# THE SOILS OF THE AREA BETWEEN HOLA AND WENJI, TANA RIVER, KENYA

(BURA IRRIGATION SCHEME)



by

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October 1974



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October 1974

*Prepared for*
*MITCHELL COTTS SERVICES LTD.*
*COTTS HOUSE*
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*LONDON*

ACKNOWLEDGEMENTS

This report is based on fieldwork carried out between 2nd July and 26th July 1974. The ease and facility with which the fieldwork was undertaken would not have been possible without the help of a number of people to whom I am deeply grateful :

Mr S Sponder, Managing Director, Mitchell Cotts Holdings (East Africa) Ltd.

Mrs A Lutton, Personal Assistant to Mr Sponder.

Mr E Khayumbi, Manager of the Hola Pilot Project.

During the course of the fieldwork, I was also fortunate to hold discussions with soil scientists and agriculturalists from a number of organisations; Mr B Ambrose (Tana River Authority), Dr J Coulter (Rothamsted Experimental Station), Mr M'buru (Director of Agriculture), Mr Mirie (General Manager, National Irrigation Board), Dr Nyandat (Head of the Soil Survey of Kenya), Mr Spykman and Mr J Van Lidth (ILACO) and Mr J.Yelf (Group Agricultural Adviser, Mitchell Cotts Services Ltd). To these and all others who helped on the project, I should like to express my thanks.

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Chapter 1

## INTRODUCTION

### 1.1 Terms of Reference

The object of the soil survey was to assess the general suitability of the soils between Hola and Wenji, on the west bank of the Tana River, with a view to the commercial cultivation of cotton. At the outset of the project, it was envisaged that such a commercial irrigation scheme would include a total cultivated area of up to 16,000 hectares.

The area had not been surveyed in any detail by either of the two earlier surveys in the area, Acres - ILACO (1967) and ILACO (1973). It was hoped that if a suitable area could be identified it would lie at an elevation of less than 250ft O.D. The approximate boundaries of the survey area were to be :

on the east, the flood plain of the Tana River

on the north, northing 9830 on Kenya 1:100000 D.O.S.523 (Series Y633) maps.

on the west, easting 603

on the south, northing 9801

In practice, it was found necessary to go one kilometre further west than was laid down in the original terms of reference.

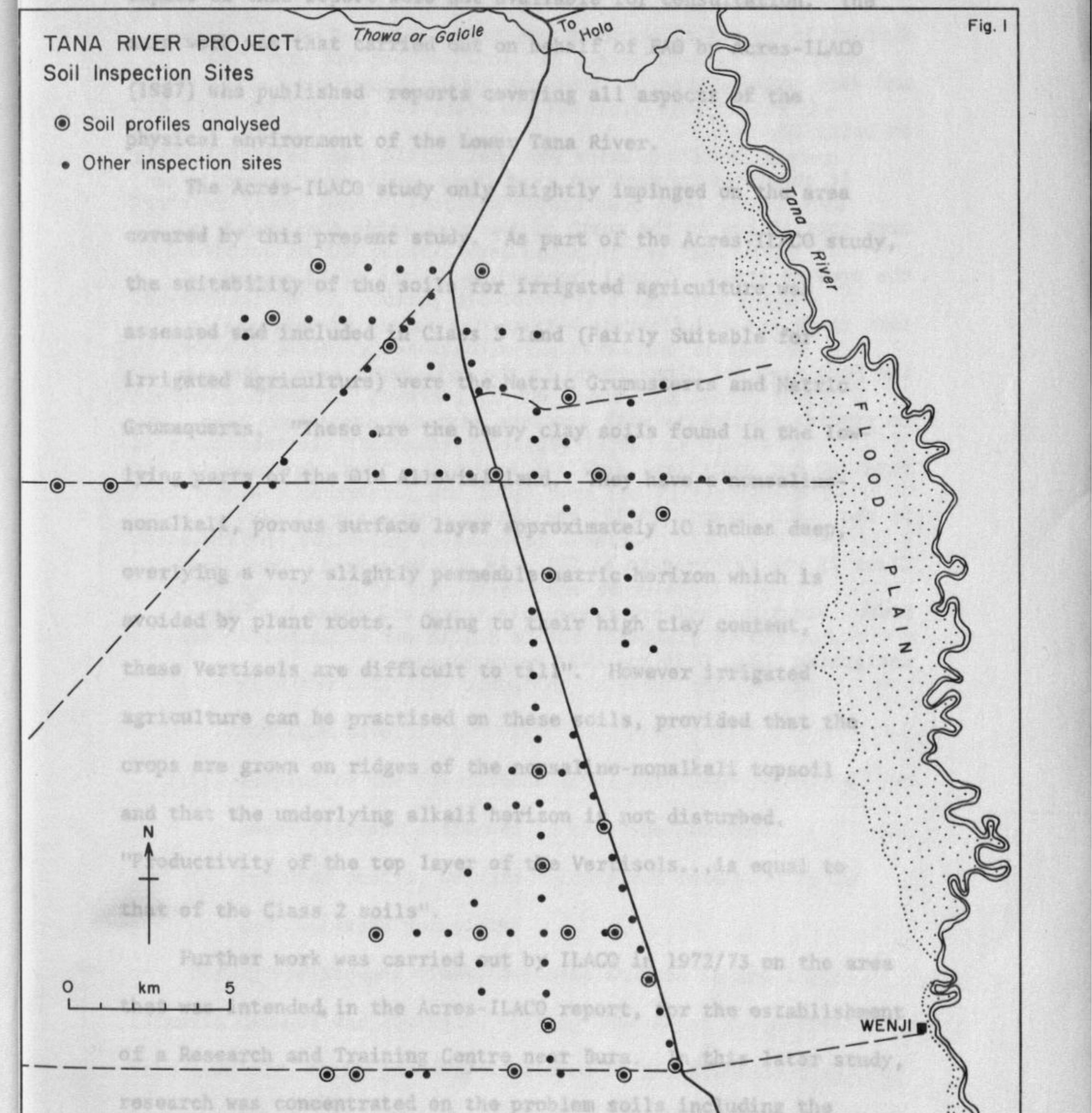
### 1.2 Survey procedure

Preliminary air photograph interpretation (1:80,000 flown in 1963), study of earlier reports for adjacent areas and reconnaissance traverses showed that in the area demarcated by the terms of reference, the dominant soil types were Vertisols-Grumaquerts and Grumusterts. Since earlier work had categorised these soils as being either Class 2B or Class 3(i.e. at least fairly suitable for irrigated agriculture), it was evident that survey effort should be concentrated on the clay plains adjacent to the main Hola-Garsen road. Away from the clay plains, soils are poorer, topography becomes too irregular for irrigated agriculture while the 'natural' vegetation becomes much denser.

In view of the scale of the maps and air photographs, and the objectives of the project, the survey scale is basically a semi-detailed one having a number of purposes : resource inventory, project location and feasibility study. It should be pointed out that to fully isolate management problems, if it is decided to go ahead with the project, will require a much more detailed study on a scale of 1:10,000. One major road (Hola-Garsen) ran approximately NNW-SSE through the area, while traces cut in the bush by the oil company when prospecting, provided access lines for east-west movement. The roads and the oil company traces provided the basic grid for the soil survey and the aim was to site auger holes or pits to a depth of 1m or more with a frequency of about 1 site / 125 hectares. By and large, the clay plains are characterised by their uniformity of soil, slope and vegetation and, at this stage, greater intensity of either inspection sites or sample pits was not considered necessary, the survey being basically required to demarcate the areas of the clay plains and to collect soil samples from type locations for analysis. The locations of inspection sites and sample pits are shown on fig.1. 98 samples from 27 locations were collected for detailed analysis in the laboratory while 125 determinations of electrical conductivity (for salt) and pH were made in the field for sites different from those sampled for laboratory analysis.

## 1.3 Previous work

With the Tana River being the main river in the country, a certain amount of survey work has been carried out in the past.



The earliest scientific survey was a reconnaissance study made by E. Bellis (then Chief Soil Chemist) in the late 1950's but copies of this report were not available for consultation. The main work was that carried out on behalf of FAO by Acres-ILACO (1967) who published reports covering all aspects of the physical environment of the Lower Tana River.

The Acres-ILACO study only slightly impinged on the area covered by this present study. As part of the Acres-ILACO study, the suitability of the soils for irrigated agriculture was assessed and included in Class 3 land (Fairly Suitable for irrigated agriculture) were the Natric Grumusterts and Natric Grumaquerts. "These are the heavy clay soils found in the low-lying parts of the Old Alluvial land. They have a nonsaline-nonalkali, porous surface layer approximately 10 inches deep, overlying a very slightly permeable natric horizon which is avoided by plant roots. Owing to their high clay content, these Vertisols are difficult to till". However irrigated agriculture can be practised on these soils, provided that the crops are grown on ridges of the nonsaline-nonalkali topsoil and that the underlying alkali horizon is not disturbed. "Productivity of the top layer of the Vertisols...is equal to that of the Class 2 soils".

Further work was carried out by ILACO in 1972/73 on the area that was intended, in the Acres-ILACO report, for the establishment of a Research and Training Centre near Bura. In this later study, research was concentrated on the problem soils including the Natric Grumusterts. As a result of these studies, the Natric Grumusterts were classified as being 2B if the nonsaline-nonalkali topsoil had a thickness of 0.25-0.30m and it was considered that such soils "do not pose any problems" for irrigated agriculture.

However, if the natric horizon was found at a depth of about 0.15m, then the soils were downgraded and placed in class 3 which is regarded as being only fairly suitable for irrigated agriculture. Such soils tended to occur in the lowest parts of the landscape and were somewhat heavier than the Natric Grumusterts classified as being 2B.

It should be pointed out that these soils were mapped in an area some 60 kms to the north of the area being considered in the present study. Visual impressions in the field suggested that there was a difference between the Natric Grumusterts in the Bura area and those found in the Hola-Wenji area. However, to provide continuity with previous work the names have been retained but additional suffixes employed. Thus, for example, in the ILACO report (1973), the Natric Grumustert placed in Class 2B was referred to as GU1 - in the Hola-Wenji area, grey brown, brown and red brown variants occur and these have been designated GU1g, GU1b and GU1r respectively.



# Chapter 2

## THE PHYSICAL ENVIRONMENT

### 2.1 Geology

Underlying the project area, at depths greater than 1650m, are rocks of Eozoic, Paleozoic and Mesozoic ages. While the greater part of East Africa remained above sea level during Tertiary times, lower Tertiary strata have been encountered in boreholes in the coastal area north of the Tana river (Saggerson, 1972). During mid-Tertiary times, the absence of tectonic activity resulted in the formation of the Sub-miocene peneplain. However, in the lower Tana basin, there is a considerable thickness (possibly 1570m) of middle and late Tertiary sediments, and these have led Pulfrey(1960) to postulate the following sequence of events:

(i) maturation of the Sub-miocene peneplain

(ii) flooding to the margin of the peneplain by the sea, with the coastline occurring at about the present 105-125m level.

(iii) warping of the Sub-miocene level with deposition of lower Pliocene sediments in the Tana embayment

(iv) regional uplift, seaward tilting and formation of an end - Tertiary peneplain

During Pleistocene times, eustatic changes in sea level, climatic changes and continued tilting have meant that streams like L.Galole, which probably developed in mid-Pliocene times, became further incised in the area to the west of the project area, while the latter was an area of aggradation. It has been suggested (Acres-ILACO, 1967) that the clay plains are the truncated remnants of "an infilled drainage system of very large extent" which "was deeply incised into the end-Tertiary sediments but became aggraded with heavy clay". These deposits have been subsequently eroded as have the higher lying (10-15m) end-Tertiary peneplain which generally lies to the west of the project area, though small areas of clay are also found within the latter. Thus the Old Alluvium, the clay plains, represents a Pleistocene surface while the contemporary floodplain of the Tana river consisting of New Alluvium is considered to be Holocene infill.

2.2 Physiography

Reworking of the older deposits by eastward flowing streams, such as L.Galole, have done much to modify the physiography of the study area and there is considerable diversity in the area which has been termed "the clay plains". The physiographic divisions are shown in fig.2.

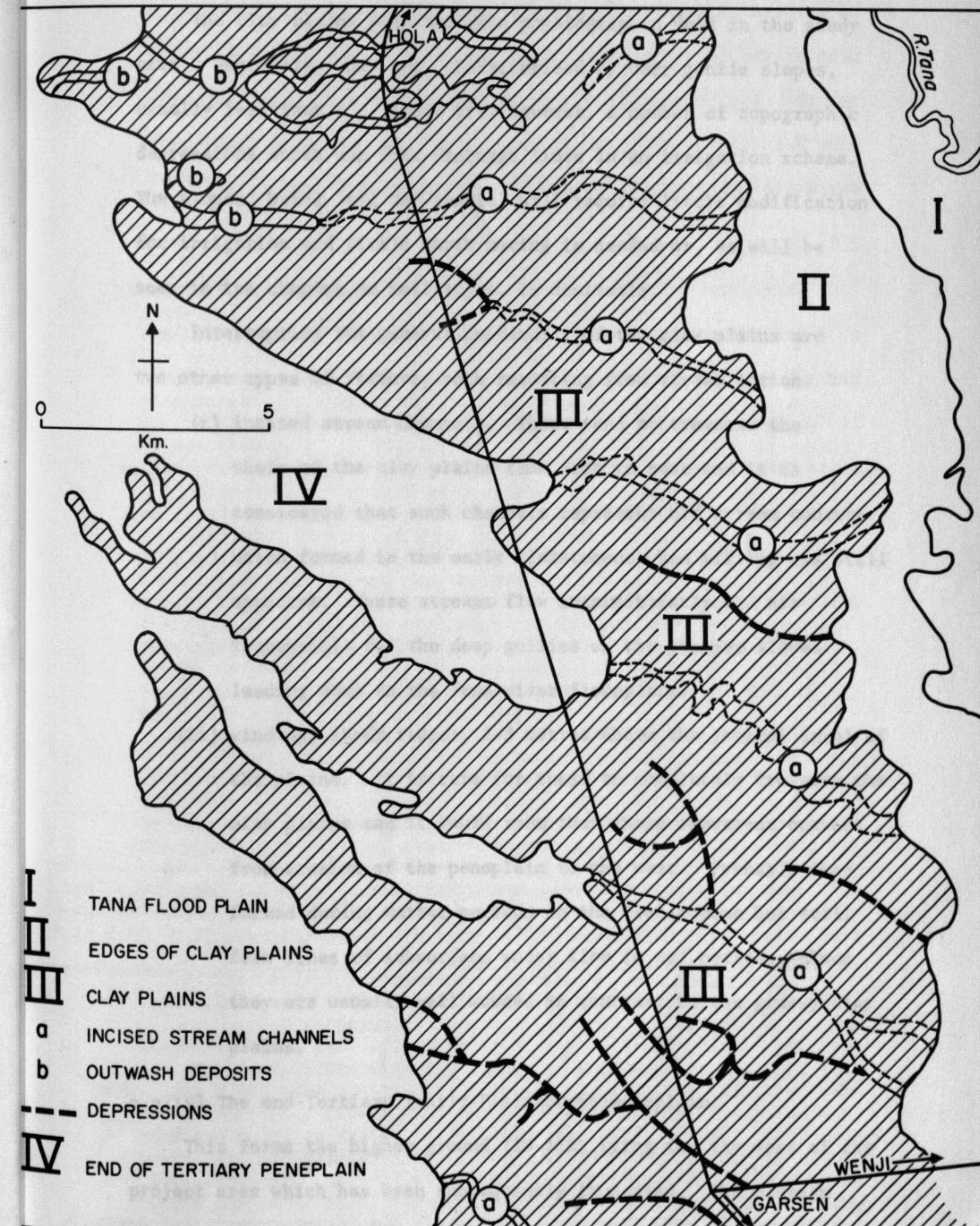
2.2(i) The Tana floodplain.

The Tana floodplain consists of levees and a meander floodplain which becomes inundated with water whenever the Tana river is in flood. The flooding can cause part of the levees to be washed away while the floodwaters reach as far as the edge of the higher lying Old Alluvium.

2.2(ii) Edges of the Clay Plains.

The clay plains slope down to the present Tana floodplain over a distance of about 4-6kms in places. The slopes are steeper (up to 8°) than those found elsewhere in the study area and they are not uniform. In places, there are extensive areas of flat lands which may represent old terraces of the Tana river. Some of the luggas (intermittent streams) which have flowed from the west have eroded the clay plains and have caused gullying on the steeper slopes by cutting down into the clay sediments. Elsewhere along the edge of the clay plains, gully erosion is in evidence.

Fig 2 PHYSIOGRAPHIC UNITS



2.2(iii) The Clay Plains.

The clay plains form the main physiographic unit in the study area. Generally, they are characterised by very gentle slopes, usually less than 1°. There are, however, a number of topographic depressions which can form drainage lines in an irrigation scheme. The slopes, being long and gentle, will require little modification for irrigation and little earth moving is needed or, as will be seen in the chapter on soil types, is desirable.

Interrupting the general uniformity of the clay plains are two other types of feature, both resulting from stream action:

(i) incised stream channels. These tend to traverse the whole of the clay plains from west to east and it is considered that such channels represent old stream courses which formed in the early Pleistocene when tilting was still apparent. These streams flow intermittently and are responsible for the deep gullies on the steeper slopes leading down to the Tana river floodplain.

(ii) winding, sandy ridges, 2-3 metres above the general level of the plains. It is rare for these to completely traverse the clay plains and it would seem that these represent outwash from erosion of the peneplain to the west. Probably they formed during wetter periods in the Pleistocene but still form lines of subsurface water flow in wet periods, since they are usually well wooded in contrast to the grassy clay plains.

2.2(iv) The end-Tertiary (early-Pleistocene)peneplain.

This forms the higher ground (10-15m) lying to the west of the project area which has been subsequently truncated. The plateau consists of sandy deposits which are covered with a dense bush vegetation.

However, stream action has caused considerable erosion and, instead of being a uniform surface, is rather broken up by numerous luggas. Some of the latter are obviously relics of past wetter conditions for they can be very broad (up to 1km in width) and floored with clay deposits not dissimilar from those that form the clay plains, sensu stricto, though the clay is of more recent deposition.

2.3 Climate

In general terms, Acres-ILACO (1967) consider that the climate of the study area consists of two rainy seasons, in late April and May and in late October and November. A 'cool' dry winter occurs in June, July and August with a summer season from January to late-April. However, such a description can be extremely misleading when the climate is analysed with respect to cultivation practices.

Meteorological observations have been kept at Hola since 1956, just after the irrigation scheme was established. Rainfall records have been kept since the start and appear to be relatively complete-at the time of fieldwork, records from July 1973 onwards were not available but analysis of 17 years' records (1956-1972 inclusive) shows that rainfall can occur at any time of the year (table 2.1). There is, however, considerable variability not only from year to

| Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 21.4 | 14.0 | 36.6 | 76.0 | 40.8 | 27.8 | 17.0 | 16.2 | 33.0 | 38.0 | 90.3 | 51.8 |

Table 2.1 Average monthly rainfall (mms) at Hola 1956-1972.

year but also spatially. For instance in 1967 the annual rainfall total amounted to 773.5 mms while in 1970 it was only 274.9 mms. When considered monthly, there is even greater variation which can make management of the heavy clay soils very difficult. In April 1965 only 16 mms of rain fell and consequently the cotton crop relied entirely upon irrigation. Two years later (April 1967) the rainfall amounted to



248.2 mms and little irrigation was necessary. Problems can be caused by receiving rainfall when it is not expected in any quantity. July and August are dry months, even though rain may fall on 4 or 5 days, when cotton is being picked, but rainfalls, such as the 61.1 mms received in August 1969, could seriously interfere with cotton picking, especially if machine picking is to be considered.

The locations of Matanya and Kiarakungu mentioned on page 9 could not be determined. It is thought that they are fairly near to Hola.

at Matanya, kms to the of Hola, it was 189.7 mms while at Kiarakungu, kms to the of Hola, it was 33.2 mms.

Temperature has only been recorded at Hola since 1964 but it is clear that it is much more regular than the rainfall. In the summer, average maximum temperature may exceed 38°C and even in the coldest months (May and June) the average maximum temperature rarely drops below 29°C. The average minimum temperature may fall as low as 19°C in July and August.

Limited records of relative himidity are also available. These show that relative himidity is usually above 80% at 0900 hrs throughout the year and that it is between 70% and 80% at 2100 hrs. However, there is greater variability during the afternoon:

| | | | |
|---|---|---|---|
| 1500 hrs | January - April | relative humidity | 70 - 76% |
| | May - November | | 60 - 70% |
| | December | | < 60% |

Thus, while the climate is generally favourable for cotton growth, it can seriously affect management of the soils and the amount of water required for irrigation. For the commercial cultivation of cotton, there will, of necessity, have to be considerable flexibility in timing of mechanical and irrigation operations.

eased for small farmers than large operations. Bdy.

## 2.4 Vegetation

While the clay plains are basically grasslands, the other physiographic units usually have a bush cover of varying thickness. However, it is not considered that grassland is the natural vegetation community on the clay plains since there is considerable evidence of burning. In the past, it is likely that the bush and tree vegetation has been progressively burnt out so as to provide extensive grazing not only for cattle but also wild animals. During the course of the survey a rough count was made of the wild animals and in the survey area the main species recorded were Grant's Gazelle (432) Zebra (421) Oryx (126) and Eland (120). Elephant are also common in the area and these wild animals must also have an effect on the vegetation.

On the clay plains two types of vegetation are encountered:

(i) Shrub grassland/open bushland vegetation. This is the most common association encountered and it is extremely variable on account of human interference and pressures caused by the wild animals. ( The Tana River is an area where there has been a concentration of wildlife due to the absence of any extensive areas of cultivation). Grass species include <u>Aristida sp.</u>,<u>Chlorus spp</u>, <u>Schoenfeldia transiens</u> and <u>Sporobulus helvolus</u>,the latter species being a good grazing grass. Tree and bush species tend to be infrequent due to burning, especially in the southern part of the area. In the northern part of the study area, <u>Grewia spp</u> attain some importance in the wetter parts of the landscape, but elsewhere <u>Acacia reficiens</u>, <u>Acacia mellifera</u>, <u>Salvadora persica</u> and <u>Dobera loranthifolia</u> are scattered across the landscape. <u>Sansieveria spp</u> are occasionally found grouped around the base of bushes and



and trees, while <u>Abutilon pannosum</u>, in almost pure stands, is characteristic of areas which have standing water for periods.

(ii) Closed bushland/shrub thicket. This is an intergrade association associated with drainage courses across the clay plains, in particular the sandy outwash areas in the northern part of the study area. While the grass species are identical with the shrub grassland/open bushland association, there are a wider range of tree species, including, in addition <u>Boscia sp</u> and <u>Commiphora spp</u>. On these sandy soils, there is greater availability of water, particularly as they appear to be underlain by the clays and there is also the appearance of annual species.

Away from the clay plains bush vegetation is dominant on the sandy soils of the end-Tertiary peneplain, a Shrub thicket vegetation association occurs, including a wider variety of tree species than the Closed bushland/shrub thicket with an increasing dominance of annual species. On the other hand, the edges of the clay plains are characterised by open bushland. While grass species are mainly perennial ones, the open bushland becomes dominated by <u>Commiphora spp</u> and <u>Acacia tortilis</u>.

In terms of irrigation development, the clay plains do not present any difficulties for land clearance. Because of past burning, the Shrub grassland/open bushland vegetation association only consists of scattered trees which can easily be removed without damaging the soil while areas of <u>Grewia spp</u> should be easily cleared with chains,thus causing the minimum of disturbance to the soil. Only the small areas of Closed bushland/shrub thicket may cause some difficulty but the areas so affected are not essential to the proposed project. They do provide some variety in what is otherwise a rather featureless landscape.

# Chapter 3

## SOIL CHARACTERISTICS

### 3.1 Soil Classification

The soil units have been classified in accordance with the Seventh Approximation System of the United States Department of Agriculture (1960) so as to facilitate correlation with earlier surveys. Five Great groups were identified, Psammustents, Natrargids, Grumsterts, Grumaquerts and Hapludents. These will all be briefly discussed, but the main emphasis will be placed on the soils of the clay plains, the Old Alluvium. The distribution of soils on the latter is to be found within the end cover (fig.3).

#### 3.1(i) Psammustents

The psammustents are coarse textured soils commonly associated with the end-Tertiary peneplain. The soils are characterised by having a thin (2-5cm) dark grey brown surface horizon containing up to 3% organic matter, overlying a series of sandy textured horizons, low in organic matter, of varying hardness. These soils often have an acid reaction throughout the top metre of the profile (table 3.1) though there are slight traces of soluble salts. The acidity is a

| Depth(cms) | pH(1:1 $H_2O$) | pH(1:5 $H_2O$) | EC(1:1)mmhos/cm | Clay % |
|---|---|---|---|---|
| 5 - 10 | 5.6 | 6.7 | 0.35 | 4.5 |
| 30 - 35 | 5.7 | 6.8 | 0.17 | 5.0 |
| 60 - 65 | 5.9 | 6.8 | 0.12 | 5.5 |
| 100 - 105 | 6.0 | 7.4 | 0.19 | 10.0 |

Table 3 : Analytical data, Psammustent. Profile 32 8 kms west of trig point SKT 18.

reflection of the decomposition of the organic matter - where there was a grass cover the pH tended to be just above 7.0 while the lower pHs were found where the vegetation consisted of scrub thicket.

These soils have not been considered suitable for cultivation since they are mainly found on irregular topography under thick bush. Furthermore, they occur



on the highest parts of the landscape in the study area and provision of irrigation water would be extremely difficult.

#### 3.1(ii) Hapludents.

Hapludents are soils that show little profile morphology and are found in three distinct locations in the study area:

(i) the floodplain of the Tana River. These soils were not investigated.

(ii) along the courses of the larger luggas (intermittent streams) which are tributaries of the Tana.

(iii) in small patches on the end-Tertiary peneplain where erosion has caused depressions and stream courses to occur. The soils found in such depressions are not dissimilar from some of the Grumusterts and Grumaquerts discussed later, though they lack the well-structured nonsaline-nonalkali horizon and tend to have higher clay contents (over 60%). The amount of exchangeable sodium also tends to be slightly less in the hapludents. They would be quite suitable for cultivation provided alternative drainage from the surrounding higher ground was provided so as to remove the hazard of standing water. Since they rarely occur in patches greater than about 20 hectares, development would be best by individuals if local water sources could be found.

#### 3.1(iii) Natrargids

The Natrargids are, again, features of the high lying end-Tertiary surface. Their characteristics include a sandy surface horizon, rarely more than 30 cms in thickness overlying an alkali or saline-alkali sandy clay/loam horizon. This latter horizon is usually capped by a hardpan - above the hardpan pHs are usually 6.0 - 6.5 though they rise to over 8.2 in the saline-alkali horizon. The soils tend to be poorly drained due to impedance caused both by the pan and the high levels of exchangeable sodium.

Natrargids are also to be found on the clay plains where they tend to occupy the higher parts of the landscape. They appear to be found where sandy outwash from the end-Tertiary surface has been deposited over the Old Alluvium These soils will be discussed in more detail later.

3.1 (iv) Grumusterts and Grumaquerts

These soils, of the Vertisol order, are the dominant soils on the Old Alluvium and they are the soils that appear to offer the greatest agricultural potential and consequently the main emphasis of the study has been on these soils. The Grumaquerts are the soils of the lowlying areas and consequently suffer from poorer internal drainage.

3.2 Natric Grumusterts

Grumusterts are Vertisols that have chromas of more than 1.5* throughout the top 30cms of the profile and lack distinct mottling in the top 75 cms. The soils are self-mulching (i.e. they lack a surface crust) and contain more than 35% clay, the clay type having an expanding lattice. In the Tana river area of Kenya, such soils occupy the 'higher' parts of the clay plain landscape and generally consist of up to 35cms of a sandy clay or clay loam topsoil that has good structural development (small angular blocks, granules and crumbs) and which is nonsaline and nonalkali. This horizon overlies a hard, when dry, saline and alkali horizon with evidence of carbonate accumulations. The carbonate accumulations tend to reach a maximum at about 70-90cms while the horizon becomes softer with depth. The horizon is a clay loam or clay and slickensides are apparent. There is frequently an horizon change at about 90cms to similar textured material but which is browner in colour. Two colour variants have been recognised- brown (GU1b, GU2b) and red (GU1r). The 1 and 2 in the notation for the brown grumustert reflect the depth of the nonsaline, nonalkali topsoil, GU1 representing topsoil that is deeper than 25 cms while GU 2 represents shallow topsoil.

3.2(i) Brown Natric Grumusterts

The brown grumusterts, having 10YR3/2, 4/2 and 7.5YR3/2, 4/2 colours in the topsoil and usually the alkali horizons are located on the higher parts of the

* Munsell colour notation



Old Alluvium where drainage is slightly better. The shallow phase (GU2b) tends to be found on the highest parts of the landscape while the deeper phase (GU1b) occurs on the freely draining slopes where there has been some accumulation of nonsaline, nonalkaline topsoil.

The topsoil tends to consist of a porous, granular and crumb structured clay loam or clay. This overlies an alkali and progressively saline horizon which is extremely hard when dry and contains cracks to a depth of at least 1m. The cracks become filled with topsoil in the dry periods so that in wet periods swelling and heaving of the soils occur, though water would only appear to enter the saline alkali subsoil through the cracks. Slickensides are common features of the subsoil.

| | GU1b | | | GU2b | | |
|---|---|---|---|---|---|---|
| Depth in cms | 0-10 | 30-40 | 100-1110 | 0-10 | 30-40 | 100-110 |
| pH(1:1) | 7.7 | 8.0 | 8.0 | 7.6 | 8.2 | 8.0 |
| Conductivity (1:1)-mmhos | 1.13 | 1.70 | 6.08 | 0.52 | 1.74 | 5.40 |
| Carbonates-% | 2.8 | 4.0 | 4.6 | 2.3 | 5.5 | 5.0 |
| Clay - % | 44.8 | 47.8 | 56.8 | 42.7 | 50.7 | 60.5 |
| Sand - % | 40.2 | 36.4 | 28.0 | 37.8 | 36.8 | 27.0 |
| Organic matter % | 1.67 | | | 1.65 | | |
| Nitrogen-% | 0.08 | | | 0.08 | | |
| Available phosphate-ppm | 163.1 | | | 83.0 | | |
| Available potash-ppm | 99.1 | | | 73.5 | | |
| Ca-meq /100g | 26.5 | 26.2 | 30.7 | 21.8 | 29.5 | 34.5 |
| Mg " | 10.2 | 11.6 | 13.6 | 11.6 | 12.4 | 12.9 |
| Na " | 5.0 | 10.7 | 19.3 | 4.6 | 7.2 | 21.2 |
| Cation Exchange Capacity | 44.2 | 47.0 | 56.9 | 42.0 | 45.7 | 58.8 |
| Exch.Na-% | 11.3 | 22.6 | 34.0 | 11.2 | 15.9 | 36.1 |

Table 3.2. Analytical data for Brown Natric Grumusterts

Analytical details (averages) for eight profiles of GU1b and two profiles of GU2b that were examined are given in table 3.2. There is comparatively little difference in the chemical and physical properties of these two soils except in depth of topsoil. pHs tend to increase with depth, in response to the increase in exchangeable sodium, though not to levels that might be expected with ESPs in excess of 20. Reasons for this may relate to the presence of the carbonates which are visible in soil profiles at depths usually in excess of 60cms. The soils also tend to become heavier with depth (i.e. there is an increasing clay content) while salinity also increases. The presence of free carbonates and also soluble salts affects the cation exchange determinations - in particular the most abundant soluble salt appears to be sodium chloride and it may be that the exchangeable sodium figures for some of the lower horizons may be artificially enhanced by some of the soluble salts being included. This is very evident in table 3.2 where the sum of the cations (K is not included as levels remain low, < 2meq/100grms) considerably exceeds the cation exchange capacity.

While analyses have been undertaken with regard to the chemical fertility of the soil, this will change considerably once irrigated agriculture is practised and fertilizers etc. are added to the soil. Topsoils are relatively low in organic matter, possibly due to past burning of the clay plains, while the amount of nitrogen is also low - cultivation will require the addition of nitrogenous fertilisers. The amounts of available phosphate and potash are very variable, probably due to cattle movements across the area, but in general appear to be adequate. There may be small areas, however, where after cropping experience it might prove advantageous to add small quantities of phosphatic fertilizers.

The analytical results are slightly different from those quoted in the Acres-ILACO(1967) and ILACO(1973) reports for the area basically to the north of Hola. To what extent these are real differences, rather than differences due to the analytical techniques used, is unclear, though the textures of the topsoils did appear, in the field, to be slightly lighter in the study area than around Bura. However, there appears to be a much greater area of the GU1b phase (i.e. soils having a topsoil deeper than 25 cms) in the study area, while salinities, particularly at a depth of 1m appear to be significantly less.



3.2(ii) Red Natric Grumusterts

Small areas of red grumusterts are to be found along the crest of the slope which leads down to the Tana River. Such soils exhibit 5YR colours in their profile to a depth of at least 50 cms. Only the deep phase, GU1r, was recognised in the current study.

The one profile that was examined in the laboratory showed many of the features present in the other grumusterts. However pHs tended to be higher (5-10cms 8.1, 30-35 cms 8.3, 60-65 cms 8.7, 100-10cms 8.4) while the levels of clay were significantly lower (<50% clay in all samples). Since ESPs were about the same, it may be that the lighter texture in the subsoil does not have the same buffering capacity and consequently higher pHs are recorded.

3.3 <u>Natric Grumaquerts</u>

The Natric Grumaquerts are the vertisols that have chromas of 1.5 or less throughout the upper 30cms. Between Hola and Wenji, these Grumaquerts tend to have colours of 10YR3/1 or 10YR4/1 in the topsoil and this colour often remains throughout the top metre of the profile, though in a number of cases, the profile becomes browner with depth (10YR3/2 or 10YR4/2). The Grumaquerts occupy the lowest parts of the landscape of the clay plains, with the profiles that are grey throughout at least the top metre of the profile occurring in the major depressions. Like the Natric Grumusterts, the Natric Grumaquerts have been subdivided into two phases -GA1 where the depth of the nonsaline-nonalkaline topsoil exceeds 25cms and GA2 where the corresponding depth is less than 25cms.

The Grumaquerts are essentially similar to the Grumusterts in terms of their profile morphology. The only differences are their colour, the presence of mottles, particularly in the lower part of the profile, and the quantities of carbonate accumulations which appear to be significantly less, particularly below 75 cms. This is partly emphasised in the table of analytical data (table 3.3) which, if compared with table 3.2, shows that carbonate contents at 1m in the natric grumaquerts are about 2.5-3.0% compared to figures of 4.6-5.0% for the brown natric grumusterts.

Analytical data for six natric grumaquert profiles (3 GA1 and 3 GA2) are given in table 3.3. Though there are comparatively few differences with the grumusterts, it would appear that:

| | GA1 | | | GA2 | | |
|---|---|---|---|---|---|---|
| Depth in cms | 0-10 | 30-40 | 100-110 | 0-10 | 30-40 | 100-110 |
| pH(1:1) | 7.6 | 8.1 | 8.0 | 7.8 | 8.2 | 8.1 |
| Conductivity (1:1)-mmhos | 1.14 | 1.84 | 5.78 | 0.87 | 1.47 | 6.70 |
| Carbonates-% | 2.0 | 5.0 | 2.5 | 3.5 | 3.3 | 3.0 |
| Clay-% | 43.7 | 48.5 | 63.3 | 40.8 | 52.2 | 62.0 |
| Sand % | 37.3 | 37.3 | 18.0 | 38.7 | 31.7 | 21.0 |
| Organic matter-% | 1.87 | | | 2.27 | | |
| Nitrogen-% | 0.08 | | | 0.09 | | |
| Available phosphate-ppm | 87 | | | 81.2 | | |
| " potash-ppm | 107.2 | | | 81.3 | | |
| Exchangeable Ca-meq/100g | 28.4 | 28.1 | 31.3 | 27.9 | 28.8 | 31.8 |
| Mg- " | 11.6 | 15.1 | 15.9 | 10.7 | 15.5 | 16.1 |
| Na- " | 5.3 | 10.2 | 17.5 | 4.0 | 7.9 | 16.7 |
| Cation exchange capacity | 47.1 | 52.2 | 58.3 | 41.8 | 45.8 | 61.9 |
| Exchangeable Na-% | 11.1 | 19.4 | 31.0 | 9.7 | 17.3 | 29.3 |

Table 3.3 Average analytical data, Natric Grumaquerts.

(i) the clay content in the subsoil is slightly higher than with the grumusterts. This may be a reflection of the relative position of these two soil types in the landscape, with fine material being washed out of the topsoils on the relatively higher parts of the landscape and washed down cracks in the grumaquerts.

(ii) organic matter contents are higher. The low lying areas will receive more moisture and, since the water release characteristics of these soils are similar, vegetative growth will be enhanced.



(iii) there are differences in the composition of cations comprising the exchange complex. Exchangeable sodium percentages are slightly lower, but of particular note is the increase in the amount of exchangeable magnesium in the subsoil which is about 25% greater than in the grumusterts.

## 3.4 Natrargids

Small areas of these soils occur in the project area. Red natrargids are commonly found along the break in slope at the edge of the clay plains and the slopes leading to the Tana River while the brown variant tends to occur where outwash sandy deposits from the high-lying older surfaces have covered the clay plains.

The soils tend to have a sandy clay loam or sandy loam topsoil overlying clay loam horizons at depth. Both topsoil and subsoil tend to be alkaline with ESPs of over 20 occurring in the topsoils of the brown variant, though the red variant tends to have much lower ESPs, being barely alkali in the topsoil. In many respects, the red natrargid is an intergrade between the natrargids and the red grumusterts.

A second characteristic of the natrargids is that they usually have a fairly dense cover of scrub and trees. While organic matter contents in the soil are similar to the grumusterts, this being due to the paucity of ground vegetation, pH values in the topsoil may be slightly acid (6.6), though more usually values are in the range, 7.0 - 7.3. With continued leaching, the soil surface may become acid due to the process of solodization and some of the soils examined during this study are transitional between the natrargids and the albolls.

The areas occupied by the natrargids are relatively small and impinge little on the proposed project area. They do present some problems in their utilisation and these soils should not be included in the planned area.

## Chapter 4

## SUITABILITY OF SOILS FOR IRRIGATED AGRICULTURE

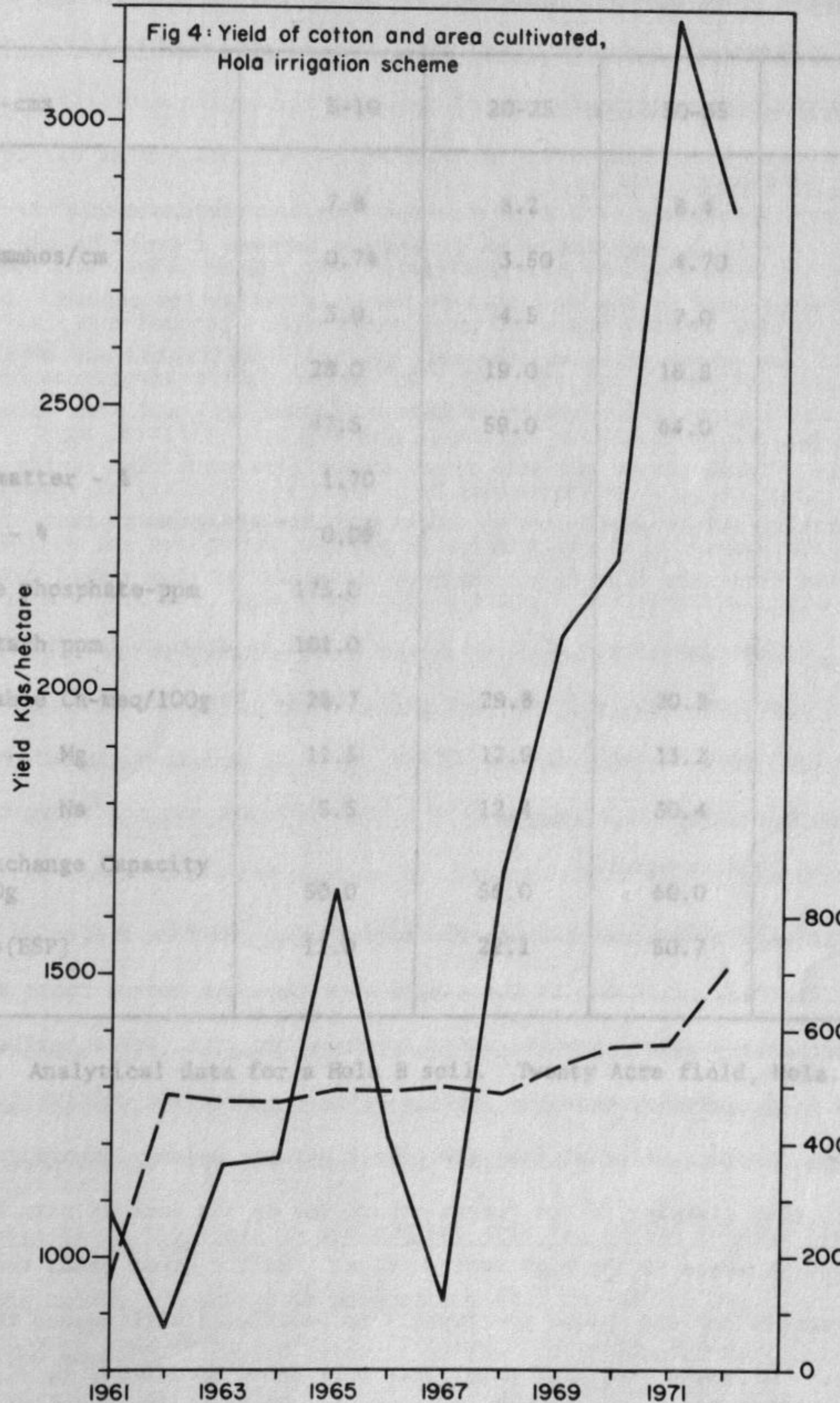
### 4.1 Existing irrigated agriculture

The only irrigation scheme in the area is that at Hola. This was established in 1955 and now extends to over 900 hectares. The main emphasis is on cotton cultivation with UKA/59/240 being the variety grown. Small areas of maize and groundnuts are also grown.

The cotton is now grown on a variety of soils - Hola A which is a Halorthid, Hola A/B and Hola B which have the closest affinities with natric grumusterts, and even the sandy Hola C soil. None of the specific soil types were identified in the project area though the Hola A/B and Hola B soils have some affinities with the GU2b and GA2 soils. Analytical data for a profile of the Hola B soil type is given in table 4.1. The Hola B soil can be reddish brown or greyish brown in colour and is a Natric Grumustert. The main differences would appear to be the heavier textures and the higher ESPs that are apparent in the subsoil of the Hola B soil. The alkali horizon, when dry, of the Hola B soil appeared to be much harder, presumably due to the enhanced ESP values. In terms of the profile morphology, the structure of the nonsaline-nonalkali topsoil, while soft and viable, was not so well developed with comparatively few granules and crumbs. Furthermore, the depth of the topsoil of the Hola B soil rarely exceeded 20cms while in a number of instances it was as shallow as 15cms. Such depths of topsoil in the Grumusterts and Grumaquerts of the study area were extremely rare (<2% of profiles examined).

Fig.4 relates the yields of cotton to the area under cultivation. It is noticeable that average yields of cotton per hectare have dropped substantially in years when sizeable areas were added to the irrigated area e.g.1962, 1972. When the soils are cultivated for the first time, yields are unlikely to be high and this results in a depression of the overall average value - it is impossible, from data available, to predict what yield is likely to be on newly

Fig 4: Yield of cotton and area cultivated, Hola irrigation scheme



| Depth-cms | 5-10 | 20-25 | 50-55 | 100-105 |
|---|---|---|---|---|
| pH (1:1) | 7.8 | 8.2 | 8.4 | 8.4 |
| EC-(1:1)mmhos/cm | 0.74 | 3.50 | 4.70 | 6.90 |
| $CaCO_3$-% | 3.0 | 4.5 | 7.0 | 6.5 |
| Sand-% | 28.0 | 19.0 | 16.5 | 5.5 |
| Clay-% | 47.5 | 59.0 | 64.0 | 75.5 |
| Organic matter - % | 1.70 | | | |
| Nitrogen - % | 0.09 | | | |
| Available phosphate-ppm | 175.0 | | | |
| " potash ppm | 101.0 | | | |
| Exchangeable Ca-meq/100g | 28.7 | 29.8 | 20.8 | 34.5 |
| Mg | 11.3 | 12.9 | 13.2 | 14.9 |
| Na | 5.5 | 12.4 | 30.4 | 33.7 |
| Cation Exchange Capacity meq/100g | 50.0 | 56.0 | 60.0 | 71.3 |
| Exch.Na-%(ESP) | 11.0 | 22.1 | 50.7 | 47.3 |

Table 4.1 Analytical data for a Hola B soil. Twenty Acre field, Hola.

developed land but it is unlikely to exceed 1500kgs/hectare. However, yields rapidly increase given correct management as can be seen in the average yields for the years 1962-1965 and more particularly 1968-1971. The current management techniques were established in 1967.

4.2 Current management practices

The Hola A soil is regarded as an intergrade between a typic halorthid and a vertic natrargid and is the best soil in the Hola irrigation scheme. In the early days of the scheme, this was the soil generally cultivated but later the scheme included a greater proportion of Hola B (grumustert) and even Hola C (sandy) soils. These latter two soil types do not give such high yields as the Hola A soils, unless great care is taken with the management practices, yet, as can be seen from the figure, yields have certainly not diminished overall.

The key to the management of these soils is not to disturb the underlying saline-alkali horizon. While cotton can tolerate high ESPs (in the Sudan, cotton yields have been good on soils having ESPs of up to 25 and also containing quantities of some salts(Robinson,1971.J.Soil Sci))the high ESPs are not conducive to maintenance of good structure.

Good yields are obtained because the cotton only grows on ridges of nonsaline-nonalkaline topsoil. Pits dug in the ridges show that the cotton roots do not penetrate the saline-alkali horizon since, when wetted, the latter horizon becomes impermeable. If, however, when the land is being prepared for cultivation by ploughing or discing, material from the alkali horizon becomes incorporated in the topsoil, then slumping of the ridges occurs due to the lack of structural stability attributable to the high sodium values. On the other hand, the presence of an impermeable horizon below the topsoil is beneficial with regard to water distribution - a furrow length of 100m takes only about 20 minutes to fill and the ridge absorbs sufficient moisture in a further 15 minutes or so. This means that irrigation of plots can be remarkably rapid and irrigations only need



to be given every fortnight.

Effectively, all that is being cultivated is the topsoil. With the Hola A soil, the topsoil may be as deep as 40cms but elsewhere it is restricted to 25cms or less. This allows little scope for amendment and it is important to main fertility. It is not feasible to incorporate cotton and maize residues into the soil due to phytosanitary control necessary with the intensive cropping that is practised. The roots, though, are disced and this does add some organic matter to the soil - one topsoil sample taken from the older part of the irrigation scheme had an organic matter content of 5.2%. The low C:N ratios suggest a relatively high fertility and the only amendment necessary is the application of nitrogenous fertilizers. At present 60 units/hectare N as sulphate of ammonia are applied to the better soils (Hola A) while up to 90 units/hectare N may be applied to the Hola A/B, Hola B and Hola C soils. This application is given about one month after germination. Over a period of time, it would be expected that pH values would tend to fall as a result of applications of sulphate of ammonia but evidence quoted by ILACO(1973) is inconclusive in this respect. A further 40 units/hectare N as sulphate of ammonia are applied to areas given over to the maize crop. One other feature of management is that the burning of the maize and cotton stalks will cause additions of potash to the soil in an available form.

Herbicides (Camex and Diuron) are applied to up to 60% of the cotton crop to aid weed control. The crop is planted, sprayed and then irrigated within 48 hours. There is no evidence that the use of such herbicides has any effect on soil properties.

4.3 Suitability of the soils in the project area for cotton cultivation

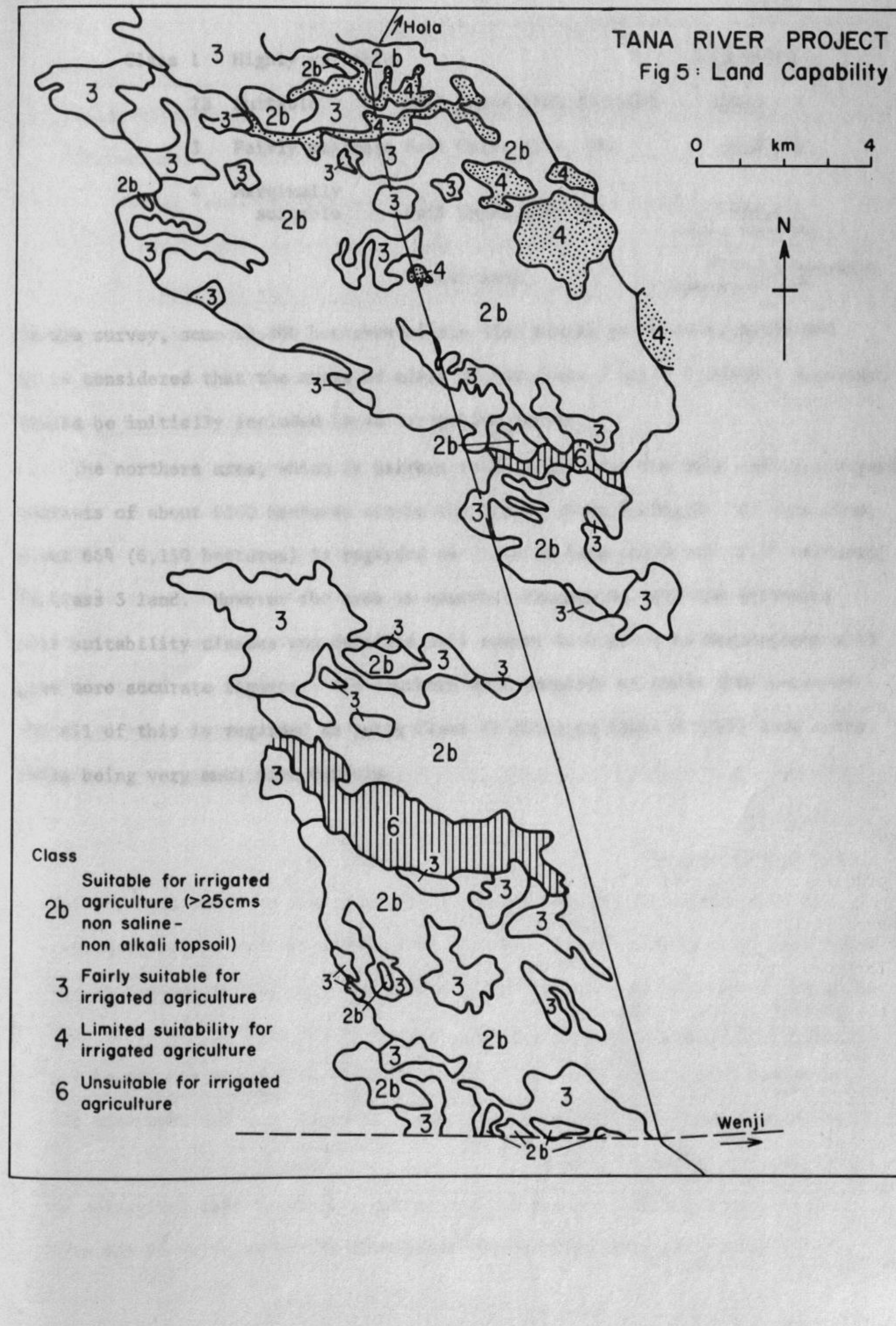
At the outset, it should be pointed out that few of the soils in the project area fit the normally accepted criteria of the U.S. Bureau of Reclamation scheme for irrigated agriculture (1953 ) since, as commented by ILACO (1973) the criteria for salinity and alkalinity do not fit those as laid down in The Diagnosis and Improvement of Saline and Alkali soils (1954). However, the Hola Irrigation Scheme provides visible evidence that these soils can be cultivated and good yields obtained over a considerable period of time.

In 1973 ILACO linked the soils at Hola with the suitability classification that had been used for the Tana River Basin Survey :

| | | | |
|---|---|---|---|
| Hola A | Class 2A | - | well suitable |
| Hola A/B | 2B | - | suitable |
| Hola B | 3 | - | fairly suitable |
| Hola C | 4 | - | marginally suitable |

In this study the major emphasis has been placed on the grumusterts and the grumaquerts and, in terms of the Tana River Basin these soils may be categorised as either Class 2B or Class 3. The division is somewhat arbitrary being based on the depth of the nonsaline-nonalkaline topsoil - where the topsoil is greater than 25cms then the soils have been placed in Class 2B. This involves all the soils mapped as GU1 or GA1, while GU2 and GA2 soils, where topsoil depths are less than 25cms, have been put in Class 3. However, there are small areas of GU2 soils where the topsoil is less than 15cms and such soils should be regarded as being only marginally suitable for irrigated agriculture. Areas of these soils are too small to be shown on either Fig.3 or Fig.5. While, at this stage, correlation with Hola soils is only tentative, GU1r soils may have similarities with the Hola A soil and it is possible that GU1r soils might be considered as properly belonging to class 2A. The Natrargids, too, have been somewhat arbitrarily classified - certainly those which represent the outwash of the end-Tertiary surface are characterised by somewhat irregular topography slightly above the general level of the clay plains. Such areas could be incorporated into the scheme, either as productive land, or forming the main access lines. On the other hand the red Natrargids, along the eastern edge of the study area on the break of the slope leading down to the Tana River, may more properly be incorporated into soil suitability class 3 once some cropping investigations have been carried out.

Within the area covered by this pre-investment study, it is considered that



TANA RIVER PROJECT
Fig 5 : Land Capability

the areas of the different suitability classes are as follows:

| | | | | |
|---|---|---|---|---|
| Class 1 | Highly suitable | | | 0 hectares |
| 2B | Suitable | Soil Units | GU1b,GU1r,GA1 | 10395.2 h |
| 3 | Fairly suitable. | Soil Units | GU2b, GA2 | 4463.5 h |
| 4 | Marginally suitable | Soil Units | NAr, NAb | 906.4 h |
| | | Total Area | | 15765.1 hectares |

In the survey, some 19,400 hectares of the clay plains were investigated and it is considered that the areas of class 2B and class 3 soils ( 14858.7 hectares) should be initially included in an irrigation scheme.

## Chapter 5

## CONCLUSIONS AND RECOMMENDATIONS

### 5.1 Conclusions

This survey had the aim of assessing the suitability of soils in the Hola-Wenji area of the Tana River for irrigated agriculture. A considerable part of the area, composed of the end-Tertiary surface remnants, is not considered suitable due to topographic characteristics and poor soils. It is important that such areas should be retained for the wildlife.

It is clear that the soils of the clay plains do offer considerable scope for irrigated agriculture provided that correct cropping procedures are followed. Initially, about 14,850 hectares might be included in an irrigation scheme. The areas of Class 2B and Class 3 soils are shown on fig.5 and an irrigation scheme should be retained within the limits of these two classes.

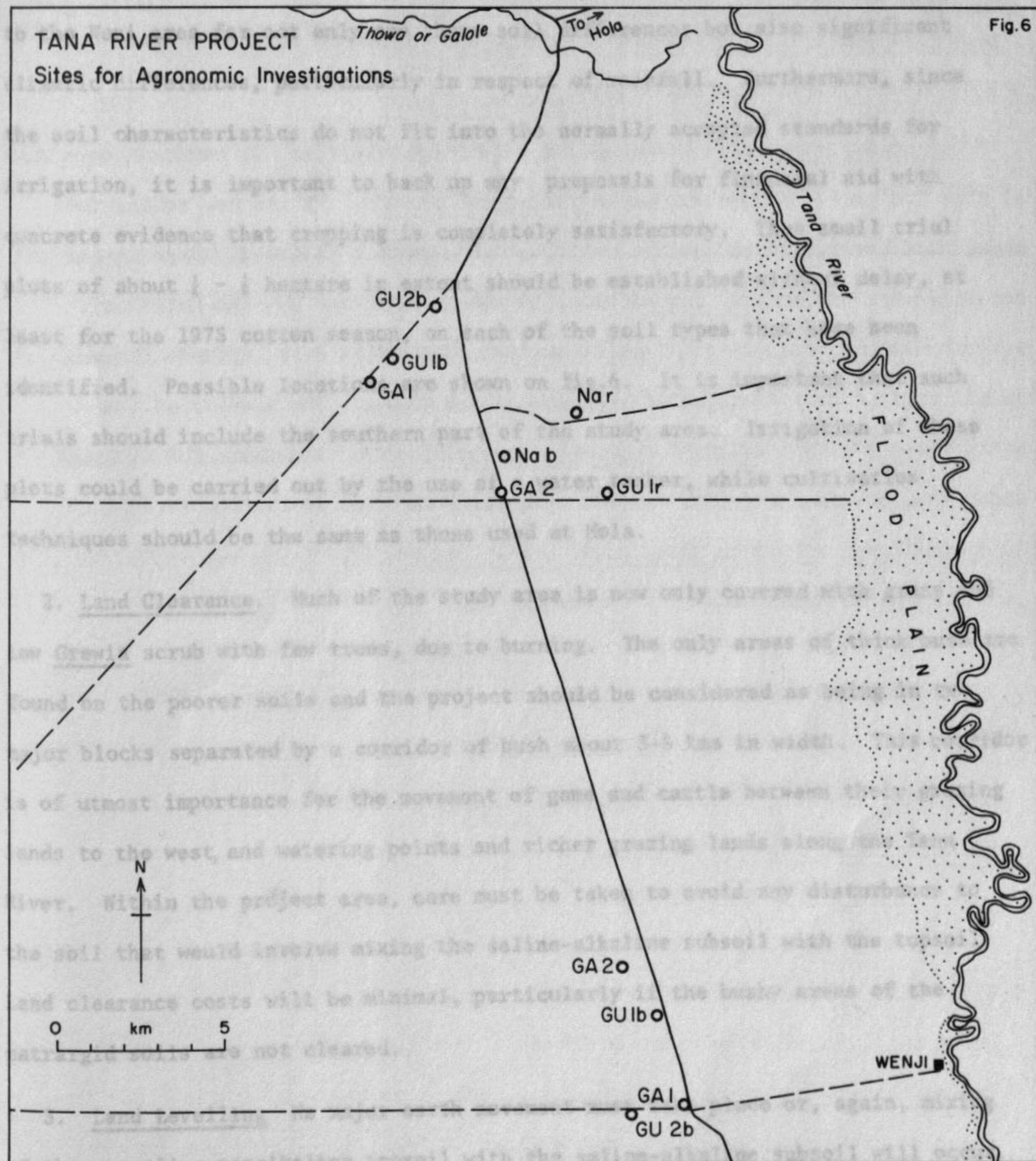
There is somewhat more variability exhibited in the vertisols of the study area than was at first apparent, while the area also includes examples of natrargids. How important these variations are in terms of agronomic potential is unclear until further cropping studies have been carried out. Before any irrigation scheme is fully developed, detailed soil survey work is required so as to demarcate areas where soil characteristics may specifically affect cropping practices or design layout.

### 5.2 Recommendations

In this study, the big unknown has been the amount of water from the Tana River that is available for irrigation, particularly in view of the proposals being put forward in relation to the Bura scheme. Alternative sources of additional irrigation water might be investigated, such as to the west of the study area, where flood waters from rivers such as the Thowa (Galole) sink below the ground surface. If additional water was present in this area, it would have the advantage of irrigating any scheme by gravity.

The recommendations are put forward in the expectancy that irrigation water will be available for the satisfactory management of the majority of the area





deemed suitable for cultivation.

1. <u>Cropping Potential</u>. Soil variability may cause significant agronomic differences. It would be wrong to interpolate results from the Hola scheme to the Weni area for not only are there soil differences but also significant climatic differences, particularly in respect of rainfall. Furthermore, since the soil characteristics do not fit into the normally accepted standards for irrigation, it is important to back up any proposals for financial aid with concrete evidence that cropping is completely satisfactory. Thus small trial plots of about $\frac{1}{4}$ - $\frac{1}{8}$ hectare in extent should be established without delay, at least for the 1975 cotton season, on each of the soil types that have been identified. Possible locations are shown on fig.6. It is important that such trials should include the southern part of the study area. Irrigation of these plots could be carried out by the use of a water tanker, while cultivation techniques should be the same as those used at Hola.

2. <u>Land Clearance</u>. Much of the study area is now only covered with grass and low <u>Grewia</u> scrub with few trees, due to burning. The only areas of thick bush are found on the poorer soils and the project should be considered as being in two major blocks separated by a corridor of bush about 3-5 kms in width. This corridor is of utmost importance for the movement of game and cattle between their grazing lands to the west, and watering points and richer grazing lands along the Tana River. Within the project area, care must be taken to avoid any disturbance to the soil that would involve mixing the saline-alkaline subsoil with the topsoil. Land clearance costs will be minimal, particularly if the bushy areas of the natrargid soils are not cleared.

3. <u>Land Levelling</u> No major earth movement must take place or, again, mixing of the nonsaline-nonalkaline topsoil with the saline-alkaline subsoil will occur. While slopes are extremely gentle, this should not affect irrigation due to the impermeable nature of the alkali horizon when wetted. On no account should heavy earth moving equipment be used - at Hola Irrigation Scheme the only land levelling equipment is a land plane.

4. Irrigation. Because of the nature of the soils, it is anticipated that efficiency of irrigation will be relatively high. Seepage losses should be minimal but, for the scheme to be successful, there will need to be very strict control over the irrigation. The success of irrigation schemes is to a major part due to correct irrigation techniques.

5. Cropping practices. A considerable body of expertise has now been developed at Hola Irrigation Scheme which has given good results. If the new scheme goes ahead then the practices used at Hola should be closely followed. Experimentation should always precede any innovations. There is no reason why the Hola-Wenji area should not be equally successful as Hola, but, like Hola, success can only be achieved if management is extremely firm and strong. The success of the Hola scheme, on what would be regarded by many as soils unsuitable for cropping, stems from the insistence on correct soil management and irrigation techniques by the manager.



## BIBLIOGRAPHY


Acres - ILACO, 1967. Survey of the Irrigation Potential of the Lower Tana River Basin. Vol.III Soils and Vegetation. FAO.Rome

ILACO, 1973. Tana River Feasibility Studies : The Bura Area. Holland

Pulfrey, W. 1960. Shape of the Submiocene Erosion Bevel in Kenya. Geol. Survey,Kenya. Bull.3.

Robinson, G.H. 1971. Exchangeable Sodium and Yields of Cotton on Certain Clay Soils of Sudan. J.Soil Sci.22.3. 328-335

Saggerson,E.P. 1972. Geology in East Africa: its peoples and resources (ed. W.T.W. Morgan). Nairobi.

U.S.Bureau of Reclamation,1953. Irrigated Land Use. Pt.2. Land Classification U.S. Department of the Interior, Washington.

U.S. Salinity Laboratory,1954. Diagnosis and Improvement of Saline and Alkali Soils (ed. L.A. Richards). U.S. Department of Agriculture, Washington.

# BIBLIOGRAPHY


Acres - ILACO, 1967. Survey of the Irrigation Potential of the Lower Tana River Basin. Vol. III Soils and Vegetation. FAO. Rome

ILACO, 1973. Tana River Feasibility Studies : The Bura Area. Holland

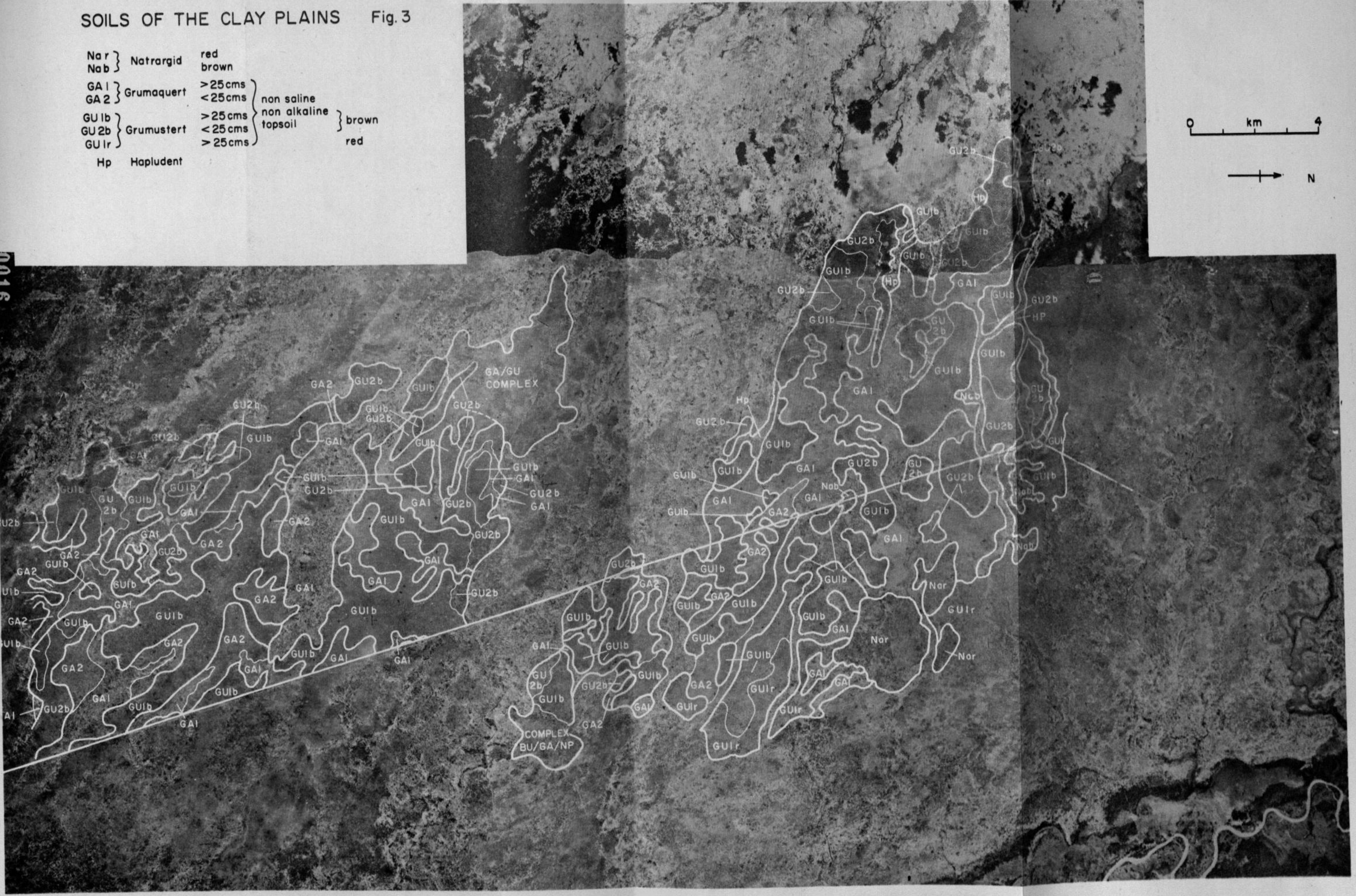
Pulfrey, W. 1960. Shape of the Sub-Miocene Erosion Level in Kenya. Geol. Survey, Kenya. Bull. 3.

Robinson, G.H. 1971. Exchangeable Sodium and Yields of Cotton on Certain Clay Soils of Sudan. J. Soil Sci 22:3, 328-335.

Saggerson, E.P. 1972. Geology in East Africa: its Peoples and resources. (ed. W.T.W. Morgan). Nairobi.

U.S. Bureau of Reclamation, 1953. Irrigated Land Use, Pt. 2. Land Classification. U.S. Department of the Interior, Washington.

U.S. Salinity Laboratory, 1954. Diagnosis and Improvement of Saline and Alkali Soils (ed. L.A. Richards). U.S. Department of Agriculture, Washington.


SOILS OF THE CLAY PLAINS Fig. 3