0-25	25-50	0-20	20-80
Chemical Test Results				
pH	7.7	7.9	7.2	6.8
Na me%	0.18	0.22	0.14	0.26
K me%	0.68	0.58	0.68	0.54
Ca me%	5.6	6.0	2.8	6.4
Mg me%	1.3	1.1	1.9	3.6
Mn me%	0.50	0.58	0.48	0.61
P.p.p.m	10	15	5	3
N%	0.04	0.02	0.04	0.04
C%	0.32	0.25	0.31	0.27
EC (millimhos)	0.2	0.2	0.2	-

APPENDIX A.3

THE PIEDMONT ALLUVIUM

PIEDMONT SECTION

Location: Machukwa River

Field Ref: C.036

Depth (cm)	Description
0 - 20	Very dark brown (10YR2/2) loamy sand; clear smooth boundary.
20 - 50	Very dark brown (10YR2/2) sandy loam; clear smooth boundary. Sample F041
50 - 90	Dark brown (10YR3/3) sandy loam; clear smooth boundary Sample: F042
90 - 140	Dark brown (7.5YR3/2) sandy clay loam; gradual smooth boundary. Sample: F043
140 - 180	Dark reddish brown (5YR3/3) sandy clay loam; gradual smooth boundary. Sample: F044
180 - 220	Dark reddish brown (5YR3/4) sandy clay; clear smooth boundary. Sample: F045
220 - 270	Dark reddish brown (5YR3/4) gravelly sandy clay; abrupt smooth boundary. Sample: F046
270 - 340	Reddish brown (5YR 4/4) gravelly sandy clay with cobbles; abrupt smooth boundary. Sample: F047
340 - 420	Dark reddish brown (2.5YR3/4) sandy clay; calcium carbonate concretions; Sample: F048

Note: The figure overleaf is a pictorial representation of the soil layer descriptions above. This figure is also reproduced as Figure 3.2.

Section through Piedmont Alluvium

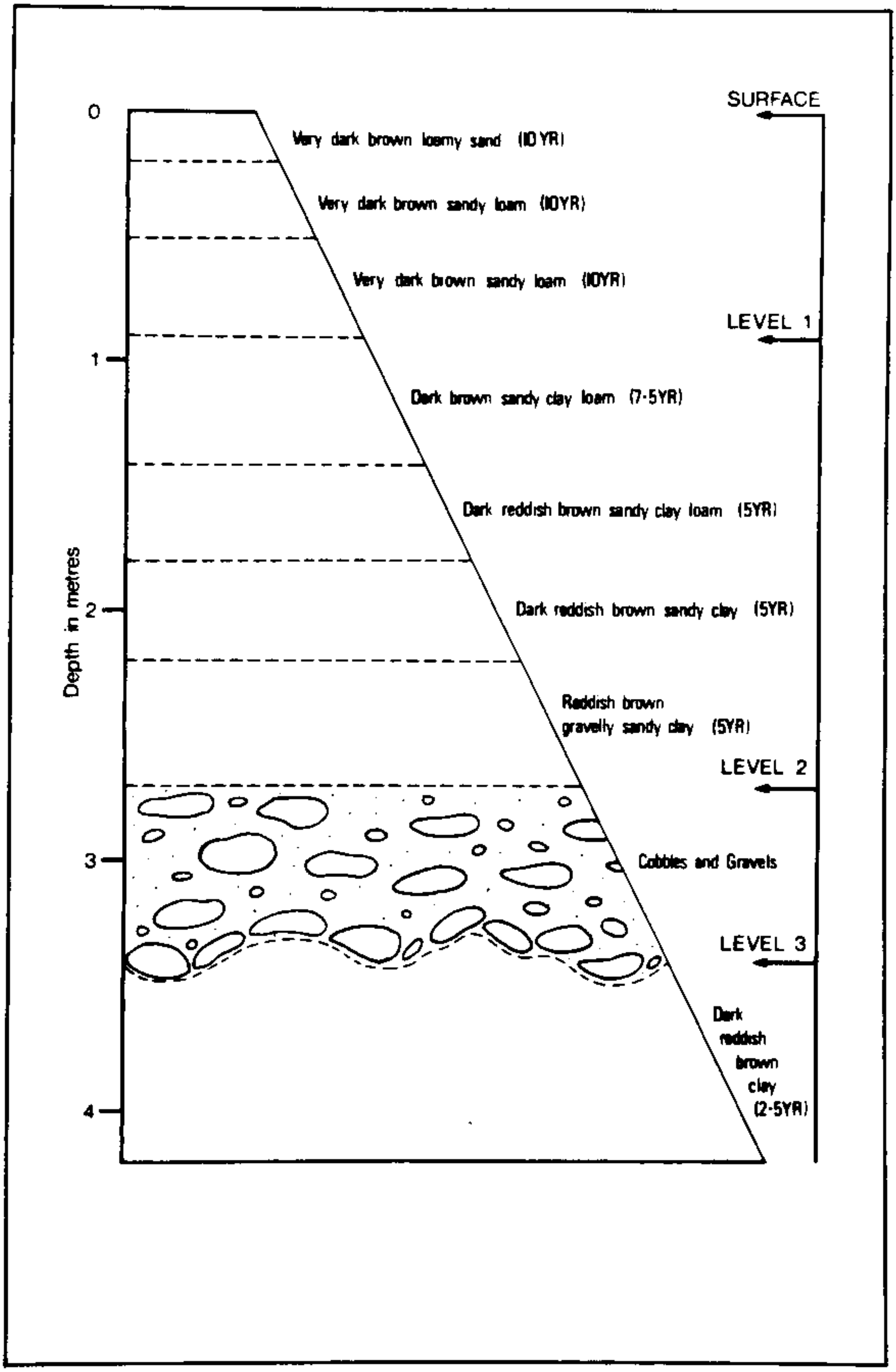

TABLE: A.1 CHEMICAL DATA FOR PIEDMONT ALLUVIAL SECTION

Field Ref:	P041	P042	P043	P044	P045	P046	P047	P048
Depth in cm	20-50	50-90	90-140	140-180	180-220	220-270	270-340	340-420
Lab. No./87	7057	7058	7059	7060	7061	7062	7063	7064
Gravel %	-	-	-	-	-	-	-	-
Sand %	60	56	56	58	52	56	60	64
Silt %	14	16	16	14	22	20	16	16
Clay %	26	28	28	28	26	24	24	20
Texture Class	SCL	SCL	SCL	SCL	SCL	SCL	SCL	SCL
pH-H_2O 1:2½ Suspension	8.4	8.4	8.6	8.9	8.9	8.0	8.6	8.8
PH-KCl 1:2	6.9	7.1	7.0	6.9	7.2	6.6	7.0	7.2
EC(mmhos/cm) 1:2½	0.12	0.17	0.14	0.17	0.18	0.10	0.09	0.15
C%	1.12	0.46	0.33	0.23	0.15	0.09	0.09	0.07
N%	-	-	-	-	-	-	-	-
Cat.Exch.Cap.(me/100g)	20	22	26	26	25	23	22	19
Exchangeable Cations								
Ca(me/100g)	13.4	13.8	13.6	15.1	12.5	12.6	11.0	10.8
Mg(me/100g)	3.1	3.2	5.1	7.2	8.0	8.0	8.8	9.2
K(me/100g)	0.32	0.22	0.26	0.26	0.26	0.18	0.22	0.16
Na(me/100g)	0.3	0.5	0.6	0.5	0.7	0.4	0.5	0.4
Sum Cations	17.1	17.7	19.5	23.0	21.4	21.2	20.5	20.6
Base Saturation % (BS)	86	81	75	88	86	92	93	100
ESP	2	2	2	2	3	2	2	2
Qualitative $CaCO_3$	++	+++	+++	+++	+++	+++	+++	+++

APPENDIX B

ROUTINE PIT AND
ANALYSIS RESU

FERTILITY ANAL

Bore No.						
Soil Classification						
Field Designation	C.001	C.002	C.003	C.004	C.005	C.006
Lab. No/87	7065	7066	7067	7068	7069	7070
Depth in cm	0-25	25-50	0-25	25-50	0-25	25-50
Chemical Test Results						
pH	7.3	7.7	6.9	6.9	7.6	7.2
Na me%	0.26	0.22	0.14	0.22	0.14	0.14
K me%	0.40	0.36	0.64	0.28	0.86	0.64
Ca me%	8.4	7.6	4.8	7.2	6.8	6.0
Mg me%	3.0	2.0	1.5	2.8	2.2	2.2
Mn me%	0.58	0.44	0.54	0.50	0.68	0.68
P.p.p.m. (Olsen)	8	9	7	9	10	6
N%	0.04	0.04	0.04	0.04	0.10	0.07
C%	0.37	0.32	0.10	0.34	0.82	0.64
EC(Millimhos)	0.2	0.2	-	-	0.2	0.3

Bore No.						
Soil Classification						
Field Designation	C.007	C.008	C.009	C.010	C.011	C.012
Lab. No/87	7071	7072	7073	7074	7075	7076
Depth in cm	0-25	25-50	0-25	25-50	0-25	25-50
Chemical Test Results						
pH	7.2	6.9	6.0	6.6	6.5	6.3
Na me%	0.14	0.14	0.18	0.14	0.14	0.18
K me%	0.40	1.24	0.86	0.72	0.72	0.43
Ca me%	3.2	3.2	2.8	3.2	3.2	4.8
Mg me%	1.5	2.8	1.5	1.5	1.4	2.8
Mn me%	0.50	0.38	0.61	0.44	0.64	0.54
P.p.p.m.(Olsen)	8	10	12	7	6	5
N%	0.06	0.05	0.08	0.04	0.08	0.04
C%	0.39	0.36	0.54	0.42	0.78	0.40
EC(Millimhos)	-	-	-	-	-	-

Bore No.		
Soil Classification		
Field Designation	C.013	C.014
Lab. No/87	7077	7078
Depth in cm	0-25	25-50
Chemical Test Results		
pH	6.7	6.9
Na me%	0.18	0.22
K me%	1.12	2.00
Ca me%	4.4	8.0
Mg me%	1.7	4.6
Mn me%	0.72	0.92
P.p.p.m.(olsen)	4	4
N%	0.10	0.12
C%	0.53	0.93
EC(Millimhos)	-	-

C.016	C.017	C.018
7080	7081	7082
25-50	0-25	25-50
6.2	7.5	7.6
0.26	0.14	0.14
0.40	0.36	0.28
8.0	5.6	5.2
3.9	2.0	1.8
0.61	0.61	0.40
3	12	8
0.08	0.05	0.03
0.53	0.35	0.23
-	-	-

Bore No.						
Soil Classification						
Field Designation	C.019	C.020	C.021	C.022	C.023	C.025
Lab. No/87	7083	7084	7085	7086	7087	7088
Depth in cm	0-25	25-50	0-25	25-50	0-25	0-25
Chemical Test Results						
pH	7.1	6.6	6.5	6.6	6.9	6.8
Na me%	0.14	0.32	0.28	0.28	0.50	0.14
K me%	0.82	0.22	0.82	1.24	0.82	0.40
Ca me%	3.2	9.6	3.6	9.2	13.6	5.6
Mg me%	2.1	3.4	2.4	3.7	3.2	2.4
Mn me%	0.54	0.38	0.54	0.40	0.50	0.54
P.p.p.m. (Olsen)	3	3	2	2	3	6
N%	0.05	0.04	0.04	0.03	0.03	0.02
C%	0.14	0.34	0.25	0.18	0.10	0.21
EC(Millimhos)	0.1	-	-	-	-	-

Bore No.						
Soil Classification						
Field Designation	C.026	C.027	C.028	C.029	C.030	C.031
Lab. No/87	7089	7090	7091	7092	7093	7094
Depth in cm	0-25	25-50	0-25	25-50	0-25	25-50
Chemical Test Results						
pH	6.5	7.2	6.7	7.2	7.1	7.1
Na me%	0.18	0.11	0.18	0.14	0.18	0.18
K me%	0.50	0.93	0.22	1.32	0.54	0.97
Ca me%	6.0	2.8	2.0	4.0	5.2	3.2
Mg me%	2.4	1.5	2.3	1.5	2.7	2.3
Mn me%	0.44	0.24	0.10	1.5	2.7	2.3
P.p.p.m.(Olsen)	5	6	3	10	10	10
N%	0.03	0.02	0.01	0.03	0.01	0.03
C%	0.21	0.23	0.09	0.25	0.25	0.24
EC(Millimhos)	-	-	-	0.2	0.1	0.2

Bore No.						
Soil Classification						
Field Designation	C.032	C.033	C.034	C.035	C.036	C.037
Lab. No/87	7095	7096	7097	7098	7099	7100
Depth in cm	25-50	0-25	25-50	0-25	25-50	0-25
Chemical Test Results						
pH	6.8	6.9	6.7	6.7	6.5	6.9
Na me%	0.28	0.22	0.32	0.18	0.62	0.14
K me%	1.08	1.00	0.54	0.68	0.72	0.86
Ca me%	5.6	3.6	3.6	4.0	7.2	3.2
Mg me%	2.6	2.6	3.6	4.0	7.2	3.2
Mn me%	2.6	2.6	3.6	2.5	4.0	1.7
P.p.p.m.(Olsen)	8	0	0	14	14	14
N%	0.05	0.03	0.03	0.04	0.03	0.03
C%	0.47	0.39	0.34	0.44	0.37	0.39
EC(Millimhos)	-	-	-	-	-	-

Bore No.			
Soil Classification			
Field Designation	C.038	C.039	C.040
Lab. No/87	7101	7102	7103
Depth in cm	25-50	0-25	25-50
Chemical Test Results			
pH	7.2	7.4	7.7
Na me%	0.22	0.18	0.28
K me%	0.62	0.68	0.54
Ca me%	8.8	4.8	8.0
Mg me%	1.6	1.4	2.7
Mn me%	0.62	0.44	0.50
P.p.p.m. (Olsen)	10	13	8
N%	0.02	0.02	0.08
C%	0.27	0.20	0.20
EC(Millimhos)	0.1	0.1	0.3

APPEND

TERMS OF REFERENCE F

ASE 2 STUDIES

TERMS OF REFERENCE FOR PHASE 2 STUDIES

C.1. Introduction

The reconnaissance soil survey has delineated some 1500 ha of land of which some 1200 ha have potential for irrigation development, both to surface and/or sprinkler type water application.

Those soils which appear favourable for development still require additional study to delineate their boundaries. The most important step is to separate those soils which are irrigable from those considered non-irrigable on account of soil depth, stoniness, coarse textures or degree of erosion.

Most of the land chosen as suitable for surface irrigation occurs on the more gently sloping sections of the piedmont alluvium where soil depth is not normally a constraint. It is the more steeply sloping land selected for sprinkler irrigation which often has constraints of soil depth, texture and/or stoniness, such variability occurring over relatively short distances.

Since only one metre of soil is required to justify a Class 1 irrigability grouping and subsoil drainage is not expected to be a problem then soil inspections need not extend below one metre depth. It is far more important to identify and exclude the shallower soils than to needlessly pursue examination of the deeper subsoils of clearly irrigable land.

Under present conditions of hard dry subsoils then soil inspections are best done by pits to a greater extent that normally specified.

Field tests for hydraulic conductivity of the subsoil and surface infiltration should be carried out at selected sites.

C.2. Procedures for Soil Studies

The initial soil survey has identified various areas, amounting in total to some 1500 hectares which include some 1200 hectares of land having potential for irrigation.

a) Carry out field inspections by means of traverses to visually identify soil boundaries, occurrence of rill and gully erosion and other factors, such as dense tree coverage, which would affect development costs.

b) At various points along traverses, inspect the soil by means of pits or bores to a depth of one metre, to give an overall density of about one site every 10 hectares. Record details onto standard soil description proformas. Site descriptions to include geology, geomorphology, parent material, vegetation or land use, slope, drainage, presence of stones, gravel and rock outcrop, microrelief and degree of erosion.

Soil descriptions to include:- depth of each horizon; colour; texture; structure; consistence; presence and estimation of volume of stones and gravel; clay skins; root distribution; details of boundary between horizons.

c) Two samples per site should be taken from alternate sites and analysed for pH and EC of a 1:5 suspension in a field laboratory. In total about 140 samples should be so analysed.

Samples should also be sent to the National Agricultural Laboratories in Nairobi for analysis of exchangeable sodium and CEC thus enabling calculation of exchangeable sodium percentage (ESP) for all those soils where pH of the 1:5 suspension exceeds 8.4.

d) Ten pits should be selected to typify the soil units and should be excavated to a depth of one metre or rock if shallower. The bottom of the pit should be probed by means of auger to a depth between 1.5 and 2.0 metres. Field tests for surface infiltration (double ring infiltrometer method) and subsoil hydraulic conductivity (pour in method) should be carried out at five of these sites.

e) Collect soil samples from representative horizons of these typical pits (40 samples in total) and submit to the National Agricultural Laboratories, Nairobi for detailed chemical analysis as follows:

- texture; pH soil-water; pH-KCl; EC1:2.5: Cation exchange capacity; exchangeable cations:sodium, potassium, calcium, magnesium.

- top two horizons (20) to cover the depth from the surface to about 50cm additionally for fertility evaluation comprising pH, macronutrients, nitrogen and carbon.

f) The detailed soil survey should conclude with a technical report supported by maps and diagrams which would define the irrigation potential of the soils. The technical report should include details of the geology, geomorphology, soil characteristics, methods of survey, interpretation and discussion of the chemical and physical data. Appendices should include descriptions of representative soil pits with full supporting chemical data. A soil map should be produced using the FAO system as modified by the Kenya Soil Survey. This map should be based on both field data and interpretation of air photographs. A land classification map showing suitability for both sprinkler and surface irrigation, utilising the concepts of the USBR systems, suitably modified to take into account Kenya conditions should also be produced. Hand drawn maps suitably coloured and at a scale of 1:2000 to show soil and land class distribution should be prepared in one copy for final cartographic presentation by the Client.