REPUBLIC OF KENYA

MINISTRY OF AGRICULTURE—NATIONAL AGRICULTURAL LABORATORIES

KENYA SOIL SURVEY

ASSESSMENT ON SOIL CONDITIONS IN SOME WATER SPREADING AND SMALL SCALE IRRIGATION SCHEMES IN TURKANA

by
A. Weeda

EVALUATION REPORT No.P81,1987

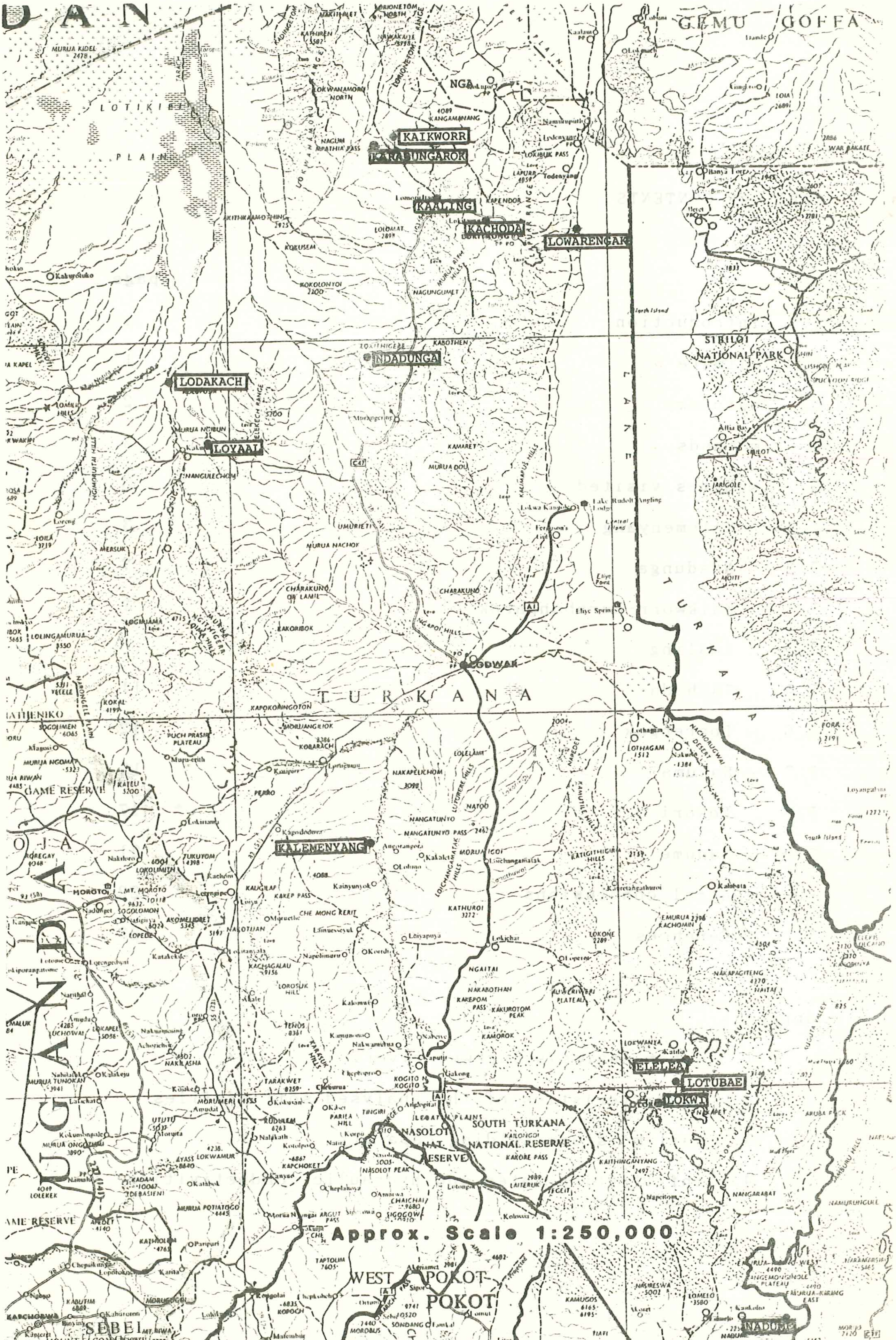
K E N Y A   S O I L   S U R V E Y

ASSESSMENT ON SOIL CONDITIONS IN SOME WATER SPREADING AND SMALL SCALE IRRIGATION SCHEMES IN TURKANA

by A. Weeda

SITE EVALUATION REPORT No. P 81, 1987

TABLE OF CONTENTS



GEMU GOFFA
LOTIKIPI PLAIN
KAIKWORR
KARASUNGAROK
KAALING
KACHODA
LOWARENGAK
NDADUNGA
LODAKACH
LOYAAI
LAKE TURKANA
TURKANA
LODWAR
KALEMENYANG
UGANDA
MOROTO
ELELEA
LOTUBAE
LOKWI
NASOLOT NAT. RESERVE
SOUTH TURKANA NATIONAL RESERVE
WEST POKOT
POKOT
SEBEI
MOUNT ELGON FOREST
NADOME
Approx. Scale 1:250,000

1. INTRODUCTION

The Turkana Rehabilitation Project had requested the Kenya Soil Survey to assess the soil conditions in the areas in Turkana District, where water harvesting, water spreading and small scale irrigation developments occur, with specific attention to their general chemical and physical properties. It was decided that short site evaluations were required in each of the areas. During the period from 29th of September to 14th of October 1986, the Kenya Soil Survey staff members Messrs PT.Kamoni, EM.Mare and A.Weeda, visited the various areas for the evaluation of the soil conditions.

2. CLIMATE in general.

Due to the scattered location of the visited schemes and the few meteorological stations throughout Turkana District, only some general information will be given.
For orientation purposes rainfall data of four stations are given in the table below:

Average monthly rainfall data of some stations in Turkana District (in mm).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	total
Kakuma	11	9	34	47	46	23	28	37	32	11	45	2	325
Lodwar	9	8	21	49	25	9	20	10	4	10	17	11	193
Lokitaung	11	24	47	115	48	21	27	11	8	14	39	26	391
Lokori	16	30	26	34	55	42	44	11	38	21	28	3	348

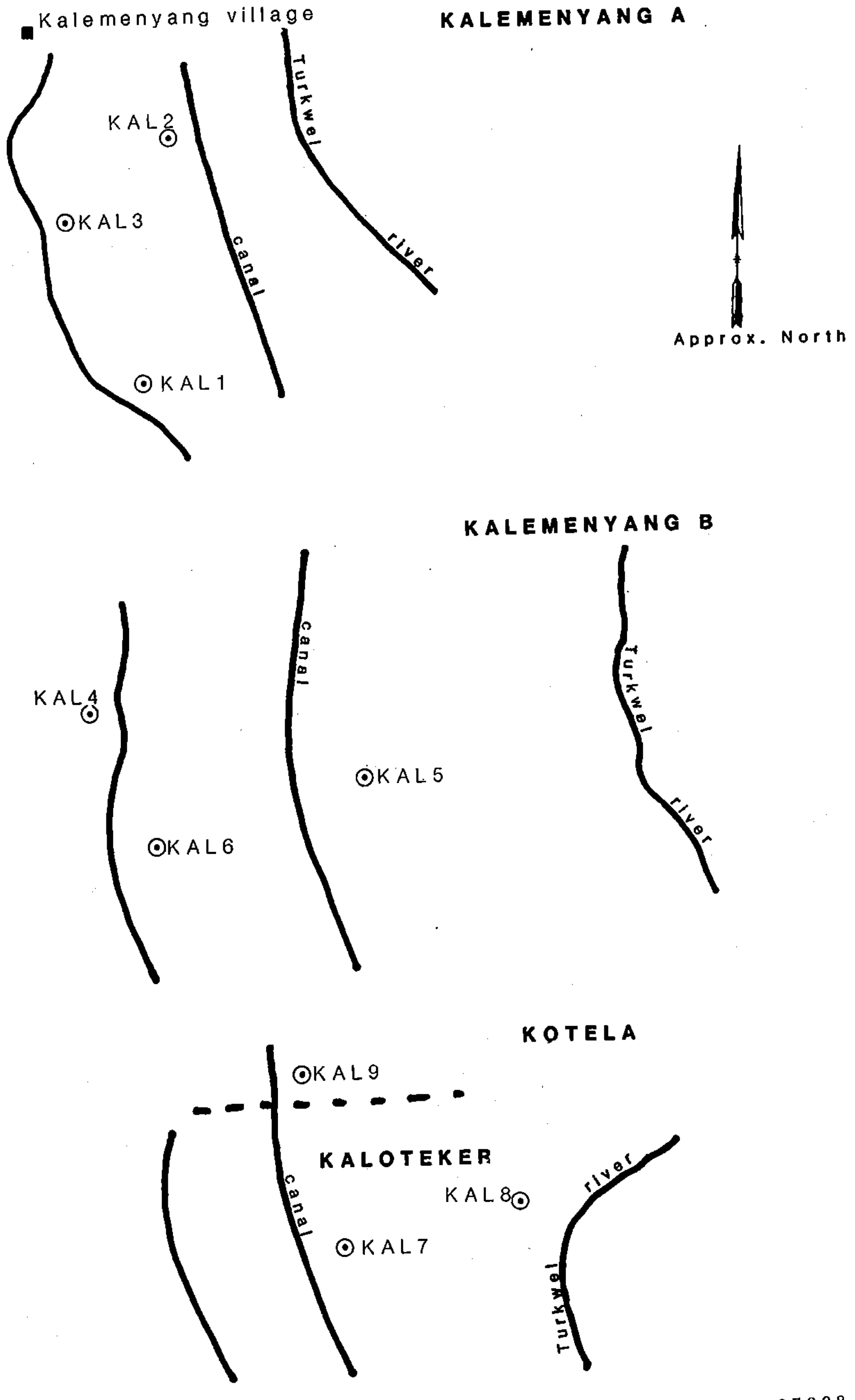
source: (litt 2) for Kakuma 9 years, Lokitaung 44 years,
Lokori 6 years of observations,
(litt 3) for Lodwar 61 years of observations.

According to the Kenya Soil Survey agro-climatic zonation (litt 5) most of the areas visited will fall in the VII-1 zone (very arid and fairly hot to very hot), but Nadume in the Rift Valley near Mt Maralal, could be placed in zone VI-1 (arid and fairly hot to very hot). Additionally to classifying for the warmest zone of the KSS zonation system, these areas with their high monthly average temperatures varying between 27.8 and 30.5 degrees Celsius are among the hottest in the country (litt 4).

3. AGRONOMY in general.

Most of the visited schemes are destined to produce sorghum for grain or fodder. It should be realized that sorghum is a crop that can tolerate short periods of waterlogging and drought, and that it is moderately sensitive to higher salt concentrations and exchangeable sodium in the soil.
The rainfall in the area is erratic, and due to the irregular additional water supply by the introduced waterharvesting systems, the degree in which the crop water requirements are met, is not easily controlable. Similarly some of the small scale irrigation schemes can not always obtain enough water for the optimal irrigation dose from the river.
In some places other plants than sorghum, will be used as fodder; the selection of plants and species should be based on the resistance to drought and the tolerance to some of the plant growth limiting characteristics of the soil e.g. high salinity.

SITE LOCATION SKETCH (not to scale)



Drawing No. 87028

4. METHODS

During short visits to the different areas a limited number of soil checks were executed by auger and visual observations, completed by some field measurements of infiltration rates and permeabilities, field soil analysis for pH and the electrical conductivity for salt contents (EC, soil: water ratio of 1:2.5), and sampling for laboratory analysis principally for chemical and some physical properties. The water storage capacity of easily available water has been estimated for the various profiles over a depth of 120 cm based on the texture, or shallower if

consolidated or very compact layers could be assumed to be limiting for the rooting system.

5. SCHEMES VISITED

5.1 KALEMENYANG area

The small scale irrigation scheme called Kalemenyang consists of four blocks namely Kalemenyang A and B, Kaloteker and Kotela, all located in the floodplain of the Turkwel river.

Due to their location on alluvial deposits, the soils of the scheme might vary considerably over relatively short distances.

<u>Kalemenyang A</u>

The irrigation block called Kalemenyang A comprises 20 hectares located south of the village, and is occupied by 42 families. Three auger observations on selected sites were made to analyse the main problems existing within this block.

The first site (KAL 1) is located on the lower part of the older floodplain; the river actually does not flood this area. It is called a 'bad spot' due to the low yields or poor growing characteristics of the plants. According to local information, 30 cm of water supplied by an irrigation water application may cause ponding for a period of one month, resulting in problems for the management of soil and crop growth.

An important feature is the strong crust and seal formation, most probably caused by the sedimentation of material carried by irrigation water. Furthermore the stratified profile has mainly moderate calcareous, clay loam to clayey textures intercalated by a loamy layer at 50-70 cm depth. The soil is imperfectly drained.

Although the general pH is high, the measured salt concentrations (EC) and the Exchangeable Sodium Percentages (ESP) of the different horizons do not give any indication of limiting concentrations of salts and as such is not the cause for any production decrease.

The measurements by using the inversed augerhole method reveal low to moderate permeabilities. In relation to the imperfect drainage care should be taken not to detiorate the drainage condition further for longer periods by excessive water applications. Together with the high soil moisture storage capacity of the soil, this should lead to special attention for aspects of water management such as the timing and the depth of water application; the smaller water gifts, that should be applied, will influence the water distribution schedule within the scheme.

KAL 2 situated 100 m North of the former site, has been taken for reasons of comparison. The site shows a rather good stand of sorghum. The profile, located on a better drained part of the floodplain has a clayey upper soil of about 70 cm over sand. The better drainage and the moderate water storage capacity contribute to suitable properties of this soil for irrigation. The slight sealing characteristcs of the topsoil might contribute to some management problems, specifically during the period of germination and will reduce the water intake velocity during irrigation slightly.

The third auger site (KAL 3) is located again in a depressional area, with fine textures (high soil moisture storage capacity) and low infiltration rates. The drainage is poor to very poor, and the topsoil has a moderate degree of salt accumulation (S2). Sites like this one should not be used for irrigated sorghum.

Kalemenyang B

Two representative sites were choosen within this block, and an other site was selected at a short distance from the scheme where the population is planning for the production of rainfed sorghum, supplemented with some water from the existing small lugga, West of the Kalemenyang block B.
KAL 5 site was choosen for comparison with the soil profile of KAL 6. The high soil moisture storage capacity, the good drainage conditions of the soil and the actual absence of any significant salt accumulation in the profile are among the factors to explain the relatively good productivity.

KAL 6 is located in a depressional area between KAL 5 and the upland areas. The soil has an impeded drainage (imperfectly drained) and it is locally known that irrigation water stands for a long time on the surface (low infiltration rates). At a depth of 50 cm an increase of the salinity is detected upto a level of 'slight salinization'. Adequate water supply in the form of frequent small quantities will reduce the ponding effect, but the amount of water should be large enough to avoid the upwards salt movement. On the other hand the moisture storage capacity of the soil is high: the soil can store efficiently relative large quantities of water per irrigation gift.

The site outside the block (KAL 4) has a very calcareous profile that consists of a 30 cm thick toplayer of silty clay over sand, giving rise to an overall moderate to low soil water storage capacity. The topsoil shows a slight degree of salt accumulation, and a strong crust formation. A low soil fertility can be expected. These mentioned factors give an indication of the problems to be faced with in the near future. Salt leaching is recommended whenever water supply is adequate.

Kaloteker

In this irrigation scheme several sites were analysed. The major part of the soils consist of alluvial material of sandy textures showing low productivities under the actual management system (KAL 8). For comparison the neighbouring KAL 7 was taken as being 'a good spot' according to the farmers.

Profile KAL 7. The soil in and around this site shows a high water holding capacity, and together with adequate infiltration rates, this makes it suitable for irrigation practices. The soil is strongly calcareous, but this will not affect crop growing much. The pH (8.2) - although somewhat high - and the low salt concentrations actually present in the soil, are at acceptable levels for sorghum.

The profile KAL 8 has a low water storage capacity (72 mm/120 cm) as can be estimated from the predominantly sandy textures. The overall fertility turned out to be low, although the fertility of the shallow topsoil - besides the nitrogen deficiency - is classified as moderate. The pH is acceptable, but the accumulated salt contents throughout the profile are close to the slightly saline level, with only some slight consequences for the growth of sorghum. It should not be encouraged, that these soils with very sandy textures - with depth increasing proportion of sand - occurring in a stretch from the Turkwel river towards the northwest, are used for irrigated crop growing.

Kotela

A reasonable sorghum ratoon crop was growing on the site KAL 9. The soil shows a strongly stratified profile of varying textures with an overall water holding capacity that

has been classified as moderate. The absence of difficulties for sorghum growing related to salt accumulation or extreme pH's, and the presence of good nutrient levels with the exception of nitrogen, makes the soil, from this point of view, relatively acceptable for crop production.
Although only a little water was standing in the Turkwel river itself at the time of the fieldwork (at the end of the dry season), the chemical quality of even this water is of good quality for irrigation purposes (see appendix 1).

5.2 NDADUNGA

On the road to Kaaling / Kaikworr a very short visit was paid to the Ndadunga water spreading scheme.
Within the first bund an augerhole was made and the soil was sampled. The profile shows a recent 30 cm thick sediment layer (silty loam to silty clay) on top of the old surface (compact clay with some stones at depth). The presence of moderate thick crusts at the surface and the underlying compact clay will give rise to low infiltration rates. The soil water holding capacity, assumed upto 120 cm depth, is high. It has been observed that at a depth of 30 cm and deeper (sampling done upto 70 cm depth) some salt accumulation takes place upto slight to moderate salinization levels. Apart from the deficiency in nitrogen and the high pH, the other fertility factors show reasonable levels.

5.3 KAIKWORR-KARABUNGAROK

Kaikworr

In Kaikworr, an area with water harvesting schemes, bunds have been constructed across the shallow lugga which is crossing the village.
The soils have generally heavy textured stratified material, on top of which recent deposits of silty clay upto 50 cm

thickness can be observed. The soils are moderately well drained, and the pH is high to very high (from 8.3 at the surface upto 9.0 at 120 cm depth) with low salinity levels. The high pH certainly will influence the productivity; the ESP of 7 of the topsoil and the low available phosphorus also strongly contribute to the lower yield levels.
As the hydraulic conductivity of the subsoil is rather low, ponding of water for longer periods should be avoided by adapting the bunds.

Karabungarok

The construction of the scheme, a flood diversion and water spreading type, for which a lugga has been nearly completely diverted, finished recently.
Located at the end of the 1 km long diversion canal, the first bunds show rather heavy sedimentation.
The first observation site (KAR 1, inner side of the first bund) shows a sediment layer of 40 cm silty loam - in places upto clay - produced after the very few inundations that took place since the functioning of the scheme. This layer is overlying the original soil of a clayey texture with some gravels. No infiltration tests could be carried out during this fieldwork period because of the high amount of smaller cracks, through which the applied water disappears immedeately; after wetting by rain or flood water the swelling of the soil will close these cracks, the infiltration will be reduced and can be measured. Contrary to the topsoil, the subsoil reveals very slow hydraulic conductivities (measured 10 cm/day by inversed augerhole method).
The total water holding capacity upto 120 cm depth is high. The EC figures are within the acceptable range, while the pH and ESP data of the topsoil are showing levels at which production problems can be expected. Similar characteristics were observed in one of the last bunds, only that there the sedimentation layer is less pronounced (about 5 cm thick). Here as well the soil directly underlying is

the clayey material with low hydraulic conductivity. It might be noted that although the salinity in the profile is low, the pH is reaching strong to very strongly alkaline levels (upto 9.3) and the ESP reaches the critical level of 6 %. Also the available P is low.

In the area of the proposed extension, further downstream of the actual scheme, the soils are comparable with the first ones, with the difference that the moderate thick sedimentation layer is not present, but on top of the gravelly clay, some shallow sandy deposits might be found. In places some crusts with cristalizations of salt have been observed, but this is also regularly occurring within the actual scheme, and also very common along the diversion canal. It must be realized that the pH and ESP are at somewhat higher levels (ESP 6 -10) than inside the scheme, further downstream the levels of ESP might be expected to increase further (Solonetz?).
All in all the proposed extension is not an area, where without further detailed investigations on soil constraints a programme for increased fodder productivity could take place.

5.4 KAALING area

Southwest of Kaaling, several smaller water harvesting schemes were visited:
- Kangamoti
- Loito
- Nakapelewoi
- Nalilearii.

Kangamoti

At the site called Kangamoti twelve microbunds had been constructed to catch the runoff. The soil has a rather shallow loam to loamy sand layer over very gravelly loam. The layer starting at 20 cm has a gravel content of over 60 %, reducing largely the water holding capacity and the effective rooting volume of the soil. Although the salt and pH measurements give acceptable values, reasonable productivity of the soil can not be expected, not even with the applications of manure.

Loito

In the recent past the soils in this scheme (that lacks good maintenance) have shown very low yields of grains. Additionally, other technical causes might be brought forward, but as the water holding capacity of the rather medium to coarse textured soil is very modest, the lack of moisture in the rooting zone during the growing season is the most important reason for growth limitation. An adequate reconstruction of the bunds for an improved water distribution could improve this situation. On the other hand the topsoil of the site had high levels of the ESP (upto 22), being of great hindrance for the development of the roots of the plants; this in addition to the low fertility levels specifically for nitrogen and available phosphorus.

Nakapelewoi

The deep loamy soil of this site has good water holding characteristics.

A more functional design of the bunds could improve the potential for production of grains considerably. The EC and pH measurements showed acceptable levels for the growth of sorghum, but the available P level is low. Addition of manure will lead to furhter improvement of the productivity.

Nalilearii

The scheme is constructed on an erodable soils with slopes of 5-8 %. It shows a layer of 50 cm silty clay loam over very gravelly subsoil. Hence the water holding capacity is low, and labour intensive maintenance of the bunds is required to prevent increased erosion to take place on spots where the bunds are damaged.

5.5 KACHODA area

Several small water harvesting sites around Kachoda were visited:

Kachoda, Manalongoria, Kabarait and Lomareng.

Kachoda block I

Located at short distance West of the village Kachoda, this site receives water from a small lugga and as well from local runoff. The soil has a medium to coarse textured sandy loam) very permeable toplayer over an impermeable very gravelly sandy clay layer at 20 cm depth. The water holding capacity of the soil is rather low; more frequent watergifts (by natural rainfall ?) will be required for better results. If despite this low water holding capacity, the soil will have to be used, the incorporation of manure will be beneficial as the overall fertility level of the soil is very low.

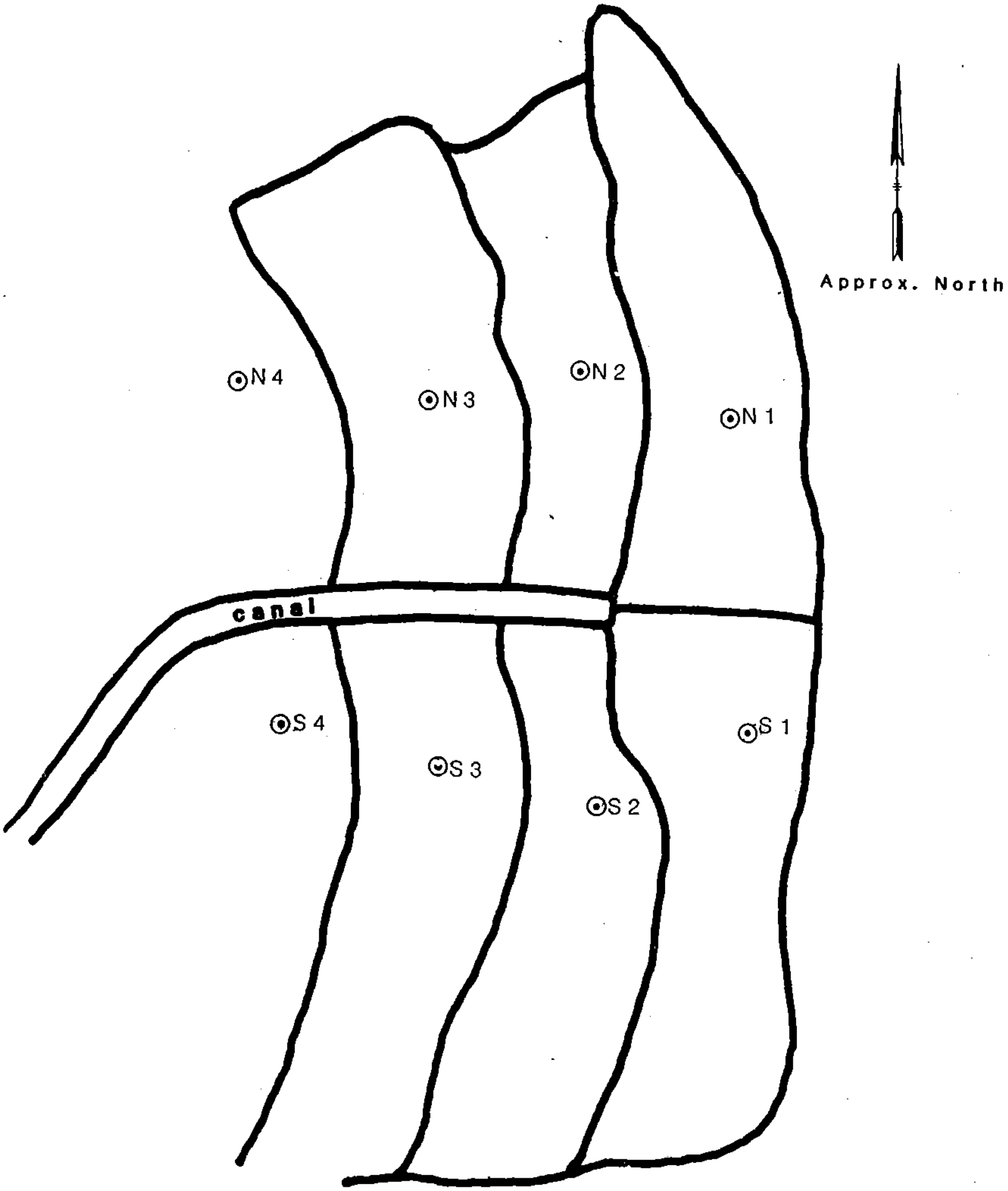
Manalongoria II

On plot 1, the deep soil consists of a 40 cm thick toplayer of loamy sand material overlying loam with some gravels. The incorporation of manure will increase the productivity if crop water requirements on this soil with a moderate water holding capacity are reasonably well met. The level of management and lay-out of these plots seem to be well balanced in the light of the soils, and needs and management capacities of the local population.

Kabarait II

Plot 3 shows the same characteristics as Manalongoria, and an acceptable yield for the region can be obtained.
Only the stronger sealing characteristics at the surface of the sandy loam topsoil might limit the germination of the sorghum plant to some extent, if no measures are taken.

LOARENGAK scheme (not to scale)



Lomareng

Lomareng plot 2, located South of Kachoda, has a soil with a moderate water holding capacity estimated from the observed 60 cm thick clay loam layer over compact silty clay loam with some gravels. As the infiltration rate is low, a good water management is required. The soil pH is high, but the accumulation of salts reaches only to low levels.

5.6 LOARENGAK area

Ngolekodos

Ngolekodos is situated about 13 kilometers North of Loarengak. Here several microbunds were constructed in an area that is susceptable to strong gully erosion. The measures taken are clearly ment to reduce further erosion and to provide fodder. The very stratified soil is made up by alternating moderately thick layers (upto 25 cm thick) of loamy sand and sandy loam, giving an overall moderate water storage capacity. The low soil fertility can be improved by addition of manure, and the formation of the strong surface crusts might be prevented by breaking up the surface at regular time intervals.

Loarengak

This flood irrigation scheme (construction started in 1982, and modified in 1985) has obtained variable results during the last season. A total of six basins of 5 to 7 hectares each have been constructed. Observations and sampling have been executed in each of the six basins. Also two additional have been made outside the western blocks of the scheme (N4 and S4). Situated on north-south oriented beach ridges, around 75 % of the soils have sandy loam and the remainder 25 % sandy textures in the topsoil.

basin N1

The observed soil has a 50 cm thick loamy toplayer over silty loam to silty clay loam. The water holding capacity is high. If water supply could be supplied at regular intervals, an acceptable productivity can be obtained, together with the incorporation of manure which will increase the fertility. Only a slight productivity depression might be expected by the sodium-content in the soil (ESP 6).

basin N2

Though part of this basin shows a thick overwash of sandy or gravelly sandy material. The remainder of the basin due to its medium textures has a high water storage capacity. The lower parts of the basin show the exceptional situation in which at 50 cm depth the soil - even at the end of the dry season - still contains some moisture usefull for crop production: a ratoon crop of sorghum is still developing well. No negative indications were derived from the pH (although somewhat high) and the electrical conductivity tests.

basin N3

The soil profile is characterized by an alternation of sandy and loamy materials, giving a moderate soil moisture holding capacity. The ESP and the pH are slightly high in the topsoil. At 70 cm and deeper high salt concentrations were detected, which are limiting plant growth. Also the pH is high at depth.

site N4, west of basin N3

The soil, principally consisting of sandy material, has a water holding capacity which is too low to store enough water for the plant during any longer period without rain and correctly has been left out of the scheme.

basin S1

The profile consists of clay loams or silt loams, and shows a slight increase of the salt content at 85 cm depth. The water holding capacity is high, and whenever some cautious slight leaching of the deeper salts can be practized, it will benefit the plant growth. But leaching of the topsoil should be executed with care as the ESP (around 9) should not be allowed to increase.

basin S2

This soil is similar to the soil of S1, but at 90 cm it is underlain by a gravelly sand layer. From a depth of 40 cm onwards slight saline conditions are detected. The topsoil has an ESP of 7, indicating production problems.

basin S3

Of all the basins this one has received most of the sediments from the main canal during the last flood: a 10 cm thick layer of materials had been deposited. This layer, with easily dispersable materials, has a low infiltration rate when moist. To improve the water holding capacity and the infiltration rate, an experiment has been undertaken by the local project management to mix this layer with the underlying sand layer. Although this practice might improve the situation in the top 20 cm, the underlying sandy or loamy, very permeable layers can not supply very much moisture to the plant due to the low water holding capacity of the soil. Although the topsoil fertility has, except for a strong deficiency of nitrogen, an acceptable level, the remainder of the profile lacks nutrients. Some improvement can be obtained by the application of manure.

site S4, west of basin S3
Similar to site N4, this sandy soil has a too low water holding capacity and too low fertility, being the correct justification to leave this area outside the scheme.

5.7 KAKUMA area

Loyaal
This water harvesting scheme, located several kilometers east of Kakuma, was recently constructed and the first production results were hopefull (local opinion), specifically the lower row of bunds, which receives additional water from the adjacent lugga.
One of the most important features of the calcareous soils in this scheme is the very compact clayey layer starting at a depth of 50-60 cm depth, which limits the water infiltration and the rooting depth, reducing the available water holding capacity to low levels. Taking into account very high permeability of the topsoil, only frequent water applications by flooding (if nature allows it) can solve the problem of water availability for the plant.
Samples taken from the highest row of bunds showed salt accumulations upto slight to moderate salinization level in the topsoil.

Lodakach
The most ambitious of the water spreading schemes in size, this spate diversion area located on the interfluve of two luggas, 40 km north of Kakuma, is still under construction. From one of the luggas water will be diverted towards the large bunds.
The character of the lugga give rise to the expectation that the higher part of the scheme will suffer from very strong

sedimentation and large quantities of water during the floods. This will lay a heavy load on the shoulders of those responsable for the regular maintenance work.
The soil examined on several spots within the scheme, seems to be rather homogeneous:
a 10-30 cm silty loam over strongly stratified fine sands upto a depth of 50-60 cm. This whole packet is overlying compact silty clay loam.
The infiltration rate (double ring method) was around 0.8 m/day (after 2 hours of infiltration), which is suitable under normal irrigation practices, but may be too low for the water required in this scheme:
It has been observed that the water infiltrating through the infiltrometer could not penetrate the layer of stratified and slightly cemented sands during the 2 hours observation period, resulting in a considerable lateral flow of water. Under the actual circumstances very low infiltration rates are obtained after the first 30-50 mm of water has entered the soil. Very high hydraulic conductivities - mainly horizontal - have been measured in the sand layer. Due to the existance of the very compact silty clay loam layer which is limiting the effective rooting depth, the water holding capacity is rather limited.
Although the figures obtained for the electrical conductivity are acceptable, the pH for the underlying silty clay loam is very high (pH 9.1). Also the ESP of 10 in the topsoil is far from ideal for plant growth.

5.8 LOKORI area

Lokwi

Being the first area of our investigation along the Kerio river around Lokori, part of the Lokwi irrigation scheme has been taken as a sample area to analyse the existing general problems of the soils and the effects of the irrigation on the productivity of the soils at a more detailed level. It can be assumed that the problems present in this scheme are also existing in the three other schemes, perhaps in variable degrees, as all the schemes are located in the same old floodplain of the Kerio river.

In the following individual plots with production problems soil observations have been made.

Lokwi block 1

area 3.3.22/24. Due to the micro-topographical unevenness of the surface, and the sandy texures of the soil, this area has a deficient water supply, giving rise to water deficiencies for the crop during the growing season. The accumulation of salts will contribute to the observed low yield levels too: the salt levels are varying from 2 mS/cm at the surface to roughly 6 mS/cm at a depth of 70 cm. Also the overall low fertility levels are contributing to the reported stunted growth.

area 3.3.16. The observation site in the direct neighbourhood of the former plot, shows a good crop growth on a soil with slightly finer texture and significantly lower salt contents (<0.3 mS/cm).

area 3.5.23. This site has a low to moderate water holding capacity. The fertility of the topsoil is low, and the pH of 8.8 and higher starting at 10 cm depth will not miss its negative influence on the productivity.

area 4.7.12. The soil has a moderate water holding capacity and shows high salt levels starting in the topsoil, varying irregularly from 2 to 3.5 mS/cm at depth. The very high ESP of the topsoil of 22, is also one of the causes for the low yields.

area 4.13.6. The loamy layer of 70 cm thickness lies abruptly over coarse sand, resulting in a total low water holding capacity and high infiltration rates. The topsoil pH is high (8.6).

area 4.14.5. The deep sandy soil has a low water holding capacity and a high infiltration rate, reducing the efficiency of the water application. The very high pH of the subsoil (pH 9.2) is also indicating that nutrient and/or toxicity problems will have to be expected.

Lokwi block 4

area 1.1.5. The augering showed a soil with medium to coarse textures. The estimated values for the water holding capacity are low, with the consequences for the water management and its efficiency.

Moreover there is formation of a strong crust at the surface which will result in lower water intake velocities.

The moderate high pH and low availability of phosphorus are depressing the productivity levels.

Lokwi proposed extension

In the proposed extension of the Lokwi scheme several observations have been made.

The first observation in the southern part, shows a soil with a moderate water storage capacity, without any significant salt accumulation, but with a pH of around 8.9 (high) and an ESP of 9 in the topsoil.

The second one in the eastern sector reveals a high moisture storage capacity. Further additional sampling is required for determination of the chemical characteristics of that site and its surroundings, as some high ESP values might be expected.

The third profile showed acceptable results: high storage capacity, pH between 7.5 and 8.0, and salt levels which are low in the topsoil but tend to increase to the slight salinization level in the deeper subsoil.

The area for the extension should be concentrated around the better observations, but the picture is to be completed with some more additional observations before an extension of the scheme might be established in the indicated area.

<u>Elelea</u>

Elelea proposed extension.

The observation in the proposed extension of the irrigated area of the Elelea scheme showed a good, deep loamy soil with a high water storage capacity upto 120 cm depth. The slight level of salinization should be taken care of. It may be necessary to include some additional applications of water to promote leaching processes of the salts that are actually present in the profile. Additional observations in the form of the analysis of soil pits/augerings and some tests for pH and EC are recommended for the remainder of the area, although the first impression might give the idea that the soil is rather homogeneous.

Elelea block 1
In the northern part of block 1, the farmers identified a field on which virtually no growth had been possible. Field observations revealed that this part of the block has very sandy soils, with a low water holding capacity, on which the crop easily can suffer from water shortages (also water supply problems has been mentioned by the farmers). It has also been observed that the accumulated salt levels are high at least at the surface (high sodium contents?). The soil fertility can be assumed to be very low.

Elelea block 2
The southern part of this block along the main irrigation canal showed spots with a dark coloured surface, being salt accumulations. Measurements of the electrical conductivity showed figures of around 28 mS/cm, which is classified as very high. The ESP is 25, which is also high. Without doubt these characteristics contribute to the very poor growth of sorghum.

Lotubai
In the Lotubai scheme one specific block (block number 1) with problems was indicated, and an investigation of the soil has been requested. Two possible causes for crop failure could be identified. As the water supply for the plant does not reach this very sandy area frequently enough, the water requirements are not met at all. Even with the normal gift, there will be a heavy deep-percolation, bringing a large portion of the water to the deeper layers of the soil, outside the reach of the roots of the plant. The other problem is the accumulation of salts. White and dark coloured surface crusts have been formed within a

distance of 50 m from the irrigation canal. In part the seepage through the sandy dyke along the canal could have brought excessive amounts of salt into the surrounding fields. Measurements gave results of between 26 and 33 mS/cm and high ESP figures of around 25. Crops normally do not perform at all under these circumstances. These two important characteristics lead to the recommendation to exclude these (or similar) fields from any type of agricultural use.

Morulem

During a short visit to this irrigation scheme, several problem areas were shown. The field observations revealed that in all cases the texture of the soil is very coarse (medium to coarse sand), with result that the water holding capacity is too low at the irrigation frequencies applied. Also the soil fertility is too low to assure a good crop performance.

A neighbouring field has a soil with sandy loam (65 cm) over sand (upto at least 120 cm depth) showing all together a very acceptable growth, even with the maize, that is cultivated here.

5.9 NADUME

The shambas in the Nadume area are located on the Rift Valley bottom at the eastern side of the valley, near the slopes of Mt. Maralal. The schemes occupy a very limited area and are fed by rainwater and with water diverted from a small lugga.

The actual shambas are producing well on the rather good soils of a loamy texture with low contents of gravel and stones at depth (>90 cm). Some intercalations of sandy loam layers are present but in general the moisture holding capacity and the infiltration rates can be expected to be good. The fertility can be expected to be of a moderate level: the only limitation is the slight nitrogen deficiency.

6. GENERAL CONCLUSIONS

As observed during the fieldwork throughout Turkana District the soils of the schemes are rather variable in their composition, which has various consequences for the soil and water management. As the artificial watersupply is by water spreading or irrigation, the main soil characteristics important for the water management are the water holding capacity of the soil within rooting depth of the crop and the infiltration rate. For crop production the low storage capacities should be avoided unless the frequency of water supply can be high enough. Care should be taken to avoid the accumulation of salts within or slightly below the rooting zone (leaching requirements).

In general fertility levels of nitrogen are low, but reasonable improvements might be obtained with the application of manure.

In future before new schemes or extensions of the older ones are established, it is strongly recommended to execute an evaluation of the soils to avoid disappointments, due to the type of soil problems mentioned in this report.

7. REFERENCES

1. Ecosystems ltd 1985
Turkana District Resources Survey 1982-1984
Main report, Nairobi.

2. Howlett DJB 1984
A case study on a water harvesting project in Turkana-Kenya.
thesis, draft, Swithland, U.K.

3. KMD 1984
Climatological statistics for Kenya.
Kenya Meteorological Department, Nairobi

4. Morgan WTW 1971
Land units of the Lokori area.
The South Turkana Expedition
Scientific papers IV, The Geogr. Journ.
vol 137 (1) 14-36, UK

5. Sombroek WG, HMH Braun and BJA van der Pouw 1982
Exploratory Soil map and Agro-climatic zone map of Kenya.
Kenya Soil Survey, report E1, Nairobi

6. Vleeshouwer JJ and DO Michieka 1974
Irrigation suitability of the soils and waters of the flood plain of the Kerio river NE of Lokori (Turkana District).
Kenya Soil Survey, report P17, Nairobi

Appendix 1. Water analysis Turkwel river (Oct 86)

pH	9.1
conductivity micro S/cm	145
sodium me/l	.6
potassium me/l	.11
calcium me/l	.3
magnesium me/l	.2
carbonates me/l	.32
bicarbonates me/l	1.16
chlorides me/l	.4
sulphates me/l	nil
sodium adsorption ratio	1.2

Appendix 2. Characteristics of the analysed soil profiles (summary)

site + no	depth cm	texture	EC2.5 mS/cm	class	pH	CEC me/100g	ESP	exch K	exch Na	exch Ca	exch Mg	P ppm	C %
								me / 100 g					
KAL 1 Kalemenyang A	0-20	silty clay	.25	So	8.0	17.5	.02	.9	.3	10.7	4.1	17	.4
	20-50	clay	.32	So	8.1								
	50-70	loam	.35	So	8.3								
	70-90	clay											
	90-120	silty clay											
	120-200	clay											
KAL 2 Kalemenyang A	0-10	silty clay	.31	So	8.5	37.5	.02	2.8	.7	26.2	11.4	13	.9
	10-20	silty clay	.17	So	8.2								
	20-40	clay											
	40-70	clay	.36	So	8.2								
	70-120	sand											
KAL 3 Kalemenyang A	0-30	clay	2.60	Sl	7.4	31.2	.03	2.0	.8	24.5	7.0	20	.8
	30-90	clay											
	90-110	loam											
	110-120	clay											
KAL 4 Kalemenyang B	0-5	silt clay	1.20	Sl	7.6								
	5-30	silt clay	.58	So	8.2	29.0	.03	.9	1.0	26.9	6.9	13	.5
	30-60	sand	.42	So	8.0								
	60-120	sand	.18	So	8.6								
KAL 5 Kalemenyang B	0-30	silty clay	.29	So	8.4	26.3	.03	1.1	.7	20.8	5.6	17	.2
	30-40	clay											
	40-100	clay	.54	So	7.8								
	100-180	sandy clay											
KAL 6 Kalemenyang B	0-30	silty clay	.99	So	7.9								
	30-50	silty clay											
	50-70	sandy clay loam	1.81	Sl	7.6								
	70-90	sandy clay loam											
	90-100	sandy loam											
KAL 7 Kaloteker	0-10	silty clay	.40	So	8.2	30.2	.02	1.1	.5	27.8	6.2	21	.3
	10-50	clay	.50	So	8.2								
	50-70	loamy sand											
	70-100	loamy sand	.25	So	8.3								
	100-120	sandy clay loam											
KAL 8 Kaloteker	0-20	silty loam	1.32	Sl	7.8	32.0	.01	2.0	.4	27.8	4.5	32	.8
	20-50	sandy loam	1.05	So	7.7								
	50+	coarse sand											
KAL 9 Kotela	0-10	silt loam	.53	So	8.0	22.0	.02	1.1	.5	20.4	3.9	24	.4
	10-30	loam	.33	So	8.0								
	30-50	sand											
	50-70	loamy sand											
	70-100	loam	.48	So	8.3								
	100-120	clay											

site + no	depth cm	texture	EC2.5 mS/cm	class	pH	CEC me/100g	ESP	exch K	exch Na	exch Ca	exch Mg	P ppm	C %
								me / 100 g					
Ndadunga	0-20	silty clay	.54	So	8.1	29.0	.05	1.0	1.6	29.9	6.6	21	.3
	20-30	silty loam											
	30-80	clay	2.45	Sl	8.2								
	80+	stone											
KAI 1 town Kaikworr	0-20	silty clay	.40	So	8.3	24.7	.07	.8	1.8	29.8	5.0	14	.5
	20-50	silty clay	.29	So	8.7								
	50-55	sand	.29	So	8.6								
	55-90	clay	.41	So	8.7								
	90-105	clay											
	105-120	clay and stones	.21	So	9.0								
KAR 1	0-40	silt loam	.64	So	8.1	33.5	.06	1.1	1.9	29.8	5.6	35	.4
	40-120	grav clay											
KAR 2	0-20	grav clay	.34	So	9.3	35.7	.08	1.2	3.0	31.7	4.9	6	.3
KAR 2 a	0-3	sand											
	3-20	grav clay	.89	So	8.9	18.3	.03	1.1	.6	20.9	2.8	12	.3
	20-80+	grav clay											
Kangamoti	0-20	loam	.22	So	8.1	22.3	.03	1.4	.7	18.8	3.5	23	.4
	20-60	very grav loam											
Loito	0-20	sandy loam	.36	So	8.1	31.0	.22	.9	7.0	28.1	3.5	9	.4
	20-120	loamy sand											
Nakapelewoi (A)1	0-20	loam	.47	So	8.1	25.0	.02	1.1	.6	23.7	2.5	8	.4
	20-120	loam											
Nalilearii	0-50	silty clay	.23	So	8.0	21.0	.04	.9	.9	20.6	2.8	30	.3
	50+	gravel											
Kachoda 1	0-20	sandy loam	.48	So	8.1	24.5	.03	.7	.7	18.8	4.1	29	.4
	20+	gravel											
Manalongoria II	0-30	loamy sand	.17	So	8.0	18.0	.04	.7	.7	22.5	4.3	15	.3
	30-50	loam											
	50-70	grav loam											
	70+	stone											
Lomareng plot 2	0-50	clay loam	.56	So	8.4	37.5	.03	1.3	1.1	32.6	6.3	20	.4
	50-60	grav silty clay											
Ngolekodos	0-10	loamy sand	.26	So	8.3	16.5	.04	.7	.7	13.9	2.2	15	.4
	10-30	sandy loam	.26	So	8.3								
	30-50	loam											
	50-80	sandy loam											
	80-120	loamy sand											
Loarengak N1	0-50	loam	.24	So	8.3	27.0	.06	1.2	1.5	37.3	6.0	25	.6
	50-80	silt loam	.51	So	8.3								
	80-100	silt loam											
	100-120	silty clay loam	.76	So	8.3								

site + no	depth cm	texture	EC2.5 mS/cm	class	pH	CEC me/100g	ESP	K (exch me / 100 g)	Na (exch me / 100 g)	Ca (exch me / 100 g)	Mg (exch me / 100 g)	P ppm	C %
Loarengak N2	0-5	silt loam											
	5-20	loamy sand	.20	So	8.4	19.2	.05	.5	.9	21.6	3.3	19	.3
	20-50	sandy loam	.19	So	8.2								
	50-60	loamy sand											
	60-80	loam	.17	So	8.6								
	80-100	silty loam	.42	So	8.2								
	100-120	silty clay loam	.36	So	8.4								
Loarengak N3	0-15	loamy sand	.22	So	7.7	19.5	.07	.5	1.3	18.8	3.4	23	.3
	15-50	sandy loam	.15	So	8.1								
	50-60	grav loamy sand	.48	So	8.0								
	60-80	silty clay loam	1.80	S1	8.7								
	80-120	silty clay loam	4.09	S2	8.4								
Loarengak N4 outside scheme	0-20	loamy sand											
	20-50	grav sand											
	50-70	loam											
	70-90	grav loamy sand											
Loarengak S1	0-35	silty clay loam	.53	So	8.4	22.3	.09	.7	1.9	18.9	5.3	19	.4
	35-85	clay loam	.63	So	8.9								
	85-100	clay loam	1.16	S1	7.5								
loarengak S2	0-40	silty loam	.20	So	8.2	18.5	.07	.5	1.3	15.2	4.4	13	.3
	40-70	silty clay loam											
	70-90	silty clay loam	1.22	S1	7.9								
	90-120	grav sand	1.10	S1	7.6								
Loarengak S3	0-10	sand mixed with silt	.80	So	7.5	13.8	.07	.5	1.0	17.7	2.2	17	.2
	10-20	sand	.18	So	8.1								
	20-60	sandy loam	.67	So	7.8								
	60-90	loamy sand											
Loarengak S4 outside scheme	0-10	sandy loam	.17	So	8.0								
	10-30	loam	.20	So	8.4								
	30-120	sand +stone											
Loyaal 1	0-10	silty clay loam	.55	So	8.1	29.3	.05	1.2	1.5	29.1	5.2	12	.6
	10-30	silty loam	.55	So	8.2								
	30-40	silty clay loam	.36	So	8.3								
	40-50	silty clay	.33	So	8.6								
Loyaal 2	0-10	silty loam	2.20	S1	7.8	26.3	.07	1.4	1.8	28.0	4.6	26	.6
	10-30	silty clay loam	.70	So	8.2								
	30-50	silty clay	.73	So	8.3								
Lodakach	0-10	silt loam	.71	So	8.5	25.0	.10	.8	2.5	23.8	5.0	21	.4
	10-30	fine sandy loam	.71	So	8.6								
	30-50	fine sand	.28	So	8.9								
	50-60	silty clay loam	.48	So	9.1								
Lokwi 1 4 7 12	0-10	sand	2.67	S2	7.7	12.7	.23	.2	2.9	15.5	.6	26	.2
	10-50	loamy sand	2.02	S1	7.9								
	50-60	sand	3.55	S2	8.0								
	60-70	loamy sand											
	70-80	sand											
	80-90	loamy sand	3.44	S2	8.1								
	90-120	sandy loam	2.88	S1	7.9								

site + no	depth cm	texture	EC2.5 mS/cm	class	pH	CEC me/100g	ESP	K	Na	Ca	Mg	P ppm	C %
								exch me / 100 g					
Lokwi 1 4 14 5	0-10	sand	.15	So	8.8	14.0	.04	1.1	.6	13.8	.8	12	.1
	10-30	loamy sand	.16	So	7.9								
	30-50	sand	.14	So	8.4								
	50-70	sand											
	70-110	loamy sand	.15	So	9.2								
	110+	coarse sand											
Lokwi 1 3 5 23	0-10	sand	.17	So	8.3	11.5	.03	1.1	.4	10.0	.9	17	.1
	10-50	loamy sand	.13	So	8.8								
	50-60	sandy loam											
	60-110	loamy sand	.42	So	8.8								
	110-120	sand	.20	So	9.1								
Lokwi 1 3 3 16	0-20	sandy loam	.32	So	8.2	30.0	.03	1.0	.8	16.1	1.9	15	.4
	20-120	sandy loam											
Lokwi 1 4 13 6	0-50	loam	.18	So	8.6	12.5	.03	1.1	.4	11.5	1.2	19	.3
	50-70	sandy loam	.30	So	8.3								
	70-120	coarse sand											
Lokwi 1 3 3 22/24	0-10	sandy loam	1.98	S1	7.5	14.3	.03	1.5	.5	13.9	.5	15	.3
	10-60	fine sandy loam	3.09	S2	7.8								
	60-120	fine sandy loam	5.45	S3	7.5								
Lokwi 4 1 1 5	0-10	grav sandy loam	.17	So	8.6	25.3	.05	.9	1.3	21.6	4.3	12	.3
	10-30	silty loam	.17	So	8.6								
	30-40	sandy loam											
	40-50	loamy sand											
	50-120	sand											
Lokwi ext 1	0-20	sand	.18	So	8.9	8.2	.09	1.0	.8	9.3	1.2	24	.2
	20-30	loamy sand	.18	So	8.9								
	30-40	sandy loam											
	40-50	sandy clay											
	50-70	loam											
	70-120	loamy sand											
Lokwi ext 2	0-10	silty loam											
	10-50	loam											
	50-60	silty loam											
	60-70	loamy sand											
	70-120	loam											
Lokwi ext 3	0-10	silty loam	.17	So	7.7	28.0	.03	4.0	.9	21.6	3.3	15	.7
	10-30	loam	.78	So	7.5								
	30-60	silty clay loam	.77	So	8.1								
	60-70	loam											
	70-80	silty loam	1.04	So	7.7								
	80-85	loamy sand											
Elelea A 1	0-15	silty loam	1.45	S1	7.5	34.3	.05	1.3	1.6	29.3	7.2	33	.6
	15-40	loam											
	40-60	silty loam											

site + no	depth cm	texture	EC2.5 mS/cm	class	pH	CEC me/100g	ESP	K (exch, me / 100 g)	Na (exch, me / 100 g)	Ca (exch, me / 100 g)	Mg (exch, me / 100 g)	P ppm	C %
Elelea block 1	0-20	loamy sand											
	20-50	sand											
	50-120	loamy sand											
Elelea block 2	0-30	sandy loam (dark surface)	28.10	S4	7.2	29.0	.25	1.5	7.2	38.1	8.6	27	.5
Lotubai block 1	0-20	loamy sand											
		(dark surface)	33.10	S4	7.6								
		(white surface)	26.90	S4	8.2								
	20+	sand											
Kabarit 11 pl 3	0-30	sandy loam											
Morulem 1	0-20	sandy loam											
	20+	coarse sand											
Morulem 2	0-120	sand											
Morulem 3	0-65	sandy loam											
	65-120	sand											
Nadume	0-80	loam	.22	So	7.8	25.7	.03	1.9	.8	21.3	3.8	29	.9
	80-120	sandy loam	.23	So	8.6								

note 1
classification of the degree of salinization

none	So	0-1,2 mS/cm
slight	S1	1.2-2.5
moderate	S2	2.5-5.0
strong	S3	)5.0

note 2
EC 2.5 electrical conductivity measured in 1:2.5 vol/vol soil- water extract.

note 3
P ppm measured according to the Olsen method.

Appendix 3. Soil moisture holding capacity.

site + no	total mm	class	site + no	total mm	class
Elelea A 1	123	high	LodaKach	77	low
Elelea block 1	78	low	Loito	96	mod
KAI 1	121	high	Lokwi 1 3 3 22/24	107	mod
KAL 1	132	high	Lokwi 1 3 5 23	81	mod
KAL 2	99	mod	Lokwi 1 4 13 6	91	mod
KAL 3	122	high	Lokwi 1 4 14 5	71	low
KAL 4	81	mod	Lokwi 1 4 7 12	81	mod
KAL 5	124	high	Lokwi 4 1 1 5	76	low
KAL 6	128	high	Lokwi extension 1	91	mod
KAL 7	142	high	Lokwi extension 2	126	high
KAL 8	72	low	Lokwi extension 3	113	mod
KAL 9	109	mod	Lomareng plot 2	89	mod
KAR 1	112	mod	Lotubai bl 1	64	low
Loarengak N1	127	high	Loyaal 1	66	low
Loarengak N2	117	mod	Loyaal 2	68	low
Loarengak N3	111	mod	Manalongoria II	84	mod
Loarengak N4	72	low	Nadume	120	high
Loarengak S1	124	high	Nalilearii	81	mod
Loarengak S2	103	mod	Ndadunga	104	mod
Loarengak S3	86	mod	Ngolekodos	97	mod
Loarengak S4	53	low	Morulem 3	80	mod

note 1:

Estimated values for easily available moisture:

	%		%
sand	5	clay loam	10
loamy sand	7	clay	10
sandy loam	8	loam	11
sandy clay	9	silty clay loam	11
silt loam	10	silty clay	12

note 2:

Classification criteria for total easily available soil moisture, calculated over 120 cm soil depth:

very high	160-200
high	120-160
moderate	80 -120
low	40 - 80
very low	< 40 mm

Appendix 4. Infiltration rates and hydraulic conductivities.

site + no	inversed augerhole method			double ring method
	depth cm	description	cm/day	m/day
Lodakach	0-15	very rapid	350	0.8
	0-30	slow-mod	80	
	0-60	mod-mod rapid	100	
Loyaal 2	0-17	very rapid	500	
Loarengak S3	0-6	very rapid	480	
Lomareng plot 2				0.1
KAL 1	0-20	slow-mod	60	
	0-95	slow-mod	50	
Kachoda I	0-15	very rapid	300	
KAR 1	0-65	slow-mod	30	
	0-90	very slow	10-15	
KAR 2	0-65	slow to mod	30	