FAO/SF: 10/ETH

IMPERIAL ETHIOPIAN GOVERMENT
UNITED NATIONS SPECIAL FUND PROJECT

REPORT ON

SURVEY OF THE AWASH RIVER BASIN

VOLUME II

UNITED NATIONS SPECIAL FUND
FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

REPORT ON

SURVEY OF THE AWASH RIVER BASIN

Volume II

SOILS AND AGRONOMY

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

UNITED NATIONS SPECIAL FUND ROME 1965

PREFACE

The Report on the Survey of the Awash River Basin comprises the following volumes:

Volume I	General Report
Volume II	Soils and Agronomy
Volume III	Climatology and Hydrology
Volume IV	Water Storage and Power Development
Volume V	Irrigation and Water Planning.

These volumes are all issued on the authority of the Special Fund of the United Nations and the Food and Agriculture Organisation.

Volume I is a comprehensive Report covering concisely all aspects of the Survey, and setting out the conclusions reached and the recommendations made. It is wholly prepared by FAO. It embraces and is based on the contents of the other volumes.

The other volumes were all drafted by the Sub-Contractors, S.O.G.R.E.A.H. of Grenoble, France, who carried out the main work of the Project. They have subsequently been edited by FAO. Each of these volumes in its more specialised field provides and analyses the relevant data, discusses the results, and sets out the conclusions to which they point. The discussions in one volume of course have reference to and depend on the discussions in other volumes.

The scope of Volume II, as will be seen from the Table of Contents, covers the following:

A. Geomorphology - Soil Formation - Methods of Soil - Prospecting and Survey.

B. Soil Classification by Reconnaissance and Semi-detailed Surveys - Parent Materials - Main groups of Soils.

C. Land Classification for Irrigability - Major Traditional Regions of Land and Climate.

D. Types of Present Utilization of Land - Agriculture - Pasture - Erosion and its Control.

E. Improvements in Grazing - Improvements in Croplands in the Upper Basin.

F. Prospective Land Use in Irrigated Zones - Water Requirements - Quality of Irrigation Water.

The information and conclusions provided by Volume II are used in the discussions contained in other volumes, notably Volumes IV and V, and of course Volume I.

REPORT ON SURVEY OF THE AWASH RIVER BASIN

CONTENTS

LIST OF TABLES

GRAPHS AND FIGURES

APPENDICES

MAPS IN FOLDER

LIST OF PHOTOGRAPHS

INTRODUCTION

Among the various preliminary investigations whose object is to prepare the development of the Awash River Basin, the promoters of the United Nations Special Fund Project quite rightly emphasized on those concerned with soils and land use.

The choice of suitable areas to raise crops under irrigation and for pasture was based on a soil reconnaissance survey which amply covered the 700,000 hectares of land provided for in the Plan of Operations, and which produced a general classification of the various soils and soil maps to a scale of 1:250,000.

In the areas selected for potential development - that is to say, over 150,000 hectares of land - semi-detailed soil surveys were carried out, followed by the classification of the soils into series and mapping to a scale of 1:100,000.

Present land use in the entire river basin was analysed for agriculture and pasture, with full allowance for serious erosion problems.

Recommendations were made for the potential use of this land under the heading of soil conservation, the improvement of agricultural and pasturing methods, and especially the development of irrigation, the main technical data of which were covered in detailed proposals.

I. GEOMORPHOLOGY OF THE AWASH RIVER BASIN

I - 1. General Structure

The Awash River Basin is a wide rift valley or 'graben' opening out in the form of a wide 'V' towards the Red Sea. Basalt trap plateaux to the north and south form the arms of the 'V'. These plateaux are generally held to be of Cretaceous origin and overlie sedimentary series ranging from the Triassic to the Cretaceous period. The transition from these plateaux at an altitude of 2,000 - 2,500 metres to the plain occurs in the form of cliffs, which are often sheer and sometimes followed by steps or scree cones. These cliffs forming the two arms of the 'V' are characteristic features of the western flank of the basin all the way from the upper Kesem valley to Debre Sina and Dese, and of its southern flank between the rivers Geleta and Mulu at the foot of the Chercher plateau.

The cliffs converge towards the south-west, but do not meet; they are kept apart at about 1,500 metre altitude by the substantial 'couloir' connecting the Nazret area to lakes Ziway and Awasa.

Faults, running roughly from south-west to north-east, divide the Upper Basin into :

(i) Steps corresponding to the Teji depression south-west of Adis Abeba, the lower Mojo plains, and the Koka and Wenji basin;

(ii) Several rifts with shearing faults; for instance, the Upper Robi and Upper Borkena valleys.

Faults in the same direction divide the central rift valley through which the Awash flows into a series of basins extending from Metehara to the river Awadi, and then from the Maro Gala plain to El Weha.

A fault system from north-west to south-east (i.e., practically perpendicular to the one above) marks the boundaries of a wide rift valley extending from Tendaho to lakes Gamari and Afembo, before the last rift in which lake Abe lies.

Volcanoes of more recent origin than the trap, and differing from them by their generally scoriaceous facies and well-preserved topographical outlines, are observed at the following places :

(i) In the Upper Basin : volcanoes in the Mojo region, the Zikwala, and the volcanoes between Nazret and Metehara.

The very eroded Yerer and Wachacha hills near Adis Abeba are considered to be an older formation (except for Menegasha hill, which is of more recent origin).

(ii) In the central Rift Valley; the Fentale, Gurmile, Dofan, Ehaili, Dabita Ale and Azelo Volcanoes, all aligned due north-south, and the Asebot and Afdem volcanoes with a general south-west to north-east alignment.

(iii) In the lower Rift Valley from Tendaho to lake Gamari : the Kurub, volcanic outflows north of Dubti, and the Borauli volcano north of Asayita. Signs of very recent volcanic activity are noted in this depression; there are small mud volcanoes aligned with the faults.

All the steps and rifts contain a well-developed hydrographical system, which has 'dissected' the basalt plateaux, steps, volcanoes and more recent volcanic formations. The rivers generally run in a north-westerly to south-easterly direction; e.g., perpendicular to the fault system in the Upper Basin. They are steep and, in digging into the steps, have formed series of falls, some of which are now being harnessed for hydro-power production. Sediment from these rivers is gradually filling the rifts. The Awash flows through the central region, parallel to the faults, generally from south to north between Awash station and Tendaho.

I - 2. Special Geological Features

The rift valleys and some steps (e.g., in the Mojo-Koka area) have filled up with materials eroded from the plateau and with recent volcanic outflows, but as they were still sinking, the outflows over alluvia have rapidly been covered over themserves by fresh alluvia. Thus, the distinctive feature of this region is its variogated alluvium, ranging in size from boulders to gravel and down to loam with intermittent miscellaneous volcanic rock bars of varying thickness. Tuff, volcanic ash, scoria and weathered material from this rock are also found between the outflows (Mojo-Koka area). Faults have frequently formed in these various layers during sedimentation; e.g., in the old alluvium extending from the Kesem to El Weha along the left bank of the Awash. The faults show up on the air photographs as a set of parallel hill ranges.

All these deposits in the central rift valley have undergone reworking during successive different climate periods. The extension of the lakes, which took place during a major pluvial period, was marked by the deposition of lacustrine and fluviatile sediment (clay, gravel and diatomites) which has been identified at the following places :

(i) In the Upper Basin : in open sections in the Mojo valley, and in deep horizons in the Koka-Wenji area.

(ii) In the Middle Valley : at the northern end of lake Gedebasa, sometimes in the form of diatomite.

Fossils have also been found in this area.

These sedimentary formations are frequently saline and generally severely eroded, resulting in the particular topographical form referred to as 'badlands'.

Numerous lakes witness to a past extension of the pluvial period (Beseka, Lyadu, Hertale, Gedebasa, Gamari, Afembo, Bario). They are partly supplied by springs, frequently warm and saline.

The interpluvial period was marked by the deposition of windborne sand and the formation of calcareous crust. There is distinct evidence of this in the central rift valley and in the calcareous deposit formation on the basalt.

In a more recent period, the present alluvia containing loam, clay and gravel were deposited, forming the terraces still visible in alluvial areas (Melka Sedi).

A large part of the soil survey concerns the present alluvial formation area, the relative age of which depends on topographical position; e.g., altitude in a given area.

I - 3. Main Natural Regions

The geomorphology of the river basin is illustrated by a 1:1,000,000 scale diagrammatic map showing the various formations: (Map No. 1)

(i) Teji depression;

(ii) High plateaux consisting of farmland and basalt hills, occasionally on steep slopes severely marked by erosion;

(iii) Plains in the Koka - Nazret - Welenchiti area;

(iv) Small Metehara plain;

(v) Vast alluvial plains in the central Awash rift valley;

(vi) Plains surrounding the Gewani marsh, including the Maro Gala plain;

(vii) Rift valleys extending from the Robi to the Borkena;

(viii) Vast alluvial plains in the lower Awash rift valley up to lake Abe; the Mile plains can also be included.

Other formations include:

More or less weathered basalt, lava outflows, volcanic tuff, occasionally on steep slopes.

Very faulted old alluvia, frequently gravelly and run through by volcanic rock bars; these are very pronounced on the left bank of the Awash.

The map also shows the most recent volcanic formations (symbol V) and 'badlands'.

For Survey purposes, the river basin has been divided into three major natural regions:

(i) The Upper Basin including the high plateaux, the Teji depression and the Koka-Nazret plains.

(ii) The Middle Valley, comprising the plains from Metehara to lake Gedebasa.

(iii) The Lower Plains, from Tendaho to the lower lakes.

II. SOIL FORMATION AND PHYSICAL FEATURES

II - 1. Soil Formation Factors

The main soil formation factors depend on the morphological features of the river basin; namely, its climate, types of parent rock, certain types of hydraulic action associated with the local stream and river systems and ground water conditions, and the existence of saline warm springs.

Vegetation is also a soil formation factor; in the upper basin this depends on climate, and in the more arid regions on the amount of water supplied to the soil. As the region is fairly densely populated, natural soil formation conditions have been affected more than elsewhere by human intervention (e.g., deforestation, cultivation) and by severe erosion.

The use of the land in the other areas mainly for grazing has only resulted in limited degradation of the soil, except in a few plantations.

II - 2. Climatic Factors

The climatic study, discussed in detail in volume three reveals the existence of several climatic zones at different heights above sea level, and with differing soil groups and types of agriculture. For comparison with other regions in Africa, an attempt has been made to relate these zones to the classification of groups, types and sub-types of climate throughout the world drawn up by G.T. Trewartha (which is a modified Köppen classification) cited by F. Fournier in his book "Climate and Erosion". The various divisions in this classification are defined numerically in terms of temperature, rainfall and rainfall regime.

The various climatic zones are:

(a) Arid to semi-arid, tropical and subtropical, arid in winter, where evapotranspiration is greater than rainfall. This zone is found below 1100-1200 m and covers the Awash Middle Valley and Lower Plains. The mean annual temperature varies from 28°C in the warmest part below 700-800 m, to 23°C for the higher parts. Evapotranspiration is high and rainfall is under 500 mm, occuring irregularly and only allowing the growth of an ephemerous form of vegetation or one particularly adapted to such conditions (acacia). The annual inflow/outflow balance shows a high deficit which, in some years, may be equivalent to almost the entire evapotranspiration quantity. These conditions have produced ground water salt concentrations leading to saline soil formation.

(b) Tropical zone, with winter dry season and summer rains and temperatures in the coolest month around 18°C or more. This zone lies at between 1200 and 1800 m and covers a large part of the Upper Basin and the piedmont areas. The mean annual temperature varies from 18 to 21°C and the rainfall at 1800 m may vary from 1200 mm to 750 mm depending on position relative to the wind. Evapotranspiration is lower and the ground is saturated during part of the wet season. Tropical and subtropical crops such as cotton, sorghum, tobacco and citrus fruits, can be grown, often without irrigation in the wettest areas.

(c) Wet subtropical, with dry winters and temperatures in the coolest month under 18°C. This zone lies between 1800 and 2500 m in height and covers the upper part of the Upper Basin. The range of crops is limited by the minimum temperatures. The mean annual temperature is under 16°C and rainfall at 2500 m varies between 1000 and 1600 mm. Cereals are grown over large areas. The ground is saturated during the wet season. In this zone and the wettest areas of the preceding zone the saturation of the soils during part of the hot season enables weathering of the rocks to take place, with release of hydroxides (iron hydroxide). Thus in the Upper Basin and the wettest piedmont areas the soils show signs of reddening.

(d) Mountain climate zone, where the mean annual temperature approximates to 10°C and rainfall may exceed 2000 mm. This climate is only found on the higher mountain tops and covers only a small part of the Upper Basin. During the last geological period the climate in the Awash basin has varied considerably, from semi-arid to wet subtropical and tropical and this has been responsible for the formation of saline horizons and mostly fossile calcareous crusts.

II - 3. Parent Rock

Volcanic rock and their weathered materials cover a substantial part of the basin. Low-lying and piedmont areas are blanketed over with alluvia and colluvia produced by erosion and weathering of this rock. Saline concentrations - some very pronounced - have resulted from the circulation of ground water frequently containing bicarbonates within this alluvium and from the various humid and arid phases of the climates. Thus, two parent rock types found in the Awash river basin are:

II-3 1. Basalt and other volcanic formations

Types of basalt vary considerably, and their chemical compositions are also fairly different. The mount Yerer basalts contain large quantities of silicium, are severely eroded, and apparently not very weathered. Basalt in the high plateaux is generally basic, and contains large quantities of calcium, magnesium, and sometimes sodium. In the more recent volcanic series basalt sometimes contains very large quantities of alkaline elements (Fentale pantellerite) like tuff and pumice.

Table 1. Analysis results for a few rock samples from the Upper Basin and Middle Valley (1) are:

Type of rock	Percentage by weight											
	S_1O_2	T_1O_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	H_2O
Olivine basalt (St.George's Church, Ababa)	45.59	2.16	14.23	3.33	9.33	0.20	8.72	10.96	2.17	0.72	0.42	2.50
Basalt (Ababa)	46.66	0.78	21.86	0.39	7.77	0.16	7.61	9.60	2.57	1.18	n.d.	1.90
Pantellerite (Fentale)	70.99	0.38	9.18	3.15	4.67	0.25	0.19	0.71	6.07	4.24	0.28	0.79
Pantellerite(Metehara)	68.69	0.40	9.98	8.52	0.68	0.14	0.03	0.76	5.84	4.23	0.07	0.83
Pantellerite(Chefedonsa-Balchi)	72.9	-	12.4	3.0	2.4	-	0.5	0.1	4.4	4.3	-	0.4
Doleritic basalt (Awora Melka)	46.30	1.80	20.10	2.70	10	-	7.80	9.30	2.90	0.70	-	-

(1) Data taken from works by Dainelli and Rohr on the geology of Ethiopia.

As Table 1. shows, respective proportions of silicium and alumina and of alkaline (Na 20, K_2O) and alkaline-earth metals (CaO, MgO) vary considerably in the various basalt facies. Rock containing the highest proportions of silicium is generally deficient in alkaline-earth metals and alumina. The chapter on water quality for irrigation will show that surface and ground waters in the middle valley and lower plains have high sodium content in relation to the more recent and sodic volcanic rocks in that area.

In the Upper Basin, weathering of this rock produces montmorillonite and illite-type clay; in areas more liberally supplied with water, even more pronounced weathering results in the formation of kaolinite and illite and the releasing of hydroxides, especially iron hydroxide. Illite is found mixed with montmorillonite in the Middle Valley.

II-3 2. Alluvia and Colluvia

Old alluvia types vary considerably; some contain diatomites, frequently with volcanic tuff deposit or basalt outflow intercalations. These alluvia contain varying amounts of clay and lime, and some may be saline and alkaline.

The recent alluvia vary in texture and, in certain depressions, may contain as much as 60 - 70 percent clay. Materials finer than 2 μ are the result of weathering of basalt rock; they are montmorillonite and illite in the Middle Valley, and probably greater proportions of montmorillonite in the lower plains.

On the river bank levees, these alluvia are very cross-bedded and occur in the form of thin silty clay horizons with loam or silty loam horizons between them. Fine-texture horizons are thicker in the depressions and, in former marshland, may even become clay.

In the Middle Valley, alluvia from the left-bank tributaries of the Awash (Kesem, Kebena and Awadi) generally have a moderately fine texture; they contain little lime, and the only signs of salinity are patches revealing the existence of saline water tables. Depressions alongside the Awash contain more clay.

On the right river bank, the slightly or non-calcareous Awash alluvia generally contain more clay, except on the bank levees of channels or former river beds. Salinity is evenly distributed in patches, as on the left bank. Calcareous colluvia frequently occur in the side valleys, generally with a medium to moderately fine texture and with clay content increasing on gentler slopes. A point to note is the presence in the Metehara area of colluvia containing high proportions of sodium, which have resulted from the weathering of highly alkaline basalt rock.

The alluvia in the Lower Plains are calcareous, with a higher pH than in the Middle Valley; texturesare distributed much in the same way as in the Middle Valley, but vary considerably due to the pronounced reworking this region has undergone - and is still undergoing - by the rivers. A large part of the oldest alluvia are affected by salinity. The colluvia, some of which are stony, are also apt to be very saline in the deeper horizons.

II - 4. Hydraulic Action

II-4 1. Effect of flooding

Flooding by streams and rivers has a marked effect on the water-holding capacity of the various soils in the flood plain of the Awash (Angelele and Gewani marshes in the Middle Valley, Boyale marsh and lakes Gamari and Bario in the Lower Plains), though the amount of land subject to regular flooding in the Middle Valley has decreased considerably since the Koka reservoir went into service.

Vegetation of a special kind grows in these areas and, in slowly decomposing, supplies large quantities of organic matter.

The seasonal floods bring large quantities of loam with them, which helps to fill certain marshes (Gedebasa, Boyale, Dit Bahri, marshland north of Asayita) and to build up natural bank levees. The soil also stores sufficient water for the growth of trees, steppe or pseudo-steppe grasses.

II-4 2. Effect of groundwater

Hydromorphic features due to waterlogging of the soil by permanent ground water are observed only in marsh areas. Some minor ferruginous deposits have been noted in soils on recent alluvia, and signs of gley formation on poorly-drained flat ground in the upper basin.

The effects of saline ground water containing bicarbonates in large quantities are especially seen around the warm springs in the Middle Valley (lake Beseka, Filweha, Kada Bilen, lake Hertale and Metaka springs).

In the recent alluvia, the water table generally lies at a medium depth below the surface (30 metres in Tendaho area, 10 to 15 m in Dit Bahri area), but has been subject to major variations during past climate periods, as is shown by the existence deep down of saline horizons or horizons with carbonates.

The chemical composition of the ground water will be studied in the chapter on quality of water for irrigation.

III. SOIL PROSPECTING AND SURVEY METHODS

III - 1. General Working Method

The Awash River Basin soil survey was carried out in several phases. Each involved different types of work:

(i) Obtaining general information about the river Basin from available documents on climate, geology, geomorphology, soil and vegetation.

(ii) Use of existing 1:500,000 and 1:1,000,000 scale map and the interpretation of aerial photographs (approximate scale 1:60,000 for the upper basin and 1:40,000 for the Middle Valley and Lower Plains) in preparing the planimetric background maps to serve as a basis for the prospection work and to illustrate the survey data.

(iii) Field prospecting work, including the taking of soil profiles (test pits and auger borings) and soil samples.

(iv) Soil sample analysis in a specially equipped laboratory run by a chemist.

(v) Interpretation of analysis results with due allowance for field observations and aerial photograph details.

(vi) Soil classification and mapping.

III - 2. Soil Prospecting

Because of the size of the Awash Basin and the difficulty of access to its various areas, the soil prospection program was carried out in several phases:

III-2 1. Initial selection of prospection areas

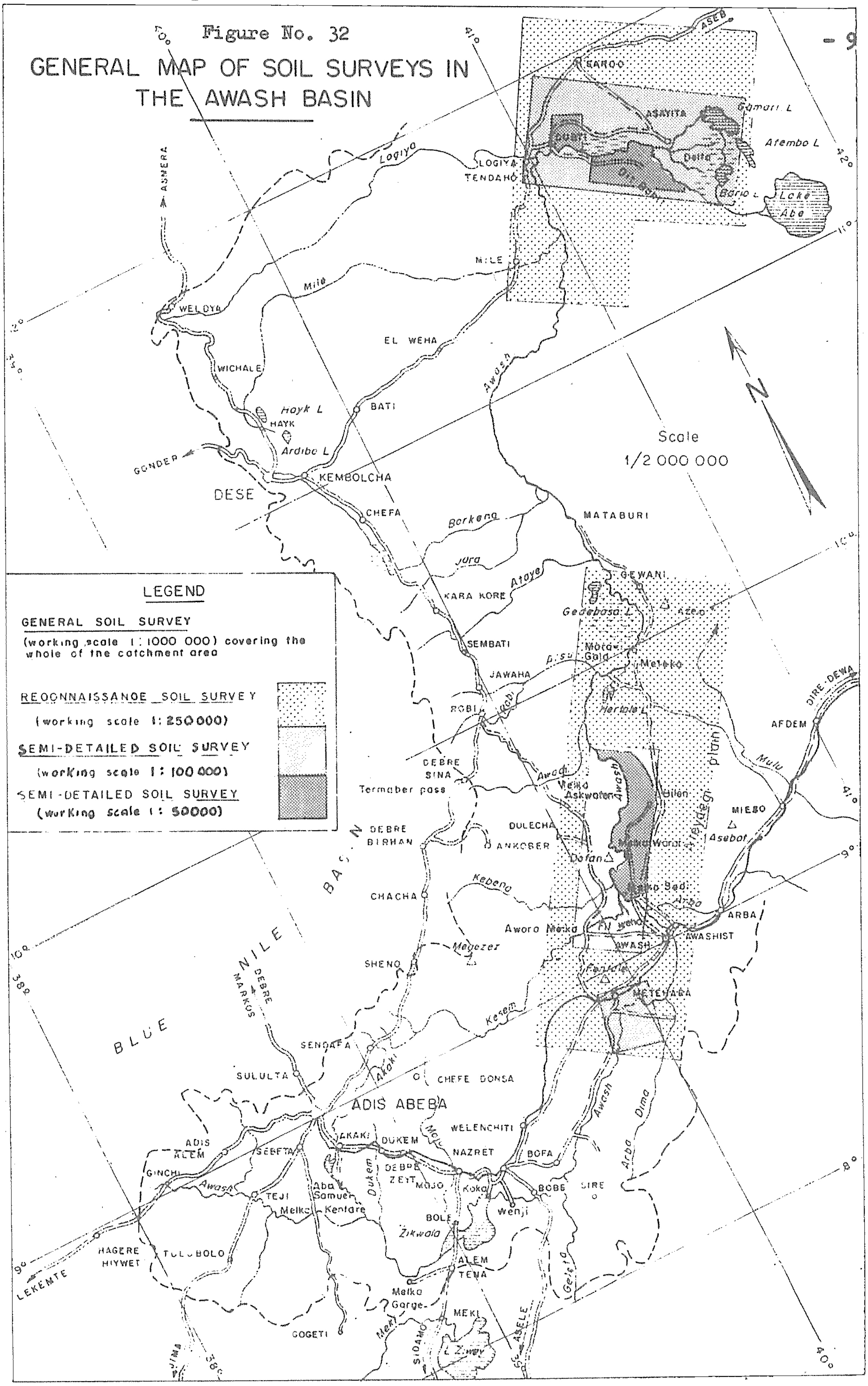
A preliminary reconnaissance from the air followed by ground checks made possible an initial selection of areas likely to be suitable for development under irrigation, and also of land suffering from poor drainage and erosion.

III-2 2. Soil reconnaissance survey

The purpose of this survey was to define the type and extent of various soil groups and sub-groups as regards soil genesis, to narrow down the choice of areas containing potentially irrigable soils, and to establish suitable classification criteria for use in the semi-detailed soil survey. An initial interpretation was made of the aerial photograph data before the reconnaissance survey, in order to define suitable map units in terms of topographical location, slope and relief (presence of basalt), signs of erosion, run-off, occasional or permanent flooding, and natural or cultivated vegetation.

Figure No. 32

GENERAL MAP OF SOIL SURVEYS IN THE AWASH BASIN



By observing profiles in these various units and interpreting the analysis results, the soil groups and sub-groups can be defined according to their parent rock and the nature and degree of their evolution. About one profile was analysed for every 500 or 600 hectares of ground in potentially irrigable areas. Where irrigation was expected to be difficult (saline soil), only one profile per 1,500 - 2,000 hectares was analysed.

The soil reconnaissance survey covered the entire alluvial area to either side of the Awash between Awash station and the lower lakes. The soils were mapped on a 1:250,000 scale sketch map covering the whole of this part of the Basin.

III-2 3. Semi-detailed soil survey

This was carried out on land selected in the reconnaissance survey. Its purpose was to enable soil series and phases (where applicable) to be defined and the corresponding units to be mapped with the accuracy required to give at least a clear definition of patches of land of 25 - 30 hectares. The soils were subsequently classified according to irrigability.

Further photo-interpretation work was done before the semi-detailed survey of each area, to ensure as comprehensive a sketch map as possible. From an initial classification based on the morphological features of the profiles in the various units on this sketch map, it was possible to draw a provisional soil map to a scale of 1:50,000. Maps of this type were obtained by transferring the area boundaries to the photographs in the 1:40,000 scale mosaic and then reducing to a scale of 1:50,000. After adding the finishing touches to the soil classification from analysis results, the final soil map was drawn to a scale of 1:100,000.

About one profile for every 200 or 300 hectares of land was analyzed in the Middle Valley, and one for every 300 hectares in the Lower Plains, except in the Dubti area where one profile was analyzed for every 150 hectares, because of the added complication of "imbricated" saline soils.

III-2 4. Extension of the soil prospection survey to the entire river basin

A very general prospection survey was then carried out of the entire catchment area. Together with further photo-interpretation, the survey enabled the soil maps to include the entire Basin, in addition to the potentially irrigable areas.

The general soil classification established on this basis allows for all the soil formation and climate factors in the Basin, and also includes all the groups and sub-groups identified during the reconnaissance survey.

The necessary 1:1,000,000 scale map was obtained by reduction from a complete background on a scale of 1:250,000. This was established both from the previously prepared map of the alluvial area and by assembling the aerial photographs of the Upper Basin; the whole was finally adjusted with the aid of existing 1:500,000 scale maps.

III - 3. Interpretation of Analysis Results

III-3 1. Inventory of analysis work carried out

Full analysis results classified according to areas investigated were provided to Government. They included the following types of physico-chemical analysis:

(i) Current texture, lime, pH, organic matter and nitrogen analysis.

(ii) Saturated extract analysis to determine salinity characteristics.

(iii) Base exchange capacity analysis to determine the state of saturation of the complex and the nature of the exchangeable cations, especially for the presence of sodium and its relation to the total exchange capacity.

(iv) Analysis of other physical soil properties, such as available moisture and structural stability (measured by the percentage of aggregates remaining stable when exposed to water and in benzene).

The analysis methods used are described in Appendix 1.

III-3 2. Current analysis interpretation

Soil texture enabled a first differentiation to be made between soils with a view to their classification. The amount of mechanical analysis could be reduced thanks to a correlation between saturation moisture and clay content (see graph). Classification standards are those of the U.S. Soil Survey Manual.

Lime content of the Middle Valley soils is low, less than in the Lower Plain soils (see graph). Other graphs were also plotted, one for each area. By analysis of the profiles for the various classification curves, the following distinctions were made for the areas covered in the reconnaissance and semi-detailed soil surveys:

Very slightly or non-calcareous parent rock containing an average 1% - 2% $CaCO_3$, corresponding to the recent alluvia in the Middle Valley.

Slightly calcareous parent rock containing less than 5% $CaCO_3$, from which some vertisols in the Middle Valley have formed.

Calcareous parent rock corresponding to the recent alluvia in the Lower Plains and generally to old alluvia and colluvia. This rock contains an average 7 % - 8% lime, and frequently over 10%. A higher average content is also noted in the Asayita delta soils.

pH is on the average higher in the Lower Plains (8.6) than in the Middle Valley (8.2).

Calcareous soils generally have a pH of about 8, as was found, for instance, on calcareous soil samples from the Melka Sedi and Amibara areas.

pH rises above 8.5 for certain vertisol series, especially if overlying older alluvia (Aleydegi plain). The frequent occurrence of ground water containing high proportions of sodium carbonate and bicarbonate shows up on the graph by its becoming stable where pH exceeds 9.5 (Metehara, Kesem, Kebena and Melka Sedi plains).

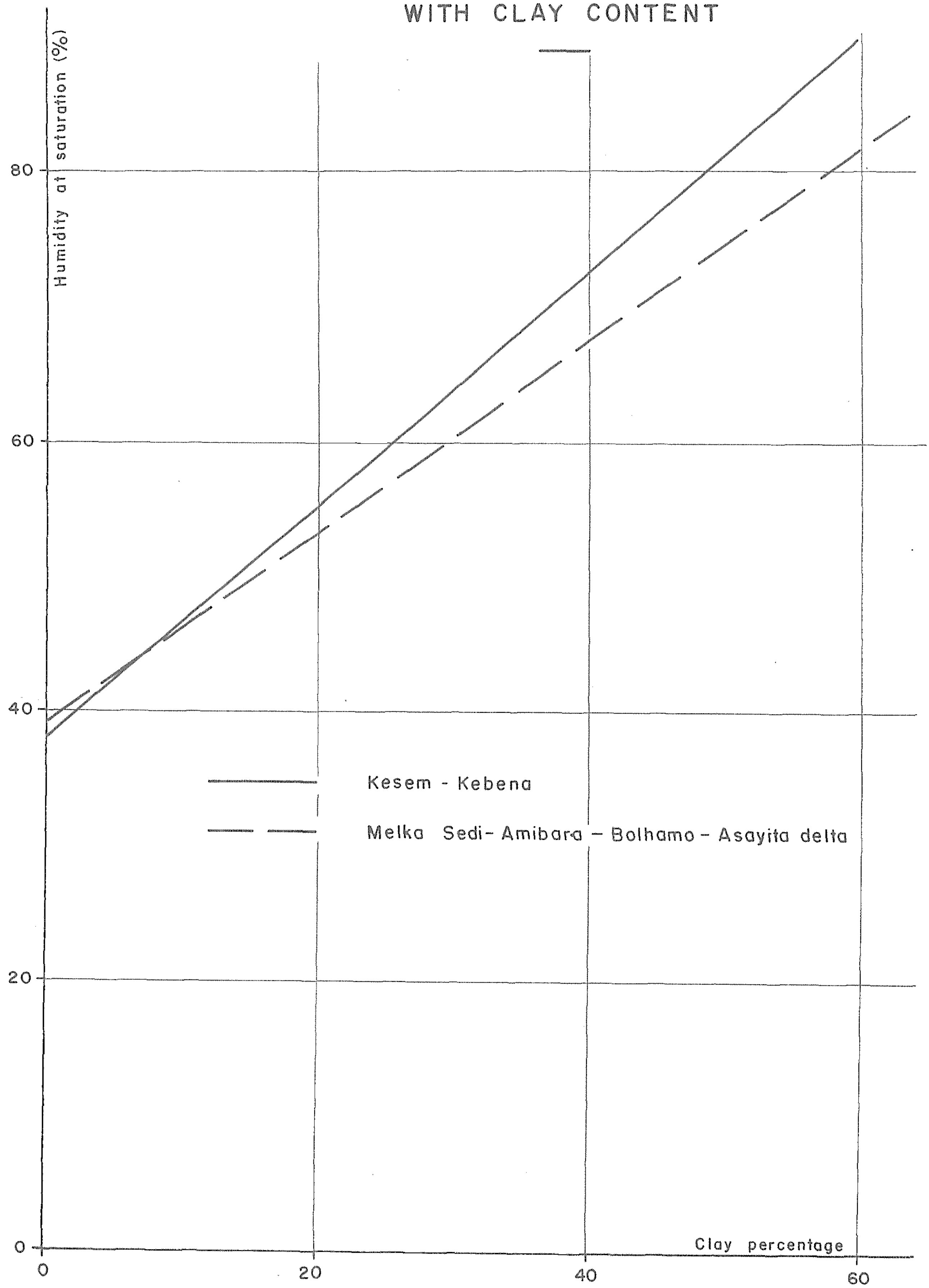
Soils in the Maro Gala plain have an average pH of about 8, e.g., lower than the other soils in the Middle Valley.

Organic matter content varies considerably in the two regions.

Most soils in the Lower Plains contain less than 1% organic matter. This low rate is associated with an arid climate. Very low rates sometimes denote saline clay

FIG. I

CORRELATION OF HUMIDITY AT SATURATION WITH CLAY CONTENT



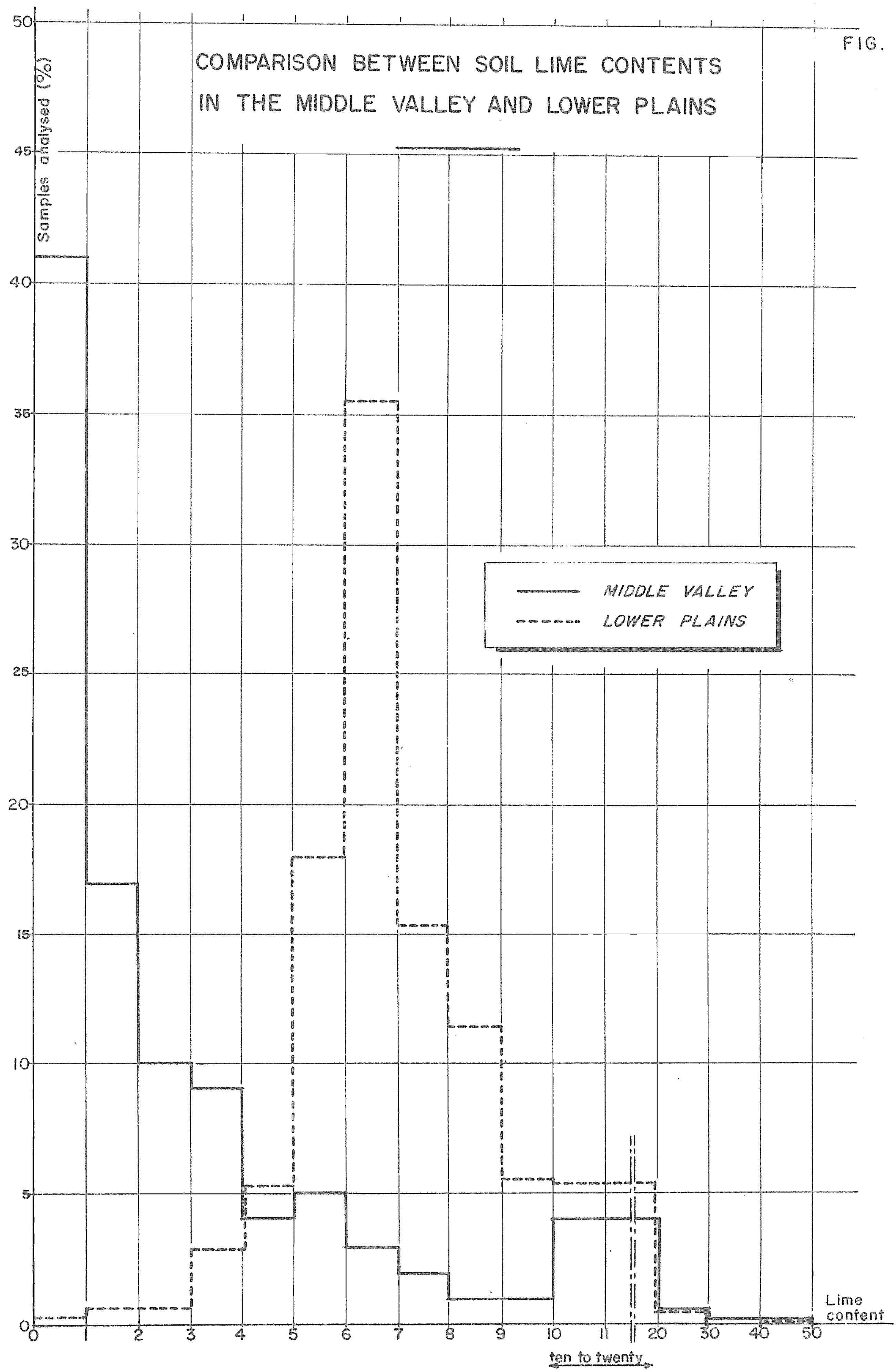

COMPARISON BETWEEN SOIL LIME CONTENTS
IN THE MIDDLE VALLEY AND LOWER PLAINS
Samples analysed (%)
50
45
40
35
30
25
20
15
10
5
0
MIDDLE VALLEY
LOWER PLAINS
0
1
2
3
4
5
6
7
8
9
10
11
20
30
40
50
Lime content
ten to twenty

FIG. 2

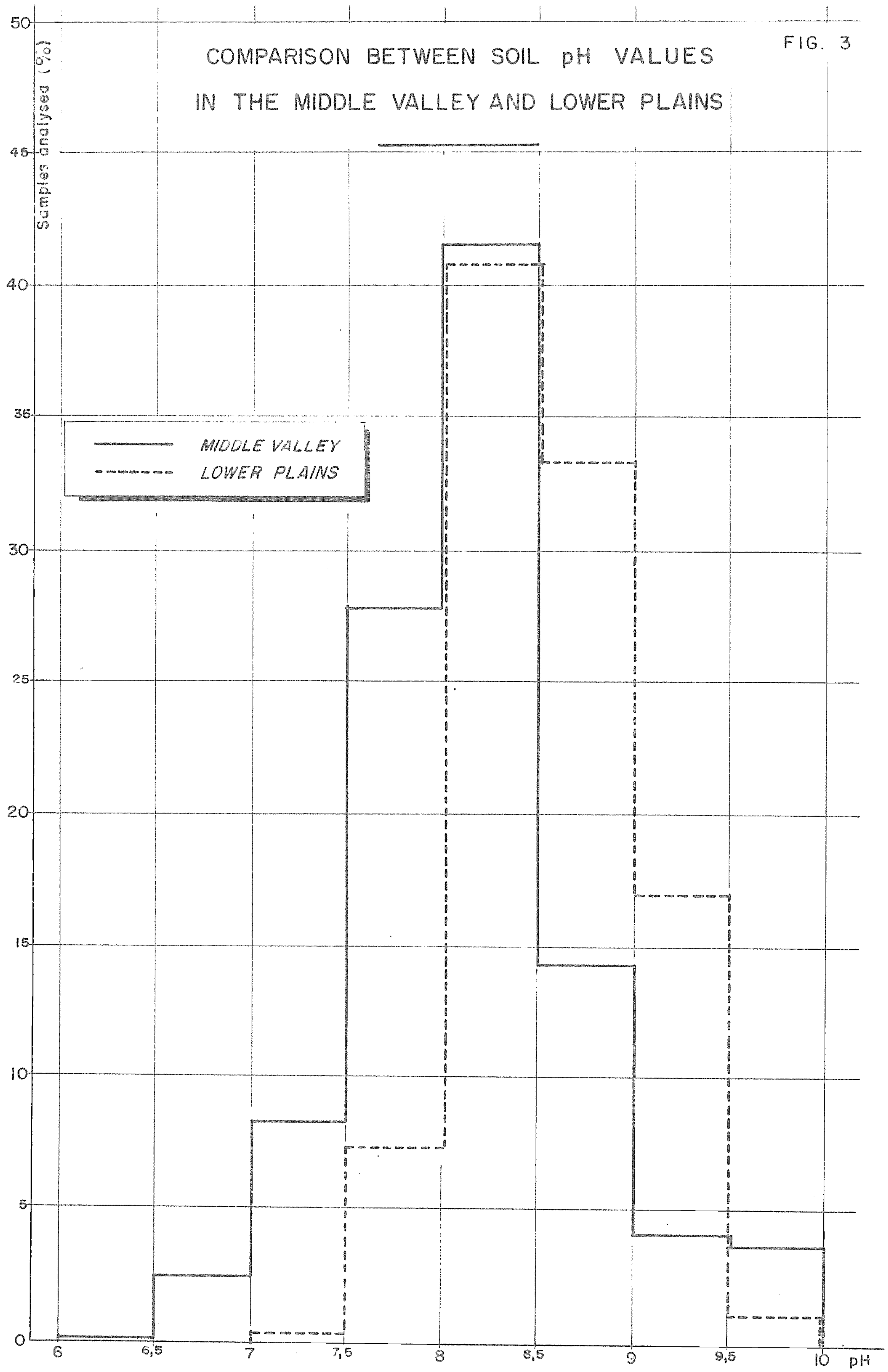
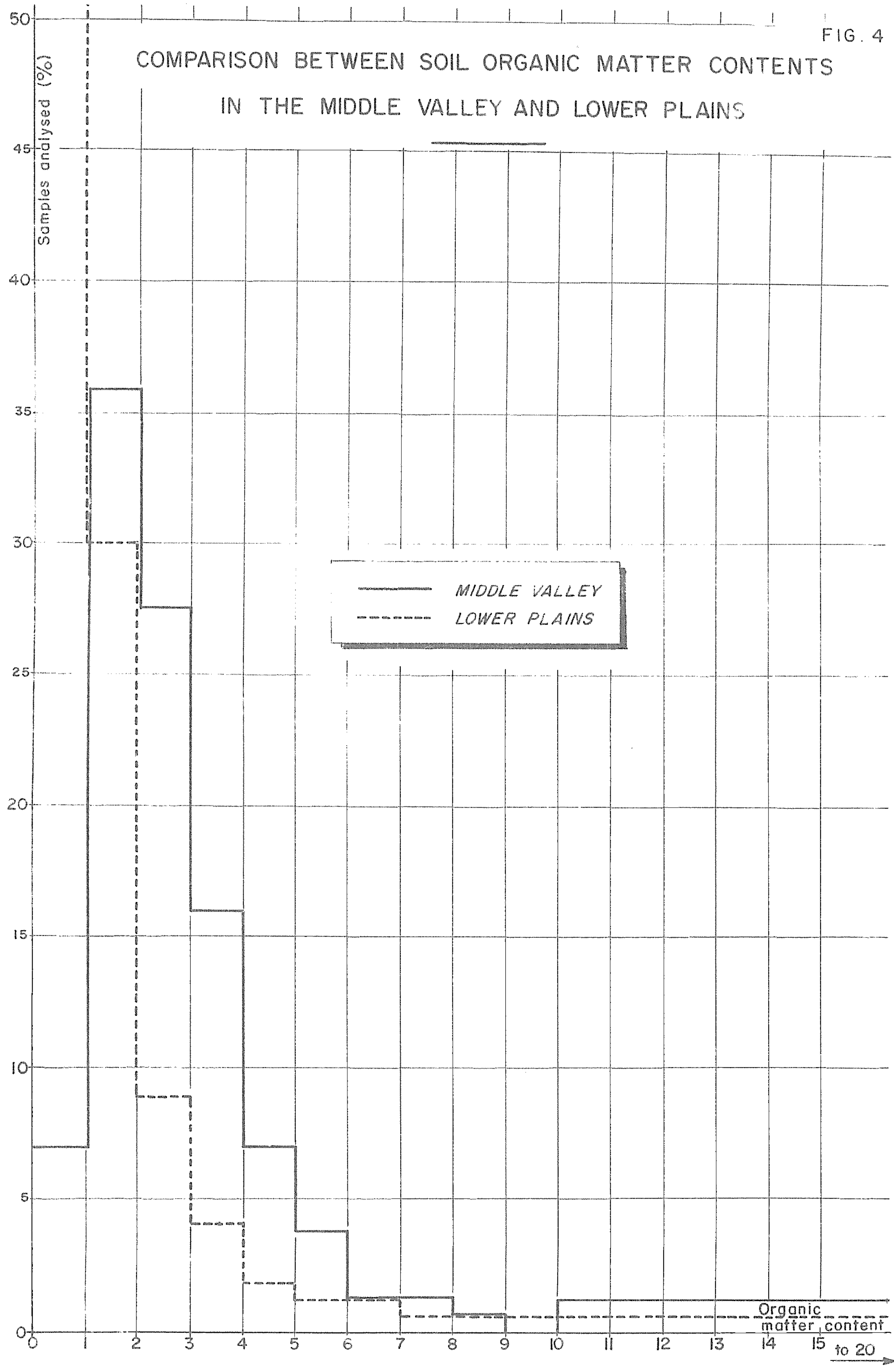


FIG. 3
COMPARISON BETWEEN SOIL pH VALUES
IN THE MIDDLE VALLEY AND LOWER PLAINS
MIDDLE VALLEY
LOWER PLAINS
Samples analysed (%)
50
45
40
35
30
25
20
15
10
5
0
6
6,5
7
7,5
8
8,5
9
9,5
10
pH

FIG. 4


COMPARISON BETWEEN SOIL ORGANIC MATTER CONTENTS
IN THE MIDDLE VALLEY AND LOWER PLAINS
Samples analysed (%)
50
45
40
35
30
25
20
15
10
5
0
MIDDLE VALLEY
LOWER PLAINS
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
to 20
Organic matter content

soils. Soils in areas subject to flooding (Asayita delta) or which have recently dried out (north of Asayita and near Dit Bahri), or near hills (soils over colluvia near Dit Bahri) contain more organic matter (2% - 3%).

Organic matter content in the Middle Valley usually exceeds 1%. Perusal of the curves for organic matter content in the various areas shows the effect of runoff and temporary flooding in the Metehara and Maro Gala areas.

Organic matter content however, varies considerably with vegetation cover. Which itself depends on the "micro-climate" (proximity of streams or rivers) and such factors as the continued presence of cattle on small areas of pasture land and the erosion of medium-texture surface soils (Kesem, Kebena and Bolhamo plains).

Total nitrogen rates are generally low with C/N ratios ranging between 10 and 15, due to the inhibition of organic matter transformation by drought or waterlogging.

III-3 3. Salinity analysis interpretation

Inspection of the saturated extracts shows salinity in the Lower Plains to be due to sodium chloride and sodium and calcium sulphate, which frequently occur in equal proportions. Sodium nitrate may also be a contributory cause where salinity rates are high. Salinity is classed in terms of saturated extract conductivity.

Sodium is usually the prevailing cation in the medium to high salinity range. The saturated extract invariably contains bi-carbonates in quantities varying between 2 me/l and 5 me/l. Certain soils with a salt crust contain substantially more bi-carbonate, possibly up to over 10 me/l or even 20 me/l in the saturated extract.

Salinity in the Middle Valley is generally connected with circulating ground water containing chlorides and bicarbonates. Horizons rich in bicarbonate, sulphate and chloride are observed; salt crusts generally consisting of mixed sodium sulphate and bicarbonate are also liable to form; for instance, near the Filweha and Kada Bilen warm springs.

Sodium is again the prevailing cation in the medium to high salinity range. High proportions of sodium with pH exceeding 9.0 are observed in certain areas; for instance, on soil formed from very alkaline rock at the foot of the Fentale. A pH of nearly 10 was noted on a saline crust sample (Na and K cations prevailing) taken near lake Beseka.

Soils in the Upper Basin are either only very slightly saline or not at all (Ca and Mg cations prevailing). Bicarbonate quantities are very small, except locally on volcanic tuff.

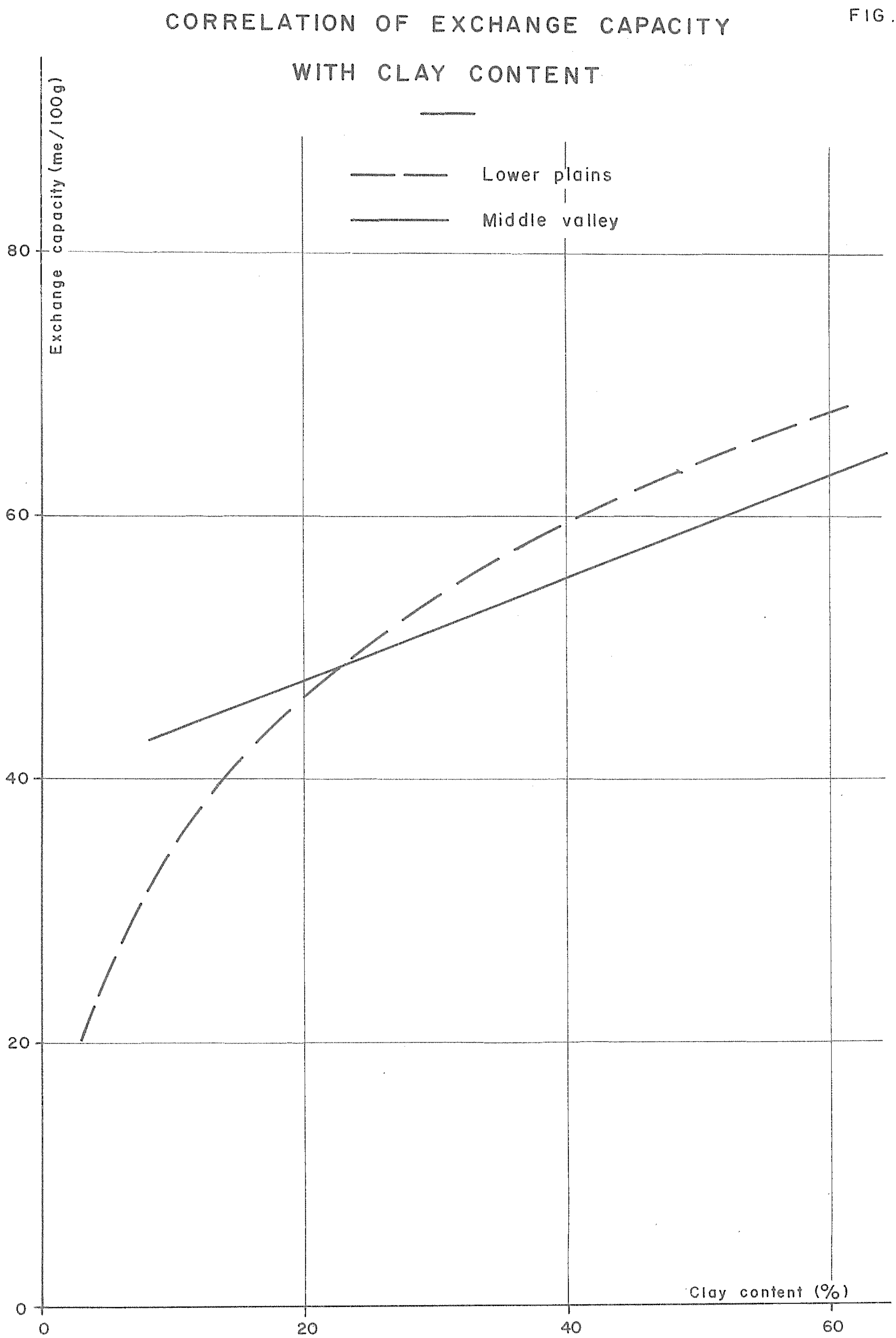
III-3 4. Exchange complex analysis interpretation

This involved two different types of analysis:

(i) Chemical analysis to determine the exchange capacity and proportions of the various cations.

(ii) X-ray analysis to determine the nature of the clay in the various soil groups.

FIG. 5


CORRELATION OF EXCHANGE CAPACITY
WITH CLAY CONTENT
Lower plains
Middle valley
Exchange capacity (me/100g)
80
60
40
20
0
Clay content (%)
0
20
40
60

The chemical analysis shows that the base exchange capacity varies with clay content. As the graph shows, it peaks at 70 - 80 me per 100 grammes of soil. Values between 40 me and 60 me are fairly well grouped, and give a satisfactory correlation with clay content. Exchange complex saturation rates generally vary between 90% and 100%.

The proportion of sodium in the complex is important in classifying soils according to irrigability. A soil can be considered alkaline if the proportion of sodium to the exchange complex reaches 15%. Alkalinity mainly affects the saline and very clayey soils in the Lower Plains and Middle Valley, some vertisols on calcareous alluvia, and certain soils associated with a saline water table.

Exchange complexes in the Upper Basin are not saturated, and there is little to correlate their still high exchange capacities with clay content (except in red weakly ferralitic soils).

X-ray analysis - the results of which are discussed in Appendix 2 - reveals the large quantities of clay minerals, montmorillonite and illite, in the $< 2\,\mu$ size range of soils on alluvia and colluvia in the Middle Valley and Lower Plains. Attention is drawn to the substantial proportions of illite in the Middle Valley soils, and also to the invariable occurrence of quartz. Analysis of a sample from the Lower Plains at an extreme exchange capacity (about 80 me for 100 grammes of soil) revealed a very high proportion of montmorillonite to the detriment of the other constituents, illite and quartz.

Swelling clay is thus general in alluvial area soils tending to vertisols if containing high proportions of clay.

Kaolinite is only found in the Upper Basin soils above the altitude of, say, the Koka Mojo area, where rainfall is quite appreciable. Proportions of illite and quartz remain high in the grey vertisols on non-differentiated materials in the valleys. Proportions of montmorillonite and illite are also high on brown vertisols on basalt slopes.

Kaolinite and hematite contents increase distinctly at the slightest tendency towards soils reddening, this being accompanied by a drastic decrease in proportions or the disappearance of montmorillonite, though illite still remains. This composition is typical of the red weakly ferralitic and reddish brown vertisols containing little montmorillonite around Ababa.

III-3 5. Interpretation of hydrodynamic characteristics

The capacities of the soil for water at pF 4.2 and 2.8 are the basic factor in assessing the suitability of soils for development; the difference between the moisture content corresponding to these two figures gives the available moisture from which the quantity of water actually available for use by the plants can be calculated for various root penetration depths.

The results of measurements of this type (see Table 2.) show that available moisture is low to medium, being generally in the 10% - 15% range (of the weight of dry soil). Clay content and available moisture do not appear to be correlated. Very clayey soils, especially vertisols into which roots have difficulty in penetrating, will only be able to retain small quantities of water for the plants.

Infiltration rates were measured at a certain number of points, and were found to vary between 1 cm/hr and 2 cm/hr in alluvial soils with cross-bedded very clayey horizons, and less than 1 cm/hr in vertisols.

Structural stability was investigated on a number of samples taken at suitably distributed points throughout the river basin. Examination of the percentage of aggregates stable in water shows that the Upper Basin soils (brown and grey vertisols) are more stable than the Middle Valley and Lower Plain soils, except in certain cases where they contain a lot of organic matter. Their lower stability is probably associated with the proportions of sodium in the complex and saturated extracts.

Table 2. Available moisture for selected soil samples

Profile	Depth (cm)	Equivalent moisture (%)	Moisture at pF 42 (%)	Avaliable moisture (%)
UPPER BASIN				
UU 002	0-10	48	30.7	17.3
	10-35	43	26.7	16.3
	50-60	30.6	16.1	14.5
UU 008	0-5	58.2	38.9	19.3
	5-10	62.2	41.6	20.6
UU 011	0-25	31	14	17
	25-40	21	11	10
	50-90	39.4	25.7	13.7
UU 012	0-10	46.4	31.1	15.3
	10-40	44	29.1	14.9
UU 015	10-30	30	20.6	9.4
UU 017	0-5	49	36.1	12.9
	5-10	48.5	41.8	6.7
	10-40	51.7	38.4	13.3
UU 018	0-10	53.9	43	10.9
	10-30	64.4	48	16.4
	30-75	58.8	37.7	21.1
UU 019	0-20	30	13.4	16.6
	30-40	43	25	18
UU 020	0-20	32	14	18
	25-60	47	30.4	16.6
UU 021	0-20	55	38.1	16.9
	20-40	65	37.5	27.5
UU 022	0-20	36.5	27.2	9.3
	20-45	46.5	39.5	7
UU 023	0-12	40.5	31	9.5
UU 029	150-170	31.3	20.5	10.8
UU 030	0-15	30	17.8	12.2
	15-60	27.5	20.8	6.7
	60-80	34.5	22.7	11.8
URB 001	0-20	39	33.2	5.8
	20-100	40.2	29.8	10.4
URB 002	0-40	24	14.1	9.9
UCF 001	0-20	53.2	38	15.2
	20-70	43	31.1	11.9

Table 2. Available moisture for selected soil samples (cont'd.)

Profile	Depth (cm)	Equivalent moisture (%)	Moisture at pF 42 (%)	Available moisture (%)
UPPER BASIN (continuation)				
UCF 002	0-10	46.5	37.6	8.9
	25-70	50	32.7	17.3
UCF 003	0-15	41.7	31.8	9.1
	25-60	45	32.9	12.1
UCF 004	0-10	36	27.8	8.2
	20-70	38.7	31.9	6.8
UCF 005	0-30	22	10.7	11.3
UB 003	0-15	28.5	16.5	12
	15-60	33.8	19.6	14.2
UGL 004	0-12	33	21.2	11.8
	12-50	35	18.3	16.7
UGL 006	0-15	39	31.5	7.5
	25-45	38.5	24.8	13.7
MIDDLE VALLEY				
HMH 401	0-15	38.5	25.2	13.3
	15-50	35.5	23.3	12.2
HMH 402	0-10	35	22.8	12.2
	30-80	37.5	25.4	12.1
KK 001	0-10	18.5	13.5	5.0
	10-40	19.5	12.2	7.3
KK 002	0-20	33.2	21.9	11.3
	20-50	19	10	9
KK 008	0-20	24.5	10.9	13.6
KKB 007	0-20	42.5	15.9	26.6
	30-45	46.5	32.2	14.3
KKB 401	0-15	27.2	15.1	12.1
	15-35	33.7	16.1	17.6
KKB 402	0-25	20	12.5	7.5
KKB 403	0-20	35.5	21.8	13.7
	20-30	35.7	21.8	13.9
MMS 102	0-10	34.7	25.8	8.9
	30-60	37	25.4	11.6
MMS 109	0-8	49	34.5	14.5
	8-40	49.5	31.8	17.7
MMS 318	0-20	55.5	37.8	17.7
	20-55	31.5	21.7	9.8
	55-120	42	27	15
MMS 342	0-15	46.7	36.4	13.3
	15-30	36.5	26.1	10.4
MMS 343	0-3	42.5	29.4	13.1
	15-60	45	39.5	5.5

Table 2. Available moisture for selected soil samples (cont'd)

Profile	Depth (cm)	Equivalent moisture (%)	Moisture at pF 42 (%)	Available moisture (%)
LOWER PLAINS				
TMT 003	0-10	31.7	16.8	14.9
TMT 004	0-25	22	15.8	6.2
	25-45	35.5	17.2	18.3
TMT 023	0-7	27.7	17.9	9.8
	7-40	29.2	19	10.2
DRD 001	0-5	52	20.1	31.9
	10-30	40	26.7	13.3
	60-100	46	31.7	14.3
DAR 008	0-10	39.7	29.9	9.8
	60-70	42.5	39	3.5
DRD 123	0-5	41.2	31.3	9.9
	15-45	29.8	20.4	9.4

IV. GENERAL SOIL CLASSIFICATION

IV - 1. Principle

A soil classification sets out all the relevant data, so that the nature of a given soil and its differences from, and similarities to, other soils can be defined.

Soils are classified in groups, sub-groups, series and phases. Classification criteria are established from the soil profiles; in other words, from the different horizons resulting from different types of parent rock, topographical features, climate, the effect of floods, biological factors (plants, animals, human), and the time they have taken to develop.

Soil classification is a delicate matter, if only because of the seemingly endless soil profile variations, especially in alluvial ground. It is often possible, however, to establish an average profile for a given area, from which the other profiles differ insignificantly.

From this synthesis follows the "soil series" notion. It is an elementary classification unit covering an area of a certain size in which all the profiles can be associated with the "typical profile" for the series. This profile is "typical" for its average features of colour, texture, structure, pH, organic matter, salinity and/or alkalinity. Most soil series include several phases which depend on main land use factors:

Waterlogging by overflowing rivers or where runoff collects.

"Microrelief", of which one pronounced form occurs where old channels still exist.

Gravel, or medium-textured horizons deep down, which are apt to assist drainage.

Soil depth and type of subsoil.

In view of the size of the Awash Basin and to facilitate soil comparisons between different regions or between regions not investigated with the same intensity, all the soil series have been arranged within a more general framework comprising groups and sub-groups. They differ mainly in their types of parent rock.

IV - 2. Major Soil Groups

The overall classification and soil mapping units are summed up in Table 4. This classification, which is applicable to the whole Basin, features nine soil groups.

Alluvial soils formed from very cross-bedded recent alluvia generally along streams, rivers or natural water channels in the alluviation areas of the Awash. Their lime content and pH depend on their geographical location. In the Middle Valley, they generally contain little or no lime, with their pH varying between 7 and 8, but are calcareous with pH exceeding 8 in the Lower Plains. Saline or calcareous horizons have been noted in these soils, probably caused by local water table at certain times in the past.

Vertisols, which are distinctive by their dark colour and the fact that they contain swelling clay. They can be differentiated as:

Very slightly or non-calcareous grey vertisols, containing large amounts of clay, with a pH of nearly 7 and often pronounced selfmulching properties. The clay component is a mixture of illite (often the predominant constituent) and montmorillonite. They have a high exchange capacity (over 50 me for 100 grammes of soil), contain up to 4% organic matter and show C/N ratios varying between 12 and 20. They occur in the Upper Basin of the Awash on alluvia and materials weathered from basalt, also on the very slightly or non-calcareous alluvia in the Middle Valley.

Grey vertisols on calcareous alluvia. These have a higher pH and show slight saline or alkaline tendencies. They are found in deeper horizons, more especially in the Lower Plains.

Brown and reddish-brown vertisols with a pH slightly exceeding 7 and containing less clay. Their organic matter content is less than 3%, and C/N ratios are less than 15. Base exchange capacity is around 50 me for 100 grammes of soil. These soils occur on hillsides in the upper basin, generally over volcanic material; i.e., tuff and pumice.

The reddish-brown soils show more pronounced evidence of pedogenetic evolution. In addition to illite and montmorillonite, they are also apt to contain hematite and kaolinite. They occur in the more humid climate zones (region between Debre Sina and Dese).

Semi-arid brown soils which have formed in the arid to sub-arid climate zone from alluvia frequently mixed with volcanic materials. Though they are generally calcareous, the lime is apt to migrate in concretion form. Organic matter content varies between 2% and 3%.

Saline and saline alkali soils, typified by horizons containing up to over 0.6% salts. These are generally calcareous with a pH invariably exceeding 8 and liable to rise to 9 or 10 in very alkaline soil. They frequently contain gypsum, and also occasional salt crusts in certain regions featuring a deep saline water table. Exchangeable sodium exceeds 20% in alkali soils. Organic matter content is low, usually less than 1%.

These soils mostly occur over older alluvia and colluvia in the lower plains.

Hydromorphic soils in badly-drained areas or along the edges of marshland. These are dark soils containing large quantities of organic matter. The following differentiation is made in terms of pH:

Hydromorphic soils with pH about 5 in badly-drained areas on the high plateaux. These contain a high proportion of organic matter (4% - 12%) and show C/N ratios varying between 12 and 17. They are rich in clay, but their complex is far from saturation.

More or less calcareous hydromorphic soils with a pH of over 7. These are found in the Awash valley, especially in the Lower Plains and in certain depressions in the Upper Basin. They generally contain a lot of organic matter.

Organic soils in permanent marshland (lower plains).

Erosion regosols. These are in the arid to semi-arid area over semi-arid brown soils formed from various types of parent rock, including alluvia and weathered material from volcanic rock. They are often in association with brown vertisols in areas bordering the Upper Basin, in which they have also developed locally from slightly ferralitic red soils. Where they have developed over old saline clayey alluvium, they form the type of complex referred to as "badlands", covering large areas between the Middle Valley and Lower Plains.

Lithosols on volcanic rock, frequently in association with grey vertisols in the Upper Basin.

Classification units of sub-groups and series will be described in the soil reconnaissance (1:250,000 scale map) and semi-detailed (1:100,000 scale mapping) surveys.

IV - 3. General Soil Map for the Entire River Basin (Map No. 2)

The 1:1,000,000 scale map of the Awash Basin shows the various groups and the main sub-groups obtainable by differentiation of certain types of parent rock. It was sometimes impossible to establish a spatial soil distribution relationship; in such cases, the map unit covers the corresponding "soil chain", as follows:

Grey vertisols on slopes, also skeletal soils - or lithosols - on very steep slopes of hilltops.

Brown and reddish-brown vertisols on sloping ground, also lithosols on steep slopes or hilltops.

It is difficult to distinguish between vertisols and hydromorphic soils in certain flat areas on the high plateaux. Due to the humid climate, they are water-logged for part of the year. The typical features of those areas are their low fertility and the burning (denshering) of top soils by the farmers. These associations of soils are plotted on the general soils map (with the numbers 3 and 4) as distinct mapping units.

The mapping units refer to seven major groups.

Alluvial soils on recent calcareous (lc) or non-calcareous (lnc) alluvium.

Vertisols, including:

Grey vertisols, some of which occur over alluvia (2 nc and 2 c), and others over non-differentiated materials (2 nd) comprising materials weathered from various types of volcanic rock, and alluvia.

Grey vertisols associated with hydromorphic soils (4) and lithosols (3).

Brown and reddish-brown vertisols associated with lithosols on basalt (5).

Brown vertisols associated with lithosols on various types of volcanic rock (6).

Semi-arid brown soils on old alluvia and colluvia (7 a) or on non-differentiated materials (7 nd) possibly partly consisting of tuff, pumice or other volcanic materials.

Saline soils and regosols, which can be distinguished as:

Saline soils (8) and saline alkali soils (9) on recent alluvia.

Saline soils and severely eroded regosols (10) on non-differentiated materials originating for the greater part from old alluvium.

Hydromorphic soils. Frequently under water, these soils occur over calcareous (11 c) or non-calcareous (11 nc) alluvium, and form marshland where there is a prolonged waterlogged condition (12).

Regosols, which are distinguished according to the state of evolution of their parent rock, which may either have originated from sub-arid brown soils (13 b), red weakly ferralitic soils (13 r), or from a non-differentiated soil complex ranging from a brown soil to a vertisol (13 nd). Sandy regosols (14) are included in this group.

Lithosols, which can be associated with vertisols (3, 5, 6), or which may predominate in units mapped on basalt (15) or non-differentiated materials (15 nd).

IV - 4. Summary of Areas Covered by the General 1:1,000,000 Scale General Soil Map

As the Table 3 shows, vertisols alone or associated with lithosols and vertisol-lithosol associations cover almost a third of the Basin, and are of a different type on the high plateaux and basalt hills from those in the alluvial areas; the latter only extend over 300,000 hectares, - i.e., 4.5 % of the overall Basin - and the alluvial soils proper amount to 2.5 %.

The sub-arid brown soils bordering the recent alluvial areas in the Middle Valley and Lower Plains cover about 12.5% of the overall River Basin.

Regosols account for 10 % of the total area; they occur in the piedmont area at the foot of the cliffs bordering the Rift Valley and generally in the sub-arid brown soil area, also on the volcanic hill slopes. Small tracts of the latter - less than 1% of the total surveyed area - are the red weakly ferralitic soils.

Hydromorphic soils are generally found in the depressions. In major flooding and marsh areas (Teji, Borkena, Gewani and Lower Plains), these have been mapped to a scale of 1:1,000,000.

Saline and saline alkali soils, which also include part of the regosols, are generally found on old and recent alluvium, especially to the north of Gewani in the Middle Valley, and covering about 100,000 hectares in the Lower Plains.

Lithosols and skeletal soils cover more than a quarter of the total river basin area. They are mainly found between Nazret and lake Abe, where various-sized sub-arid brown soil or vertisol patches are observed.

Table 3. Areas covered by the major soil groups and mapping units.

Soil Group	Area covered hectares	Area covered %	Mapping unit	Area covered hectares	Area covered %
ALLUVIAL SOILS	165,000	2.4	Alluvial soils (1 c, 1 nc)	165,000	2.4
VERTISOLS	1,065,000	15.2	Grey vertisols (2 c, 2 nc, 2 nd)	1,015,000	14.5
			Grey vertisols and hydromorphic soils (4)	50,000	0.7
VERTISOLS ASSOCIATED WITH LITHOSOLS	1,340,000	19.1	Grey vertisols and lithosols (3)	355,000	5.1
			Brown and reddish-brown vertisols and lithosols (5)	835,000	11.9
			Brown vertisols and lithosols (6)	150,000	2.1
SEMI-ARID BROWN SOILS	880,000	12.6	Semi-arid brown soils (7a, 7 nd)	880,000	12.6
SALINE AND SALINE ALKALI SOILS INCLUDING REGOSOLS	450,000	6.4	Saline soils (8)	25,000	0.3
			Saline alkali soils (9)	105,000	1.5
			Saline soils and regosols(10)	320,000	4.6
HYDROMORPHIC SOILS	210,000	3.0	Hydromorphic soils (11 c, 11 nc)	155,000	2.2
			Organic hydromorphic soils(12)	55,000	0.8
REGOSOLS	1,110,000	15.9	Regosols (13 p, 13 r, 13 nd)	1,100,000	15.7
			Sandy regosols (14)	10,000	0.2
LITHOSOLS	1,780,000	25.4	Lithosols and skeletal soils (15 v, 15 nd)	1,780,000	25.4

IV - 5. Larger Scale Soil Mapping

The soil classification is also shown on the 1:250,000 scale reconnaissance survey and 1:100,000 scale semi-detailed soil survey maps.

On the reconnaissance survey map, all the soil groups and sub-groups are featured to map scale, as differentiated according to the origin and type of their parent rock. Each unit has been given a symbol, and each soil group - i.e., soils from parent rock of the same type and origin - is identified by a specific colour. Thus, different colours have been used to denote soil groups originating from parent rock of the same type but of a different origin (recent or old alluvia). The minimum size of a mapping unit to 1:250,000 scale is about 400 - 500 hectares.

Elementary mapping units resulting from the semi-detailed soil survey are featured inside the reconnaissance survey mapping units. They mainly include soil complexes too difficult to feature in detail. This is invariably true of the alluvial areas, where river bed anastasmosis has resulted in considerable heterogeneity and frequent cross-bedding of recent alluvial deposits with vertisols. The mapping units, therefore, simply include soils showing average texture and cross-bedding features. In certain cases, however, interpretation of aerial photographs or detailed prospection work has made it possible to break down a mapping unit corresponding to a soil series into separate phases. An instance of this are certain vertisols in the Middle Valley containing deep loamy horizons ensuring adequate drainage. Where such a feature appears sufficiently frequently within a series, it can be shown separately on the map.

The minimum size of the units mapped in this way is about 25-30 hectares where soil limits are easily established. Other units mapped to the 1:100,000 scale are roughly 100 hectares in size, which represents about one observation per 100 hectares and at least one profile observed and analyzed per 150 - 200 hectares.

The units to this map scale are featured as patches, each with a number denoting its series and phases, and coloured according to the parent rock (old or recent alluvium, colluvium, calcareous, non-calcareous).

IV - 6. Special Remarks

It is often difficult to distinguish between textures necessary to characterise a series, because of the cross-bedding of deposits whose thickness is apt to vary between about 1 cm to 20 cm or more. The average texture of the horizons in the observed profiles is, therefore, taken as the characteristic texture for the series.

Where particular horizons are frequently encountered at depth, (for instance, a loamy horizon under vertisols, or a black clayey horizon under recent loamy soils,) a distinction is made at phase level.

Texture is always considered to be "fine" in vertisol series. Soil structure governs potential land use, as it determines both the "workability" of the soil and the extent of root penetration. The depth of vertisols varies according to the conditions under which deposition takes place. Detailed prospecting surveys are essential to characterise this type of soil.

It is not always easy to make a colour distinction between vertisol and alluvial soil series; e.g., in the Lower Plains, certain fine-texture alluvial soils are similar in colour to the vertisols.

Slight hydromorphic features (e.g., minor ferruginous deposits) are sometimes observed in the alluvial soils.

It is sometimes difficult to distinguish the hydromorphic soils in the alluvial area that are only waterlogged at certain periods from those permanently in that condition. True hydromorphic gley soils only occur on the humid tropical zone.

Certain soil series have only been differentiated in terms of salinity, where other properties (e.g., texture) are such that the soil can be developed without undue difficulty despite its saline horizon. Other soils are saline throughout the profile. Their texture and geographical location make it difficult to use them.

Regosols in a series are differentiated according to the origin of their parent rock.

IV - 7. Scope of Soil Surveys

The type of soil survey for which classification and mapping procedures are described above is henceforth limited to the two major natural regions in the Awash Basin : the Middle Valley and the Lower Plains. It includes :

(i) A reconnaissance survey to enable irrigable areas to be selected on the basis of an initial land irrigability classification.

(ii) Semi-detailed surveys of selected zones within the irrigable areas, to enable a final classification of the land to be made in terms of irrigability.

The reconnaissance survey starts with an examination of soil formation conditions, followed by a description of mapping units corresponding to the various soil groups and sub-groups, including their distribution and the sizes of areas covered. Irrigable areas will finally be selected from a land classification into three irrigability classes.

The semi-detailed survey includes for each region a description of typical profiles for series corresponding to each of the above groups and sub-groups. The size and distribution of these groups and sub-groups are established from the sizes of areas covered by the series in a given group or sub-group. The land is classified into six potential development categories on the strength of the soil survey results and criteria considered in assessing irrigability.

V. ORIGIN AND DESCRIPTION OF THE PARENT MATERIALS IN THE REGION

A. MIDDLE VALLEY

A subsidence of the land, north to south, created the Middle Valley. A series of faults, running north-east to south-west together with a succession of volcanic flows then dissected the valley.

V - 1. Metehara Plain

These phenomena are clearly exposed from the entrance of the Awash into the Middle Valley: the Metehara plain was isolated and hemmed in by recent lava flows in the north, and by faults along the rest of its perimeter. Along the Awash River, some of these faults have created waterfalls, such as the Cotu Falls. Along the

edge of this small plain, from which basalt outcrops emerge here and there, soils were formed on the eroded materials and sometimes very alkaline colluvium from volcanic rocks.

West of Metehara, Lake Beseka has helped to produce a large circular patch of saline and of saline-alkali soils. The lake is fed by waters from very saline hot springs and from runoff.

Sediment recently deposited by the Awash covers a strip varying in width, along both banks of the river. It is narrow at first and widens as the river bed becomes increasingly sinuous. A decrease in flow speeds due to rock barriers further downstream is probably the cause of this special sedimentation.

V - 2. Old Alluvium and Colluvium

In the Middle Valley, the plains between Awash Station and Lake Gedebasa were also formed by erosion followed by deposition. They extend eastward to the foot of the chain formed by the Asebot, Azelo, and Amdisa mountains. Westward they continue as hills formed from ancient alluvium and more or less eroded colluvium. The colluvium is stony or saline in places. The plains are dissected by faults and volcanic protrusions running north-east to south-west in an almost continuous band. Gorges mark the passage of the Awash across the protrusions.

It is reasonable to assume that, during a first phase, the Awash and its tributary, the Arba River, deposited old alluvium from the Aleydegi plain at a relatively high elevation. Parts of a stony alluvial terrace are visible on the right bank of the Awash in the vicinity of Melka Sedi, at a slightly lower elevation than that of the plain.

Ancient alluvium and colluvium are found, in particular, at the foot of the basalt outcrops which restrict the Aleydegi plain within its present boundaries. They are also found south-east of the Aleydegi plain (colluvium from the Gumbi and Asebot mountains) and north-east of the plains on the left bank; they are frequently faulted and dissected by basalt flows or volcanic tuffs.

Erosion molded this ancient alluvium and colluvium, creating a succession of valleys and ravines, hills and hillocks, with sides of varying steepness depending on the intensity of erosion and the hardness of the material at a particular spot. The system of valleys and hills generally runs east to west, perpendicular to the system of faults. This type of terrain is called "rough broken land". 1/ Only clumps of dwarf acaccias and sparse grasses can subsist under the local dry climate.

Very eroded older alluvium with a saline calcareous crust forms the "badlands", 2/ extending beyond Gewani, along the right and left banks of the Awash.

1/ Rough broken land: consists of steep land, ordinarily not stony, broken by numerous intermittent drainage channels. It is used for grazing. It has a cover of vegetation. Rough broken land is deeply dissected by narrow V-shaped valleys and sharp tortuous divides, and geologic erosion is active.

2/ Badland: is steep nearly barren land, ordinarily not stony, broken by numerous intermittent drainage channels. The geological erosion is active. Badland has no agricultural value. The relief of the Badland is similar to that of Rough Broken Land which has a cover of vegetation.

V - 3. Recent Deposition

Under the influence of variations in climate, and the subsistence of the river bed, the Awash has largely eroded these formations and, silted up low areas. The river is shaped by the obstacles along its path: it bumps against the Dofan volcanoes, skirts the hills of Lyadu Lake and Dabita Ale, and collides with the old alluvium hills in the Gewani region.

The settling out of the waters from the Awash in a chain of troughs created the present plains of the Middle Valley. The finest sediment settled out on the downstream side of depressions. It produces black soils with a high content of swelling clay (vertisols and a strong tendency to shrinkage (region north of Kadabilen). Some troughs are yet to be completely filled. A few floodable depressions still exist, notably near Angelele.

The enormous trough containing the Gewani swamp is unique: the core is Lake Gedebasa covering an area of approximately 2,500 hectares; the swamp proper extends south of the lake over more than 5,000 hectares; the whole outer edge of the swamp, an area of 20,000 to 25,000 hectares, may be submerged when the Awash is in spate.

The tributaries of the Awash, mostly on the left bank, have also contributed to the formation of the plains of the Middle Valley. They have deposited large detrital fans:

- plains of the Kesem and Kebena Rivers, where the rivers have abandoned innumerable stony beds upstream;

- the plain formed by torrents from the north (Dofata, Gesano, Adendaba, and Kokai); as soon as the torrents enter the plain, they disappear under their own deposits;

- the Awadi plain where deposition built soils with a particularly fine texture downstream;

- the Maro Gala plain built by the Arsu River and by torrents parallel to the Arsu; the plain pushed the Awash back towards the foot of the hills in the east.

V - 4. Salinity

Warm springs due to volcanic activity in the region contributed to the salinization of some alluvial deposits all along the river which flows out of the Filweha Springs; around the Kadabilen springs; near the source of the Meteka; and near Lake Hertale.

Local saline patches are found in the Kesem-Kebena plain, near Melka-Sedi, where the growth of doum palm trees reveals their existence. They are probably due to once active warm springs which have since disappeared. This may also be true of salt patches between Lake Hertale and the Gewani Swamp.

V - 5. Effects of Submersion

Inundations from small intermittent tributaries of the Awash, or from the Awash and its larger tributaries, have quite different effects. Spreading of flood waters from temporary torrents results in a local wetting of the soil and permits only the seasonal development of grass pastures.

Flooding from the Awash and its larger tributaries greatly influences soil genesis. It has a more important bearing on vegetation along the banks of the river and its defluents and even on vegetation growing along the lower course of its tributaries. Areas at lower elevations may be flooded several times a year. In low areas, temporary marshes may form where natural drainage is insufficient. On land covered by flood waters for a brief time only, due to deep percolation or rapid surface runoff, prairies can grow. Close to the river, in places which remain moist throughout the year, even forests of good stands of large acacias thrive. These special conditions give rise to hydromorphic soils or relatively moist soils, rich in organic matter produced in fairly large amounts by the plentiful vegetation.

In areas at higher elevations, where flooding is less frequent and/or soils are more clayish, moisture is insufficient for an abundant permanent vegetation. Plant life tends to disappear during the dry season. Only annual grasses thrive. The only trees are a few dwarf acacias and capparis bushes.

Successive wettings followed by drying has here created a particular microrelief which, depending on the texture of the alluvium, may be of the gilgai type and exhibit large shrinkage cracks. The microrelief is more or less pronounced depending on the proportion and the distribution of clays, and on the frequency of submersions. Organic matter is still fairly abundant, but it is more thoroughly decomposed.

In areas which are only rarely flooded, soils are almost permanently dry. They have large shrinkage cracks and even open holes. Vegetation is scarce, although the existence of a few trees is evidence that submersions were once more frequent than now. This change in the frequency of flooding is a general phenomenon and results from the accumulation of different types of deposits in the course of time, and the deepening of the river bed.

In like fashion, the operation of the Koka Dam has noticeably reduced the duration and the extent of inundations from the Awash. As a result, large acacia populations are disappearing, including some not too far from the river.

V - 6. Parent Materials

The soils of the Middle Valley can be grouped according to the parent materials from which they were formed:

(i) volcanic materials, generally skeletal soils, agriculturally useless, except for soft soils (e.g., pumice);

(ii) ancient alluvium and celluvium, varying in phase: fine, stony, saline and alkali;

(iii) recently deposited alluvium, at the bottom of depressions; the texture of these soils, and whether they are hydromorphic or alkali, depends on how they were formed, or deposited.

B. LOWER PLAINS

V - 7. Formation of the Lower Plains

The Lower Plains in the Awash Valley were formed by the silting up of a series of rift troughs which are traversed by the Awash and its intermittently flowing tributaries. The plains are circumscribed by faultedbasalt chains running in a general south-east to north-west direction. Recent volcanic flows, consisting of basalt, lavas, and sometimes ashes, cover the alluvium in some places. The flows are almost horizontal tables, and are everywhere very thin - not more than about one to a few meters thick. Such flows can be observed north of Logiya in the direction of Dubti. In the middle of the plains, other volcanic flows have created isolated hills such as Kurub, north-east of Dubti, and Foro, south of Asayita.

The lower plains of the Awash Valley are distributed over a total area of about 300,000 hectares, in three main depressions:

upstream and downstream from the Mile and Awash confluence;

between Tendaho and Asayita, the Dubti plain on the left bank;

and the Dit Bahri plain on the right bank of the Awash;

downstream from Asayita to the lower lakes in the Asayita Delta.

It is probable that, in the past, extensive lakes filled these troughs, especially the last mentioned. Due to an increase in land elevation caused by deposition and to the erosion of sills, the depressions evolved into their present form, after going through a deltatic phase. A living delta of this type does still exists upstream and downstream from the town of Asayita. A proof of the former existence of deltas is in the shell banks, similar to those now found on the shores of Lake Gamari, which dot the landscape. Aerial photographs reveal innumerable fossil beds in the present plains.

V - 8. Plain of the Mile and Awash Confluence

The plain of the Mile and Awash confluence has a special place in this general scheme. In ancient times, and under different climatic conditions, different fine and stony materials filled this trough. They became badlands along the basalt flows, on the left and right banks of the Awash, as well as in the vicinity of Logiya. Fed by its tributaries, the river eroded these ancient deposits and then built up a narrow alluvial terrace, 2 to 3 km in width, through which it flows at the present time, with many meanders.

V - 9. Dubti and Dit Bahri Plains

The whole northern part of the Dubti plain, formed from ancient alluvium and colluvium, and subjected to markedly arid climatic conditions, has a desert-like aspect. On both banks of the Awash, in areas of deposited alluvium, humid and marshy in places, forests and pastures grow.

The soil in the Dit Bahri plain consists of saline and calcareous alluvium and colluvium. On the whole, the layers of alluvium are fairly deep. They may attain depths of 10 or so meters. Deposition by a delta system induces the intermingling of deposits of different textures, varying from clay to fine sand.

Deltaic deposition is now taking place in areas incompletely silted up, adjoining the Dubti and Dit Bahri plains. The Boyale defluent feeds a vast swamp more than 30 kilometers long and 3 kilometers wide. Very anastomosed, secondary channels, separated from one another by earth spits, barely emerge at low water. After depositing their silt, clear waters return to the Awash below the swamp. The humped banks of the river contain deposits with a coarse to average texture, becoming powdery when dry, whereas the hollows behind the banks consist of fine dark-colored materials (vertisols).

Basic variations in amounts of water available, both surface and ground waters, together with high evaporation rates, have led to the salinization and alkalinization of some of these alluvia. There exist hard horizons rich in limestone, similar to those in the old alluvia in the Middle Valley. Erosion has molded these materials into pebbles around the edge of old depressions in the plains on the left bank of the Awash, from Dubti to Asayita.

Recent or current secondary volcanic activities (geyser, mud volcanoes, and fumeroles) have contributed to local spotty salinization of the alluvia. This accounts, for example, for the presence of a few salty patches north of the Dubti plantation.

This alluvium, whether saline or non-saline, is no longer subjected to periodic flooding from the Awash. By contrast, certain alluvial fans, particularly south of Sardo subject to direct flooding from intermittent streams flowing from the basalt strata, benefit from a natural leaching. Locally this reduces salinity and permits the growth of a scanty vegetation, including a few trees. Wind erosion gives the landscape an accumulation of dunes north of the Boyale Swamp, west of Kurub, and on the right bank of the Awash south of Dubti.

V - 10. Asayita Delta

The Asayita Delta is a vast alluvial fan which, from Asayita at its summit, develops radially to the interior lakes Gamari, Afembo and Bario. The upper part of the fan has been well silted up, but immense and impenetrable marshy surfaces announce the approach to the lakes. The hydrography is characterized by a network of palm-like diverging channels. One arm of this network, the Awash after having found its present course along the foot of the hills which delimit the delta to the north, some decades ago, is now active and still floods its deposits. The network of channels helps to spread the flood waters from the Awash and thus makes possible the development of agriculture through flood irrigation.

Except for a narrow strip of talus and colluvium around the foot of the basalt hills, soils in the Asayita delta consist of recently or currently deposited alluvia. A few saline patches appear in the northern part of the delta, which is no longer flooded and is now drying up.

V - 11. Salinization and Alkalinization

Soils from recent or current alluvia are non-saline or only slightly saline. By contrast, the different layers of old alluvium contain accumulated salts. These have become stable because of the aridity of the climate and the great depth at which salt layers are found. Irrigation would, however, put them back into circulation. If large amounts of water were applied, the salts would be flushed downward and concentrate in deeper horizons where, since the quantities of water would be insufficient to cause dissolution in situ, they would then move back toward the surface by capillary action, and remain there because of evaporation. This phenomenon has caused the formation of whitish deposits along some of the canals in the Dubti plantation.

Hydromorphic soils on fine or very fine textured deposits, and especially soils at their edge are alkaline, usually with a high pH (above 9) and percentages of exchangeable sodium on the absorbing complex from 15 to 20 or more. Alluvium recently deposited by the Awash is rarely alkaline. Along the edge of certain humid areas, such as north of the Boyale Swamp, however, soils may be somewhat alkaline.

V - 12. Parent Material

Parent materials can be classified in order of increasing interest, as follows :

- different type of volcanic debris;
- dunes;
- very saline eroded deposits (badlands);
- saline and alkali alluvia;
- highly saline alluvia and colluvia;
- stony or crumbling old alluvia;
- hydromorphic alluvia, in swamps and seasonally waterlogged deposits;
- non saline or slightly saline recently or currently deposited alluvia.

VI. DESCRIPTION OF THE MAIN SOIL GROUPS OR SUBGROUPS

A. SOILS ON RECENT ALLUVIA

A-1. Alluvial soils on recent calcareous deposits

Map colouring : Yellow - AC

These soils are nearly always cross-bedded deposits with a platy structure, sometimes with thin clayey intercalations. Profile textures are medium to fine (loam, silt loam, silty clay, clay).

Soil colour is fairly light, varying between 10 YR 4/1 and 10 YR 5/4.

pH values are between 8 and 8.5. Sometimes, alcalinity (pH about 9) can be observed at deeper levels in fine textured horizons in low lying areas. Lime contents are over 5 %, but seldom exceed 10%.

Organic matter is present in small quantities, usually amounting to about 1 - 2 % ; higher rates may occasionally be observed in certain profiles with a thicker vegetation cover.

"Micro-relief" features are not very marked, but there are marked more or less ramified channels varying in depth. The larger carry water and, during floods, act as defluents : The Farite and Boyale defluents on the left bank, the latter of which permanently carries water, and the Isa and Arab arms on the right bank, which drain off some of the water west of Mount Foro. Channels are more frequent in the Asayita delta, where some are used for irrigation.

Nearly all these soils occur in the low plains of the Awash :

- Upstream from the Mile River confluence, but only covering a small area in the form of a strip 2.5 km wide by about 25-30 km long, which lies almost entirely along the right bank of the river;

- Between the Awash river and Boyale swamp in the left bank area (Dubti area);

- In a very extensive area along the right bank, between the older alluvium, the Awash and the Foro basalt hills. (Dit Bahri area);

- In the Asayita delta zone, from Asayita village to the swamp between Lakes Gamari and Bario.

A-1 1. Water relations

The land along active defluents is frequently flooded during high water periods. Some small islands in the Boyale swamp are inadequately drained, due to their position. The farmers make the most of the additional water thus supplied to the soil by growing crops on the lowest-lying land when the floods are receding (cotton, maize). There are possibilities of supplying additional water to the growing crops at certain places, especially in the Asayita delta.

Soil permeability is generally satisfactory, but depends on the thickness of the heavy clay horizons. The effective water-holding capacity of these soils is low, probably not exceeding 10 % by volume.

A-1 2. Fertility

Recent alluvia contain high proportions of plant nutrients. Total P_2O_5 contents are above 1,000 p.p.m ; nitrogen rates for pH values exceeding 8 are adequate at Asayita, but low at Dubti and Dit Bahri. The soil at Asayita invariably contains more nitrogen than that in the two other zones, as moisture conditions are more suitable for the accumulation and decomposition of organic matter which help to increase the soil nitrogen content.

A-1 3. Use

These soils are suitable for irrigation, but some special precautions are necessary to maintain the present fertility level in the Asayita zone and to improve the soils in the Dit Bahri and Dubti zones by increasing their organic matter and nitrogen contents. The generally weakly developed soil structure should be improved.

To smooth out the microrelief of this land, it may be necessary to carry out substantial levelling work, and especially to clear the acacia trees.

A-1 4. Soil series

The soil unit includes soil series which are differentiated by their texture and occasional alkalinity. They are defined by typical profiles, descriptions of which will be given subsequently :

- Medium to moderately fine interlayered texture : profile TMT 53. Phases can be distinguished according to seasonal waterlogging and microrelief;

- Moderately fine to fine interlayered texture, occasionally alkaline at deeper levels : profile TMT 51. Phases are based on seasonal waterlogging;

- Moderately fine to fine interlayered texture, occasionally alkaline : profile DRO 123.

A-2. Alluvial Soils on Recent Very Slightly or Non-Calcareous Deposits

Map coloring : Yellow - Anc

Typical features of these soils are their comparatively light colour and underdeveloped condition. They have formed over medium to heavy (texture alluvia, sandy loam, silt loam, silt, clay loam), and are brown loam soils coloured 10 YR 4/2 - 5/2 - 6/2.

They do not contain any dark horizons, except occasionally on a surface very rich in organic matter.

Their structure is weakly developed, usually platy of varying fineness depending on the grain size of the deposit, and tending to develop into a blocky structure with block dimensions depending on local moisture conditions and clay content.

Organic matter content may be as high as 10 %, but the average rate is about 2 %.

Lime content is low, generally below 5 %, though pH values are on the high side (7.5 - 8.5), without the exchangeable sodium rate ever exceeding 10 % of the exchange capacity.

These soils are found on the river levees in the Middle Valley, in the alluviation zones up-river from the plains and along them, and on alluvial cones of major tributaries. Recent deposits have sometimes formed over former swamp areas with fine to very fine texture darker soil.

Wide drying cracks or holes are typical of the microrelief. Other differences refer to texture and its homogeneity in the soil profile. Reference to these is made in the soil series.

A-2 1. Water relations

Except where they occur over former swamp areas* these soils have adequate natural drainage with an average permeability of 1 to 2 cm/hour. Like most soils in the Awash valley, they have a low water-holding capacity (i.e. moisture available between pF 4.2 and pF 2.5), which is at most 10 % by volume.

A-2 2. Fertility

In view of the high proportions of plant nutrients they contain, the alluvial soils on recent deposits are very fertile. Total P_2O_5 rates exceed 1,000 p.p.m. Considering the high pH values, nitrogen rates also appear to be adequate. Exchangeable K appears to be medium to high (generally over 2 m.e. for 100 g of dry soil.

A-2 3. Use

These are some of the best soils in the valley. There should be no major obstacle to their development under irrigation, nor are they likely to be subject to rapid salt-contamination. Their organic matter content will require maintaining or increasing, however, especially to prevent soil structure deterioration and a reduction in water-holding capacity.

---

* On this case, soil phases have been differentiated inside the series.

A-2 4. <u>Soil series</u>

The soil units include the following soil series which are differentiated by their texture and are defined by typical profiles, to be described later :

- Medium texture : profile KK4;
- Medium to moderately fine interlayered texture : profiles BKB 27 and MM 552. Phases are distinguished when horizons of different texture and colour occur in depth;
- Moderately fine to fine texture : profile MMS 302.

A-3. <u>Alluvial Soils on Recent Saline Deposits</u>

<u>Map colouring</u> : yellow - As

These soils have much in common with the two previous units (Ac and Anc), but the conditions (especially the seasonal drying up) under which they have formed, contributed to their salinization. Several reasons can be advanced :

- In the Middle Valley, it may be due to either underground salt water circulation or to the nature of the alluvial deposits which are somewhat older than those associated with unit Anc and are less adequately supplied with water by the hydrographic network.
- The alluvium in the Lower Plains undergoes alternate flooding by the Awash and intense drying, which results in an increase in its soluble salts content, especially in shallow depression zones.

These soils have horizons in which saturated extract conductivity rates vary between 4 mmhos/cm and over 20 mmhos/cm ; they are higher in the Middle Valley than in the Lower Plains, where distribution of the profiles with saline horizons, inside the series, is less uniform.

A-3 1. <u>Water relations</u>

Soils in this unit have generally formed (and still do) under drier soil climate conditions than those considered previously. Because they occur on former river levees or in areas no longer affected by flooding, they remain almost dry throughout the year. These soils are suitable for irrigation in the Middle Valley. In the Lower Plains, salinity rates are irregular and even apt to vary in the same profile. Providing sufficient water is available for leaching, this is not a major obstacle to development.

A-3 2. <u>Soil series</u>

The soil unit includes the following soils series which are differentiated by texture and lime content. These series are defined by typical profiles to be described later :

- Medium to moderately fine interlayered texture on calcareous deposits, profile AAS 62.
- Medium to fine texture on very slightly or non-calcareous deposits, profile MAL 18.

A-4. Vertisols on Calcareous Alluvial Materials

Map colouring : Brown - Vc

In the Lower Plains, these vertisols occur in depression areas filled with clayey deposits. They are generally found between recent alluvial and hydromorphic soils.

In the Middle Valley, these soils have formed over recent deposits originating from older alluvium similar to that in the Aleydegi plain. They show the same principal properties, but are sometimes under light-coloured colluvial loam.

Because of the conditions of their deposition, these soils have a very fine texture (clay - silty clay). Their colour is very dark : 10 YR 2/1 to 10 YR 3/2. Surface structure may be fine (granular type) or coarse (alkaline-tendency vertisols along the floodable northern edge of the Boyale swamp). Alcalinity (pH about 9) can be observed in coarse structure. Deeper layers have a coarse prismatic-type structure, sometimes also slightly blocky.

The vertisols in the Lower Plains may have a "gilgai" 1/ type microrelief, with numerous holes where the ground has caved in. Fairly deep very ramified channels occur in low-lying zones left behind by swamps since filled-in and dried out (especially along the right bank of the Awash). In the Middle Valley the vertisols have a fairly typical microrelief with grass tussocks, between which cattle and runoff have eroded the ground down to several tens of centimetres.

A-4 1. Water relations

The vertisols generally only have a low content in available water. Owing to their high proportions of high swelling capacity of clay of the montmorillonite or montmorillonite and illite type, they are associated with a high wilting point 2/. Though they need a lot of water, the plants can only use a small part of the water the soil receives. The vertisols in the Middle Valley have a slightly less heavy texture and perhaps a slightly higher effective capacity for water. Soil permeability rates vary considerably. Shrinkage cracks disappear with increasing soil moisture, when infiltration also gradually slows down.

A-4 2. Fertility

These soils contain adequate quantities of fertilizing elements, except along the left bank in the low plains, where nitrogen rates for the pH values are average. Exchangeable potassium and phosphoric acid rates exceed 1,000 p.p.m.

A-4 3. Use

It will not always be easy to use this land. Although there should be no major difficulty in dealing with the channelled-type microrelief, the "gilgai" features will be a much more serious matter due to their tendency to form agair as

1/ "Gilgai" is the name given to a special kind of microrelief associated with soils usually containing high proportions of swelling clays. Its typical features are a succession of very small depressions and mounds together forming a practically flat ground surface. This microrelief pattern is due to the alternating swelling and drying out of the soil at varying moisture conditions.

2/ See available moisture analysis results.

soil moisture falls off after cultivation (e.g., during the harvest); this requires further land-levelling work or, alternatively, steps to maintain a sufficiently high moisture rate to prevent further "gilgai" formation. The high clay content of vertisols makes them difficult to work. Frequent irrigation with small amounts of water is necessary because of their poor water-holding capacity.

This land is now under pasture of poor quality (Gramineae, or dry bulb Cyperaceae in the Lower Plains).

A-4 4. Soil series

The above soil unit includes the following soil series which are differentiated by structure and lime content. These series are defined by typical profiles, to be described later :

- Fine structure on calcareous materials profile DRD 13.
- Coarse structure on calcareous materials, alkaline subject to flooding profile DRD 107.
- Fine structure on slightly calcareous materials; profile MMS 358.
- Coarse structure on slightly calcareous materials; profile MMS 312.

A-5. Vertisols on Very Slightly or Non-Calcareous Alluvial Materials

Map colouring : Brown - Vnc

The characteristic features of these vertisols are their swelling clay content of over 35 % and their exchange capacity of over 40 meq/100 g dry soil. They are dark in colour, ranging from black to brownish-black (10 YR 2/1 - 2/2 - 3/1 - 3/2 - 4/1) with a moderately fine to fine texture (clay, clay loam, silty clay loam, sandy clay, silty clay). The clay is self-mulching 1/, giving a loose granular surface, - followed deeper down by a prismatic structure with wide shrinkage cracks and slicken sides when dry with an underlaying massive structure. The slickensides indicate mass movements each time the soil is wetted.

The vertisols in the Middle Valley are not calcareous (lime content less than 3 %). Though their pH value varies between 7.5 and 8.5, they are not sodic; they contain about 2.5 % organic matter.

The "gilgai" microrelief, which is a succession of very small depressions and mounds over a generally flat area, is best observed on this soil unit.

These soils occur exclusively in the Middle Valley, where they cover the downstream part of the alluviation zones and the lowest-lying ground, where they are associated with a fairly dense channel network.

A distinction is made between two main surface structures, one fine and the other a coarse structure associated with more marked hydromorphic features

1/ Self-mulching, refers to the tendency of many clays to form a loose granular surface mulch as a result of wetting and drying. If the granulas are destroyed by ploughing when wet, they reform, usually on a single drying.

(a differentiation similar to the Grumaquerts and Mazaquerts of the U.S. Department of Agriculture's 7th "approximation"). There is a further differentiation within these structures in terms of soil thickness and the type of underlying material.

A-5 1. Water relations

When in a very dark condition with extensive cracking, these soils are very pervious, but when the cracks close up as the clay swells, they become practically impervious. They have very poor natural drainage properties, except thin and overlying pervious material. Despite their high clay contents, the Awash Valley vertisols have only a low effective water-holding capacity, as the moisture percentages at pF 4.2 are very high.

A-5 2. Fertility

As these soils contain very high proportions of plant nutrients, they could be considered very fertile, if their physical properties were not such a limiting factor.

A-5 3. Use

Vertisols must be distinguished in terms of layer thickness :

(i) Deep vertisols (more than 30 cm). Very difficult for use because of their poor drainage properties associated with their low effective water-holding capacity, also the difficulty in working them.

Substantial pre-irrigation appears to be an essential requirement for their cultivation, in order to wet the ground down to a fairly appreciable depth (for instance about 1 metre), followed by small water applications at frequent intervals. It would be interesting to experiment with sprinkler irrigation at night.

(ii) Thin vertisols (less than 30 cm). Where over more pervious material, they are excellent soils because of their satisfactory drainage properties and high nutrients content. Their only limitations are associated with pH and effective water-holding capacity.

A-5 4. Soil series

The soil unit includes series distinguished by structure and slight alkalinity. Differentiation are made inside the series according to soil thickness and the type of underlying material. They are defined by typical profiles, to be described later.

Fine self-mulching structure in which the following phases can be distinguished :

- deep with highly developed mulch profile MMS 120 ; a fine texture with gilgai microrelief.
- moderately deep on loamy horizons, profile MMS 317.
- shallow on interlayered alluvia.

Coarse structure slightly alkaline with a deep phase corresponding to moderately fine to fine texture : profile MMS 352 ; a moderately deep phase on interlayered alluvia : profile KKB 120.

Coarse structure, slightly hydromorphic, subject to seasonal waterlogging during floods, profile MMS 327.

A-6. Hydromorphic Soils on Calcareous Alluvial Materials

Map colouring : light blue - Hc

These soils are confined to depressions not completely filled up and to former swamps subjected to fairly short annual flooding (about one month) through the river changing its bed and the occurrence of flow peaks.

The hydromorphic features are more or less distinct ferruginous stains in the upper horizons of the soil profile; they frequently show up more distinctly in the subsoil.

Soil colour is dark, ranging from 10 YR 3/1 to 10 YR 2/1. Organic matter content is high, especially in the surface horizons. Interlayered horizons with a platy structure may occur in the profile, due to the formation of these soils as Awash river loam deposits.

These hydromorphic soils are calcareous, though slightly less so than those on recent alluvia, because of slight leaching in the surface horizon.

C/N ratios are about 10 ; pH values do not exceed 8.5 where alkalinity is low, but may reach 9 where alkalinity rates are about 10 % - 13 % Na/T ratios are generally below 16, and conductivity rates are less than 45 mmhos/cm at 25 %.

The soils do not occur very extensively in the low plains of the Awash; most are found along the right bank (Dit Bahri).

A-6 1. Water relations

The soils have a fairly low water-holding capacity and are not very pervious. A further appreciable obstacle to development is their poor drainability due to their heavy texture and low altitude.

A-6 2. Use

Agricultural development appears to be a difficult problem. There are no natural outlets for surplus water because of the low-lying position, and floods cannot be controlled without dyking the Awash or regulating its flows. A large proportion of this land is used as pasture outside flood periods; the grass fodder is coarse, but of quite a high standard for the region. Annual flooding is essential for maintaining this pasture land.

A-6 3. Typical profile DRD 27

The soil unit can be defined by a typical profile : DRD 27.

A-7. Hydromorphic Soils on Very Slightly Non-Calcareous Alluvial Materials

Map colouring : pale blue - Hnc

These soils occur in low-lying areas flooded annually in which water stagnates for fairly long periods (more than one month).

Hydromorphic features show up as ochre stains in the upper profile horizons and brown stains below 80 cm depth. The lime is leached from the surface and accumulates as granules and small concretions below 80 cm. The soil's pH value varies from 7 on the surface to over 8 at greater depth. Along the edge of the lake Gedebasa depression, the water table is 3 - 4 m below ground surface.

The soils are black (10 YR 3/1 - 2/1) with a heavy texture and a high organic matter content. The structure of the surface horizon is affected by organic matter; the subsoil structure becomes fine prismatic with depth, with very numerous oblique slip faces giving it a blocky compound structure. Shrinkage cracks forming during dry periods enable organic matter to infiltrate down to the deeper soil layers.

In the Middle Valley, the soils have formed at the downstream ends of filled-in depressions. Lakes remain in the lowest parts of some of them and the filling process is still going on (e.g., Lakes Bada near the Dofan, Lyadu, Gedebasa, and the Angelele swamp).

A-7 1. Water relations

The hydrodynamic properties of hydromorphic soils are generally unsuitable for development under irrigation (no drainage, very low permeability).

A-7 2. Use

Use of this land depends on its drainability. As its topographical location precludes gravity drainage, expensive pumping plant would be required. Even with adequate drainage, it would still not be very suitable for irrigation, especially because the deep soil horizons are easily waterlogged. It is now mainly used as pasture during the dry season, and would be difficult to develop for any other purpose.

A-7 3. Typical profile : profile MAL 20 can define the unit.

A-8. Organic Hydromorphic Soils

Map colouring : dark blue - Ho

These soils are permanently waterlogged and occur in swamps with numerous channels. Where more substantial local deposits have formed and raised the ground level, the soils are only under water during the part of the year when the initial floods occur.

The soils are generally rich in organic matter, and usually fine textured. They occur at:

- The lake Gedebasa zone in the Middle Valley, where, flooded by numerous defluents, they are thickly overgrown with Gramineae up to 2 m tall (Echinochloa, Vetiveria).

- The marshy zone (Cyperaceae and Vetiveria) between Dubti and Asayita in the Lower Plains, where they form a long narrow strip about 2 to 4 km wide by 35 km in length, behind the natural levees of the Awash river. A substantial proportion of the river flow passes slowly through these marshes, sheds its sediment in the process, and returns clear to the river (except during floods).
- The eastern and especially south-eastern ends of the Asayita delta, which are gradually silting up, but frequently contain small lakes without any vegetation. Lakes Gamari, Afembo and Bario are almost certainly the last of the big lakes which formerly occupied the Awash valley plains at various times.

A-8 1. Use

Due to their permanent submersion, these organic hydromorphic soils cannot be considered for agricultural development at present.

A-8 2. Typical profile

Profile TTN 25 defines the unit.

A-9. Alkaline Hydromorphic Soils

Map colouring : dark blue background with red stripes - Ha

These are the soils in the warm spring marsh areas; their hydromorphic features are due to their almost permanent salt waterlogged condition. In the upper horizons, these features mainly take the form of ochre stains and a high saturation percentage. Signs of alkalinity pH values (above 9) and Na/T ratios exceeding 40 % ; average saturated extract conductivity is only 8 mmhos/cm at 25° which is comparatively low. The water from the warm springs and the saturated soil extract both contain a fairly high proportion of bicarbonates.

The principal warm springs are Filweha, Kadabilen, Meteka in the Middle Valley, and Alalabada east of Tendaho.

The very alkaline soils (Na/T ratio exceeding 77% at depth) in the Metehara region have been included in this group. These are less hydromorphic, and their alkalinity may be due either to volcanic parent rock or to former salt springs now dried up.

A-9 1. Use

The soils are unfit for cultivation, but occur only over small areas.

A-9 2. Typical profile

The soil unit is defined by the profile MAL 4.

B. SOILS ON OLD ALLUVIA AND COLLUVIA

B-1. Vertisols on Calcareous Materials

Map colouring : light green - Vf and Vl

B-1 1. Vf : fine structure

These soils mainly cover the vast Aleydegi plain. Typical properties are a high pH value (average 8.5), sodic properties shown up by Na/T ratios varying between 5 % and 20 %, and a lime content of about 10 %. Dark in colour (10 YR 2/1 to 10 YR 3/3), they have a fine texture (clay loam, silty clay, loam and occasionally silty loam).

Their structure is mostly platy with a coarse blocky tendency, and, though less frequently, prismatic in the deeper layers. Gypsum is found in flaky crystal from below a depth of 80 cm in most profiles, indicating former evaporation areas along the edges of depressions. Saturated extract salinity of deep samples can be as high as 12 mmhos/cm at 25°C. The soils are comparable to those north of Dubti, in which the same crystals are found, but which are much more saline because of the dry climate (the saline black horizons they contain are not very thick).

Rainfall in the Aleydegi plain results in a comparatively dense growth of grass (Gramineae) covering about 40 % to 60 % of the land. Organic matter content of the soil is about 2 %.

Outside the Aleydegi plain, soils at roughly the same topographical level are found near Awash station, along the left bank of the Awash, and upriver from the Metehara plain.

B-1 2. Use

Because of their poor drainage properties and the alkalinity and salinity of their deeper horizons, the soils are of medium to poor irrigability. They are considered unfit for irrigation, because the Aleydegi plain is at least 70 metres or more above the level of the Awash.

B-1 3. Vl : course structure

This is a very similar soil group, except that these soils are subject to occasional flooding and drying, which gives them a coarser structure with 5 cm to 10 cm wide shrinkage cracks. They occur in the centre of poorly drained depressions (e.g., in the middle of the Aleydegi plain). When the temporary lakes in the Lower Plains (e.g., Lake Gargori) dry out, polygonal mud cracks about 10 cm wide form soil prisms measuring about 40 cm along their edges between them. Salinity is fairly high on the surface, but with sulphates predominating.

B-1 4. Use

Lack of adequate drainage would make use of this land very difficult.

B-1 5. Soil series

The soil units include the following soil series which are differentiated by structure and slight salinity. Phases can further be distinguished according to salinity. The series are defined by typical profiles, to be described later.

- Fine structure, slightly saline at deeper levels, profile AAS 64;
- Coarse structure, salinity low to nil : profile HMA 53;
- Coarse structure, slightly saline with different phases : medium salinity in the top soil; profile; AAS 55; slightly saline at deeper levels; profile LLD 31.

B-2. Vertisols on Calcareous Materials in the Runoff Zones

Map colouring : orange - Vr

These soils occur at the foot of slopes or in valley bottoms along the Middle Valley. They are a transition between the alluvial soils in the plain and the brown sub-arid type hill or plateau soils. They represent a soil complex with fairly variable properties depending on the type of parent rock (i.e., whether alluvium or colluvium).

On gently sloping hillsides and in the valley bottom, they are subject to short-duration flooding due to surface runoff and fairly frequent reworking. 1/ This makes them very heterogeneous; they may be covered over by silt deposited by runoff, or themselves cover various formations. On pervious ground, local moisture conditions may result in a downward movement of the lime and allow a seasonal growth of vegetation; where this happens, organic matter rates are fairly high, usually above 2 %.

The soil is found along the edges of the rough broken land east of the Melka Sedi plain, also between the tributary cones especially the Kokay and Awadi, and in southern parts of the Metehara plain unaffected by marked erosion and subsequent filling in.

B-2 1. Use

The hydrodynamic properties and fertility of the soils are suitable for their cultivation under irrigation. This was confirmed experimentally at Metehara, where high yields have been obtained from crops grown under irrigation. Local development limitations are associated with salt contamination, erosion or inadequate soil depth; though the land is sometimes also at too high an altitude for gravity irrigation.

B-3. Semi-Arid Brown Soils on Soft Calcareous Materials with a Local Limestone Crusts

Map colouring : Brown - Bc

Soils in this unit can form over alluvial material (near the Mile confluence,

---

1/ This term is used here to describe the washing away of deposits by surface runoff, soil displaced and transferred by wind action, solifluxion, all of which result in complex soils and heterogeneous parent materials.

in the small plains near Awash station, etc.), or over non-stony colluvial material (area south of the Dit Bahri plain, east of Gewani, etc.)

The characteristic features are their colour (brown to light brown ; 10 YR 4/2, 5/2, 5/3, 6/2, 6/3) and a fine lime mycelium or lime-cemented gravel, and, though less often, calcareous crusts. These are mainly found in the plain west of Awash station, through which the road runs ; they are of ancient origin, and more often than not in a very broken-up condition. The present soils have probably formed from former eroded soils.

Lime content is fairly variable, usually between 5 % and 10 % ; lower values may be found where the lime occurs in the form of concretions over 2 mm in size or crusts.

They are medium-texture soils of the silt or silty loam type (very rarely with heavy or light textures), with a comparatively weakly developed structure (granular tendency on the surface and blocky deeper down).

Organic matter rates seldom exceed 2 %.

pH values generally range between 8 and 8.5, and conductivity rates are low, i.e. less than 4 mmhos/cm. Soils south of the Bahri backing against basalt hills, however, show some signs of salinity, with slightly higher conductivity values in the deeper horizons. Their pH values may be as high as denoting their alkalinity, which may then exceptionally be very pronounced with Na/T ratios of 15 %. In the Maro Gala and Kesem plains, conductivity values sometimes exceed 4 mmhos/cm at 25°C.

Soils in this unit occur very extensively in the Mile River plain and cover fairly large areas south of Dit Bahri.

In the Middle Valley they form most of the plateau extending to the west and north of Awash station, and are also observed on the rough broken hill land along one edge of the plains.

B-3 1. <u>Water relations</u>

Due to their higher altitude than the alluvial material, these soils are not flooded by the Awash; they receive water only from runoff from the higher-lying ground. Their soil climate is dryer than that of the alluvial materials in the plains, so that they are more sparsely overgrown with vegetation. They can be expected to have satisfactory water-holding capacities and permeabilities.

B-3 2. <u>Fertility and use</u>

These fertile soils are irrigable, but their use is severely restricted by ground features, state of erosion and the difficulty of irrigating them. Lime or gravel crusts or salinity occasionally affect their irrigability.

B-3 3. <u>Typical profile</u>

The soil unit can be defined by the profile MMS 314 to be described later.

B-4. Semi-Arid Brown Soils on Gravelly Calcareous Materials

Map colouring : Brown background with a dot pattern - Bg

This is a weakly developed ground which has formed over the stony remnants of old river beds or stony alluvial fans. In the profile, gravel is found in the loam or sandy loam from the surface downwards, with a fairly dense lime mycelium. The gravel itself is white due to a fine lime deposit.

The parent rock is in a less weathered condition deeper down. The gravel is coarser (about 10 cm dia.) and occurs in greater quantities; the loam is brown, ochre or yellowish in colour (7. 5 YR 4/2 - 10 YR 6/4). Initial signs of lime cementation are occasionally observed at about 1 m depth.

The soils occur along the edges of the rough broken ground areas, with the gravel deposits sometimes forming an inverted relief ; they also form part of the rough broken land zone east of Melka Sedi. In the Mile-Awash plain, the deposits mainly occur along the left river bank, where they are remains of former alluvial fans which have been partly protected against erosion by a small chain of basalt hills running from north to south.

B-4 1. Use

The land is unsuitable for irrigation because of its location and the size of its material, except in a few places where more colluvial runoff deposits have formed.

B-4 2. Typical profile

The above soil unit can be defined by one profile : MMS 65, to be described later.

B-5. Semi-Arid Brown Soils on Volcanic Tuff and Basalt Debris

Map colouring : Brown background with purple stripes - Bp

The parent rock is a more or less weathered volcanic tuff consisting of angular elements embedded in an ash or pumice cement, which contains some sandstone, (volcanic breccie, probably pantelleritic).

The soils are not very thick (about 0.50 m) ; they contain little lime, but are strongly alkaline because of the basic properties of the parent rock, which is mainly sodic with pH values sometimes exceeding 9. They are only found near the Fentale volcano; they cover especially a small area in the Metehara plain.

B-5 1. Use

Irrigability of the soils is poor because of their alkalinity, lack of depth and altitude.

B-5 2. Typical profile

The unit is defined by one typical profile : MMH 26, to be described later.

B-6. Saline Soils on Calcareous Materials

Map colouring : red - S

The salinity of these Lower Plain soils is generally due to a concentration resulting from the evaporation of more or less strongly saline water. In the Middle Valley, salinity is mostly due to the existing warm salt water springs at Filweha, or to former salt springs in the Metehara region.

The soil texture is medium to moderately fine, nearly always with occasional cross-bedded very thin clayey layers. Textures generally tend to become slightly heavier with depth (silty clay loam). The soil structure is platy and varies in development ; the thin clayey horizons have a fine granular structure.

Soil colour is fairly light, ranging from 10 YR 4/2 to 5/2, and occasionally even to 10 YR 6/1 - 6/2 on the surface. Lime content is invariably over 5 %, but never exceeds 10 %.

Saturated extract conductivity is generally less than 8 mmhos/cm at 25°C on the surface, but is apt to rise to 10 or 20 mmhos deeper down. It is very difficult to localize individual patches of soil with different salinity rates, as conductivity rates vary from one profile to the next. Salinity variations can also be observed in a same profile, with less saline horizons in the deeper layers than near the surface, though this is less frequent. White "salt flowers" caused by irrigation are seen on the ridge tops in ploughed fields under cultivation and canal banks ; saturated extract conductivities at the top and bottom of a ridge in this condition are 7.4 mmhos and 0.96 mmhos respectively. This shows the effect of the high evaporation rates in the Lower Plains on the formation of saline soils. The conductivity of the profile is low (less than 2 mmhos), because of a leaching process due to a nearby irrigation canal.

In the Lower Plains, the saline soils are confined to the Dubti plain and the right bank of the Awash south of Tendaho. In the Middle Valley, they occur around the warm springs, (Filweha, Kadabilen), at Metehara, and over old alluvium in the Maro Gala plain.

B-6 1. Use

The soils are not very suitable for development under irrigation. Not only does their salinity restrict the number of possible crops, but use of this land would imply substantial leaching water applications to get rid of its dissolved salts, and hence a drainage system to prevent the watertable from rising. The limited water supplies should be allotted to land with more suitable chemical and physical properties.

B-6 2. Soil series

The above soil unit includes the following soil series, differentiated by texture, which are defined by typical profiles, to be described later.

- Medium texture with medium salinity at deeper levels : profile TT 29.
- Moderately fine texture medium to high salinity at deeper levels : profile TMT 17.

B-7. Saline Alkali Soils on Calcareous Materials

Map colouring : dark grey - Sa

These soils are more saline, and part of their exchange complex is saturated with sodium (na/T about 50 %). Their general appearance is similar to that of saline soils (structure and colour), but their surface textures are sometimes a little heavier.

Between depths of 40 cm and 60-70 cm, they feature a horizon rich in gypsum above a heavier-texture horizon, which is occasionally clayey. The gypsum occurs in fibrous or "saccharoid" form and its origin may be associated with warm saline springs or small mud volcanoes. A few volcanoes can still be seen in a group in the plain. Analysis shows a predominance of calcium and magnesium sulphates in the saturated extract, which seems to confirm the assumption.

Salinity near the surface is not very high (average 4 - 8 mmhos/cm); below 40 - 60 cm, however, the conductivity of the saturated extract rises to a high value, nearly always over 30 mmhos/cm. The exchange complex is saturated with sodium ions, and NA/T ratios are apt to vary between 20 % to (occasionally) over 40 %. pH values vary between 9 and 9.5 in the deeper horizons, and between 8 and 8.5 near the surface.

The soils cover a large area centered roughly on the Kurub. They occur around the Alalabada hot spring on the left bank.

B-7 1. Use

The soils are practically unfit for development. Very high salinity and the high sodium saturation percentage of their exchange complex rule out the great majority of crops. Only a few plants (Halophilae and Aristidae) grow on them during the short rainy period, where they form a sparse covering grazed by camels. It is reasonable not to consider the development of this land under irrigation, but to keep it as grazing land and to use available water supplies for more suitable land elsewhere. Available water supplies, by no means unlimited, would certainly not suffice to irrigate all the land capable of development.

B-7 2. Typical profiles

The soil unit can be defined by two profiles : one in the Middle Valley, the other in the Lower Plains, to be described later. These profiles are : KAW 22 and TT 37.

B-8. Regosols Resulting from Erosion

Map colouring : deep pink Er and E

B-8 1. Er : on differentiated materials

At the western foot of the Awash rift valley, weathering debris which fell as rubble or was washed down from the rocks on the high plateaux and hills farther up-river, forms a huge cone with an average slope of 10 %. This heterogeneous formation suffered severe erosion and is covered with tree and shrub steppe vegetation, which gradually thickens to woods at higher altitudes nearer the humid zone.

These soils form locally over very restricted areas and gradually go from the semi-arid brown to the brown subtropical type. No differentiation has been made in their classification. They are very scattered and cover very small areas.

B-8 2. E : on semi-arid brown soils

These soils resulted from erosion of the sub-arid brown soils which formed over the old alluvia and colluvia on the hillsides above the recent alluvium area. A pseudo-steppe type of vegetation grows on them; with Gramineae and a few trees and shrubs, especially in thalwegs in which runoff collects. Sheet and gully erosion are always pronounced, and more so on steeper slopes.

B-8 3. Use

On the whole, this zone is unfit for agriculture because of the severe erosion affecting its slopes and its shallow soils. A few dozen hectares could be developed here and there under irrigation from the many permanently flowing tributaries ; this is already practized along the Kesem and the Awash.

B-8 4. Soil series

The soil units include the following series differentiated by the parent materials and defined by typical profiles, to be described later :

- On soft alluvia and colluvia : profile MMS 16
- On gravelly alluvia and colluvia : profile MMS 349
- On basalt gravel colluvia : profile MMH 16
- On soft pumice and volcanic tuff colluvia MMH 3
- On gravelly pumice and volcanic tuff colluvia

B-9. Saline Soils and Recosols on Non-Differentiated Materials

Map colouring : brown background with black stripes - Sr

These form the "badlands" in the rough broken semi-arid barren areas where intense erosion has made a dense and dry ravine network into the ground. The mounds between the ravines vary between rounded, sharp spur or table shapes. The "badlands" lie downstream from Awash station, where they cover large areas between Gewani and Tendaho, and in the Mile and Logiya river basins.

Analysis results on samples taken at Gewani and Logiya appear very similar. The soil is highly saline silty clay loam (80 - 100 mmhos/cm at 25°C); this salinity is associated with sulphates and bicarbonates. Sodium accounts for nearly all the ions. pH values are above 9.

The greyish recent saliferous marl from which these soils have formed nearly always overlies light brown calcareous loam (lime content over 25 %) with a more or less encrusted upper part.

B-9 1. <u>Use</u>

The land is totally unfit for agricultural development. It covers 4,500 sq. km in the Awash Valley.

B-9 2. <u>Typical profile</u>

The soil unit is defined by one typical profile : GMGW 1, to be described later.

C. SKELETAL SOILS ON ROCK AND BASALT ROCK DEBRIS

<u>Map colouring</u> : purple - R

This is rough generally basaltic volcanic high ground overlooking the plains. The biggest formations surround the Lower Plains and are run through by rivers which carry water only when it rains and bring colluvial and/or saline alluvial material down into the plain where it forms local deposits. The soils are usually shallow, with scattered basalt blocks on the surface.

A range of basalt hills in the Middle Valley runs from north-east to south-west and forms one of the plain boundaries. The most substantial massifs are the Fentale, Dabita Ale, Azelo and Amdisa, and the Dofan, with discontinuous basalt outflows between them.

This land, totally unfit for development, might be used as wild life reserve.

D. SOILS ON SANDY DEPOSITS

<u>Map colouring</u> : black spots - D

These are either very distinct dune formations covering fairly large areas, or very sandy zones in which dunes will eventually form. They occur only in the lower plains at Dubti on the left bank, and at Dit Bahri on the right bank, wherever the ground is dry enough for medium-sized to coarse material to be picked up by the wind and deposited to form dunes. They vary greatly in size according to wind speed and direction.

Surface features and instability make the land unfit for development.

E. AREAS COVERED BY THE RECONNAISSANCE SOIL SURVEY

The sizes of areas covered by individual soil groups and sub-groups in the Middle Valley and Lower Plains of the Awash basin are listed in Table 5. General comments are :

(i) Skeletal soils take up about half the surveyed area.

(ii) Old alluvial and colluvial areas are comparatively extensive in both regions. They cover an area roughly twice the size of the recent alluvial area.

(iii) Alluvial soils predominate amoung the soils on recent deposits. They cover a bigger area in the Middle Valley than in the Lower Plains.

(iv) Vertisols come next, again covering a bigger area in the Middle Valley than in the Lower Plains.

(v) Appreciable quantities of hydromorphic soil are observed along the Awash in the Middle Valley.

(vi) A comparatively large area is taken up by marshland in the Lower Plains.

(vii) Predominant among soils on old alluvia and colluvia are semi-arid brown soils, vertisols and regosols in the Middle Valley and mainly saline and semi-arid brown soils in the Lower Plains.

Recent alluvial land most suitable for irrigation is thus fairly limited when compared with the old alluvial areas, especially rough rocky ground or basalt outflows.

Table 5. Amount of Land in Various Soil Groups and Sub-Groups

Soil groups or sub-groups	Middle Valley		Lower Plains	
	ha	%	ha	%
I - Soils on recent alluvia				
Alluvial soils (Anc, Ac, As)	113,000	10.1	62,500	7.5
Vertisols (Vnc, Vc)	45,000	4.0	18,900	2.2
Hydromorphic soils (H_{nc}, Hc)	20,000	1.8	4,700	0.6
Organic Hydromorphic soils Ho)	7,500	0.6	40,600	4.9
Alkaline hydromorphic soils (ha)	4,200	0.4	300	-
TOTAL	189,700	16.9	127,000	15.2
II - Soils on old alluvia and colluvia				
Vertisols on calcareous alluvial and colluvial materials (Vf, Vl)	142,000	12.7	1,900	0.2
Vertisols on calcareous materials in the runoff zones (Vr)	13,800	1.3	-	-
Semi-arid brown soils (Bc, Bg, Bp) .	206,000	18.4	90,000	10.8
Regosols resulting from erosion (E,Er)	160,000	14.1	-	-
Saline soils on calcareous materials(S)	7,500	0.6	43,300	5.2
Saline alkali soils on calcareous materials (Sa)	-	-	94,000	11.3
Saline soils and regosols on non differentiated materials (Sr)	27,000	2.4	37,500	4.5
TOTAL	556,300	49.5	266,700	32.0
III - Skeletal soils on volcanic materials(R)	375,000	33.6	441,000	52.7
IV - Soils on sandy deposits (D)	-	-	1,300	0.1
TOTAL AREA	1,121,000	100.0	836,000	100.0

VII. LAND CLASSIFICATION FOR THE CHOICE OF IRRIGABLE ZONES

VII - 1. Purpose and Principle of the Classification

The purpose of the 1:250,000 scale land classification is to define the boundaries of arable land for which irrigation is possible. Irrigation is a definite requirement for agricultural land development in the Middle Valley and the Lower Plains of the Awash. From the climate conditions and known water requirements in these areas, it is evident, that rainfall alone cannot ensure normal crop development.

It is necessary to classify this land in terms of soil quality and favourable or unfavourable factors for its development under irrigation. This appraisal is based on the results of the soil survey, the estimation of limiting factors, and the geographical position of the land.

In view of the limited water supplies in the Awash Basin, which could not ensure full irrigation for all the considered plains, it is reasonable to consider only the most suitable land for irrigation for the initial development stage. When more accurate estimates are made, the less irrigable land can be included in the development.

VII - 2. Classification Criteria

The classification criteria listed below enable the land to be subdivided into a number of classes of a definite irrigation suitability. They can be expressed by three notations :

(i) In capital letters where major difficulties completely rule out irrigation.

(ii) In small letters where development-limiting factors can be expected to cause appreciable difficulties, but would not rule out irrigation.

(iii) No notation, where no major limiting factors are associated with the land (to a scale of 1:250,000). This land is arable and the most suitable for irrigation.

The following symbols have been adopted :

R : Rock, or rough stony ground, or very eroded rough stony ground.

W : Wet land, marshland, swampy areas.

D : Sand dunes.

ES : (Erosion-salinity). Very eroded, highly saline "badlands", frequently with a very marked "microrelief".

S : Very saline or saline alkali soils unsuitable for development.

r : Land with a stony surface or stony horizons in the soil profile severely restricting its potential use. (Difficulty in working the soil, much less water readily available for the plants, shallower soils, etc.).

w : Hydromorphic zones. Without suitable reclamation measures, their use will remain limited by high water table levels or prolonged flooding.

e : Eroded land, the surface horizons of which have been washed away, occasionally with medium-size gully formation, reducing soil fertility and making the land more difficult to work. This land is frequently found on steep or very steep slopes.

s : Land in which generally medium to high salinity (sometimes also associated with alcalinity problems) considerably limits the choice of possible crops, which must have a reasonably or very high resistance to salts. This land requires a more substantial water application to wash the salts out of it, and also special draining arrangements for the leaching water so as to prevent rise in the water table level. Special cultivation methods require developing.

l : (Location). This symbol frequently denotes soils with suitable inherent properties for immediate irrigation (soil class I), but for which hydraulic development projects would be less recommendable because of their location. The symbol has been used for :

(i) Land too high up for gravity irrigation (e.g., Aleydegi plain, plain at the Mile confluence, Awadi plain).

(ii) Wedges of land in a zone less suitable for irrigation (e.g., good land surrounded or cut off by basalt or volcanic exudate barriers and featuring scattered "islands").

(iii) Land too remote from a convenient development area and requiring expensive development works (e.g., a long feeder canal at the head of the irrigation system).

VII - 3. Soil Classification by Irrigation Suitability

These land classes relate to present suitability for development under irrigation :

Class A : land suitable for development under irrigation.

Class B : arable land non-irrigable in its present state except under certain conditions (construction of hill ponds, deep well-water supplies, or other local installations); and arable land of indeterminate irrigability but generally unsuitable for irrigation under present conditions. The class includes any stony, hydromorphic, or eroded land with marked relief or "microrelief" features; land suitable for only a limited range of crops because of its salinity; and land which, though arable, is either too remote or badly situated for irrigation to be recommended. Land in this class, especially with the symbol "l", would be suitable for pasture.

Class C : is non-arable, non-irrigable land, i.e., rock, very stony ground, dunes, swamps, very saline land and "badlands".

VII - 4. Mapping Details

Each land class is identified by a distinctive set of colours and symbols :

Class A : green ; no overprint.

Class B : orange ; one small letter denoting the sub-class.

Class C : red ; one or two capital letters denoting its sub-class.

VII - 5. Areas of Land in Various Irrigability Classes

VII-5 1. Middle Valley

A total area of 1,121,000 hectares was mapped in the Middle Valley soil survey. Part overlies alluvia and colluvia and the remainder is represented by various basalt formations (lithosols and skeletal soils).

Table 6. Sizes of areas of land in the Middle Valley in each irrigability class and percentages of total alluvial and colluvial area.

	Total area (ha)	Alluvial and colluvial area		Irrigability
		ha	%	
Class A	125,000	125,000	16.8	Irrigable land.
Class B	601,000	601,000	80.5	Not irrigable in its present condition, or of indefinite irrigability.
Class C	395,000	20,000	2.7	Non-irrigable
TOTAL	1,121,000	746,000	100.0	

Class A land includes all irrigable areas and amounts to 16.8 % of the total alluvial and colluvial area.

In the Metehara region, land in this class is represented almost exclusively by vertisols in the runoff areas and by semi-arid brown soils on soft calcareous deposits. They occur in a quadrilateral about 5 - 7 km wide by 20 km long, through which the Awash flows, with saline areas along a considerable length of its northern boundary (saline soils near lake Beseka, and hydromorphic alkali soils along the Awash downstream).

In the centre of the Middle Valley, Class A land includes almost all the alluvial soils (except only those north of the river Isi, because of their remote position and height above the Awash), the vertisols on recent alluvia, a large part of the vertisols in the runoff areas, and a few minor semi-arid brown soil areas.

This land comprises the Melka Sedi plains over recent alluvia on the right bank of the river and the Kesem, Kebena and Bolhamo plains on the left bank. Development possibilities are limited by very fine-textured vertisols, most of which are on the right bank of the Awash. (Limited drainage and selection of crops).

Appreciable amounts of land to either side of the river Awadi would be fairly easy to develop if full use were made of the water available from this river (e.g., out-off walls to divert underflow).

Most land in the Maro Gala plain farther north is in Class A. The plain contains a few fairly limited saline areas (Class C) in its central portion consisting of alluvial soils and vertisols on recent alluvia. Only part of the land can be supplied with water under gravity. Access is still difficult, and the land around the Gewani marsh is periodically flooded.

Class B land covers more than 400,000 hectares; i.e., 80 % of the total alluvial and colluvial area.

Limitations are mainly associated with its geographical or topographical situation (l), erosion (e) and, over much smaller areas, with hydromorphic features and flooding (w), salinity (s), and in high proportions of stones or rock fragments in the soil (r).

Certain land of medium to marginal irrigability has been included in class B solely because of its geographical or topographical situation; e.g., the vertisols in the Aleydegi plain and in the plains north and south of Awash station. Rough broken land along the edge of the recent alluvial area comprising severely eroded regosols, semi-arid brown soils and vertisols in the tributary valleys is included in Class B.

Class B land can generally be made suitable for pasture if the requisite number of water supply points are created. This is especially true of the Aleydegi and Awash station plains.

Class C land covers 20,000 hectares in the alluvial and colluvial area (2.7%). It includes :

(i) Excessively saline land alongside the Beseka, Hertale, Gedebasa, Kada Bilen and Filweha lakes or springs (symbol S).

(ii) Saline marl "badlands" west of Gewani. This severely eroded land is unfit for cultivation (symbol ES).

(iii) The marsh south of lake Gedebasa, containing numerous channels of varying activity depending on flood severity. This marsh and the lake are both gradually filling up.

The map area includes skeletal soils and basalt hills totalling 571,000 hectares (Fentale, Dofan, Dabita Ale, Azelo).

VII-5 2. Lower Plains

A total area of 836,000 hectares has been mapped in the Lower Plains, including 395,000 hectares of alluvial and colluvial land. The remainder is skeletal soil and volcanic rock. The total does not include lakes, amounting to about 1,100 hectares.

Table 7. Areas of land in the Lower Plains in each irrigability class and percentages of the total alluvial and colluvial area.

Total area (ha)		Alluvial and colluvial area		Irrigability
		ha	%	
Class A	75,000	75,000	19.0	Irrigable
Class B	125,000	125,000	31.6	Not irrigable at present, or of indefinite irrigability.
Class C	636,000	195,000	49.4	Non-irrigable.
TOTAL	836,000	395,000	100.0	

Class A land covers 75,000 hectares, i.e., 19 % of the total alluvial and colluvial area, extending from the plains south of the Mile confluence to Lake Abe and in the subsidence forming the Lower Plains. A small part of this land occurs at the level of the Awash-Mile confluence and along the left bank of the Awash as far as its confluence with the Agasuri. Most of the Class A land is found on the right bank of the Awash (Dit Bahri area), and especially in the Asayita delta.

This class A land comprises nearly all soils over recent alluvia (except for a few areas subject to flooding and some vertisols in the recent alluvium area). It does not include land with a water table near the surface or subject to prolonged flooding. Efficient drainage is necessary for irrigation in the Dit Bahri area and the Asayita delta to prevent a water table rise and secondary salinization of the soil.

Class B land covers 125,000 hectares, i.e., nearly a third of the total alluvial and colluvial area (31.6%). Its irrigability is limited by remoteness or topographical situation (l), hydromorphic features (w) and salinity (s).

Irrigation possibilities in the Mile-Awash area are limited by its high altitude above the Awash; the land to the west of the hills along the edge of the alluvial area also suffers from its remote situation. An adverse factor is the frequently stony nature of the semi-arid brown soils throughout the Mile area. Only a few flatter portions along the Awash would be less difficult to irrigate. Part of this area will be under water when the dam is built at Tendaho. Other areas affected by their remoteness (l) are a few periodically flooded by runoff north of the Kurub and south of the Foro basalt hills.

Salinity (s) is very pronounced in the Dubti area, to the north of the Boyale marsh and along the edge of the basalt hills surrounding the Lower Plains. Special measures and prior experimentation are needed for their development.

Land identified by the symbol (w) occurs in areas with a microrelief featuring holes and depressions, run through by numerous distributaries and flooded by the Awash at high water. It overlies vertisols or hydromorphic soils to either side of the Awash (alongside the Boyale marsh, in the Dit Bahri flood area, along the shores of lake Gamari and south of the Mamule defluent). This land will be difficult to develop unless flows in the Awash are controlled.

Class C land covers 195,000 hectares in the alluvial and colluvial area; i.e., nearly half its total area (49.4 %). It includes :

(i) Boyale marsh and those south of the Asayita delta and along the western edge of lake Gamari.

(ii) Dunes at Dubti and Dit Bahri.

(iii) Severely eroded very saline marl "badlands" in the Mile and Logiya basins and north of the Alalabada springs.

(iv) Extensive saline alkali soils north of the Boyale marsh and around the Alalabada springs.

Volcanic formations (lithosols) are extensive outside the alluvial area (441,000 hectares have been mapped).

Table 8. Areas mapped in the Middle Valley and Lower Plains. Percentages of the total alluvial and colluvial area (Middle Valley and Lower Plains), excluding lithosols.

	Middle Valley		Lower Plains		Total area	
	ha	%	ha	%	ha	%
Class A	125,000	10.9	75,000	6.6	200,000	17.5
Class B	601,000	52.7	125,000	10.9	726,000	63.6
Class C	20,000	1.8	195,000	17.1	215,000	18.9
Total alluvial and colluvial area	746,000	65.4	395,000	34.6	1,141,000	100.0
Lithosols	375,000	46	441,000	54	816,000	100.0
Total mapped area	1,121,000		836,000		1,957,000	

The largest areas of the most irrigable land are in the Middle Valley (10.9), compared with only 6.6 % (75,000 hectares) of land in the Lower Plains which would be made irrigable with average improvement, especially with drainage.

Class B land in the Middle Valley alone accounts for nearly half (52.7%) of the total alluvial and colluvial area, compared with only 10.9 % (125,000 hectares) in the Lower Plains. In the Middle Valley, most of this land can be made suitable for pasture, if the necessary water supply points are installed.

Class C land is very extensive in the Lower Plains (17.1 %) (i.e. nearly 200,000 hectares), but there is not very much in the Middle Valley. This class of land cannot be made irrigable. (Lithosols cover substantial areas, and are totally unfit for use.)

VIII. SEMI-DETAILED SOIL SURVEY

A. SELECTION OF THE AREAS

The Middle Valley and Lower Plains contain fairly large areas of recent alluvium which could be irrigated under gravity. Irrigation could be extended to some older alluvium and colluvium not so saline as to require excessive leaching water applications. The areas selected are :

a) In the Middle Valley

The Metehara, Melka Sedi, Amibara, Kesem-Kebena and Bolhamo irrigation areas, covering an overall gross area of about 100,000 hectares. These are mainly Class A land. Decisive elements in this choice were land quality, irrigability under gravity, and the proximity of ways into and from the areas concerned. The Awadi and Maro Gala areas were considered to be less suitable because of their remoteness and the smaller amounts of potentially irrigable land they contain.

b) In the Lower Plains

The choice was more difficult for this region because of its poor accessibility and vulnerability to flooding by the Awash at high water. An appreciable amount of this land is so saline that its development requires above-average quantities of water. Alkalinity in the low-lying parts of the area ("bottom-lands") is also a problem. Adverse features affect each selected area.

The Dubti area is selected, among others, because of its recently introduced cotton growing activities. It offers a larger expanse of level land which appears to lend itself well to irrigation under gravity.

Receding-flood crops are already raised in the Asayita delta. The presence of farmers and the possibility of extending irrigation to the north of this area warrants its selection for a semi-detailed soil survey.

B. SOIL CLASSIFICATION AND LEGENDS FOR THE SEMI-DETAILED SURVEY

The soil units of the semi-detailed survey resulted from a splitting at the series and phase levels of the broad units of the reconnaissance survey. The criteria at the series level are more often the texture of the parent material, sometime the structure of the surface horizon or the salt content. At the phase level, they are the water regime, micro-relief, depth or salinity.

The legends used in the two semi-detailed areas are given below. (Detailed description of profiles typical for these soil units are given in Appendix 3).

MIDDLE VALLEY

I. SOILS ON RECENT ALLUVIA

1. Alluvial Soils on Very Slightly or Non-Calcareous Deposits

   Medium texture

   Interlayered medium to moderately fine texture

   Deep

   Dark-coloured horizon with moderately fine texture at deeper levels.

   Moderately fine to fine texture : micro-relief with holes

2. Alluvial Soils on Very Slightly Calcareous and Occasionally Saline Deposits

3. Vertisols on Very Slightly or Non-Calcareous Materials

   Fine self-mulching structure

   Homogeneous, fine texture; gilgai micro-relief

   Homogeneous, with highly-developed mulch

   Moderately deep on loamy horizons

   Moderately shallow on interlayed alluvia; micro-relief with holes

   Coarse structure, slightly alkaline soils

   Moderately fine to fine texture

   Moderately fine texture on interlayered alluvia : micro-relief with holes and channels in dried-up areas

4. Vertisols on Very Slightly or Non-Calcareous Materials Subject to Seasonal Waterlogging During Floods

5. Vertisols on Slightly Calcareous Materials

   Fine structure

   Coarse structure

6. Hydromorphic Soils

   On very slightly calcareous materials

   On alkaline materials

II. SOILS ON OLD ALLUVIA AND COLLUVIA

7. Vertisols on Calcareous Materials Slightly Saline at Deeper Levels

Fine structure

Coarse structure

8. Semi-Arid Brown Soils and Vertisols on Calcareous Materials of the Areas of Rough Broken Land

Vertisols on calcareous materials in the runoff zones

Deep
Moderately deep on basalt gravel colluvia
Moderately deep with basalt gravel generally covered by runoff loam

Semi-arid brown soils on calcareous colluvial materials (with local limestone-crust)

Semi-arid brown soils on colluvial or old gravelly alluvial materials

Semi-arid brown soils on volcanic tuff and basalt debris

9. Regosols Resulting from Erosion

On soft alluvial and colluvial materials
On gravelly alluvial and colluvial materials
On basalt gravel colluvial materials
On soft pumice and volcanic tuff colluvial materials
On gravelly pumice and volcanic tuff colluvial materials

10. Regosols and Saline Soils

11. Saline Soils

12. Saline Alkali Soils

III. LITHOSOLS AND SKELETAL SOILS

On basalt

LOWER PLAINS

I. SOILS ON RECENT ALLUVIA

1. Alluvial Soils on Calcareous Deposits with Interlayered Textures

Medium to moderately fine texture

Subject to seasonal waterlogging during floods

Zone of dried-up channels : micro-relief of holes and channels; medium salinity (occasionally high salinity: symbol "S")

Moderately fine to fine texture, occasionally alkaline at deeper levels, strongly marked micro-relief

Subject to seasonal waterlogging during floods

Zone of dried up channels

Moderately fine to fine texture, moderately deep on horizons of variable texture and colour, occasionally alkaline (zone of dried up channels)

2. Vertisols on Calcareous Materials

Fine structure - gilgai micro-relief

Coarse structure - alkaline soils - subject to flooding

3. Hydromorphic Soils on Calcareous Materials

Soils rich in humus subject to temporary flooding
Organic soils

Subject to seasonal waterlogging during floods
Permanently waterlogged

II. SOILS ON OLD ALLUVIA AND COLLUVIA

4. Saline Soils

Medium texture

Low to medium salinity
Medium salinity at deeper levels

Moderately fine texture

Medium salinity at deeper levels

5. Saline Alkali Soils

6. Fine Textured Alluvial Soils in the Depressions or Dried-up Lakes

Salinity low to nil

Medium salinity in the top-soil

7. Sandy Regosols on Dunes

III. LITHOSOLS AND SKELETAL SOILS

On basalt and lava

On shells and calcareous tuff

C. SIZES OF AREAS COVERED BY THE SEMI-DETAILED SOIL SURVEY

Table 9. Areas covered by Semi-detailed Survey - Middle Valley (less Metehara Area)

	Area ha		Area %	
I - SOILS ON RECENT ALLUVIA				
Alluvial soils on very slightly or non calcareous deposits (11, 121, 122, 13)	37,520		16.8	
Alluvial soils on very slightly calcareous and occasionally saline deposits (2)	5,860		2.6	
Vertisols on very slightly or non calcareous materials, fine self-mulching structure (311, 312, 313, 314)	18,620		8.3	
Vertisols on very slightly or non calcareous materials. Coarse structure, slightly alkaline soils (321, 322)	6,570		2.9	
Vertisols on very slightly or non calcareous materials subject to seasonal waterlogging during floods (4)	6,700		3.0	
Vertisols on slightly calcareous materials(51,52)	3,970		1.8	
Hydromorphic soils on very slightly calcareous materials (61)	2,250		1.0	
Hydromorphic soils on alkaline materials (62)	1,750		0.8	
		83,240		37.2
II - SOILS ON OLD ALLUVIA AND COLLUVIA				
Vertisols on calcareous materials slightly saline at deeper levels (71,72)	11,530		5.1	
Vertisols on calcareous materials in the runoff zones (811, 812, 813)	7,020		3.1	
Semi-arid brown soils	35,020		15.6	
Regosols resulting from erosion (91, 92, 93, 94)	13,820		6.2	
Regosols and saline soils (10)	1,300		0.6	
Saline soils (11)	2,250		1.0	
Saline alkali soils (12)	450		0.2	
		71,390		31.8
III - LITHOSOLS AND SKELETAL SOILS (13)		69,370		31.0
T O T A L A R E A		224,000 excluding the lakes		100.0

Alluvial soils on recent alluvia account for roughly 25 % of the overall alluvial and colluvial area. They are mainly in the Kesem-Kebena plains, in the higher part of the Bolhamo plain and in the Melka-Sedi and Amibara plains. Soils with deep saline horizons cover about 6,000 hectares in these areas.

Finely-structured vertisols on recent alluvia extend along the Awash, especially in the right-bank portion of the Melka-Sedi plain.

Coarsely structured slightly alkaline or calcareous vertisols are found in the depressions generally left over from former beds of the Awash. Some are subject to flooding when the river is running in flood, especially in the Angelele plain.

Hydromorphic soils occur in depressions waterlogged for part of the year. Some are alkaline due to the warm springs (Filweha, Kada Bilen).

Soils on old alluvia and colluvia are mainly of the brown semi-arid type and vertisols and are found in runoff areas. Some calcareous vertisols among these (about 7,000 hectares) would be suitable for irrigation, were it not for their high altitude.

The lithosols and skeletal soils isolating each area make up a third of the total mapped area.

Table 10. Areas covered by Semi-detailed Survey - Metehara Area

	Area			
	ha		%	
I - SOILS ON RECENT ALLUVIA				
Alluvial soils on very slightly or non calcareous deposits (11)	150		0.4	
Vertisols on very slightly or non calcareous materials subject to seasonal waterlogging during floods (4)	1,950		5.2	
Hydromorphic soils on alkaline materials (62)	1,100	3,200	2.9	8.5
II - SOILS ON OLD ALLUVIA AND COLLUVIA				
Vertisols on calcareous materials slightly saline at deeper levels with fine structure (71)	1,750		4.6	
Vertisols on calcareous materials in the runoff zones (812,813)	5,500		14.5	
Semi-arid brown soils (82, 84)	5,550		14.6	
Regosols resulting from erosion (91, 93, 94, 95)	10,600		18.2	
Saline soils (11)	2,300		6.0	
Saline alkali soils (12)..................	1,800	27,500	4.8	62.7
III - LITHOSOLS AND SKELETAL SOILS (13)		7,300		28.8
T O T A L A R E A		38,000		100.0
	excluding the lakes			

The recent alluvial area is very small and consists almost entirely of vertisols and alkaline hydromorphic soils along the Awash.

The vertisols, which are affected by frequent short-duration flooding by runoff, take up 20% of the total surveyed area. They mainly occur on the left bank side of the Awash.

Semi-arid brown soils and regosols occur extensively on alluvial cones at the foot of basalt cliffs. Saline alkali soils, amounting to about 10 % of the overall area, occur around lake Beseka.

The area also contains numerous basalt outflows together covering roughly 30 % of its total surface.

Table 11. Areas covered by Semi-detailed Survey - Lower Plains

		area ha		area %	
I -	SOILS ON RECENT ALLUVIA				
	Alluvial soils on calcareous deposits with interlayered textures (111, 112, 121, 122, 13)	52,000		21.7	
	Vertisols on calcareous materials (21, 22)....	16,000		6.7	
	Hydromorphic soils rich in humus on calcareous materials (31)	6,000		2.5	
	Hydromorphic organic soils on calcareous materials (321, 322)	20,800	94,800	8.7	39.6
II --	SOILS ON OLD ALLUVIA AND COLLUVIA				
	Saline soils (411, 412, 42)	34,000		14.2	
	Saline alkali soils (5)	34,700		14.5	
	Fine textured alluvial soils in the depressions or dried up lakes (61, 62)	900		0.3	
	Sandy regosols on dunes (7)	7,300	76,900	3.0	32.0
III -	LITHOSOLS AND SKELETAL SOILS (8)		68,300		28.4
TOTAL AREA	....	excluding the lakes:	240,000 (7,800)		100.0

Alluvial soils cover about one-third of the surveyed area (excluding lithosols and skeletal soils). They are particularly developed in the Dit Bahri plain and Asayita delta, along the Awash and its defluents.

Vertisols account for 16,000 hectares; most occur in dried-out depressions.

Hydromorphic soils are found in the quasi-permanent marshes and along their flood fringes. The biggest marshes are along the left bank of the Awash (Boyale) and around lake Gamari.

Saline soils over old alluvia and colluvia cover 34,000 hectares, mainly in the Dubti area and on the colluvia south of the Dit Bahri plain. Their salinity varies, but some are suitable for irrigation.

Saline alkali soils extend over nearly 35,000 hectares north of Dubti.

Dune soils cover an appreciable area (7,300 hectares).

Very clayey dried-out lake soils (Gargori) account for 1,000 hectares of land north of Asayita.

Lithosols and skeletal soils are mainly corresponding to the two basalt ranges separating the Dubti and Dit Bahri plains from the Asayita delta.

IX. LAND CLASSIFICATION ACCORDING TO IRRIGATION SUITABILITY

IX-1. Principle and Purpose of Classification

Soils in the Middle Valley and Lower Plains are subjected to considerable evaporation, while local rainfall is insufficient. Irrigation is, therefore, essential for their agricultural development. In classifying this land in terms of irrigability, it is necessary to allow for its physical and analytical properties liable to affect it.

A land irrigability classification must clearly show the possible obstacles to development (limiting factors) and the principles of the treatment and development work required to deal with them; e.g., salinity, or alkalinity, depth of soil, slope, flooding risks, vulnerability of the land to erosion. The irrigability classification will result from regrouping into "development units" areas with similar properties.

IX-2. Limiting Factors

Table 12 sums up the limiting factors, which are also shown on the 1:100,000 scale irrigability maps, where "major limiting factors" are denoted by a capital letter and "secondary limiting factors" by a small letter. A secondary limiting factor is by itself insufficient for down-grading land from one class to the next below it ; but it is down-graded, if two secondary factors apply at the same place.

Classes II, III, IV, V and VI are divided into sub-classes on the map. Each is determined by limiting factors denoted by the following symbols :

In Class II : W, S, F, M, D, E or two small letters.

In Class III : One or two capitals, occasionally with a small letter.

In Class IV)
(One or more capitals.
In Class V)

In Class VI : A special symbol; for instance, R for rough rocky land, W for marshes, D for dunes, S for saline land, A for alkaline land.

Table 12. Land Classification - Limiting Factors

Factor and symbol	Meaning	Highest class in which classifiable
DRAINAGE W	Minor drainage difficulties	II
	Medium drainage difficulties	III
	Major drainage difficulties	IV
AVAILABLE MOISTURE AM	Moderate - 10 % - 13 %	II
	Low - 6 % - 10 %	III
	Very low - under 6 %	IV
SALINITY S	Saturated extract conductivity 4-8 mmhos/cm at 25°C	II
	Saturated extract conductivity 8-16 mmhos/cm at 25°C	III or IV
	Saturated extract conductivity over 16 mmhos/cm at 25°C	V or VI
ALKALINITY A	Na/T = 10 % - 15 %	II
	Na/T = 15 % - 20 %	III
	Na/T = 20 % - 30 %	IV
	Na/T over 30 %	V or VI
FLOODING F	Only exceptional flooding	II
	Major floods every two or three years, or for short periods each year	III
	Major floods each year	IV or V
DEPTH D	Deep = 0.75 m - 1.5 m	II
	Moderately deep = 0.25 m - 0.75 m	III
	Shallow = 0.25 m	IV or V
EROSION E	Medium to slight erosion	II
	Severe erosion	III
	Very severe erosion	IV or V
SLOPE T	3 % - 6 %	II
	6 % - 8 %	III
	8 % -25 %	IV
	over 25 %	V or VI
MICRO-RELIEF M	Scattered holes and ditches up to 60 cm in depth	II
	More densely distributed deeper holes and ditches	III

IX - 3. Discussion of Limiting Factors

IX-3 1. Drainage

The water table is generally at a considerable depth, except in certain local areas; e.g., in the approaches to the Lower Plains or along the river and natural defluents. Drainability is expressed simply in terms of soil texture in the horizon below a depth of 0.50 m :

(i) Fine texture (i.e., clay exceeding 60 %) : Class III, or IV if at the bottom of a depression.

(ii) Moderately fine texture : Class II.

(iii) Moderately fine to medium texture with interlayered medium to moderately coarse textured horizons + satisfactory drainability (for example recent alluvial soils).

If the first horizon below 0.50 m is not very thick (e.g., less than 0.20 m), the texture of the one immediately below is considered.

In the Lower Plains, these limitations for the movement of water within the soil and surface drainage possibilities mainly apply to the hydromorphic soils and vertisols and to fine and very moderately fine textured alluvial soils (occasionally containing much exchangeable sodium at depth) in the low-lying areas; e.g., Dit Bahri and the northern Asayita area.

In the Middle Valley, the vertisols in the Melka Sedi region, the hydromorphic soils near Angelele on the right bank side of the river and the Bolhamo vertisols on the left bank side also have these limitations.

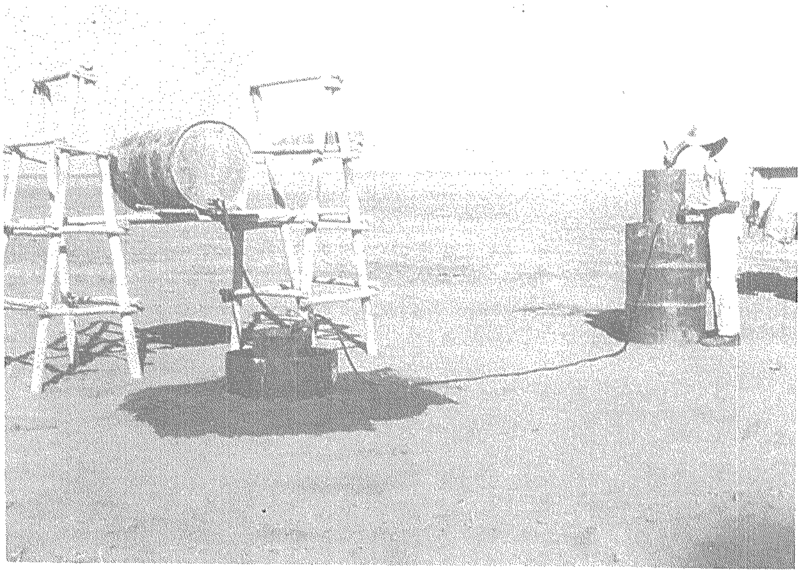
IX-3 2. Available moisture

This was estimated from about a hundred samples taken at points suitably distributed throughout the Awash Basin, based on moisture measurements at pF 2.5 and pF 4.2; available moisture was estimated as the difference between the two moisture rates.

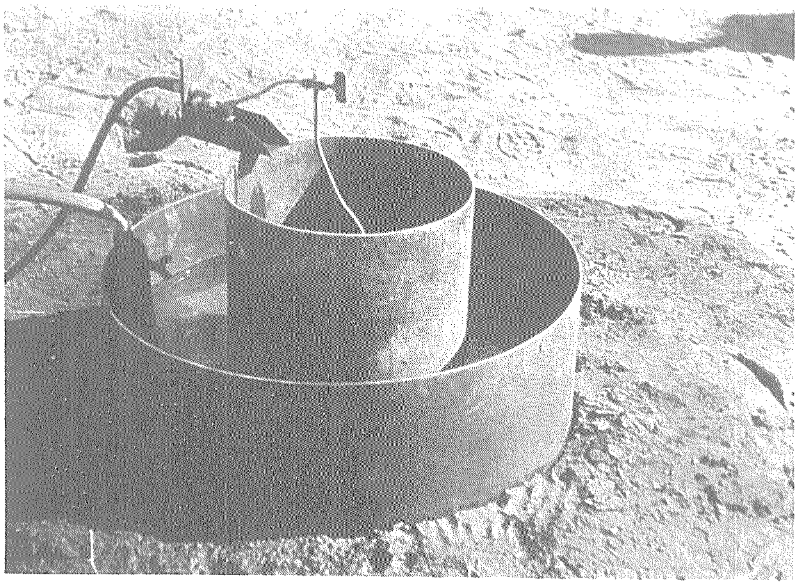
These results showed that there is no relationship between soil type and available moisture. The available moisture rates of 85 % of the samples analyzed ranged from 6 % to 13 %, which is fairly low. Frequent water applications are necessary to develop these soils, which will be a nuisance. This is why none of the soils in the Awash Basin has been put in Class I ; even the best land, in the Melka Sedi - Amibara area, can only be considered fit for Class II.

IX-3 3. Salinity

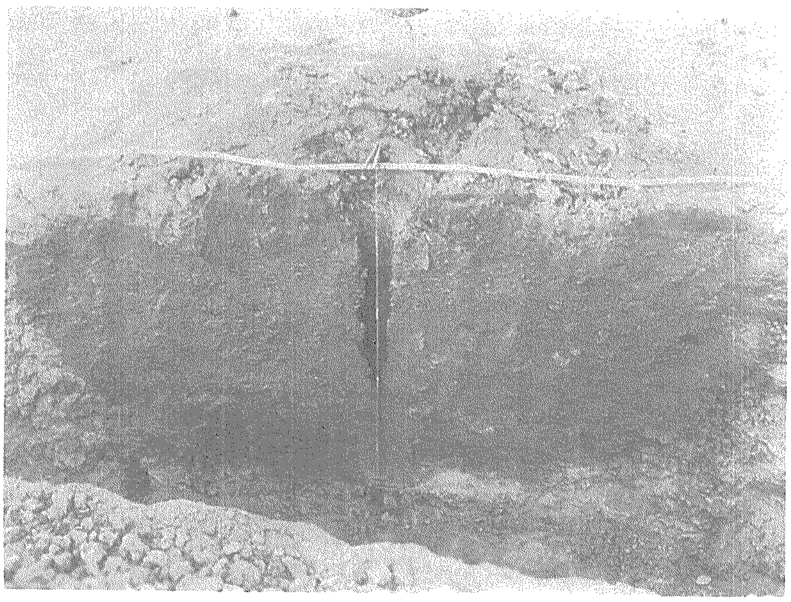
The results of the leaching tests on certain medium-salinity soils in the Lower Plains (see Appendix 5) appear to confirm that they could be improved by leaching. To estimate the average salinity of the various profiles, the texture has been taken in account, instead of the permeability which controls the drainage.



I A
Leaching tests in the saline lands near DUBTI



I B
Leaching tests in the saline lands near DUBTI : cylinders maintaining a constant head



I C
Leaching tests in the saline lands near DUBTI : wet section of the profile

A few saline soil patches are observed in the Middle Valley, some of which are still developing due to saline ground water or salt springs like those giving birth to the Filweha and the Lake Hertale defluent.

Saline marl forming part of the "badlands" occurs mainly between Maro Gala and Dubti, also a few patches between Metehara and Melka Sedi.

In the Lower Plains, saline soils are found especially over old alluvium and over colluvium along the left bank of the Awash around the Boyale marsh and along the right bank upstream from Dit Bahri. They are generally very saline (content over 0.65 %) and alkaline with high Na-T ratios.

The soils overlying recent alluvia show little salinity, except for a few local upper horizons with a salt content of up to 0.3 %; for instance north of Asayita.

IX-3 4. Alkalinity

High pH and a high proportion of exchangeable sodium in the exchange complex (high Na/T ratio) are characteristic signs of alkalinity. Middle Valley and Lower Plains soils overlying recent or old alluvium generally show high pH values, which usually increase with depth. Figures are :

(i) Middle Valley ; pH ranging between 7.5 and 9.0 for very nearly 90 % of the samples, with a medium value of about 8.0.

(ii) Lower Plains : pH ranging between 8.0 and 9.5 for about 90 % of the samples, with a medium value of 8.5.

These soils can be considered alkaline, probably due to the sodium bicarbonate in some water in the catchment area. Analysis of the exchange complex shows that Na/T ratios for some (generally saline) soils exceed 15 % ; such a high proportion of sodium has a considerable effect on the physical soil properties, especially in the leaching of saline soils. Some crops are also sensitive to large quantities of sodium. The soil classes have been differentiated in terms of their Na/T ratios, as shown in Table 12.

In the Middle Valley, Na/T ratios are high only for vertisols overlying old alluvial or colluvial material (Aleydegi plain), and for soils with alkaline deposits or volcanic tuff in the Metehara region, expecially around Lake Beseka (hot springs) and in the Fentale, Filweha and Kadabilen piedmont areas.

In the Lower Plains, high Na/T ratios have been observed for the vertisols and hydromorphic soils in the Dit Bahri area along the right bank of the Awash, especially for saline alkali soils over alluvium and colluvium to either side of the river.

The exchange complexes of soils over recent alluvia in the Middle Valley and Lower Plains generally contain smaller quantities of sodium on the surface, but tending to increase with depth.

IX-3 5. Flooding

The extent and duration of flooding at high water have been roughly assessed by aerial observation, by examination of the geographical positions of floods and their high-water marks, and by the interpretation of information collected from nomadic tribespeople.

The main alluvial areas flooded are in the Lower Plains. The land is permanently under water in the Boyale marsh on the left bank and around lakes Gamari and Bario. Flooding is temporary on the alluvial land directly alongside the river and its distributaries, but is more prolonged in the depressions at their downstream ends. Flooding and drainage are thus the two most important limiting factors in the potential development of irrigable land in the Lower Plains.

In the Middle Valley, the extent of temporary flooding will be limited by the Koka dam to a strip of alluvial soil beside the Awash, which is only a minor problem. On the other hand, the hydromorphic soils and vertisols in the Angelele depression and around lake Gedebasa are regularly flooded with certain rivers, (e.g., the Kesem) overflowing into the Awash confluence area when in flood.

Runoff from rough broken land in the hills also causes very temporary submersion of the vertisols in the thalwegs and the alluvial and colluvial soils at the foot of the hills. This is mainly observed in the Metehara region along the right bank, and sometimes in the Melka Sedi region. It may occur, though much less frequently, in alluvial areas downstream from torrents whose catchment areas mainly consist of lithosols over basalt.

IX-3 6. Depth

The depth of a soil is seldom a decisive limiting factor for its irrigability. In the Middle Valley, the depth of soil overlying old alluvium and colluvium is limited by gravel beds and calcareous crusts. Skeletal soils and regosols on volcanic formations are very extensive along faults. Their depth is limited by rock banks or basalt boulders (Metehara plain).

In the Lower Plains, the soils over saline marl or basalt, and those over old stony alluvium (the latter along the Mile plains) are also not very suitable for development because of their shallow depth, salinity or relief features.

IX-3 7. Erosion

Gully erosion is the form most commonly encountered, mainly affecting the old alluvium on the hillsides above the recent alluvial plains both on the right and (especially) the left bank of the Awash (Kesem, Kebena, Bolhamo and Awadi plains). Class II and Class III soils over recent alluvium, which are the most promising for development under irrigation, are subject to local erosion along river and distributary banks. The fine materials washed away are deposited further downstream, as can be observed where the Lower Plains contain numerous flood water channels (Dubti and Dit Bahri areas).

IX-3 8. Slope

Slope is not a very serious limiting factor and, except for soils over old alluvium and colluvium (alluvial cones and the edges of terraces of faulted deposits), seldom occurs as such in the area surveyed for the 1:100,000 scale soils map. Slopes of up to 2 % - 3 % are observed on the torrential tributary cones in the Metehara area and on the edges of old terraces in the Melka Sedi area.

IX-3 9. Microrelief

The microrelief of the vertisols and hydromorphic soils affected by temporary submersion is generally of the "gilgai" or the deeply channeled type. This is observed in the dried-out areas around Melka Sedi and Bolhamo (especially around marsh areas in the Lower Plains) and, to a lesser extent, in depressions which have dried-up but are still marked by pronounced channelling.

IX - 4. Improvement of Irrigable Land

Various additional measures will be necessary to overcome difficulties due to developments of the limiting factors. Project implementation and running costs will thus rise in proportion to the number of limiting factors to be dealt with. Additional costs, however, will not be strictly proportional to the number of factors which are interrelated so closely that the improvement of any one is liable to improve the others; e.g., land-levelling work carried out to suppress microrelief will improve drainability, which in turn reduces salt contamination risks.

IX-4 1. Drainage

Surface drainage is very important for developing land affected by flooding or black soils containing a lot of clay. With saline land, or where there is a salt water table, irrigability depends on drainability.

The disposal of surplus surface water from river floods and rain or irrigation runoff requires a network of shallow drainage ditches. Where flooding is frequent, this system can be associated with cultivation on suitably wide ridge tops between furrows.

The disposal of surplus water in the ground requires a system of comparatively deep drains (at 1 metre depth, for instance), which can be provided for at the irrigation project design stage and put into effect later on, should irrigation subsequently cause a dangerous rise in the ground water level or the formation of a perched aquifer.

IX-4 2. Available moisture

There is no "universal" method for improving the available soil moisture content. The best results are obtained with cropping methods conducive to a fine breaking-down of the soil and an increase in its organic matter content. Irrigation systems for soils containing little available moisture should provide for frequent water applications. This, while not affecting the initial project costs, pushes up the distribution network operating costs quite appreciably.

IX-4 3. Salinity

Though very summary, the leaching tests described in Appendix 5 show that saline soils with a conductivity of less than 16 mmhos/cm at 25°C can be irrigated and farmed, provided salt-resisting plants are grown. The cost of farming the land would be heavy because of the careful land-levelling work required and the need for submersion basis as a means of periodically applying considerable quantities of leaching water; e.g., for cotton, the annual water requirement would be at least one and a half times the amount needed for non-saline land. Depending on the leaching water application and frequency, one might have to contend with a noxious saline ground water rise after a few years. A costly dense drainage network would then be essential.

IX-4 4. Alkalinity and sodicity

Except for fruit trees and legumes in general, most plants are rather tolerant to exchangeable sodium. Alkalinity degrades the physical properties of the soil so much that it is difficult to make use of it. Soil improvers have then to be added to acidify the soil and replace the sodium in the complex by calcium. Gypsum has been found suitable for this purpose where soil salinity is not too high. Otherwise, the application of quantities of sulphur, calcium sulphide and iron proportionate sulphate to sodicity gives satisfactory results. For instance, suitable application rates for exchangeable sodium amounting to 5 - 10 milli-equivalents are :

1 - 3 tons of gypsum to the hectare ;

0.5 - 1 ton of sulphur to the hectare.

Any cultivation methods which result in a better soil structure are to be recommended; e.g., burying green manure and stubble mulching.

IX-4 5. Flooding

All conventional flood control methods are suitable for the Awash basin. Their practical aspects will be considered more fully in the various hydraulic development project designs.

First, there is the control given by large dams (e.g., Koka) over natural flow conditions. The proposed dam at Tendaho should iron out the flood peaks in the Lower Plains of the Awash, and perhaps even eliminate them.

Secondly, systematic dyking of rivers can help to regulate floods. This has been done locally,(e.g., along the Wenji and Chefa plantations), but could be extended to certain sections of the Awash in the Middle Valley. In the Lower Plains, it will be important to control the effects on numerous natural distributaries typical of this part of the Awash, in addition to the regulating effect of any dam at Tendaho.

Third, warping of "bottom land" in depressions would be carried out as a longer-term policy, by controlled diversion of the river water and permeable dykes to slow down the flow and produce the right conditions for sedimentation.

IX-4 6. Depth, slope, erosion

In view of the comparative shortage of water supplies in the Awash Basin, only the best land can be at present set aside for irrigation. Irrigation of shallow, steep or eroded land seems unlikely to become general.

Shallow soils could be deepened locally by subsoiling and slopes reduced by tiered levelling if less than 5 %. Land sloping at more than 5 % is sensitive to erosion, however, and would need recontouring before it could be irrigated. This involves constructing terraces and excavating drainage ditches. They should be secondary measures affecting small areas. It will be necessary systematically to ring irrigated areas with ditches as protection against runoff from the nearby hills.

IX-4 7. Microrelief

Though this is not generally a major obstacle to development, two of its forms - the type featuring deep channels and the "gilgai" type - warrant closer attention. Very substantial quantities of earth will have to be moved to fill up the channels associated with the former type, and further quantities must be added a few years later to complete filling. If possible this earth should not be obtained locally, as this would remove the well-structured highly organic top soil layer and make large tracts of land, at least temporarily, barren.

No major quantities of earth need moving to level the "gilgai" type of microrelief. This type forms as the result of mass movements of the soil during successive wetting and drying out, and it is liable to reappear under irrigation, especially during the substantial preirrigation water applications designed to wet the grounddown to a fairly considerable depth. Experience should show which methods of irrigation most effectively prevent the formation of a gilgai-type microrelief.

IX - 5. Land Irrigability Classes

Soils in the Middle Valley and Lower Plains can be subdivided into six irrigability classes.

Class I - Arable land : None of the land in these areas is up to this standard. Soils along the right bank of the Awash in the Middle Valley (Melka Sedi-Amibara plain) might have been included, but their water-holding capacity is so low that they would require frequent applications of small quantities of water. They represent, however, the best soils in Class II, and have been given the map reference II am.

Class II (Yellow on the map) is arable and moderately good irrigable land. It has a lower productive capacity than land in Class I and is suitable only for a limited number of crops because of certain preparation and irrigation difficulties. It requires moderate levelling, flood protection and drainage. There may be some slight salinity or alkalinity problems. The Class II land in the Middle Valley is better than that in the Lower Plains because it is less alkaline, contains more organic matter, and shows very little salinity.

Class III (Orange on the map) is marginally irrigable arable land with a more restricted cropping suitability than land in Class II. "Limiting factors" for development are the same as for Class II, but they assume a greater importance. A denser drainage system will be required, land levelling will require greater quantities of earth to be moved, and it may be necessary to prevent salinization or alkalinization. Salinity, pH and Na/T ratios of these soils are higher than for Class II, which restricts the range of potentially suitable crops.

Class IV (Brown on the map) is neither arable nor irrigable in its present state, but with suitable treatment under the right conditions, it could be made fit for certain crops or pasture. Even with treatment, however, its productive capacity would remain limited. This land is affected by severe flooding (frequency and duration) with a risk of flood damage. It is poorly drained, very saline and/or alkaline, and has a pronounced microrelief.

Class V (Violet on the map) is non-arable land of indetermined suitability for irrigation. Unless technical and economic studies show a possible use, this land is unlikely to be developed for irrigation at present. This class includes any land that is very saline and/or alkaline, too shallow, gravelly or excessively steep.

Class VI (Red on the map) is neither irrigable nor arable. The class includes soils permanently unfit for use, especially rock, basalt, lava, dunes and excessively saline or alkaline soil.

IX - 6. Areas in Various Classes of Land

IX-6 1. Middle Valley

Excluding the Metehara area, the land mapped in the Middle Valley covers 224,000 hectares, of which 154,000 hectares are in the alluvial and colluvial area, between basalt hills with lithosols and skeletal soils, and very gravelly soils on slopes.

Table 13. Areas and Percentages of Lands in Various Land Classes - Middle Valley, excluding Metehara area

	Total amount of land (hectares)	Amount in alluvial and colluvial area (hectares)	Percentage of total alluvial and colluvial area	Remarks
Class II	52,400	52,400	33.9	Total irrigable land 103,100 hectares, i.e., 66.7 % of total alluvial and colluvial area.
(Class IIam included in above)	(24,700)	(24,700)	(16.0)	
Class III	50,700	50,700	32.8	
Class IV	29,000	29,000	18.7	Occasional salinity and wetness problems in the alluvial area.
Class V	4,300	4,300	2.8	
Class VI	87,600	18,300	11.8	
T O T A L	224,000	154,700	100.0	

Land in Class II denoted II am, covering 24,700 hectares, (i.e., 16 % of the alluvial area along both banks of the Awash), is the best land for irrigation. Its low water-holding capacity is here its only limitation. This is probably due to the nature of the clays in the exchange complex. The land corresponds approximately to the medium to heavy-textured soils overlying recent alluvia, it covers 18,700 hectares in the left-bank Kesem-Kebena areas, and 6,000 hectares in the right-bank Melka Sedi area.

There are also 23,700 hectares of ordinary Class II land. Its potential agricultural development is limited by the following factors :

(i) On the left bank : mainly slight salinity and microrelief problems, or temporary flooding.

(ii) On the right bank : drainage problems due to the presence of fine-textured soils or vertisols, temporary flooding, microrelief, and possibly salinity (near Debu).

Class II land (including IIam) covers an overall area of 52,400 hectares; i.e., 33.9 % of the alluvial and colluvial area along both banks of the Awash. Half is good irrigable land, but lacks adequate available water reserves.

The Class IIam land appears to be potentially the most productive in the entire valley, with reasonably low farming costs. With irrigation methods adapted to the low available water in the soil and suitable crops for the local climate, high yields should be possible.

The range of crops for other land in Class II may be smaller because of the finer textures and/or slight salinity of some soils. Development costs may be higher, because of the need for certain drainage, flood protection measures, and land-levelling work for soils with a pronounced microrelief.

Class II land in the Middle Valley is potentially more productive than in the Lower Plains, because it is less alkaline, contains more organic matter, and is affected by few or non-salinity problems.

Land in Class III accounts for 32.8 % of the alluvial area; i.e., 50,700 hectares. It includes :

(i) Hydromorphic soils and generally deep vertisols at the Kesem-Awash confluence, along the left bank of the Awash, and in the right bank Angelele region north of Melka Sedi. They are usually temporarily submerged when the river is in flood.

(ii) Medium-salinity soils along the foot of the hills overlooking the recent alluvial area, also locally in patches in the Kesem-Kebena plain.

"Limiting factors" for Class III land are the same as for Class II, but more marked : drainage is more difficult (especially in the deep vertisols) the microrelief needs more levelling work, flood protection is more difficult, and stricter salinity control is necessary. East of the track from Awash to Awora Melka, salinity and the shallow depth of the soil make up the limiting factor.

The vertisols of the older alluvial areas along the left bank of the Awash between Awash station and Melka Indesa and in the Aleydegi plain along the right bank are at about 100 m above the river level and suffer from drainage difficulties because of their texture and the alkalinity of their subsoil. Class III land is thus of medium irrigability, and will require crops very well matched to the various soil types.

Class IV land covers 29,000 hectares; i.e., 18.7 % of the alluvial and colluvial area. It mainly consists of moderately shallow or gravelly ravined (and occasionally saline) brown soils or vertisols over old alluvium and colluvium. It is at a higher topographical level than Classes II and III land, and forms a succession of rolling hills and vales, or river cones deeply marked by runoff channels (left bank of the Awash), so that it is difficult to irrigate. Given suitable preparation, it might be used for certain crops or pasture, but its productive capacity would remain limited, except in gently sloping thalwegs with deeper soil layers.

There is also some Class IV land in the alluvial area, but it either lacks adequate drainage and is affected by temporary flooding (Angelele), or is very saline (Dobu and Kada Bilen areas on the right bank, and Awora Melka area on the left bank, where erosion is an additional limiting factor). This land requires special preparation (leaching, drainage, thalweg improvement), which would be not only prohibitively expensive, but also sometimes difficult to put into practice (drainage of low-lying land).

Class V land takes up only 4,300 hectares of the alluvial and colluvial area; i.e., 2.8 %. It is difficult to irrigate because of its salinity and generally shallow depth, or because of coarse or fine gravel. It generally occurs along the edges of saliferous marl areas or saline deposits from the hot springs, especially near the rough broken land (rolling hills) on the right bank side of the Awash.

Class VI land covers 18,300 hectares; i.e., 11.8 % of the alluvial and colluvial area. It consists of :

(i) Very saline soil and regosols on sulphate and carbonate deposits in the Filweha and Kada Bilen areas, also Melka Dawdo and Melka Sedi marl on the right bank side of the Awash.

(ii) Very gravelly soils on medium to steep slopes, which are in a very eroded condition, with basalt bars running across them.

In view of its high salinity, gravel and basalt fragments, this land is not suitable for irrigation.

The mapped area also includes 63,000 hectares of skeletal land and basalt hills; e.g., the Dofan, the Ehaili on the Awash left bank, and basalt outflows from the fault separating the Aleydegi plain from the recent Awash alluvia.

The amount of irrigable land can be put at roughly 103,000 hectares (Classes II and III), making up 66.7 % of the alluvial and colluvial areas which is roughly all the commanded land. The best land in the valley is found along the banks of the Awash. It amounts to 24,700 hectares (included in the above 103,000); i.e., 16 % of the alluvial and colluvial area.

IX-6 1.1 Middle Valley - Metehara area

Land mapped in this area amounted to 38,000 hectares, including 30,700 hectares in the valley bottom filled with alluvium from the Awash and colluvium from the local hills.

Table 14. Areas and Percentages of Lands in Various Land Classes - Metehara area

	Total amount of land (hectares)	Amount in alluvial and colluvial area (hectares)	Percentage of total alluvial and colluvial area	Remarks
Class II	4,200	4,200	13.7	Total irrigable land (Classes II + III) 11,500 hectares, i.e. 37.5 % of alluvial and colluvial area
Class III	7,300	7,300	23.8	
Class IV	11,100	11,100	36.1	
Class V	5,600	5,600	18.3	
Class VI	9,800	2,500	8.1	
T O T A L	38,000	30,700	100.0	

Class II land covers 4,200 hectares, i.e., 13.7 % of the area mainly overlying vertisols on recent alluvia along the Awash, or on alluvial cones along the right bank of the river. Main limitations are associated with drainage on both sides of the river over certain fine-textured vertisols, and also with flood protection along the Awash. This Class II land is potentially more productive than the other land in the Middle Valley downstream Awash station.

Class III land amounts to 7,300 hectares; i.e. 23.8 % of the alluvial and colluvial area. On the right bank side of the Awash, limitations are assocciated with the risk of flooding by runoff, and the existence of basalt gravel beds within the soil. Salinity is medium in the land along the left bank and in a small area on the right bank. Potential use of land on colluvia beside the hills is limited by average problems associated with microrelief and topography.

Class IV land amounts to 11,100 hectares, i.e. 36.1 % of the colluvial and alluvial area. It is generally too shallow or too eroded or too saline and alkaline for economic use. With an average amount of preparation, it could be used for certain crops or for pasture. It mainly extends northwards from the left bank of the Awash and around Lake Beseka, where limiting factors are alkalinity and salinity.

Class V land covers 5,600 hectares; i.e. 18.3 % of the total alluvial and colluvial area. As these are shallow, very alkaline soils (very high Na/T ratio), their development under irrigation would be subject to previous experimentation, especially beside the Awash near the eastern end of the alluvial area.

Class VI land includes skeletal soils, lithosols, the very saline alkali soils around Lake Beseka and the very eroded soils along the edge of the plateau above the recent Awash alluvia. Class VI land amounts to 9,800 hectares, including 7,300 hectares of skeletal soil.

The Metehara area probably contains 11,500 hectares of medium to good quality land; i.e. 30 % of the alluvial and colluvial area, the main limiting factors for the development of this land being drainage and flooding by runoff. The range of suitable crops will depend on drainage possibilities and whether there are any gravel beds or horizons of average salinity in the soil. Classes IV and V land will require special treatment and experimentation before it can be made fit for use. Class VI land is at present unfit for agricultural use, and would be extremely difficult to develop.

IX-6 2. Lower Plains

240,000 hectares of land have been mapped in the Lower Plains (excluding 7,800 hectares taken up by lakes). This includes 171,700 hectares of land of alluvial or colluvial origin. Skeletal soils and basalt formations account for the remainder.

Table 15. Areas and Percentages of Lands in Various Land Classes - Lower Plains

	Total amount of land (excluding lakes) (hectares)	Amount in alluvial and colluvial area (hectares)	Percentage of total alluvial and colluvial area	Remarks
Class II	30,000	30,000	17.5	Total Classes II + III 69,000 hectares of irrigable land, i.e. 40.2 % of total
Class III	39,000	39,000	22.7	
Class IV	33,000	33,000	19.2	
Class V	15,000	15,000	8.7	
Class VI	123,000	54,700	31.9	
T O T A L	240,000	171,700	100.0	

Class II land amounts to 30,000 hectares; i.e., 17.5 % of the alluvial area prospected between Tendaho and lakes Gamari and Bario. Development difficulties for this land are mainly due to minor limiting factors, such as short-duration flooding which generally occurs every year. There is only moderate drainability because of the existence of fine-textured layers with an Na/T ratio of about 15 % (Dit Bahri area). Potential productivity and crop rotation possibilities may be limited by alkalinity (pH generally exceeding 8) and low organic matter content. Class II land in the Lower Plains usually consists of soils on recent alluvia along the Awash or its main distributaries. It occurs in the following areas :

(i) Left bank area : around Dubti, along the river and along the old or recent distributaries discharging into the Boyale marsh. Some slight salinity problems are encountered along former distributaries now dry.

(ii) Right bank area : around Dit Bahri, along the Awash, and going towards the hills, where former beds of the Awash can still be identified on aerial photographs. Alkalinity is often fairly high in the deeper layers of these soils.

(iii) Asayita delta : along the present course of the Awash and the Mamule distributary, where the annual flooding of the land by the river allows crops to be grown. Drainage problems are associated with the topography of the area (depressions with more clayey soil) and the existence of a water table at varying proximity to the surface. This area contains the greatest proportion of Class II land.

Class III land covers 39,000 hectares; i.e., 22.7 % of the considered alluvial and colluvial area. It is slightly more than Class II. It mainly occupies the low-lying areas ("bottom lands") most readily affected by flooding alongside the Awash and in the recently dried-up northern part of the Asayita delta, which contains slightly saline fine to moderately fine-textured soils in the deeper horizons. In the Asayita and Dit Bahri areas, the water table may rise fairly rapidly and increase the salinity of the soil. Class III land occurs less extensively in the Dubti area and is moderately to very saline ; however judging by its texture, its leaching seems possible, if adequate drainage measures are taken to prevent secondary salinization.

Class IV land amounts to 33,000 hectares; i.e., 19.2 % of the alluvial and colluvial area. Most is flooded whenever the Awash is in spates and features numberous channels and depressions. It occurs around the Boyale marsh on the left bank side of the Awash and around Dit Bahri beside the present right bank flood distributary channels. Near Dit Bahri and in the Asayita delta, Class IV land occupies the largest depressions. It needs suitable flood protection, fairly dense drainage systems and levelling work conditioned by the size and density of existing channels.

Its productive capacity is restricted by difficult drainage, due to its frequent proximity to marshland, lakes or fine-textured and alkaline soil (central Dit Bahri depression). It is generally under pasture. Class IV land too saline or eroded for development is observed along the hills near Dit Bahri.

Class V land covers 15,000 hectares; i.e., 8.7 % of the total alluvial and colluvial area. Because of its excessive salinity and/or alkalinity, it would be difficult to develop economically. It occurs along the northern edge of the Boyale marsh and in some depressions of the saline alkali soil area farther north, also along the left bank of the Awash upstream from the Dit Bahri area, and beside the hills.

Class VI land accounts for 123,000 hectares of the overall mapped area. It includes :

(i) 68,000 hectares of lithosols and skeletal soils overlying basalt. These are unfit for use.

(ii) 47,400 hectares of land too saline and alkaline (SA) to consider its large-scale development. This also includes permanent marshland.

(iii) 7,300 hectares of dunes.

The 54,700 hectares of land in (ii) and (iii) make up 31.9 % of the alluvial and colluvial area. Class VI amounts to 51.3 % of the mapped area.

Land in the Lower Plains which could be made irrigable with an average amount of preparatory work (Classes II and III) covers 69,000 hectares; i.e., 40.2 % of the alluvial area. Land unsuitable for irrigation without prior experimentation and substantial preparatory work (Classes IV and V) accounts for 48,000 hectares; i.e., 27.9 % of the alluvial area. In the alluvial and colluvial area land totally unfit for use under present conditions (Class VI SA and O) amounts to 54,700 hectares; i.e., 31.9 %.

IX - 7. Conclusions

Most of the best irrigable land is in the Middle Valley (Class II land), where it covers 56,000 hectares; i.e., 15.9 % of the colluvial and alluvial area. The Lower Plains contain 30,000 hectares of Class II land; i.e., 8.4 %, the physical and chemical properties of which are not quite up to the standard in the Middle Valley.

Class III land, which is slightly more difficult to irrigate because of its drainage, microrelief and salinity features, covers 58,000 hectares (16.2 %) in the Middle Valley, and 39,000 hectares (10.9 %) in the Lower Plains. It can be made irrigable with a fairly large amount of preparation. Areas mapped in the Middle Valley include part of the Aleydegi plain and of the plain north of Awash station.

Classes IV and V land, which is only irrigable under certain conditions (e.g., sufficient soil depth) and for specific crops or pasture selected after appropriate technical and economic investigation, covers 50,000 hectares in the Middle Valley, (14 % of the alluvial and colluvial area) and 48,000 hectares in the Lower Plains, (13.5 %).

Class VI must be excluded from present irrigable land for technical and economical reasons. It amounts to 20,800 hectares in the Middle Valley (5.8 %) and 54,700 hectares (15.3 %) in the Lower Plains.

The total amount of good irrigable Class II land in all the areas prospected and mapped to a scale of 1:100,000 amounts to 86,600 hectares; i.e., about a quarter of the total area investigated. Class III land, of marginal irrigability, accounts for 97,000 hectares, only part of which can be irrigated under gravity.

Land of indeterminate or doubtful irrigability makes up 99,000 hectares; i.e., over a quarter of the considered alluvial and colluvial area.

Land unfit for use (Class VI) amounts to 75,000 hectares. The area mapped also contains 144,900 hectares of skeletal soils and lithosols permanently unfit for development.

Table 16. Distribution of the various land classes in the areas prospected in the Middle Valley and Lower Plains and percentage of the overall alluvial and colluvial area.

	Metehara		Rest of Middle Valley		Lower Plains		Total area	
	ha	%	ha	%	ha	%	ha	%
Class II	4,200	1.2	52,400	14.7	30,000	8.4	86,600	24.3
Class III	7,300	2.0	50,700	14.2	39,000	10.9	97,000	27.1
Class IV	11,100	3.1	29,000	8.1	33,000	9.3	73,100	20.5
Class V	5,600	1.6	4,300	1.2	15,000	4.2	24,900	7.0
Class VI without lithosols and skeletal soils	2,500	0.7	18,300	5.1	54,700	15.3	75,500	21.1
TOTAL ALLUVIAL AND COLLUVIAL AREA	30,700	8.6	154,700	43.3	171,700	48.1	357,100	100.0
Lithosols and skeletal soils	7,300		69,300		68,300		144,900	
TOTAL MAPPED AREA	38,000		224,000		240,000		502,000	

X. MAJOR TRADITIONAL REGIONS 1/

According to the usual Ethiopian Tradition, the Awash Basin is divided by altitude, climate and vegetation, into four fairly different zones.

X - 1. The Dega (Tropical Highland)

The Dega agricultural region of the Awash Basin bounds the gently rolling plains of Adis Abeba - Adis Alem, Adis Abeba - Debre Sina, and the Dese areas with more rolling and steeper terrains. It makes up only 7 % of the total area of the basin. It lies at more than 2,500 metres above sea level. The temperature varies between 10 and 15 degrees centigrade during the day with cold nights. It has two rainy seasons; the short rainy season from April to May and the long rainy season from July to October. The yearly average rainfall varies between 1.200 and 1.500 mm.

The soils range from red or reddish brown clay (some of it stony) with level to gently sloping topography, and from dark to very dark highly clayish soils of rolling plains. Generally the surface soils of the flat area are deeper than those of the sloping terrain of Debre Sina. They are granular in structure. Features of hydromorphy are marked on the flat areas of gley soils. Drainage is a problem in most parts of these areas, but erosion is a severe problem on the slopes. Most soils are usually slightly to strongly acid, fair to high in total nitrogen and organic matter, and relatively high in available nutrients.

The land has a natural vegetation of thornbush shrub, giant thistles (Echinops sp.), trees of Acacia Abyssinica, Hagenia Abyssinica, Pygeum Africanum, Gymnosperia Species, Juniperus Proceda, Podocarpus Gracilior and grasses of Pennisetum and Hyparrhenia Species appearing usually after cultivation. Eucalyptus trees are usually around towns and villages which provide firewood and building material. The biggest eucalyptus forest of Ethiopia is also located in the vicinity of Adis Abeba. Without the eucalyptus forest, firewood and building materials would be serious problems.

The principal crops in this region are barley, wheat, horsebeans, chick peas, flax (for oil seed, but not for fiber crop), teff, and many species of small grains and legumes.

X - 2. The Woina Dega (Tropical to Subtropical Plateau)

The Woina Dega agricultural region of the Awash Basin bounds the Ginchi, Teji, Debre-Zeyt, Chefedonsa, Karakore, and Ardibo-Hayk areas. It accounts for 13 % of the total area of the Basin. It lies between 1,800 and 2,500 metres above sea level. The temperature varies between 15 and 18 degrees centigrades and is more constant with prominent variation between the night and the day. Like the Dega, it has two rainy seasons, the short rainy season from April to May and the long rainy season from July to October. The yearly average rainfall varies between 800 - 1.200 mm.

The soils range from dark grey to nearly black clay on the flat terrain, from reddish brown to grey brown clays and clay loams on the gently rolling to sloping topography, and from brown to dark brown clay (some of it stony) on the gently rolling terrain. Generally, the surface soils are deep to very deep, deeper than the Dega soils with granular structure. The surface soils of the steep slopes are shallow, not more than 10 - 20 cm deep. They have more hydromorphy features on the gley soils

1/ This chapter is contributed by the Counterpart Agronomist Ato Mamo Desta, Graduate of the Alemaya College of Agriculture + Mechanical Arts.

of the flat lands in the Woina Dega than in the Dega.

Erosion is a serious problem where the fluvials from the Dega create breaks, gullies, deep gorges and valleys. This is caused by the nature of the terrain and the high torrential flows during the rainy season. Some areas have drainage problems. They are slightly acid to neutral, medium to high in organic matter and total nitrogen, medium in available phosphorus, and high in available potassium, calcium and magnesium.

The land has a natural vegetation of olives, juniper, podocarpus, acacia, and other indigenous trees of Ethiopia which are found also in the Dega zone. The crops are teff, wheat, noog, chick peas, barley, peas, sorghum, lentils, sunflower and fruits such as lemon, oranges, and wine grapes ("Woina").

X - 3. <u>The Kolla (Hot Lowlands)</u>

The Kolla agricultural region of the Awash Basin bounds the Koka, Wenji Nazret, Sire, Robi, Chefa, Kembolcha and the Asebot areas and represents 22 % of the total area of the Basin. It lies between 1,500 - 1,800 meters above sea level. The temperature varies between 18 to 22 degrees centigrade with very little change between night and day temperatures.

It is necessary to distinguish between the Zones of the humid and the dry Kolla although Ethiopian tradition classifies both areas as Kolla (hot lowlands).

(a) <u>The humid Kolla</u> covers about 4,500 km2 in the Robi - Borkena valleys and the hills of Kembolcha, Bati and upper Mile, which is about 6 % of the total area.

It has two rainy seasons; the short rainy season from April to May and the long rainy season from July to October with an annual rainfall varying from 1.200 - 1.800 mm. The soils of the humid Kola range from dark brown to very dark grey or black clay loams on the rolling to nearly level terrain and in the valleys; from black clay loam to gravelly clay loam on the hills and intervening valleys. Generally, the surface soils are deep in the valleys of Robi - Chefa - Kembolcha areas with granular to prismatic structure, whereas in the Bati area they are shallow with undevelopped structures. Heavy features of hydromorphy are seen in the depressions of the valleys.

The Borkena valley has a serious problem of drainage where the swamps are fed by the Borkena river, other rivers flowing from the Albuko mountains, the hot springs, and runoff water from the surrounding hills. A drainage system which gives on outlet to the stagnant waters would bring a large area under cultivation.

In the mountainous areas of Bati, where the most serious problem is erosion, the mountainous farming is common. The soils are predominantly neutral, some slightly acid, medium in organic matter and total nitrogen, and from fair to high in available nutrients of phosphorus, potassium, calcium and magnesium.

(b) <u>The dry Kolla</u> region of Nazret, Alemtena and Asebot areas covers 16 % of the total area. It has an annual rainfall ranging from 500 - 800 mm. The agricultural land of the dry Kolla are deep black clay to brown sandy clay loam which are neutral to moderately alkaline, medium in organic matter and total nitrogen, medium to high in available nutrients of phosphorus, potassium, calcium and magnesium, with erosion problems on the slopes, and a problem of drainage in the depression or in the low-lying lands. Soils on the vicinities of Mieso and Asebot are grey brown in color, loamy sands, sandy loams or silt loams in texture, generally calcareous in reaction, low in organic matter, low to fair in total nitrogen, high in phosphorus, potassium and calcium, and medium in magnesium, with lack of moisture as a problem.

The agricultural region has a natural vegetation of acacia, bamboo, thornbush shrub, Euphorbia Candelabrum, cactus, grasses of Cyperaceae, Hyparrhenia and Andan grass. The principal crops, widely grown in the agricultural region, are sorghum, corn (maize), teff, wheat, peanuts, castor beans, tobacco and cotton where the rainfall is high enough for growth. Fruits and sugar cane are grown under irrigation.

X - 4. The Bereha (Semi-Arid to Subdesert)

The Behera region bounds the alluvial plains of Metehara, the lower plains of Kesem-Kebena, Melka Sedi, Awadi, Gewani, Dubti, Dit Bahri, Asayita, and the colluvial plains of Aleydegi and Bolhamo. It includes the huge tracts of hilly and rocky lands on both banks of the Awash. The semi-arid to sub-desertic Bereha region covers almost 60 % of the total area of the basin, but is subject to very severe climatic conditions, lying less than 1,500 metres above sea level. Temperatures range from 22 to 40 degrees centigrade and the annual rainfall varies from 150 to 600 mm, with showers of rain mainly from April to August. It has a scattered vegetation of acacia, thornbush shrub, cactus and grasses of gramineae.

No rainfed agriculture could develop, but large tracts of land are propitious for irrigated agriculture in the Metehara, Kesem-Kebena, Melka Sedi, Amibara and Dit Bahri areas. So far, operating agriculture covers no more than 150 - 200 km2 of land. The soils are described in the pedological part of this Report.

The principal crops grown under modern irrigation on the Metehara and Awora Melka plantations are cotton, ground nuts, sugar cane, and fruit such as orange, banana, papaya and mandarine. In the Lower Plains, large scale Dubti and Barga plantations grow cotton only, but they are experimenting with rotational crops. In the Asayita Delta, peasants cultivate, under primitive irrigation conditions, mainly cotton, maize, sorghum and sesame.

XI. PRINCIPAL TYPES OF LAND UTILIZATION

XI - 1. Introduction

Because statistical data on land utilization in the Awash River Basin were not available, photointerpretation was employed in drawing the map of the land use.

Contact prints used for the interpretation were to the scale 1:40,000 for the lower parts of the Awash Basin and 1:50,000 for the upper parts of the catchment area. Findings of the photointerpretation were plotted on the sketch map drawn out of the uncontrolled mosaics reduced to the scale of 1:250,000. The maps were carefully checked during numerous field trips by car and aircraft. The areas with different types of land use were measured with a planimeter. The map itself was reduced to the scale of 1:1,000,000. Table 17 shows the surfaces of the identified categories of the land use.

To make it easily comparable with other maps and descriptions of natural vegetation in Ethiopia, the classification in Table 17 follows, whenever possible, that proposed by Huffnagel in his book on Agriculture in Ethiopia and by Scientific

Council for Africa south of the Sahara. This classification corresponds rather well to the traditional delimitation into big geo-climatic regions which have been previously discussed. In the upper reaches of the Basin, where a better climate promoted agriculture, the settlement has greatly influenced the natural vegetation, even on uncultivated land. Deforestation, overgrazing of mountainous grassland and the resulting heavy erosion indicate the human influence on vegetation.

XI - 2. Cropland

Cropland, cultivated or fallow, accounts for one-fourth of the Basin area, covering nearly 19,000 km2. 1/

XI-2 1. Agricultural land on level or slightly undulating ground

This type of agricultural land covers about 11,700 km2, mainly in the upper reaches of the basin in the geo-climatic regions of Dega, Woina Dega and in the valleys of the Kolla. In general, the soils under farming are black vertisols, associated sometimes with lithosols or hydromorphic soils on the bottom of lowerings. In the regions of dry Kolla they may be brown vertisols.

XI-2 2. Agricultural land on sloping ground

In similar conditions, but on the slopes, often on the steep slopes, farming is made on the terraces. The soils are mainly brown or red brown vertisols, which become slightly lateritic in the Dega.

XI-2 3. Irrigated agricultural land

Irrigated agriculture covers relatively small areas widely scattered along the Awash River and its tributaries. It is developed on the alluvial soils, and grey vertisols, hydromorphic in the Upper Basin (Wenji).

XI - 3. Land with Natural Vegetation 2/

XI-3 1. Short grass Savanna

Pasture lands - fair to good - are estimated at about 4,000 km2. They are mainly associated with alluvial and/or colluvial soils. Sometimes good grass stand grows on sub-arid brown soils. They are on the flood plains (Middle Valley, Maro Gala, Dit Bahri) or gently undulating grounds of the higher terraces (Aleydegi plain). Burning of grasses before the rainy season is a common practice on the pasture lands. Lack of water is the most serious impediment to their rational exploitation.

XI-3 2. Woodland and bush

(a) Dense Forest covers only about 1,000 km2 in the Awash Basin. It is found in the highlands, where it is represented merely by the remnants of the original forest cover, preserved sometimes on steep slopes and in the ravines. Isolated blocks of no more than a few hundred hectares are distributed in the mountainous regions of the catchment area, mainly along the line of the watershed. (Mount Menegasha near Adis Abeba and Mount Membret near Ankober).

1/ Agriculture crops, farming practices and methods are discussed in Chapter XII.

2/ Identification of trees and shrubs has been kindly given by the Haile Selassie I University Forest Institute.

Table 17. Land use in the Awash Valley

	Area (km2)			Percentage of the total area		
CROPLAND	18,850			26.9		
Agricultural land on level or slightly undulating ground		11,700	11,700		16.7	16.7
Agricultural land on sloping ground ..		6,850	6,850		9.8	9.8
Irrigated agricultural land		300	300		0.4	0.4
LAND WITH NATURAL VEGETATION	43,250			61.8		
Short grass savanna		3,900	3,900		5.6	5.6
Woodland and bush		18,700			26.7	
Dense forest (montane and riparian)			1,000			1.4
Woodland and savanna			8,300			11.9
Open woodland and bush			4,750			6.8
Shrub savanna			4,650			6.6
Tree and shrub steppe and subdesert steppe		19,900			28.4	
Tree and shrub steppe			6,150			8.8
Tree and shrub steppe with occasional trees			1,650			2.3
Subdesert steppe			12,100			17.3
Marshes		750	750		1.1	1.1
WASTE LAND	7,500			10.7		
Desert		3,000	3,000		4.3	4.3
Sand dunes		100	100		0.1	0.1
Badlands		4,400	4,400		6.3	6.3
LAKES	400	400	400	0.6	0.6	0.6
	70,000 km 2			100 %		

Depending on the microclimate, they belong either to the Podocarpus or to the Juniperus association.

There is no systematic exploitation of these forests. When not protected as National Parks, they yield only building material and fire wood for farmers.

On both sides of middle and lower reaches of the Awash river and up along some of its tributaries, the forest is merely riparian. It is associated with rich soils of recent alluvium. Its largest block stretches north of the Gewani swamps in a narrow gallery 1 to 5 km wide and more than hundred kilometres long. Large tracts of this gallery forest are frequently flooded and the ground beneath remains swampy most of the year. It forms an impenetrable thicket with dense undergrowth interlaced with climbers. Big species of trees are Ficus sp., Tamarix africana, Cadaba farinosa, Pistacia lentiscus, Pittosporum abyssinicum. Lower storey consists of Schrebera alata, Rhus vulgaris, Jasminum abyssinicum. Tall acacia trees grow on the higher grounds on the outskirts of the forest gallery.

Another type of riparian forest may be identified on the marshy lands in the Lower Plains and in the Delta area, as well as on the confluence of two great tributaries, Kesem and Kebena. This type of forest may be associated with hydromorphic soils frequently flooded. Tall acacia trees form an almost continuous canopy and shrub are rare. Palm trees Phoenix and Hyphanae sp. occur in bunches along river channels. In the lowest storey under the acacias, grasses are dense and grow well in the shade, providing fair pastures. Tamaris trees also grow on the river banks and sometimes form closed stands; e.g., at the confluences of Arsu and Mile, or in the lower reaches downstream of Tendaho.

The economic value of the riparian forest seems very limited. Exploitation for timber or fire wood is nearly non-existent. Nomadic pastoralists graze their cattle whenever some grass is available during the dry season and the shaded pastures of the high acacia forest are heavily overgrazed. Pastoralists obtain supplementary fodder, mainly for camels and goats, by breaking branches. The animals eat leaves and twigs, but mostly the trees die. Many patches of several hectares of dead forest are found along the river.

(b) Woodland and savanna may be either a rather dense stand of trees and shrubs with savanna grasses on the lower storey, or a more open savanna with sparsely growing trees and shrubs. They cover the greater part (more than 8,000 km2) of the lands in the middle and lower reaches of the Basin and grow mainly on the alluvial and colluvial sub-arid brown soils, in the north-western slopes of the Chercher range and on the hills in the upper eastern reaches of the Basin (humid Kolla).

Acacia species like A. tortilis, A. senegal, A. seyal, A. pennata, A. Eggelingii prevail in the open woodlands together with Mimusops Kummel, Rersama abyssinica, Ritchiea steudtneri, Vernonia amygdalia and tall bush like Myrsine africana and Jasminium abyssinicum, north of the railway line. Smaller shrubs as Capparis tomentosa, Sida schimperiana and Abutilon mauritania are frequent.

In the lower storey grasses are relatively dense - often savanna-like - and provide fair grazing land to nomadic cattle, camels and small livestock. Where trees and bush are sparser, a fine savanna is developing, good grasses are abundant and potential pastures are good to very good.

Whereas tree species other than acacia are rare in the drier areas, there is more diversity where the rainfall is higher along the rivers like Awash, Arba Dima and Geleta. Thus, Olea chrysophylla, Catha edulis, Ficus spec., Millettia ferruginea, Dicrostachys cinera, Premna viburnoides, Terminalia sp., Lachnoyphylis congesta, Erythrina abyssinica and Euphorbia sp., are frequent. These tracts of vegetation are often dense and closed, and shrubs like Euddleja polystachya, Grewia ferruginea, Osyris abyssinica, Jasminum abyssinicum form the lower storey. Climbers like Mikaniopsis clematoides, Cissus sp., Combretum paniculatum, Stephania abyssinica may also be found. The density of the upper storey vegetation does not facilitate the pastoral use of the thicker woodlands, although good grasses occur in the glades. The main resource of these woodlands is the exploitation of charcoal. Shepherds and even farmers follow the woodmen.

To the south-east of the lake Gelilea, where the Rift valley forms the plateau of lakes, the open woodland forest and tall bush grow on the brown vertisols evolving from volcanic ashes and pumices. Here the exploitation for charcoal is even more intensive, owing to the good transport facilities and the ready market in the capital. Farmers take advantage of clearings and the continuous thinning of the woody vegetation and farming lands are spreading.

Although the timber and wood resources of the open forest have little value, intensive exploitation contributes to the overall deforestation of the country. In view of the growing erosion hazards in these area and silting of the rivers and reservoirs, legislation on woodcutting appears advisable.

(c) Open woodland and bush : On lower altitudes and with lighter rainfall, whereas trees and bushes grow sparsely, grass cover becomes thinner. Taller trees belong mostly to the Acacia Species and Balanites aegyptiaca, but shrubs like Capparis tomentosa, Maerna rotundifolia, Maytenus senegalensis, Abutilon mauritania, Dichrostachys glomerata are still numerous. This type of vegetation often grows on the rough broken lands on the foothills of Chercher and on the slopes of the mount Asebot, which are classified as skeletal soils. Almost 5,000 km2 may be classified under this category.

On more evolved soils occur fine grass stand forming patches of fair pastures. These and scarce perennial as well as annual grasses forming herbaceous cover in the open woodland and bush provide grazing lands of higher carrying capacity than some tracts of savanna. This is due to the relatively easier supply of drinking water in the rivers running across the area. Livestock in the open bush of the foothills appears to be less strictly nomadic, but roaming along the rivers.

A supplementary resource of the open bush may be Senseveria. It occurs at places in thick growth and may be harvested and processed for industrial purposes (textile industry).

(d) Shrub savanna : Depending on altitude and rainfall, woodlands give way to a bush-type of vegetation (mainly on the eastern slopes of the Central High Plateau) on more than 4,500 km2. It is associated mostly with the semi-arid brown soils. Trees and shrubs like Terminalia sp., Delonix elata, Erythrina abyssinica, Abutilon mauritania, Sida schimperiana, Calotropis procera are often found. Perennial grasses, although often growing in sods, on the erosion built tussocks, present fine stands. They do not grow as tall as in the grass savanna, but the association of lower storey grasses, trees and bushes is still characteristic. Annual grasses would grow into a continuous cover after the rains.

Numerous rivers running across this land supply relatively abundant water for some 4 to 6 months a year. It is, therefore, the normal terrain for the migration of nomadic livestock, chiefly camels and goats ; but only small herds of cattle and sheep have been seen.

XI-3 3. Tree and shrub steppe and subdesert steppe

(a) Tree and shrub steppe. On more than 6,000 km2 of land, a vegetation cover classified as tree and shrub steppe is located mainly in the northern-eastern reaches of the Bereha region. Like the previous type, this steppe has an open vegetation of shrubs and trees, but more widely spaced. The lower storey consists of perennial and annual grasses growing discontinously and in between occur patches of uncovered ground. Where brown sub-arid soils are deeper, the ligneous vegetation occurs in arid climatic conditions and provides scanty protective shade to the perennial grasses. Diferent species of dwarf acacia, Caesalpinia sp., Lawsonia inermis, Commiphora sp., Sideroxylon sp., Euclea schimperi could be identified. Herbaceous cover consists of perennial grasses growing in sods and forming tussocks built by the wind action. Annual grasses grow after rains but, except in small patches around trees and shrubs, disappear quickly.

These appear to be grazing lands not only for nomadic camel herds but also for nomadic cattle, sheep and goats which move in after the rains. It is not clear for how long the tree and shrub steppe provides grazing for nomadic livestock. Quite large tracts of the steppe seem to be undergrazed. As they are relatively far from the permanent watering points, scarcity of water supply is the limiting factor in using this land. Small ponds and tanks are scattered in the steppe, but, owing to the extensive evaporation, cannot provide drinking water for more than a few weeks after the rain.

(b) Tree and shrub steppe with occasional trees. With shallower and more rocky soils, trees and shrubs become scarcer and grass cover thinner, although similar types of vegetation may be found. Pastoral utilization of this kind of steppe is reduced to rather occasional grazing after heavy rains. The largest tract about 1,650 km2 of poor tree and shrub steppe is in the Bereha (lower reaches of Ledi and Mile river).

(c) Subdesert steppe. Subdesert steppe covers in the central and northern part of the Basin huge tracts of lithosols and skeletal soils as well as brown sub-arid heavily eroded soils. Its area is estimated at about 12,000 km2. Perennial grasses are sparsely distributed in sods; wind erosion forms tussocks with grass on the top. A few shrubs and occasionally dwarf acacia treesgrow mostly on the rocky outcrops. In the hollows where rain water accumulates and which may be flooded for several days, the grasses are more vigorous.

Although some valuable grasses may be found in the subdesert steppe, its utilization for grazing is limited by the lack of watering places : water holes, mainly in the beds of torrents are scarce. Nomadic herds, mostly camels, graze on the subdesert steppe probably no more than a few weeks a year. The present economic value of this land is very limited.

XI-3 4. Marshes

Marshes and swamps account for 750 km2 of the area and are located near rivers and lakes (Gedebasa, Gamari, Bario) as well as at the mouth of small torrents and rivulets flowing into closed basins. Although the marshy areas represent only 1 %

of the Basin, nearly half the total cattle population of the Awash lowlands live on, or near, the marshes.

Cattle graze merely on the outskirts and on shallows and follow the receding water during the dry season; but big tracts of the marshes cannot be grazed, even at the peak of the dry season, because the ground is too soft and covered with a too deep layer of water. The typical vegetation of the more or less permanently inundated marshy areas are species of Phragmites, Typha, Vetiveria, Cyperus and Junous, but on the outskirts of the swamps there is a number of good and palatable grasses. They provide abundant pastures and carry a dense population of cattle, which seems to be sedentary or almost sedentary. It appears to be nomadic in a rather restricted area. Pastoralists burn old grasses before the water level in the marshes is expected to rise.

XI - 4. Waste Land

Waste land, both desert and very rough broken lands with almost no vegetation, covers more than 10 % of the total surveyed area.

XI-4 1. Desert and sand dunes

Desert lands and dunes are in the northern parts of the Basin, mostly on saline soils. Flat tracts of saline alluvial and colluvial soils partly alkaline and often covered with fine gravel alternate with broken basaltic hills and recent lava flows. Very scanty vegetation grows only in the beds of torrents, in ravines or on sand dunes. It consists of thorn bush and dwarf acacia trees and a few species of perennial grasses. Immediately after occasional heavy rains, these lands bear ephemeral vegetation which disappears within a few days. Nomads occasionally graze herds of camels on thorny bushes in the ravines. About 3,000 km2 are classified in this category.

XI-4 2. Badlands

Very broken and severely eroded tracts of saline regosols developed a typical landscape of badlands on about 4,500 km2. Only occasional thorn bush or acacia trees and no herbaceous vegetation are found. This category of land provides almost no grazing for livestock or wild animals. It may be assimilated to desert.

XI - 5. Lakes

Several artificial and natural lakes are located in the Awash catchment area and cover about 400 km2 ; in the highlands, reservoirs of Abe Samuel and Koka dams, lakes Hayk and Ardibo (without surface outlets); in the Middle Valley, lakes Beseka, Lyadu, Hertale and Gedebasa; in the Lower Plains, lakes Gamari, Afembo, Bario and Abe, where terminal flow of Awash evaporates. Development of fishing in the lakes might produce an appreciable quantity of fish for local consumption as well as for commerce.

XII. GENERAL OUTLINE OF PRESENT AGRICULTURE *

XII - 1. Chief Agricultural Crops

The chief agricultural crops of the Awash Basin are grain crops, oil seeds, sugar cane, cotton and fruits. They are distributed according to their adaptability and the density of the population. The bulk of the agricultural land of the Dega, Woina Dega and Humid Kolla regions of Awash Basin, where the thickly populated towns are located, produce grain crops and oil seeds. In the lower regions of dry Kolla and Bereha, which are thinly populated because of malaria and water problems, sugar cane, cotton and fruits are grown under irrigation.

XII-1 1. Grain crops

The chief grain crops in the Awash basin are teff, barley, wheat, maize (corn) and sorghum.

(a) Teff (Eragrostis Abyssinica) is an annual grass of gramineae family; as the staple food for the people, is the most important grain crop. It is best adapted and grows well at altitudes from 1,700 to 2,800 metres, which covers the Woina Dega and the lower reaches of the Dega, on red or black clays and loamy soils with good permeability. Brown or red teff is better adapted to higher altitudes, while white teff which is more exigent and more appreciated by the consumers does well only on the medium altitudes.

It is sown from July to August and harvested from October to November, ripening in about three and half or four months. Sowing is broadcast by hand after the seedbed is prepared thoroughly by ploughing three or four times, harrowing, levelling and digging the shallow trenches for drainage.

Teff has a good nutritional value with 8 % protein and 99 % flour content. It is widely grown in the Debre Zeyt, Teji, Karakore and Dese area. Debre Zeyt is the highest producer per hectare with the best quality. Usually the yields per hectare in this area are more than 10 quintals. In the upper Borkena valley with good soils, climatic conditions and managements, yields of over 20 quintals per hectare have been reported in the Chefa plantation. Teff straw is used by the farmer, both as a fodder and in preparing wall-plastering material, which is made up of mud mixed with chipped straw of teff to bind together the soil particles.

(b) Barley is an important grain crop grown at altitudes above 1,900 metres, Dega and Upper Woina Dega region, on well-drained reddish-brown to black clayey and loamy soils. It is sown between the middle of July and the middle of August during the main rainy season and harvested in November and December. The early maturing barley which ripens in 87 days is grown at altitudes above 2,100 and up to 3,000 metres. It is sown at the beginning of the small rainy season, sometimes with supplementary irrigation, and harvested before the start of the long rainy season. In Awash Basin, barley comes next to teff as the most important grain crop used to make the local beverage "tala" and bread, as well as for the industrial production of beer. The straw is used as a fodder, roofing material and for preparing wall-plastering material.

The Debre Sina area is well known for the production of barley with yield ranging between 10 and 15 quintals per hectare.

---

* This Chapter is contributed by the Counter part Agronomist Ato Mamo Desta, Graduate of the Alemaya College of Agriculture + Mechanical Arts.

(c) Wheat is grown at altitudes between 1,500 and 2,500 metres on different types of soils ranging from reddish-brown to black clay and loamy soils. It is generally sown in July and August, and harvested in November and December. In the Teji area on the Awash flood plain, it is sometimes sown after the long rainy season when the fields are well-drained.

A suitable altitude and climate makes the Debre Zeyt area a big producer of wheat. The yield ranges between 11 and 13 quintals per hectare. It is used for making macaroni, spaghetti, biscuits and wheat flour. Most industries engaged in processing wheat flour and its products are located inside the perimeter of the Awash Basin. The straw is used as a fodder as well as a building material, like teff and barley.

(d) Maize (corn) is grown in the Awash Basin as a rainfed or irrigated crop at lower altitudes, well below 2,100 metres. As a rainfed crop, it is sown during the small rainy season from March to May, harvested in October and November after 5 to 7 months of growing period. Under irrigation it is sown almost exclusively in the Asayita delta in October after the flooding has receded, and harvested in March. It is grown on a large scale in the Borkena valley, Nazret plain and Asayita delta, as well as on the smaller scale on the rolling terrains of Bofa, Bati, Dese and upper Mile. The yield ranges from 8 - 9 quintals per hectare. It is used for local beverages and consumed cooked or roasted. Stalk are used as fodder, fuel and building material.

(e) Sorghum is grown very widely as a rainfed or irrigated crop throughout the agricultural regions of the Woina Dega, Kolla and Bereha up to the altitudes of 2,500 metres. The best sorghum producing area is found around 1,800 metres of altitude. It is well adapted to deep heavy clayey soils with loose structure. It is sown in March and May and harvested in November and December, in 7 - 8 months of growing period when it is grown as a rainfed crop. In the Asayita delta, where it is an irrigated crop, it is sown in October after the floods have receded, and harvested in March and April. The Robi - Chefa - Kembolcha area, the rolling lands of Bati, upper Mile, Welenchiti, Asebot-Mieso, and the Asayita delta are well known for producing sorghum. The yield is usually between 8 - 10 quintals per hectare. It is an important food crop. Stalk is used as fodder, fuel and building material.

XII-1 2. Oil seeds and pulses

The most important oil seeds grown in the Awash Basin are noog, linseed, sesame, ground nuts and castorbeans.

(a) Noog - Niger (Quizotia Abyssinica Can.) is an important oil crop grown at altitudes from 1,800 - 2,500 metres, generally on poor wet soils. It is sown in July and August and harvested in October and November. The average yield is very low, ranging from 4 - 5 quintals per hectare. It has an oil content of more than 40 %, when properly pressed. It is grown in the Debre Zeyt, Teji and Sire areas of the Awash basin.

(b) Linseed (Linum Usitatissimum) is grown at higher altitudes of the Dega region as an oil crop, but not as a fiber crop. It is grown on a smaller scale in the Debre Sina area with very low yields per hectare. It is mostly used for therapeutical purposes, linseed oil meal or cake.

(c) Sesame (Sesamum Indicum L.), an oil crop, is also grown on a small scale in the Awash basin with irrigation water, expecially in the Bereha agricultural region (Asayita delta) at altitudes of about 350 metres. It is also planted in small areas in the region of Rasa Mountain at an altitude of 1,200 - 1,500 m.

(d) Other crops. Ground nuts (peanuts) and castorbeans are grown under irrigation in the Middle Valley on Awora Melka and Metehara plantations, but also as a rainfed crop at altitudes between 1,300 - 2,000 m.

Pulses such as broadbeans, horsebeans (Vicia Fabe), chickpeas, peas, lentils and guaya are widely grown in the Awash Basin in rotation with grain crops and oil seeds. They are usually sown at the end of the rainy season and harvested at the beginning or at the end of February. They are well-adapted to altitudes above 1,800 metres. In Debre Zeyt, Chefedonsa, Debre Sina and Dese areas, pulses are grown very widely with yields between 8 and 15 quintals per hectare. They are used as food, fresh, cooked, roasted or made into sauce.

XII-1 3. Industrial and other crops

(a) Tobacco (is cultivated in the Robi valley at altitudes between 1,100 and 2,000 metres with an annual rainfall of 500 - 800 mm. The plantations are supervised by the Imperial Ethiopian Government Tobacco Monopoly, which operates drying and curing plant at the place.

(b) Ensete - Edule, a banana-like plant, is grown in the foothills of Gurage at altitudes ranging from 1,800 - 2,450 m, on almost all types of fertile soils. Planting or reproduction is done by suckers which takes place after the long rainy season or after harvesting. It takes three to nine years to be ready for harvest, depending on the soil and climate. It is best adapted and grows faster in warmer than in colder regions. It is widely grown in the Tefki - Teji area of the Awash Basin. The starchy pulp of stems are used for making a sort of bread and plays a role in supplying food for thousands of Ethiopians. The fiber, extracted from the leaves for rope-making, is sold on local markets as a by-product. Usually a small plantation of 300 - 500 plants is sufficient for a family's annual consumption.

(c) Sugar cane is grown at an altitude of about 1,500 metres on the deep black clay soils of Wenji with irrigation from the Awash river. Cuttings are planted in rows and harvested after a growing period of about 20 to 24 months from November to June. Wenji and Shoa sugar cane plantations with about 6,000 hectares of land are the only plantations which supply the country's sugar demand. The yields are reported to be very high, reaching the mark 200 tons of cane per hectare, whereas the average yields of sugar are estimated at 15 tons per hectare. On a large-scale sugar cane plantation at Metehara, cane used to be grown for the processing of alcohol.

Sugar cane is also cultivated by many peasants, mainly in Debre Zeyt and Chefa areas. It is grown as a horticultural crop on small plots near the farm yard and irrigated from small water courses. It is sold on nearby markets as well as in Adis Abeba and consumed as a chewing cane.

(d) Cotton as a rainfed crop, is grown in most parts of the Awash Basin between 1,000 - 1,400 metres, where the annual rainfall is about 600 to 800 mm. In the areas below 1,000 metres it can be only grown under irrigation. Although an annual crop, rainfed cotton is cultivated as a perennial shrub for periods of 3 to 10 years. It is planted towards the end of the long rainy season rather than at its beginning. This is because planting after the first shower would increase germination, growth of enormous weeds during the big rains, and the risk of a wet-weather fungus disease. Cotton stainers, the Capsid Helopettis and boll worms are important pests which attack cotton plants. Late planting brings late maturity, which gives a low production after 16 to 18 months of planting. Rainfed cotton is grown in the Bofs, Robi and Bati valleys on a rather small scale for use by the cottage craft industry. Production for rainfed cotton is as low as 80 - 100 kg of lint per hectare.

Cotton under irrigation is cultivated on big scale plantations (Awora Melka and Dubti) as well as by the peasants in the Lower Plains. Yields on the commercial type plantations are 10 - 20 quintals per hectare, while 2 - 3 quintals per hectare are cropped by the peasants.

(e) Fruit. Tropical and subtropical fruits are grown below 2,200 metres of altitude, mostly under irrigation. Fruits in the Awash Basin include bananas, papayas, grapes, peaches, strawberries and a large variety of citrus fruits like oranges, lemons, limes, tangerines and grape fruit. A specific variety of date-palm giving a rather poor quality dates is grown in the Asayita delta.

Some of Ethiopia's most important commercial fruit plantations (Debre Zeyt, Tibila, Awora Melka, Karakore, Wichale and Bati) are inside the perimeter of the Awash Basin, which shows that there is a great potentiality for fruit growing.

The yields on Awora Melka fruit plantation for some of the fruits are reported to be :

Bananas : 100 - 120 quintals/ha (for the first 1 1/2 - 2 years) and over 120 - 250 quintals/ha (after 2 years),

Papayas : 200 -250 quintals/ha,

Citrus : 250 up to 550 quintals/ha (after 6 years).

(f) Spices. Above an altitude of 1,500 metres, spices such as Nech Azmud (Corum Capticum), Tikur Azmud (Negella Sativa), fenu-greek (Trigonella Foenumgraecum L.), red pepper (varieties of Capsicum) and onions are grown widely in the different agricultural regions of the Awash Basin, mostly for local consumption. Their economic incidence is too limited for detailed discussion.

(g) Coffee and Khat (Catha Edulis Forst) are grown on very small and unimportant scales with irrigation water in the Arbibo-Hayk region.

XII - 2. Methods of Cultivation

XII-2 1. Cultivation

Tillage is usually done with the plough drawn by two bullocks or with the pick-axe by hand digging. Hand digging is practiced where the land is too steep for animal drawn ploughs and when farmers on small holdings cannot afford to buy a pair of bullocks. Another reason for not using ploughs, especially in the Asayita delta, is the difficulty of buying bullocks from the cattlemen. Even if they buy, another cattleman claims the bullocks as his own, since there are no cattle brands to differentiate between groups of cattle.

2 A
Hand digging replaces deep ploughing in the upper reaches of the Awash Valley

2 B
Hand digging is practiced after a long fallow

The plough drawn by bullocks is simply constructed. It is a bent wooden plough beam with a metal plough-point, attached to its lower end, which ploughs from 5 to 15 cm. Since it is a breaking plough, which does not turn the soil, ploughing is done (criss-cross) 3 to 5 times, according to the crop to be grown. First ploughing is done in the dry season, which facilitates soil aeration and good water absorption during the rainy seasons. During the small rainy season, the second ploughing kills the weeds that started to grow, and is followed by sowing of sorghum or corn. The third ploughing is done to cover the sown seeds, or for seeding other crops when the long rainy season begins.

Seeding is broadcast by hand. The seeds are covered by shallow ploughing, which is a sort of harrowing. In some parts, cultivation (particularly for corn and sorghum) is done by another ploughing or hand hoeing, for thinning and weeding. When careful preparation is needed, deep ploughing is also done by a hoe-like tool which has a handle with two points at the end, a pair of conical-shaped sleeves attached to the points. This is mostly used to break virgin soils and is followed by ordinary ploughing, especially for ensete and eucalyptus planting.

XII-2 2. Harvesting and threshing

The sickle is used for cutting or mowing crops. Threshing is done by a team of oxen which tramples the outspread sheaves until the straw and the grains are separated, on an open air threshing floor which is mud-plastered and smoothed so as not to lose grain through soil cracks. Sorghum-like crops are usually threshed by beating the heap with clubs, as a team operation performed by 5 or 10 men. Winnowing is by hand with wooden forks and shovels. The threshed grain is thrown in the air against the wind, which separates the chaff from the grain. With teff, whose seeds are very small, the separation is done by operating a circular fan over the heap to remove the chaff from the grain.

XII-2 3. Storage

Grain is stored in wickerwork bins which are mud-plastered and supported off the ground by poles, or placed on a stone floor. Earthen jars are especially used for the storage of small grains like teff and noog. Wickerwork bins and earthen jars are usually used by the Dega, Woina Dega, and humid Kolla farmers, while ground silos are used by dry Kolla farmers. In the Bereha region (Asayita delta) goat or sheep skin sacks are used for storing small grains, sacks made of palm leaves for cotton. Loss from rodents and insects may be about 20 % of the amount stored. To cut down the losses, the Ethiopian Grain Corporation has built grain elevators. Two, of the three newly constructed elevators, are in the Awash Basin.

XII - 3. Cultural Practices

XII-3 1. Irrigation

In the Awash Basin, irrigation is practiced on large-scale plantations for sugar cane, cotton and fruit production. On a smaller scale, irrigation is used in the highlands wherever water can be diverted from creeks and rivulets without heavy equipment. In the Upper Basin, irrigation is practiced for producing small grains and truck crops, especially in the dry season, to supplement the demand for the crops. Adis Abeba is supplied with vegetables grown under supplementary irrigation on many small farms in its surroundings. The Wenji sugar and the Dubti cotton plantations pump water from the Awash and use the furrow irrigation system with the more advanced irrigation and drainage networks. Other commercial type farms divert water from the Awash or its tributaries Akaki, Geleta, Kesem, Kebena, Robi, Borkena and Mile.

Irrigation projects like Likurgo and Tibila are developing in the Middle Valley. These farms have less facilities and technical know-how for running their irrigation schemes efficiently than the Wenji, Metehara, Awora Melka and Dubti plantations. 1/ In the Lower Plains, where the Awash river forms a delta, agriculture cannot depend on the scanty and erratic rainfall. Artificial waterings are essential. The waterings now given in the Asayita delta can hardly be called irrigation; the land is merely subjected to natural flooding during the rainy season when the flow of the Awash is high.

The supply canals from the Awash river to the regions to be flooded, and the distributary canals, are prepared during the season when the Awash is low. When the river level is high, the fields are flooded until sufficient water has been applied; the supply canal should then be closed, but this is very difficult while the level in the Awash remains high.

After the water has receded, the land is prepared by hand for the cultivation of cotton or other crops such as maize or sesame. If the levels in the river make it possible, a second flooding is given after planting, in a similar way to the first. Hardly any attempt is yet made to apply controlled systematic watering.

Since the construction of the Koka dam, floods are less frequent. As a result, the cultivated area is shrinking, although a more abundant permanent flow is now available. Farmers do not know how to take advantage of the present permanent flow for artificial watering. Probably between 10,000 - 15,000 ha yearly were flooded and cultivated at the risk of floods. At present this area is considerably diminished. After the floods, there is an enormous growth of weeds which the farmer do not control. Uncontrolled waterings and primitive agricultural practices account for the low production in this region.

XII-3 2. Terracing

Terracing is practiced on the steep slopes of Kembolcha, Bati, Ankober, Debre Sina areas and on the slopes of the canyons of Kesem and Kebena. Benchlike terraces are established by building stone walls on the lower side of the fields. The empty spaces behind the walls are filled by flattening the area towards the walls, or left as they are and subsequently filled and flattened by the natural movement of the soil caused by the torrential rains. In some places, irrigation and terracing are practiced side by side. The defect of the terracing system is the lack of good drainage. Channels running downwards across the slope often become big gullies after one or two torrential rains. Otherwise, the bench terraces are highly efficient without erosion. They allowed thousands of hectares to be cultivated throughout the Awash Basin.

XII-3 3. Soil burning - Denshering

Soil burning is popular with the Dega farmers of Adis Abeba - Debre Sina areas, and increases the crop production. In this process, the land is shallow ploughed, several times about 5 cm deep. The loosened soil with its grass tops and

1/ Appendix 6 gives some experimental data obtained in the Metehara irrigated plantation, by the Israeli experts working on the behalf of the owners, in 1961.

roots is piled into numerous heaps of about one metre in diameter and approximately 3 by 3 metres apart. The piles are set afire by introducing a small amount of lighted dung. The soil is treated then until the organic residues in the piles are completely burned. It is spread evenly over the field and ploughed under up to 15 cm deep. It is not recommended where fertilizers are not available or green manuring is not practiced to supplement the total nitrogen and the organic matter lost in the process, even though it increases the availability of the mineral nutrients.

XII-3 4. Rotations

Crop rotations are practiced by the farmers of the Awash Basin and different rotation systems used according to regional conditions. In the Woina Dega and Dega regions the rotation system provides for one year of leguminous crops like chick-peas, lentils, peas, horsebeans, three to five years of teff or other close-growing cereals. Most frequently 1 - 3 years of fallow, precede one or two years of close-growing crops like barley and wheat. They are followed by leguminous crops. In the Kolla region, where maize and sorghum are grown, the rotation may consist of one year of leguminous crops, one or three years of teff (close-growing crop), two or three years of corn (maize) or sorghum, and then two or more years of fallow.

XII - 4. Cooperatives in Ethiopia

Properly organized farm cooperatives do not exist in the Awash Basin or anywhere in Ethiopia, except for the first and the only marketing cooperative of Alemaya (Harar) farmers organized by the College of Agriculture of the Haile Selassie I University; but the mutual aid associations which exist in Ethiopia, however, may be assimilated to the cooperatives. They are known as Jigi, Ras Simosh, Wonphel, Eder and Ekub.

Jigi, Ras Simosh and Wonphel are different types of manual aid association through which farmers cooperate in ploughing, weeding, threshing, marketing, transporting and house building. Jigi is a voluntary and informal mutual aid association through which a farmer invites his fellow farmers to help him in various farm operations. Ras Simosh differs from Jigi in that, on the request of a hard up farmer, villagers are summoned to cooperate by the village chief. Wonphel is a formal cooperative association through which only members participate and collaborate. Eder and Ekub are mutual aid associations for financial assistance, enabling farmers to buy bullocks, pay land taxes and meet funeral or marriage expenses.

Ethiopians do not hesitate to ask for help from their fellow farmers, unless there is a serious quarrel or enmity between them. Their traditional and cooperative-like aid associations in ploughing enable arrangements to be made for the convenience of all.

After Sunday services at the church-yard meetings, requests are made by some farmers for a cooperative work. Days are allocated for each request. Usually, ploughing or threshing will not take place on holidays, Sundays or market days. These associations or cooperations are usually more common in the Christian than in the Moslem society.

Each farmer brings a team of oxen with plough to the farm where the ploughing operation takes place. On this day, the farmer whose land is being ploughed has to provide on the spot all food and drink for the cooperators and fodder for the bullocks. The supply of food and drink is obligatory in Jigi and Ras Simosh, according to the farmers' agreement. Sometimes also in Wonphel. In Wonphel, it is compulsory to work for each and every farmer of the cooperative once a membership is attained. Wonphel is usually done for ploughing, weeding and harvesting. They are common farm operations for all farmers.

Threshing, whether under Jigi, Ras Simosh or Wonphel, is different from other farm operations and is somewhat like a feast. This is done after months of hard labour, when the sun shines after a long rainy season, when crops are matured and harvested ready to be threshed. On that day the farmer will gather his farm yield, which means his full yearly income. Farmers of the association come to the site of the threshing area with their bullocks or threshing clubs. Their wives help to prepare the food and drink. Group dancing takes place at the end of the threshing day.

Another type of cooperation is to pool the pack animals for transporting crops to the market. Each member of the association brings his donkeys, mules or horses with ropes and bags which are necessary to sack and load the crop. After selling his products, the farmer whose crop was marketed buys drink and food for those who helped to transport the farm products.

In house building, farmers cooperate to cut or prepare construction materials, dig trenches, construct walls and roof, and plaster walls. The farmer whose home is built has to invite farmers and their wives for a house-warming. Transporting and house building are usually Jigi-type cooperatives.

Eder is a mutual aid association formed to give financial or material assistance to members, and to enable them to meet their expenses in death and adversity. Money is raised regularly once or twice a month. The rate per member varies from 20 to 50 cents at each contribution. Ekub is an informal small savings association enabling farmers to buy bullocks, ploughs, clothings and to meet marriage expenses. It follows the same principles as the Eder: weekly, fortnightly or monthly contributions for the members, ranging from 50 cents to 4 E$ at each contribution. It seams easy to form well-organized cooperatives among Ethiopian farmers. The only draw-back is their lack of education. Once the farmer is educated, it will not be difficult to organize cooperatives among those who already belong to a cooperative-like aid association.

XII - 5. Farming Standards

XII-5 1. Sources of information

Information on agricultural statistics is scanty. The few sample surveys so far conducted were designed for different purposes. Their findings may hardly be of direct help for assessing the prevailing farming standards. Nevertheless an attempt was made to use some data available from the sample surveys, and (after processing, if necessary) to present a handful of figures related to the farm structure and farming standards. Results of investigations carried on by the Project's counterpart personnel with individual farmers and local officials are also included. The value of the figures is uneven. They must be regarded as merely indicative; they should not be generalized nor extrapolated. They may be of some use, however, in a first approach to the problem.

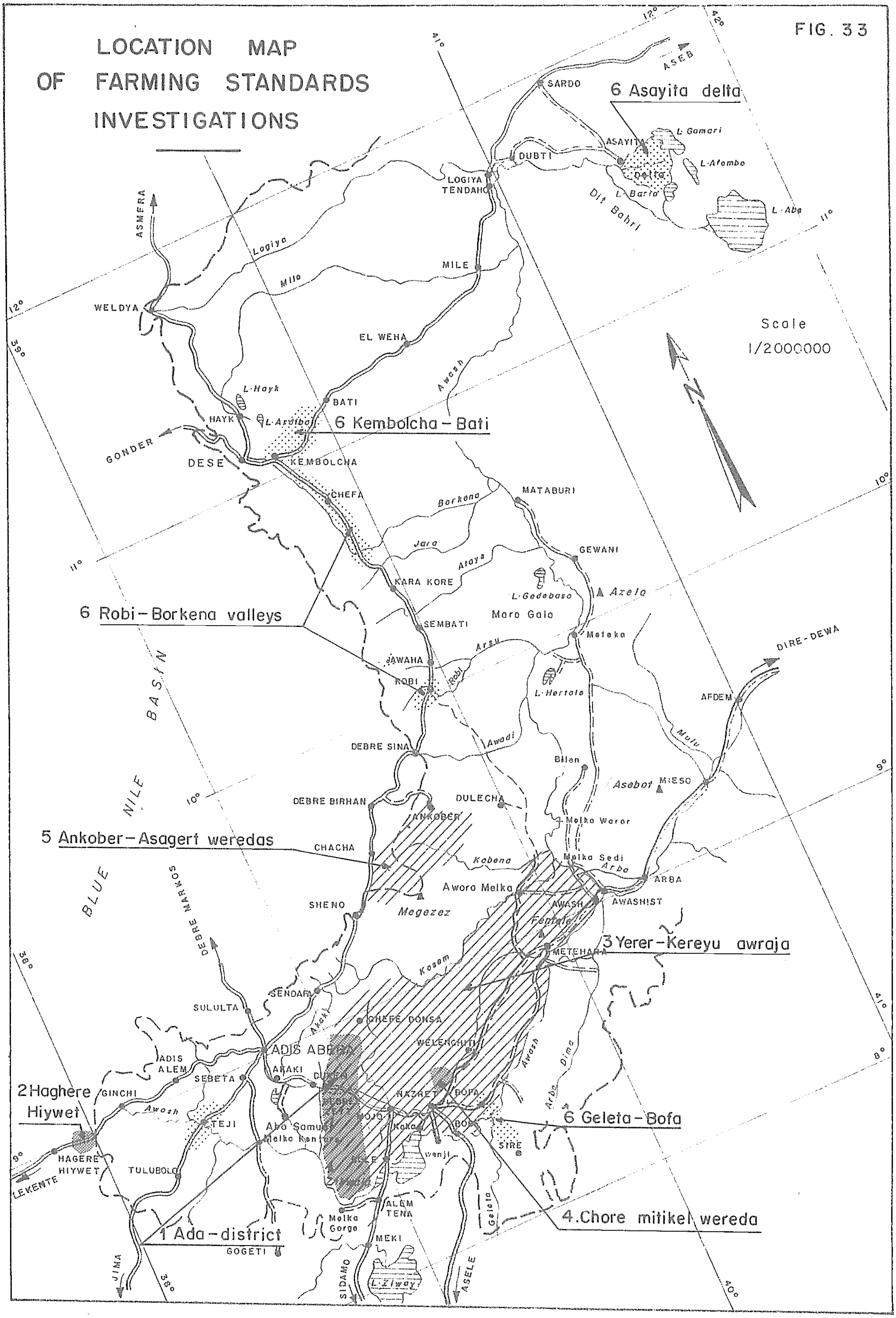


FIG. 33
LOCATION MAP OF FARMING STANDARDS INVESTIGATIONS
Scale 1/2000000
N
1 Ada-district
2 Haghere Hiywet
3 Yerer-Kereyu awraja
4. Chore mitikel wereda
5 Ankober-Asagert weredas
6 Asayita delta
6 Kembolcha-Bati
6 Robi-Borkena valleys
6 Geleta-Bofa
ASMERA
WELDYA
GONDER
DESE
HAYK
KEMBOLCHA
BATI
EL WEHA
MILE
LOGIYA
TENDAHO
DUBTI
SARDO
ASAYITA
ASEB
L. Gamari
L. Afombo
L. Abe
Dit Bahri
CHEFA
KARA KORE
SEMBATI
AWAHA
ROBI
DEBRE SINA
DEBRE BIRHAN
ANKOBER
CHACHA
SHENO
SENDAFA
SULULTA
ADIS ABEBA
ADIS ALEM
SEBETA
GINCHI
TEJI
HAGERE HIYWET
LEKEMTE
TULUBOLO
JIMA
GOGETI
MEKI
SIDAMO
L. Ziway
ASELE
NAZRET
WELENCHITI
CHEFE DONSA
METEHARA
AWASH
AWASHIST
ARBA
AFDEM
MIESO
DIRE-DEWA
MATABURI
GEWANI
DULECHA
BLUE NILE BASIN
DEBRE MARKOS
Awash
Logiya
Mille
Borkena
Jara
Kebena
Kasam
Megezez
Melka Sedi
Aworo Melka
L. Hayk
L. Ardibo
L. Gadabasa
L. Hertale
Mara Gala
Azelo
Asebot
Wenji
ALEM TENA
Melka Gorgo
Melka Kontura
Abo Samuel
Akaki
BOFA
SIRE
Geleta
Arba
Dima
12°
11°
10°
9°
8°
38°
39°
40°
41°
42°

Following sources of information were used for compiling the Tables :

(1) Report to the Government of Ethiopia on Debre Zeyt district sample survey, 1961, J.E. GHOLL (FAO).

(2) Blue Nile River Basin investigations, agricultural and economic working, paper no. 13, Water Resources Department, 1961.

(3) Sample survey in Yerer-Kereyu awraja, Central Statistical Office, 1964.

(4) Pilot field study in systems of land tenure and landlord tenant relationship. Chore mikitel wereda (Shoa) by H.S. Mann (FAO Rural Institution Officer) 1964.

(5) Advanced findings of the sample survey in the Tegulet-Bulga awraja, under processing by the Central Statistical Office, 1964; Weredas Ankober and Asagert have been considered.

(6) Investigations and queries with the selected farmers carried out in the areas of Geleta - Bofa plains, Robi - Borkena valleys, and Asayita delta by the Project's counterpart personnel and officials of the Statistics Department of the Ministry of Agriculture.

(7) Investigations with the local officials and on the market places in the Kembolcha - Bati and Teji regions carried out by the Project's counterpart staff.

XII-5 2. Agricultural and actually cropped land

The areas of agricultural land in the Awash Basin were measured with the help of planimeter on the land use map. It was found that the agricultural land represents 27 % of the total area of the Awash catchment area. This may be compared with the estimates of Dr. Wunderlich, who indicated for the country as a whole a figure 9.1 % cropland.

Cropland and fallows cannot be differentiated on the aerial photograph. Fallowing is common with the Ethiopian farmers and leaves idle a part of the fields either for a short period (rotation fallow), or for several years. Long duration fallows are commonly used as grazing lands. It is difficult to assess the extent of fallows by interviewing farmers, the more so as the cadastral maps do not exist and holdings' boundaries are hard to identify. If the findings of photo-interpretation are compared with those of full scale sample survey, the proportion of idle agricultural land may be more easily evaluated. The recent survey of the Yerer-Kereyu awraja provides an opportunity for such an evaluation. The area covered by the survey appears on the land use map as one where the proportion of agricultural land is the biggest. This region accounts for roughly 23 % of the total agricultural land measured on the land use map.

The figures in Table 18 suggest that little more than 1/3 of agricultural land is actually cropped and almost twice as much is left idle, as either short or long duration fallow. If the same proportion of idle and fallow lands is admitted for the total area of the Awash Basin, the percentage of actually cropped land works out to about 9 %. This is more consistent with Wunderlich's statement.

Table 18. Comparison between the land use map and the sample survey's finding for agricultural and cropland.

(Percentages of the total area of the Yerer-Kereyu awraja)	Land use map	Sample survey
Agricultural land	48.1	
Registered land		58.4
Cultivated area determined by the sample survey as per agricultural or registered land	35.7	28.5
Cultivated land determined by the survey as per total area of the Yerer-Kereyu awraja	17.2	16.8

Field observation appears to corroborate the findings for observers are often impressed by the extent of idle land. Investigators of the Blue Nile survey noted that land used for actual crop production is lower than anticipated. The unusually high proportion of idle and fallow lands suggests a wide scope for agricultural development.

XII-5 3. Holdings

Table 19. Average size of Holdings (Cropping Areas) and Percentage of Land in Tenancy.

	Average size of cropland holdings (ha)	Number of persons per holding	Percentage of tenants	Percentage of landowners
Hagere Hiywet	-	5.4	83.0	17.0
Teji	8.4	-	48.0	52.0
Debre-Zeyt sub-district	3.78	-	72.0	28.0
Yerer-Kereyu awraja	3.0	4.6	-	-
Chore mikitel wereda	2.25	4.9	55.4	44.6
Geleta-Bofa	1.46	4.0	61.2	38.8
Ankober-Asagert weredas	6.5	4.1	36.5	58.3 *
Robi-Borkena valleys	0.86	6.5	70.0	30.0
Kembolcha-Bati	3.6	-	48.0	52.0
Asayita delta	6.34	3.6	17.3	82.7

* Balance : landless people.

Holdings in the Kolla region, and particularly in the humid Kolla, appear noticeably smaller than in the cooler climatic zones. The relatively big holding size in the Asayita delta may be related to the particular type of flooding agriculture. The proportion of tenants and landlords was estimated when interviewing the farmers. It indicates that the tenancy is the prevalent land tenure system. The fragmentation of holdings, although existing, would not appear excessive.

Table 20. Fragmentation of Holdings.

	Average number of parcels per holding	Number of holdings involving									
		1,	2,	3,	4,	5,	6,	7,	8,	9or10	
		parcels									
Debre Zeyt sub-district	4.85	6	11	18	13	6	8	8	9	3	6
Yerer-Kereyu awraja	3.38	19	18	29	12	7	6	2	3	1	3
Chore mitikel wereda		71.5%	24.8%		3.3%		0.8%				

XII-5 4. Areas under particular crops

Table 21. Proportion of Cultivated Land Devoted to Different Crops

(%)	Teff	Wheat	Barley	Sorghum	Maize	Chickpeas	Beans	Horsebeans	Peas	Lentils	Noog	Sesame	Flax	Cotton	Others
Hagere Hiywet	26.3	29.6	6.0	4.2	3.3	4.4	-	-	1.1	-	12.6	-	-	-	12.5
Debre Zeyt sub-district	32	15	6.4	2.1	15.2	8.0	7.6	-	7.4	-	-	-	-	-	4.3
Yerer-Kereyu awraja	24	19	10	10	15	6	-	-	6	3	-	-	-	-	7
Geleta-Bofa	17.7	8.6	14.2	4.3	13.7	-	-	-	-	-	3.3	-	-	-	40.2
Ankober-Asagert weredas	18.7	28.0	18.4	16.6	1.2	8.5	3.8	-	-	-	-	-	-	-	4.7
Robi-Borkena valleys	21.2	3.6	-	57.8	12.0	-	-	-	-	-	-	-	-	2.4	3.0
Kembolcha	43.0	-	-	29.0	21.0	-	-	-	-	-	-	-	-	-	7.0
Bati	13.0	7.0	-	67.0	-	-	-	-	-	-	-	13.0	-	-	-
Asayita delta	-	-	-	9.1	35.3	-	-	-	-	-	-	-	-	55.6	-

Maize and sorghum are indicated as staple crops in lower altitudes. They give way to teff in the middle altitudes of Woina Dega. Wheat and barley are the main crops where the climatic conditions are those of Dega. Pulses are grown as rotational crops primarily at higher altitudes.

XII-5 5. Yields

Yields, as reported by the farmers, appear rather low in general. That they are probably higher in reality is shown by the cutting experiments conducted under the sample survey of the Debre Zeyt sub-district. Yields recorded by the Yerer-Kereyu awraja have been adjusted (upgraded) on the basis of this crop-cutting experiment. Figures for the areas of Teji and Kembolcha-Bati are less reliable for they were obtained by interviewing local officials and farmers mainly in the market place.

Table 22. Average yields of principal crops.

(q/ha)	Teff	Wheat	Barley	Sorghum	Maize	Chickpeas	Peas	Beans	Horsebeans	Lentils	Noog	Sesame	Flax	Cotton
Hagere-Hiywet Guder	5.6	6.8	7.9	7.3	8.0	5.3	7.6	12.0	12.5	-	5.6	-	3.6	-
Teji	6.0	8.0	3.0	3.0	-	8.0	3.0	3.0	-	2.0	2.0	-	-	-
Debre Zeyt sub-district	*6.74	7.8	6.75	3.3	6.9	4.8	5.5	4.9	-	6.8	-	-	-	-
Yerer-Kereyu awraja	5.7	5.9	7.0	5.1	7.0	6.9	7.8	6.5	-	3.6	-	-	-	-
Geleta-Bofa	8.0	11.3	12.0	14.2	10.4	-	-	-	-	5.5	-	-	-	-
Ankober-Asarget weredas	3.2	4.0	15.4	5.6	3.6	3.6	-	-	1.8	-	-	-	-	-
Robi-Borkena valleys	16.0	5.33	-	19.2	15.6	-	-	-	-	-	-	-	-	-
Kembolcha-Bati	2.5	-	-	6.7	8.0	-	-	-	-	-	-	1.0	-	1.9
Asayita delta	-	-	-	11.2	12.8	-	-	-	-	-	-	4.1	-	2.2

* Cutting experiments on 39 plots have given a yield in teff of 10.8 q/ha : 8 plots yielded more than 16 q/hs and 2 plots more than 20 q/ha.

XII-5 6. Livestock

Important livestock population is reported in the holdings. The figures in Table 23 are comparable except for the Asayita delta, where figures are much higher. An explanation may be that the interviewed farmers of the Asayita delta belong mainly to the Danakil tribe of agriculturists, who are supposed to keep bigger herds of animals.

Table 23. Livestock per Holding

	Cattle	Sheep	Goats	Donkeys	Mules	Horses	Camels
Hagere-Hiywet-Guder	7.7 animal units						
Teji	6.0	2.0	3.0	1.0	1.0	1.0	-
Yerer-Kereyu awraja	5.3	1.4	1.5	0.5	0.1	0.1	-
Geleta-Bofa	5.4	1.4	1.5	0.5	-	0.4	-
Ankober-Asarget weredas	3.5	1.35	2.25	0.4	0.12	-	-
Robi-Borkena valleys	7.5	2.2	2.9	0.4	-	-	-
Kembolcha-Bati	6.0	3.0	3.0	2.0	-	-	-
Asayita delta	23.4	11.0	16.7	0.5	-	-	2.9

XII-5 7. Value of agricultural production

An attempt has been made to evaluate the agricultural income, on the basis of declared crops and local market prices. The yearly expenditure per family has also been assessed. The results are shown in Table 24. The highest income per surface unit was in the very fertile valleys of Robi and Borkena, where the beautiful stands of both maize and sorghum are easily seen from the main road. The highest return per holding is recorded in Asayita, where cotton is largely cultivated and sometimes sold at prices even higher than those offered by the commercial ginnery. In general, incomes are low and reflect the poor living standards of the rural population.

Table 24. Average Value Declared per Holding

(E $)	Expenditure per family	Production per holding	Production per ha
Hagere Hiywet	183.15	-	-
Debre Zeyt sub-district	-	-	93.6
Yerer-Kereyu awraja	218	244 *	81.30 *
Geleta-Bofa	155.5	130.4	89.3
Robi-Borkena valleys	155.1	195.6	227.4
Asayita delta	108.6	780	123.4

* Computed from the report of Central Statistical Office. See page 101 (3)

XIII. PASTURE LANDS

XIII - 1. Nature and Origin of Grasslands

Pastures and grasses grow on many different soils. Types of plants depend on climatic conditions in particular areas. The density of vegetation and the carrying capatity of grazing lands vary greatly. Erosion problems in the Awash Basin have shown that only the arid and semi-arid regions in the Middle Valley and Lower Plains still bear extensive natural grasslands. Here are found about the only natural pastures in the Awash catchment area.

Different varieties of vegetation grow sparsely on shallow rocky or skeleton soils, of which large tracts are found in the semi-arid lowlands. By contrast, the best grazing lands are on lands with relatively deeper top-soil, largely of alluvial and/or colluvial origin.

The grasslands, plotted in yellow colour on the Land use map, can be divided into three main types :

(i) Flooded grasslands where plant life is conditioned by fairly regular inundations similar to these from the Awash in spate;

(ii) Herb and grass steppes characterized by tufts of perennial grasses where the land is subjected to alternating periods of wetting and drying. The soil may be wetted either by rain or by less frequent and less regular floods than those which occur on flooded grasslands. The size and density of the tufts depend on the amount of water available which, in turn, depends on the hydrodynamic properties of the soil; e.g., its absorption capacity or permeability. Thus herb and grass steppes grow both on sandy and gravel soils with a low retention capacity and on impermeable black clay soils.

(iii) Sub-desert steppes where xerophytes grow under a hot climate with low rainfall on silty soils. Runoff is negligible because of the permeability of the soils and the flatness of the land. Here annual grasses grow after each heavy rain.

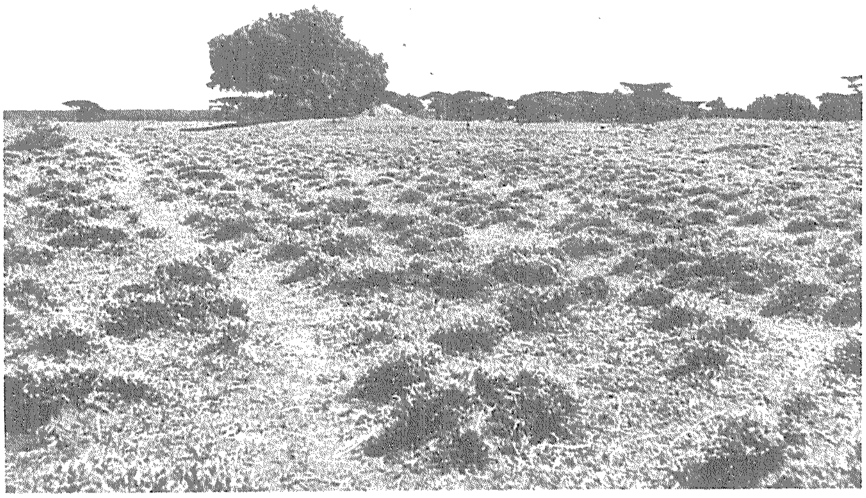
XIII - 2. Importance and Location of Grasslands

The following types of grassland have been identified:

(a) In the Middle Valley, the Koka dam and the regulation of water flows have changed the vegetation. Many previously flooded grasslands gradually become herb and grass steppes. The lands on the left bank of the Awash are still inundated by floods from the large tributaries of the Awash such as the Keisem, the Gezane and the Kekay Rivers. The Middle Valley still contains two fairly large flooded prairies; at Angelele and especially the grasslands around the Gewani Swamp. Herb and grass steppes cover the trough between Metehara and Awash Station and the Aleydegi plain. They grow along the edge of marshland and in formerly flooded grasslands in the river valleys.

There are relatively few sub-desert steppes in this region, and these grow in the alluvial plains on recently deposited permeable soils (designation Anc and Ac on the soil map to a 1:250,000 scale). Downstream from the Gewani Swamp, flooded

3 A
Overgrazed grassland
near the river during
dry season



3 B
Ungrazed grassland
far from the river
during dry season

grasslands and herb and grass steppes gradually give way to sub-desert steppe to scrub and finally to desert lands.

(b) In the Lower Plains, the regulation of flood waters by the Koka Dam has little effect except during the dry season. Large floods still come from the tributaries flowing into the Awash on its left bank downstream from the Gewani Swamp. The flooded grasslands in Dubti areas are quite small, as most of the Dubti flood plain is already occupied by fairly large permanent marshes. These grasslands often look like herb and grass steppes, since the climate is more arid than in the Middle Valley.

At a distance from the river and its flood plains, grasslands give way to sub-desert steppes. Herbaceous cover, although similar to that of the grasslands, becomes discontinuous, thinner and changes gradually into sub-desert steppe and finally into desert. Sub-desert steppe is found north of Dubti and Asayita and along the edge of the highlands which border the Dit Bahri plain in the south-west. On more rocky ground, shrubs and trees form an open bush with their grasses. In open wood-land areas on the slopes of the Central plateau (western side of the Valley) grasses similar to those on the steppes are found.

XIII - 3. Types of Vegetation

On the grasslands several characteristic types of vegetation have been identified according to the classification in 'The grass cover in Africa'*.

(i) A-10 - Aristida sp.

This type occurs in desert lands where, after rain, a temporary cover of grasses, including species of the genus Aristida, grow. Aristida of undetermined species are found in the Dubti and Dit Bahri areas, in association with Zygophyllum or Fagonia, generally more or less characteristic of gypsum soils. Annual or bi-annual Sesbania, which make an excellent forage crop, are found in clay lowlands. By comparison Aristida, especially perennial varieties, are tough unpalatable plants with few leaves; but they make fair grazing for camels.

(ii) CH-5 - Chrysopogon aucheri var-quinqueplumis - Paspalidium desertorum - Coelachyrum poseflorum - Andropogon sp. On gypsum soils : Sporobolus somalensis, Sporobolus ruspolianus, Sporobolus longibrachiatus, Tripogon subtilissimum.

This type is associated with semi-arid sub-desert type of bush. It forms a transition between the desert of the Low Plains and the steppes of the Middle Valley. A special survey of the region was not made, since much of the region is badlands where a very sparse vegetal cover is growing only at the bottom and along the edges of ravines and forms scanty pastures.

(iii) Association of CH-4 - CE-3 - S-3 Types

CH-4 - Chrysopogon aucheri var. quinqueplumis
Tetrapogon villocus - Tetrapogon tenellus
Cenchrus ciliaria - Sporobolus variegatus.

* See Bibliography. The full list of typical plants on the grazing lands in the Awash Valley is given at the end of this Chapter.

These graminea grow together with spares xerophyts shrubs. Rainfall varies from 250 to 500 mm, and altitudes vary between 200 and 1,100 meters.

CE-3 - Cenchrus ciliaris - Chloris sp. Hyparrhenia sp.
Sporobolus sp. - Aristida sp. - Eragrostis sp.
Brachiaria sp. - Pennisetum sp. - Bothriochlea sp.
Setaria sp. - Heteropogon contortus - Panicum sp.

These graminea grow with savanna woodland of varying densities. A large proportion of the trees are of the genus Acacia and Capparis. They grow at altitudes of between 450 and 1,200 meters under annual rainfall of from 500 to 1,000 m.

S-3

Where the bush is sparser and on relatively dry strips, the following types are found :

Cenchrus ciliaris - Chloris roxburghiana, Echinochloa - Enteropogon somalensis - Heteropogon contortus - Nicrochloa abyssinica - Panicum hygrocharis - Perotis patente - Setaria pallide - Fusca - Sporobolus festivus - Sporobolus indicus.

This type of vegetation grows at altitudes varying from 750 and 1,500 meters under an annual rainfall of 1,000 mm distributed over the summer months. In the Middle Valley, the three vegetations are found growing together, depending on local moisture conditions and the nature of the soil. Thus, CE-3 and S-3 types grow in more humid areas than do the CH-4. S-3 type is often found on poorly drained black clay soils. The Cenchrus type seems characteristic of steppes. CE-3 and S-3 types are therefore found in association in the steppes of Aleydegi plain, consisting of heavy black soils. Chrysopogon auchevi is characteristic of sub-desert steppe in the same region with drier soils which are never flooded.

XIII - 4. Forage Value of the Grasslands.

For a very rough estimate of the forage value of the surveyed pastures, seven square meter samples were taken in the Middle Valley, where grazing lands seem richer than in the lower reaches of the Basin, and tested for their nutritive value. The exact locations of the seven samples were :

(i) rich grassland between Fentale Mountain and Metehara, 25 km from Awash station.

(ii) grasslands near the old airport, 8 km from Awash station.

(iii) grazing lands associated with shrubs on rocky ground between Arba river and Aleydegi plain (Open woodland and bush on the land use map). As grass cover was rather thin, the sample was taken on 4 m2.

(iv) short grasses on the black soils of Aleydegi steppe, from Awash station.

(v) once floodable grassland between Melka Sedi and Melka Warar.

Table 25. Composition of Grasses Harvested on Selected Plot

No. of Sample	H_2O (%)	Total dry matter (%)	Crude protein Nx6.25	Crude Fiber (%)	Ether extract (%)	N.free extract (%)	Ash total (%)	Insol. Chlorh. (%)	Ca %	P %	U.F/kg	Digest. crude protein (g/kg)
1	12.60 -	87.40 100.00	3.88 4.44	32.10 36.75	1.44 1.65	38.68 44.22	11.30 12.94	9.07 10.38	0.283 0.324	0.123 0.141	0.29	7.5
2	17.20 -	82.80 100.00	4.14 5.00	31.55 38.10	1.56 1.88	33.91 40.96	11.64 14.06	9.03 10.91	0.322 0.389	0.222 0.268	0.25	8.0
3	12.90 -	87.10 100.00	3.79 4.35	30.40 34.90	1.45 1.67	41.42 47.55	10.04 11.53	7.26 8.34	0.419 0.481	0.047 0.054	0.34	9.0
4	11.75 -	88.27 100.00	4.49 5.09	24.80 28.10	1.32 1.50	36.34 41.17	21.30 24.14	13.14 14.89	0.972 1.101	0.053 0.060	0.32	15.0
5	14.20 -	85.80 100.00	2.81 3.28	31.25 36.45	1.23 1.43	40.93 47.67	9.58 11.17	4.46 5.20	0.474 0.552	0.108 0.126	0.30	5.0
6	18.35 -	81.65 100.00	4.86 5.95	27.85 34.10	1.11 1.36	37.87 46.39	9.96 12.20	4.20 5.14	0.497 0.609	0.111 0.136	0.33	18.0
7	14.15 -	85.85 100.00	7.37 8.59	26.80 31.25	1.14 1.33	39.09 45.49	11.45 13.34	4.59 5.35	0.628 0.731	0.092 0.107	0.41	31.0

NOTE : U.F. Forage Unit, equivalent to the nutritive value of 1 kg of barley

(vi) Wooded savanna on the left bank of the Kesem river.

(vii) Floodable grasslands between Kesem and Kebena rivers.

All plants growing on a selected representative plot of 1 m2 were harvested and sent for analysis to the Laboratory of 'Institut d'Elevage et de Médecine Vétérinaire des Pays Tropicaux' at Maisons-Alfort near Paris. Table 25 shows the results. Tentative estimates of the possible production capacity of the surveyed pastures were also made by the same Laboratory. Tables give these estimates.

Table 26. Production Capability per Hectare of Surveyed Pastures

Grassland corresponding to the sample n°	Total weight of grasses per ha (kg)	Energy value U.F. per ha	Crude protein kg per ha	Digestible protein kg per ha
1	3000	870	116	22.5
2	2900	725	120	23.0
3	750	250	28	6.7
4	900	290	40	13.5
5	1700	510	48	8.5
6	1800	600	87	32.5
7	700	290	50	21.7

Table 27. Grazing Possibilities of the Grasslands

Grassland corresponding to the sample n°	Grazing days per ha in respect of		Deficiency of Digestible protein gr.	Daily intake in kg required to satisfy nutritive needs in	
	Energy value U.F.	Digest. protein	Energy value U.F. (%)	Energy kg/day	Protein kg/day
1	145	75	- 50	21.0	40.0
2	120	75	- 40	24.0	37.0
3	40	20	- 50	17.5	33.0
4	45	45	0	18.5	20.0
5	85	30	- 70	20.0	60.0
6	100	110	Excess	18.0	16.5
7	45	70	Excess	14.5	10.0

Tables 26 and 27 indicate that the amount of forage available per hectare varies considerably according to the type of grassland. In general, the content of the digestible crude protein shows a rather high deficit and phosphorus content is too low. For a modern livestock industry, concentrates would have to be supplied to the animals.

A single sampling is insufficient for computing the admissible load capacity of the pastures, but a rough estimate may be made on the basis of theoretical nutritive requirements. If the average weight of Ethiopian cattle is about 300 kg, and if the theoretical nutritive value of the animal's daily ration is equivalent of 6 U.F. and includes about 300 g of digestible crude proteins, the load capacity of the grasslands in the Middle Valley would be between 4 and 12 hectares per head of cattle. On the rocky grazing lands under shrub, this figure will be as high as 15 - 20 ha per head of cattle.

XIII - 5. Present Use of Pasture and Grazing Lands

In the Middle Valley and the Lower Plains, grazing is mainly nomadic. The Danakil herds make long trips for fresh grasslands and water. In the Lower Plains, when grass is scarce from December to March, herds migrate from the Rift highlands to Asayita, a distance of some 200 kilometers. In the Middle Valley, the herds move a shorter distance, but may still move as much as 100 km. The Kereyu herds, grazing above Awash Station, move within a circle with a diameter of approximately 60 km. The herds generally return to the lowlands during August, but they go to the rich pasture lands of the high plains when rain is abundant. The lowland pastures are often undergrazed through lack of watering facilities. The pastoralists dig small reservoirs which are filled by runoff.

The migration of herds and the dispersion of pasture lands make an accurate estimate of cattle numbers difficult; but as fair to good grassland accounts only for a fraction of all the grazing lands on which the nomadic herds live, it can be assumed that an average of one head of cattle grazes on about 20 ha. In the valley as a whole, the cattle population may be very roughly estimated at about 200,000 animals. Wild animals make the animal population much denser; but in general, the load of pastures is within acceptable limits, except at the height of the dry season.

XIII - 6. Typical Plants Identified in the Grazing Lands

GRAMINEA : Aristida sp.
Andropogon distachyus

Brachiaria deflexa (Schumach.) Hubb. ex. Robyns
Brachiaria sp.
Bothriochloa sp.

Cenchrus ciliaris L.
Cenchrus setigerus Vahl
Chloris myriostachya
Chloris roxburghiana
Chloris virgata Sw.
Chloris sp.
Cynodon dactylon
Cynodon plectostachyus (K.Schum.) Pilg.
Coelachyrum praeflorum Chiov.
Chrysopogon aucheri (Boiss.) Stapf var. quinqueplumis (A.Rich.) Stapf

GRAMINEA (cont'd) : Danthoniopsis barbata Hubb.
Dactyloctenium aegyptium (L.) P. de B.
Dactylotecnium scindium

Echinochloa colona
Enteropogon macrostachyus (Hochst.) Munro ex Benth.
Enteropogon somalensis
Eragrostis sp.
Eragrostis cilianensis (All.) Link. ex Vignolo-Lutati
Eriochloa nubica (Steud.) Hach. et Stapf ex Thell.

Heteropogon contortus (L.) P. de B. ex Roem. et Schult.
Hyparrhenia sp.
Hyparrhenia hirta

Microchloa abyssinica

Panicum atrosanguineum Hochst. ex A. Rich.
Panicum maximum Jacq.
Panicum hygrocharis
Pennisetum villosum R. Br.
Pennisetum advense
Pennisetum sp.
Pothriochloa pertusa
Perotis patents

Rhynchelytrum villosum (Parl.) Chiov.

Setaria verticillata (L.) P. de B.
Sorghum sp.
Setaria pallide-fusca (Schum.) Stapf et Hubb.
Sorphastrum sp.
Sporobolus robustus Kunth
Sporobolus confertiflorus
Sporobolus filiferus
Sporobolus phyllotrichus
Sporobolus festivus
Sporobolus indicus
Sporobolus sp.

Tetrapogon cenchriformis (A.Rich.) W.D.Clayton
Tetrapogon tenellus (Roxb.) Chiov.
Tetrapogon apathaceus
Tragus berteronianus Schult

Urochloa cf. Trichopus (Hochst.) Stapf

ACANTHACEAE : Blepharis linariifolia Pers.
Peristrophe bicalyculata (Retz.) Nees

AMARANTHACEAE : Achyranthes aspera L. (S.l.)

ASCLEPIADACEAE : Leptadenia hastata (Pers.) Decne

CAESALPINIACEAE	:	Cassia gracilior (Ghesq.) Cassia mimosoides L.
COMPOSITAE	:	Chrysanthellum americanum (L.) Vatke
CONVOLVULACEAE	:	cf. Seddera latifolia Hochst. et Steud. ex Hochst. (in very bad condition)
CYPERACEAE	:	Fimbristyllis sp.
CYPERACEAE-CYPERUS	:	cf. Rotundus L.
HELIOTROPIUM SUBALATUM		
LABIATAE	:	Leucas urticifolia (Vahl) Benth.
MALVACEAE	:	Sida sp.
PAPILIONACEAE	:	Crotalaria polysperma Crotalaria laburnifolis Crotalaria spinosa Indigofera hochstetteri Bak. Tephrosia purpurea (L.) Pers. Trifolium sp.
RUBIACEAE	:	Borreria chaetocephala (DC.) Hepper
SCROPHULARIACEAE	:	Striga gesnerioides (Willd.) Vatke
ZYGOPHYLLACEAE	:	Tribulus terrestris L.

XIV. PROBLEMS OF EROSION IN THE AWASH BASIN

XIV - 1. Agents of Erosion

XIV-1 1. General Causes of Erosion

Settlement of the southern highlands is apparently fairly recent. The centre of Ethiopian power moved southward around the tenth century for reasons related to the exhaustion of the soil in Tigre, after several centuries of excessive exploitation and deforestation. At the beginning of the nineteenth century, the Emperor Sahela Selassie lived at Ankober, and then at Entoto. In 1883, Menelik II founded Adis Abeba. The northern slope of the upper basin of the Awash river was then much more wooded. The founding of the capital city of Ethiopia contributed to its deforestation and to the cultivation of the cleared virgin lands. Elsewhere, except in the highlands, (nomadic regions with a low population density), erosion is mainly due to natural agents, i.e., climate and relief. Those agents will be discussed later in relation to the specific degradation of the soil measured in tons/year/km^2 and expressing the net exportation of materials from a fairly big area.

XIV-1 2. Climate

Climatic data show a definite rainy season during July, August and September, and a long dry season interrupted during the period March to May by stormy rains, especially in April. The mean annual rainfall varies from under 500 to over 2000 mm in the various climatic zones.

When precipitation is heavy, only a small part of the rainfall is stored by the soil. An analysis of rainfall data reveals that, in Adis Abeba, there is a surplus of about 550 mm of water during the rainy season and a deficiency of about 500 mm, from November to March.

Detailed study of daily rainfall distribution shows that heavy rain (60 to 100 mm per day) only affects the zone lying between 1800 and 2500 m. Such rain is moreover very localized and is of low frequency. Rainfall of the type capable of producing large-scale erosion is thus limited in both time and extent.

XIV-1 3. Relief

Geologically, the Awash Basin is very young and still in evolution. The terrain is, therefore, rugged. An altitude of 3,000 metres decreases to 900 metres over a distance of 200 kilometres, from Entoto to Awash station, but the distance is only 30 kilometres, between Ankober to Dulecha. Average slopes may be around 10 %.

Those steep slopes, particularly acute in the western part of the Rift, are eminently responsible for a high degree of erosion.

XIV - 2. Forms of Erosion

XIV-2 1. Sheet erosion

This is caused by surface washing of a sheet of water which carries soil particles with it and wears away successive layers of top soil. Though difficult to identify in homogeneous soils, it is clearly visible on soils with light-coloured subsurface horizons. Lighter patches appear on slopes and at the top of hillocks. It is common on all cultivated lands in the Basin, except bottom lands.

4 A
V shaped gully in the BALCI area

4 B
Broken V shaped gully in the region of KASSO

4 C
U shaped gully North of MOJO

XIV-2 2. Rill erosion

Between grass tufts in pasture lands, a tight mesh of tiny channels forms which concentrates runoff and feeds it into streams or rivulets. Streaming then causes a raising of the tufts relative to the land surface, and a denuding of their roots. Where the land is fairly steep, the rills quickly become gullies. In the highlands, pasture lands do no longer exist. Cattle feed on weeds which grow on fallow land, or along the edge of roads, fields, and ditches. During the dry season, the vegetal cover gradually disappears, and the ground is completely bare when the first rains begin.

In semi-arid regions, overgrazing promotes erosion, mainly in the areas near watering points. Especially along the Awash river, soils are heavily eroded either by runoff in rills or by the wind, depending on the type of soil and the season.

XIV-2 3. Gully erosion

Following the micro-relief of the land, runoff forms rills and rivulets, increasing in volume and in speed. The flow becomes erosive, cutting deeper into the soil and forming gullies which then become ravines. This erosion is agressive in character. Gullies grow in size, and deepen from down to upstream, with successive collapses of the gully sides and bottom. Sills, waterfalls and gorges can be formed.

This is the most characteristic and spectacular form of erosion in the Awash Basin. It is the final phase in soil degradation and may be observed on the area drained by large torrential tributaries on the left bank. Gully systems may be over 25 kilometre long in an area of 1 km^2, and cover 25 % of the land surface.

It is important to distinguish between the several different types of gullies.

(a) V-shaped gullies. This is the initial shape of all gullies. It persists, as the gully grows and widens, if the deeper soil horizons are less erodible than the upper horizons. They always occur on soils underlain by fairly hard rock or tuff, and particularly on black soils. They are seen in the upper Mojo basin between Balchi and Chefedonsa. In arid or semi-arid regions, heavily eroded terrain without vegetation is called "badlands". This final erosion is due to the soil which, because of its toxicity or impermeability, limits or prevents the development of a protective vegetal cover. The slightest shower, however rare, causes intense erosion with inumerable, usually V-shaped gullies.

In the Awash Basin, the badlands already occur downstream of Awash station, but they are most prevalent between Gewani and Tendaho and in the Mile and Logiya river basin. Moreover, these rivers, when in flood, carry the greatest amount of sediment.

(b) U-shaped gullies. If the deeper soil underlying horizons are softer than the upper horizons, the gully walls are vertical. Undermined from below, they collapse from top to bottom. This form of erosion generally seems to occur on light-coloured soils, especially brown soils. If the soil profile includes a hard or encrusted horizon, a U-shaped gully may be topped by a V- or even a broken V-shaped gully. Such gullies are found in the Kaso and Geleta areas.

(c) Gullies formed from tunnelling. The closer soils, especially swelling clay soils, are to the banks of channels or gullies, the more thoroughly they dry up. They have many large shrinkage cracks, which at their bottom grow into tunnels into which runoff waters rush. As the water flows towards the gully, side slopes are undermined and collapse. At the same time, soil layers may start to slide, especially as the underlying horizons in vertisols are often massive in structure, with slickensides. Fairly spectacular landslides of this kind occur in the Chefedonsa area. In the easily erodible soils, (e.g. soils on volcanic ashes and pumices in the area between the Meki river and the lake Gelilea,) a similar gullying occurs. Gullies grow from a crack or a hole into a series of tunnels, which finally collapse.

XIV-2 4. River and torrent erosion

The erosive power of a river depends on its sediment load. River erosion consists mainly in the undermining of river banks and cutting away hard layers and sills in the bed. Erosion by rivers is clearly visible in all the alluvial plains over which the Awash and its tributaries have wandered and meandered; in the Teji plain, the plain upstream from the lake Gelilea and the plains in the Middle and Lower Valley.

Erosion by the torrential tributaries of the Awash, such as the Kesem river, is natural or geological. It consists mainly in the transport of weathered materials, from rocks covered merely by a thin layer of skeletal soils. In such case, movements of land masses : avalanches, cave-ins, and landslides are prevalent.

XIV-2 5. Wind erosion

Here the erosive agent is the wind, which transports particles of saline or arid soil, or of soil laid bare by cultivation or over-grazing. Where the speed of the wind decreases on meeting an obstacle or a land mass, the particles are redeposited and form dunes. In the Awash valley, air vortexes are frequent when warm air currents from desert areas meet cold air currents from the highlands. Dunes exist in the Lower Plains north and south of Dubti. In the Middle Valley, they are neither numerous nor large, and are small local heaps.

XIV - 3. Consequences of Erosion

As soon as the first rains begin, rivers of red mud flow through the streets of Adis Abeba. After flowing out of the lake Gelilea, where the waters of the Awash settle, they soon become muddy again, especially downstream from the confluence with the Arba and the Kesem. The sediment load of the Awash and some of its tributaries may sometime exceed 50 g/l. Sediment is deposited downstream, most of it in the Lower Plains. It silts the marshes, and helps to change the location of river beds. Shifting the course of waterways seems to be more and more marked and frequent, especially along the section between Tendaho and Asayita. Is this increasing frequency due to increased erosion in the upper basin ?

Degradation of the Awash basin is a natural phenomenon under prevalent geographical and climatic condition and is mostly due to geological erosion. However, cultivation of almost all of the available land in the high plateaux, together with the present cultivation practices, seem to be activating and accelerating erosion.

If the upper Awash basin is not to become within the next few centuries only, a true rocky desert like that of Mount Megezez, a program of erosion control must be immediately devised and implemented.

XIV - 4. Types of Erosion in Traditional Geoclimatic Zones

Information and large scale maps needed for delineating areas subject to different types of erosion are lacking and therefore an attempt has been made to relate the erosion phenomena to the traditional geo-climatic zones, as shown on the map attached to this volume. Another map, published in another Volume as a consequence of the sediment transportation study, will give the variations of the specific soil degradation. Both maps do not coincide completely, because the erosion is considered in this chapter as a field degradation which does not correspond to a definitive exportation of materials from a bigger area. (See Map No. 12, Vol. II and Vol. III)

The Dega was a region of forest and pastures. The slightly ferralitic red soils with steep slopes are fairly eroded after deforestation. The black hydromorphic soils are less sloping and consequently less eroded.

In the Woina Dega, a distinction must be made between :

(i) The intensively cultivated plain south-west of Adis Abeba where almost all the soils are fairly stable, rich black vertisols. Their erodability depends on the permeability of the underlying parent rock. Heavy rains erode the slightest slope, in particular, in the Bantu Liben area and on the western slopes of the Yerer and Dalota Mountains, which form a natural boundary of the Woina Dega.

(ii) The steeply sloping mountain land in a narrow strip in the western part of the basin between the Kesem river and Dese. Here, erosion is intense, when the natural vegetation has disappeared through cultivation.

Because of its slope, the land should be used for pastures and forests, except for a small portion which can be cultivated if land management practices of the kind currently by cultivators are used, and systems for removing excess water are improved.

A distinction also must be made between the dry and the humid parts of the Kolla. In the dry Kolla, cultivated soils are the most heavily eroded of all cultivated regions (Mojo basin). Here, rains are still fairly abundant but the dry season is long and hot. At the time of the first rains, the dry top soil of fallow lands is easily eroded. The many shrinkage cracks on the soil surface become gullies. In the humid Kolla, there are many well built terraces, but sometimes the outlets are eroded. Terracing of steeply sloping cultivated land as well as gently sloping land should be encouraged. If not terraced, the land even when gently sloping is eroded at the beginning of the rainy season.

In the Bereha, erosion differs according to the altitude and the climate. In semi-arid Bereha, altitudes vary between 800 and 1,500 metres, with an average temperature of 25°C, and an annual rainfall between 500 and 800 mm.

It includes the region between Nazret and Awash station, and a wide band at the edge of the Rift Valley, where erosion is tied to the efficiency of the natural vegetation. Erosion may vary widely, according to the density of the local grass or bush cover growing on shallow or gravelly soils.

The arid Bereha or middle Awash Valley, at altitudes between 600 and 800 metres covers the area downstream from Awash station to the confluence of the Awash with the Borkena river. It is a region of steppe and bush on young alluvial soils, currently or recently deposited. Average temperatures are high, between 25 and 30°C, and annual precipitation averages 400 to 500 mm. The scattered but intense rainfall provided by storms, which is characteristic of this region, are sufficient to cause a considerable erosion from runoff. Here, the soil is generally unprotected by vegetation, and the lightest rainfall may erode any slope. Wind erosion, also, is becoming serious.

The sub-desert Bereha covers the lower plains which are a vast area of deposition of eroded materials. After flooding, a portion of these lands is used for crop-growing (wild flooding of cropland in the Asayita delta).

Altitudes are below 600 metres, temperatures are above 30°C, and the average rainfall is less than 400 mm. Wind erosion is marked, especially in desert areas where dunes are formed.

The climatic zones, traditionally distinguished in the Awash Basin, can be classified in order of decreasing degrees of erosion :

Dry Kolla.................	(Heaviest erosion met on cultivated areas - (Accelerated erosion
Woina Dega	(Very severe erosion of accelerated character
Semi-arid and arid Bereha	(Severe erosion of sustained character
Humid Kolla	(Severe erosion of accelerated character
Dega	(Normal erosion
Sub-desert Bereha	(Wind erosion - Sedimentation zone

The area in each climatic zone, and its size as a percentage of the total area of the basin is given in the following table :

Table 28. Climatic Zones

Climatic zone	Area (km²)		As a percentage of the total area of the basin (%)	
Dega	4,600		6.6	
Woina Dega	9,200		13.2	
Plains		6,100		8.7
Hills		3,100		4.5
Dry Kolla	10,950		15.6	
Plains		4,000		5.7
Hills		6,950		9.9
Humid Kolla	4,450		6.3	
Plains		1,050		1.5
Hills		3,400		4.8
Semi-arid Bereha	11,800		16.9	
Arid Bereha	18,500		26.4	
Sub-desert Bereha	10,500		15.0	
TOTAL AREA	70,000	-	100.0	-

XV. PRINCIPLES AND METHODS OF EROSION CONTROL

XV - 1. Existing Methods

Simple structures for erosion control have been built in the Awash Basin, but they cover only a small portion of the total area. They are of three types.

Terraces with dry stone embankments are constructed on steeply sloping land, usually of brown soils (Aliyu Amba, Dese, Bati). They were probably at first constructed more or less along natural terraces produced by faulting followed by land subsidence at successive intervals. They gradually became popular and more numerous. They are narrow (about 10 to 30 m in width) and supported by a vertical or slightly sloping uncemented stone embankment. Along their upper side, there is no drainage for excess water. The earth is level with the foot of the embankment. A side ditch towards the main slope is used for drainage. Under heavy rain, the water flows over the embankment.

Earth terraces or benches are constructed on less steeply sloping land of relatively permeable, brown, or brown to red, soils. The farmable cross-sections vary in width from 20 to 50 m, and their slope is less than the natural slope. Embankments are 2 to 3 m in height and seem level. There is no drainage channel along the upper side of the embankment. A little sheet erosion can be seen in the fields. There is considerable rill erosion on slopes, although they have a grass cover. The embankment were probably built gradually, with manual labour and simple tools.

As systems for removing surface water a network of small furrows (about 10 cm in depth) has been dug on much of the cultivated land of black soils and with relatively little slope. During the rainy season, excess water flows through the furrows. They were in fact constructed to prevent smothering of plants and to increase yields. As they are not always properly dug, they often grow into gullies and become an important factor in eroding black soils.

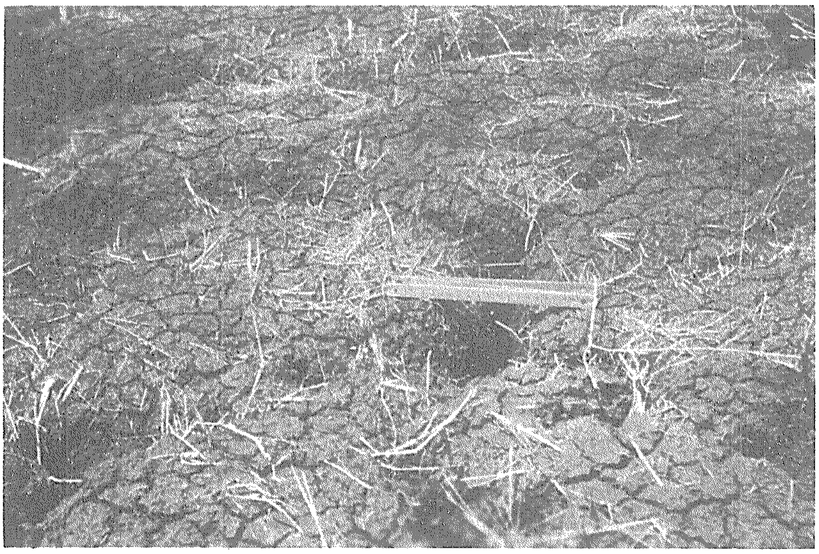
XV - 2. Current Problems in Erosion Control

Present methods of erosion control may sometimes accelerate erosion instead of preventing it. The main difficulties are due to :

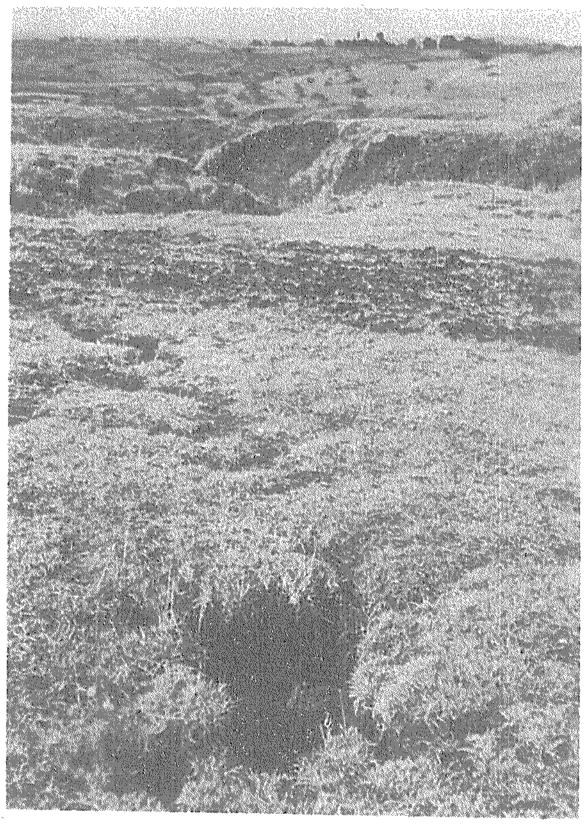
(a) The severity of natural erosion which cannot be arrested by simple manual means. The mountainous terrain, where rainfall is very heavy and very unevenly distributed throughout the year, is the most vulnerable to erosion. The Ethiopian highlands should be listed among the regions of the world where natural erosion is most severe.

(b) Marked dryness for long periods, all the more detrimental because high altitudes increase evaporation rates, results in soil crumbling and innumerable, large and deep shrinkage cracks in the soil surface. Soils then become extremely erodible. Each crack may in time grow into a gully.

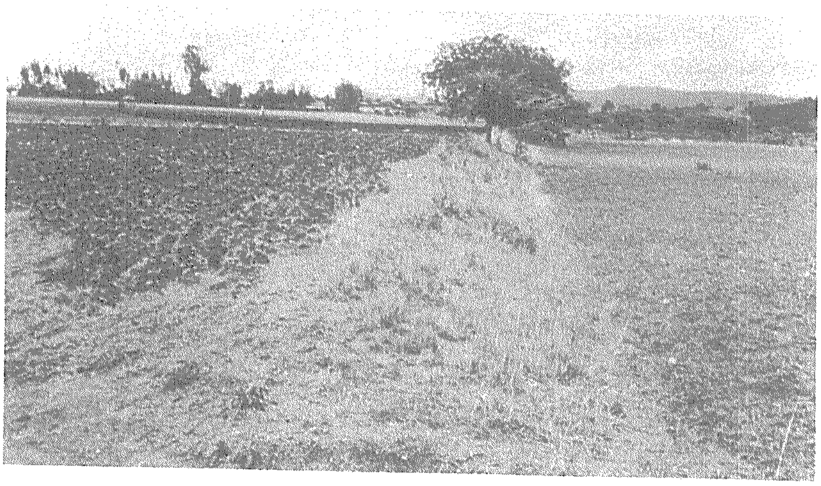
(c) Little water only can be stored in impermeable black soils, where excess water content may cause landslides. Still more important, the top soil becomes waterlogged and yields decrease through plant smothering and nitrogen deficiencies. For these reasons, black soils are no longer terraced.



5 A
Deep fissures near
ZIKWALA mountain



5 B
Cave-ins and tunelling near
CHEFE DONSA



5 C
Countour bunding near
BOLO-SELASSIE

XV - 3. Recommended Principles and Methods

In view of the extension of erosion ridden areas in the basin, previous study and experimentation are prerequisite to any large scale erosion prevention scheme.

Methods of erosion control in the Awash Basin should be found which do not prevent the existence of vegetative cover at the time when rainfall of an erosive nature is expected. They might include deforestation of slopes which are too steep or too severely eroded, cropping systems which provide better cover and prevent the drying up of the soil (particularly, with very limited irrigation), and dividing the cultivated slopes by diversion ditches.

Most of the surface runoff would have to circulate over the cultivated areas. As a general rule, however, erosion control would consist not in retaining all the runoff during the rainy season, but in diverting a portion into the rivers without causing land erosion.

XV-3 1. Field methods

For the purpose of defining the work to be done, studies must first be made of its economic feasibility, the agricultural potential of different types of soil and, for each, the limiting slope beyond which soils cannot be cultivated without danger of excessive erosion. In general, land with a slope above 30 % should not be cultivated.

Constructions must favour the removal of water. The land must not be absolutely level, since the cumulation of too much water could lead to waterlogging and land slippage. A certain amount of slope must be maintained in the direction of the main slope. A cross-slope of about 0.5 % is recommended. The general scheme of protection and drainage system is shown in Graph 6.

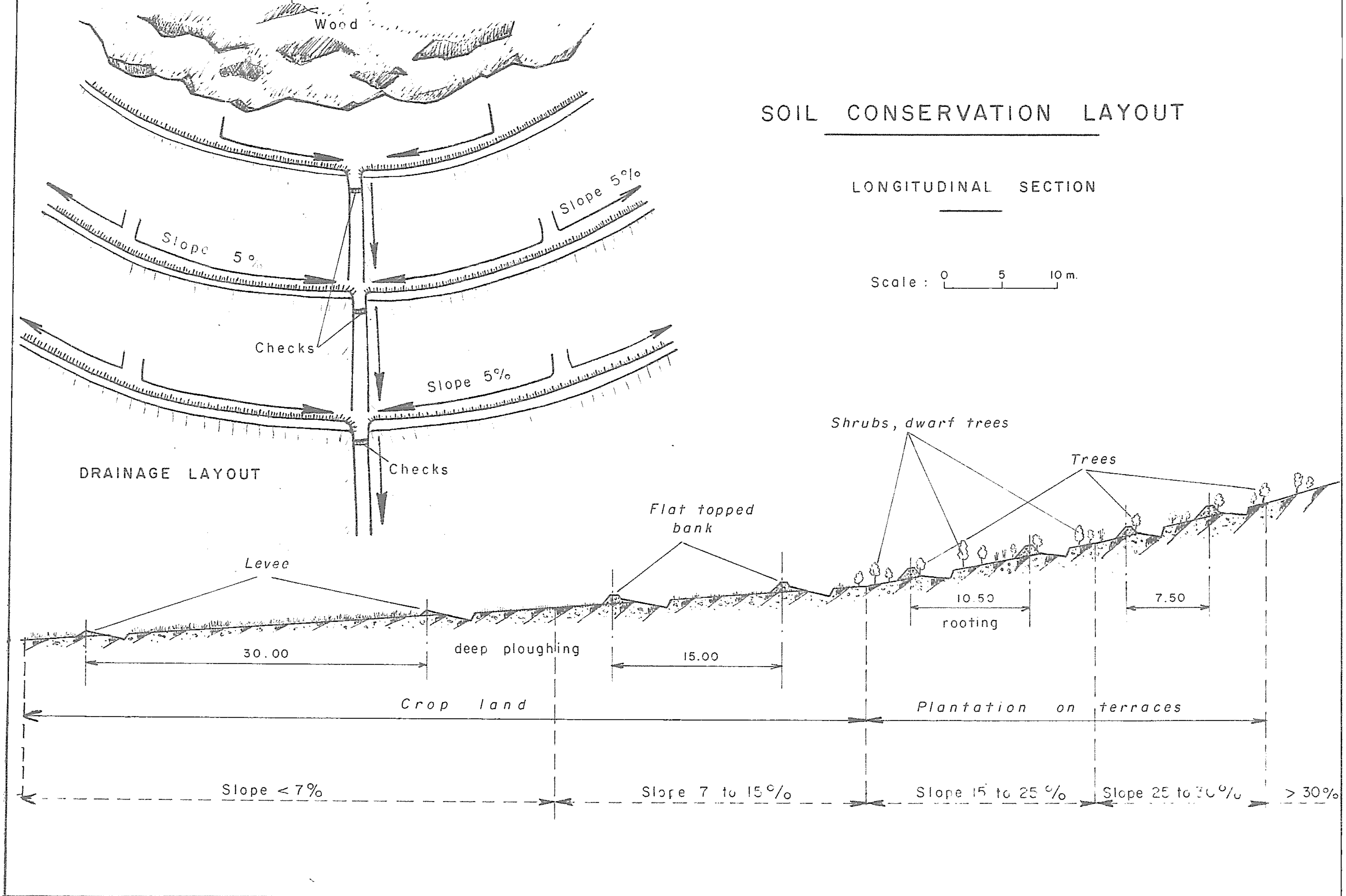
The exact amount of slope in both directions depends on the type of soil and its erodability. It is desirable to have double purpose structures. These are designed for the removing of water during the rainy season, but they can also be used for retaining the small rainfall during the dry season.

For natural slopes of less than 15 %, the methods of gently sloping bench terraces, contour strip cropping, and deep ploughing (rooting) might be tested. Surface drainage should be adapted to the nature of the soils : the heavier and the more impervious are the soils, the larger must be the amount of excess water to be removed. Drainage networks should be at a closer interval and the canals cross-section planned for a higher discharge.

For slopes of more than 15 % and less than 30 %, the existing system of terracing can be generally adopted. Its effectiveness depends on proper maintenance, which is usually done where the cultivator is also the owner. In any case there must be a proper drainage system.

Stubble mulching consists in preserving crop residues for the protection of the land. It is an extremely effective method, but difficult to apply in Ethiopia, where crop residues never, or rarely, exist; grains are consumed by man, leaves and straw by cattle, and stems are used in building huts. Nevertheless, experiments should be made to test the effect of stubble mulching in reducing shrinkage cracks, which seem to be a main cause of primary erosion.

FIG. 6



SOIL CONSERVATION LAYOUT
LONGITUDINAL SECTION
Scale : 0 5 10 m.
Wood
Slope 5 %
Slope 5°/o
Slope 5°/o
Checks
Checks
DRAINAGE LAYOUT
Levee
Flat topped bank
Shrubs, dwarf trees
Trees
30.00
deep ploughing
15.00
10.50
rooting
7.50
Crop land
Plantation on terraces
Slope < 7%
Slope 7 to 15°/o
Slope 15 to 25 °/o
Slope 25 to 30 °/o
> 30%

Experiments should be made in pre-sowing land preparation at the beginning of the rainy season. Before the rains, the dry land is ploughed and pulverized, and very easily eroded when the rains begin. Deeper ploughing, which produces larger clods of earth may help to reduce erosion.

Reforestation should be undertaken on all land with a slope above 30 %, although, it will be difficult and require a long time to recreate the forest as it formerly existed. Systematic reforestation should be accompanied by strict regulation of the use of existing forests, especially forests on sloping land.

The planting of Eucalyptus trees is not sufficient for erosion control. They were introduced to Ethiopia, where climatic conditions favour their growth, around 1880. Cut very young, they are used in building houses made from logs covered with mud. They are not very effective for soil conservation, since not much of vegetal cover can grow with them, and the land remains subject to erosion. Eucalyptus plantations should be regarded not as forest, but merely as a crop to be subjected to erosion control.

Pasture lands have practically disappeared from the Upper Basin. They still exist only as green fallows in the Dega highlands, a region where land is cultivated after burning, usually about one year only out of every five. Their improvement cultivation under a system of rotation should be considered. They should be drained and sowed in nutritive species of grasses, and system of cultivation which popularized the periodic regeneration of grasslands should be encouraged. Pastures should be reseeded on sloping impermeable soils in other regions. Control of erosion on pasture lands consists mainly in regulating grazing, dividing cultivation into plots along the contour, and building embankments and ditches for the removal of excess water.

XV-3 2. Drainage systems

Excess water during the rainy season must be so drained into rivers or reservoirs that the speed of flow of the water over the land never causes erosion. Speed depends on the amount of flow, the slope of the land and its roughness. To decrease flow speeds, slopes can be artifically reduced and roughness increased.

The structures for stabilizing gullies would be a series of masonry or wood-brush check dams. On the bottom and sides of the gullies, a vegetal cover, protected from animals, should be planted. A protective strip - of a width to be determined, perhaps 10 to 20 m - of grasses or trees should also be planted along the side of gullies, and properly fenced. It should be irrigated during the dry season. This is indispensable for establishing and maintaining any protective vegetation, and for preventing shrinkage cracks along the side of gullies.

Graph 7 represents a gully treated with three kinds of structures to reduce the velocity of the flow. Wood brush check dam may be considered in small gullies, where flow is still moderated. Rock and gabion check dams would be better for larger gullies where the flow already gathers momentum. Protective vegetation cover and fencing are also shown on the graph.

For controling erosion of the banks of permanent waterways, standard methods can be used : cutoff of meanders, man-made falls, and gabion or rock embankments. Because of the large number of gullies (several kilometres of gullying for each square kilometre of cultivated land) and the extensive development of the river system, the control of erosion along waterways requires large and costly structures. They must be built from up to downstream, so that flooding does not destroy structures located further downstream.

XV-3 3. Control of deposition

Control measures are effective only after a long period of time. Meanwhile the reservoirs behind dams risk silting up. To decrease silting, stilling or deposition basins must be created upstream. Obstacles to slow down the speed of flow and to remove suspended elements before the river waters flow into the reservoirs are required.

For the Koka reservoir, silt could be deposited in the swamps upstream from the Sidamo road. The Mojo river might be totally diverted into these swamps through the existing bed of one of its branches. Diverting the river is a simple task of constructing dikes. This is all the more necessary since the Mojo river transports large amounts of sediment. Later on, the upstream portion of the Koka reservoir might also be used for deposition. The Gewani and Boyale swamps might also be progressively filled. Once they are silted up, they can become rich crop lands.

XV - 4. Long-Term Consequences of Erosion Control

Long-term control measures in the entire Awash Basin may retard or completely arrest erosion. The productive potential of the land will be maintained, or even increased by preserving top soils and storing larger amounts of water once the rainy season ends and during the dry season.

Increased production of the land in the high plateaux means a decrease in headwaters. Less water will be available for the plains in the Middle and Lower Valley. In compensation, the greater regularity in flow will facilitate irrigation.

Increased infiltration of water in the highlands might also resupply the springs downstream. Many are at present saline, but, regularizing the rate of flow of the Awash river will make sufficient amounts of water available at all times to dilute harmful salts.

XV - 5. Program of Action for Erosion Control

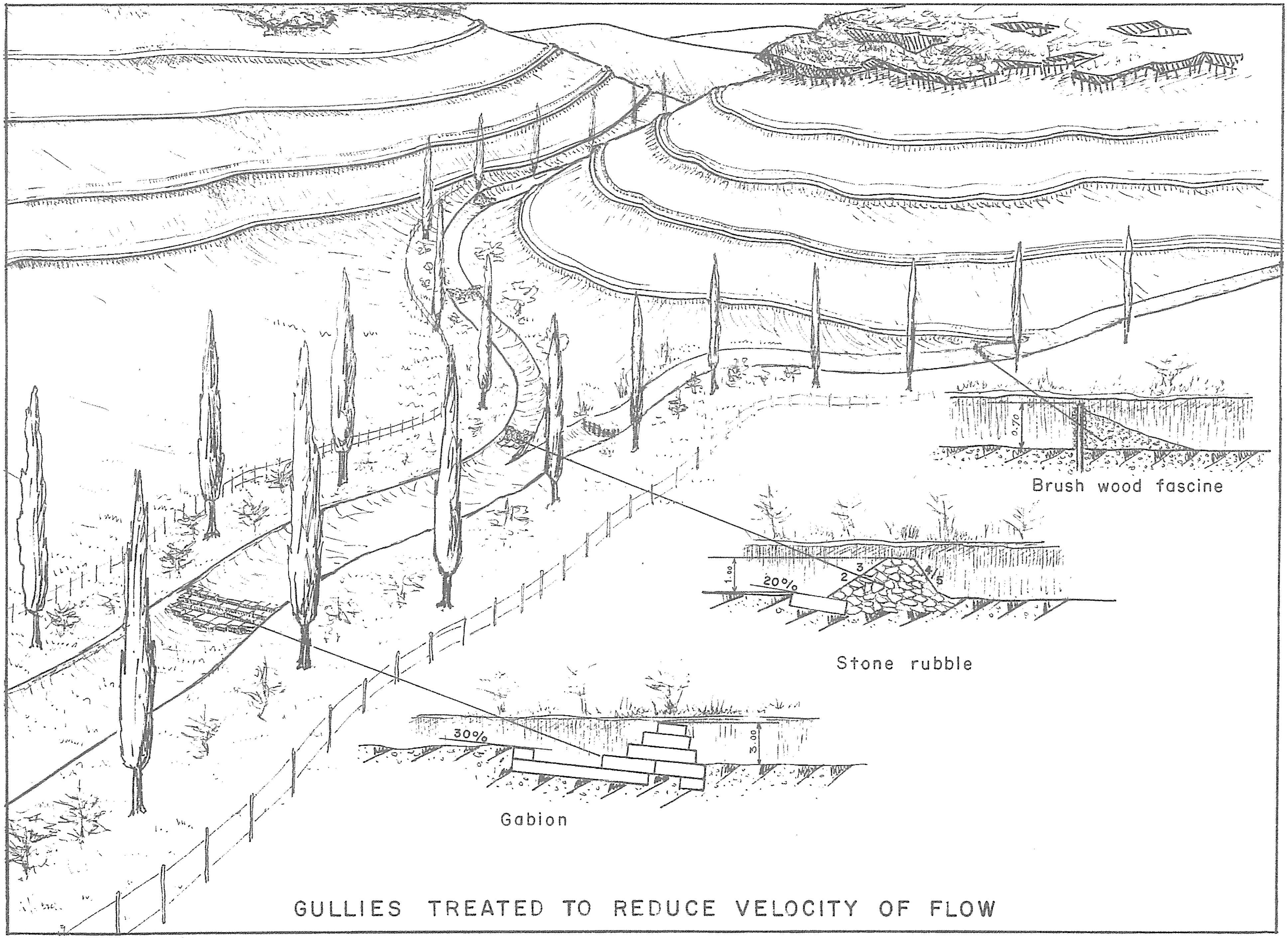
Erosion control is complex. It must be based on a <u>real philosophy</u>. Measures taken must be concentrated to cover an organic whole, such as an entire watershed. If measures are not related to each other, they may be not only inefficient, but soon nullified, either by erosion from upstream waters or by regressive erosion. Continuity of action in space and in time is indispensable. If a portion of the treated area were to be abondoned, and again subjected to erosion, structures in many other places would probably suffer.

No program of action can be effective unless it is based on <u>surveys covering the entire Awash Basin</u>, including :

(i) Relief (relief map drawn to a scale of 1/50,000) ;

(ii) Soils (map, drawn to the same scale, showing land suitability and the different forms of erosion) ;

FIG. 7



GULLIES TREATED TO REDUCE VELOCITY OF FLOW

(iii) Transport of solids (continuation of the measurements at present being made, classification of watersheds according to their degree of erosion).

Before measures for soil conservation are taken or popularized, they must be tested. Different cultivation practices should be tested on small plots equipped to measure the amount of soil eroded.

Except on large plantations, cultivators possess neither the requisite material nor technical and financial means to control waterways or silting areas. This is the State's task. The State should first plan special projects to define the type, technique and costs of the structures required. Surveys, experiments, and special projects would form the bases for drawing up a general plan of erosion control, establishing a budget, and defining priorities. For its implementation the plan requires :

(i) the establishment of a national organization for water and soil conservation ;

(ii) the subdivision of the Awash river basin into regions and into districts, each of which covers only one watershed ;

(iii) the training, and placement of technical staff to educate farmers in cultivation practices and to direct operations for the control of waterways.

It would be best to control erosion first in the most severely eroded areas; that is, in the cultivated areas in Kolla and Woina Dega. As a pilot district for experimentating in, and implementing of methods of soil conservation, the Chefedonsa district might be suggested. There soil erosion has reached disastrous proportions.

XVI. PROSPECTS FOR THE IMPROVEMENT OF GRAZING LANDS

The development of the livestock industry and grazing lands in the Middle Valley and Lower Plains must be based on the use of irrigated pastures. Before a program of irrigated pastures is fully implemented, certain improvements should be made.

XVI - 1. Basic improvements in pastures productiveness

Regenerating existing grasslands and introducing new species of grasses are very important for increasing the value and the productiveness of pasture lands. Experimentation takes time. Prolonged efforts are needed before the results can become popularly accepted.

XVI - 2. Prevention of overgrazing

Regulating the use of existing pastures should prevent overgrazing those along the banks of the Awash river. This is feasible because cattle seem not to have suffered greatly from lack of forage. The relatively short period of drought enables the livestock to have a reasonably balanced diet of dry and green feed.

XVI - 3. Establishment of water holes

The livestock industry cannot be properly developed unless grasslands are more fully used than they are now. Under-grazing of large tracts of pasture lands is mainly due to a lack of watering facilities. Investigations in areas far from the Awash River should be made for building :

(i) reservoirs or ponds to collect and conserve runoff during the rainy season for use during the dry season ;

(ii) wells drawing from the water table or from deeper ground water layers ;

(iii) small dams across seasonal water courses.

Studies on rainfall and runoff, the location and movement of ground waters and the types of structures required are essential for this program. The actual work could be done by the occupants of irrigated pastures. They are likely to have heavy equipment at their disposal. As an example, a program of research of underground waters, resulting from a preliminary hydrogeological survey, in 1963 to investigate ground water resources in the Aleydegi plain, is described in Appendix 7.

Apart from making remote grasslands productive by immediately establishing water holes in their areas, the psychological impact of the program is important. The nomads will appreciate new watering facilities. They may become less reluctant to break their traditional isolation and to join the market economy.

XVI - 4. Distribution of flood waters

Spreading flood waters from intermittent streams over range pastures topographically best suited to flooding is another way of making some grasslands more productive. Small dams across intermittent streams and a network of drainage ditches help to spread flood waters at little cost. These structures are particularly recommended wherever flooded pasture lands are located above irrigated land. Dikes would probably have been built around the irrigated area to protect it from unusually large and fast flood waters, which can thus spread over the pasture lands above them. At the same time, the drainage ditches of the irrigated area will help to drain progressively the pastures at moderate rates of flow and to regulate both the depth of water and the time during which the flooded pasture lands are submerged. In grasslands above irrigated areas, the flood waters should be still further distributed over the largest possible surface by ridges and ditches.

XVI - 5. Reclamation of marshlands

Irrigation systems in the Middle Valley and the Lower Plains will contribute substantially to a partial reclamation of marshlands such as those at Gewani, Boyale, Dit Bahri, and in the Asayita Delta. Their reclamation through drainage and partial silting can be expected because water consumed by irrigation will reduce the size of floods; large dams will regulate the rates of flow ; structures can control the liquid and solid intake of certain marshes ; the shape and size of existing natural drainage channels can be improved ; and smaller drainage ditches can be dug.

Even if the partially reclaimed marshlands are not best suited to crop growing they can be used for improved pastures, for a full control of flows makes it possible to regulate the amount of water entering the marshlands. The right amounts of soil moisture can be maintained over the entire year.

XVI - 6. Harvested fodder

One ranching difficulty in semi-arid regions is the concentration of the annual rainfall over relatively short periods. Grasses age rapidly and become fibrous, less palatable and less nutritious. If adequate supplementary fodder were available, much larger numbers of livestock could be supported on existing grazing lands. The best pastures consist of young and tender grasses. To derive maximum benefits from them, the livestock should be removed once the season of succulent grasses is over.

When pastures are no longer productive, the herds could be fed from irrigated pasture lands, either by producing hay or silage and selling it to the pastoralists or by buying livestock from them when water and grazing facilities are exhausted. Nomadic pastoralists are reluctant to buy fodder for their animals. They will not be quickly persuaded to change their centuries-old habits.

XVI - 7. Using irrigated lands for livestock

The purchase of lean stock for feeding on irrigated farms seems to be the most practical solution. Fattening and finishing could be done on the farms.

Irrigated farms could start buying cattle when the dry season is advanced, and nomadic stock are forced to stay close to watering points in the river or canals. The cattle could be fed intensively, at first on good grazing lands and later on irrigated pastures and on harvested fodder, either hay or silage. The fattening period would probably last 4 to 6 months. About one hectare of land would support three or four heads of cattle. If the fodder is harvested, a larger number can be fed from one hectare of irrigated land.

Irrigated farms could provide not only forage, but also another kind of animal food. It is highly probable that with the growing of important cash crops such as cotton and ground nuts, the oil processing industry will be established in irrigated regions. One by-product, oil seed cakes, could easily become a valuable supplement feed concentrate for a better finish of the animals. All stages of fattening and finishing could be completed in irrigated areas.

XVI - 8. Animal health

Veterinary and general sanitation services are badly needed wherever a livestock industry is developed. Irrigation farming should greatly facilitate the health inspection of nomadic stock. Housing facilities would be available for veterinary services, access would be improved, and periodical markets might be organized. Buyers of livestock on irrigated farms might help the Government to improve animal health, and, in co-operation with the Government Veterinary Services, become responsible for the health of some nomadic herds.

XVI - 9. Conclusions

Frequent contact with the nomadic pastoralists would probably be a most valuable means of building a prosperous cattle fattening business. Nomads might appreciate constant help during their wanderings. To haul out a few tanks of water to a remote but rich pasture might be relatively easy for a big, well-equipped farmer, but is could save a number of animals from thirst or starvation. When disease spreads among the stock, a timely intervention may later on pay dividends. The enterprising farmer will then be able to obtain more and better stock just when he wants it.

If existing livestock resources were quickly exhausted and the supply of cattle became too limited to assure a permanently profitable business to the fattening industry, importing young animals from other cattle raising regions might be contemplated. This might help to persuade nomads to sell their animals. They hesitate to sell their stock because the number of head owned is a mark of social prestige. The possibility, of exchanging adult for young animals might overcome their reluctance, for the total number of head in their herds would remain the same. Such a scheme would also improve livestock quality.

The integration of nomadic livestock owners into a market economy is not easy. Irrigated agriculture may play an important part in making the nomads gradually more sedentary. In the long run, it may be more effective than any direct attempt to change centuries-old ways of life and occupations.

XVII. RURAL IMPROVEMENT IN THE UPPER BASIN

XVII - 1. Introduction

Present farming practice in the Upper Basin is described in Chapter XII. It can be summed up as follows :

(i) Basic crops are sown before the main rainy season, (from March to July), and harvested between October and December.

(ii) Catch crops are grown only on small areas. Their yields depend almost entirely on when the first minor rains set in and their duration (between December and April).

(iii) There is, as a general rule, no ploughing. The soil is simply 'scratched' on the surface two or three times during the season. The last time this is done , the seeds are buried.

(iv) Crop residues are used for forage or building material, if not burned. Manure is dried and converted into caked fuel.

(v) The crops are grown to feed the local population. All farm labour is manual.

(vi) There is practically no pasture, and the undernourished - and too numerous - livestock survive on what they can find in the cultivated fields and along track edges.

(vii) Erosion-control structures, (terraces), are practically only built on permeable land.

(viii) The local farmers show a lively spirit of cooperation and effectively assist one another.

Suggested improvements are based on the absolute need to stop erosion and to increase soil fertility. They are mainly concerned with matching crops to climate (especially to the very special rainfall conditions), the popularization of more productive methods, stock-breeding, land development, a higher standard of living and better working conditions for the farmers.

XVII - 2. Matching Crops to Climate

XVII-2 1. Economic use of water resources in the ground

The erosion control methods described in Chapter XV improve the soil water balance. Soil moisture only exceeds the wilting point for three or four months of the year. The ground dries out very quickly after the rainy season, and herbaceous plant growth ceases after early November. Only trees are then still able to use water stored deeper underground.

To make the most of the rainy season, annual crops should be planted as early as possible, for crops sown early produce the highest yields. Sowing tends to be comparatively late at present because the farmers are afraid of Cryptogamic diseases, which they cannot control. Systematic experimentation to find the best planting times for various crops is advisable.

A method of keeping the moisture in the soil for a longer period is to store recent rain water once the ground is no longer saturated, or else to reduce evaporation by mulching and billowing. This implies crops grown in rows to provide access to the fields. The burying of crop residues also helps to slow down evaporation, because of its modifying effect upon the structure of the top soil layer.

The introduction of perennial and arboraceous species should also be considered. If irrigated during the first few years of their growth, they make better use of the water stored in the deeper soil layers. Olive, fig, senna (Gleditoia), carob, walnut, pecan-nut, apricot, almond, peach or plum trees, and arborescent lucerne (woody grass) are examples of such species. Apart from helping to control erosion, tree plantations act as efficient wind breaks locally affecting ambient humidity conditions. They help to keep evaporation down.

XVII-2 2. Selection and introduction of new species and varieties

Although near to the Equator, the Upper Basin belongs to the Northern Hemisphere. Altitude - the effect of which is still by no means fully understood - also plays an essential part in determining plant life.

Spring occurs twice (in April - May and October - November) in this region. Neither period is followed by rainfall sufficient for a normal growth of vegetation. These special aspects of the climate must be carefully considered when selecting new plant species or varieties. There must be lengthy and delicate research before substantial progress in agriculture can be achieved. This is amply illustrated by the successful results achieved with 'teff' and 'noog' - both local species - compared with poorly-adapted species recently introduced (with the notable exception of Eucalyptus).

XVII - 3. Popularizing More Advanced Methods

XVII-3 1. Modernization of light farm equipment

All farming is still done by manual labour or with crude implements wasting time and energy. Inexpensive modern equipment would bring farming costs down, enable more land to be farmed and leave the farmers free to spend time on other jobs (e.g., improving their homes, tracks, reforestation and stock-farming).

Some authorities consider that the ploughs now in use (wooden implements with an iron spike) are best suited to local conditions, facilitate infiltration and slow down surface runoff. This may be true when comparing untilled land with land tilled with this type of plough. On the other hand, where the furrows do not run perpendicular to the line of steepest slope, they may form trickles of water, which are more erosive than sheet flow and rapidly swell to torrential proportions. As most soils feature deep shrinkage cracks before the rainy season, which do not fill up until the soil becomes saturated, tillage can only affect water absorption within the top soil layer; i.e., only down to a depth of about 5 - 10 cm.

The serious disadvantage is that, in failing to turn the soil over properly, this ploughing method facilitates the growth and spreading of weeds and allows only a limited nitrification of organic matter. The farmers rely on burning and densher-ing to convert the nitrogen into a assimilable form and to destroy the weeds, but this practice also destroys the organic matter and makes the top soil more vulnerable to erosion and rapid drying-out.

Weeding is done with this plough and by hand, harvesting by sickle, threshing by trampling with cattle, winnowing and sorting by hand, and all carrying with donkeys, etc. All these operations could easily be done with simple animal-drawn equipment, produced cheaply in Ethiopia. Meanwhile, experiments could be made with such imported implements as : Vineyard ploughs of the French 'vigneronne' type; disc-ploughs; flat-tooth cultivators; sharp-tooth scarifiers; harvesters; threshers, and winnowers; trucks, and processing equipment.

XVII-3 2. Use of fertilisers and improvers

A few tests, although neither properly listed nor systematically used, appear to confirm the value of fertilisers, especially for regenerating nitrogen and phosphoric acid. The following yields were obtained about five years ago from a teff plantation at Debre Zeyt experimental station :

With urea .... :	25 quintals/hectare against 10 quintals/hectare on a control plot
With ammonium sulphate :	44 quintals/hectare against 15 quintals/hectare on a control plot
With phosphoric acid :	21 quintals/hectare against 7 quintals/hectare on a control plot

Only so-called 'all purpose' fertilisers are at present available commercially. They are expensive and not suitable for all types of soil. The popular use of fertilisers will depend on more efficient marketing of products adapted to the real requirements of the various soils.

Animal manure is almost never used because there are no stables. What little is taken from the fields is converted into fuel. Green manure crops are unknown, but their introduction would help to produce a better, richer top soil and to protect it against erosion and drying.

XVII - 4. Stock-Farming Improvement

Almost no pasture is left on the high plateaux. Most beasts are unhealthy because they lack a properly balanced green and dry fodder diet. During the three months of the rainy season, the fodder contains too much water, but is reduced to straw during the seven-month dry season. Cattle receive properly-balanced nourishment only during the interim period, i.e., for only two months. In the Middle Valley, they are bigger and better built than the upland cattle. This indicates a lack of calcium on the high plateaux, due to the soil. Food concentrates could be a compensation. A certain amount of organized stock-farming might be considered, for instance, breeding cattle in the Middle Valley for use in the upland areas when full-grown. This program would involve creating of pasture on suitable land (i.e., shallow, impervious or clay soils); constructing of stables; introducing a pasture rotation system, on properly fenced land (there are no fences at present); and selecting suitable local strains (Borana, Harar Fugara, and Begait).

XVII - 5. Generalization of Major Development Works

XVII-5 1. Soil protection and restoration *

Farmers in the gently sloping peneplain area seem unaware of soil conservation methods applicable to steep slopes. Yet efficient erosion control measures are applied on rough land and practically flat fields ravaged by dendritic and gully erosion only a few kilometres away. Farmers thoroughly familiar with erosion control methods might be persuaded to demonstrate them in villages where they are not practiced. 'Neighbourly' advice and assistance may well go down much better than an official training program implemented by State officials. 'Farmer-instructors' would have to be paid for their additional work. At first this would be a matter for the Government authorities, but, in the long run, the idea of the farmers paying their own instructors does not seem unrealistic.

XVII-5 2. Land reclamation

At least 20,000 hectares of land on the high plateaux is marshland or subject to flooding. Most would be fairly easy to drain for reclaiming substantial additional areas for agriculture and stock-farming, provided only that the projects ensured the conservation of soil moisture during the dry season. The suggested reclamation of Borkena marsh, discussed in Volume Five, would be the main operation of this type.

XVII-5 3. Irrigation

On the high plateaux, only fruit, vegetables and gardens are at present under irrigation. Although irrigation has also been considered as a means of erosion control, its basic object is the substantial improvement of agricultural production. The need for auxiliary irrigation is most noticeable in the comparatively hot dry Woina Dega and Kolla areas, where water application could take place before or after the rainy season for normal crops, and between March and May for catch crops. Water requirements vary from year to year. They are probably around the 2,000 cu.m per hectare mark.

The rough surface in the present farmland areas seems particularly suitable for erecting small earth or rock storage dams. A more comprehensive idea of irrigation possibilities in the Upper Basin for increasing farm production could be gained by a systematic prospecting for suitable sites.

---

* For the main recommendations on this subject, see Chapter XV.

XVII - 6. Improving Farmers' Living Standards

Improvement in rural productivity depends on the Ethiopian farmers' standard of living and working conditions. Primitive dwellings, the shortage of adequate roads and communications, remoteness of water supply points, and inadequate power supplies all restrict rural development. The most important requirement, however, is agrarian legislation under which the farmers can rely on enjoying the benefit of their land and are encouraged to make long-term investment in their holdings. Only when the farmers feel sufficiently secure in their farms and can look forward to the same standard of living as in the towns, will they listen to any advice on how to achieve higher productivity and better living conditions.

XVIII. PROSPECTIVE LAND USE IN THE IRRIGATED AREAS

A. GENERAL CONSIDERATIONS

I. Introduction

The soil maps and those of suitability for irrigation indicate large tracts of good soils in the Middle Valley. The lands on both river banks upstream of Metehara may be similarly good. They were not selected for the semi-detailed soil survey, because early in the Project operations it was realized that the water supply in the upper reaches of the Middle Valley might be insufficient for all irrigable lands in this region.

To take advantage of the water from the big tributaries draining the lower part of the catchment area, (the Borkena and Mile rivers), relatively poorer soils had to be selected in the Lower Plains. The actual take-off of development in the region and the existence of indigenous agriculture in the Asayita delta had also to be considered.

As the agricultural value of the two development regions appears unequal, the choice of prospective land utilization patterns is discussed separately for the Middle Valley and the Lower Plains. The range of the crops which can be grown in both regions is probably similar. The main problem, therefore, is the cropping intensity pattern.

II. Natural Conditions in Relation to the Intensive Irrigation

II - 1. Soil alkalinity

The Lower Plains are an arid country in which, under the hotter and drier climate, soils have developed a more alkaline reaction, as indicated by pH often higher than 8.5. An alkalinity hazard must be reckoned with, when developing the areas of Dubti, Dit Bahri and, to some extent, the Asayita delta. Their soils must be handled with more caution. Under continuous irrigation, ample water supplies must be carefully applied to prevent raising the ground water table and causing the detrimental accumulation of salts in the root zones. At the same time, the utmost care must be taken to maintain good soil structure and avoid reducing soil permeability. If these conditions cannot be easily fulfilled, lower irrigation intensity appears advisable.

II - 2. Drainage

Alkaline soil reaction is closely associated with drainage conditions, for where alkalinity progresses soils tend to puddle and become impervious. The processes may be more difficult to control when large quantities of water are frequently applied under an intensive irrigation scheme aimed at producing two or more crops annually.

Although no shallow underground water table became evident from the soil survey, a noticeable rise in the water table should be expected after several years of irrigation. It will rise earlier and higher in areas where larger annual rates of water are applied. Its maintenance at a depth admissible for plant growth will be more difficult in the regions with poorer natural drainage. In the Lower Plains, where natural outlets, river branches, channels and creeks are shallow, artificial drainage facilities will have to be excavated, and the problem will be aggravated by too flat a slope of the terrain; but in the Middle Valley the natural slope of the terrain is greater and the river bed itself is fairly deep and may provide a sufficient natural drain, to which ditches can be connected.

II - 3. Water quality

The water quality in the same river often changes not only with the seasons, but also along its course. This is particularly true in the arid regions and where the river flows through marshes and swampy gallery forest. Many warm springs discharge into the Awash fair quantities of mineralized water. It is advisable to use as much as possible of the available fresh water in the upper reaches before soluble salts concentrate in swamps and marshes.

II - 4. Consumptive use

Consumptive use of water varies greatly according to climatic conditions. Particularly important are rainfall, solar radiation, temperature, and humidity of the air. The drier the air, the higher the temperature and the smaller the rainfall, the greater are the amounts of irrigation water to be applied. If differences in consumptive use of water between two potentially irrigable areas are likely to be significant, selection of the region with smaller consumptive requirements for intensive irrigation schemes will result in substantial saving of water. The arid climatic conditions in the Lower Plains, indicate that the same supply of water may suffice to grow noticeably more crops in the Middle Valley.

The natural conditions for developing higher intensity irrigation farming appear more favourable in the Middle Valley than in the Lower Plains. This is particularly true if schemes for double cropping are contemplated. Double cropping is a target wherever natural conditions are favourable, because it is conducive to the highest returns from the assets being usually in short supply, that is the good land. Obviously it implies higher farming standards which are often difficult to implement. Therefore a brief discussion of some agronomical management problems related to the farming practices under intensive irrigation would appear useful.

III. Some Farming Problems

III - 1. Selection of the growing season

The growing season for different crops needs to be carefully selected. Harvesting and planting operations should be timed to meet the biological requirements of the rotational crops. The right timing of field preparation, planting and pest control operations often determines the yield and general success of the project. The vegetation cycle of a crop has to fit into the climatic pattern of the region. Longer daylight and more intense insolation may shorten the vegetation period and give a better opportunity to a subsequent crop.

The rotational pattern must include long and short vegetation cycle crops. Careful selection of varieties and strains will have to be undertaken in order to pick out most suitable ones. However, there will be always a competition between the crops for suitable planting seasons. Substitute and complementary crops must often be introduced.

To reduce the spoiling of a crop by insects and pests its planting season should be so selected that the most vulnerable stage in its growth cycle does not correspond to the period of intense breeding of pests. This selection is not easy, for plant breeders and phytopathologists can have contradictory points of view. The timing of planting selected by the agronomist and that recommended by the irrigation engineer can also be contradictory. The latter wants to have the irrigation stopped during the peak consumptive use of water, whereas the farmer prefers the biologically most suitable planting time.

III - 2. Maintenance of the soil fertility

There cannot be intensive cultivation, especially under irrigation, without fertilizers, even if fodder crops and green manures are included in the rotation. Frecuent waterings are conducive to leaching and depletion of nutritive elements from the soils, and they must be replenished by farm or green manure and fertilizers. Production of farm manure is subject to stalling of cattle, which at present, is achieved only in highly developed markets, demanding dairy products. Green manures are relatively uneconomic, particularly where irrigation water is scarce, as they do not provide direct incomes. Fodder crops, or irrigated pastures for meat production, will more often be the sole betterment crop in the rotation. Thus the fertilizers become the chief purveyors of soil nutrient elements, and must be extensively applied to maintain the high productivity of the land. Types of fertilizers, methods and doses of application depend on field trials and experimentation.

III - 3. Irrigation practices

As soon as an irrigation project is to be developed, there must be an equitable apportionment of the available water to the users. This is usually the task of an irrigation authority which also maintains the distribution system. A distribution schedule has to meet the watering requirements of the planted crops. An agricultural program must be elaborated for the whole area of the Project and the dates of planting, cultivation, treatment and harvest operations have to be anticipated. Water will be delivered at the fixed dates and applied to the fields. Strict synchronisation of field operations and the water delivery schedule is essential.

The omission or postponement of a scheduled watering may unduly delay the vegetation cycle of crops, which will then stand longer in the field. If merely one crop a year is grown and several months elapse between the harvesting and planting period, there will be no disturbance in the future irrigation schedules. The only consequence of the farmer's negligence is that he probably reduces the yield of his own crop.

Not so, when double cropping is generalized. For all-year-round irrigation, adherence to watering schedules must be meticulous. The application of each allocated head of water should be strictly timed, as periodicity of watering will be frequent. Any delay will postpone a subsequent tour of irrigation. This will be detrimental to the other plots and/or farmers. Distribution services must be highly organized and collaborate closely with the agricultural management of the Project.

III - 4. Experimentation and extension services

The management of an irrigation project may be vested with many responsibilities for promoting the technical and economical prosperity of all the farms. They may range from experimental and extension work to providing for the farmers credit and marketing facilities.

Experimental work is essential for determining different agronomical features important for irrigated farming. This will be a long process and actual development cannot be postponed until all the results of experimentation are known. Experimental work should be done simultaneously with the development and its results progressively applied. Factual information will have to be made readily available to the farmers, who must be prepared to apply it without delay.

This involves an efficient extension service with numerous and highly trained staff of technicians, whose task is not only to bridge the gap between the experimentation services and the farmers, but also to ensure that farming operations are performed in time and up to standard. Extension services are essential in double cropping schemes. Elsewhere many projects broke down because of the lack of adequately organized agricultural extension.

III - 5. Farm unit

Double cropping is particularly difficult if the intensive irrigation project is combined with a settlement scheme. Even an active extension service may be of little help if the farmers educational standard, receptivity and openmindedness are too low. Greater flexibility in the less ambitious and less intensive farming pattern is better suited to the settlement schemes, so that more time in the hollow periods of the year can be given to training the farmers.

Difficulties in running a highly intensive irrigation scheme may be more easily overcome on a commercial farm, where the distribution control, at least on the irrigation unit basis, is secured by the farm management itself. Operations can be planned in perfect consistency with the water distribution schedule. The results of the experimentation may be closely followed and the relevant instructions easily implemented. Many tests and experiments can be made on the spot by the technicians assigned to the farm. Thus, less risk is involved in starting a double cropping, highly intensive irrigation project on the commercial type of farms.

IV. Financial Implication of Intensive Irrigated Farming

The comparative analysis of suggested schemes and their financial implication may prevent many costly mistakes in the selection of the development projects. Thus, a high irrigation intensity pattern may prove more economic in that smaller areas will have to be provided with costly irrigation and drainage facilities. The overall capital outlay for developing an irrigation scheme aimed at a given output will be smaller, and fixed costs per product unit are likely to be considerably lower. Shorter canal and drainage network will be constructed. Structures and crossings will be less numerous. Levelling and clearing will be carried out on smaller surfaces. Thus, it appears, higher irrigation efficiency and a sizeable saving of the water supply could be more easily achieved. Farm surface may be reduced because two crops yearly will provide, particularly to settlers, more income per surface unit. Farming will be more labour intensive, and more people can be settled on the same area.

On the other hand, capital outlay per surface unit is likely to be higher, as more sophisticated distributory systems will have to be designed. Farm working capital must be much higher to enable farmers to do all the preparatory work in the short time allowed by a tight succession of crops. Farm implements will be more sophisticated, draught power more abundant. Harvest operations will probably be mechanized to get fields free for a successive crop at the earliest date. Imputs in the form of improved seeds, fertilizers and pesticides will be needed. There will be a large demand for credit facilities. Unless easy and favourable credit is made readily available and efficiently distributed, the increased farming expenses, resulting from the high intensity pattern of irrigation, can seldom be met by the operations of family-sized farms. Commercial farms are better prepared to raise the necessary funds from private sources.

V. Conclusion

In designing a Development Plan for the Awash Basin, the Government is offered the choice between a purely economic approach to the problems of agricultural development and a long-term policy based both on economic and social factors. The former would be focused on the achievement of highest economic return in a more or less immediate future ; the latter would involve perhaps smaller financial results and longer period of time in which to reap the development.

Natural conditions for the development of an intensive irrigation farming would appear more favourable in the Middle Valley than in the Lower Plains. Operational difficulties in the running of an intensive irrigation project may be more easily overcome on the commercial rather than on the family farms. If high productivity of the agricultural investment is the target, commercial farms will have to be given priority, at least provisionally, in the Middle Valley.

Since the lower irrigation intensity seems more suitable for the settlement schemes, the promotion of family size farming appears advisable in the Lower Plains.

B. MIDDLE VALLEY

I. Social and Human Problems

As has been shown, natural conditions in the Middle Valley are probably more favourable for the intensive irrigation patern and for agricultural production than those in the Lower Plains. Some tracts may even be marginal dry-farming areas. A few plots of maize, cotton and teff are actually cultivated by the employees of the railway, near the stations of Melka Jilo, Metehara and Awash. Although their yields are irregular and subject to the vagaries of rainfall, they witness to the sharp contrast between the desert of the Lower Plains and savanna type bush of the Middle Valley. Clearing of the bush and setting up of new farms may be seen in the upper reaches of the Middle Valley, in the vicinity of Welenchiti and Tibila.

It would appear highly advisable that a pilot scheme be established in this region for experiments on farming practices for rain-fed agriculture. When these practices are perfected and drinking water supply secured, an extensive development of rain-fed agriculture under settlement schemes may be justified. Further to the east, however, social conditions would appear less propitious to the inflow of settlers.

The region is only sparsely populated and there are no significant settlements along the river. Even the shores of Gewani Swamps, in many ways similar to the Asayita delta, have not stimulated any agricultural settlement. If the nomads' huts are numerous around the swamps, they are inhabited only during the dry season. When the rain comes and the swamps expand, nomads move to other grazing lands.

No settled agriculture has ever been attempted in the vast tracts of land of the Middle Valley between Metehara and Gewani, and no immigrants other than civil servants, town people or plantation workers have ever settled. Although, two plantations have been operating for many years in this region (40 and 30 years) they have not induced people to settle permanently. An attempted settlement of tenants in the Metehara concession lands, it is reported, resulted in only 40 families cultivating around 20 hectares. The labour on these plantations is almost totally imported from other regions. Workmen and their families do not take root and often act as seasonal labour. They seem to avoid intercourse with the indigenous pastoralists. There is sometimes racial tension between the two communities.

The Middle Valley is a border land between at least three tribal groups. Tribal animosities, still rather strong between nomads, partly account for the lack of immigrants from more thickly populated regions. In the foreseeable future the settlement schemes, even if Government-sponsored and subsidized, may prove difficult to start and run. Implementation may be easier, after the pioneering work has been done by the large scale farming, less vulnerable and less dependable on the social climate. This path-breaking towards sedentary agriculture may help to create better conditions for family-size farming so long as concession and lease agreements are sufficiently elastic to avoid hampering long-term development through settlements.

II. Economic Opportunities for Development

By contrast, large-scale farming seems attracted by the flow of the river, now regulated by the Koka dam, and by the relative proximity of markets along the railway line. These include not only the capital and other several important Ethiopian cities, but also the port of Djibouti. Communications were greatly improved by reconditioning the existing road Adis Abeba - Dire Dewa. They may be improved still more by constructing the highway Awash Station - Aseb, now under survey.

The distance from the potential development areas to the railway station averages less than 40 km. The high tension power line, which follows roughly the railway, can secure easy power supply to any processing activities. Private investors seem to be interested in the region. Excellent returns from the plantation of Awora Melka have stimulated a new private development project upstream of Metehara near Melka Bokara, now being implemented. The H.V.A. company, which successfully operates the Wenji Sugar cane plantation, is negotiating the taking over of the Metehara concession. A project is being prepared for completely reshaping sugar cane production including the extension of the plantation. Tendaho Share Company, which operates a large cotton plantation in the Lower Plains has also taken an option for developing a big scale farm in the area of Melka Sedi - Amibara. The Ministry of State Domain started a development scheme for producing bananas at Abadir, near Metehara. The Haile Selassie I Foundation (Welfare Trust) is developing a project for producing fiber crops, mainly cotton, on the right bank of the Kebena river. The Ministry of Agriculture is establishing the cotton experimental station on the right bank of the Awash river at Melka Warar.

A rather strong investment trend in the Middle Valley is manifest. Economic conditions appear particularly favourable for an intensive investment of capital in its agriculture, which could take the form of high capital expenditure per surface unit. Its purpose will be to make the turnover as speedy as agricultural business will allow. Two or more crops a year, a continuous occupation of the irrigable land, and almost permanent irrigation will be the objectives of capital intensive agriculture. Water saving through a perfect irrigation system may be highly economic.

III. Potential Cropping Pattern

Most types of crops usually grown under irrigation seem suitable for the Middle Valley. In general, their selection and rotations will be subject to economic rather than to agronomical conditions.

III - 1. Fiber crops

As natural fiber is now in great and steadily incrasing demand in Ethiopia, fiber yielding industrial crops are likely to attract investors.

Cotton production is actively promoted by the Government and seems well adapted to the natural conditions in the region. Good yields have been recorded in the plantations of Awora Melka and Metehara, and up to 30 quintals per hectare of seed cotton harvested on individual fields. These yields are reported to be subject to the time of planting. Cotton planted before the rainy season appears to produce higher yields. Information is scanty on the most suitable varieties and especially on the opportunity of introducing the long staple cotton, which probably requires a longer growing period.

Kenaf (Hibiscus Cannabinus) finds a ready home market for kenaf fiber. Export possibilities are also reported. Some experiments in the Middle Valley indicate that kenaf is doing well and the yields are good. As it has a somewhat shorter growing period, it can be included in rotations in which the long vegetation cycle of cotton is incompatible with those of other crops.

The steadily growing home demand for coarse vegetable fiber justifies the cultivation of sisal, which has also a good international market. It can be successfully grown without irrigation in the wet provinces of the highlands. Its growth under irrigation should be no longer authorized in the Middle Valley, when the shortage of water supply through the development of additional irrigation schemes might hinder the production of other crops.

III - 2. Oil seeds

Ground nuts (Arachis Hipogea) will have a special interest if the large-scale experimentation determines the most suitable varieties and the appropriate farming practices. Edible ground nuts are successfully grown on light texture soils of the Awora Melka plantation. Yields of 16 to 18 q/ha are reported.

Large tracts of comparable soils, mainly on the left bank of the river, seem well adapted for ground nuts. Varieties could be carefully selected for the oil industry and their production mechanized, thus supplying raw material for processing plants. The oil industry will be stimulated when ample supplies of cotton seeds and other oil-seeds may also be introduced in the region.

Soya beans probably deserve extensive field trials. Experiments were carried out in the Jima agricultural technical school, and yields of 22 to 24 q/ha were reported. Ground nuts and soya beans are both leguminous crops. To include them in the rotation of irrigated farming is highly advisable.

Castor beans should do well in the Middle Valley, where numerous native castor trees show that the natural environment is favourable. Information on possible yields is not available. No castor beans under irrigation are yet grown in Ethiopia.

Sunflower, which yields an excellent edible oil, should do well in the heavier black soils. A dwarf variety, practically unknown in the country and which may be harvested mechanically, will have to be imported and tested. Care must be taken to avoid losses caused by birds.

Small grain oilseeds like colza (Brassica Rapa), noog (Quixotia Abyssinica) and safflower (Carthamus Tinctorius) might be grown in the irrigation projects on heavier soils not suitable for other oilseeds.

III - 3. Cereals and pulses

Subsistence crops will probably not appeal to commercial farmers. Cereals and pulses should be considered as exportable grains subject to marketing conditions.

Presumably there is no agronomical limitation to the growing of the cereals, and carefully selected hybrid strains of maize would be advisable. High productivity of the hybrids may eventually offset the handicap of low unit prices and make the cultivation of maize more attractive. A particular problem relates to rice cultivation. Although good yields were reported in the Metehara plantation, its cultivation was discontinued because of heavy losses by birds.

Pulses seem to have a good market both at home and abroad. Lentils, different peas, and particularly haricot beans may interest commercial farming. Large tracts of suitable soils seem available in the irrigable areas.

III - 4. Vegetable and spices

Truck crops are successfully produced on the plantations and marketed in Adis Abeba. Although some possibilities to extend the marketing and to export fresh vegetables to Djibouti exist, their processing and canning appear essential for large scale production. Good, light texture soils appear mainly on the left bank of the river.

Red pepper (Capsicum sp.) and onions are an exportable product in fair demand, and bring profit to commercial farms. Almost all soils in irrigable areas are suitable for them.

III - 5. Fruit trees

Fruit production is a big possibility. Plantations are producing sizeable quantities of bananas, citrus, mangoes, avocato pears, papayas and grapes. Orchards and fruit production, after saturation of a slowly but steadily expanding home market for fresh fruits, may support the processing and canning plants. Exporting to Red Sea countries is also possible.

III - 6. Sugar cane

Natural conditions appear entirely satisfactory for producing sugar cane. The vegetation period might be somewhat shorter than in the higher altitude at Wenji. Sugar content is also likely to be higher. Research and experimentation will help to determine the farming practices, but three or four ratoons might be harvested.

III - 7. Fodder crops

To implement rotational forage crops, necessary to the farming pattern for agronomical reasons, may be difficult under present conditions. Nomadic live-stock breeders are not dependent, as in the Lower Plains, on the scantly sub-desert grazing lands. Extensive, fair to good pastures are located on both sides of the Awash, where herds find abundant grasses.

If the main irrigation canals bring water to the outskirts of the commanded areas, nomadic shepherds will probably water their beasts in the canals. Grazing on the pastures located further from the river will become feasible, and the putting under irrigation of the pastures contingent to the river will not call for their substitution by the cultivated forage crops.

At first it will be difficult to persuade the pastoralists to take advantage of fodder crops, but later the nomad shepherd may become associated with the irrigated agriculture.

Irrigated farms may start buying cattle when the dry season is advanced and nomadic stock is kept close to the watering points. The purchased cattle may then be intensively fed on the irrigated pastures with the help of harvested fodder. Other sources of animal food will also be available on irrigated farms. An oil-processing industry will be probably established in the irrigated areas. Cakes of oil seeds will then be available as a valuable concentrated food for "finishing off" the animals. The fattening business may be conducted through all its stages in the irrigated areas. Markets for meat cattle would be easily found, for Ethiopia is now striving to export its meat. Several projects are already operational, (e.g., the Shashemane abattoirs).

In the long range planning or farming pattern, forage crops should be included in the rotation. Though they will be principally lightly irrigated pastures, different kinds of pastures must be made available. Lean cattle reared on dry grasses must be progressively accustomed to more succulent food. Hence irrigated pastures should provide mainly grassy forage for the early stage of fattening and another rich leguminous fodder for the period of more intensive feeding. Hay crops of alfalfa and clovers, such as berseem (Trifolium Alexandrinum) may be cultivated if justified by marketing conditions.

Dairy farming is almost unknown in the Ethiopian low-lands, but irrigation projects in the Middle Valley may give a good opportunity for its development. Dairy cattle breeding might be profitable if good and abundant fodder is available. Climatic conditions seem fairly convenient and good access and transportation facilities will favour the marketing of dairy products, many of which are now imported. Their consumption is bound to increase with the growing living standards. Dairy farming, however, will call for intensively irrigated forage crops with several cuttings in a season to replace lightly irrigated pastures. Green manures may then be necessary to maintain rotational equilibrium.

III - 8. Green manures and fallows

Green manuring is not excessively popular with the farmers, chiefly because it does not provide any direct income. Many taking into account expenses for seed, irrigation and preparation of seed, prefer fallows to green manuring. It is generally believed, however, that fallowing is far less beneficial to the soil than green manuring, and that fertilizers are more efficient when applied to a soil with abundant organic matter, biologically sound and well structured.

The possibility of using green manure for feeding livestock will stimulate green manuring practices. It may be advisable to experiment with the high growing sweet clover (Melilotus sp.), which is an excellent, deep rooted, organic matter building and soil improving plant. It can supply reasonably good forage when grazed or cropped sufficiently young. The outsprouting aftermath can be ploughed under to incorporate a great amount of green matter in the soil. Green manuring with sweet clover may help to generalize the practice of ploughing under the leguminous outsprouts on the regular irrigated pastures and provide greater surfaces of grazing for implementing cattle-fattening schemes. Maintaining a high fertility status of the soils is essential to secure returns on capital invested in expensive irrigation schemes. In the Middle Valley, fallowing practices should be discouraged and green manuring strongly recommended.

IV. Rotations (See Graph 8)

Crop rotation is essential for effectively controlling soil productivity. Alternating appropriate crops in accordance with a pre-established schedule helps to keep soil in good biological condition and to control the erosion risk, increases its moisture-holding capacity, provides an adequate supply of organic matter, (thus helping to take full advantage of fertilizers), prevents the unbalanced depletion of plant nutrients, and counteracts the possible development of the toxic substances.

In irrigated farming, crop rotations help to make the most effective use of the available water resources. The overall water consumption may be more evenly spread over the whole year in accordance with the requirements of crops in the rotation. The highest intensity of the cropping pattern can be achieved by an almost continuous occupation of the land. The effective irrigation of cultivated land may last an average of 9 to 10 months a year. Suitable rotations will serve to generalize double cropping on the areas not reserved for the crops, such as sugar-cane or orchards. The raising of a long vegetation cycle crop succeeded by a short one in twelve months appears feasible, as demonstrated on the Awora Melka plantation, where ground nuts were successfully grown after cotton.

The selection of the rotational pattern and the proportion of the different crops as well as the date for starting the cycle must await extensive and systematic experimentation. Scanty information from the Awora Melka plantation about the planting time is unreliable as there is no control of the water supply at the main offtake.

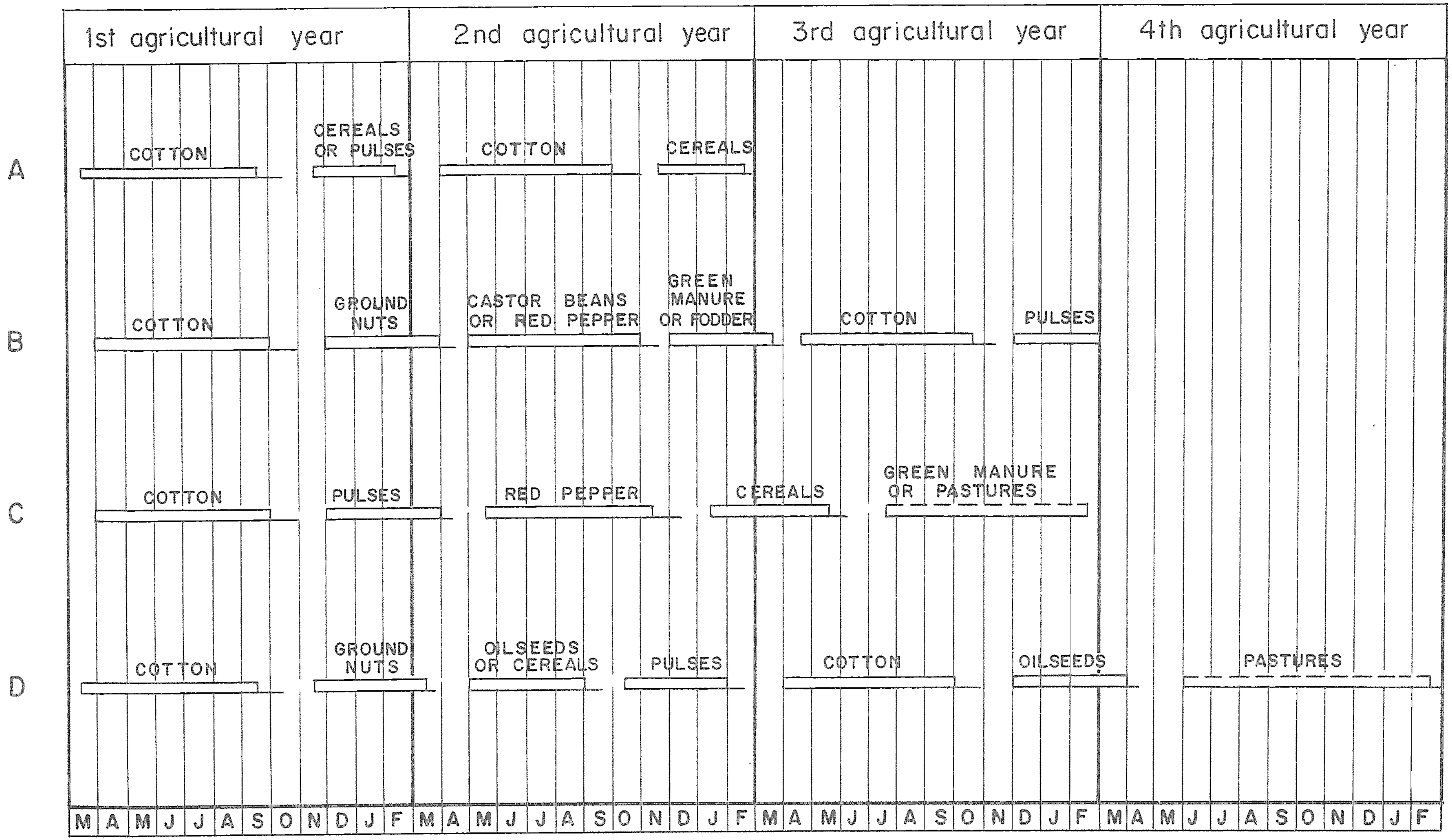
If an adequate control of water supply were available and there were no handicapping agronomical factors, the planting period might be advanced well before the rainy season and thus allow a substantial saving of irrigation water. Full agronomical information is lacking, although it is believed that the agricultural cycle in the Middle Valley would probably begin some time between March and July.

Thus rotation A is aimed mainly on cotton production. It provides for 9 months of irrigation in a year, and shows a land occupation coefficient of about 90 %. Cotton occupies the land to a proportion of about 65 %. An improving leguminous crop occurs every two years. Cereal crop at the end of the two years rotation may be omitted if a delay in cultural operations occurs. Then a similar cropping intensity may be achieved if the long staple cotton variety is introduced in the second year. Best, well aerated, light and rich soils should be reserved for this rotation.

Rotation B is more diversified and provides for a long vegetation cash crop other than cotton in the second year. It will probably accommodate to the relatively light, but not particularly rich soils. Effective irrigation will last on an average for 9 1/2 months per year. Land occupation coefficient will be about 90 %. Cotton share in the cropland amounts to 45 %. As the cash crop of the second year may be soil exhausting, a higher proportion of leguminous crops is included in the rotation. The fodder crop by the end of the second year gives the rotation some flexibility, for stand in the field can be shortened to make up for any delay due to the cultural operations.

VOL.I-DRAWING Nº 9
VOL.II-FIG.8

SUGGESTED CROP ROTATION SCHEMES
MIDDLE VALLEY



For the water requirement computations, the agricultural year has been positioned as shown on the above calendar

Normal irrigation — Land occupation — Slight irrigation

Rotation C provides for irrigated pastures, occupying the land for at least 7 months. Their irrigation is supposed to be only a light one, roughly corresponding to a half of usual depth. Waterings for this rotation will extend for about 8 months each year. Land occupation coefficient will be about 85 %. Cotton accounts for 25 % of the cropland. This rotation seems suitable for heavier soils.

Rotation D is given some flexibility by inserting two short cycle crops during the second year. This may ease the adjustment of the cultural operations. The irrigated pastures will stand in the field for about 9 months, but only light waterings must be applied. Water requirements of this rotation will correspond to slightly more than 8 months of normal irrigation. Land occupation coefficient may be about 85 %. Cotton proportion works out to about 35 %.

Permanent plantations, like sugar cane and orchards, must be irrigated all the year round, and their water consumption will be the highest. The rotational crops, most probably green manures, may occur only every 4 years on the sugar cane plantations. Cover crops will probably be recommended for the orchards.

This brief discussion has revealed a great range of the crops and rotations which may eventually prove suitable in the region. The final recommendations regarding the crops to be selected and the relative proportion to be assigned to each crop cannot be formulated until the economic conditions and the potential markets are surveyed.

V. Arboriculture

Several hot springs of appreciable discharge are located in the Middle Valley. At least four (e.g., Filweha and Kada Bilen), are in marshy areas with a slightly saline underground water. A thick growth of palm trees, (some doum palms and the others belonging to the Borassus family) are seen on the outskirts of the marshes and the pools formed by the warm springs. These palm trees may be replaced by highly productive date palm trees (Phoenix Dactylifera) which could probably raise the nutritional standards of the nomadic people. Early experimentation with them is recommended.

When planning the irrigation layout, full advantage should be taken of the riparian forest for establishing the future wind screens. High acacia trees might serve well as wind screens supplemented, if need be, by some lower type of trees.

In areas not to be put under irrigation, the existing riparian formation, which consists of rather valueless trees and shrubs, could be replaced by productive varieties of trees. Eucalyptus and poplars are quick-growing and useful species for paper pulp production and the packing industry. Both grow well with the high water-level and experiments should be made particularly in the marshy portions of the forest gallery.

C. LOWER PLAINS

I. Geographical Features

In the whole basin of the Awash river below 1,200 m of altitude, the Asayita delta is the only area of centuries-old settlement by indigenous farmers. Here agriculture is totally dependent on periodic inundations. Planting occurs when flood waters recede, but hardly any attempt towards controlled artificial waterings is now made. At present the available water resources appear sufficient to supply a few thousand hectares with irrigation water, possibly by pumping.

Recent natural changes in the hydrography of the delta resulted in the shrinkage of cultivated lands. The principal channels of the river are progressively silted up and certain areas once periodically inundated are now beyond reach of the floods. Farmers have begun to realise that a much smaller area of their cultivated land is now flooded and they ask the authorities to dredge and clean the silted channels, but this would be useless without an efficient flood control.

Farming in the Asayita delta seems closely associated with animal husbandry. It would appear that a greater part of the cattle and camels reared by the settled farmers of one of the Danakil tribes, the Madima, are not transhumant but permanently kept in the delta area or in its immediate vicinity. Animals seem to graze mainly on the non-cultivated fields and, after harvest, on stubble.

II. Present Settlement Trend

Population, both agricultural and pastoral, is relatively dense in the region of Asayita. The town itself is developing. The recent establishment in the vicinity of a concessionary cotton plantation has stimulated the peasants' interest for this cash crop, and its cultivation is rapidly spreading. Some farmers, whose land has been dried out, are reported to have moved to other, as yet marshy, tracts ; others try to settle on the shores of the Boyale swamp. A noticeable inflow of settlers from other regions of the country is taking place : they clear small plots along the river banks upstream of Asayita and develop "squatter wise" cotton cultivation. There is also a particular type of seasonal farming ; highlanders come into the region at the planting time, cultivate cotton and return to their villages just after picking and selling the crop.

New settlers from the agricultural region on the edge of the Rift valley escarpment sometimes meet acquaintances and relatives among the local people, who seem to be of mixed origin, partly descendants of old immigrants. They appear to be assimilated to the indigenous Adal tribes, mainly Madima, who are settled agriculturists. The new immigrants are likely to be rather easily assimilated with the old settlers. This favourable factor may accelerate the migration trend. The proximity of the densely populated northern povinces of Tigre and Erithrea may facilitate group migrations and a large-scale settlement.

These features have undoubtedly influenced the Government's preference to give priority to the development schemes in the Lower Plains. The establishment of a cotton ginning mill stimulates the inflow of settlers by offering marketing facilities, although the new market facilities may have merely catalysed the already existing settlement trend. The rapidity of the inflow of settlers (several hundred hectares are said to have been brought into cultivation during the last three years) is certainly influenced by the tradition of a sedentary agricultural nucleus. It indicates the region's adaptability to settlement schemes based on family size farms. For small-size farms operated by the settlers, a lower cropping intensity is more suitable. It would be also consistent with natural conditions in the Lower Plains.

The rotational pattern will probably help to determine the right size of family holdings, which should be related to the income to be derived from the irrigated surface unit and limited by labour availability. If the labour requirement for main cash crops such as cotton and red pepper is estimated at 120 to 150 working days per hectare, a family could cope with 1.5 to 2 ha of cash crop. The size of a family holding should probably not exceed 4 hectares.

The Government may be well advised to sponsor settlement schemes, and perhaps refrain from granting new concessions in the region. The already established large-scale farming may be sufficient to act as supplier of marketing facilities, improved seeds and pesticides for cotton or other crops grown by the settlers.

III. Potential Cropping Pattern

The selection of the crops for family farming, eventually to be confirmed by experimentation, should include cash crops as well as subsistence crops for family and/or local consumption. Because of the less intensive cropping pattern and relatively shorter irrigation period, the length of their vegetation cycle must be taken into account.

III - 1. Cotton and other long-cycle cash crops

The principal cash crop will be, at present, cotton which ripens in 6 - 7 months and to which most of the soils in the region seem suitable. In the future, experiments should be made with long-staple cotton. Settlers should follow the concession holders' recommendations in the selection of strains and varieties ; the planting of seed supplied by the ginning mills should be strongly urged, if not made compulsory. Pest control should also be compulsory, the whole of the area treated by plane, and hand operations applied vigorously and at the right time.

Although there is ample evidence that cotton can be planted continuously for several years, a rotational pattern might be more effective for pest control and building up organic matter, which is not plentiful in the Lower Plains. As the ploughing-under of cotton stalks is a possible hotbed for pests and insects, rotational crops appear necessary for maintaining enough organic matter in the soil.

Red pepper is also a long cycle crop and requires 6 to 7 months to ripen. It is suitable for family farms and could be grown on large areas of the soil identified in Dit Bahri and delta area.

Castor beans will probably have a vegetation period of 6 to 8 months. Although they are likely to grow well on large tracts of soils in the Lower Plains, their introduction should be preceded by a particularly careful experimentation on varieties and farming practices.

III - 2. Oilseeds

Oilseeds are mainly short vegetation crops. As Sesame is already cultivated in the delta area, its generalization therefore should not be difficult, but cultural practices need to be improved.

Particular attention should be given to ground nuts, which could probably be harvested in 4 months, or even less. Cultural experiments on the variety should be carried out on lighter soils in the delta area. They yield a sizeable amount of green leaves which may be consumed as excellent fodder or ploughed back in the soil to build up organic matter. This crop is soil improving and enriching, particularly for the family farm.

The sunflower could be profitably cultivated on heavier black soils, but experiments on the introduction of production varieties are necessary. Its vegetation period will probably be 4 to 5 months.

The safflower takes about 4 months to ripen and will grow on practically all soils in this region. Because of its thorny leaves it is difficult to harvest by hand. Its introduction on the concessions rather than on family farms would be more suitable.

III - 3. Pulses

Several species of pulses would probably find suitable conditions mainly in the delta. Some horse beans now grown could be profitably replaced on heavier soils by garden beans (Vicia Faba) for family and local consumption. Haricot beans might quite well accommodate to the lighter soils of the delta and become a subsistence crop as well as on easily marketable cash crop. The introduction of highly productive strains is recommended. The lentils and peas should be carefully considered as crops for family farming. Pulses have a short vegetation cycle and might be raised in 3 to 4 months.

III - 4. Subsistance crops

Maize is the most common subsistence crop in the delta area. Sorghum is less frequent, but its extension would probably not be difficult. Strong stands of maize have been seen even where it is grown with practically no irrigation. Plenty of soils are suitable for this crop. New strains must be introduced to shorten the unusually long vegetation cycle, now reported to be over 6 months. The introduction of hybrid maize is also advisable. Many vegetables will find suitable conditions mainly on the delta soils, and can be cultivated on family farms. Their production for local consumption should be promoted to diversify the diet and improve nutritional standards. Marketing fresh vegetables on the expanding market of aseb should be investigated.

III - 5. Date palms

Palm groves (Phoenix Dactylifera) exist at Kerem (Eritrea), at an altitude of 1,600 m, and at Aseb, at an altitude of 100 m, but the dates are of mediocre quality and locally consumed. Each year, Ethiopia imports 1,000 tons of dates valued at about E$ 200,000. This quantity could be grown on a small area of 100 to 200 hectares. Since the dates are at present considered as fruit of inferior quality, it is reasonable to assume that a market for top quality fresh dates exists particularly in Adis Abeba.

There are striking similarities of climate in the Lower Plains and in parts of the world where the date palm is cultivated. In southern Tunisia, Algeria, and the Imperial Valley of California, the average annual temperature is above 23°C, the average annual rainfall below 200 mm, and the relative humidity less than 60 %. Amounts of sunshine differ only because of a difference in latitudes : 11°30 N at Asayita and 34° N in southern Tunisia. Soil and water quality in the Asayita delta are perfectly suited to date cultivation, and a few date palms are found in the delta growing near the defluents of the Awash river (Mamule channel). They produce fruit similar to dried dates, Degla Beida palms.

The establishment of an experimental palm-grove in the Asayita delta would be a worthwhile project. Its site must be determined by the possibilities for year-round watering. The palms must grow in sandy-loam soils; i.e., in the humped river banks. A pilot experiment of 100 plants in an area of approximately 1 hectare should first be made. The trees are usually planted in April - May in squares, 10 m x 10 m.

Offshoots of the best variety (Deglet en Nour) are not easily obtainable, because each tree produces only about 20 during its hundred years of existence; they must come from the best oasis, either Tozeur in Tunisia or the experimental station at el Arfiah in Algeria. Aerial transport would be advantageous (a hundred trees with packing materials would weigh about 1.5 ton). Since the palm is a dioecious tree, each lot of 100 offshoots must include one or two male plants.

Basin or border irrigation is advisable and the annual requirement is 15 to 20,000 m3 of water per hectare. As date palms suffer in stagnant water, good drainage is absolutely indispensable, and a drain at a depth of 1.2 m every 50 m (i.e., every 5th row), must be provided.

About the fifth year after planting, the trees will bear their first fruits. The economic life of the date palm is enormous, about a century. Yields vary from 60 to 120 kg per tree for 10 to 15 date clusters, or 6 to 10 t/ha.

III - 6. Fodder crops

It is usually a tough job to insert a fodder crop in the irrigated rotational pattern, unless highly organized livestock raising, and particularly dairy husbandry, is integrated in the agricultural business. The high cost of irrigation is seldom compensated by adequate returns from the fodder crops.

In the Asayita delta, however, a significant number of cattle is actually raised by the settled farmers. Cattle are usually grazed after cropping on the cultivated plots and left until the next planting season on the fields, subject from time to time to the natural flooding. Because the farmers are already accustomed to graze their cattle on the fields after inundation, it may be less difficult to insert an irrigated fodder crop into the rotation.

Irrigated pastures can be established by sowing on a roughly prepared seedbed the leguminous and gramineae seeds. Cheap clovers and vetches may be sown together with Sudan grass (Sorghum sudanense) or other grasses with an abundant growth and easy outsprout. They will not need intensive irrigation. Several waterings only, (say, once a month), may be sufficient to maintain a fair vegetation stand. An irrigated pasture, which at first serves only for grazing, can later be progressively substituted by an actual forage crop, grazed only after several cuttings have been taken, and thus able to support more and better cattle per surface unit. This would be satisfactory for family farms.

Large-scale commercial farms must find some other approach. In the Lower Plains, cattle is raised by nomads who, by ancient custom, do not plant or buy any fodder. In the first stages of the development, cropping of fodder and marketing hay or silage may not be profitable. On the other hand, scanty pasture lands are all occupied by the pastoralists and no scope for ranching business is left to the concession holders. Some association agreement might be reached then to graze with the nomadic pastoralists allowing their cattle on the pastures sown with forage crops and irrigated by the plantation. On large farms, the fields are big enough to allow numerous cattle to graze and still keep it at a distance from the canals, ditches and drains, thus avoiding damage to irrigation structures by trampling.

At first, this association would bring almost no cash income to the plantation, but it would make for good neighbourliness and help to maintain and increase soil fertility. The cow dung left in the field would be beneficial as green manure and less expensive.

III - 7. Green manures

For large-scale farming green manuring may be an alternative to irrigated pastures. Suitable varieties of green manures and the adequate irrigation depths can be determined after careful experiment. Deep-rooted forage plants such as alfalfa, different clovers and grasses aerate the soil and, by their root residues, increase the organic matter content.

Advantage might be taken of Sesbania sp., a leguminous plant which grows spontaneously in the region. Very beautiful and abundant growth has been observed on some fields, before they have been taken into cultivation, in the hollows where water was accumulating after the rains. It grows up to two meters high as a weed in cultivated cotton fields. It provides a palatable forage for cattle, and particularly for the camels. Only the tender leaves are eaten and the stalks left in the field, so that, when ploughed under, they provide substantial organic matter. On big-scale farms in the Lower Plains, slightly irrigated fields of Sesbania may solve the problem of including improving leguminous plants in the soil rotation.

Fallowing is not advisable in the area. Without irrigation, no vegetation grows on the so called "green fallows". They remain a barren land, so that practically no build-up of organic matter will result from fallowing. Cultivated fallow is supposed to facilitate intake of rain moisture in dry farming, but rainfall is too erratic and too scanty to allow any sizeable accumulation of moisture on it.

IV. Rotations. (See Graph 9).

A selection of rotations cannot be made, even tentatively, without extensive experimentation, but a few guiding principles can be indicated.

The natural conditions and available water resources of the Lower Plains make it advisable that, in the early stages of development, crops should not stand in the field for more than eight months a year. This means an irrigation period of no more than six to seven months. This is also consistent with the general farming pattern which, as suggested, will probably develop in large Government-sponsored settlement schemes. Thus either one crop with long vegetation cycle or, at most, two crops with short vegetation cycle should be planted each year.

Rotations for the Lower Plains may be based mainly on cotton as a cash crop. Other cash crops will probably be needed for family farming only.

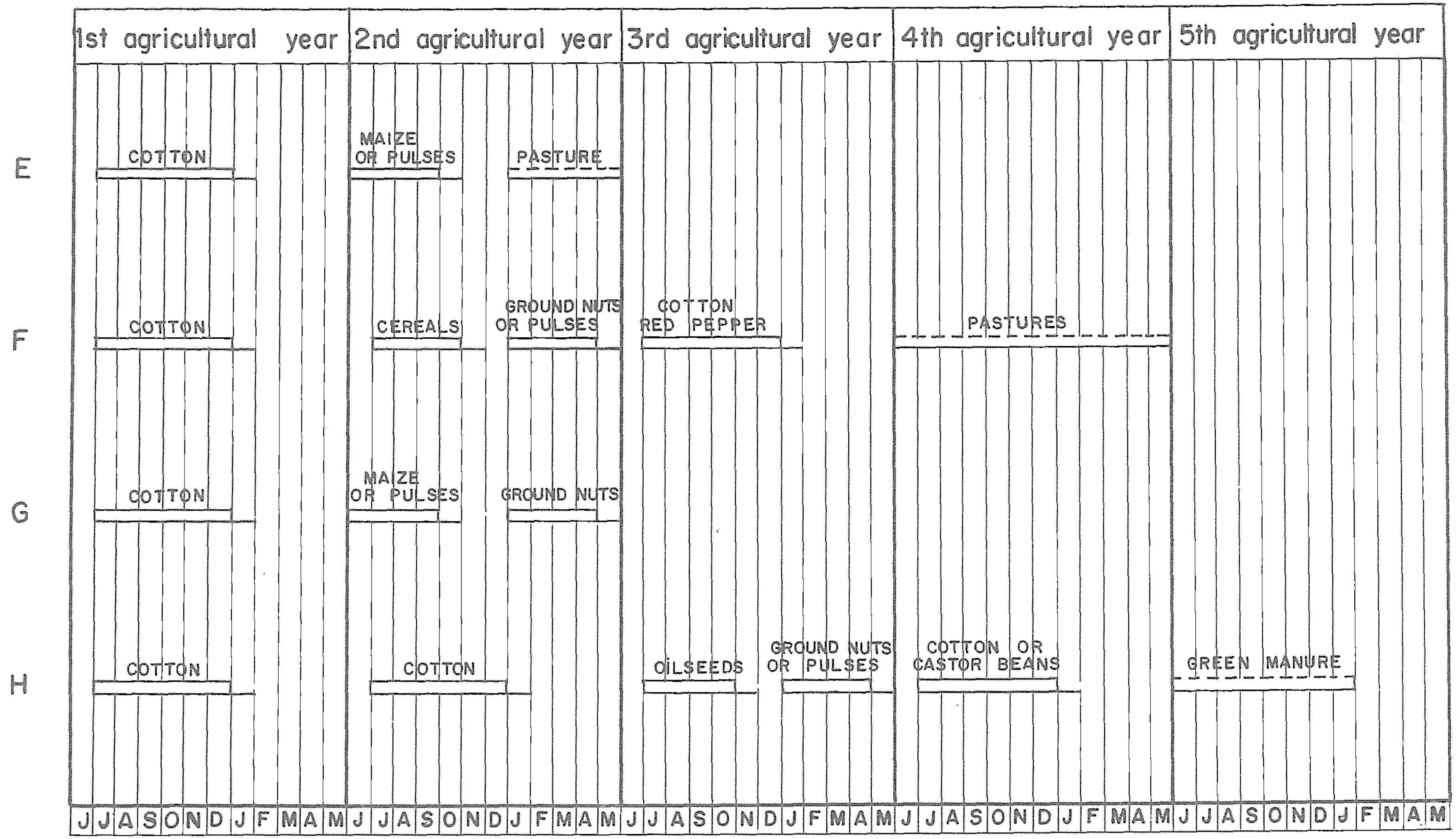
To determine the agricultural cycle and the most suitable planting time must be the task of experimental stations. Experience of a high flow of the river and its flooding periods developed planting practices which may be discarded where the water supply is plentiful. For the transitional period and before the discharge of the river is under effective control, the planting season for the long vegetation cycle crops will probably be between July and August. The short cycle crops may perhaps be planted early in February or March, when the discharge of the river noticeably rises. Because of the lack of agronomical information the few examples of rather intensive rotations shown on Graph 9 should be regarded as a tentative suggestion for experimental work in the Lower Plains. Other less intensive rotations can be implemented if they will call for less water supply and provide more time for the farm operations between the subsequent crops.

Rotation E is suggested for the early stage of development mainly on family farms. It gives flexibility, in that, time for harvesting and preparing the successive crops is plentiful. Provision for an irrigated pasture every two years would probably maintain an adequate fertility status without application of fertilizers. Thus it may be suitable for any irrigable soil. Pastures are supposed to be slightly irrigated (at a half the usual depth), so that water consumption will correspond to an irrigation during 6 months per year. Land occupation coefficient will be roughly 70 %, cotton proportion in the cropland about 40 %.

Rotation F also appears suitable for family farming. More skill will be required from the farmers because, in the second year, two short cycle crops are to be raised. A leguminous crop occurs at the end of the second year and an irrigated

VOL.I - DRAWING Nº 10
VOL.II - FIG. 9

SUGGESTED CROP ROTATION SCHEMES
LOWER PLAINS



For the water requirement computations, the agricultural year has been positioned as shown on the above calendar

Normal irrigation — Land occupation — Slight irrigation pasture only every fourth year. Thus the rotation will probably be for the relatively richer soils. Yearly water requirements will correspond to about 6 1/2 months period of irrigation. Land occupation coefficient amounts to 75 %. Cotton proportion of cropland amounts to 40 %, if it is planted also in the third year.

Rotation G is the adaptation of the rotation A used on the commercial farms. It may be advisable for the poorer lands on which cotton should occur only every other year. The fertility status may be maintained by the frequently occurring leguminous rotational crops instead of fodder crops. Irrigation will spread during 7 months per year. Land occupation coefficient will be 70 %, cotton proportion in the cropland 40 %.

Rotation H is more differentiated and might be profitable for the commercial farms. Cotton occurs three times if it is planted on the fourth year, and occupies 50 % of the cropland. Short vegetation crops (legumes), in the third year preceding immediately the long cycle cash crop should help to keep the soil in good fertility status. Green manuring occurs every fifth year, thus improving the chances of the two subsequent crops of cotton. Land occupation coefficient is about 70 %; water consumption corresponds to an average irrigation period of about 6 1/2 months per year. An alternative derived from this rotation provides for two successive cotton crops followed by a leguminous crop like peanuts. Though it has been introduced in early development stage, the agronomical conditions are not yet fully known.

Other different rotations should be devised and examined for the Lower Plains before a definite cropping pattern is formulated.

XIX. ESTIMATED IRRIGATION WATER REQUIREMENTS

XIX - 1. Introduction

In the absence of experimental data regarding crop water requirements under various weather conditions in the Awash Basin, these will be evaluated by calculations which include climatological factors.

Annual rainfall in the Upper Basin above 1,500 m is fairly abundant. It varies between 800 mm and 2000 mm, so that irrigation is only one means of improving agricultural production. But in the lower regions of the Basin, (the Middle Valley at 600 m to 1000 m altitude between Metehara and Gewani, and the Lower Plains at between 300 and 400 m altitude between the Mile confluence and the Asayita Delta), insufficient rainfall makes irrigation essential for agricultural development. Here it is most important to know the water requirements.

Most climatological observation stations are in the Upper Basin. The few stations elsewhere have been operational only for a short time. Water requirements for the Upper Basin could be calculated from the substantial mass of available climatological information. It could provide a fairly reliable approximation of the geographical distribution of the data and show how they vary with time; but such a vast study is outside the scope of the present project. The Upper Basins water requirement estimate will be illustrated only with a few reference data. For the Middle Valley and Lower Plains, as much information as possible will be derived from the small quantity of available data. They will be compared with data for the Upper Basin.

XIX - 2. Calculation of Potential Evapotranspiration

A first step in studying water requirements is to determine potential evapotranspiration. This gives the quantity of water required for maximum crop production.

XIX-2 1. Formulas used

Two formulae have been used to calculate potential monthly evapotranspiration:

(i) The well-known Blaney-Criddle formula is :

$$ETp = 0.254\ K\ (1.8\ t + 32)\ P$$

where :

ETp Potential monthly evapotranspiration in millimeters,

t Mean monthly air temperature in °C,

P Daylight factor,

K A coefficient depending on the type of crops and general climate. K = 1, which refers to evaporation from an open sheet of water, has been taken as the upper limit. A lower figure could have been chosen for certain specific crops (0.65 for cotton in an arid zone).

(ii) Turc's formula is more recent. It applies to almost any climate and, providing the crop adequately covers the ground, is independent of the plant species grown. It is :

$$ETp = 0.4\ \frac{t}{t + 15}\ (Ig + 50)\ (1 + \frac{50 - hr}{70})$$

where :

Ig Total direct and diffused solar radiation in small calories per square centimeter horizontal surface per day;

hr Percent relative humidity (only taken into account if less than 50 %).

XIX-2 2. Necessary climatological data

The basic climatological data used in applying the above formulae have been taken from the climatological study discussed in the second part of volume three, and are listed in Table 29.

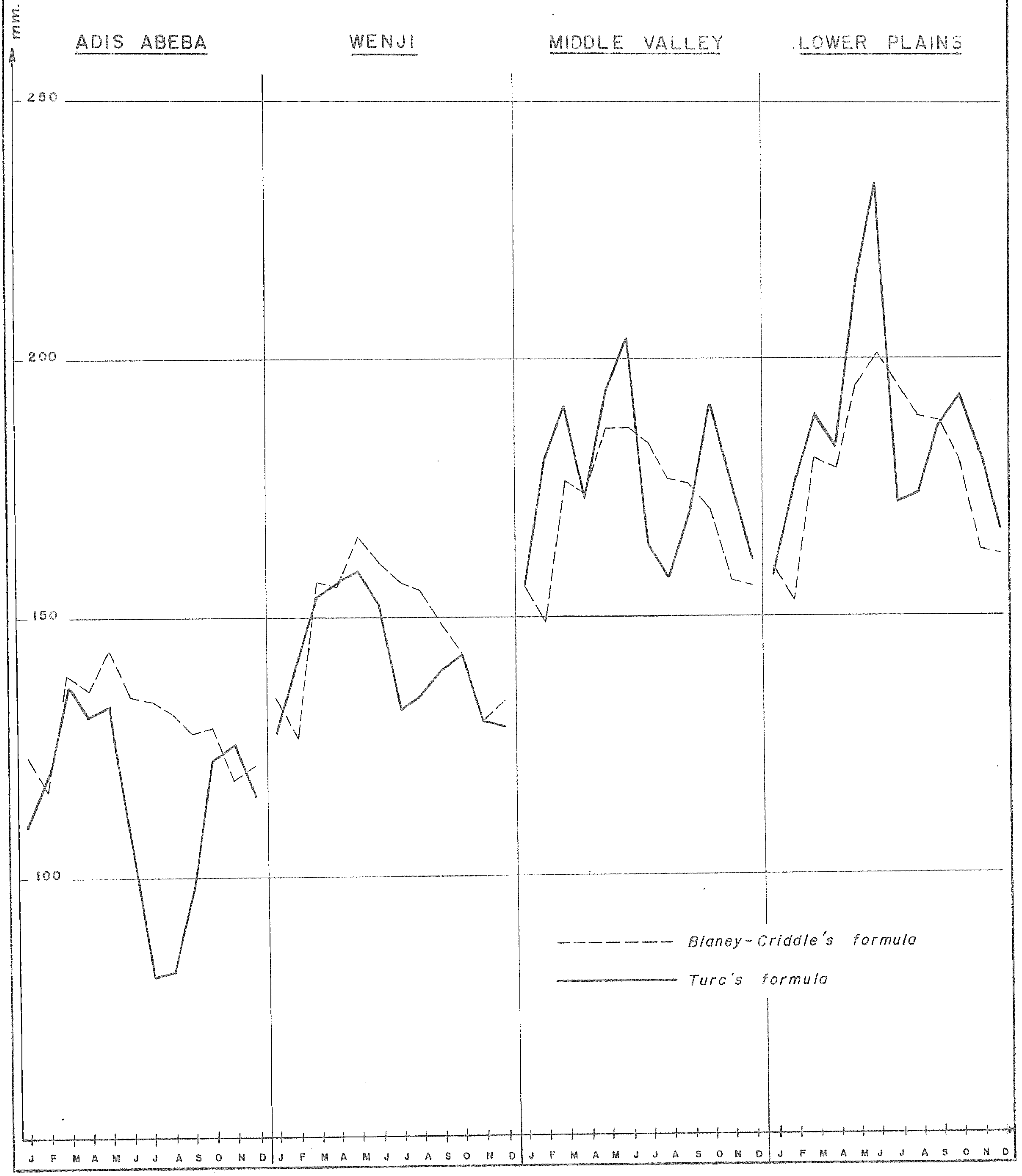
The data for Adis Abeba and Wenji provide a reference for conditions in the Upper Basin at about 2,500 m and 1,500 m altitude. The temperature and rainfall data are mean values from measurements covering fairly long periods at each station; The total solar radiation data also come from direct measurements, but over shorter periods. No relative humidity data are quoted, as this is at least 50 % throughout the Upper Basin.

Application of the formulae to the four climatological stations in the Middle Valley (Metehara, Awash airport, Awora Melka and Gewani) shows slight discrepancies between the annual potential evapotranspiration data. For instance, Turc's formulae

VARIATION OF MONTHLY

FIG. 10

POTENTIAL EVAPOTRANSPIRATION VALUES



applied to the two extreme stations (Metehara and Gewani) gives 2,045 mm and 2,181 mm. The data for Awora Melka are representative of conditions throughout the Middle Valley to within 4 per cent. They will be adopted for present purposes.

The only climatological data available for the Lower Plains are those common to Dubti and Asayita, which represent the two 'development poles' of this region.

All the data used represent normal conditions, and also yield evapotranspiration values.

XIX-2 3. Calculation results

The calculated potential evapotranspiration data are listed in Table 30 and plotted on a graph for comparison. The following points should be noted :

(i) Respective annual values supplied by the two formulae do not differ very appreciably, i.e., by 14 % for Adis Abeba, by 4 % for Wenji, by 3 % for the Middle Valley, and by 4 % for the Lower Plains.

(ii) Throughout the Awash Valley, Blaney-Criddle's formulae gives less scattered values than Turc's.

(iii) In the Upper Basin, values calculated by Blaney-Criddle's formulae are generally higher than those given by Turc's. The opposite applies in the Lower Plains.

(iv) Evapotranspiration calculated by Turc's formulae shows more pronounced month-to-month modulation than by Blaney-Criddle's. There is a fairly similar trend to that associated with evaporation from a free water surface.

Turc's formulae will be given the final preference, for it yields more representative monthly potential evapotranspiration variation data. This is because it also allows for essential climate factors (especially solar radiation) in addition to temperature. The study of evaporation from a free water surface (discussed in Volume Three) shows a mutual relationship between this type of evaporation and solar radiation.

Neither formula directly allows for altitude and atmospheric pressure. Just as evaporation from an open expanse of water increases with decreasing atmospheric pressure, so may potential evapotranspiration become increasingly higher with altitude than those given by the usual formulae; but even if this assumption turned out to be true, it would still hardly affect the calculation of plant water requirements in the irrigation areas, for they are all below 1,000 metre altitude.

The important point is that the data finally adopted and used to estimate irrigation water requirements in the Middle Valley and Lower Plains will, in principle, all represent normal conditions. Climatological data so far available for these regions are too few for determining the series of evapotranspiration values for various degrees of probable occurrence.

Table 29. Climatological Data Used in the Computations of the Water Requirements

Months		J	F	M	A	M	J	J	A	S	O	N	D	Year
UPPER BASIN	t(°C)(1902-39)	15,8	16,9	18,1	17,7	18,1	16,6	15,3	15,2	15,6	15,8	15,3	15,3	16,3
ADIS ABEBA	Ig(cal/cm2-d)	485	515	585	555	560	445	350	355	430	550	575	525	495
Climatological Institute	P(mm)(1902-39)	15,4	39,3	62,1	83,3	92,0	132,6	276,5	291,3	197,5	24,4	14,6	6,3	1235,3
UPPER BASIN	t(°C)(1951-59)	18,6	19,8	22,7	22,9	23,5	23,2	21,0	20,9	21,2	19,5	18,4	18,6	20,9
WENJI	Ig(cal/cm2-d)	530	575	590	600	600	575	515	530	550	575	540	535	560
	P(mm)(1951-59)	9,2	22,0	47,4	75,6	31,9	70,2	206,5	193,6	93,4	37,9	1,1	10,2	799,0
MIDDLE VALLEY	t(°C)	24,4	26,6	27,9	27,6	28,8	30,0	27,9	26,6	28,2	26,8	25,8	24,6	27,1
	Ig(cal(cm2-d)	580	610	635	620	630	620	580	565	600	600	580	580	600
AWORA	hr (%)		45	45		44	40				40	43	48	
MELKA	P (mm)	17,6	21,2	37,2	56,8	27,4	23,6	93,5	131,0	52,3	10,6	12,7	6,1	490
LOWER PLAINS	t(°C)	25,3	27,6	28,8	28,8	30,8	33,5	30,6	29,4	31,4	29,4	27,4	26,2	29,1
	Ig(cal/cm2-d)	580	610	650	645	650	630	590	605	640	630	605	590	620
DUBTI	hr (%)		48	48		40	33				45	45	48	
ASAYITA	P (mm)	6,9	7,2	17,4	58,0	18,7	6,1	50,0	85,5	58,2	6,7	3,2	2,1	320

Table 30. Potential Consumptive Use in the Awash Basin

Depth of water in mm		MONTHS												
		J	F	M	A	M	J	J	A	S	O	N	D	Yearly Total
UPPER BASIN	Blaney-Criddle	124	117	139	136	144	135	134	132	128	199	119	122	1559
ADIS ABEBA	Turc	110	120	137	131	133	104	81	82	98	123	126	116	1361
UPPER BASIN	Blaney-Criddle	135	127	157	156	166	161	157	155	149	143	130	134	1770
WENJI	Turc	128	142	154	157	159	152	132	135	140	143	130	129	1701
MIDDLE	Blaney-Criddle	156	149	177	174	187	187	184	177	176	171	157	156	2051
VALLEY	Turc	156	181	191	173	194	204	164	157	170	191	175	161	2177
LOWER	Blaney-Criddle	160	153	181	179	195	201	195	189	188	181	163	162	2147
PLAINS	Turc	158	176	189	183	215	234	172	174	187	193	182	167	2230

XIX - 3. Basic Irrigation Water Requirements

Water requirements (Bi) per hectare of land actually irrigated at the head of the irrigation network are found by subtracting available rainfall (Pu) from potential evapotranspiration (ETp) and dividing the difference by the overall irrigation efficiency :

$$Bi = \frac{ETp - Pu}{\flat}$$

Useful rainfall (Pu) is the amount of rain water the radicular zone is able to hold; i.e., the part of the total rainfall (P) not lost by surface runoff or deep infiltration. Assumptions are that $Pu = 0.7\ P$ for $P > 10$ mm, and that $Pu = 0$ for $P < 10$ mm.

The values of P considered were the normal values listed in Table 31. With more complete information on climate conditions in the irrigation areas it might have been possible to determine a particularly dry year, instead of a normal one, so as to achieve a more reliable estimate of water requirements.

The formulae are meant to give a maximum evapotranspiration figure (i.e., one conducive to maximum crop growth), but yields do not usually fall far below their maximum values, even for a large reduction in the water supplied to the land. This means that the best yields are not obtained under sub-normal rainfall conditions.

To allow for irrigation water conveyance and application losses, it is assumed that the irrigation efficiency (i.e., the ratio between quantities of water actually used by the crops and those supplied at the head of the network) is 70 %. This is a suitable average figure for irrigating crops for the development areas by an earth canal system; but, an efficiency of only 60 % is assumed for the Lower Plains. If the family farms prevail in that area, the same high degree of water economy will not be attained as with the large commercial farms.

XIX - 4. Irrigation Water Requirements With Crop Rotation

Various crop-rotation plans were suggested for the Middle Valley and Lower Plains in the foregoing study of prospective land use in the irrigated areas. To enable month-by-month irrigation water requirements to be calculated, the following dates have been chosen for the beginning of the agricultural year, as shown in Table 32 : 1st March for the Middle Valley, and 1st June for the Lower Plains.

The monthly water requirements for each rotation plan can thus be calculated, giving the results listed in Table 32. For the Middle Valley, this Table gives the water requirements for plans A, B, C, and D and, on line P, for a field under such virtually permanent crops as sugar cane or fruit trees. Their water requirements are assumed to amount to 90 % of the basic requirements.

The estimated irrigation water requirements were computed to allow for crop rotation by taking the arithmetic mean of the water requirements for all the crop rotation schemes for each region, i.e., :

$$\frac{A + B + C + D + P}{5}, \quad \text{for the Middle Valley}$$

$$\frac{E + F + G + H}{4}, \quad \text{for the Lower Plains}$$

Table 31. Basic Irrigation Water Requirements (Without Considering Crop Rotations)

Depth of water in mm		J	F	M	A	M	J	J	A	S	O	N	D	Yearly Total
UPPER BASIN	ETp	110	120	137	131	133	104	81	82	98	123	126	116	1361
	Pu	11	28	43	58	64	93	194	204	138	17	10	0	860
ADIS ABEBA	ETp - Pu	99	92	94	73	69	11	-113	-122	-40	106	116	116	501
	Bi	142	131	134	104	99	16	0	0	0	0	166	166	967
UPPER BASIN	ETp	128	142	154	157	159	152	132	135	140	143	130	129	1701
	Pu	0	15	33	53	22	49	145	136	65	27	0	7	552
WENJI	ETp - Pu	128	127	121	104	137	103	-13	-1	75	116	130	122	1149
	Bi	183	181	173	149	196	147	0	0	0	104	186	174	1493
MIDDLE VALLEY	ETp	156	181	191	173	194	204	164	157	170	191	175	161	2117
	Pu	12	15	26	40	19	17	66	92	37	7	9	0	340
	ETp - Pu	144	166	165	133	175	187	98	65	133	184	166	161	1777
	Bi	206	237	236	190	250	267	140	93	190	263	237	230	2539
LOWER PLAINS	ETp	158	176	189	183	215	234	172	174	187	193	182	167	2230
	Pu	0	0	12	41	13	0	35	60	41	0	0	0	202
	ETp - Pu	158	176	177	142	202	234	137	114	146	193	182	167	2028
	Bi	264	294	295	237	335	390	228	190	244	322	304	278	3381

Note : When ETp-Pu is negative, which is the case in the Upper Basin during the rainy period, a reserve of moisture builds up in the soil which can be used by the crops. This moisture attains a maximum of 100 mm. During the months immediately after the rainy season, when ETp-Pu has become positive again, allowance is made for the gradual consumption of this water by the crops, when working out the water requirements Bi.

Table 32. Irrigation Water Requirements (For Crop Rotations)

m3/ha		MONTHS												
		J	F	M	A	M	J	J	A	S	O	N	D	Yearly Total
MIDDLE VALLEY	Bi	2 060	2 370	2 360	1 900	2 500	2 670	1 400	930	1 900	2 630	2 370	2 300	25 390
	A	2 060	1 185	590	1 900	2 500	2 670	1 400	930	1 425	0	1 185	2 300	18 145
	B	2 060	2 370	1 180	950	2 500	2 670	1 400	930	1 900	1 315	0	2 300	19 575
	C	1 373	1 778	1 573	1 267	1 667	1 780	1 050	775	1 583	1 315	790	1 150	16 101
	D	1 803	1 333	1 180	950	1 875	2 336	1 225	814	950	658	1 185	2 013	16 322
	P	1 854	2 133	2 124	1 710	2 250	2 403	1 260	837	1 710	2 367	2 133	2 070	22 851
	bi	1 830	1 760	1 330	1 355	2 158	2 372	1 267	857	1 514	1 131	1 059	1 967	18 600
LOWER PLAINS	Bi	2 640	2 940	2 950	2 370	3 350	3 900	2 280	1 900	2 440	3 220	3 040	2 780	23 810
	E	660	735	738	593	838	1 950	2 280	1 900	2 440	1 610	1 520	1 390	16 654
	F	990	1 103	1 106	889	419	488	1 995	1 663	2 135	2 818	1 900	1 738	17 244
	G	1 320	1 470	1 475	1 185	0	1 950	2 280	1 900	2 440	1 610	1 520	1 390	18 540
	H	792	588	590	474	0	390	2 052	1 710	2 196	2 898	2 128	1 946	15 764
	bi	941	974	977	785	314	1 194	2 152	1 793	2 303	2 234	1 767	1 616	17 050

Bi – Basic water requirement per hectare regardless of rotation.
A, B, C, etc. : Basic water requirement per hectare for rotation A, B, C, etc.
bi – Potential water requirement per hectare for cropping plan.

COMPARISON BETWEEN MONTHLY WATER REQUIREMENTS IN THE MIDDLE VALLEY AND LOWER PLAINS

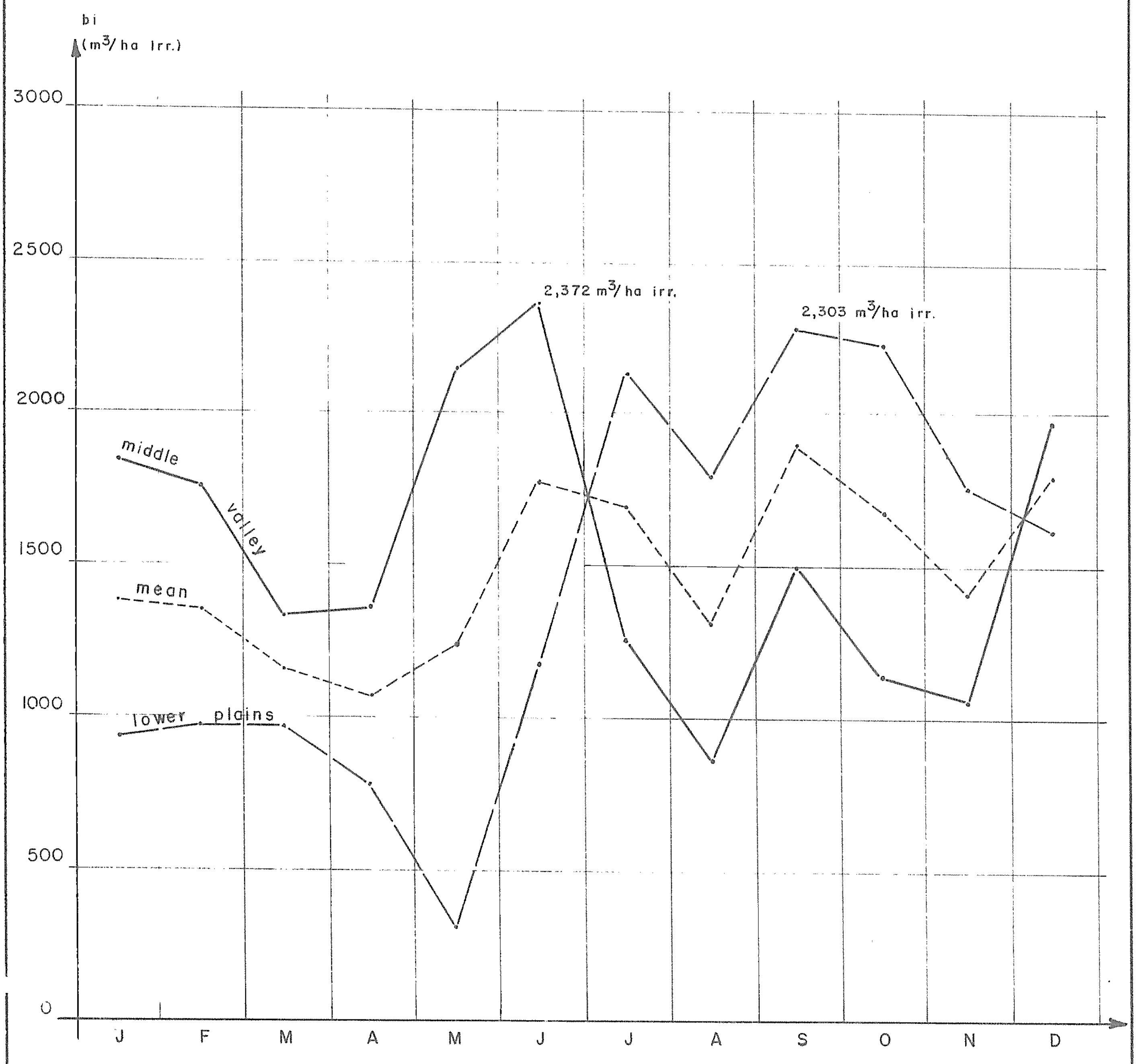


FIG. 11

This assumes that all the selected crop rotation schemes can be considered with equal probability in a sufficiently large area (say, a few thousand hectares). Average characteristics would be :

Irrigation intensity	(Middle Valley	87 %
	(Lower Plains	72 %
Proportion of cotton	(Middle Valley	34 %
	(Lower Plains	34 to 43 %

The calculated crop rotation water requirements (bi) are listed in the Table 32. The total annual requirements $\sum$bi for the Middle Valley (18,600 cu.m/hectare irrigated) are higher than for the Lower Plains (17,050 cu.m/hectare irrigated), despite the substantial difference between the basic water requirements $\sum$ bi (25.390 and 33,810) cu.m per irrigated respectively). This is evidently because cropping intensity considered for the Lower Plains is distinctly lower than for the Middle Valley. (See chapter XVIII).

The highest values of (bi) occur at different months in the Middle Valley (2,372 cu.m per irrigated hectare in June) and in the Lower Plains (2,303 cu.m per irrigated hectare in September). This is shown in the Graph 11, which illustrates the well-balanced water requirements in all the various irrigation areas.

Where saline land is to be reclaimed, as in part of the Lower Plains, the irrigation water requirements should in principle be increased by 20 % - 25 %. No oversizing of canals will be required, for, once the 'infrastructure works' are built and the canals and drainage ditches dug out to the standard dimensions, the best available land may be cultivated and normally irrigated. Saline tracts may be leached with excess water supplied by standard size canals and not required so far for irrigation. Once the land is leached, systematic cultivation can be undertaken and developed, with irrigation requiring only normal quantities of water.

'Maintenance' leaching is recommended to prevent renewed contamination of reclaimed land by salt due to irrigation. This applies to any irrigation area supposed to contain readily drainable soils. The operation should be carried out about once every two years by less frequent application of significantly higher irrigation water quantities.

This may be done by applying for every single watering a greater depth of water than is justified by the soils' water holding capacity (e.g., 1000 to 1500 cu.m). Part of this water will infiltrate deep in the subsoil and wash down soluble salts from the rooting zone. An objection might be that during the longer intervals between the successive waterings, overall water supplies to the cultivated crops will be less than the potential evapotranspiration requires; but as this is a maximum requirement, there would be no reason to expect a major drop in yields, even with an appreciably lower allotment.

To sum up, therefore, no increase will be applied to the previously calculated irrigation water requirements, for they should easily cover all soil leaching requirements.

XIX - 5. Practical Irrigation Features

XIX-5 1. Water requirements in terms of commanded area

The figures so far computed apply to the net irrigable area. To express water requirements in relation to the commanded area, it is assumed that about 10 % of the land will be occupied by canals and irrigation structures. Allowing for 90 % of net irrigable area in the projects, the figures to be considered - especially when comparing water requirements and available resources and ascertaining their needs for control - will have to be adjusted. Following are the assumed monthly water requirements (bd) expressed in cu.m. per hectare of commanded area.

Months	J	F	M	A	M	J	J	A	S	O	N	D	Year
Middle Valley	1645	1585	1195	1220	1940	2135	1140	770	1365	1020	955	1770	16740
Lower Plains	845	875	880	705	285	1075	1935	1615	2075	2010	1590	1455	15345

These figures apply only to areas above a certain size (i.e., a few thousand hectares) and to a cropping pattern in which all previously discussed rotations are considered in roughly equal proportions. On smaller areas, particularly where the cropping pattern will differ from the one assumed in this Chapter, more detailed studies of wâter requirements are needed. Specific water requirements for the selected rotations and/or crops, allowing for the quality of the soils, methods of farming and irrigation (whether on a family, co-operative, or large plantations basis), etc., would have to be considered.

XIX-5 2. Nominal specific discharge

In dimensioning an irrigation network, it is important to select a 'nominal' rate of supplied flow. This depends on :

(i) The peak month water requirement (bd), i.e. 2,135 cu.m. per hectare of the commanded area, occurring in June for the Middle Valley, and 2,075 cu.m/hectare in September for the Lower Plains.

(ii) The effective water application time during the peak months, i.e. 18 hours out of every 24. Such a long irrigation day must be limited to the peak month only.

The calculations give the following figures :

Middle Valley : 1.10 l/sec. per hectare of commanded area.
Lower Plains : 1.07 l/sec. per hectare of commanded area.

Only one value - 1.1o l/sec./hectare of commanded area - will be considered in the irrigation study discussed in Volume V. This rate of flow should be applied for dimensioning the canals and structures fed from equalizing reservoirs, in which water needed for irrigation during 18 hours may accumulate all through the day and night.

In dimensioning structures for smaller irrigation areas (e.g., a few hundred hectares) it is prudent to assume that crop rotation schemes with maximum water requirements will run throughout them. The nominal discharge at their head should be equivalent to the peak monthly water application, i.e. :

2,670 cu.m/hectare irrigated in June in the Middle Valley :

$$\frac{2,670,000 \times 0.9}{30 \times 18 \times 3,600} = 1.235 \text{ l/sec/hectare}$$

2,898 cu.m/hectare irrigated in October in the Lower Plains

$$\frac{2,898,000 \times 0.9}{31 \times 18 \times 3,600} = 1.295 \text{ l/sec/hectare}$$

For practical purposes, a figure of 1.30 l/sec/hectare will be considered throughout.

XIX-5 3. Depth and frequency of watering

Although reliable field watering data can only be ascertained experimentally and from practical experience, it is useful to indicate the possible quantities required in preparing the irrigation layout.

For certain soils with low water holding capacity, it is advisable to select an irrigation schedule which provides frequent, but rather light, waterings with the delivery of water quantities not exceeding 600 cu.m per hectare. With an allotment of 500 - 600 cu.m in peak monthly requirements - June in the Middle Valley (2,670 cu.m per hectare for rotations A and E) and October in the Lower Plains (2,898 cu.m for rotation H) - may be delivered in five waterings at six days' intervals. A fairly substantial 'pre-irrigation', however, must be applied before planting. The depth of the 'pre-irrigation' may be as much as 1000 - 1500 cu.m per hectare. This the ground should be able to absorb through its shrinkage cracks which are wide open at that time. Waterings after planting can be lighter and the balance of monthly water requirement delivered without inconvenience and up to the schedule.

XIX-5 4. Watering discharge and irrigation unit

Delivery rate should be fairly high for 'pre-irrigation', and 60 l/sec seems adequate. To divide this discharge into, say, two discharges of 30 l/sec would be advisable for applying the normal quantities of water conveniently.

During the peak months, (i.e., when the 'hydromodule' will be 1.3 l/sec/ha, at the field offtake, with a watering discharge of 60 l/sec (or two of 30 l/sec)) it is possible to ensure continuous irrigation of the following area :

$$\frac{60}{1.3} = 46 \text{ hectares of commanded area}$$

For the purpose of designing the preliminary lay-out the irrigation areas will be divided up into units not exceeding 40 hectares in size (which coincides to one gasha).

XX. CHEMICAL COMPOSITION AND QUALITY OF IRRIGATION WATER

The chemical composition of the water in the catchment area has been studied in relation with the soils and their development under irrigation, for which the following were considered :

(i) The Awash and its tributaries. A distinction was made between :

- (a) the Upper Basin : areas upstream from Koka dam ;
- (b) the Middle Valley from Metehara to Tendaho; and
- (c) the Lower Plains from Tendaho to Lake Abe.

(ii) Ground water, including shallow water tables (8 - 10 m), deep water tables (25-30m), and warm salt springs partly supplying tributaries of the Awash. The temperature of the warm springs generally varies between 40°C and 60°C, but reaches 100°C at the Alalabeda geyser in the Lower Plains.

(iii) The Koka reservoir (Gelilea Lake) and marsh lakes fed by the Awash.

Analysis results are listed in the Appendix 9 for water samples from various gauging stations on the Awash and its tributaries, also for ground water and lake and marsh water samples.

River water chemical composition variations were studied in relation with the river gauging periods at the stations equipped for hydrological survey measurements (see Volume III). This study includes : (a) Salinity variation with silt content, and (b) Chemical composition of water for various sediment concentrations in the Upper Basin, Middle Valley and Lower Plains.

XX - 1. Salinity Variation With Sediment Content

Electrical conductivity data (mmhos/cm at 25°C) are plotted on Graph 12 against sediment content (grammes/litre) for water samples taken at various stations and times of the year (low water and flood periods). Graph 12 shows in its lower part how these two quantities vary when silt concentrations are low, which is usual at low water.

XX-1 1. Low sediment (less than 0.15 gramme/litre)

The Awash above Teji (station 1), the left-bank tributaries in the Upper Basin (e.g., the Upper Kesem (station 14-15), the Upper Kebena (station 12) - and the right-bank tributaries - e.g., the Arba Dima (station 29) - generally show low salinity, with electrical conductivities always between 0.1 and 0.2 mmhos/cm at 25°C. The Meki River (station 27) is in this category.

Salinity varies more below Teji - i.e. between Melka Kentare and Metehara - with higher rates at the beginning of and during the dry season, also at the onset of the rainy season. Conductivity rates vary between 0.15 and 0.35 mmhos/cm, which is probably related to the less regular rainfall and the existence of saline sedimentary formations in the area. At low water, conductivity rates in the Mojo - a left-bank tributary draining a more gently sloping catchment area - to exceed 0.3 mmhos/cm, and may be as high as 0.5 mmhos/cm. At rising flood condition, when the sediment concentration of this river exceeds 10 grammes/litre, its conductivity decreases to 0.2 mmhos/cm.

Downstream from the Koka dam, conductivity rates exceed 0.25 mmhos/cm, due to fairly considerable saline inflows from salt springs (Bulbula, Sodere). Salinity at Metehara is not very high (conductivity less than 0.25 mmhos per cm) due to low-conductivity inflows from right-bank tributaries (e.g., the Geleta, with less than 0.2 mmhos/cm). Salinity falls off when the Awash is in spate with conductivity less than 0.25 mmhos/cm.

After Awash Station in the Middle Valley, salinity rates increase and conductivity invariably exceeds 0.25 mmhos/cm. The latter decreases to below this figure when the river is in flood. Rates in the affluents at their point of entry into the recent alluvial area are invariably over 0.25 mmhos per cm, and frequently reach 0.35 of 0.40 mmhos/cm due to the presence of warm springs (Upper Kesem, Fil Weha, Lake Hertale outlet). Average salinity in the Awadi is equivalent to a conductivity rate of about 0.35 mmhos/cm.

The left-bank tributaries of the Awash below the Kesem and Kebena confluence (especially the Jawaha, Jara and Borkena) are partly fed by warm salt springs in the Robi Borkena rift valley. Salinity is particularly pronounced in the Borkena, with conductivity rates as high as 0.6 mmhos/cm where the river leaves the swamps after receiving inflows from the warm springs. These rates fall off very rapidly at flood condition (conductivity less than 0.25 mmhos/cm).

Downstream from Gewani, where Lake Gedebasa is in communication with the Awash at certain periods, conductivity rates are apt to reach 0.4 mmhos/cm during the dry season.

Silt contents in the Lower Plains appear to be invariably high, with medium salinity throughout the year and conductivity rates of 0.4 mmhos/cm (similar to the Mile, which varies between 0.4 and 0.45 mmhos/cm). Salinity rates are higher in marshes (Boyale) and lakes (Gamari) fed by the Awash, and conductivities range from 0.5 to 0.6 mmhos/cm.

XX-1 2. High sediment concentrations

General salinity vs. flood and suspended sediment content curves are shown on the upper part of Graph 12. In the Upper Basin and Middle Valley, salinity generally decreases fairly sharply with increasing sediment content, with conductivity rates falling below 0.2 mmhos/cm, which also applies to the Mojo River. Silt content remains low in the Upper Basin upstream from Kentare and becomes high further downstream, especially in the Mojo, a river with its basin in a severely eroded area (brown and grey vertisols on volcanic tuff).

In the Lower Plains, salinity in the Awash increases with silt content, probably due to the substantial quantities of silt the Mile carries when in spate. Conductivity rates again exceed 0.25 mmhos/cm and may reach 0.3 or 0.4 mmhos per cm. The Mile basin is probably affected by very severe erosion in an area containing saline soil.

XX - 2. Chemical Characteristics of Surface and Ground Water

In determining these water characteristics, use was made of a certain number of analyses. Their results were plotted on logarithmic charts based on Schoeller diagrams, which enable water to be classified in terms of its chemical properties. Distinctions were also made between water containing little suspended sediment (usually associated with low-water conditions) and the high concentrations associated with flood conditions.

XX-2 1. Water in the Awash and its tributaries

Graph 13 shows that in the Upper Basin as far as Station 4, (Gelilea lake),(i.e., before the Mojo confluence and Koka reservoir) the Awash water contains more Ca and Mg than Na, with little change at flood condition. Na and bicarbonates increase below Teji during the dry season, however, and at flood condition decrease to roughly the same content as above Teji. Na and CO_3H both increase sharply in the Mojo during the dry season, and contents remain high during the flood period. Characteristics of the Akaki and Upper Kesem - both Upper Basin tributaries - are the same as for the Awash above Teji. Na and CO_3H contents in the Akaki, Geleta and Upper Kesem are higher during the dry season. The water in the Meki shows a slightly different composition containing more Mg and Na.

The water in the Middle Valley contains much more sodium than that in the Upper Basin, with little decrease during the flood. Bicarbonate content is about the same as in the Upper Basin. Sulphate content is higher. The left-bank tributaries show the same properties, especially at their point of entry into the recent alluvial area (Kesem, Kebena).

Awash water in the Lower Plains is apt to contain up to 3 meq/l of sodium, and both SO_4 and CO_3H contents are also higher. The chemical composition of the water remains the same at flood condition. The Mile shows similar properties, though its Mg and Na contents increase at flood condition.

FIG. 12

RELATION BETWEEN SEDIMENT CONTENT AND EL. CONDUCTIVITY

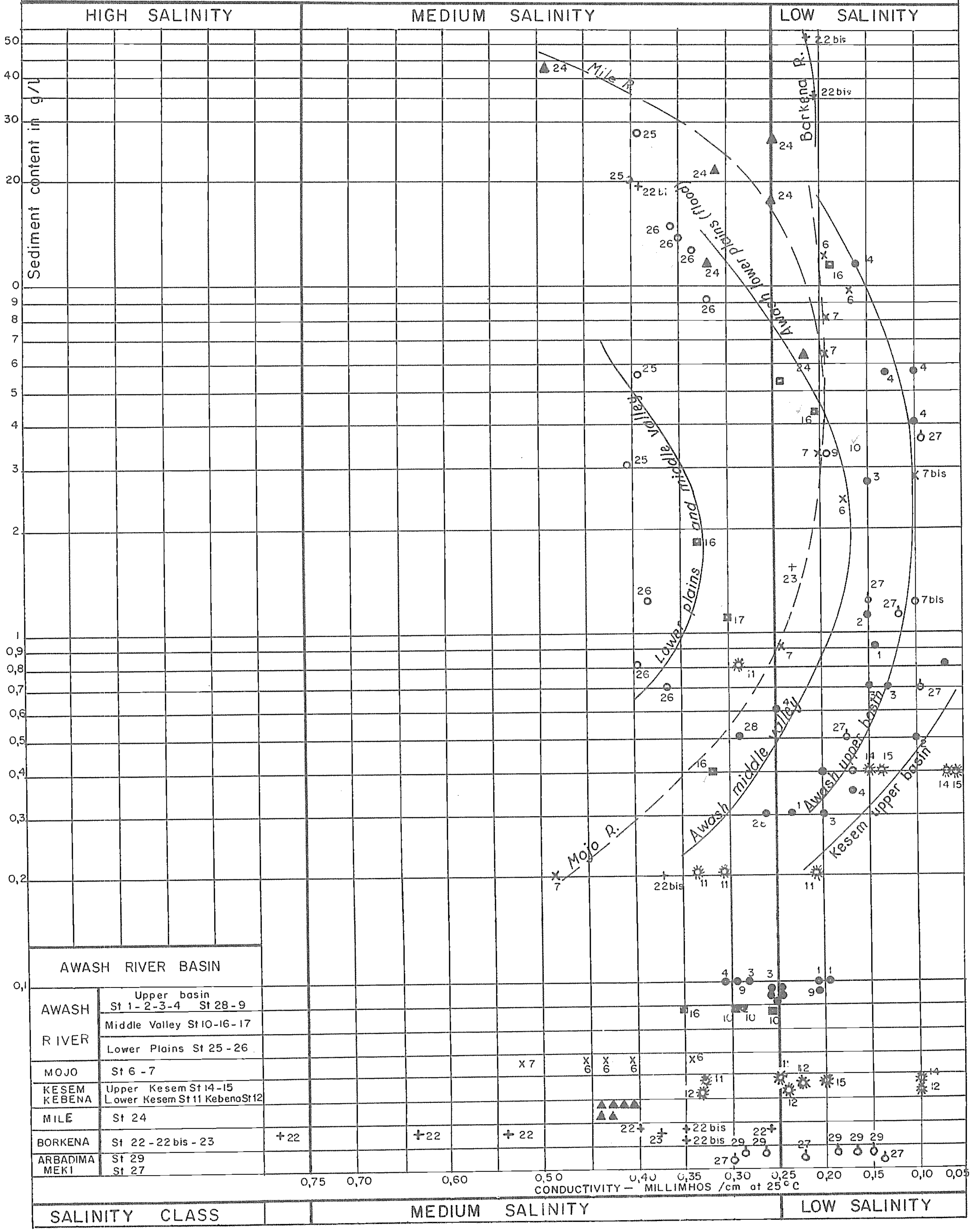
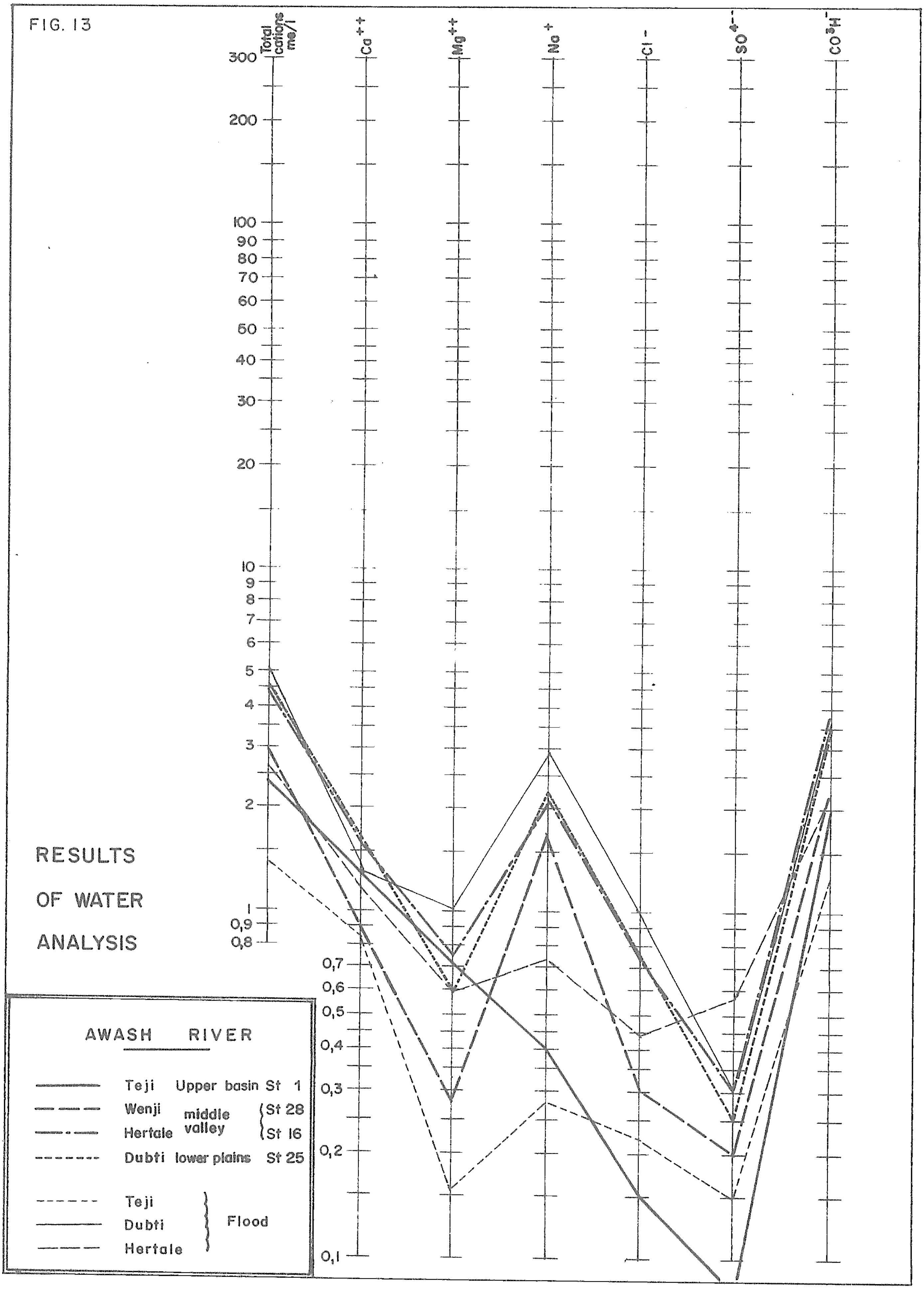
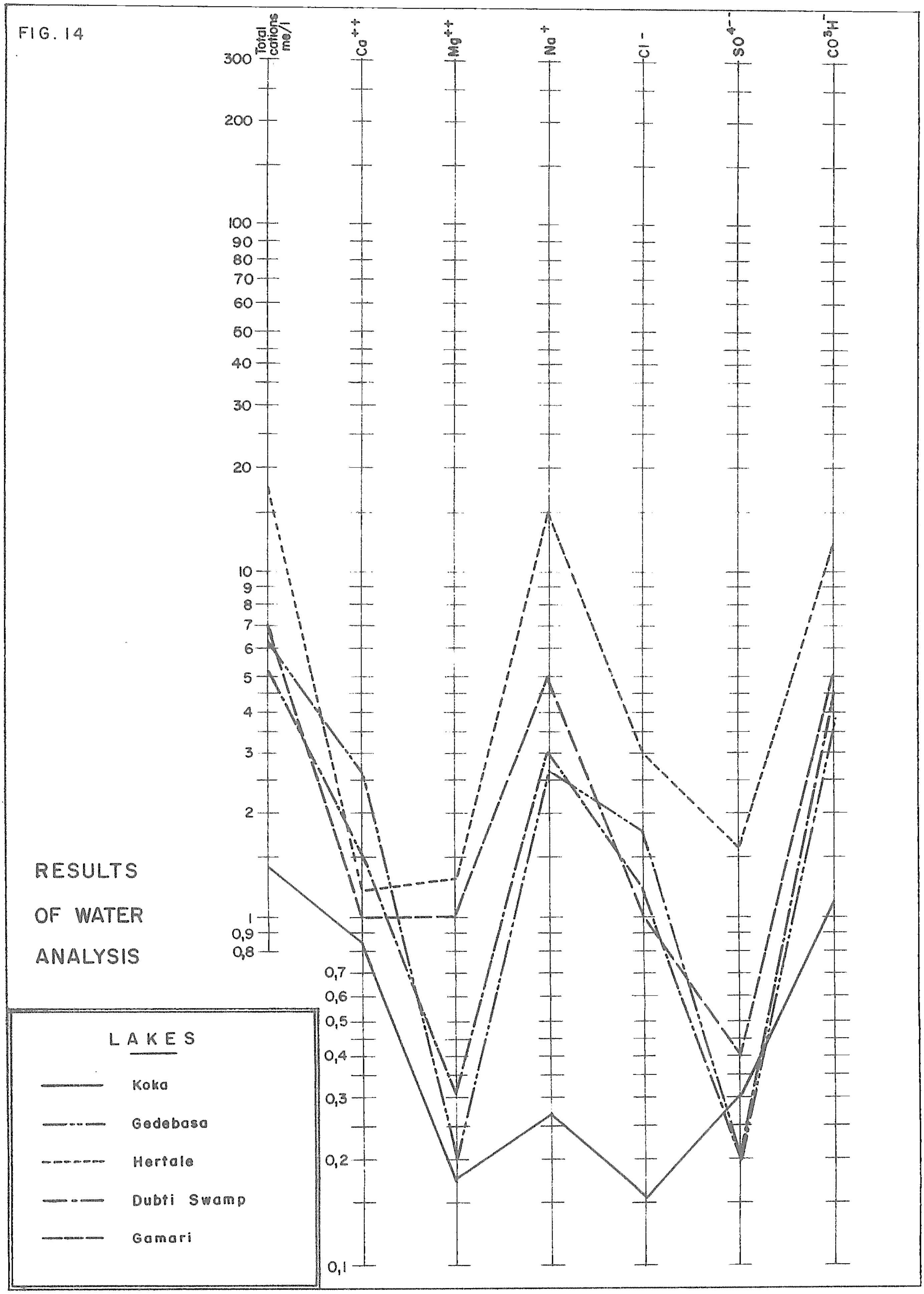


FIG. 13



Total cations me/l
Ca++
Mg++
Na+
Cl-
SO4--
CO3H-
300
200
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
2
1
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
RESULTS
OF WATER
ANALYSIS
AWASH RIVER
Teji Upper basin St 1
Wenji middle valley St 28
Hertale St 16
Dubti lower plains St 25
Teji
Dubti
Hertale
Flood

FIG. 14



RESULTS OF WATER ANALYSIS

To sum up, Na content of the Awash increases in relation to Ca and Mg from the Upper Basin (Na/(Ca + Mg) less than 0.4) towards the Lower Plains (Na/(Ca + Mg) nearly or exceeding 1). Proportions of Mg in relation to Ca and those of CO_3H and SO_4 all increase.

Tributaries in the Upper Basin show the same features, except for the Mojo. Their composition is apt to vary considerably - in the case of tributaries from the Robi Borkena rift valley due to warm springs and irregular flows.

Awash water composition downstream from Teji shows considerable annual variation, due to the less regular rainfall conditions, but they become only slight in the Middle Valley and practically disappear in the Lower Plains. Before the Koka dam was built, they were probably quite considerable in the Middle Valley and Lower Plains, with substantial increases of salinity during the dry season.

XX-2 2. Spring water

There are many mineral water springs in Ethiopia, and they have been investigated under a special program by the Institut Pasteur. The most important supply appreciable quantities of water to the Awash.

The temperature of their water varies between 40°C and 60°C, except for the Alalabada geyser in the Lower Plains, where temperatures of 100°C are recorded.

The following can be identified on Graphs 26 and 27 in Appendix no. 8 :

(i) Chlorinated and bicarbonate sodic springs in the Upper Basin and Middle Valley as far as Hertale, with conductivity rates of about 2 mmhos/cm. The Bulbula 'springs' contain the least salts, as the Bulbula seems to be fed by infiltration from the Koka reservoir. (Gelilea lake).

(ii) Springs at Meteka, Hertale and Marogala, which are also sodic and slightly sulphated. Conductivities are low for the first two (1.2 - 1.6 mmhos/cm), and higher for Marogala.

(iii) Sodic sulphated springs in the Robi Borkena rift valley with conductivity rates varying between 1.2 and 1.8 mmhos/cm.

XX-2 3. Ground water

Ground water composition data for the various geographical parts of the basin are shown in Graphs. Like the spring water, the ground water is sodic, bicarbonated and of medium to high salinity, with conductivities varying between 0.6 and 1.8 mmhos/cm. In the Upper Basin, it contains less sulphate than in the Middle Valley(underflow to Lake Gedebasa), and Lower Plains. The deep water table in the Lower Plains (at a depth of 25 - 30 m) contains far more salts, mainly consisting of sulphates and chlorides (conductivity up to 3.27 mmhos/cm). The ground water in the Awash Basin can be considered highly sodic and bicarbonated.

Ground water in the Upper Basin contains less sulphate than in the Middle Valley and Lower Plains, and some is less sodic. Its composition is generally similar to that of the surface water, but with more concentrated sodium and bicarbonates, especially in the Upper Basin. There is a connection between these high sodium and bicarbonate concentrations and the high pH values of the soils in the Middle Valley, and even more so in the Lower Plains. The water in the shallow flooded areas in the Lower Plains also contains high concentrations of sodium and bicarbonate.

XX - 3. Water Classification According to Suitability for Irrigation

This classification is based on the criteria used in Riverside Handbook No. 60, which are the electrical conductivity C in mmhos/cm and the sodium absorption ratio (SAR) given by the expression :

$$\frac{Na}{\sqrt{\frac{Ca + Mg}{2}}}$$

Conductivity and SAR values are plotted in Graph 15 for a certain number of samples of representative compositions, including surface water (Awash water with low and high suspended sediment contents) ground water, and lake and marsh water. Data for water in the tributaries are shown in two Graphs (Appendix 8)

XX-3 1. Water in the Awash, its tributaries and in reservoirs

As Graph 15 shows, the river water in the Upper Basin and Middle Valley is in category C_1S_1 when suspended sediment concentrations are high. Its salinity is low and it contains little sodium, and therefore does not cause any increase in the amount of exchangeable sodium, in the soil. Sensitive fruit trees may suffer from an excess of sodium. Leaching resulting from normal irrigation is adequate, except for very clayey soils (grey vertisols). Water in the Koka reservoir, (Gelilea lake) the river Meki, and the Upper Basin tributaries - Akaki, Mojo, Upper Kesem, Upper Kabena, Robi, Upper Borkena and Jara on the left bank, and Geleta and Arba Dima on the right bank - are in this category.

Conductivity and SAR below Koka both increase at low water, and the water in the Awash is then in category C_2S_1 as in the Middle Valley and Lower Plains. Salinity and SAR of the tributaries (especially the Mojo) also increase. Springs - some saline and warm - partly supply the Borkena, Jara, Jawaha, Ataye, Kesem and Kebena before their entry into the recent alluvial area. They fall within category C_2S_1, as do also the Arba Dima on the right bank, the Akaki and Robi on the left bank, and the Meki.

The Awash in the Lower Plains and certain rivers with very irregular flows - e.g., Awadi and Mile on the left bank, and Arba on the right bank - are in category C_2S_1. Water in category C_2S_1 is suitable as irrigation water for soils to which a certain amount of leaching can be applied, and on which crops with average tolerance for salt are grown. The SAR is unlikely to cause an increase in the exchangeable sodium content, except in the Lower Plains, where its value may exceed 2.

XX-3 2. Lakes Gedebasa and Lyadu in the Middle Valley, Lake Gamari, and Lower Plain marshes supplied by the Awash

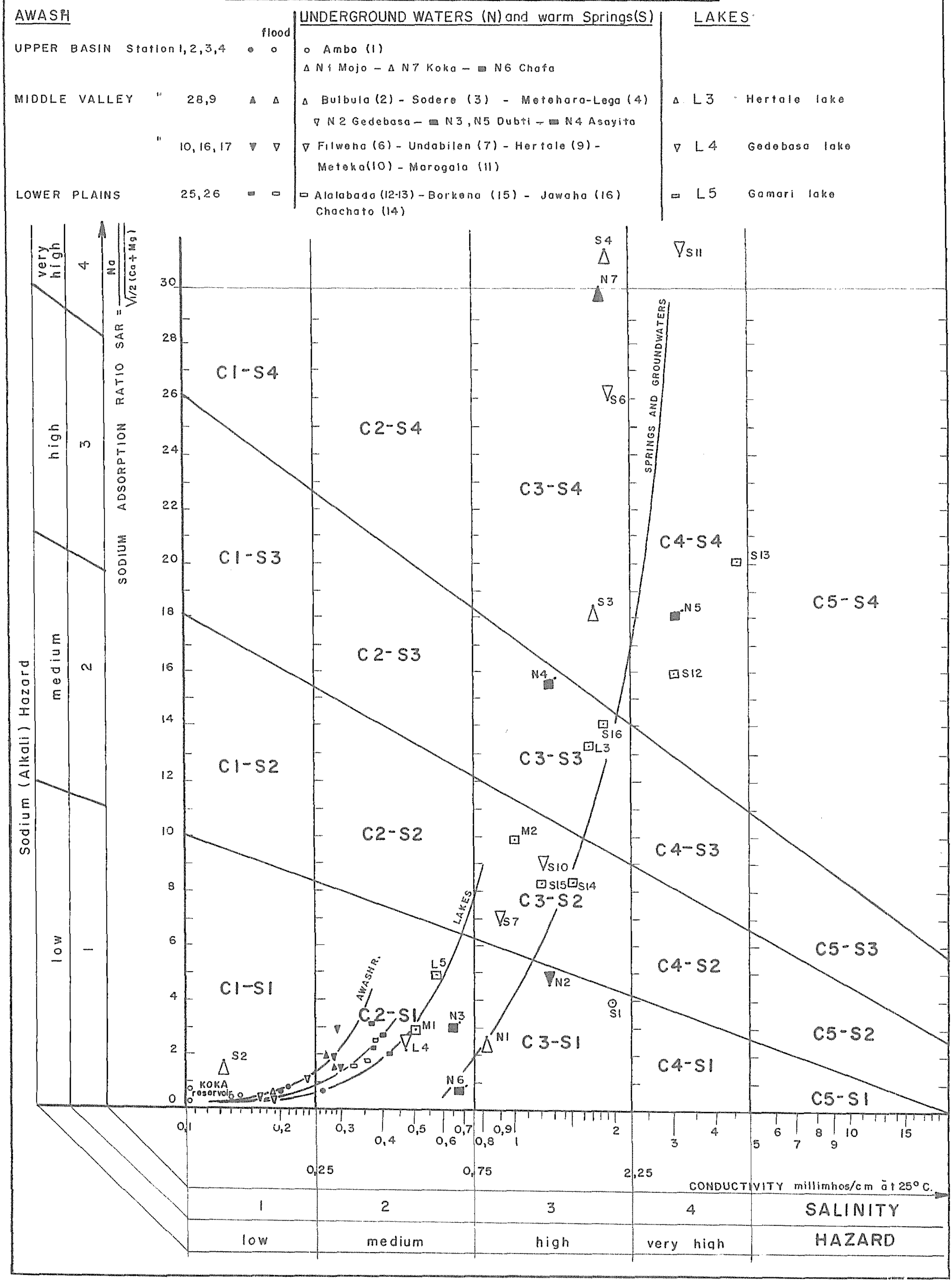
As all these are in category C_2S_1, the water in the reservoirs in the Middle Valley and Lower Plains may be in this category, though the water in the shallow flodded areas in the Dubti marshes was in category C_3S_2, and thus difficult to use for irrigation without adequate drainage. Lake Beseka near Metehara is very saline (about 30 grammes/Litre), sodic and carbonated (pH 10.5). Its composition resembles that of Lakes Shala and Hora Abiyata on the Lake Plateau. Lake Hertale in the Middle Valley is in category C_3S_3. Its water would be difficult to use for irrigation.

XX-3 3. Ground water

Ground water and warm spring water are featured in Graph 15. The points form a curve running beside the Awash curve, with more rapidly increasing conductivity and

FIG. 15

CLASSIFICATION OF IRRIGATION WATERS



SAR values. Only the water tables in the Borkena valley and beside the river at Dubti are in category C_2S_1. In this category (requiring well-drained soils, salt-resisting plants and salinity control measures) are the Mojo water table in the Upper Basin, the one fed by underflow from rivers discharging into Lake Gedebasa, and Ambo (Hagere Hiywet) spring.

Water of conductivity class C_3 includes most of the warm springs, except for the Marogala spring in the Middle Valley, the Alalabada geyser, and the deep water table (30 m) at Dubti in the Lower Plains, which are all in category C_4S_4, and useless as irrigation water.

The SAR for this sodic bicarbonated water varies between S_2 and S_3, and sometimes S_4, making it of very little use for irrigation. Where the SAR is of Category S_2, high exchange capacity clay soils difficult to leach may be exposed to alkalinization, unless gypsum is present. The Na content of high-pH lime soils can be reduced by adding gypsum. Deep homogeneous vertisols cannot be irrigated with water in this category. With a higher SAR, (S_3), this water alkalinizes most soils, making efficient drainage essential, as well as effective leaching and the addition of organic matter. This water may be suitable only for gypsum soils. The use of chemical fertilizers is difficult because the water is already saline (C_3).

XX - 4. Conclusion

Except for such rivers as the Mojo at certain times of the year, the surface water in the Upper Basin and the water in the Koka reservoir (category C_1S_1) is suitable for unrestricted use on all soils unless of very low permeability (grey vertisols). SAR values are generally less than 1.

Surface water in the Middle Valley beyond Awash Station and in the Lower Plains, and the water in the lakes or marshes fed by the Awash is slightly sodic and belongs to Category C_2S_1; its use requires moderate leaching and crops with an average resistance to salt. SAR values of about 2 or more, mainly in the Lower Plains, restrict the growth of crops sensitive to sodium, and especially certain fruit trees. Reservoir water in these two areas would probably be in category C_2S_1.

Spring water, ground water, the Fil Weha and the Lake Hertale outlet are all sodic and bicarbonated. Categories range from C_3S_2 to C_3S_4, and this water would be difficult to use, for well-drained soil is necessary because of its sodium content, and as it contains large quantities of salts, only limited use could be made of chemical fertilizers.

APPENDIX 1.

SOIL ANALYSIS METHODS

1. Preparation

The samples are sorted out at the laboratory according to the order of the analysis order vouchers. Each sample is given a laboratory number. After being left to dry for a few days, the samples are placed in a ventilated oven for further drying at a temperature of 45°C for at least 48 hours. They are then reduced to fine earth by moderate crushing and by passing them through a sieve with 2 mm dia.round holes. Gravel (over 2 mm dia.) is weighed to determine its percentage in the soil.

2. Natural moisture

Where a natural moisture determination is required (e.g., for irrigation tests), the sample is weighed wet and then again after drying at 45°C. By further drying of a small part of the sample at 105°C, the moisture content can be determined as a percentage of the weight of soil dried at 105°C.

3. pH

This is measured with a glass electrode pH-meter in a 1:2.5 soil/water suspension after leaving the soil in contact with the water for 2 hours.

4. Grain size

Owing to difficulties in dispersing the clay fraction, the following method has been systematically applied :

(i) Repeated exposure to warm hydrogen peroxide.

(ii) Sieving under water to 50 .

(iii) Drying of the fraction exceeding 50 , followed by sieving when dry.

(iv) Mechanical dispersion of the fine fraction with a mixer.

(v) Chemical dispersion with sodium hexametaphosphate.

(vi) Study of suspension specific gravity variation with time.

5. Total lime content

The lime content of a soil is found from the volume of carbonic acid released under exposure to cold hydrochloric acid.

6. Organic matter - Organic carbon

The organic carbon in the sample is oxidised with potassium bichromate in a sulphuric acid medium at 150°C. Excess bichromate returning is determined with Mohr's salt in the presence of diphenylamine.

7. Total nitrogen

The nitrogen is transformed into ammonium sulphate by prolonged exposure to concentrated sulphuric acid in the presence of a catalyst. Next, with excess soda, the ammonia is carried away by water vapour, collected in a boric acid solution and its proportions determined with $H_2 SO_4$, in the presence of a coloured indicator.

8. Moisture at pF 3 (or 4.2)

After soaking in water for 24 hours, the sample is exposed to nitrogen at a pressure of 1 atmosphere (or 15 atmospheres) for two days in a Riverside-designed extractor. Residual moisture is stated as a percentage of soil dried at 105°C.

9. Exchange complex

If the soil sample is not saline (saturated extract conductivity 1 mmho/cm), it is stirred up in neutral ammonium acetate to make the ammonium displace the sodium and potassium in the complex, which are then determined by flame photometry. If the soil sample is saline with chlorine predominating, the soluble salts are leached out by washing the sample in alcohol before proceeding as described above. If the soil sample is saline but contains little chlorine, Na and K are extracted and their proportions determined as above. The soluble Na and K values determined in the saturated extract are subtracted from those thus measured.

Normal sodium acetate (pH 8.2) is made to percolate slowly through the soil sample. The sodium displaces the calcium and magnesium, proportions of these then being determined by complexometry. For a saline soil, the calcium and magnesium determined in an aqueous extract with a soil/water ratio similar to the soil/sodium acetate ratio as applied to percolation are deduced from the values found.

The soil saturated with sodium by percolation for the Ca and Mg determination is washed in alcohol, which eliminates the sodium acetate. The absorbed sodium corresponding to the total exchange capacity is moved by percolation with normal neutral ammonium acetate and its proportions determined by flame photometry.

10. Salinity

A saturated paste is prepared and left to stand for 12 hours, whereupon the soil solution is extracted by filtration under vacuum. The next step is to calculate saturation moisture, after which the conductivity of the saturated extract is measured with an electrical conductivity meter. The proportions of the following are then determined :

Carbonates and bicarbonates, by progressive acidification with diluted sulphuric acid, first with phenolphthlein and then with methylorange.

Chlorides by silver nitrate with potassium chromate.

Sulphates by nephelometry with barium sulphate.

Nitrates by colorimetry with phenol-disulphonic acid, after eliminating chlorides and carbonates.

Sodium and potassium by flame photometry.

Calcium and magnesium by complexometry.

11. True density

The volume of a known mass of soil is given directly by a Beckmann differential pressure pycnometer.

12. Permeability

This is measured on a specially prepared sample under constant head by a method developed by the Prof. Henin.

13. Structural stability

By the Prof. Henin method, this is found by comparing the stability in an aqueous medium of aggregates of soil samples specially pre-treated in alcohol, benzene or distilled water.

APPENDIX 2.

X-RAY ANALYSIS OF CLAY SAMPLES

The following results were established in the Laboratory of Geology and Mineralogy of the Science Faculty of the University of Grenoble. Analysis conditions were :

Apparatus : PHILIPS PW 1010 recording diffractometer

Radiation : Fe K 1,935 Å

Voltage : 28 kV

Current : 10 mA

Tape speed : 200 mm/h

1. Red weakly ferralitic soils

SAMPLE UU 0301 (0-10 cm, 7.5 Y 5/6, 40 % clay, T = 31 meq) (Adis Abeba), (Gafarsa)

Montmorillonite content : nil
Illite content .... : high
Kaolinite content ..... : fairly high
Quartz content .... : very high
Hematite content ...... : fairly high

SAMPLE UU 0302 (60-80 cm, 5 YR 5/6, 60 % clay)

Montmorillonite content : nil
Illite content .... : high
Kaolinite content ..... : fairly high
Quartz content .... : high (certainly of detrital origin, mixed with clay)
Hematite content ...... : low

2. Reddish brown and brown vertisols on basalt

SAMPLE UU 029 (150-170 cm, 5 YR 5/2, 54 % clay) Reddish brown vertisol on basalt (Adis Abeba area)

Montmorillonite content : probably low
Illite content .... : high
Kaolinite content ..... : high
Quartz content .... : very high
Hematite content ...... : relatively high

SAMPLE UCF 002 (0-10 cm, 10 YR 4/2, 51 % clay, T = 80 meq) Brown vertisol (Chefa area)

Montmorillonite content : high (at least equal to illite)
Illite content .... : high
Kaolinite content ..... : probably traces
Quartz content .... : relatively low
Hematite content ...... : low

3. Grey vertisols on non differentiated material

SAMPLE UU 007 (60-70 cm, 7.5 YR 4/0, 52 % clay, T = 50 meq at 0-10 cm) (Teji area)

Montmorillonite content : low
Illite content .... : high
Kaolinite content ..... : nil
Quartz content .... : high
Hematite content ...... : traces

SAMPLE UU 018 (0-10 cm, 10 YR 6/1 - 5/1, 49 % clay, T = 60 meq) (Dukem area)

Montmorillonite content : fairly high
Illite content .... : high
Kaolinite content ..... : low
Quartz content .... : high
Hematite content ...... : low

4. Grey vertisols on non-calcareous alluvial deposits

SAMPLE MMS 342 (15-25 cm, 10 YR 6/2, 38 % clay) (Melka Sedi area)

Montmorillonite content : fairly low
Illite content .... : relatively low (by comparison with other constituents)
Kaolinite content ..... : nil
Quartz content .... : relatively high
Hematite content ...... : low

SAMPLE MMS 103 (20-35 cm, 10 YR 5/2 - 5/1, 55 % clay) (Amibara area)

Montmorillonite content : fairly high
Illite content .... : high
Kaolinite content ..... : nil
Quartz content .... : high
Hematite content ...... : low

5. Alluvial soils on non-calcareous deposits

SAMPLE UKK 002 (0-20 cm, 10 YR 4/2, 32 % clay)

Montmorillonite content : fairly high
Illite content .... : high
Kaolinite content ..... : nil
Quartz content .... : high
Hematite content ...... : low

SAMPLE UKK 002 (170-250 cm), 10 YR 7/2, 34 % clay)

Montmorillonite content : low
Illite content .... : high
Kaolinite content ..... : traces
Quartz content .... : fairly high
Hematite content ...... : low

<u>SAMPLE UKK 001</u> (70-80 cm, 10 YR 5/3, 12 % clay, T = 33 meq from 30 to 50 cm)

Montmorillonite content	:	fairly high
Illite content	:	fairly high
Kaolinite content	:	nil
Quartz content	:	low
Hematite content	:	low

6. <u>Alluvial soils on calcareous deposits</u>

<u>SAMPLE TMT 007</u> (50-60 cm, 10 YR 5/2, T = 86 meq) (Dark colour horizon, Dubti area)

Montmorillonite content	:	exceptionally high
Illite content	:	relatively low
Kaolinite content	:	nil
Quartz content	:	low
Hematite content	:	low

APPENDIX 3.

SELECTED PEDOLOGICAL PROFILES TAKEN IN THE MIDDLE VALLEY

A. SOILS ON RECENT ALLUVIA

1. Alluvial Soils on Very Slightly or Non-Calcareous Deposits

1.1 Medium texture

/Mapping/ : Soil type nr 11 - Colour yellow

/Field description/ : profile nr KK4

Location : Kesem-Kebena area. Aerial photo nr. 1994, run 23.

Relief and microrelief : flat

Erosion : slight

Drainage : good

Natural vegetation : gramineae in tussocks (local name : Durfu)

Profile description :

0 - 20 cm	Texture : sandy loam - Colour 10 YR 6/3 pale brown - Humidity : dry - Single grain structure - Consistence : friable - Fine roots.
20 - 30 cm	Texture : fine sandy loam - Colour : 10 YR 6/2 light brownish grey - Humidity : dry - Single grain structure - Consistence : friable.
30 - 50 cm	Texture : loamy sand - Colour : 10 YR 6/3 pale brown - Humidity : dry - Single grain structure - Consistence : friable.
50 - 100 cm	Texture : fine sand mixed with gravels - Colour : 10 YR 6/2 light brownish grey - Humidity : dry - Single grain structure.
100 - 140 cm	Texture sand - Colour : 10 YR 6/2 - Humidity : moderately dry - Single grain structure.

/Analytical results/ : Profile n° KK 4

Depth (cm)	Particle size distribution (%)						pH	Lime (%)	Organic matter (%)	Carbon (%)	Nitrogen (%)	C/N	P_2O_5 total (ppm)	Moisture capacity at pF 2.5 (%)	Real density
	<2 µ	2-20µ	20-50 µ	50-100µ	100-200µ	200µ 2 mm									
0-10	4	19	21	19	23	14	8.6	1.0	0.7	0.41					
40-50	1	10	10	18	32	29	8.5	1.5							

Depth (cm)	Exchangeable cations (me/100 g)							Saturation soluble extract									
	S	Ca	Mg	K	Na	T	Na/T	Humidity at saturation	E.C. (mmho-cm)	Cl	SO^4	CO^3	CO^3H	Ca	Mg	K	Na
										(me/l)							

1.2 Interlayered medium to moderately fine texture

1.2 (1) Deep

/Mapping/ : soil type nr 121 - Colour : yellow

/Field description/ : profile nr BKB 27

Location : Bolhamo plain - Aerial photo nr 1949, run 22

Relief and microrelief : flat

Erosion : none

Drainage : good

Flooding : floods rare (July - October)

Natural vegetation : gramineae and acacia trees scattered in some places

Profile description :

0 - 20 cm	Texture : silty-loam to silty clay loam - Colour : 10 YR 4/3 dark brown to brown - Humidity : dry - Structure : granular to crumb - Consistence : friable - Many fine roots.
20 - 50 cm	Texture : silty-loam and layers of very fine sandy loam - Colour : 10 YR 4/3 dark brown to brown - Humidity : dry - Structure : granular to crumb tendency to platy - Consistence : friable - Fine roots.
50 - 90 cm	Texture : silty-loam, thin layers of very fine sand, and very fine layers of dark clay - Colour : 2.5 Y 5/2 greyish brown - Humidity : dry - Structure : platy - Consistence : friable - Some yellow patches of iron between layers of loam - Some roots.
90 -100 cm	Texture : sandy - Colour : 10 YR 4/3 dark brown to brown - Humidity : dry - Single grain structure - Consistence : friable

/Analytical results/ : Profile n° BKB 27

Depth (cm)	Particle size distribution (%) <2 µ	2-20µ	20-50 µ	50-100µ	100-200µ	200µ 2 mm	pH	Lime (%)	Organic matter (%)	Carbon (%)	Nitrogen (%)	C/N	P_2O_5 total (ppm)	Moisture capacity at pF 2.5 (%)	Real density
0-10	27	54	12	4	2	1	7.6	0.4	4.1	2.4					
25-30	13	56	21	6	3	1	8.1	1.4							
70-80	22	56	11	4	4	3	7.9	0.6							

Depth (cm)	Exchangeable cations (me/100 g) S	Ca	Mg	K	Na	T	Na/T	Saturation soluble extract: Humidity at saturation	E.C. (mmho-cm)	Cl (me/l)	SO^4 (me/l)	CO^3 (me/l)	CO^3H (me/l)	Ca (me/l)	Mg (me/l)	K (me/l)	Na (me/l)
0-10								57	1.06								0.2
25-30								51	0.65								0.35
70-80								53	1.23								1.4

1.2 (2) Dark-coloured horizon with moderately fine texture at deeper levels

/Mapping/ : soil type nr 122 - Colour : yellow

/Field description/ : profile nr MMS 52

Location : Melka Sedi plain - Aerial photo nr 1737, run 21

Relief and microrelief : flat, slightly wavy

Natural vegetation : Capparis sp. - Sanseveria sp. - Gramineae, thorny plants.

Profile description :

0 - 20 cm Texture : silty clay loam - Colour : 10 YR 4/2 - 4/3 dark greyish brown to brown - Humidity : dry - Structure : crumb Consistence : friable - Many roots.

20 - 50 cm Texture : silty loam - Colour : 10 YR 4/2 dark greyish brown - Humidity : dry - Structure : tendency to crumb, granular - Consistence : friable - Many roots.

50 - 70 cm Transition horizon.

70 -120 cm Texture : silty clay - Colour : 10 YR 2/2 very dark brown - Humidity : moderately dry - Structure : prismatic - Consistence : hard - Vertical cracks (1 cm broad) - Few roots.

/Analytical results/ : Profile n° IHS 52

Depth (cm)	Particle size distribution (%)						pH	Lime (%)	Organic matter (%)	Carbon (%)	Nitrogen (%)	C/N	P_2O_5 total (ppm)	Moisture capacity at pF 2.5 (%)	Real density
	<2 μ	2-20μ	20-50 μ	50-100μ	100-200μ	200μ 2 mm									
0-10	37	41	16	3	2	1	7.4	0.2	3.2	1.9	161	12			
30-40	18	45	19	10	7	1	8.1	2.5	1.1	0.62					
80-90	44	42	8	3	2	1	8.0	1.2							

Depth (cm)	Exchangeable cations (me/100 g)							Saturation soluble extract									
	S	Ca	Mg	K	Na	T	Na/T	Humidity at saturation	E.C. (mmho-cm)	Cl	SO^4	CO^3	CO^3H	Ca	Mg	K	Na
										(me/l)							
0-10	50	42.4	4.4	3.05	0.13	51.6	0.25	66	0.64								0.19
30-40								56	0.55								0.73
80-90								65	0.35								0.49

1.3 Moderately fine to fine texture : microrelief with holes

/Mapping/ : soil type nr 13 - Colour : yellow

/Field description/ : profile nr MMS 302

Location : Melka Sedi plain

Relief and microrelief : flat (small tussocks, holes)

Flooding : former flood area

Natural vegetation : annual gramineae in tufts, acacia trees, capparis sp.

Profile description :

0-25 cm Texture : silty clay loam - Colour : 10 YR 5/2 greyish brown- Humidity : dry - Structure : blocky, size medium - Consistence : slightly hard - Light mulchy on the surface - Many roots.

25-80 cm Texture : silty clay - Colour : 10 YR 4/3 brown to dark brown Humidity : dry - Structure : blocky, tendency to prismatic - Consistence : very hard - Vertical cracks (about 1 cm broad)

80-120 cm Texture : silty clay loam to silty clay - Colour : 10 YR 3/3 dark brown - Humidity : moderately dry - Structure : blocky, tendency to prismatic - Consistence : less compact than 25-80 cm - Shiny faces on the aggregates.

/Analytical results/ : Profile n° MS 302

Depth (cm)	Particle size distribution (%)						pH	Lime (%)	Organic matter (%)	Carbon (%)	Nitrogen (%)	C/N	P_2O_5 total (ppm)	Moisture capacity at pF 2.5 (%)	Real density
	<2 µ	2-20µ	20-50 µ	50-100µ	100-200µ	200µ 2 mm									
0-10	30	35	20	8	6	1	8.1	1.8	1.6	0.95	0.91	10			
70-80	40	43	13	4			8.3	2.9	1.5	0.90					
90-120	38	49	10	3			8.0	2.6							

Depth (cm)	Exchangeable cations (me/100 g)							Saturation soluble extract									
	S	Ca	Mg	K	Na	T	Na/T	Humidity at saturation	E.C. (mmho-cm)	Cl	SO^4	CO^3	CO^3H	Ca	Mg	K	Na
										(me/l)							
0-10								62	0.67								0.86
70-80																	
90-120								78	4.0								16.5

2. Alluvial Soils on Very Slightly Calcareous and Occasionally Saline Deposits

/Mapping/ : soil type nr 2 - Colour : yellow

/Field description/ : profile nr MAL 18

Location : Melka Sedi plain - Aerial photo nr 1739, run 21

Relief : flat

Erosion : none

Natural vegetation : Capparis sp. - Few bushy acacias - gramineae (local name:: Hamiltou)

Profile description :

0 - 10 cm Texture : silty loam - Colour :2.5 Y 5/2 greyish brown - Humidity : very dry - Structure : powdery to blocky - Consistence : very friable - Roots.

10 - 45 cm Texture : silty clay loam - Colour :2.5 Y 5/0 grey - Humidity : very dry - Structure : no structure and powdery - Roots.

45 - 70 cm Texture : silty clay - Colour :2.5 Y 5/0 grey - Humidity : dry - Consistence : friable - Roots.

70 - 100 cm Texture : silty clay loam - Colour :2.5 Y 5/0 grey - Humidity : dry - Hydromorphic iron.

100 - 120 cm Texture:loam - Colour :2.5 Y 5/0 grey - Humidity : dry - Structure : tendency to platy - Hydromorphic iron.

Analytical results : Profile n° MAL 18

Depth (cm)	Particle size distribution (%)						pH	Lime (%)	Organic matter (%)	Carbon (%)	Nitrogen (%)	C/N	P_2O_5 total (ppm)	Moisture capacity at pF 2.5 (%)	Real density
	<2 µ	2-20µ	20-50 µ	50-100µ	100-200µ	200µ 2 mm									
0-5	11	42	31	11	3	2	8.2	1.1	2.7	1.6	1.0	16			
50-60	13	38	30	15	4		8.1	2.6							
120-130	7	34	30	18	10	1	8.1	2.8							

Depth (cm)	Exchangeable cations (me/100 g)							Saturation soluble extract									
	S	Ca	Mg	K	Na	T	Na/T	Humidity at saturation	E.C. (mmho-cm)	Cl	SO^4	CO^3	CO^3H	Ca	Mg	K	Na
										(me/l)							
0-5								46	1.09	1.6	3.5	0	8.0	8.6	3.0	1.6	0.2
50-60								48	21.4								11.9
120-130								41	5.36								41

3. Vertisols on Very Slightly or Non-Calcareous Materials

3.1 Fine self-mulching structure

3.1 (1) Homogeneous, fine texture, gilgai microrelief

/Mapping/ : soil type nr 311 - Colour : brown

/Field description/ : profile nr MAL 21

Location : Angelele plain - Aerial photo nr 1500, run 19

Relief and microrelief : flat - holes filled-in - cracks below a 5 cm thick mulch

Erosion : very slight

Natural vegetation : pasture land - some Capparis and big acacia trees graminaceous

Profile description :

0 - 5 cm Texture : clay - Colour : 10 YR 3/3 dark brown - Humidity : dry - Structure : granular - Consistence : non friable - Some roots and organic debris.

5 - 20 cm Texture : clay - Colour : 10 YR 3/3 dark brown - Humidity : dry - Structure : coarse prismatic (with tendency to platy), the prisms are 5 to 10 cm broad - Consistence : hard - Cracks - Shiny faces on the aggregates

20 - 70 cm Texture : clay - Colour : 10 YR 3/3 dark brown - Humidity : dry - Structure : prismatic, coarser than 5-20 cm (tendency to platy) - The prisms are 10 to 30 cm, cracks (about 2 to 4 cm) - Consistence : hard - Shiny faces on the aggregates.

70 - 90 cm Texture : clay - Colour : 10 YR 3/3 dark brown - some thin layers of loamy clay a little lighter in colour - Humidity: moderately dry - Cracks less important, prismatic, tendency platy to granular, shiny faces on the aggregates.

90 -120 cm Texture : clay - Colour : 10 YR 3/3 dark brown - Humidity : dry - Structure : prismatic and platy - Consistence : compact - Few thin roots, shiny faces on the aggregates.

/Analytical results/ : Profile nr MAL 21

Depth (cm)	Particle size distribution (%) <2 µ	2-20µ	20-50 µ	50-100µ	100-200µ	200µ 2 mm	pH	Lime (%)	Organic matter (%)	Carbon (%)	Nitrogen (%)	C/N	P_2O_5 total (ppm)	Moisture capacity at pF 2.5 (%)	Real density
0-5	54	33	10	3			8.0	0.9	3.3	1.9			1100		
20-30	66	23	10	1			8.5	1.0	2.0	1.2	0.6	19	1340	56	2.36
70-90	66	19	14	1			8.0	0.9							

Depth (cm)	Exchangeable cations (me/100 g) S	Ca	Mg	K	Na	T	Na/T	Saturation soluble extract: Humidity at saturation	E.C. (mmho-cm)	Cl (me/l)	SO^4 (me/l)	CO^3 (me/l)	CO^3H (me/l)	Ca (me/l)	Mg (me/l)	K (me/l)	Na (me/l)
0-5								74	1.70	5.5	2.1	0	4.1	12.8	1.8	0.6	2.3
20-30	75	82.9	4.0	2	6.1	76	8.0	75	1.31	2.0	4.2	0	8.2	4.2	0.5	0.3	8.4
70-90								81	7.15								39.8

3.1 (2) Homogeneous, with highly-developed mulch

/Mapping/ : soil type nr 312 - Colour : brown

/Field description/ : profile nr MMS 120

Location : Melka Sedi plain, Aerial photo nr 1954, run 22

Microrelief : tussocks - erosion between the gramineae tufts

Natural vegetation : Capparis, acacia trees with yellow bark (local name : wach) - Big acacia trees (white spines) - Graminaceae (local name : hamiltou - hamentou)

Profile description :

0 - 10 cm	Texture : clay - Colour : 10 YR 3/2 very dark greyish brown- Humidity : dry - Structure : granular (mulch) - Consistence: not friable - Roots.
10 - 40 cm	Texture : clay - Colour : 10 YR 2/2 very dark brown - Humidity : dry - Structure : blocky, tendency to prismatic - Consistence : hard, compact - Roots, cracks.
40 - 110 cm	Texture : clay - Colour : 10 YR 2/2 very dark brown - Humidity : dry - Structure : blocky - tendency to prismatic - Consistence : hard, compact - Roots, cracks.
40 - 110 cm	Texture : clay - Colour : 10 YR 2/2 very dark brown - Humidity : moderately dry - Structure : coarse prismatic (slickensides) - Consistence : hard, very compact - No roots.

Analytical results : Profile nr IMS 120

Depth (cm)	Particle size distribution (%) <2 µ	2-20µ	20-50 µ	50-100µ	100-200µ	200µ 2 mm	pH	Lime (%)	Organic matter (%)	Carbon (%)	Nitrogen (%)	C/N	P_2O_5 total (ppm)	Moisture capacity at pF 2.5 (%)	Real density
0-10	50	41	8	1			8.0	0.2	1.7	1.0	0.49	20			
20-40	58	33	8	1			8.1	0.3	1.4	0.85					
60-80	61	32	6	1			8.1	0.3	1.4	0.85					

Depth (cm)	Exchangeable cations (me/100 g) S	Ca	Mg	K	Na	T	Na/T	Saturation soluble extract: Humidity at saturation	E.C. (mmho-cm)	Cl (me/l)	SO^4 (me/l)	CO^3 (me/l)	CO^3H (me/l)	Ca (me/l)	Mg (me/l)	K (me/l)	Na (me/l)
0-10								72	0.45								0.86
20-40								74	0.42								1.43
60-80								80	0.62								3.3

3.1 (3) Moderately deep on loamy horizons

/Mapping/ : soil type nr 313 - Colour : brown

/Field description/ : profile nr MMS 317

Location : Melka Sedi plain - Aerial photo nr 1738, run 21

Relief, erosion : flat - no erosion

Natural vegetation : big dying acacia trees - many bushes of gramineous (local name : adaito) - Sanseveria sp.

Profile description :

0 - 20 cm Texture clay - Colour : 10 YR 2/2 very dark brown - Humidity: moderately dry - Structure : fine granular to very fine blocky - Consistence : friable - Mulch on top of the soil - Roots - Some vertical cracks.

20 - 50 cm Texture : silty clay loam - Colour : 2.5 YR 4/2 dark greyish brown - Humidity : moderately dry - Structure : blocky - Consistence : friable - Some vertical thin cracks - Porous.

50 - 120 cm Texture : silty loam - Colour : 2.5 YR 4/2 dark greyish brown - Humidity : drier than above - Structure : fine granular - Consistence : friable.

120 and below Texture : sand.

/Analytical results/ : Profile nr MMS 317

Depth (cm)	Particle size distribution (%) <2 µ	2-20µ	20-50 µ	50-100µ	100-200µ	200µ 2 mm	pH	Lime (%)	Organic matter (%)	Carbon (%)	Nitrogen (%)	C/N	P_2O_5 total (ppm)	Moisture capacity at pF 2.5 (%)	Real density
0-10	59	24	15	2			7.0	0	8.4	4.9	3.6	14			
30-40	26	47	20	4	3		7.4	0	1.4	0.85					
100-120	13	60	24	3			8.0	1.4							

Depth (cm)	Exchangeable cations (me/100 g) S	Ca	Mg	K	Na	T	Na/T	Saturation soluble extract: Humidity at saturation	E.C. (mmho-cm)	Cl (me/l)	SO^4	CO^3	CO^3H	Ca	Mg	K	Na
0-10																	
30-40								57	1.54								1.2
100-120								47	0.32								0.38

3.1 (4) Shallow on interlayered alluvia ; microrelief with holes

/Mapping/ : soil type nr 314 - Colour : brown

/Field description/ : profile nr MMS 319

Location : Melka Sedi plain - Aerial photo nr 1742, run 21

Relief : flat

Natural vegetation : big acacia trees - Capparis - Gramineae with bare spots

Profile description :

0-20	cm	Texture : silty clay - Colour : 10 YR 2/2 very dark brown - Humidity : dry - Structure : fine blocky to granular and platy - Consistence : not so friable - Some vertical cracks - Organic matter - Fine roots.
20-27	cm	Texture : sandy - Colour : 10 YR 4/2 dark greyish brown - Humidity : dry - Structure : tendency to blocky - Consistence: friable - Fine roots.
27-33	cm	Texture : sandy loam with some dark silt - Colour : 10 YR 3/2 very dark greyish brown - Humidity : dry - Structure : granular - Consistence : friable - Roots.
33-40	cm	Texture : very fine sand to sandy loam - Colour : 25 Y 5/2 greyish brown - Humidity : dry - Consistence : friable - Roots.
40-50	cm	Texture : silty loam - Colour : 10 YR 3/2 very dark greyish brown - Humidity : dry - Structure : fine granular - Consistence : friable - Some yellow patches of iron.
50-70	cm	Texture : mixed granules of dark silt and pale loam - Colour : 10 YR 3/1 very dark grey - Humidity : moderately dry - Structure : blocky - Consistence : not so hard - Vertical cracks - Porous - Roots.
70-100	cm	Texture : loam and sandy loam - Colour : 10 YR 5/2 greyish brown - Humidity : dry - Structure : platy - Consistence : friable.

/Analytical results/ : Profile nr LMS 319

Depth (cm)	Particle size distribution (%)						pH	Lime (%)	Organic matter (%)	Carbon (%)	Nitrogen (%)	C/N	P_2O_5 total (ppm)	Moisture capacity at pF 2.5 (%)	Real density
	<2 μ	2-20μ	20-50 μ	50-100μ	100-200μ	200μ 2 mm									
0-10	43	42	13	2			6.5	0.0	3.05	1.80	1.75	10			
40-50	20	59	18	3			8.0	2.2	2.3	1.35					
100-120							8.1	1.0							

Depth (cm)	Exchangeable cations (me/100 g)							Saturation soluble extract									
	S	Ca	Mg	K	Na	T	Na/T	Humidity at saturation	E.C. (mmho-cm)	Cl (me/l)	SO^4 (me/l)	CO^3 (me/l)	CO^3H (me/l)	Ca (me/l)	Mg (me/l)	K (me/l)	Na (me/l)
0.10								70	0.85								0.75
40.50								59	0.50								1.14
100.120								55	0.33								1.95

3.2 Coarse structure, slightly alkaline soils

3.2 (1) Moderately fine to fine texture

/Mapping/ : soil type nr 321 - Colour : brown

/Field description/ : profile nr MMS 352

Location: North of Kadabilen marsh - Aerial photo nr 1496, run 19

Relief : flat

Microrelief : start of small channels in the direction of the Awash

Natural vegetation : acacia trees (medium size - dark bark) - Graminaceae in tufts (local name : durfu) - some Capparis

Profile description :

0-2 cm Texture : clay - Colour : 10 YR 3/2 very dark greyish brown - Humidity : dry - Structure : granular - Consistence : slightly friable - Mulch - Dry bulbs of Cyperaceae.

2-14 cm Texture : clay - Colour : 10 YR 3/2 very dark greyish brown - Humidity : dry - Structure : blocky to prismatic, vertical cracks - Consistence : hard - Roots.

14-70 cm Texture : clay - Colour : 10 YR 2/2 very dark brown - Humidity : dry - Structure : big blocks (coarse prismatic), vertical cracks (2-3 cm broad) - Roots - Slickenside - Consistence : hard

70-110 cm Texture : clay - Colour : 10 YR 3/2 very dark greyish brown - Humidity : moderately dry below 100 cm - Structure and consistence : the same as 14-70 cm.

Analytical results : profile MMS 352

Depth (cm)	Particle size distribution (%) <2 µ	2-20µ	20-50 µ	50-100µ	100-200µ	200µ 2 mm	pH	Lime (%)	Organic matter (%)	Carbon (%)	Nitrogen (%)	C/N	P_2O_5 total (ppm)	Moisture capacity at pF 2.5 (%)	Real density
0-10	69	22	8	1			7.7	0.19	3.6	2.1	1.4	15			
100-120	69	22	7	2			8.1	1.4	1.6	0.95					

Depth (cm)	Exchangeable cations (me/100 g) S	Ca	Mg	K	Na	T	Na/T	Saturation soluble extract: Humidity at saturation	E.C. (mmho-cm)	Cl (me/l)	SO^4	CO^3	CO^3H	Ca	Mg	K	Na
0-10								87	0.72								4.5
100-120								95	3.5								24

3.2 (2) <u>Moderately fine texture on interlayered alluvia, microrelief with holes and channels in dried-up areas</u>

/Mapping/ : soil type nr 322 - Colour : brown

/Field description/ : profile nr KKB 120

Location : Kesem plain - Aerial photo nr 1991, run 23

Microrelief : strongly marked

Natural vegetation : acacia trees - Hyparrhenia - Gramineae (local name: Hamiltou)

Profile description :

0-10 cm Texture : silty clay loam - Colour : 10 YR 2/2 very dark brown- Humidity : dry - Structure : blocky - Consistence : hard.

10-25 cm Texture : sandy loam - Colour : 2.5 Y 5/2 greyish brown - Humidity : moderately dry - Structure : platy - Consistence : friable - porous - Patches of hydromorphic iron.

25-70 cm Texture : silty loam - Colour : 2.5 Y 4/2 dark greyish brown - Humidity : moderately dry - Structure : platy and blocky - Consistence : hard to compact - Thin layers of clay loam at 30-40-60 cm (1 to 2 cm each) with a fine subangular blocky structure.

70-120 cm Texture : silty clay loam - Colour : 10 YR 3/2 very dark greyish brown - Humidity : moderately dry - Structure : massive Consistence : hard - Thin layers of pale loam.

Analytical results : profile KKB 120

Depth (cm)	Particle size distribution (%) <2 μ	2-20μ	20-50 μ	50-100μ	100-200μ	200μ 2 mm	pH	Lime (%)	Organic matter (%)	Carbon (%)	Nitrogen (%)	C/N	P_2O_5 total (ppm)	Moisture capacity at pF 2.5 (%)	Real density
0-10	46	42	10	2			7.6	0.17	3.4	2					
30-40	24	61	14	1			7.9	0.61							
60-70	27	55	16	2			7.9	0.47							
80-120	36	52	10	2			8.0	0.82							

Depth (cm)	Exchangeable cations (me/100 g) S	Ca	Mg	K	Na	T	Na/T	Saturation soluble extract: Humidity at saturation	E.C. (mmho-cm)	Cl (me/l)	SO^4 (me/l)	CO^3 (me/l)	CO^3H (me/l)	Ca (me/l)	Mg (me/l)	K (me/l)	Na (me/l)
0-10								81	0.61								0.71
30-40								62	0.35								0.47
60-70								67	0.30								0.43
80-120								70	0.37								0.90

4. Vertisols on Very Slightly or Non-Calcareous Materials Subject to Seasonal Waterlogging During Floods

/Mapping/ : soil type nr 4 - Colour : brown

/Field description/ : profile nr MMS 327

Location : Melka Sedi area - Aerial photo nr 1501, run 19

Relief : plain - flat

Flooding : flooded during the rainy season

Natural vegetation : Graminaceae (local names : sitabu, rebrebah)

Profile description :

0 - 5 cm Texture : clay - Colour : 10 YR 3/3 dark brown - Humidity : dry - Structure : tendency to platy - Consistence : not so friable - Debris of organic matter.

5 -15 cm Texture : clay loam - Colour : 10 YR 2/2 very dark brown - Humidity : moist - Structure : blocky with tendency to prismatic - Consistence : hard - Rusty patches of hydromorphic iron along the roots - Roots.

15-110 cm Texture : silty clay loam - Colour : 10 YR 2/2 very dark brown - Humidity : moderately dry - Structure : tendency to prismatic - Consistence : hard - Below 70 cm, slickensides on the aggregates.

110-130 cm Texture : sandy-loam - Colour : 10 YR 6/2 light brownish grey - Humidity : moderately dry.

/Analytical results/ : profile MMS 327

Depth (cm)	Particle size distribution (%) <2 µ	2-20µ	20-50 µ	50-100µ	100-200µ	200µ 2 mm	pH	Lime (%)	Organic matter (%)	Carbon (%)	Nitrogen (%)	C/N	P_2O_5 total (ppm)	Moisture capacity at pF 2.5 (%)	Real density
0-10	10	40	33	13	3	1	7.9	0.73	2.5	1.48					
100-130	8	40	37	11	4		7.9	1.3							

Depth (cm)	Exchangeable cations (me/100 g) S	Ca	Mg	K	Na	T	Na/T	Saturation soluble extract: Humidity at saturation	E.C. (mmho-cm)	Cl (me/l)	SO^4 (me/l)	CO^3 (me/l)	CO^3H (me/l)	Ca (me/l)	Mg (me/l)	K (me/l)	Na (me/l)
0-10								50	0.81								0.47
100-130								56	2.4								3.3

5. Vertisols on Slightly Calcareous Materials

5.1 Fine structure

/Mapping/ : soil type nr 51 - Colour : brown

/Field description/ : profile nr MMS 358

Location: Melka Sedi plain - Aerial photo nr 1662, run 20

Microrelief : small depressions

Natural vegetation : few small Capparis-gramineae (local name : durfu) in tufts - sparse acacias (green bark)

Profile description :

0 - 10 cm	Texture : silty loam - Colour : 10 YR 6/5 light grey - Humidity : dry - Structure : fine blocky - Consistence : friable - Some roots.
10 - 30 cm	Texture : silty loam to silty clay loam - Colour : 10 YR 3/3 dark brown - Humidity : less dry - Structure : blocky tendency to prismatic - Consistence : slightly hard.
30 - 32 cm	loam mixed with basalt gravels.
32 - 70 cm	silty loam - Colour : 10 YR 5/2 greyish brown - Humidity : dry - Structure : fine granular - Consistence : friable - Roots.
70 - 72 cm	layer of loam and basalt gravels.
72 -100 cm	silty clay loam - Colour : 10 YR 2/2 very dark brown - Humidity : moderately dry - Structure : blocky - Consistence : not so friable - Vertical cracks - Some lime concretions (1-2 mm)
100 -120 cm	Texture : loam and sand - Colour : 10 YR 4/2 dark greyish brown - Humidity : moderately dry.
120 -130 cm	Texture : loam - Colour : 10 YR 3/2 very dark greyish brown - Humidity : moderately dry - Structure : powdery.

/Analytical results/ : profile MMS 358

Depth (cm)	Particle size distribution (%) <2 µ	2-20µ	20-50 µ	50-100µ	100-200µ	200µ 2 mm	pH	Lime (%)	Organic matter (%)	Carbon (%)	Nitrogen (%)	C/N	P_2O_5 total (ppm)	Moisture capacity at pF 2.5 (%)	Real density
0-10	21	48	21	3	3	4	8.2	4.7	2.3	1.35	1.40	10			
15-25							8.2	6.0							
80-90	35	44	12	2	2	5	8.6	8.1							

Depth (cm)	Exchangeable cations (me/100 g) S	Ca	Mg	K	Na	T	Na/T	Saturation soluble extract: Humidity at saturation	E.C. (mmho-cm)	Cl (me/l)	SO^4	CO^3	CO^3H	Ca	Mg	K	Na
0-10								40	0.81								1.79
15-25																	
80-90								72	0.60								6.1

5.2 Coarse structure

/Mapping/ : soil type nr 52 - Colour : brown

/Field description/ : profile nr MMS 312

Location : Melka Sedi plain - Aerial photo nr 1738, run 21

Microrelief : near an old bed of the Awash river, some holes

Flooding : former flooded area

Natural vegetation : acacia trees (with spines) small and sparse - Some Capparis - Gramineae (local name : durfu)

Profile description :

0 - 10 cm	Texture : silty loam - Colour : 10 YR 3/2 very dark greyish brown - Humidity : dry - Structure : fine blocky - Consistence: friable - Roots - Cyperus bulbs - Vertical cracks.
10 - 40 cm	Texture : silty clay loam - Colour : 10 YR 2/2 very dark brown - Humidity : dry - Structure : very coarse blocky, tendency to prismatic - Vertical cracks - (about 1cm) - Consistence : Compact - Fine roots.
40 -100 cm	Texture : silty clay loam - Colour : 10 YR 2/2 very dark brown - Humidity : moderately dry - Structure : blocky (tendency to prismatic) - Fine roots.
100-120 cm	Texture : clay - Colour : 10 YR 2/2 very dark brown - Humidity : more dry than above - Structure and consistence : the same as 40-100 cm.

/Analytical results/ : profile nr MMS 312

Depth (cm)	Particle size distribution (%)						pH	Lime (%)	Organic matter (%)	Carbon (%)	Nitrogen (%)	C/N	P_2O_5 total (ppm)	Moisture capacity at pF 2.5 (%)	Real density
	<2 µ	2-20µ	20-50 µ	50-100µ	100-200µ	200µ 2 mm									
0-10	26	51	13	4	3	3	8.1	3.0	2.2	1.30	1.12	12			
30-40							8.4	4.1							
100-120	40	37	14	5	3	1	8.3	4.9							

Depth (cm)	Exchangeable cations (me/100 g)							Saturation soluble extract									
	S	Ca	Mg	K	Na	T	Na/T	Humidity at saturation	E.C. (mmho-cm)	Cl	SO^4	CO^3	CO^3H	Ca	Mg	K	Na
										(me/l)							
0-10								60	1.26								3.7
30-40																	
100-120								71	4.1								32.6

6. Hydromorphic Soils

6.1 On very slightly calcareous materials

/Mapping/ : soil type nr 61 - Colour : light blue

/Field description/ : profile nr MAL 20

Location : North Angelele-Melka Sedi plain - Aerial photo nr 1501, run 19

Microrelief : lowland

Flooding : area flooded by the Awash in the rainy season

Natural vegetation : good pasture land - Grass (local name : sitabu) - Ecchynochloa

Profile description :

0 - 4 cm	Organic matter and dead roots not decomposed
4 -15 cm	Texture : silty clay - Colour : 10 YR 3/1 - 2/1 very dark grey to very dark greyish brown - Humidity : moist to wet - Structure : prismatic tendency to blocky - Consistence : hard - Many roots - Rusty patches of hydromorphic iron - Vertical cracks (about 1/2 cm) - Organic matter in the cracks.
15-40 cm	Texture : silty clay - Colour : 10 YR 3/1 very dark grey - Humidity : moist to wet - Consistence : the same as above - Structure : prismatic to blocky - Vertical cracks - Slickensides - Rusty patches.
40-80 cm	Texture : silty clay loam - Colour : 10 YR 3/1 very dark grey Structure : prismatic - Humidity : moist to wet - Vertical cracks (1/2 cm) slickensides - Rusty patches.
180-200 cm	Texture : silty clay loam becoming gradually sandy loam - Rusty patches

/Analytical results/ : profile nr MAL 20

Depth (cm)	Particle size distribution (%)						pH	Lime (%)	Organic matter (%)	Carbon (%)	Nitrogen (%)	C/N	P_2O_5 total (ppm)	Moisture capacity at pF 2.5 (%)	Real density
	<2 µ	2-20µ	20-50 µ	50-100µ	100-200µ	200µ 2 mm									
5-15	57	18	24	1			6.8	0	3.6	1.53		14	700	65.0	2.22
40-60	39	23	37	1			7.8	tr	1.4	0.58		14	800	59.5	2.28
150-180	44	26	29	1			8.2	0.7							

Depth (cm)	Exchangeable cations (me/100 g)							Saturation soluble extract									
	S	Ca	Mg	K	Na	T	Na/T	Humidity at saturation	E.C. (mmho-cm)	Cl (me/l)	SO^4 (me/l)	CO^3 (me/l)	CO^3H (me/l)	Ca (me/l)	Mg (me/l)	K (me/l)	Na (me/l)
5-15	61.4	46.6	11.1	2.8	0.9	62.0	1	113	0.58	5.0	0.4	0	0.2	2.8	0.8	1.6	
40-60	65.6	47.9	14.3	2.1	1.3	84.8	2	120	0.49	4.5	0.3	0	0.5	2.4	2.4	2.1	
150-180								106	0.44								

6.2 On alkaline materials

/Mapping/ : soil type nr 62 - Colour : dark blue with red streaks

/Field description/ : profile nr KK 319

Location : near Filweha - Filweha plain - Aerial photo nr 2202, run 24

Microrelief : depression

Drainage : poor

Natural vegetation : Phragmites - Cyperaceae - Vetiveria

Profile description :

0 - 10 cm	Texture : clay - Colour : 5 YR 2/1 black - Humidity : wet - Structure : massive - Consistence : plastic, compact - Roots.
10 -130 cm	Texture : clay - Colour : 5 YR 2/1 black - Humidity : very wet - Patches of hydromorphic iron, rust incolour - Structure : massive - Without consistence .

/Analytical results/ : profile nr KK 319

Depth (cm)	Particle size distribution (%) <2 µ	2-20µ	20-50 µ	50-100µ	100-200µ	200µ 2 mm	pH	Lime (%)	Organic matter (%)	Carbon (%)	Nitrogen (%)	C/N	P_2O_5 total (ppm)	Moisture capacity at pF 2.5 (%)	Real density
0-10	50	24	24	2			10.2	4.9	7.2	4.2					
100-130	58	26	15	1			8.9	3.1							

Depth (cm)	Exchangeable cations (me/100 g) S	Ca	Mg	K	Na	T	Na/T	Saturation soluble extract: Humidity at saturation	E.C. (mmho-cm)	Cl (me/l)	SO^4	CO^3	CO^3H	Ca	Mg	K	Na
0-10					36.4	75.2	48.4	123	18	64	0.9	57	91.5	1.3	0.64	1.0	231
100-130					19.6	74.1	26.5	119	2.03	5.6	11.6	0	7.8	2.0	2.00	0.34	18

6.3 On alkaline materials

/Mapping/ : soil type nr 62 - Colour : dark blue, red streaks

/Field description/ : profile nr MAL 4

Location : Melka Sedi plain - Aerial photo nr 1497, run 19

Microrelief : light microrelief - Lowland

Flooding : flooded by Kadabilen hot spring

Water table : 65 - 70 cm

Natural vegetation : Thypas - Cyperus

Profile description :

0 - 1 cm	Organic matter
1 - 15 cm	Texture : silty loam - Colour : greyish black - Humidity : wet - Consistence : sticky - Structure : undeveloped - Shells Roots, many decomposed - Layers of organic matter.
15 - 25 cm	Texture : silty loam greyish black and discolored patches - Humidity : very wet - Structure : tendency to blocky - Shells Decomposed roots.
25 - 50 cm	Texture : silty loam - Colour : grey - Humidity : very wet - Structure : tendency to fine blocky - Many roots, some decomposed.
50 - 65 cm	Texture : silty loam, gravels, spots of clay - Colour : grey Humidity : very wet - Some roots.

below 65 cm : mixed basalt gravels, sand and loam

/Analytical results/: Profile nr MAL 4

Depth (cm)	Particle size distribution (%)						pH	Lime (%)	Organic matter (%)	Carbon (%)	Nitrogen (%)	C/N	P_2O_5 total (ppm)	Moisture capacity at pF 2.5 (%)	Real density
	<2 µ	2-20µ	20-50 µ	50-100µ	100-200µ	200µ 2 mm									
0-10	17	52	27	3		1	9.8	9.2	4.9	1.93		15	1.330		
25-35	26	56	15	2		1	9.6	11.0					1.220		
50-60	17	18	11	28		46	9.5	16.0							

Depth (cm)	Exchangeable cations (me/100 g)							Saturation soluble extract									
	S	Ca	Mg	K	Na	T	Na/T	Humidity at saturation	E.C. (mmho-cm)	Cl	SO^4	CO^3	CO^3H	Ca	Mg	K	Na
										(me/l)							
0-10					42.0	53.2	76	87	11.8	70	71	0	51	3.0	10		136
25-35					27.2	50.0	54	63	8.8								100
50-60								31	2.26								

B. SOILS ON OLD ALLUVIA AND COLLUVIA

7. Vertisols on Calcareous Materials Slightly Saline at Deeper Levels

7.1 Fine structure

/Mapping/ : soil type nr 71 - Colour : green

/Field description/ : profile nr HMA 53

Location : Metehara plain - Blue Nile aerial photo nr 3882, run 1

Relief : plain - flat

Natural vegetation : very young acacia trees - Bermuda grass - very few Young Capparis

Profile description :

0 - 15 cm Texture : silty loam - Colour : 10 YR 3/3 dark brown - Humidity : moderately dry - Structure : granualr to fine blocky - Consistence : friable - Fine roots - Vertical cracks.

15 - 40 cm Texture : silty clay - Colour : 10 YR 4/2 dark greyish brown - Humidity : dry - Structure : blocky to prismatic - Consistence : hard - Vertical cracks - (about 1-3 cm wide) roots - Lime concretions - Few basalt gravels - Porous.

40 - 60 cm Texture : silty clay - Colour : 10 YR 4/2 dark greyish brown Humidity : moist - Structure : blocky - Consistence : slightly friable - Limestone concretions - Very few basalt gravels Roots.

60 -100 cm Texture : silty clay - Colour : 10 YR 3/3 dark brown - Humidity : moderately dry - Structure : massive to coarse blocky - Consistence : little more friable than above - Limestone concretions - Roots.

Analytical results: Profile mr HMA 53

Depth (cm)	Particle size distribution (%)						pH	Lime (%)	Organic matter (%)	Carbon (%)	Nitrogen (%)	C/N	P_2O_5 total (ppm)	Moisture capacity at pF 2.5 (%)	Real density
	<2 µ	2-20µ	20-50 µ	50-100µ	100-200µ	200µ 2 mm									
0-10	25	58	9	1	3	4	8.5	4.1	3.0	1.75					
30-50	51	36	7	2	2	2	9.0	7.5							
80-90	43	42	6	2	2	5	9.0	10.6							

Depth (cm)	Exchangeable cations (me/100 g)							Saturation soluble extract									
	S	Ca	Mg	K	Na	T	Na/T	Humidity at saturation	E.C. (mmho-cm)	Cl	SO^4	CO^3	CO^3H	Ca	Mg	K	Na
										(me/l)	(me/l)	(me/l)	(me/l)	(me/l)	(me/l)	(me/l)	(me/l)
0-10								54	0.68								4.7
30-50								76	1.26								12.0
80-90								76	5.9								61.7

7.2 Coarse structure

/Mapping/ : soil type nr 72 - Colour : green

/Field description/ : profile nr LLd 31

Location : Aleydegi plain - Aerial photo nr 1201, run 18

Relief : flat

Microrelief : subsidence cracks on the surface, 5 to 10 cm wide

Natural vegetation : pasture land (gramineae)

Profile description :

0 - 5 cm	Texture : silty clay loam - Colour : 10 YR 3/3 dark brown - Humidity : dry - Structure : powdery - Consistence : friable
5 - 20 cm	Texture : silty clay loam - Colour : 10 YR 2/2 very dark brown - Humidity : very dry - Structure : blocky - Consistence : very hard - Vertical cracks (3 cm wide).
20 - 60 cm	Texture : clay - Colour : 10 YR 2/2 very dark brown - Humidity : very dry - Structure : platy - Consistence : very hard - Vertical polyedral 30-40 cm wide and 30 cm high - Slight accumulation of saccharoid salt
60 -100 cm	Texture - clay to silty clay - Colour : 10 YR 2/2 very dark brown - Humidity : not dry - Structure : undeveloped - Consistence : very dark - Gypsum at 1 m - Slight accumulation of greyish white salt.
100 -110 cm	Texture : silty clay loam - Colour : 10 YR 4/2 dark greyish brown - Humidity : dry - Consistence : very compact gypsum.

/Analytical results/: profile nr LLD 31

Depth (cm)	Particle size distribution (%)						pH	Lime (%)	Organic matter (%)	Carbon (%)	Nitrogen (%)	C/N	P_2O_5 total (ppm)	Moisture capacity at pF 2.5 (%)	Real density
	<2 µ	2-20µ	20-50 µ	50-100µ	100-200µ	200µ 2 mm									
0-5	29	44	12	4	4	7	8.8	6.3	2.8	1.65					
10-20	36	41	9	3	4	7	9.2	7.2							
40-50	42	39	7	3	3	6	8.4	6.0							
100-110	38	27	7	3	5	20	7.9	5.5							

Depth (cm)	Exchangeable cations (me/100 g)							Saturation soluble extract									
	S	Ca	Mg	K	Na	T	Na/T	Humidity at saturation	E.C. (mmho-cm)	Cl	SO^4	CO^3	CO^3H	Ca	Mg	K	Na
										(me/l)							
0-5	48	40.2	5.6	0.84	2.4	56	4.3	52	0.73								4.9
10-20	51.7	37.6	5.4	0.65	9.0	48.6	18.5	56	0.67								6.9
40-50					11.0	50	22	67	8.1	4.5							77
100-110					7.8	39.6	19.7	60	7.3	29	51.5	0	4.3	27.1	5.8	0.2	71.2

8. Semi-Arid Brown Soils and Vertisols on Calcareous Materials of Rough Land

8.1 Vertisols on calcareous materials in the runoff zones

8.1 (1) Deep

/Mapping/ : soil type nr 811 - Colour : orange

/Field description/ : profile nr HMA 1

Location : Metehara plain - Blue Nile aerial photo nr 3881, run 1

Relief : flat

Drainage : good

Natural vegetation : some Capparis - Gramineae (Amharic name : lady)

Profile description :

0 - 1 cm	Texture : silty loam - Colour : 10 YR 5/2 greyish brown - Structure : when dry becomes powdery - Soft on the surface (like mulch)
1 - 10 cm	Texture : silty loam - Colour : 10 YR 4/2 dark greyish brown (when wet) - Humidity : moderately dry - Structure : fine blocky to crumb - Consistence : friable - Fine white roots
10 - 30 cm	Texture : silty loam to silty clay loam - Colour : 10 YR 3/2 to 4/1 very dark - Humidity : dry - Structure : fine granular - Consistence : friable - Some vertical cracks - Fine roots.
30 - 60 cm	Texture : clay - Colour : 10 YR 3/2 - 2/ very dark greyish brown to very dark brown - Humidity : dry - Structure : blocky medium size (1-2 cm) tendency to platy - Fine granular - Consistence : little hard - Vertical cracks, some roots.
60 -100 cm	Texture : clay to silty clay loam - Colour : 10 YR 2/2 very dark brown - Humidity : dry - Structure : blocky (medium size) tendency to platy - Consistence : more compact than above - Some slickensides - Roots.
100-150 cm	Texture : clay - Colour : 10 YR 2/2 very dark brown - Humidity : dry - Structure : medium size blocky - Consistence : harder than above - Some vertical cracks.

/Analytical results/ : profile mr HMA 1

Depth (cm)	Particle size distribution (%) <2 µ	2-20µ	20-50 µ	50-100µ	100-200µ	200µ 2 mm	pH	Lime (%)	Organic matter (%)	Carbon (%)	Nitrogen (%)	C/N	P_2O_5 total (ppm)	Moisture capacity at pF 2.5 (%)	Real density
0-1	26	58	14	2			8.6	6.0	2.7	1.58					
1-10	25	65	9	1			8.5	6.4							
40-60	71	25	3	1			8.2	5.7							
130-150	59	33	7	1			8.1	5.7							

Depth (cm)	Exchangeable cations (me/100 g) S	Ca	Mg	K	Na	T	Na/T	Saturation soluble extract: Humidity at saturation	E.C. (mmho-cm)	Cl (me/l)	SO^4 (me/l)	CO^3 (me/l)	CO^3H (me/l)	Ca (me/l)	Mg (me/l)	K (me/l)	Na (me/l)
0-1								50	0.55								0.27
1-10								60	0.48								0.46
40-60								83	1.44								5.1
130-150								80	4.3								18.6

8.1 (2) Moderately deep on basalt gravel colluvia

/Mapping/ : soil type nr 812 - Colour : orange

/Field description/ : profile nr MMS 350

Location : Melka Sedi plain - Aerial photo nr 1736, run 21, limit of the vertisols

Microrelief : tufts or grass

Natural vegetation : gramineae (local name : adaito), some Capparis

Profile description :

0 - 15 cm	Texture : silty clay loam - Colour : 2.5 Y 5/2 greyish brown Humidity : dry - Structure : medium to fine blocky - Consistence : friable roots.
15 - 30 cm	Texture : silty loam - Colour : 10 YR 3/3 dark brown - Humidity : moderately dry - Structure : blocky tendency to prismatic (platy) - Consistence : harder than 0-15 cm - Very small lime concretions, friable.
30 - 70 cm	Texture : silty loam to loam - Colour : 10 YR 4/2 dark greyish brown - Humidity : moderately dry - Consistence : slightly hard, lime concretions at 50 cm (lime crust friable).

/Analytical results/ : profile mr MMS 350

Depth (cm)	Particle size distribution (%) <2 µ	2-20µ	20-50 µ	50-100µ	100-200µ	200µ 2 mm	pH	Lime (%)	Organic matter (%)	Carbon (%)	Nitrogen (%)	C/N	P_2O_5 total (ppm)	Moisture capacity at pF 2.5 (%)	Real density
0-10	32	41	17	3	3	4	8.3	3.5	4.2	2.5					
20-30	25	48	19	2	2	4	8.2	5.2							
60-70		" crust "					8.2	31.5							

Depth (cm)	Exchangeable cations (me/100 g) S	Ca	Mg	K	Na	T	Na/T	Saturation soluble extract: Humidity at saturation	E.C. (mmho-cm)	Cl (me/l)	SO^4 (me/l)	CO^3 (me/l)	CO^3H (me/l)	Ca (me/l)	Mg (me/l)	K (me/l)	Na (me/l)
0-10								50	0.88								1.62
20-30																	
60-70								56	0.55								1.08

8.1 (3) Moderately deep with basalt gravel generally covered by runoff loam

/Mapping/ : soil type nr 813 - Colour : orange

/Field description / : profile nr HMA 6

Location : Metehara plain - Blue Nile aerial photo nr 3881, run 1

Relief : flat

Microrelief : none

Drainage : good

Natural vegetation : scattered gramineae in the microdepressions - Some Capparis

Profile description :

0 - 5 cm Texture : silty loam - Colour : 10 YR 4/2 dark greyish brown Humidity : dry to moderately dry - Structure : medium blocky to platy - Consistence : friable fine roots.

5 - 20 cm Texture : silty loam to silty clay loam - Colour : 10 YR 4/2 dark greyish brown - Humidity : dry - Structure : fine crumb Consistence : friable fine roots, some gravels.

20 - 50 cm Texture : silty clay - Colour : 10 YR 3/3 - 2/2 dark brown to very dark brown - Humidity : dry - Structure : medium coarse blocky to prismatic - Consistence : compact vertical cracks, some basalt gravels at 20-30 cm, roots

50 -100 cm Texture : silty clay - Colour : 10 YR 3/3 - 2/2 dark brown to very dark brown - Humidity : dry - Structure : medium size blocky, tendency to platy - Consistence : compact, some roots and thin vertical cracks.

100-140 cm Texture : silty loam to silty clay loam - Colour : 10 YR 3/2 dark brown

below 140 cm : texture : sandy loam to silty loam - Colour : 10 YR 4/2 dark greyish brown.

/Analytical results/ ; profile mr HMA 6

Depth (cm)	Particle size distribution (%)						pH	Lime (%)	Organic matter (%)	Carbon (%)	Nitrogen (%)	C/N	P_2O_5 total (ppm)	Moisture capacity at pF 2.5 (%)	Real density
	<2 µ	2-20µ	20-50 µ	50-100µ	100-200µ	200µ 2 mm									
0-5	21	55	12	2	4	6	8.6	3.5	2.8	1.65					
40-50	46	42	3	1	2	6	8.2	6.2							
90-100	41	43	8	1	2	5	8.4	6.9							

Depth (cm)	Exchangeable cations (me/100 g)							Saturation soluble extract									
	S	Ca	Mg	K	Na	T	Na/T	Humidity at saturation	E.C. (mmho-cm)	Cl	SO^4	CO^3	CO^3H	Ca	Mg	K	Na
										(me/l)							
0-5								47	0.65								0.64
40-50								63	1.47								3.4
90-100								67	1.84								10.8

8.2 Semi-arid brown soils on calcareous colluvia material (with local limestone crust)

/Mapping/ : soil type nr 82 - Colour : sepia

/Field description/ : profile nr MMS 314

Location : Melka Sedi plain - Aerial photo nr 1738, run 21

Natural vegetation : very few green acacias (local name : gerento), big trees (local name : gersa), some bare spots with gramineae tufts (local name: durfu)

Profile description :

0 - 25 cm	Texture : sandy loam - Colour : 2.5 Y 5/2 greyish brown - Humidity : dry - Structure : single grain - No consistence - Fine roots .
25 - 40 cm	Texture : coarse sand - Colour : 2.5 Y 5/2 greyish brown - Humidity : moderately dry - Structure : single grain - No consistence - Limestone concretions, round shaped small fine roots, gravels from 2 to 1 cm .
40 - 90 cm	Texture : silt - Colour : 2.5 Y 6/2 light brownish grey - Humidity : dry - Structure : powdery - Consistence : friable, some limestone concretions - Not hard .
90 - 95 cm	Limestone crust greyish white - Dry - After 95 cm : this horizon is powdery (like ash) without structure and consistence ; The upper part is hard, cemented by lime,

/Analytical results/ : Profile nr MMS 314

Depth (cm)	Particle size distribution (%)						pH	Lime (%)	Organic matter (%)	Carbon (%)	Nitrogen (%)	C/N	P_2O_5 total (ppm)	Moisture capacity at pF 2.5 (%)	Real density
	<2 µ	2-20µ	20-50 µ	50-100µ	100-200µ	200µ 2 mm									
0-10	5	19	16	16	23	21	8.4	3.1	0.80	0.47					
60-70	2	29	50	15	2	2	8.1	4.5							
90-100							8.9	9.4							
90-95	crust							47.0							

Depth (cm)	Exchangeable cations (me/100 g)							Saturation soluble extract									
	S	Ca	Mg	K	Na	T	Na/T	Humidity at saturation	E.C. (mmho-cm)	Cl (me/l)	SO^4 (me/l)	CO^3 (me/l)	CO^3H (me/l)	Ca (me/l)	Mg (me/l)	K (me/l)	Na (me/l)
0-10																	
60-70								45	4.2								15.2

8.3 <u>Semi-arid brown soils on colluvial or old gravelly alluvial material</u>

/Mapping/ : soil type nr 83 - Colour : seppia + ooo ooo

/Field description / : profile nr MMS 65

Location : South part of the Melka Sedi plain - Aerial photo nr 1956, run 22

Relief : summit of a hill

Erosion : very marked

Natural vegetation : small gramineae - Trees (Capparis)

Profile description :

0 - 1 cm	Small rounded gravel from 1 to 2 cm
1 - 10 cm	Greyish brown loam - Some rounded gravel - Numerous roots - Dry
10 - 20 cm	Transition horizon - Numerous roots.
20 - 50 cm	Lighter grey loam - More rounded gravel from 1 to 4 cm fairly weathered - Numerous roots.
50 - 80 cm	Darker brown loam - Less stones - Several calcareous concretions - Numerous roots.
80 -100 cm	Loam with a large quantity of weathered gravel - White streaks of limestone - Few roots.
100-120 cm	Texture : sand to silty sand, - Colour : ochre brown to yellowish brown - Incipient limestone cementation - Few roots.

/Analytical results/ : profile nr MMS 65

Depth (cm)	Particle size distribution (%) <2 µ	2-20µ	20-50 µ	50-100µ	100-200µ	200µ 2 mm	pH	Lime (%)	Organic matter (%)	Carbon (%)	Nitrogen (%)	C/N	P_2O_5 total (ppm)	Moisture capacity at pF 2.5 (%)	Real density
300	1	15	20	14	20	30	9.7	3.9							
400-500	35	42	13	2	2	6	8.6	20.2							
500-600	11	60	21	3	2	3	8.6	3.1							

Depth (cm)	Exchangeable cations (me/100 g) S	Ca	Mg	K	Na	T	Na/T	Saturation soluble extract: Humidity at saturation	E.C. (mmho-cm)	Cl (me/l)	SO^4 (me/l)	CO^3 (me/l)	CO^3H (me/l)	Ca (me/l)	Mg (me/l)	K (me/l)	Na (me/l)
300								53	0.80	1.6	1.3	0	9.9	2.7	1.12	0.07	9.1
400-500								70	9.9	76	38	0	5	17.6	17.2	0.24	96
500-600								67	17.8	5.4	234	0	2.5	22.6	5.8	0.3	206

8.4 Semi-arid brown soils on volcanic tuff and basalt debris

/Mapping/ : soil type nr 84 - Colour : sepia with violet streaks

/Field description/ : profile nr MMH 26

Location : Metehara plain - Near an old bed of the Awash

Relief : flat

Natural vegetation : gramineae (local name : durfu)

Profile description :

0 - 10 cm	Texture : loam to sandy loam - Colour : 10 YR 5/4 yellowish brown - Humidity : moderately dry - Structure : platy, medium size, not so developed - Consistence : slightly friable - Gravels (size : about 5 cm) of basalt and pumice stone
10 - 45 cm	Texture : fine sand mixed with gravels (about 5 cm) of pumice stone - Colour : 10 YR 6/4 light yellowish brown - Humidity : dry - Structure : powdery - No consistence, fine roots.
45 - 80 cm	Texture : sandy loam - Colour : 10 YR 6/4 light yellowish brown - Humidity : dry - The same structure and consistence as 10-45 cm - More gravel and pumice stone larger than 10-45 cm.
80 -120 cm	Pumice stone and gravels.

/Analytical results/: profile nr MMH 26

Depth (cm)	Particle size distribution (%) <2 μ	2-20μ	20-50 μ	50-100μ	100-200μ	200μ 2 mm	pH	Lime (%)	Organic matter (%)	Carbon (%)	Nitrogen (%)	C/N	P_2O_5 total (ppm)	Moisture capacity at pF 2.5 (%)	Real density
0-10	11	25	12	9	13	30	8.3	0.24	1.35	0.80					
40-50	3	24	14	6	2	51	8.7	1.34							

Depth (cm)	Exchangeable cations (me/100 g) S	Ca	Mg	K	Na	T	Na/T	Saturation soluble extract: Humidity at saturation	E.C. (mmho-cm)	Cl (me/l)	SO^4	CO^3	CO^3H	Ca	Mg	K	Na
0-10								43	0.45								0.98
40-50								35	18								160.5

9. Regosols Resulting From Erosion

9.1 On soft alluvial and colluvial materials

/Mapping/ : soil type nr 91 - Colour : pink

/Field description/ : profile nr MMS 16

Location : East Melka Sedi plain - Aerial photo nr 1664, run 20

Relief : slope more than 5 %

Microrelief : wavy

Natural vegetation : small acacia trees - Gramineae (local name : durfu) Capparis trees, pasture land

Profile description :

0 - 5 cm Texture : silty loam - Colour : 10 YR 6/2 light brownish grey Humidity : dry - Structure : crumb - Consistence : very friable, many roots

5 - 20 cm Texture : silty loam - Colour : 10 YR 5/2 - 5/3 greyish brown to brown - Humidity : dry - Structure : fine blocky - Consistence : very friable - Many roots - Small gravels of 1 mm size.

20 - 45 cm Texture : loam - Colour : 10 YR 6/3 pale brown - Other characteristics same as 5-20 cm.

45 - 60 cm Mixed layers similar to layer 5-20 cm and layer 20-45 cm, friable without structure.

60 - 80 cm Texture : loamy sand to loam - Colour : 10 YR 6/3 - 6/4 pale brown to light yellowish brown - Humidity : dry - Consistence: friable - Without structure : tendency to powdery - Roots.

/Analytical results/ : profile nr MMS 16

Depth (cm)	Particle size distribution (%)						pH	Lime (%)	Organic matter (%)	Carbon (%)	Nitrogen (%)	C/N	P_2O_5 total (ppm)	Moisture capacity at pF 2.5 (%)	Real density
	<2 µ	2-20µ	20-50 µ	50-100µ	100-200µ	200µ 2 mm									
0-5	22	41	15	6	7	9	8.1	8.4							
10-20							8.2	13.9							
30-40	13	30	13	12	15	17	8.3	10.1							
75-80							8.3	12.2							

Depth (cm)	Exchangeable cations (me/100 g)							Saturation soluble extract									
	S	Ca	Mg	K	Na	T	Na/T	Humidity at saturation	E.C. (mmho-cm)	Cl	SO^4	CO^3	CO^3H	Ca	Mg	K	Na
										(me/l)							
0-5								54	0.79								0.37
10-20								38	0.45								0.47
30-40								34	0.44								1.03
75-80								34	0.41								0.60

9.2 <u>On gravelly alluvial and colluvial materials</u>

/Mapping/ : soil type nr 92 - Colour : pink

/Field description/ : profile nr MMS 349

<u>Location</u> : Melka Sedi plain - Aerial photo nr 1736, run 21

<u>Relief</u> : slight slope

<u>Natural vegetation</u> : some Capparis, some gramineae

<u>Profile description</u> :

0 - 18 cm	Texture : loam - Colour : 10 YR 4/2 dark greyish brown - Humidity : dry - Structure : blocky undeveloped to single grain - Consistence : friable - Basalt gravel 1-2 cm - Roots
18 - 45 cm	Texture : loam - Colour : 10 YR 4/2 dark greyish brown - Humidity : moderately dry - Structure : blocky undeveloped - Consistence : more compact than 0-18 cm - More gravelly than 0-18 cm rounded gravels - Some very small limestone concretions.
45 - 70 cm	Texture : loam - Colour : 10 YR 5/3 brown - Humidity : moderately dry - Structure : blocky undeveloped - The same consistence as 18-45 cm - More gravelly and gravels bigger than 18-45 cm - Some lime concretions.
70 -100 cm	Texture : sandy - Colour : 10 YR 5/4 yellowish brown - Humidity : moderately dry - Structure : single grain - Consistence : hard - Gravelly.
100 cm	Very gravelly (gravel from 1 to 2 cm each, covered by white lime).

/Analytical results/ : Profile nr MMS 349

Depth (cm)	Particle size distribution (%) <2 µ	2-20µ	20-50 µ	50-100µ	100-200µ	200µ 2 mm	pH	Lime (%)	Organic matter (%)	Carbon (%)	Nitrogen (%)	C/N	P_2O_5 total (ppm)	Moisture capacity at pF 2.5 (%)	Real density
0-10	10	19	15	6	17	33	8.5	5.5.	1.3	0.75					
40-50	20	26	12	6	7	29	8.4	0.5							

Depth (cm)	Exchangeable cations (me/100 g) S	Ca	Mg	K	Na	T	Na/T	Saturation soluble extract: Humidity at saturation	E.C. (mmho-cm)	Cl (me/l)	SO^4 (me/l)	CO^3 (me/l)	CO^3H (me/l)	Ca (me/l)	Mg (me/l)	K (me/l)	Na (me/l)
0-10																	
40-50								42	33								208

9.3. <u>On basalt-gravel colluvial material</u>

/Mapping/ : soil type nr 93 - Colour : pink

/Field description/ : profile nr MMH 16

<u>Location</u> : Metehara plain - Blue Nile aerial photo nr 1470, run 2

<u>Relief</u> : river cone with a medium slope

<u>Microrelief</u> : clearly defined channels

<u>Drainage</u> : good - fairly moist zone

<u>Natural vegetation</u> : green acacias - Several large acacias - Tufts of green gramineae

<u>Profile description</u> :

0 - 10 cm Texture : sandy loam - Colour : 10 YR 5/2 greyish brown - Humidity : dry - Structure : blocky tendency to platy - Consistence : friable - Roots, basalt gravels.

10 - 35 cm Texture : sandy loam - Colour : 10 YR 5/3 brown - Humidity : dry - Structure : blocky - Consistence : slightly hard - Basaltic gravels 1 cm - Roots - Porous.

35 -100 cm Texture : loam - Colour : 10 YR 5/3 brown - Humidity : dry - Structure : blocky - Consistence : slightly hard - Not very porous - Pumice gravels.

100-140 cm Texture : sandy loam to sand - Colour : 10 YR 5/3 brown - Humidity : moderately dry - Structure : blocky.

/Analytical results/ : profile mr MMH 16

Depth (cm)	Particle size distribution (%)						pH	Lime (%)	Organic matter (%)	Carbon (%)	Nitrogen (%)	C/N	P_2O_5 total (ppm)	Moisture capacity at pF 2.5 (%)	Real density
	<2 µ	2-20µ	20-50 µ	50-100µ	100-200µ	200µ 2 mm									
0-10	9	23	15	10	14	29	7.7	0.14	1.70	1.00					
50-65	11	33	15	7	7	27	7.6	0.19							

Depth (cm)	Exchangeable cations (me/100 g)							Saturation soluble extract										
	S	Ca	Mg	K	Na	T	Na/T	Humidity at saturation	E.C. (mmho-cm)	Cl	SO^4	CO^3	CO^3H	Ca	Mg	K	Na
										(me/l)							
0-10								28	0.55								0.43
50-65								20	2.3								2.0

9.4 On soft pumice and volcanic tuff colluvial material

/Mapping/ : soil type nr 94 - Colour : pink

/Field description/ : profile nr MMH 3

Location : Metehara plain - Aerial photo nr 2196, run 24 - near the railway

Relief : flat

Erosion : in sheets

Natural vegetation : groves of small acacias, occasional large acacias, patches of gramineae (pasture), several Capparis

Profile description :

0 - 1 cm	Texture : loamy sand - Colour : 10 YR 5/2 - 6/3 greyish brown to pale brown - Humidity : dry - Structure : granular to powdery - Consistence : friable - Some roots.
1 - 25 cm	Texture : silty loam - Colour : 10 YR 5/2 - 6/3 greyish brown to pale brown - Humidity : dry to moderately dry - Structure: crumb undeveloped - Consistence : friable - Some roots
25 - 80 cm	Texture : silty clay loam - Colour : 10 YR 4/2 dark greyish brown - Humidity : dry to moderately dry - Structure : granular - Consistence : very friable - Fragments of pumice stone, roots.
80 - 120 cm	Texture : silty loam - Colour : 10 YR 5/2 greyish brown - Humidity : dry to moderately dry - Structure : granular to crumb - Consistence : very friable - Tendency to powdery - More fragments of pumice stone - Roots

/Analytical results/: profile mr MMH 3

Depth (cm)	Particle size distribution (%) <2 µ	2-20µ	20-50 µ	50-100µ	100-200µ	200µ 2 mm	pH	Lime (%)	Organic matter (%)	Carbon (%)	Nitrogen (%)	C/N	P_2O_5 total (ppm)	Moisture capacity at pF 2.5 (%)	Real density
0-10	17	48	14	10		11	7.1	0	5	2.22		13	1036	36	2.44
30-40	31	40	16	6		7	7.4						640		
80-100	24	45	15	8		8	8.0	2.0							

Depth (cm)	Exchangeable cations (me/100 g) S	Ca	Mg	K	Na	T	Na/T	Saturation soluble extract: Humidity at saturation	E.C. (mmho-cm)	Cl (me/l)	SO^4	CO^3	CO^3H	Ca	Mg	K	Na
0-10	37.8	31.4	2.9	3.2	0.3	37.4	1	47	0.56	2.51	1.0	0	1.5	4.8			8.2
30-40	39.2	33.3	2.5	3.0	0.4	40.0	1	38	0.24								
80-100					0.0	40.0	1	39	0.26								

10. Regosols and Saline Soils

/Mapping/ : soil type nr 10 - Colour : sepia with black streaks

/Field description/ : profile nr GGW 1

Location : North of Gewani - Aerial photo nr 9993, run 15

Relief : hills (like badlands)

Erosion : well defined

Natural vegetation : none

Profile description :

0 - 2 m	Grey marl - Silty clay loam
at 2 m	Crust with slight iron and basalt gravel
2 - 4 m	Grey saline marl
at 4 m	Whitish marl crusted
4 - 6 m	Beige silt, limestone very saline

/Analytical results/ : profile nr GGW1

Depth (cm)	Particle size distribution (%)						pH	Lime (%)	Organic matter (%)	Carbon (%)	Nitrogen (%)	C/N	P_2O_5 total (ppm)	Moisture capacity at pF 2.5 (%)	Real density
	<2 µ	2-20µ	20-50 µ	50-100µ	100-200µ	200µ 2 mm									
300-400	37	46	6	4	3	4	9.9	6.2							
400-600	29	33	6	4	6	22	10.0	27.0							

Depth (cm)	Exchangeable cations (me/100 g)							Saturation soluble extract										
	S	Ca	Mg	K	Na	T	Na/T	Humidity at saturation	E.C. (mmho-cm)	Cl	SO^4	CO^3	CO^3H	Ca	Mg	K	Na
										(me/l)							
300-400								69	21.5	32.5	365	0	20.8	1.0	0.5	0.2	425
400-600								52	101	701	850	26.0	52.5	0.3	0.1	0.8	1530

11. Saline Soils

/Mapping/ : soil type nr 11 - Colour : red

/Field description/ : profile nr KK 323

Location : Kesem-Kebena plain - Aerial photo nr 2204, run 24

Microrelief : stony hillocks bordering lower zones

Natural vegetation : Vetiveria usually in the microdepressions - Some gramineae

Profile description :

0 - 3 cm Texture : sandy loam - Colour : 2.5 Y 5/2 greyish brown - Humidity: dry - Structure : platy - Consistence : hard - White salt efflorescences.

3 - 20 cm Texture : silty loam - Colour : 10 YR 4/2 dark greyish brown - Humidity : moist - Structure : single grain - Consistence : hard - Some gravels.

20 - 60 cm Texture : sand (coarse) - Colour : 2.5 Y 3/2 very dark greyish brown - Humidity : moist - Without consistence.

Analytical results : profile nr KK 323

Depth (cm)	Particle size distribution (%)						pH	Lime (%)	Organic matter (%)	Carbon (%)	Nitrogen (%)	C/N	P_2O_5 total (ppm)	Moisture capacity at pF 2.5 (%)	Real density
	<2 µ	2-20µ	20-50 µ	50-100µ	100-200µ	200µ 2 mm									
0-3	19	16	10	6	11	38	10.0	2.9	0.80	1.47					
3-10	11	40	19	6	9	15	10.5	7.7							
50-60							10.3	0.80							

Depth (cm)	Exchangeable cations (me/100 g)							Saturation soluble extract									
	S	Ca	Mg	K	Na	T	Na/T	Humidity at saturation	E.C. (mmho-cm)	Cl	SO^4	CO^3	CO^3H	Ca	Mg	K	Na
										(me/l)							
								20	231	4000							7250
								40	80								1280
								28	6.6	32.4	9.0	8.0	14.2	0.8	0.26	0.14	75

12. Saline Alkali Soils

/Mapping/ : soil type nr 12 - Colour : grey

/Field description/ : profile nr KAW 22

Location : Kesem-Kebena plain - Aerial photo nr 2201, run 24

Microrelief : rounded hillocks

Natural vegetation : gramineae, Hyparrhenia - very sparse

Profile description :

0 - 3 cm	Salty calcareous crust - Colour : whitish - Texture : silty loam - Humidity : dry
3 - 5 cm	Texture : silty loam - Colour : grey - Humidity : moderately dry - Without structure - Consistence : friable
5 - 10 cm	Texture : loam to silty loam - Colour : ochre - Humidity : moderately dry to moist - Structure : single grain - Many roots
10 - 70 cm	Texture : silty loam - Colour : 10 YR 4/2 dark greyish brown - Humidity : moist - Structure : massive - Porous - Many roots
70 - 80 cm	Texture : silty loam - Colour : 10 YR 4/2 dark greyish brown - Humidity : moist - Structure : massive - Some patches of hydromorphic iron
80 -120 cm	Texture : sandy loam - Colour : 7.5 YR 4/2 brown to dark brown - Humidity : moist - Structure : massive.

/Analytical results/ : profile nr KAW 22

Depth (cm)	Particle size distribution (%)						pH	Lime (%)	Organic matter (%)	Carbon (%)	Nitrogen (%)	C/N	P_2O_5 total (ppm)	Moisture capacity at pF 2.5 (%)	Real density
	<2 µ	2-20µ	20-50 µ	50-100µ	100-200µ	200µ 2 mm									
0-3	21	43	19	14		3	10.2	8.5	0.52						
10-20	25	55	16	3		1	10.2	4.7	0.25						
70-80	19	35	24	18		4	9.7	9							

Depth (cm)	Exchangeable cations (me/100 g)							Saturation soluble extract										
	S	Ca	Mg	K	Na	T	Na/T	Humidity at saturation	E.C. (mmho-cm)	Cl (me/l)	SO4 (me/l)	CO3 (me/l)	CO3H (me/l)	Ca (me/l)	Mg (me/l)	K (me/l)	Na (me/l)
								33	14.8								
					32.0	50	64	29	10.6	70							98
								14	2.07								12

APPENDIX 4.

SELECTED PEDOLOGICAL PROFILES TAKEN ON THE LOWER PLAINS

A. SOILS ON RECENT ALLUVIA

1. Alluvial Soils on Calcareous Deposits With Interlayered Textures

1.1 Medium to moderately fine texture

1.1 (1) Subject to seasonal waterlogging during floods

/Mapping/ : Soil type nr 111 - Colour yellow

/Field description/ : *profile nr* TMT 53

Location : left bank, in the Dubti area, near the Boyale channel

Microrelief : hummocky, hillocks of vegetation, small defluents

Flooding : inundated during the Awash floods

Erosion : accumulation of silt during the floods

Natural vegetation : Cynodum - Paspalum - Sporobolus - Cyperus

Profile description :

0 - 12 cm Texture : Silt - Colour : 10 YR 4/2 dark greyish brown - Humidity : dry - Structure : undeveloped, platy to granular - Consistence : hard - Roots - Rusty patches on the surface of the aggregates.

12 - 24 cm Texture : silty loam - Colour : 10 YR 3/2 very dark greyish brown - Humidity : moderately dry - Structure : coarse crumby - Tendency to platy - Consistence : slightly friable - Vertical cracks.

24 - 60 cm Texture : loam - Colour : 2.5 Y 5/2 greyish brown - Humidity: moderately dry - Structure : thin vertical cracks, tendency to platy - Consistence : friable - Many roots - Very porous.

60 - 70 cm Texture : silty loam - Colour : 10 YR 2/2 very dark brown - Humidity : moderately dry - Structure : tendency subangular blocky with loam in the cracks - Consistence : friable - Many roots.

70 -100 cm Texture : loam to sandy loam - Colour : 10 YR 6/4 light yellowish brown - Humidity : moderately dry - Structure : tendency to platy - Consistence : friable - Porous - One thin layer of silty loam (similar to 60-70 cm) from 85-90 cm.

100 cm Texture : silty loam - Colour : 10 YR 3/3 dark brown - Humidity : moderately dry to moist - Structure : massive - Very few roots.

/Analytical results/ : profile nr TMT 53

Depth (cm)	Particle size distribution (%) <2 μ	2-20μ	20-50 μ	50-100μ	100-200μ	200μ 2 mm	pH	Lime (%)	Organic matter (%)	Carbon (%)	Nitrogen (%)	C/N	P_2O_5 total (ppm)	Moisture capacity at pF 2.5 (%)	Real density
0-10	11	67	18		4 %		8.2	5.0	2.0						
10-20	14	54	25		7 %		7.9	6.6	1.1		0.59	11			
50-60							8.1	7.5							
120-140							8.6	6.6							

Depth (cm)	Exchangeable cations (me/100 g) S	Ca	Mg	K	Na	T	Na/T	Saturation soluble extract: Humidity at saturation	E.C. (mmho-cm)	Cl (me/l)	SO^4 (me/l)	CO^3 (me/l)	CO^3H (me/l)	Ca (me/l)	Mg (me/l)	K (me/l)	Na (me/l)
0-10								77	1.21								
10-20	57.1	45.4	8.5	1.4	1.8	59	3	69	0.90	2.5	4.2	0	2.5	4	4		6.0
50-60					2.6	83.5	3	54	0.85								
120-140								69	0.94								

1.1 (2) Zone of dried-up channels : microrelief of holes and channels ; medium salinity

/Mapping/ : Soil type nr 112 - Colour yellow

/Field description/ : profile nr DRD 37

Location : right bank in the Dit Bahri area - Aerial photo nr 066, run 6

Relief : flat

Microrelief : holes and channels - Tufts of grass

Drainage : good

Natural vegetation : perennial grasses (gramineae), tufts of grass, some acacia trees

Profile description :

0 - 5 cm Texture : silty clay - Colour : 10 YR 3/3 dark brown - Humidity : dry - Structure : granular - Consistence : friable - Organic matter - Roots.

5 - 10 cm Texture : silty clay - Colour : 10 YR 3/3 dark brown - Humidity : dry - Structure : blocky - Consistence : hard - Dry Cyperus bulbs - Roots.

10 - 20 cm Transition layer.

20 -100 cm Texture : silty clay loam - Colour : 10 YR 4/3 - Brown to dark brown - Humidity : moderately dry to moist - Structure : massive, tendency to blocky - Consistence : very hard - Some roots - Porous, white spots of lime.

100-120 cm Texture : sandy loam - Humidity : moist - Structure : single grain - Consistence : friable - Spots of hydromorphic iron.

100-130 cm Texture : medium to fine sand - Colour greyish.

Analytical results : profile nr D.D 37

Depth (cm)	Particle size distribution (%)						pH	Lime (%)	Organic matter (%)	Carbon (%)	Nitrogen (%)	C/N	P_2O_5 total (ppm)	Moisture capacity at pF 2.5 (%)	Real density
	<2 µ	2-20µ	20-50 µ	50-100µ	100-200µ	200µ 2 mm									
0-10	51	41	7	2			7.8	4.3	3.7	2.2	1.7	1.3			
30-40	29	45	18	6	1	1	8.6	4.3							
90-100	31	46	17	4	1	1	8.6	5.5							

Depth (cm)	Exchangeable cations (me/100 g)							Saturation soluble extract									
	S	Ca	Mg	K	Na	T	Na/T	Humidity at saturation	E.C. (mmho-cm)	Cl (me/l)	SO^4 (me/l)	CO^3 (me/l)	CO^3H (me/l)	Ca (me/l)	Mg (me/l)	K (me/l)	Na (me/l)
0-10	73.1	53.6	15.6	1.68	2.2	84.8	2.6	75	3.3	9.4						0.48	6.4
30-40	52.5	42.2	5.8	0.98	3.49	56.8	6.1	55	1.37	2.8						0.19	7.3
90-100								62	1.98								16.3

1.1 (3) Zone of dried-up channels : microrelief of holes and channels ; high salinity

/Mapping/ : Soil type nr 112 S - Colour yellow

/Field description/ : profile nr AAS 62

Location : Asayita delta - Aerial photo nr 971, run 2

Relief : close to an overhanging river bank

Microrelief : cracks

Natural vegetation : Capparis and dead Capparis - Penisetum - Ricinus near the channel

Land use : cultivated land (corn and cotton)

Profile description :

0 - 10 cm Texture : silty loam - Colour : 10 YR 5/2 greyish brown - Humidity : dry - Structure : platy - Consistence : friable.

10 - 60 cm Texture : layers of silty clay and silty clay loam and clay - Colour : 10 YR 4/2 dark greyish brown - Structure : blocky to subangular blocky - Efflorescences on the surfaces of the agregates.

60 - 90 cm Texture : layers of silty loam and silty clay loam - Colour : 2.5 Y 5/2 greyish brown - Humidity : moderately dry.

90 - 130 cm Texture : silty clay loam to silty loam - Colour : 10 YR 4/2 dark greyish brown.

/Analytical results/ : profile nr AAS 52

Depth (cm)	Particle size distribution (%)						pH	Lime (%)	Organic matter (%)	Carbon (%)	Nitrogen (%)	C/N	P_2O_5 total (ppm)	Moisture capacity at pF 2.5 (%)	Real density
	<2 µ	2-20µ	20-50 µ	50-100µ	100-200µ	200µ 2 mm									
1-10	14	61	23	2			8.5	6.2	0.9	0.53					
20-30	40	49	10	1			7.8	6.5							
100-120	34	53	12	1			8.1	5.9							

Depth (cm)	Exchangeable cations (me/100 g)							Saturation soluble extract										
	S	Ca	Mg	K	Na	T	Na/T	Humidity at saturation	E.C. (mmho-cm)	Cl	SO^4	CO^3	CO^3H	Ca	Mg	K	Na
										(me/l)							
1-10								54	1.32	3.1	5.8	0	3.5	5.2	1.5	0.17	7.3
20-30								66	15.4	36	16.2	0	4.5	119	31	0.82	35
100-120								62	3.8	6.0	7.3	0	1.8	14.2	5.4	0.30	13.7

1.2 <u>Moderately fine to fine texture, occasionally alkaline at deeper levels; strongly marked microrelief</u>

1.2 (1) <u>Subject to seasonal waterlogging during floods</u>

/Mapping/ : Soil type nr 121 - Colour yellow

/Field description/ : profile nr TMT 51

<u>Location</u> : left bank in the Dubti area

<u>Relief and microrelief</u> : zone of old channels, wavy - Large grass tufts

<u>Natural vegetation</u> : green gramineae

<u>Land use</u> : pasture land

<u>Profile description</u> :

0 - 5 cm	Texture : silty clay loam - Colour : 10 YR 5/2 greyish brown Humidity : dry - Structure : undeveloped, aggregates with tendency to subangular blocky when dry - Consistence : hard - Vertical cracks - Roots.
60 - 70 cm	Texture : silty clay loam - Colour : 10 YR 6/4 light yellowish brown.
70 -110 cm	Texture : mixed layers of silty clay and silty loam - Colour: 10 YR 2/2 very dark brown.
110 -140 cm	Thin layers of sand and loam.
140 cm	Texture : clay - Colour : 10 YR 3/3 dark brown - Consistence: hard.

/Analytical results/ : profile TMT 51

Depth (cm)	Particle size distribution (%)						pH	Lime (%)	Organic matter (%)	Carbon (%)	Nitrogen (%)	C/N	P_2O_5 total (ppm)	Moisture capacity at pF 2.5 (%)	Real density
	<2 μ	2-20μ	20-50 μ	50-100μ	100-200μ	200μ 2 mm									
0.5	38	35	20	6	1	1	8.3	7.0	1.03	0.60	0.52	12	1775		
40-50	57	28	14	1			8.4	7.0	0.94	0.56	0.24	23	1600		
120-40	53	32	10	4	1		8.4	7.5							

Depth (cm)	Exchangeable cations (me/100 g)							Saturation soluble extract									
	S	Ca	Mg	K	Na	T	Na/T	Humidity at saturation	E.C. (mmho-cm)	Cl	SO^4	CO^3	CO^3H	Ca	Mg	K	Na
										(me/l)							
	55.6	45.2	7.4	1.81	2.16	61.8	3.5	55	1.18	4.8	5.6	0	3.8	6.0	6.0	0.3	44
	73.1	50.7	17.5	1.76	3.15	72.6	4.3	72	0.37	1.2	0.6	0	3.3	1.6	0.8	0.1	2.5
					4.70	57.6	8.2	76	1.23	1.8							

1.2 (2) Zone of dried-up channels

/Mapping/ : Soil type nr 122 - Colour yellow

/Field description/ : profile nr DRD 125

Location : Dit Bahri area - Aerial photo nr 0877, run 5

Relief : slight depression

Microrelief : holes, some channels

Natural vegetation : Paspalum - Other gramineae - Few acacias

Land use : pasture land

Profile description :

0 - 15 cm Texture : silty clay - Colour : 10 YR 3/2 very dark greyish brown - Humidity : dry - Structure : fine blocky well developed - Consistence : friable - Roots.

15 - 45 cm Texture : silty clay - Colour 10 YR 4/2 dark greyish brown - Humidity : dry - Structure : blocky and platy, medium size (1-2 cm) well developed - Consistence : friable some vertical cracks - Some lime concretions - Roots.

45 -130 cm Texture : silty clay - Colour : 10 YR 3/2 - Humidity : fresh from 50 cm - Structure : platy medium size well developed - Consistence : more compact than 15-45 cm - Roots - White deposits of lime - Many holes of roots.

/Analytical results/ : profile nr D[illegible]D 125

Depth (cm)	Particle size distribution (%)						pH	Lime (%)	Organic matter (%)	Carbon (%)	Nitrogen (%)	C/N	P_2O_5 total (ppm)	Moisture capacity at pF 2.5 (%)	Real density
	<2 µ	2-20µ	20-50 µ	50-100µ	100-200µ	200µ 2 mm									
0-10	57	37	17	6	2	1	8.3	5.9	1.25	0.72	0.70	10			
40-50	45	31	19	4	1		8.8	6.4	0.70	0.41					
120-130	49	35	12	4			8.8	6.4							

Depth (cm)	Exchangeable cations (me/100 g)							Saturation soluble extract									
	S	Ca	Mg	K	Na	T	Na/T	Humidity at saturation	E.C. (mmho-cm)	Cl	SO^4	CO^3	CO^3H	Ca	Mg	K	Na
										(me/l)							
0-10	54.8	48.8	2.8	1.7	1.5	63.6	2.3	59	1.35	3.1						0.35	3.3
40.50	59.4	50.8	3.8	1.39	3.42	65.6	5.2	60	0.53					1.1	0.9	0.09	3.7
120.130								65	0.60								3.7

1.3 Moderately fine to fine texture, moderately deep on horizons of variable texture and colour ; occasionally alkaline (zone of dried-up channels).

/Mapping/ : Soil type nr 13 - Colour yellow

/Field description/ : profile nr DRD 123 - Taken just after a flood (June 1963)

Location : Dit Bahri area - Aerial photo nr 0878, run 5

Relief : flat

Microrelief : light with some tufts of grass and channels

Drainage : good

Profile description :

0 - 5 cm	Texture : clay - Colour 10 YR 4/1 dark grey - Humidity : dry Structure : platy to fine granular or subangular blocky - Consistence : friable - Mud cracks.
5 - 15 cm	Texture : clay to silty clay - Colour 10 YR 3/1 very dark grey - Humidity : dry - Structure : medium blocky (3-4 cm) - Consistence : more compact than 0-5 cm - Organic matter - Roots.
15 - 45 cm	Texture : silty clay loam - Colour : 10 YR 5/2 greyish brown when dry - 10 YR 4/2 dark greyish brown when moist - Structure : prismatic to polyhedric coarse (5 cm) - Porous - Consistence : compact, vertical cracks, roots - Lime concretions (1 mm) friable - Humidity : dry.
45 - 90 cm	Texture : silty loam - Colour : 10 YR 5/2 greyish when dry, and 10 YR 4/2 dark greyish brown when moist - Structure : medium blocky to platy - Porous - Less compact than 15-45 cm Block lime concretions - Friable - Humidity : dry.
90 -140 cm	Texture : loam - Colour : 10 YR 4/3 brown - Humidity : moderately dry.

/Analytical results/ : profile nr DZD 123

Depth (cm)	Particle size distribution (%) <2 µ	2-20µ	20-50 µ	50-100µ	100-200µ	200µ 2 mm	pH	Lime (%)	Organic matter (%)	Carbon (%)	Nitrogen (%)	C/N	P_2O_5 total (ppm)	Moisture capacity at pF 2.5 (%)	Real density
0-10	59	27	13	1			7.8	1.1	3.0	1.76	1.19	15			
30-40	34	42	14	5	3	2	8.3	6.2	0.65	0.39					
120-140	23	25	25	19	7	1	9.1	6.2							

Depth (cm)	Exchangeable cations (me/100 g) S	Ca	Mg	K	Na	T	Na/T	Saturation soluble extract: Humidity at saturation	E.C. (mmho-cm)	Cl (me/l)	SO^4	CO^3	CO^3H	Ca	Mg	K	Na
0-10	68.1	57.6	7.0	1.74	1.74	71.4	2.3	74	1.85	4.2						0.54	3.9
30-40	49.2	40.8	5.6	0.91	1.85	50.8	3.6	51	1.20	5.3						0.18	3.95
120-140								50	1.20								9.6

2. Vertisols on Calcareous Materials

2.1 Fine structure : gilgai microrelief

/Mapping/ : Soil type nr 21 - Colour Brown

/Field description/ : profile nr DRD 13

Location : Dit Bahri area - Aerial photo nr 920, run 4

Relief : flat

Microrelief : end of the zone of channels - Fringed by fairly wide shrinkage cracks, and, between channels, surface mulch.

Natural vegetation : sparse tufts of dry Vetiveria - Gramineae, type Cynodon - Several rare green Cyperaceae alongside the channels - Sparse thorny acacias.

Profile description :

0 - 1 cm	Texture : silty clay loam to silty clay - Colour : 10 YR 2/2 very dark brown - Humidity : dry - Structure : subangular blocky to coarse granular - Consistence : slightly friable, many roots, organic matter.
1 - 10 cm	Texture : silty clay - Colour : 10 YR 2/2 very dark brown - Humidity : dry - Structure : crumb - Consistence : slightly friable - Many roots.
10 - 18 cm	Texture : silty clay - Colour : 10 YR 2/2 very dark brown - Humidity : moderately dry - Structure : blocky to subangular blocky - Many roots - Consistence : less friable than 1-10 cm
18 - 60 cm	Texture : silty clay - Colour : 10 YR 3/1 very dark grey - Humidity : moderately dry - Structure : prismatic, tendency to platy - Consistence : compact - Roots - Some lime concretions (0.5 - 1mm) - When crushed by fingers, the structure appears subangular blocky - Vertical cracks.
60 -130 cm	Texture : heavy clay - Colour : 10 YR 3/3 dark brown - Humidity : moderately dry to moist - Cracks.

Analytical results : profile nr D[illegible] 13

Depth (cm)	Particle size distribution (%)						pH	Lime (%)	Organic matter (%)	Carbon (%)	Nitrogen (%)	C/N	P_2O_5 total (ppm)	Moisture capacity at pF 2.5 (%)	Real density
	<2 µ	2-20µ	20-50 µ	50-100µ	100-200µ	200µ 2 mm									
0-10	52	33	12	3			7.1	6.3	13.3	7.8	0.67	12			
30-40	56	33	1	1			8.7	6.7	1.02	0.69	0.42	15			
100-120	51	28	9	2			8.4	5.9							

Depth (cm)	Exchangeable cations (me/100 g)							Saturation soluble extract									
	S	Ca	Mg	K	Na	T	Na/T	Humidity at saturation	E.C. (mmho-cm)	Cl	SO^4	CO^3	CO^3H	Ca	Mg	K	Na
										(me/l)							
0-10					2.1	79.2	2.6	95	1.56	2.2							4.4
30-40					2.7	60.0	4.5	81	0.53	0.72	1.5	0	2.7	1.3	0.3		2.7
100-120					8.2	62.8	13	87	3.7	20.8							27.4

2.2 Coarse structure; alkaline soils, subject to flooding

/Mapping/ : Soil type nr 22 - Colour brown

/Field description/ : profile nr DRD 107

Location : in the Dit Bahri area - Aerial photo nr 952, run 3

Relief : flat

Microrelief : grass tufts (25-30 cm height), vertical cracks on the surface (10 cm wide); the prisms have 1 m side.

Land use : pasture land (50 % of the surface is covered with grasses)

Natural vegetation : perennial gramineae - Paspalum - Panicum - Some Cyperaceae bulbs.

Profile description :

0 - 1 cm Texture : silty clay - Colour : 10 YR 5/2 - 4/2 greyish brown dark greyish brown - Humidity : dry - Structure : granular.

1 - 50 cm Texture : silty clay - Colour : 10 YR 5/1 grey - Humidity : dry - Structure : coarse prismatic, tendency platy - Consistence : very, very hard - Some small lime concretions - Vertical cracks (5 cm). The prisms are 5 cm wide.

50 -120 cm Texture : silty clay - Colour : 10 YR 4/2 dark greyish brown Humidity : moderately dry - Consistence : hard.

/Analytical results/ : profil. nr DRD 107

Depth (cm)	Particle size distribution (%)						pH	Lime (%)	Organic matter (%)	Carbon (%)	Nitrogen (%)	C/N	P_2O_5 total (ppm)	Moisture capacity at pF 2.5 (%)	Real density
	<2 μ	2-20μ	20-50 μ	50-100μ	100-200μ	200μ 2 mm									
0-1	50	32	14	4			8.7	6.2	0.9	0.53					
1-10	47	33	17	3			8.9	6.2	0.7	0.41	0.21	20			
90-110	50	34	12	4			8.6	5.8							

Depth (cm)	Exchangeable cations (me/100 g)							Saturation soluble extract										
	S	Ca	Mg	K	Na	T	Na/T	Humidity at saturation	E.C. (mmho-cm)	Cl	SO^4	CO^3	CO^3H	Ca	Mg	K	Na
										(me/l)							
0-1								67	0.73	1.6	1.9	0	3.8	2.4	0.48	0.16	5.2
1-10					5.5	57.4	9.6	68	0.54	1.6							
90-110					8.0	59.2	13.5	82	3.2	1.4							

3. Hydromorphic Soils on Calcareous Materials

3.1 Soils rich in humus subject to temporary flooding

/Mapping/ : Soil type nr 31 - Colour light blue

/Field description/ : profile nr DRD 27

Location : Dit Bahri area, near the Isa branch of Awash river - Aerial photo nr 956, run 3.

Relief and microrelief : flat

Drainage : bad - Poor - Water table near the surface : 35 cm

Natural vegetation : Gramineae - Cyperaceae - Green acacias.

Profile description :

0 - 2 cm	Organic matter slightly or not at all decomposed.
2 - 15 cm	Texture : silty clay loam - Colour : 10 YR 3/2 very dark greyish brown - Humidity : sodden - Structure : fine granular Consistence : plastic.
15 - 25 cm	Texture : silty clay loam to silty loam - Colour : 10 YR 3/ very dark greyish brown - Humidity : sodden - Structure : less developed than 2-15 cm - Consistence : less plastic than above layer.
25 - 60 cm	Texture : silty clay loam - Colour : 10 YR 3/3 dark brown - Humidity : sodden - Structure : fine subangular blocky - Consistence : plastic - Greyish black spots (hydromorphic layer)
60 -100 cm	Texture : silty loam - Colour : 10 YR 3/3 dark brown - Humidity : sodden - Hydromorphic layer - Consistence : plastic.
100-120 cm	Texture : clay - Colour : 10 YR 3/4 dark yellowish brown - Humidity : sodden - Consistence : very plastic.

/Analytical results/ : profile nr DRD 27

Depth (cm)	Particle size distribution (%) <2 µ	2-20µ	20-50 µ	50-100µ	100-200µ	200µ 2 mm	pH	Lime (%)	Organic matter (%)	Carbon (%)	Nitrogen (%)	C/N	P_2O_5 total (ppm)	Moisture capacity at pF 2.5 (%)	Real density
0-10	36	50	13	1			8.5	1.1	2.1	1.23	1.12	11			
35-45	35	47	17	1			8.7	7.5							
100-120	52	34	13	1			8.8	6.5							

Depth (cm)	Exchangeable cations (me/100 g) S	Ca	Mg	K	Na	T	Na/T	Saturation soluble extract: Humidity at saturation	E.C. (mmho-cm)	Cl (me/l)	SO^4	CO^3	CO^3H	Ca	Mg	K	Na
0-10								68	0,75								
35-45								59	0.40								
100-120					3.30	72.4	4.6	82	0.61	1.2	2.9	0	2.15	1.6	0.7	0.1	3.6

3.2 Organic soils

3.2 (1) Subject to seasonal waterlogging during floods

/Mapping/ : Soil type nr 321 - Colour dark blue

/Field description/ : profile nr TTN 25 (taken in November 1962)

Location : Dubti area - Aerial photo nr 65, run 6

Relief : flat, near a swampy area (end of depression)

Drainage : poor - Water table 90 cm down.

Natural vegetation : Gramineae and Cyperaceae - Grassland.

Profile description :

0 - 20 cm	Texture : silty clay loam - Colour : greyish - Humidity : wet - Without structure.
20 - 80 cm	Texture : silty clay - Colour : 10 YR 3/2 very dark greyish brown - Humidity : very wet - Consistence : plastic - Hydromorphic layer.
80 - 90 cm	Texture : silty clay loam to silty loam - Colour : 10 YR 3/2 to 3/3 very dark greyish brown to dark greyish brown - Consistence : plastic - Hydromorphic layer - Humidity : wet.
90 -120 cm	The same horizon as the above, but wet to sodden.

/Analytical results/ : profile nr TTN 25

Depth (cm)	Particle size distribution (%)						pH	Lime (%)	Organic matter (%)	Carbon (%)	Nitrogen (%)	C/N	P_2O_5 total (ppm)	Moisture capacity at pF 2.5 (%)	Real density
	<2 µ	2-20µ	20-50 µ	50-100µ	100-200µ	200µ 2 mm									
0-10	33	44	19	3	1	0	8.2	6.7	1.5	0.90	0.70	13			
60-80	53	34	11	2	0	0	8.4	6.5	1.1	0.62					
80-100							8.8	6.4							

Depth (cm)	Exchangeable cations (me/100 g)							Saturation soluble extract									
	S	Ca	Mg	K	Na	T	Na/T	Humidity at saturation	E.C. (mmho-cm)	Cl	SO^4	CO^3	CO^3H	Ca	Mg	K	Na
										(me/l)							
0-10								57	0.67	8.5							3.0
60-80								80	0.42	8.5							3.0
80-100								56	0.66	8.1							5.8

3.2 (2) Permanently waterlogged

/Mapping/ : Soil type no. 322 - Colour dark blue

/Description/ :

The permanently waterlogged organic soils cover all the hollows bordering the Awash, where the water flows permanently in the numerous channels : the water often overflows and fills up the ground between the channels. Inside this complex network are zones which running water reaches only during the floods. In the rainy season they form sheets of water of various depths, with frequently dense aquatic vegetation (water lilies, Typhas, Phragmites, etc.).

These soils exist especially on the left bank, between Dubti and Asayita, in the Asayita delta to the west of lake Afembo and to the north of lake Bario. Almost impenetrable, the zones offer no possibility of potential development, but serve as flood damping reservoirs for Asayita delta area. Numerous aquatic animals live in this marsh region.

B. SOILS ON OLD ALLUVIA AND COLLUVIA

4. Saline Soils

4.1 Medium texture

4.1 (1) Low to medium salinity

/Mapping/ : Soil type nr 411 - Colour orange

/Field description/ : profile nr TMT 22

Location : Dubti plain

Relief and microrelief : flat

Natural vegetation : Salicornia

Profile description :

0 - 5 cm	Texture : loam and silty loam (layers) - Colour : 10 YR 3/3 dark brown - Humidity : dry - Structure : platy and subangular blocky - Consistence : friable - Salty Mycelium.
5 - 50 cm	Texture : loam and layers of sandy loam and silt - Colour : 10 YR 5/2 greyish brown - Structure : platy - Some vertical cracks, tendency to coarse prismatic - Consistence : slightly friable - Porous - Roots - Some shells - White deposits on aggregates at 35 cm.
50 - 70 cm	Texture : very fine sand and sandy loam - Colour : 2.5 YR 5/2 weak red - Humidity : dry - Structure : platy, tendency to crumb - Consistence : friable - Porous - Rusty patches of hydromorphic iron (between 60-70 cm).
70 -120 cm	Texture : silty loam - Colour : 10 YR 3/3 dark brown - Humidity : dry - Structure : prismatic (less developed from 90 to 120 cm) vertical thin cracks up to 120 cm - Black traces of dead roots - Consistence : friable - Mycelium of lime.

Analytical results : profile nr T.T 22

Depth (cm)	Particle size distribution (%) <2 µ	2-20µ	20-50 µ	50-100µ	100-200µ	200µ 2 mm	pH	Lime (%)	Organic matter (%)	Carbon (%)	Nitrogen (%)	C/N	P_2O_5 total (ppm)	Moisture capacity at pF 2.5 (%)	Real density
0-5	26	32	12	27	3		8.6	4.9	0.70		0.17	24		29.5	2.52
30-40							8.1	8.0							
90-100	18	37	15	29	1		8.0	6.0	0.37		0.31	8			

Depth (cm)	Exchangeable cations (me/100 g) S	Ca	Mg	K	Na	T	Na/T	Saturation soluble extract: Humidity at saturation	E.C. (mmho-cm)	Cl (me/l)	SO^4 (me/l)	CO^3 (me/l)	CO^3H (me/l)	Ca (me/l)	Mg (me/l)	K (me/l)	Na (me/l)
0-5	62.4	54.2	3.5	1.2	3.5	60.5	6	64	2.78	2.0	2.4	0	2.0				22
30-40								55	7.70								
90-100					1.8	115	2	68	7.18	16	5.5	0	1.2				27

4.1 (2) Medium salinity at deeper levels

/Mapping/ : Soil type nr 412 - Colour orange

/Field description/ : profile nr TT 29

Location : Dubti area - Aerial photo nr 62, run 6

Relief and microrelief : flat (desert)

Natural vegetation : few graminaceae in tufts, some Salicornia

Profile description:

0 - 8 cm Texture : silty loam, few small gravels - Colour : 10 YR 5/2 greyish brown - Humidity : dry - Structure : single grain - Consistence : loose to soft.

8 - 30 cm Texture : clay loam - Colour : 10 YR 5/2 greyish brown - Humidity : dry - Structure : coarse crumb to subangular blocky - Tendency platy - Consistence : friable - Some shells.

30 - 40 cm Texture : loam to sandy loam - Colour : lighter than above horizon - Humidity : dry - Without structure - Consistence : soft - Some shells.

40 - 50 cm Texture : clay loam to silty loam - Colour : 10 YR 5/2 greyish brown - Humidity : dry - Structure : platy - Consistence : friable - Some shells.

50 - 60 cm Texture : loam to sandy loam - Colour : 10 YR 5/3 brown - Humidity : dry - Structure : platy.

60 - 85 cm Texture : loam and silty loam (bedding) - Colour : 10 YR 3/3 dark brown - Humidity : moderately dry - Structure : tendency to platy (strata) - Consistence : friable - Some small concretions and thin beds of small gravel.

85 - 95 cm Texture : silty clay loam to clay loam - Colour : 10 YR 3/2 very dark greyish brown - Humidity : dry - Without structure - Consistence : compact.

95 - 97 cm Texture : clay loam to clay - Colour : 10 YR 2/2 very dark brown - Humidity : dry - Structure : platy - Consistence : slightly friable - Some lime concretions.

97 -125 cm Texture : sandy loam to loam - Colour : 10 YR 5/4 yellowish brown - Humidity : dry - Without structure - Consistence : friable

Analytical results : profile n° TT 29

Depth (cm)	Particle size distribution (%) <2 µ	2-20µ	20-50 µ	50-100µ	100-200µ	200µ 2 mm	pH	Lime (%)	Organic matter (%)	Carbon (%)	Nitrogen (%)	C/N	P_2O_5 total (ppm)	Moisture capacity at pF 2.5 (%)	Real density
0-8	22	13	16		43	6	8.9	11.0	0.37						
20-30	28	21	24		25	2	9.4	8.2	0.28						
70-80	20	25	17		33	5	8.7	11.0							

Depth (cm)	Exchangeable cations (me/100 g) S	Ca	Mg	K	Na	T	Na/T	Saturation soluble extract: Humidity at saturation	E.C. (mmho-cm)	Cl (me/l)	SO^4	CO^3	CO^3H	Ca	Mg	K	Na
0-8								33	2.88	17	3.1	0	3.5				25
20-30								48	1.11	6.5	2.5	0	6.2				
70-80								49	20.4	171	24	0	tr				195

4.2 Moderately fine texture, medium salinity at deeper levels

/Mapping/ : Soil type nr 42 - Colour orange

/Field description/ : profile nr TMT 17

Location : Dubti plain

Relief and microrelief : flat (desert zone), very slight depressions

Natural vegetation : Salicornia only

Profile description :

0 - 16 cm	Texture : silty clay loam - Colour : 10 YR 5/2 greyish brown Humidity : dry - Structure : very coarse subangular blocky undeveloped - Consistence : friable - Some vertical cracks - Many Salicornia roots.
16 - 20 cm	The same characteristics, but the structure is very platy.
20 - 33 cm	Texture : silty clay - Colour : 10 YR 4/3 brown - Humidity : dry - Structure : subangular blocky - Consistence : hard - Some lime concretions - Roots - Some saccharoid salt crystals.
33 - 40 cm	Texture : silty clay loam - Colour : 10 YR 6/4 light yellowish brown - Consistence : friable - Structure : platy - Some saccharoid salt crystals.
40 - 60 cm	Texture : silty clay loam - Colour : 10 YR 4/1 dark grey - Structure : coarse prismatic ; tendency, when crushed, to coarse subangular blocky - Some shells - Vertical cracks - Few saccharoid salt crystals.
60 - 75 cm	Texture : silty clay loam - to silty loam - Colour : 10 YR 4/3 brown - Humidity : dry - Structure : platy - Consistence: friable, porous.
75 - 85 cm	Texture : silty clay to clay - Colour : 10 YR 5/2 greyish brown - Humidity : dry - Structure : platy - Consistence : slightly friable - Rusty patches of hydromorphic iron - Granules of polyhedral clay - Very hard - Some salty Mycelium on the surface of the aggregates.
85 -120 cm	Texture : clay - Colour : 5 YR 3/2 dark reddish brown - Humidity : moderately dry - Structure : coarse prismatic and, when crushed, subangular blocky - Consistence : slightly friable - Some very thin beds of loam - Salty patches - Some granules of clay have black faces.
120-140 cm	Texture : silty clay - Colour : 10 YR 3/3 dark brown - Humidity : moderately dry - The same structure and consistence as the above.

/Analytical results/ : profil n° TMT 17

Depth (cm)	Particle size distribution (%)						pH	Lime (%)	Organic matter (%)	Carbon (%)	Nitrogen (%)	C/N	P_2O_5 total (ppm)	Moisture capacity at pF 2.5 (%)	Real density
	<2 µ	2-20µ	20-50 µ	50-100µ	100-200µ	200µ 2 mm									
0-10	28	37	16	6	8	5	9.4	6.5							
50-60	38	48	11	3	0	0	7.9	6.0							
120-140	52	36	11	1	0	0	8.0	11.0							

Depth (cm)	Exchangeable cations (me/100 g)							Saturation soluble extract									
	S	Ca	Mg	K	Na	T	Na/T	Humidity at saturation	E.C. (mmho-cm)	Cl	SO^4	CO^3	CO^3H	Ca	Mg	K	Na
										(me/l)							
0-10								44	0.75								6.2
50-60								77	24.6								145
120-140								72	17.7								100

5. Saline Alkali Soils

/Mapping/ : Soil type nr 5 - Colour red

/Field description/ : profile nr TT 37

Location : part of the Dubti desert zone-- Aerial photo nr 959, run 3

Relief and microrelief : flat

Erosion : slight surface erosion

Natural vegetation : Aristida, Salicornia. Small acacias fringing the small wadis which spring from the basalt massifs.

Profile description :

0 - 20 cm Texture : silt - Colour : 10 YR 7/3 very pale brown - Humidity : dry - Structure : granular - Consistence : friable - Some roots.

20 - 40 cm Texture : silty loam - Colour : 10 YR 6/3 pale brown - Humidity : dry - Structure : tendency to platy - Consistence : friable to slightly hard - Faces of the aggregates have black streaks.

40 - 80 cm Texture : silty loam - Colour : 10 YR 6/3 pale brown - Humidity : dry - Structure : platy and subangular blocky - Consistence : hard.

80 -100 cm Texture : silty loam - Humidity : dry - Structure : the same as the 40 - 80 cm horizon - Consistence : very hard.

/Analytical results/ : profile nr TT 37

Depth (cm)	Particle size distribution (%) <2 µ	2-20µ	20-50 µ	50-100µ	100-200µ	200µ 2 mm	pH	Lime (%)	Organic matter (%)	Carbon (%)	Nitrogen (%)	C/N	P_2O_5 total (ppm)	Moisture capacity at pF 2.5 (%)	Real density
15	8	66	21	2	1	2	8.7	9.1							
35	12	46	38	1	1	2	8.8	8.0							
60	16	56	26	2	0	0	8.7	9.5							

Depth (cm)	Exchangeable cations (me/100 g) S	Ca	Mg	K	Na	T	Na/T	Saturation soluble extract: Humidity at saturation	E.C. (mmho-cm)	Cl (me/l)	SO^4 (me/l)	CO^3 (me/l)	CO^3H (me/l)	Ca (me/l)	Mg (me/l)	K (me/l)	Na (me/l)
15					20.5	38	54	51	31.2	128	292	0	6	28	3.6	1.2	415
35					25.1	41	61	53	60.5	241							
60					27.1	46.2	59	58	49	312							

6. Fine Textured Alluvial Soils in the Depressions or Dried-Up Lakes

6.1 Salinity low to nil

/Mapping/ : Soil type nr 61 - Colour green

/Field description/ : profile nr AAS 64

Location : northern part of Asayita delta

Relief and microrelief : flat

Natural vegetation : some Capparis, acacias (some of which are dead)

Profile description :

0 - 10 cm	Texture : silty clay - Colour : 10 YR 5/1 grey - Humidity : dry - Structure : granular to subangular blocky - Consistence: friable - Shells on the surface - Cracks.
10 - 50 cm	Texture : silty clay - Colour : 10 YR 4/1 - dark grey - Humidity : dry - Structure : granular - Consistence : friable - Patches of iron, rusty in colour.
50 -100 cm	Texture : silty clay - Colour : 10 YR 4/2 dark greyish brown - Humidity : dry - Other characteristics are the same as 10 - 50 cm horizon.

/Analytical results/ : profile nr AAS 64

Depth (cm)	Particle size distribution (%)						pH	Lime (%)	Organic matter (%)	Carbon (%)	Nitrogen (%)	C/N	P_2O_5 total (ppm)	Moisture capacity at pF 2.5 (%)	Real density
	<2 μ	2-20μ	20-50 μ	50-100μ	100-200μ	200μ 2 mm									
0-10	57	36	6	1			6.2	6.9							
0-40							6.4	6.2							
90-110	57	36	6	1			6.3	6.2							

Depth (cm)	Exchangeable cations (me/100 g)							Saturation soluble extract										
	S	Ca	Mg	K	Na	T	Na/T	Humidity at saturation	E.C. (mmho-cm)	Cl	SO^4	CO^3	CO^3H	Ca	Mg	K	Na
										(me/l)							
0-10								82	2.96								17
20-40								77	2.51								14
90-110								74	3.31								20

6.2 Medium salinity in the topsoil

/Mapping/ : Soil type nr 62 - Colour green

/Field description/ : profile nr AAS 55

Location : old Gargori lake

Relief : flat

Microrelief : very prominent, numerous holes 1 m deep and shrinkage cracks (due to the drying up of the lake).

Natural vegetation : numerous dead acacias - Some Capparis and green Tamaris.

Profile description :

0 - 2 cm Texture : loam - Colour : 10 YR 4/2 dark greyish brown - Humidity : dry - Structure : subangular blocky - Consistence: slightly friable - Small cracks on the surface (between the big cracks).

2 - 35 cm Texture : silty clay : 10 YR 4/1 dark grey - Humidity : dry - Structure : blocky with conchoidal breaks - Consistence : hard.

35 - 60 cm Texture : silty clay - Colour : ferruginous deposits, rusty in colour are predominating - The colour general is : 7.5 YR 5/8 (strong brown) - Humidity : dry - Structure : blocky with conchoidal breaks - Consistence : hard.

60 - 65 cm Texture : silty loam - Colour : 10 YR 5/1 grey - Humidity : dry - Structure : platy - Consistence : friable.

below 65 cm Texture : sandy loam - Colour : 10 YR 5/1 grey with ferruginous deposits 7.5 YR 5/8 in colour (strong brown) - Structure : platy - Consistence : compact - Porous.

/Analytical results/ : profile n° AAS 55

Depth (cm)	Particle size distribution (%)						pH	Lime (%)	Organic matter (%)	Carbon (%)	Nitrogen (%)	C/N	P_2O_5 total (ppm)	Moisture capacity at pF 2.5 (%)	Real density
	<2 μ	2-20μ	20-50 μ	50-100μ	100-200μ	200μ 2 mm									
0-1							7.9	3.8							
1.3	49	44	6	1			8.0	3.7							
10-15	54	37	8	1			7.9	5.8	1.5	0.90					
50-60	42	51	6	1			7.9	5.0							

Depth (cm)	Exchangeable cations (me/100 g)							Saturation soluble extract									
	S	Ca	Mg	K	Na	T	Na/T	Humidity at saturation	E.C. (mmho-cm)	Cl	SO^4	CO^3	CO^3H	Ca	Mg	K	Na
										(me/l)							
0-1								69	4	7.00	51.7	0	3.3	36	9.0	0.50	11.25
1-3								80	14.8	73.0	53.5	0	2.5	109	26	0.66	98.0
10-15	73.4	55	13.1	1.31	3.95	71.4	5.5	81	4.4	16.7		0	2.5			0.5	17.2
50-60								78	3.2	6.2	10.0	0	2.4	15.2	2.4	0.28	16.3

APPENDIX 5.

LEACHING TESTS ON SALINE SOILS IN THE DUBTI AREA

1. TEST CONDITIONS AND METHODS

In November 1962, leaching tests were carried out in the northern part of the Dubti plantation, on ground of alluvial origin with an interlayered texture. This belongs to the medium-salinity land in zones which have recently dried out (saline soils on old alluvia) and comes under irrigability classes III to IV. Its salinity varies according to the texture and colour of the various soil horizons in the profile. Its typical feature is that it contains sodium nitrate amounting to about 40 % of the saturated extract and a similar quantity of chlorides, also sulphates and small quantities of bicarbonates. Textures in the various profile horizons range from loam or silty loam with a 10 YR 5/2 colour to silty clay loam or clay loam coloured 10 YR 3/2 to 3/3. Horizon thicknesses and numbers vary : four or five successive horizons about 10-20 cm thick are sometimes observed in the top metre depth (test nr 1), but elsewhere anything up to ten different successive heavy-texture horizons all less than 10 cm thick (usually 2-5 cm) are observed down to the same depth, which are sandwiched between thicker loam or silty loam beds (test nr 2).

The salinity of this land appears to be of the type associated with certain periods of alluviation and drying out : heavy texture saline horizons of lacustrine origin with a dark 10 YR 3/2 colouring are frequently observed.

Considering the land as a whole from the surface down to a depth of 120 cm, the salinity of the soils in the above category can generally be described as :

Low; conductivity up to 4 mmhos, in the top 5 cm layer.

Medium to high; conductivity 20-30 mmhos, between 5 cm and 50 cm.

Medium; conductivity 10-15 mmhos, between 50 cm and 100 cm.

Higher salinity rates with only very slight textural intercrossing are observed in the zone further north near the Kurub.

Three tests were carried out, each with two sheet metal tubes or cylinders 30 cm and 60 cm in diameter, respectively, with the larger cylinder acting as a guard ring. A constant water level was maintained in each cylinder by a float-controlled valve. The tests were carried out under a constant head of 10 cm. Infiltration water depths were measured at regular intervals in a tank underhead connected to the constant-level valve by a length of hose.

A set of soil samples was taken within a two metre radius of the test site before the actual tests. After the tests, auger borings were made down the centre line of the smaller cylinder, and then in a test pit one face of which coincided with a diametral plane of the cylinders.

ANALYTICAL RESULTS OF THE SOIL SAMPLES (test leaching nr 2)

Depth in cm	Natural Moisture at 105°C	Humidity at Saturation	SATURATION SOLUBLE EXTRACT C.E. in mmhos/cm	pH	Cl me/l	SO^4 me/l	CO^3 me/l	CO^3H me/l	NO^3 me/l	Σ anions me/l	Σ cations me/l	Ca me/l	Mg me/l	K me/l	Na me/l
SAMPLES TAKEN BEFORE LEACHING TEST															
10-20	16.	78	23.0	7.2	108	41.2	0	3.5	130	282.7	281.2	142	18	1.2	120
40-50	19.	86	15.6	7.6	76	32.0	0	4.0	86	198	195.9	90	25	0.9	80
100-120	19.	82	9.5	7.7	18	36.0	0	10.0	78	142	133.7	54	15	0.7	64
SAMPLES TAKEN AFTER LEACHING TEST															
0-5	42.	50	1.2	8.2	5.7	10.1	0	6.7	-	22.5	28.4	11.1	2.7	6.2	8.4
20-25	43.	78	3.5	7.9	3.7	41.6	0	7.4	-	52.7	50.2	9.9	1.2	1.3	37.8
40-45	45.	99	4.9	7.6	4.8	74.0	0	6.8	-	85.6	79.0	21.6	6.4	1.0	49.2
60-65	42.	96	6.0	7.8	9.6	84.0	0	8.0	-	101.6	101.9	36.8	8.0	2.3	54.8
80-85	31.	70	30.0	7.3	232.0	24.0	0	21.0	236	513.0	395.0	266	64	7.0	58
100-105	17.	82	9.5	7.0	53.6	29.6	0	10.0	58	151.2	163.7	73.5	17.5	3.5	69.2

2. HYDRODYNAMIC PROPERTIES

Test No.	Duration (hours)	Quantity of infiltration water (cm)	Infiltration rate (cm/h) At end of test	Infiltration rate (cm/h) Mean	Wetted depth of soil (cm)	Mean moisture increase (% tot. saturation)
1	93 1/3	106.4	1.08	1.14	80	26.6
2	197 1/4	402.1	2.22	2.04	106	24.3
3	64 1/2	74.4	1.14	1.15	60	25.8

Observed infiltration depths varied between 60 cm and 105 cm, according to the test duration ; the average increases in moisture amounted to 25 % for dry soil (initial natural soil moisture rates for soil dried at 105°C were 10%-15%). The wetted depth appeared to progress much more slowly after two or three days of infiltration (infiltration bulb initially spheroidal, then tending towards a cylindrical shape).

Infiltration rates varied from 1 cm/hr to 2 cm/hr, i.e., 10-5 m/s. This was apparently due to varying degrees of intercrossing in the silty loam and silty clay loam horizon. Test nr 2, for instance, showed more marked intercrossing with the thinner silty clay horizons (2-5 cm) separated by generally thicker silty loam horizons. This test gave an infiltration rate which can be assumed to be 10-6 m/s. As this is rather on the low side, it may limit irrigation and leaching possibilities. Thus the infiltration water quantities may not refer solely to the central cylinder section, for the guard ring does not seem to have completely fulfilled its purpose.

The actual leaching water application (i.e., the quantity of water required to moisten the volume of soil found to be wet after the tests) was estimated by considering the mean moisture increase and calculating the amount of water that had infiltrated over the entire wetted area. This gave the following leaching water applications :

Test 1 ; 0.28 m - 2.800 m3/hectare

Test 2 ; 0.368m - 3.680 m3/hectare

Test 3 ; 0.218m - 2.180 m3/hectare

These figures appear to be confirmed by the ratio between quantity of infiltration water and wetted soil depth, which remained the same (i.e., 0.35) for all three tests.

3. SALT MOVEMENT

Salt leaching - especially of nitrates and chlorides - was invariably observed down to a level slightly below the wetted depth. Sulphates and bicarbonates only changed very little. Quantities leached amounted to 80 % of the total salts (measured before leaching) in the upper horizons (surface to 40 cm) and to 60 % in the lower horizons. As a rough estimate, a first leaching water application of about 5,000 m3 per hectare should be provided for, with total flooding of the land. Liberal irrigation water applications are also recommended - always providing adequate drainage is available - in order to prevent saline solutions from rising. The same result would also be achieved by a continuous vegetation cover, but only if it could be supplied with adequate quantities of water.

4. ALKALINITY

As these soils generally have a medium texture and pH values between 8 and 9, only minor alkalinity problems appear to arise. The heavier-texture soil horizons contain fairly high proportions of calcium sulphate and gypsum.

The SAR was found to vary only a little during the leaching tests. This indicates that Na, Ca and Mg cation equilibrium variations are also small, but alkalinisation risks must be watched both because of the SAR of the slightly sodic irrigation water from the Awash and because of the varying proportion of bicarbonate in these soils. The pH values slightly increase after leaching.

ANALYTICAL RESULTS OF AWASH RIVER WATER TAKEN IN DUBTI , AT THE PUMPING STATION

Date	Concentration (g/l)	E.C. in mmhos/cm	pH	in me/l									
				CO3	CO^3H	Cl	SO4	Σanions	Σcations	Ca	Mg	K	Na
10.11.62	0.6	0.61	8.1	0.6	4.0	1.7	0.6	6.9	7.5	3.1	0.4	0.08	3.9

The Awash river water, at Dubti, is in class C2-S1 according to the American standards classification which are based on salinity and sodium absorption ration (S.A.R.).

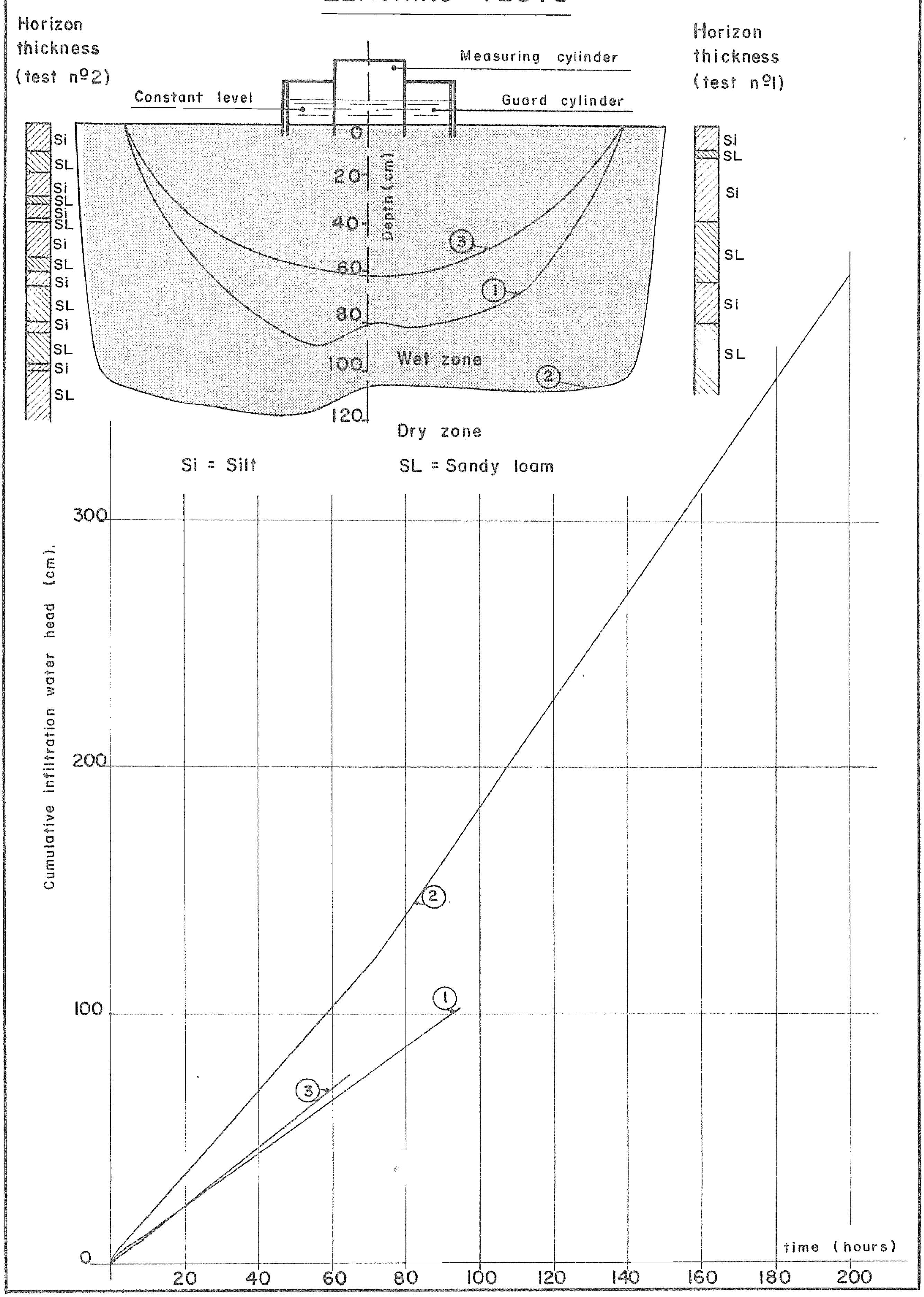
$$(S.A.R. = \frac{Na}{\sqrt{\frac{Ca + Mg}{2}}}$$. For the Awash river water S.A.R. = 3).

5. CONCLUSION

These very local results will be completed by further observations in bigger fields. They seem to show that, given suitable leaching, the medium-salinity land in the Dubti area could be farmed. This applies to medium-texture soils, and assumes that drainage measures could prevent secondary salt contamination effects due to a rise in the water table. Though alkalinization risks are small, they must be considered because of the composition of the irrigation water and the nature of the soils; rationally conducted irrigation water applications would be necessary and possibly also the use of such lime improvers as gypsum.

FIG. 16

LEACHING TESTS



APPENDIX 6.

IRRIGATED FARMING EXPERIMENTS CARRIED OUT IN 1961 AT THE METEHARA PLANTATION *
by Israeli Experts

EXPERIMENT I : VARIETY TEST OF COTTON

Aim of the experiment : To test four varieties

1.	Acala	15 - 17	Medium staple
2.	Acala	4 - 42	Medium staple
3.	Pima	32	Long staple
4.	Koker	100	Medium staple

Description of the experiment : Planting in rows 100 x 200 cm (50,000 plants/ha)

Design of the experiments : Randomized block, 4 replications (A,B,C,D)

Plot size : Rectangular plots of 5 rows 20 x 5 (100 m2)

History of the field : First crop

Conduct of the experiments :

				Date
Ploughing	:	by mouldboard plough	25 cm	28-V
Harrowing	:	a) by disk harrow	15 cm	28-V
		b) by disk harrow	10 cm	5-VI
Fertilizing	:	None		
Planting	:	By hand		25-VII
Germination	:	Full		30-VII
Cultivation	:	By hoe		30-VIII
Thinning	:	By hand		3-VIII
Weeding	:	By hand		3-VIII - 2-IX - 3-X
Irrigation	:	9 x 80 m3		25-VII - 24-VIII - 10-IX - 27-IX - 12-X - 24-X - 8-XI - 23-XI 6-XII
Rainfall	:	See records		
Insects	:	Sacadodes Pyralis, Several local insects		
Diseases	:	None		
Treatments	:	a) Dieldrin 2 kg/ha		20-VIII - 28-VIII -20-IX
		b) Endrin 2 kg/ha		30-IX - 8-X
		c) Dieldrin 1 kg/ha + Endrin 1 kg/ha		18-X
		d) Curation 4.5 kg/ha + Endrin 1 kg/ha		29-X
		e) Curation 2.5 kg/ha		11-XI - 22-XI

Time Table

May	June	July	August	September
P D	D	LIG	W XCIX	W X XIX

October	November	December	January	February
W XI X IX	IX XI	I E	H	H E

* By courtesy of Meteharo Plantation - P. Sarris - Bezabeh Sileshi and Co. Ltd.

Explanation of symbols :

C - Cultivation
D - Disking
G - Germination
H - Harvesting
I - Irrigation
L - Planting
P - Ploughing
W - Weeding
X - Treatment

Experimental results

		Yields in kg seed cotton per 100 m2 sun dried			
		Acala 15 - 17	Acala 4 - 42	Pima 12	Koker 100
A	1st picking	40.3	35.6	11.5	30.8
	2nd picking	22.9	17.0	16.3	21.5
	3rd picking	6.2	11.8	23.1	11.6
	4th picking	4.4	3.1	6.8	3.2
	Total	73.8	67.5	57.7	67.1
B	1st picking	36.8	24.1	12.6	25.3
	2nd picking	26.8	27.2	16.3	18.4
	3rd picking	6.6	8.0	19.5	7.8
	4th picking	5.0	3.2	7.2	4.1
	Total	75.2	62.5	55.6	55.6
C	1st picking	32.1	30.2	10	31.8
	2nd picking	17.2	13.6	14.4	28.2
	3rd picking	10.5	15.3	21.9	7.6
	4th picking	4.6	3.4	7.1	4.2
	Total	64.4	62.5	53.4	71.8
D	1st picking	37.3	30.2	12	26.9
	2nd picking	25.8	20.4	18.9	26.5
	3rd picking	10.8	12.7	18.7	7.5
	4th picking	3.1	4.2	6.9	5.1
	Total	77.0	67.5	56.5	66.0
Block totals(kg)		29.04	260.0	223.2	260.5
" " (t/ha)		7,260	6,500	5,580	6,512

First conclusions

1. The best medium staple variety was Acala 15-17, which yielded 760 kg/ha more than Acala 4-42 and 748 kg/ha more than Koker. The Pima 32 yield of 5,580 kg is also very outstanding.

2. During conduct of the experiment, I observed :

   a) Natural growing conditions in the area (soil and climate) are excellent for cotton ;

   b) Proper treatment against insects and well-timed irrigation can secure maximum boll development.

3. To eliminate the influence of the border rows, the experiment should be repeated in larger plots (for example, ten rows).

4. It was impossible to fix the ginning percentage of the different varieties.

5. The Pima variety was not attacked by insects, but the staple became dirty-looking during picking time.

EXPERIMENT I-B : VARIETY TEST OF CORN GRAIN

Aim of the experiment : To test Israeli hybrids :

1. Hasera 170
2. Masora 22

Design of the experiment : Randomized block, 4 replications (A,B,C,D)

Plot size : Rectangular plots of 7 rows 20 m x 5 m (100 m2)

History of the field : First crop

Conduct of the experiment :

			Date
Ploughing	:	by mouldboard plough 25 cm	22-V
Harrowing	:	a) by disk harrow 15 cm	28-V
		b) by disk harrow 10 cm	3-VI
Planting	:	by hand	25-VII
Germination	:		2-VIII
Thinning	:	by hand	5-VIII
Cultivation	:		2-VIII - 14-VIII - 22-VIII - 1-IX - 13-IX - 20-X
Irrigation	:	8 x 80 m3	25-VII - 16-VIII - 26-VIII - 8-IX - 22-IX - 30-IX - 13-X - 25-X
Rainfall	:	see records	
Diseases	:	rust	
Insects	:	many locals	
Treatments	:	2 kg/ha Dieldrin per application	5-VIII - 18-VIII
		2 kg/ha Dieldrin per application	10-IX - 28-IX - 10-X
		1 kg/ha Endrin	
Flowering	:	Hasera 170	20-IX
		Masora 22	22-IX
Harvesting	:	by hand	23-XI
Treshing	:	by hand	28-XI

Time table :

May	June	July	August	September	October	November
PD	D	PIG	WCX HIXHX	HIXHIX X	XX WI	HT

Explanation of symbols :

C - Cultivation
D - Disking
G - Germination
H - Harvesting
I - Irrigation
L - Planting
P - Ploughing
T - Treshing
W - Weeding
X - Plant protection

Experimental results :

Yields in kg grain per 100 m2 based on 12 % moisture

Blocks		Hasera 170	Masora 22
A		64,560	90,360
B		78,850	39,610
C		46,840	59,320
D		60,370	43,710
Block totals	(kg)	270,620	233,000
	(t/ha)	6,765	5,825

First conclusions :

1. The Hasera 170 variety outyielded the Masora 22 variety by 940 kg/ha. In view of point 2 and 3, there is no possibility of evaluating from the experiment the crops yields for commercial enterprise.

2. Both varieties were heavily infested by leaf rust which attacked the young plants ten days after germination. Magnesium deficiency was also observed.

3. Infestation by various insects was serious and only with five treatments the pests could be eradicated. This is very uneconomical with the existing crop prices.

4. Varieties resistant to rust should be tried. Previous experiments carried out by the Ministry of Agriculture proved that local varieties are more resistant than the imported hybrid varieties.

EXPERIMENT I-G : VARIETY TEST OF HARICOT BEANS

Aim of the experiment : To test two local varieties

1. Big local
2. Small local

Description of the experiment : Both varieties were sown in rows 70 cm x 10 cm (14,285 plants/ha)

Design of the experiment : randomized block, 4 replications (A,B,C,D)

Plot size : rectangular plots of 7 rows 20 m x 5 m (100 m2)

History of the field : First crop

Conduct of the experiment :

			Date
Ploughing	:	by mouldboard plough 25 cm	22-V
Harrowing	:	a) by disk harrow 15 cm	28-V
		b) by disk harrow 10 cm	5-VI
Fertilizing	:	none	
Planting	:	by hand	23-VII
Germination	:	big	27-VII
		small	25-VII
Cultivation	:	by hoe	10-VIII - 18-VIII
Weeding	:	by hoe	28-VII - 5-VIII - 23-VIII - 5-IX
Irrigation	:	4 x 80 m3 appr.	23-VII - 13-VIII - 24-VIII - 8-IX
Rainfall	:	see records (280 mm)	
Diseases	:	none	
Insects	:	minor damages	
Treatments	:	2 kg/ha Dieldrin per application 13-VIII - 4-IX	
Flowering	:	big	25-VIII
		small	22-VIII
Harvesting	:	by hand	6-X
Treshing	:	by hand	10-X

Time table :

May	June	July	August	September	October
PD	D	LIGW	WCIX CWI	XWI	H T

Explanation of symbols :

C - Cultivation
D - Disking
G - Germination
H - Harvesting
I - Irrigation
L - Planting
P - Ploughing
T - Treshing
W - Weeding
X - Plant protection

Experimental results :

Yields in kg grain per 100 m2, 10 % moisture			
Blocks		Big	Small
A		15,501	19,031
B		18,000	20,208
C		22,523	20,015
D		17,105	15,513
Block totals	(kg)	73,129	74,767
	(t/ha)	1,828	1,869

First conclusions :

1. The small variety yielded 41 kg/ha more than the big one.

2. According to observations, closer spacing is recommended for further trials. Row distance of 50 cm would increase the plant population by 30 %.

3. Other varieties and earlier sowings should be tried.

EXPERIMENT X-E : VARIETY TEST OF GROUND NUTS

Aim of the experiment : To test two Israeli varieties

1. Virginia selected - Hasera
2. Kongo (type)

Description of the experiment : Planted in rows 20 cm x 10 cm (142,850 plants/ha)

Design of the experiment : Randomized blocks, 4 replications (A,B,C,D) ; each block 100 m2

Conduct of the experiment :

			Date
Ploughing	:	By mouldboard plough 25 cm	22-V
Harrowing	:	a) by disk harrow 15 cm	28-V
		b) by disk harrow 10 cm	5-VI
Fertilizing	:	None	
Planting	:	by hand	21-VII
Germination	:	full	30-VII
Cultivation	:	by hand (20 cm)	16-VIII - 2-X
Weeding	:	by hand	4-IX - 20-IX - 2-XI - 10-XI
Irrigation	:	8 x 80 m3 appr.	21-VII - 25-VIII - 9-IX - 26-IX
			11-X - 24-X - 8-XI - 23-XI
Rainfall	:	see records	
Insects	:	locals (minor damages)	
		1. Fusarium wilt	
		2. Cercospora personata	
		3. Chlorosis symptoms	
Treatments	:	Dieldrin 2 kg/ha	30-X - 20-XI
		Sulphur powder 40 kg/ha	20-XII
Harvesting	:	by hand	30-VII - 5-IX
Picking	:	by hand .	25-XII

Time table :

May	June	July	August
PD	D	LICX	G X

September	October	November	December
WXX WI	C I X X	WIW XI	HC H

Explanation of symbols :

C - Cultivation
D - Disking
G - Germination
H - Harvesting
I - Irrigation
L - Planting
P - Ploughing
W - Weeding
X - Plant protection

Experimental results :

Yields in kg unshelled per 100 m2 well sundried		
Blocks	Virginia	Kongo
A	63.4	40.3
B	68.2	50.5
C	48.1	28.2
D	42.6	16.0
Block totals (kg)	222.3	135.0
(t/ha)	5,557	3,375

First conclusions :

1. The Kongo variety suffered very much from chlorosis and it therefore seems that this variety is not suitable for the area. The variety was ripe on 30-XI but harvest was delayed in order not to attract wild pigs to the experimental area where they could destroy the Virginia plots.

2. The heavy soil makes the harvest very difficult and it is assumed that by mechanical digging, a good part of the yield will be left in the soil. By growing the crop on ridges, the loss can probably be minimized.

3. Even after drying, the shells appeared black and dirty (5 % of the total weight should be deducted for soil). The nuts are not suitable for export without proper cleaning and bleaching.

4. In further experiments, the local so-called Asmera variety should also be tested.

EXPERIMENT III-A : FERTILIZING PRACTICES FOR COTTON

Aim of the experiment : To evaluate fertilizer requirement under local conditions.

Description of the esperiment :

X	No fertilizer
XX	N 60 kg/ha
XXX	K_2O 120 kg/ha
XV	N 60 Kg/ha + K_2O 120 kg/ha
V	N 60 kg/ha + P_2O_5 50 kg/ha + K_2O 120 kg/ha

Method of application : Before planting time

Variety : Acala 15-72

Design of the experiment : Randomized blocks, 4 replications (A,B,C,D)

Plot sizes : Rectangular plots of 5 rows 20 x 5 m (100 m2)

History of the field : First crop

Conduct of the experiment :

		Date
Ploughing :	mouldboard plough 25 cm	22-V
Harrowing :	a) disk harrow 15 cm	28-V
	b) disk harrow 10 cm	5-VI
Fertilizing :	According to experiment lay-out, fertilizers used :	
	1. Ammonium sulphate 21 % N	
	2. Muriate of potash 61 % K_2O	
	3. Nitrophoska 13 -13 -20	
	Fertilizers worked in by disk harrow (b)	
Planting :	by hand 100 x 20 (50,000 plants/ha)	27-VII
Germination :	full	4-VIII
Cultivation :	by hoe	20-VIII
Weeding :		3-VIII - 2-IX - 3-X
Irrigation :	5 x 80 m3	27-VII - 24-VIII - 8-IX - 20-IX - 14-X - 26-X - 10-XI 24-XI - 6-XII
Rainfall :	see records	
Insects :	sacadodes pyralis, several local insects	
Diseases :	none	
Treatments :	spraying	
	a) Dieldrin 2 kg/ha	20-VIII - 22-VIII - 20-IX
	b) Endrin 2 kg/ha	30-IX - 8-X
	c) Dieldrin 1 kg/ha + Endrin 1 kg/ha	11-X
	d) Curation 1.5 kg/ha + Endrin 1 kg/ha	29-X
	e) Curation 2.5 kg/ha	11-XI - 22-XI
Picking :	First	31-XII
	Second	12-I
	Third	29-I

Time table :

May	June	July	August
PD	D	LX	WG XCXX

September	October	November	December	January
WX XXX	W XIX XX	XX XX	X H	H H

Explanation of symbols :

C - Cultivation
D - Disking
G - Germination
H - Harvesting
I - Irrigation
L - Planting
P - Ploughing
W - Weeding
X - Plant protection

Experimental results :

Block			O	N	K	NK	NPK
	Yields in kg seed cotton per 100 m2 sun dried						
A	Picking	I	28.3	34.8	32.1	25.7	29.8
		XX	24.3	19.9	20.8	26.3	25.3
			10.8	6.5	7.4	12.0	7.3
	Total		63.4	61.2	60.3	64.0	62.4
B	Picking	X	36.0	27.0	37.1	31.9	30.6
		XX	18.8	24.1	14.7	19.0	22.2
			7.8	6.3	5.7	7.7	7.0
	Total		62.6	57.4	57.5	58.6	59.8
C	Picking	X	14.9	30.8	35.8	26.4	29.4
		IX	16.0	21.0	16.3	23.9	25.0
		XIX	7.9	9.8	5.8	9.7	7.6
	Total		58.8	61.6	57.9	60.0	62.0
D	Picking	X	31.9	30.8	33.3	36.4	35.2
		XX	20.6	22.5	17.9	16.0	17.8
			4.7	9.3	7.4	7.5	5.7
	Total		57.2	62.6	58.6	59.9	58.7
Block totals		(kg)	242.0	242.8	234.3	242.5	242.9
		(t/ha)	6,050	6,060	5,857	6,062	6,072

First conclusions :

1. No response to fertilizer.

2. Further experiments should be conducted with 10 rows to minimize the influence of the border rows, which can be very high in cotton trials.

EXPERIMENT III-B : FERTILIZING PRACTICES FOR CASTOR BEANS

Aim of the experiment : To evaluate fertilizer requirements under local conditions.

Description of the experiment :

a) Control, no fertilizer
b) N 90 kg/ha
c) K_2O 120 kg/ha
d) N 90 kg/ha + 120 kg/ha K_2O
e) N 90 kg/ha + P_2O_5 60 kg/ha + K_2O 120 kg/ha

Method of application : Before planting time

Variety : Hasera no. 4

Design of the experiment : Randomized block, 4 replications (A,B,C,D)

Plot size : Rectangular plots of 5 rows 20 m x 5 m (100 m2)

History of the field : First crop

Conduct of the experiment :

			Date
Ploughing	:	by mouldboard plough 25 cm	22-V
Harrowing	:	a) by disk harrow 15 cm	28-V
		b) by disk harrow 10 cm	5-VI
Fertilizing	:	According to experimental lay-out	
		Fertilizers need :	
		1. Ammonium sulphate 21 %	
		2. Muriate of potash 61 %	
		3. Complete fertilizer 13-13-20	
		Fertilizers worked in by disk harrow (b)	
Planting	:	by hand 100 x 100 cm (10,000 plants/ha)	29-VII
Germination	:	full	5-VIII
Cultivating	:	by hoe	18-VIII - 28-VIII
Weeding	:	by hand	10-VIII - 2-IX - 3-X - 20-X - 2-XI
Irrigation	:	7 x 80 m3 appr.	29-VII - 24-VIII - 7-IX - 27-IX - 25-X - 9-XI
Rainfall	:	see records (280 mm)	
Diseases	:	Flisia worms	10-VIII
Treatments	:	2.5 kg/ha dieldrin per appl.	11-VIII - 18-VIII
Harvesting	:	by hand	1-XII
Treshing	:	by hand	3-XII

Time table :

May	June	July	August
PD	D XX	LI	GWX GX I C

September	October	November	December
WX X	WX WX	WX	HT

Explanation of symbols :

C - Cultivation
D - Disking
G - Germination
H - Harvesting
I - Irrigation
L - Planting
P - Ploughing
T - Treshing
W - Weeding
X - Plant protection

Experimental results :

Yields in kg grain per 100 m2 well sun dried					
Blocks	a control	b N	c K	d NK	e NPK
A	16.320	16.383	12.150	16.920	17.620
B	18.720	19.080	25.442	14.525	18.180
C	17.223	16.740	18.920	17.040	20.122
D	13.500	12.842	15.244	18.900	21.125
Block totals (kg)	65.763	65.045	71.756	67.385	77.047
Block totals (t/ha)	1,644	1,626	1,794	1,684	1,926

First conclusions :

1. Additional N gave no results. 90 kg/ha K_2O added 150 kg/ha. NK lowered again the yield but additional P (NPK) added 282 kg/ha, not paying the extra costs.

2. It is proposed to continue this trial with P or a PK combination. Trials in South Africa showed clearly the P influence on castor beans.

3. The general yields were lower than those harvested from the variety test.

4. The variety under test Hasera no. 4 is not rust resistant and further tests should be carried out with Hasera no. 1.

EXPERIMENT III-C : FERTILIZING PRACTICES FOR HARICOT BEANS

Aim of the experiment : To evaluate fertilizer requirements under local conditions.

Description of the experiment :

I - no fertilizer
II - N 60 Kg/ha
III - K_2O 120 kg/ha
IV - N 60 kg/ha + K_2O 120 kg/ha
V - N 90 Kg/ha + P_2O_5 60 kg/ha + K_2O 120 kg/ha

Method of application : Before planting time

Variety : Big local

Design of the experiment : Randomized block, 4 replications (A,B,C,D)

Plot size : Rectangular plots of 7 rows 20 m x 5 m (100 m2)

History of the field : First crop

Conduct of the experiment :

			Date
Ploughing	:	by mouldboard plough 25 cm	22-V
Harrowing	:	a) by disk harrow 15 cm	28-V
		b) by disk harrow 10 cm	5-VI
Fertilizing	:	According to experimental lay-out Fertilizers used : 1. Ammonium sulphate 21 % 2. Muriate of potash 61 % 3. Complete fertilizer 13-13-30 Fertilizer worked in by disk harrow (b)	
Planting	:	by hand 70 x 10 (142,657 plants/ha)	28-VII
Germination	:	full	3-VIII
Cultivation	:	by hoe	12-VIII - 2-IX
Weeding	:	by hoe	1-VIII - 20-VIII - 30-VIII - 10-IX
Irrigation	:	4 x 80 m3	28-VII - 24-VIII - 8-IX - 24-IX
Rainfall	:	see records (280 mm)	
Diseases	:	none	
Insects	:	minor damages	
Treatments	:	2 kg/ha dieldrin per appl.	13-VIII - 4-IX
Harvesting	:	by hand	10-X
Treshing	:	by hand	13-X

Time table :

May	June	July	August	September	October
PD	FD	LI	WGCX WI W	CXIW I	HT

Explanation of symbols :

C - Cultivation
D - Disking
G - Germination
H - Harvesting
I - Irrigation
L - Planting
P - Ploughing
T - Treshing
W - Weeding
X - Plant protection

Experimental results :

Yields in kg grain per 100 m2, 10 % moisture					
Blocks	a control	b W	c K	d NK	e NPK
A	13.730	18.124	15.212	10.520	8.065
B	12.741	13.935	12.321	16.113	15.431
C	16.123	15.030	17.031	14.785	16.726
D	11.435	12.885	8.391	16.891	16.194
Block totals (kg)	54.029	59.974	52.965	58.309	56.416
Block totals (t/ha)	1,350	1,499	1,324	1,457	1,410

First conclusions :

1. N 60 kg/ha increased the yield by 149 kg/ha. This might be an uneconomic increase. It seems worthwhile to test N bacteries which can also influence the yields as well as N fertilizers.

2. K_2O gave no increase (block D lowered yield), N and K_2O gave an uneconomic increase of 107 kg/ha. Additional P gave no further increase for the block totals, since block A reduced the total yields.

3. The average yields were lower than those of the variety tests sown on 23-VII. (Further tests have to prove if the delayed sowing decreased the yields).

EXPERIMENT III-E : FERTILIZING PRACTICES FOR GROUND NUTS

Aim of the experiment : To evaluate fertilizer requirements under local conditions.

Description of the experiment :

X - no fertilizer
XX - N 80 kg/ha
XXX - K_2O 120 kg/ha
XV - N 80 kg/ha + K_2O 120 kg/ha
V - N 80 kg/ha + P_2O_5 80 kg/ha + K_2O 120 kg/ha

Method of application : Before planting time

Variety : Virginia - Selected Masora

Design of the experiment : Randomized blocks, 4 replications (A,B,C,D)

Plot sizes : Rectangular plots of 8 rows 20 m x 5 m (100 m2)

History of the field : First crop

Conduct of the experiment :

		Date
Ploughing	: by mouldboard plough 25 cm	22-V
Harrowing	: by disk harrow 15 cm	5-VI
Ridging	:	28-VII
Fertilizing	: According to experiment lay-out Fertilizers used : 1. Ammonium sulphate 21 % N 2. Muriate of potash 61 % K_2O 3. Nitrophoska 13 % N, 13 % P_2O_5, 20 % K_2O Fertilizers worked in by disk harrow	
Planting	: by hand on top of ridges	16-VIII
Germination	: full	23-VIII
Weeding	:	24-VIII - 12-IX - 30-IX - 30-X - 18-XI - 29-XI
Irrigation	: 10 x 60 m3	18-VIII - 8-IX - 24-IX - 12-X - 25-X - 9-XI - 23-XI -6-XII - 21-XII - 5-I
Rainfall	: see records	
Insects	: minor damages	
Diseases	: 1. Cercospora personata 2. Clorosis symptoms	
Treatments	: Sulphur powder 40 kg/ha	30-X - 21-XII
Harvesting	: by hand	10-II
Picking	: by hand	14-II

Time table :

May	June	July	August	September
P	FD		P	IW IW
October	**November**	**December**	**January**	**February**
X IWX	X W I W	X XI	X	X

Explanation of symbols :

D - Disking
G - Germination
F - Fertilizing
H - Harvesting
I - Irrigation
P - Ploughing
W - Weeding
X - Plant protection

Experimental results :

Yields in kg grain unshelled per 100 m2, well sun dried						
Block		0	N	K	NK	NPK
A		62.5	69.1	63.0	68.8	57.2
B		58.2	66.9	71.7	58.9	58.4
C		63.2	58.5	60.2	61.1	58.5
D		53.8	51.5	66.4	60.0	50.8
Block totals	(kg)	237.7	246.0	261.3	248.8	224.9
	(t/ha)	5,942	6,150	6,532	6,220	5,622

First conclusions :

1. Approximately 5 % of the weight should be deducted for soil fixed on the shells.

2. The best yield was with the K treatment 590 kg/ha more than control. N as the only fertilizer yielded 208 kg/ha more than control and the NK combination out-yielded by 70 kg/ha the N treatment but gave 312 kg/ha less than K treatment. NPK yielded 270 kg/ha less than control.

3. The planting method used in this experiment (on top of ridges) proved to be better than planting on flat land. The harvest was easy.

4. The ground nuts were not suitable for export without special cleaning.

APPENDIX 7.

PRELIMINARY SURVEY OF GROUND WATER RESOURCES IN THE ALEYDEGI PLAIN

1. Introduction

The Aleydegi Plain skirts the northern and north-western slopes of the Asebot and Afdem mountains. Westwards it is bounded by basalt plateaux along the right bank of the Awash. Northwards it ends at the foot of the Azelo mountain. It forms a long corridor 15 to 20 km wide, stretching south-west - north-east for about 100 km. The possibilities of using the existing pastures in the Plain for grazing are limited by the lack of a permanent source of water.

Since no direct observations, or other information, are available on the existence or location of ground waters, or on ground water conditions, an investigation of the lie, and the sources of supply of ground waters, should first be made. The existence of such waters can be assumed from a survey of the surface terrain.

Additional studies must be made on (a) sub-surface conditions, where soils are sufficiently permeable so that wells or tube wells can draw the water from the soil; and (b) sources of supply which depend on rainfall and surface runoff.

2. The Land

The soils of the Plain were formed from fine, largely silty, alluvium. In its upper reaches, much of the silt contains varying amounts of sand, while materials with a higher clay content are deposited in the lower tracts. The Arba Valley in the southern portion of the plain, and the Mulu Valley at Biltigu are sunk in 5 to 10 meters of alluvium. Such cuts in the terrain reveal strata of rolled pebbles and gravel under the surface silt, in regular bands, sometimes bulging in shape.

The seasonally flowing rivers may have been larger during the rainy seasons of the Quarternary Period and may have changed beds many times. Such occurences are common where deposition from torrential rivers is still in process. If this is so, channels in coarse alluvium must exist buried here and there in the sub-soil, but no surface condition reveals the location of their buried bed; and even less is there a way of telling how much they have been silted up. To a large extent, silting will determine the water-bearing properties of the alluvia.

The highlands aound the Aleydegi Plain are of volcanic origin. They are basalt plateaux, along the south-eastern border of the Plain, arranged in steps interrupted by faults running parallel to the Plain's length. Between the Plain and the Asebot volcano, the direction of the ravines clearly reveals this system of faults, and basalt flows are almost horizontal.

3. Surface Waters

Very few traces of runoff are to be observed in the Plain itself. Rainfall is moderate. Flatness of the surface as well as a good grass cover help to prevent surface runoff. By contrast, innumerable seasonal streams issue from the mountain sides. They flow for a few days, or even for a few hours, a year. Each rivulet usually floods a small area at the foothill and never flows beyond it, except during exceptional flood periods. During the dry season, these temporary pools dry up completely.

A small number of intermittent rivers have their source near the Chercher crests. Since their watershed is larger, and their sources at a higher elevation, the force of their waters is great enough to carve beds through the Aleydegi Plain. Such are the Arba, Mulu and Bordoda rivers. The Arba cuts the southern portion of the plain and then joins the Awash. The Mulu moves past the foot of the Afdem Mountain, flowing northward to flood the Azelo region. The Bordoda comes from the Azebot Mountain and becomes confluent with the Mulu in its flood plain.

During flood periods, a certain amount of water from these three rivers percolates through their permeable beds and banks to the watertable. The only permanent well mentioned in the entire region is at Biltigu. It was dug in alluvium deposited by the Mulu River and reaches the undelying permanent watertable at a depth of approximately 5 meters.

4. Program of Investigation

An investigation of ground water resources could be made either in the permeable alluvia near the seasonal rivers or, at a greater depth, in the underlying volcanic strata. The most likely sources of water seem to be near the principal intermittent rivers, where coarser alluvium tends to predominate.

4.1 Wells

Wells should be dug by hand in this heterogenous, usually unconsolidated material. Water can be brought to the surface with simple equipment requiring almost no maintenance. This is important in a relatively undeveloped and inaccessible region. A few wells, dug close to the larger intermittent rivers and beyond the reach of floods, would provide information on availability and amounts and of water in the alluvium.

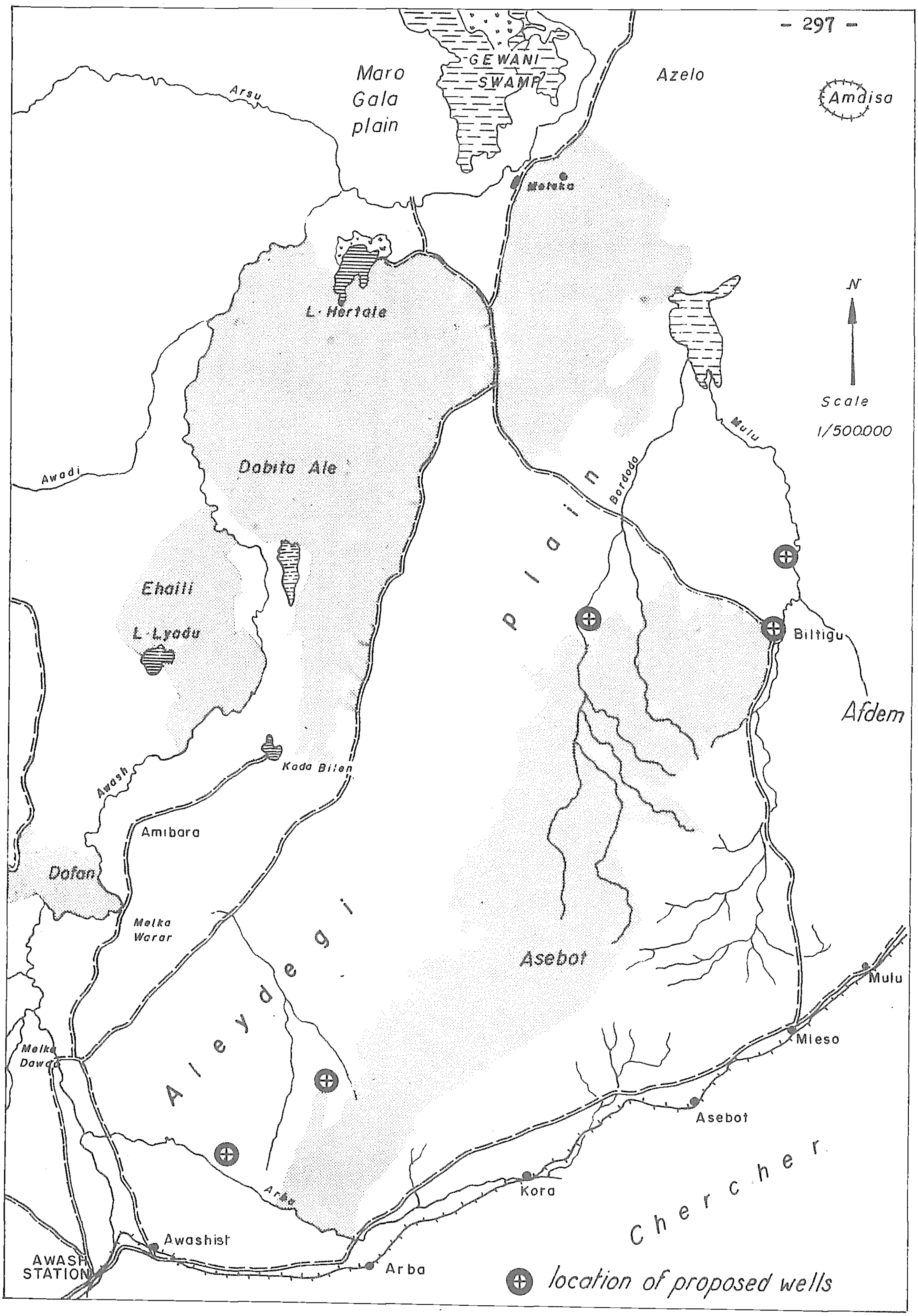
Six experimental wells could be dug: (a) one near the Arba River; (b) one at the source of an unnamed intermittent stream, 15 kilometers north of the Arba River; (c) one near the Bordoda River, in the area where its effluence begins; (d) two on the Mulu River, at Biltigu; and (e) one 10 kilometers or so downstream. Their location is shown on the map drawn to a scale of 1:500,000. If water-producing, they could meet the needs of the local pastoralists.

The well lining should be made of masonery or concrete. The well should penetrate the water table to a depth of 5 meters. Its floor and walls beneath the water table should include a gravel or sand filter. The size of the particles in the filter must be determined by the particle size in the water-bearing alluvium, so as to avoid entraining materials which would interfere with a proper functioning of the well.

4.2 Drillings

If, in addition, it is desired to establish water holes in the central part of the Aleydegi, which no sizeable river traverses, the water bearing properties of the soils below the surface silt will have to be investigated. Although the deep sub-surface structure of the soil is not well known, the region has undergone faulting. It resulted in the huge upthrows which produced the troughs known as the Rift Valley. It seems advisable, therefore, to make an underground survey to a depth of 500 meters if possible, with mechanical drills. Hydrodynamic tests could then be made in the principal water layers encountered so as to determine their potentialities.

Once these drillings had been made, the possibilities of making a geophysical study of the region could be envisaged, so as to extrapolate information on a particular locality to the region around it. These costly procedures should be undertaken only after the six experimental wells have been built.



GEWANI SWAMP
Maro Gala plain
Azelo
Amdisa
Arsu
Meteka
L. Hertale
N
Scale 1/500.000
Mulu
Awadi
Dabita Ale
Bordoda
plain
Ehaili
L. Lyadu
Biltigu
Afdem
Kada Bilen
Awash
Amibara
Dofan
Melka Warar
Aleydegi
Asebot
Mulu
Mieso
Melka Dawa
Asebot
Arba
Kora
Chercher
Awashist
AWASH STATION
Arba
location of proposed wells

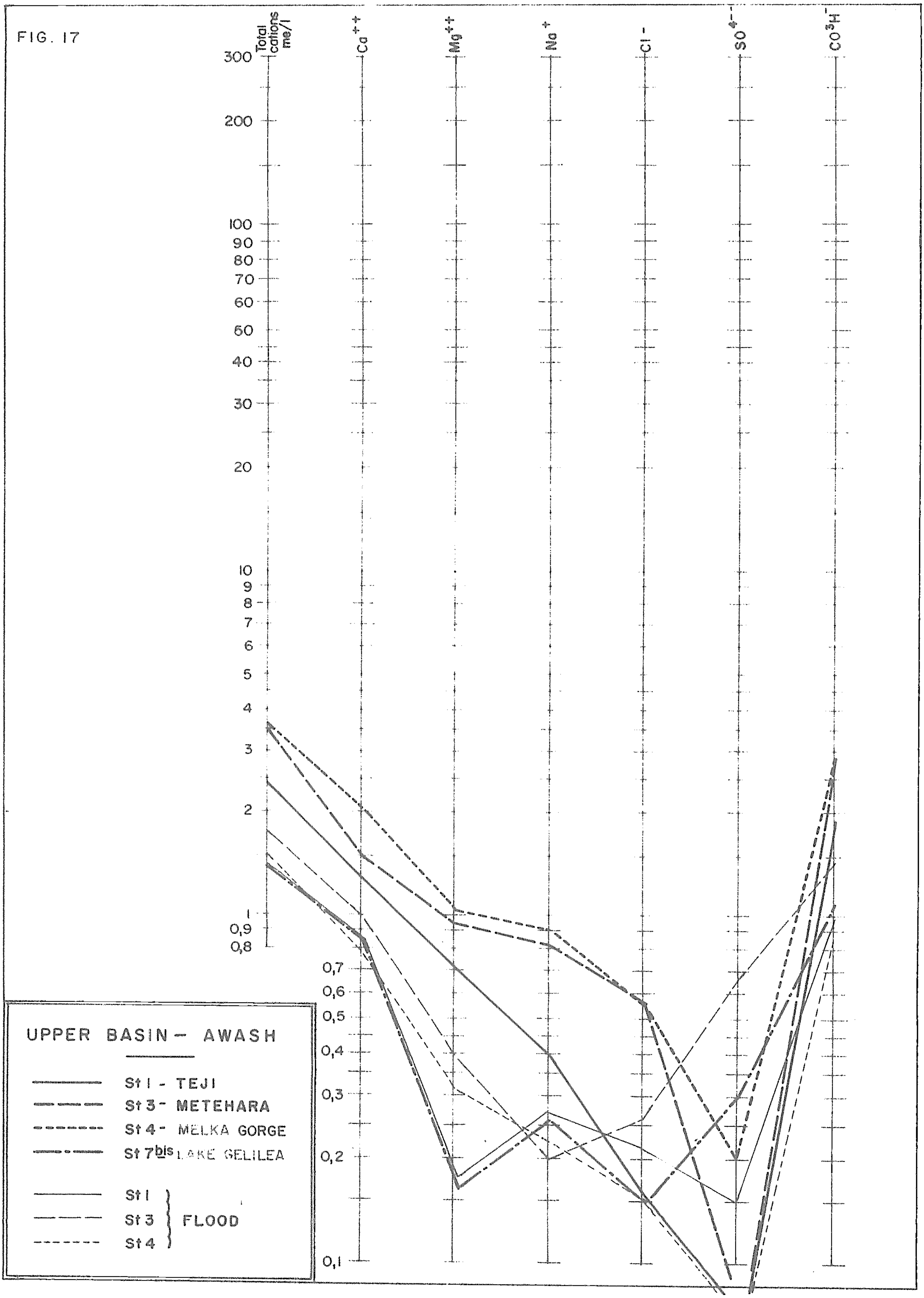
APPENDIX 8

Graphs no. 17 to 31

INTERPRETATION OF CHEMICAL ANALYSIS OF WATER SAMPLES

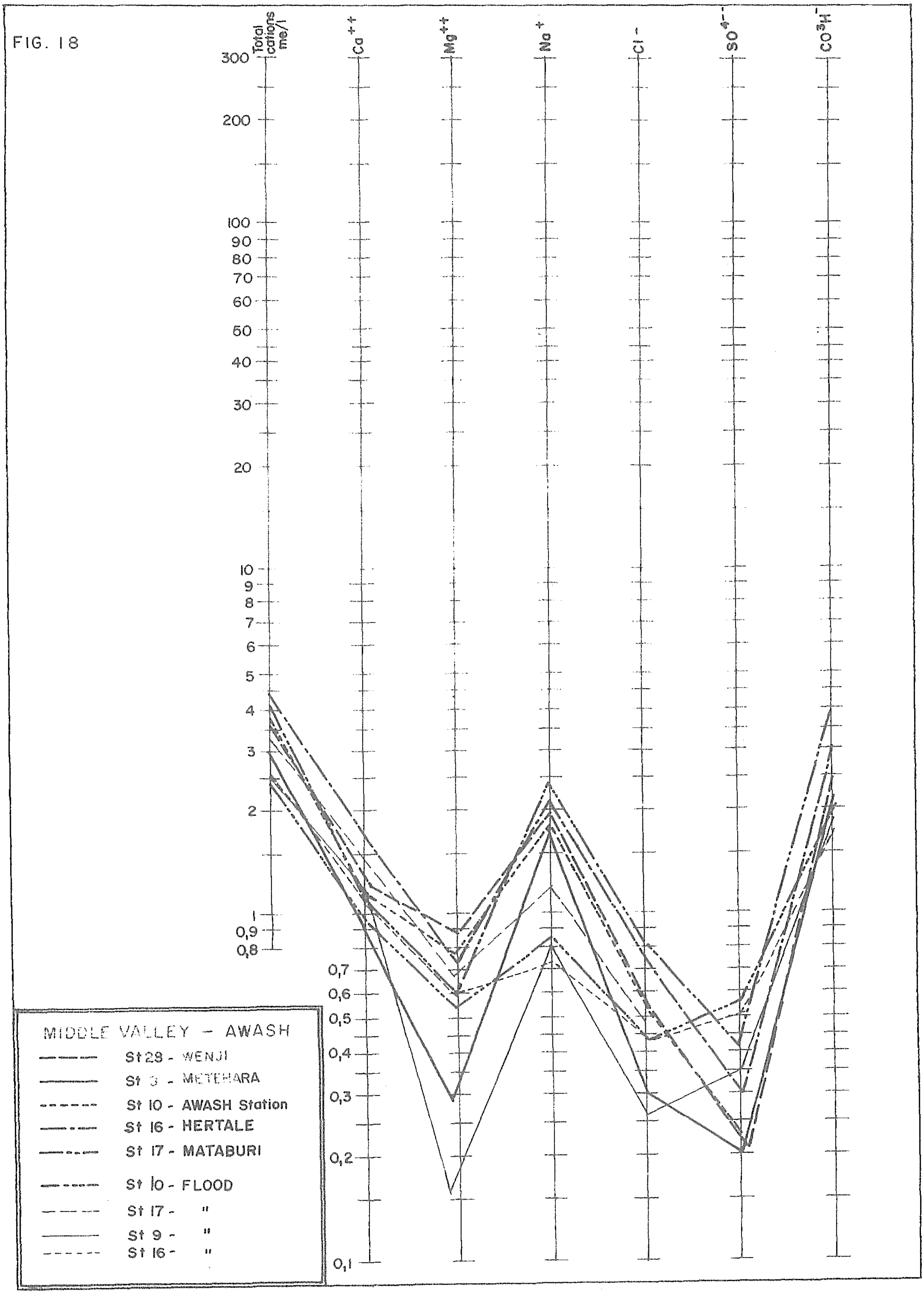
(Logarithmic Charts)

FIG. 17



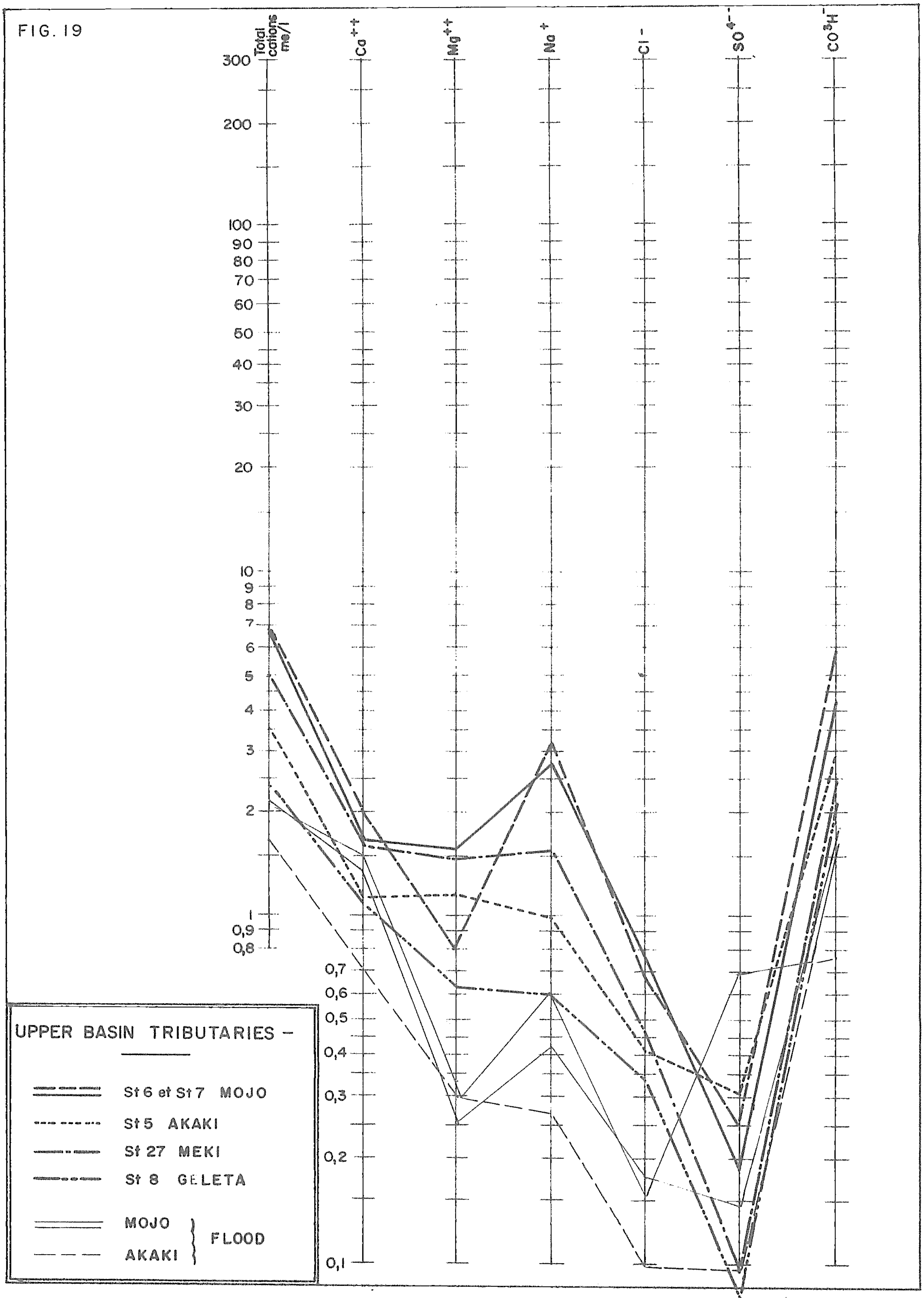
Total cations me/l
Ca⁺⁺
Mg⁺⁺
Na⁺
Cl⁻
SO⁴⁻⁻
CO³H⁻
300
200
100
90
80
70
60
60
40
30
20
10
9
8
7
6
5
4
3
2
1
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
UPPER BASIN – AWASH
St 1 - TEJI
St 3 - METEHARA
St 4 - MELKA GORGE
St 7bis LAKE GELILEA
St 1
St 3
St 4
FLOOD

FIG. 18



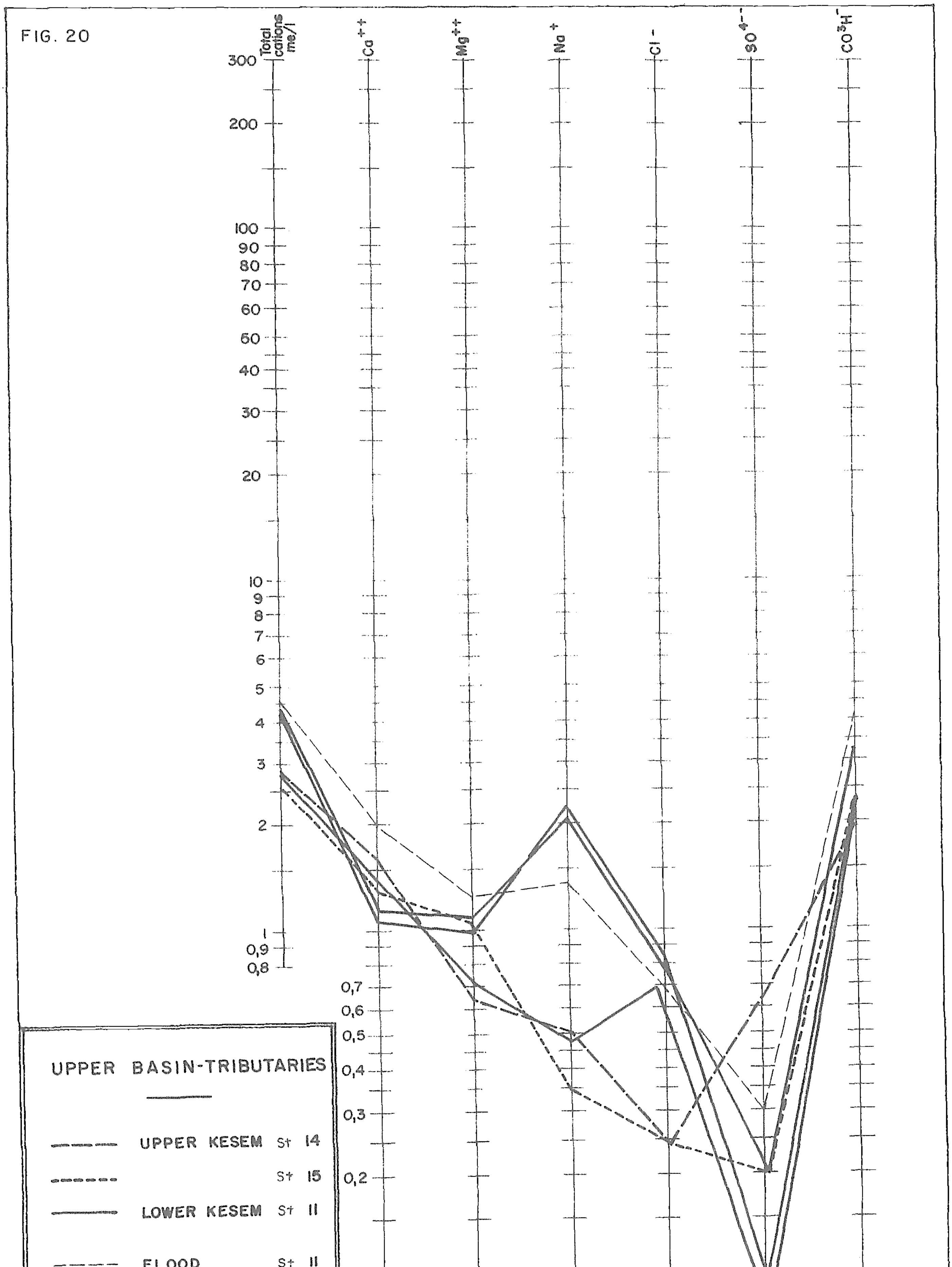
Total cations me/l
Ca ++
Mg ++
Na +
Cl -
SO4 --
CO3H -
300
200
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
2
1
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
MIDDLE VALLEY - AWASH
St 28 - WENJI
St 3 - METEHARA
St 10 - AWASH Station
St 16 - HERTALE
St 17 - MATABURI
St 10 - FLOOD
St 17 - "
St 9 - "
St 16 - "

FIG. 19



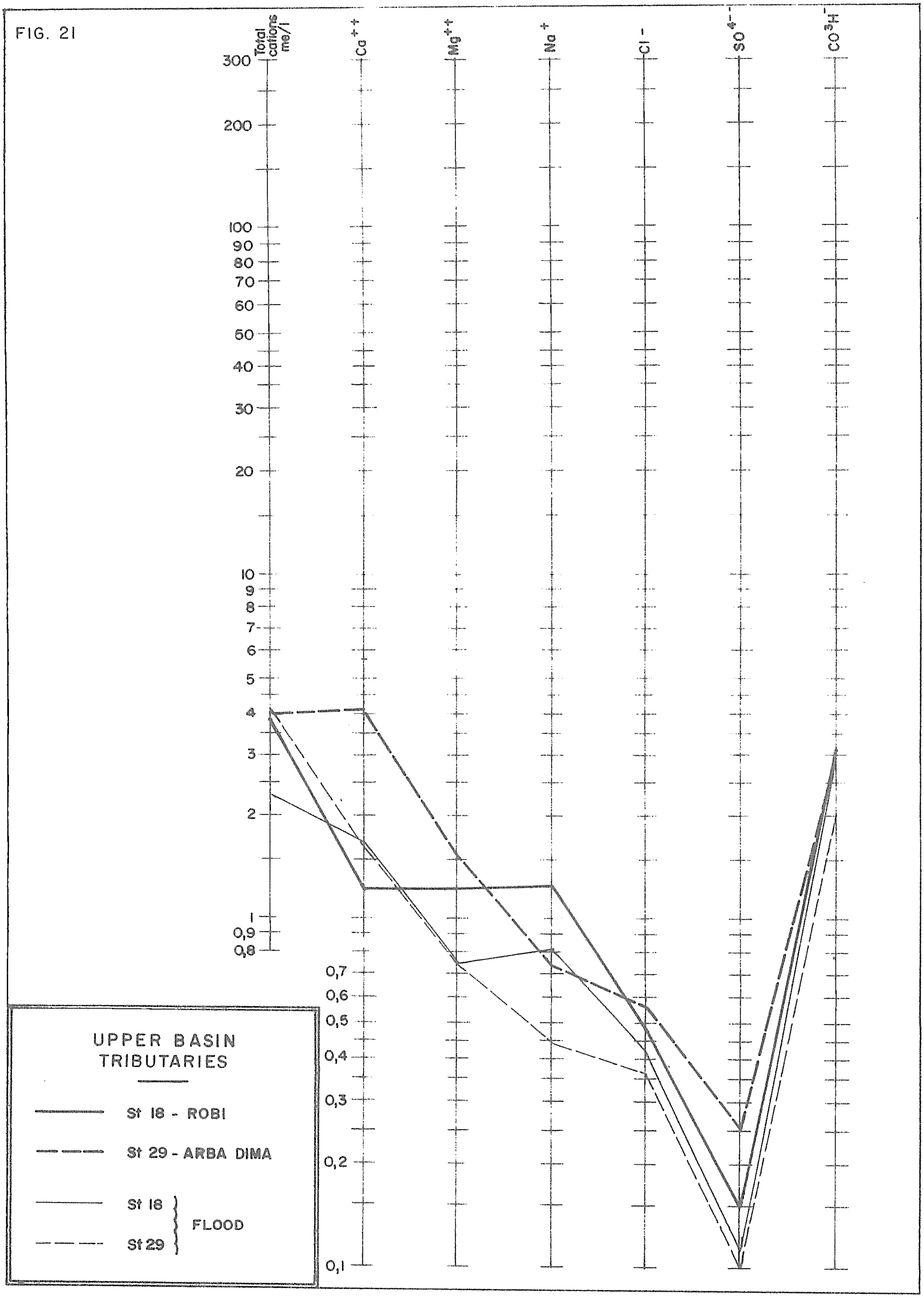
Total cations me/l
Ca++
Mg++
Na+
Cl-
SO4--
CO3H-
300
200
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
2
1
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
UPPER BASIN TRIBUTARIES -
St 6 et St 7 MOJO
St 5 AKAKI
St 27 MEKI
St 8 GELETA
MOJO
AKAKI
FLOOD

FIG. 20



Total cations me/l
Ca++
Mg++
Na+
Cl-
SO4--
CO3H-
300
200
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
2
1
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
UPPER BASIN-TRIBUTARIES
UPPER KESEM St 14
St 15
LOWER KESEM St 11
FLOOD St 11

FIG. 21



Total cations me/l
Ca ++
Mg ++
Na +
Cl -
SO4 --
CO3H -
300
200
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
2
1
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
UPPER BASIN
TRIBUTARIES
St 18 - ROBI
St 29 - ARBA DIMA
St 18
St 29
FLOOD

FIG. 22

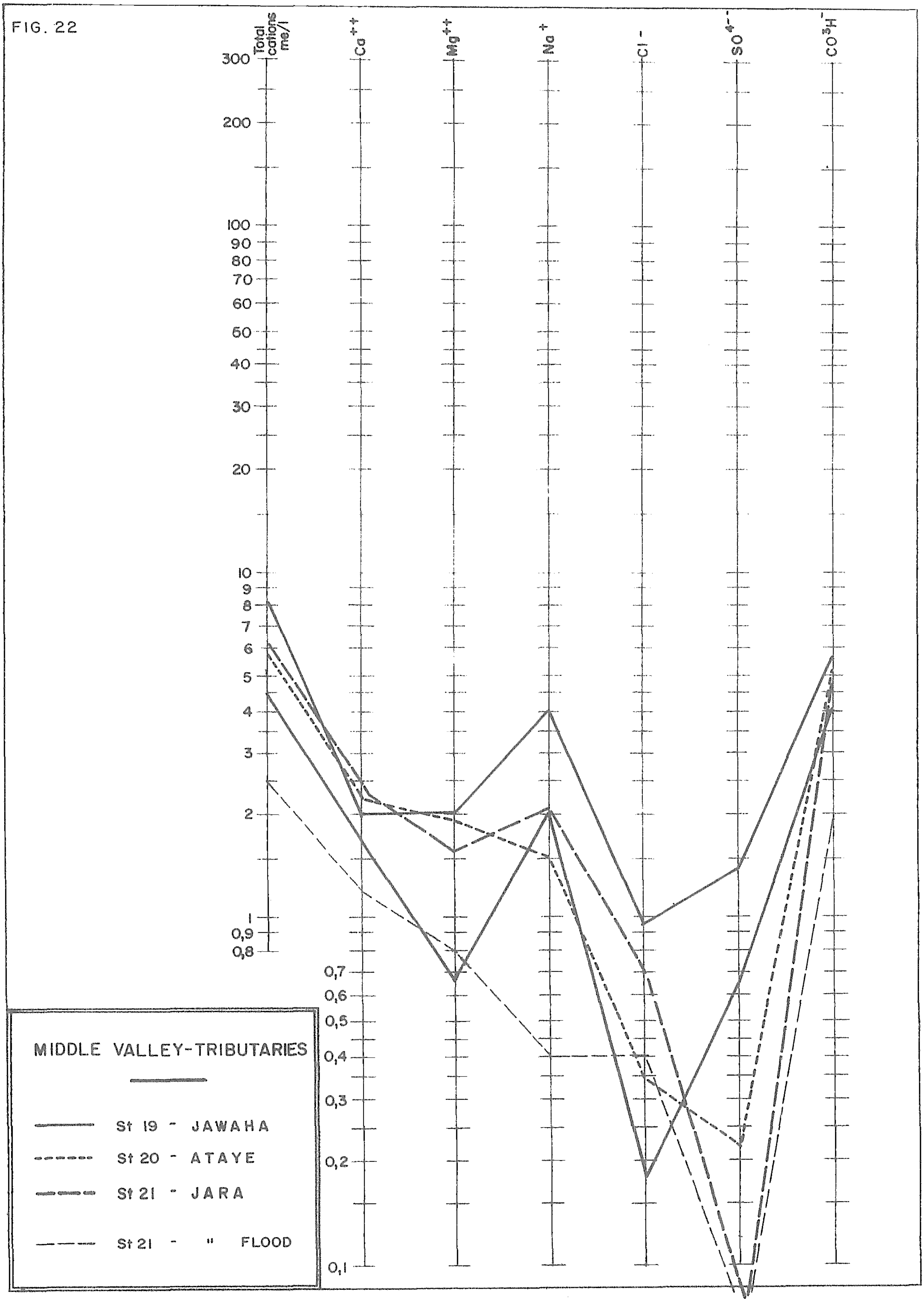
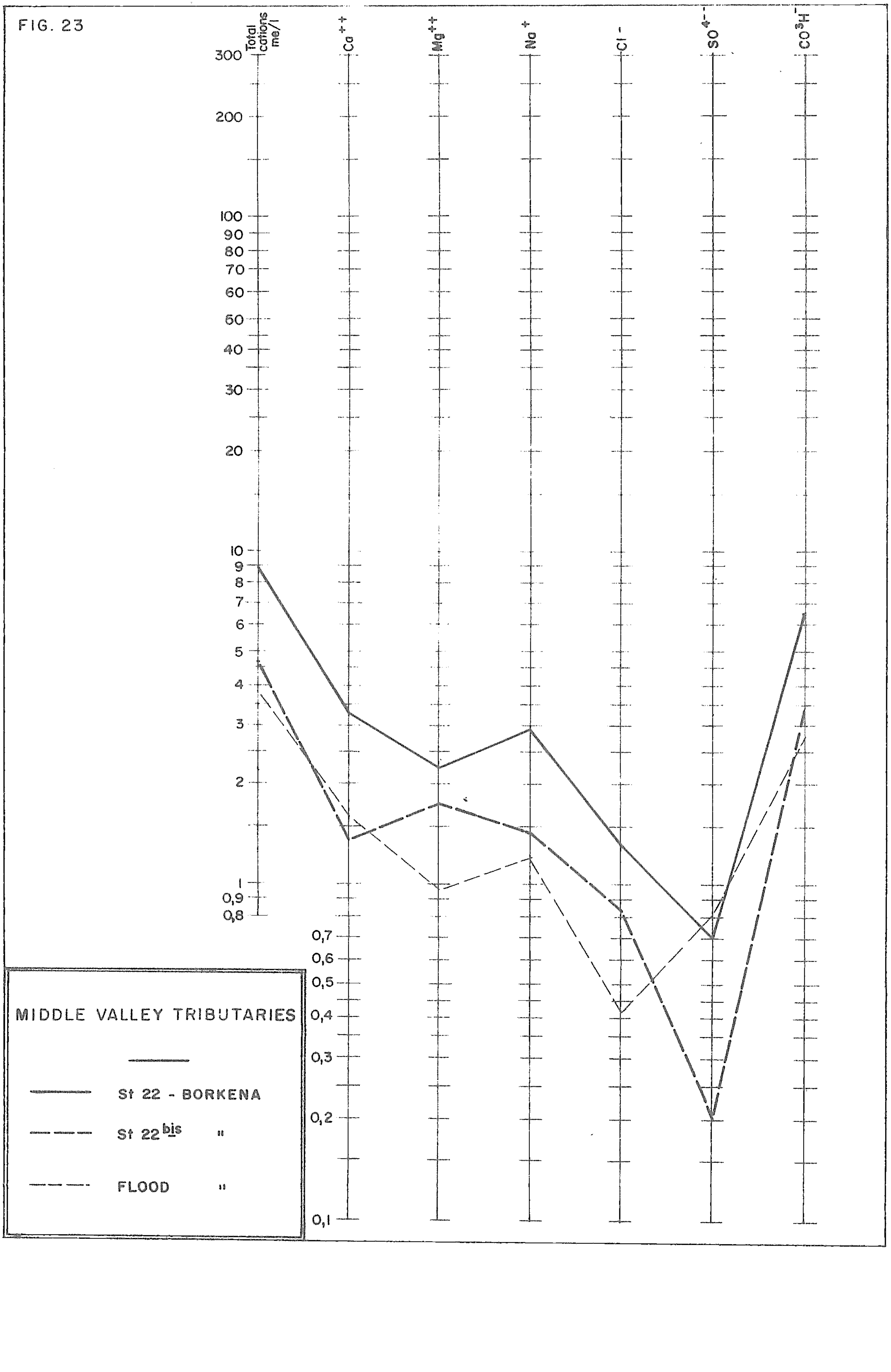
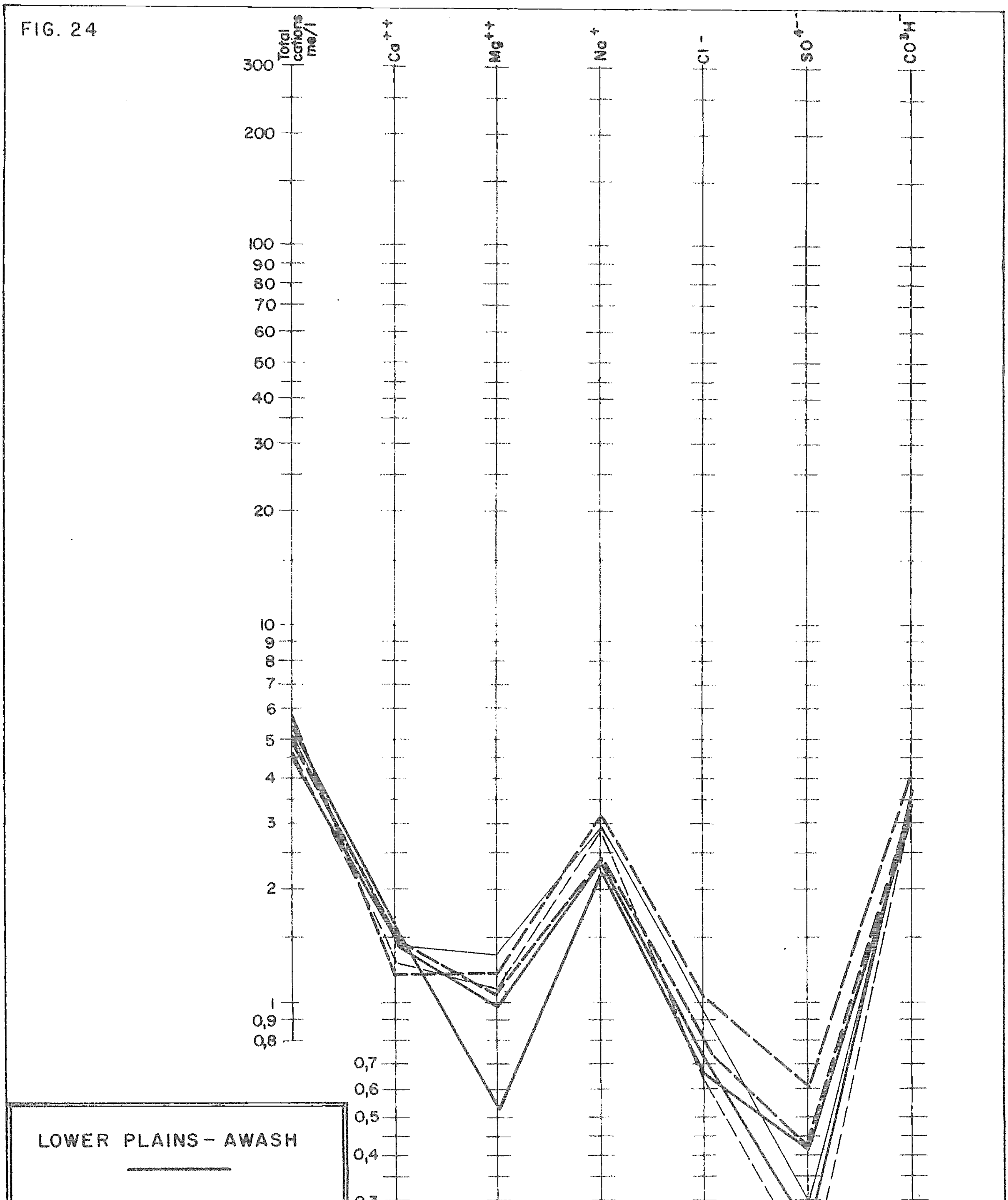

Total cations me/l
Ca++
Mg++
Na+
Cl-
SO4--
CO3H-
300
200
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
2
1
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
MIDDLE VALLEY-TRIBUTARIES
St 19 - JAWAHA
St 20 - ATAYE
St 21 - JARA
St 21 - " FLOOD

FIG. 23



Total cations me/l
Ca++
Mg++
Na+
Cl-
SO4--
CO3H-
300
200
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
2
1
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
MIDDLE VALLEY TRIBUTARIES
St 22 - BORKENA
St 22 bis "
FLOOD "

FIG. 24



Total cations me/l
Ca++
Mg++
Na+
Cl-
SO4--
CO3H-
300
200
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
2
1
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
LOWER PLAINS - AWASH
St 25 - DUBTI
St 26 - ASAYITA
St 25 FLOOD
St 26 "

FIG. 25

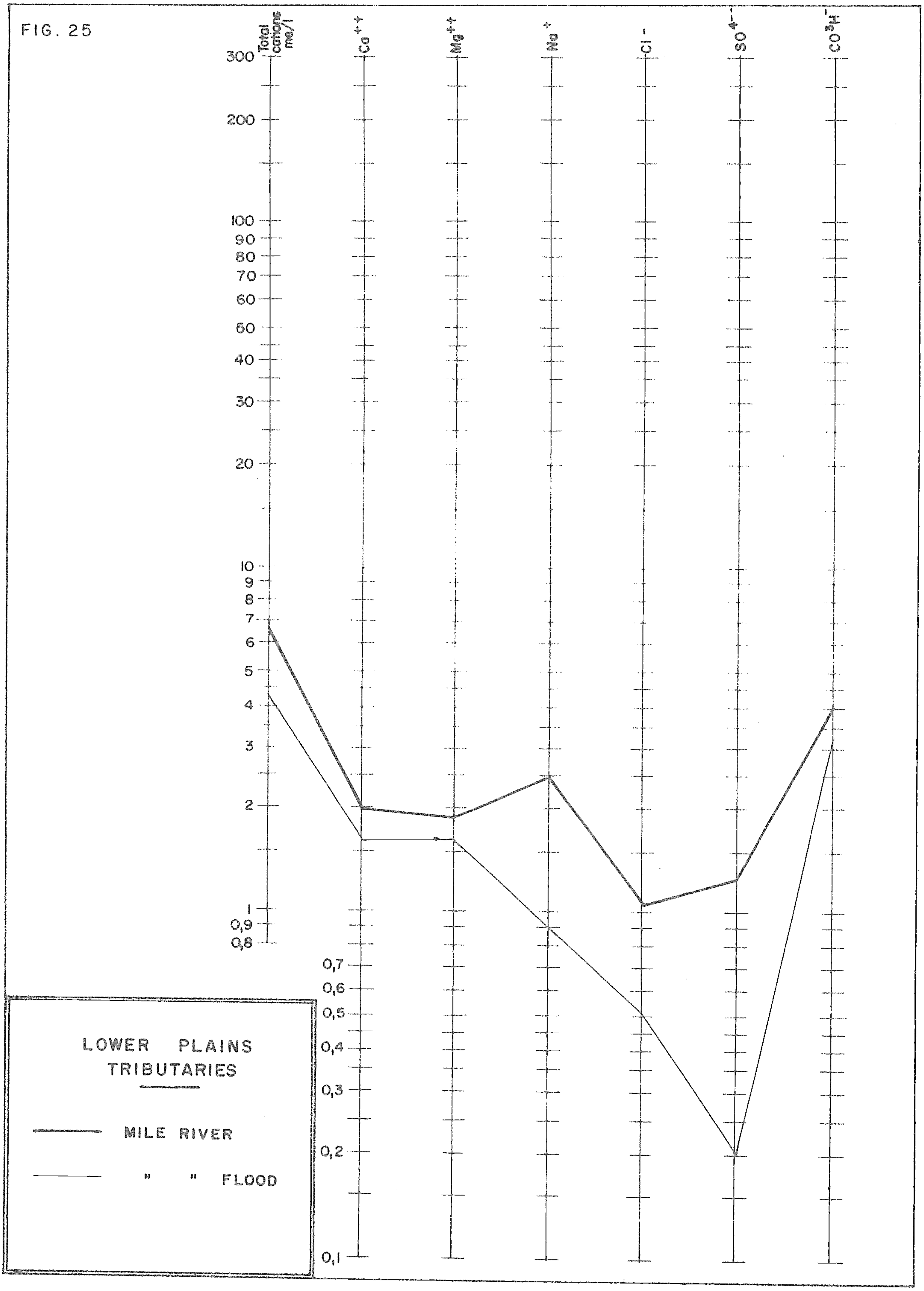
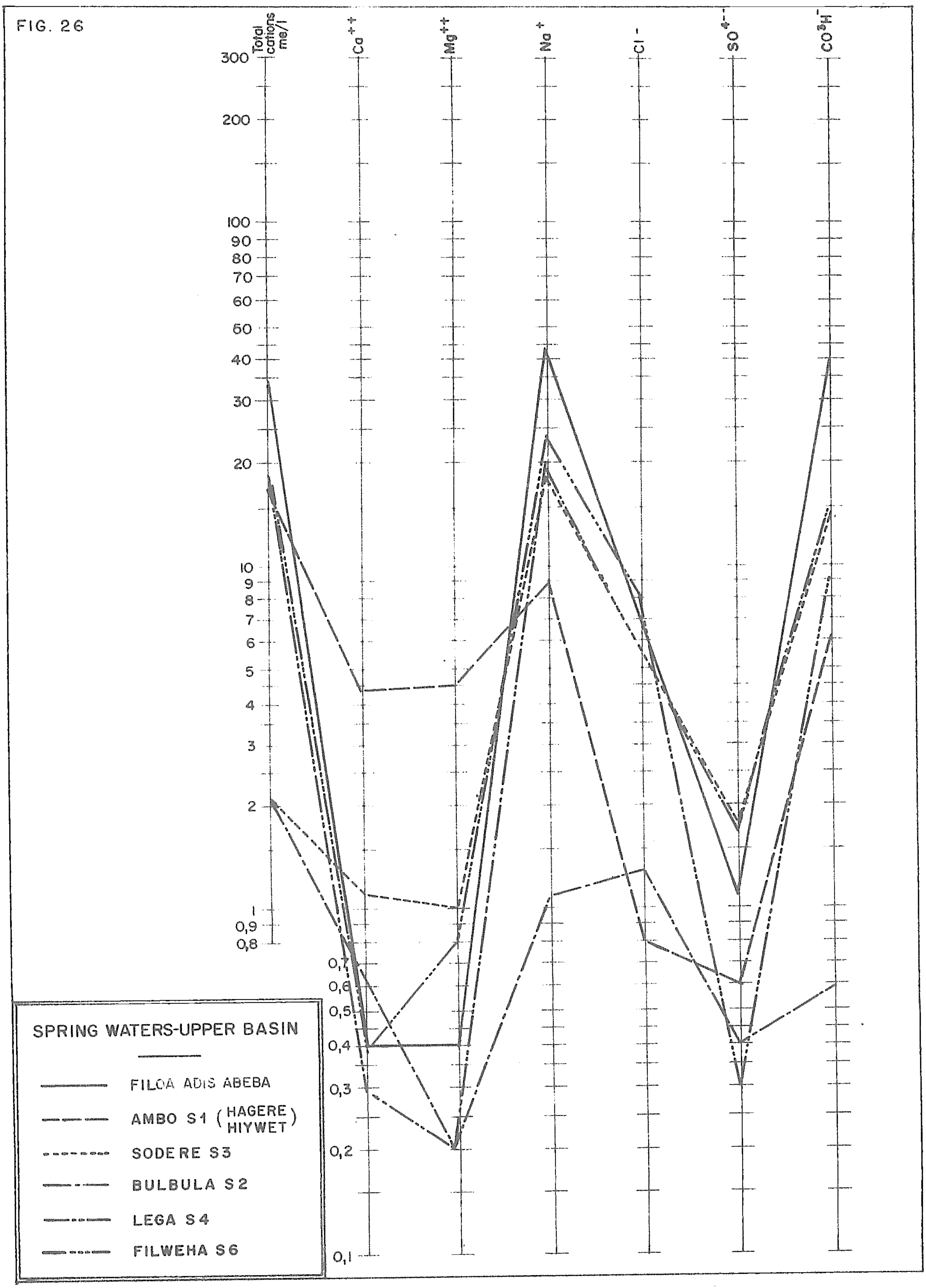
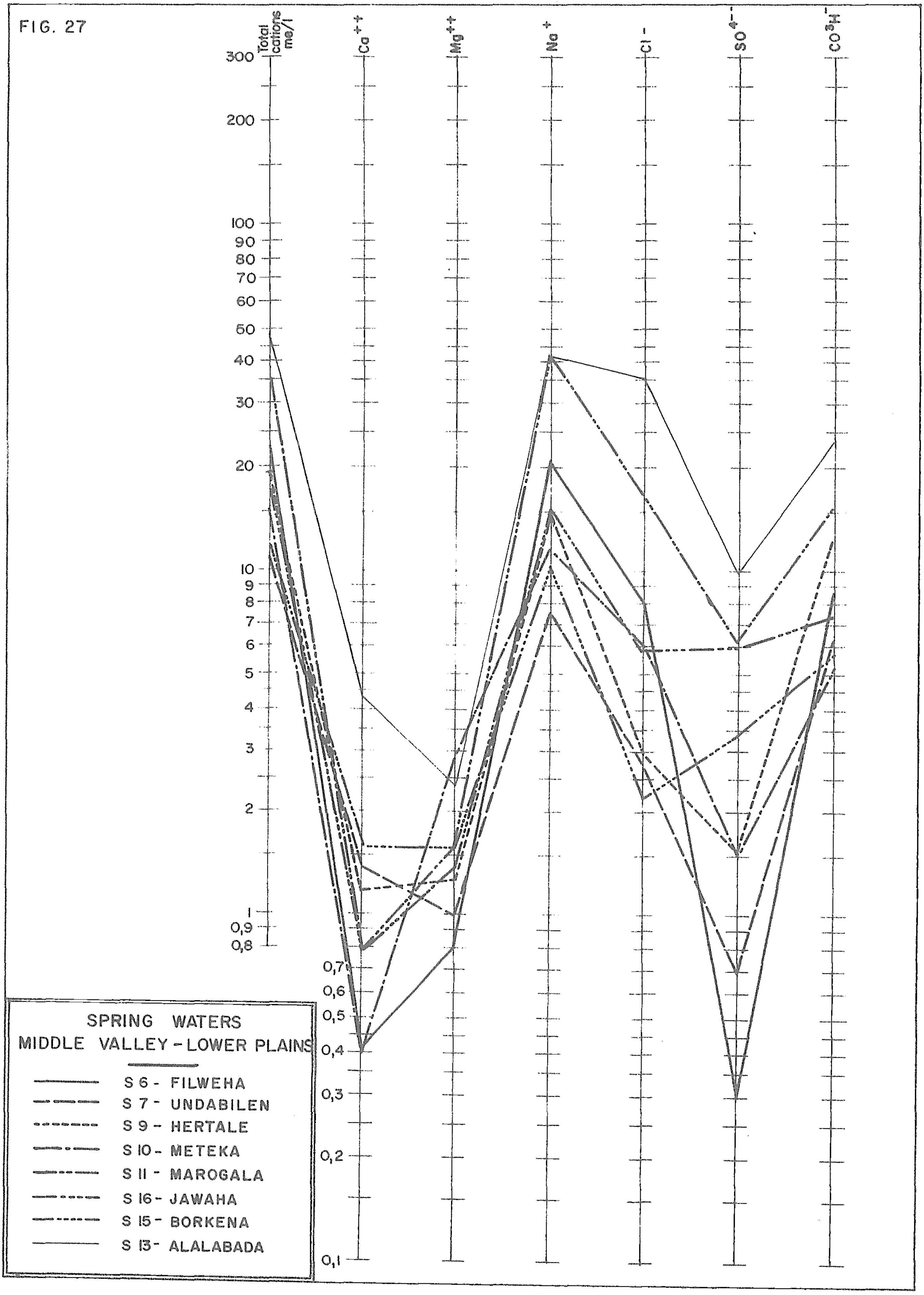

Total cations me/l
Ca^{++}
Mg^{++}
Na^{+}
Cl -
SO^{4--}
$CO^{3}H^{-}$
300
200
100
90
80
70
60
60
40
30
20
10
9
8
7
6
5
4
3
2
1
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
LOWER PLAINS
TRIBUTARIES
MILE RIVER
" " FLOOD

FIG. 26



Total cations me/l
Ca++
Mg++
Na+
Cl-
SO4--
CO3H-
300
200
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
2
1
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
SPRING WATERS-UPPER BASIN
FILOA ADIS ABEBA
AMBO S1 (HAGERE HIYWET)
SODERE S3
BULBULA S2
LEGA S4
FILWEHA S6

FIG. 27



Total cations me/l
Ca++
Mg++
Na+
Cl-
SO4--
CO3H-
300
200
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
2
1
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
SPRING WATERS
MIDDLE VALLEY - LOWER PLAINS
S 6 - FILWEHA
S 7 - UNDABILEN
S 9 - HERTALE
S 10 - METEKA
S 11 - MAROGALA
S 16 - JAWAHA
S 15 - BORKENA
S 13 - ALALABADA

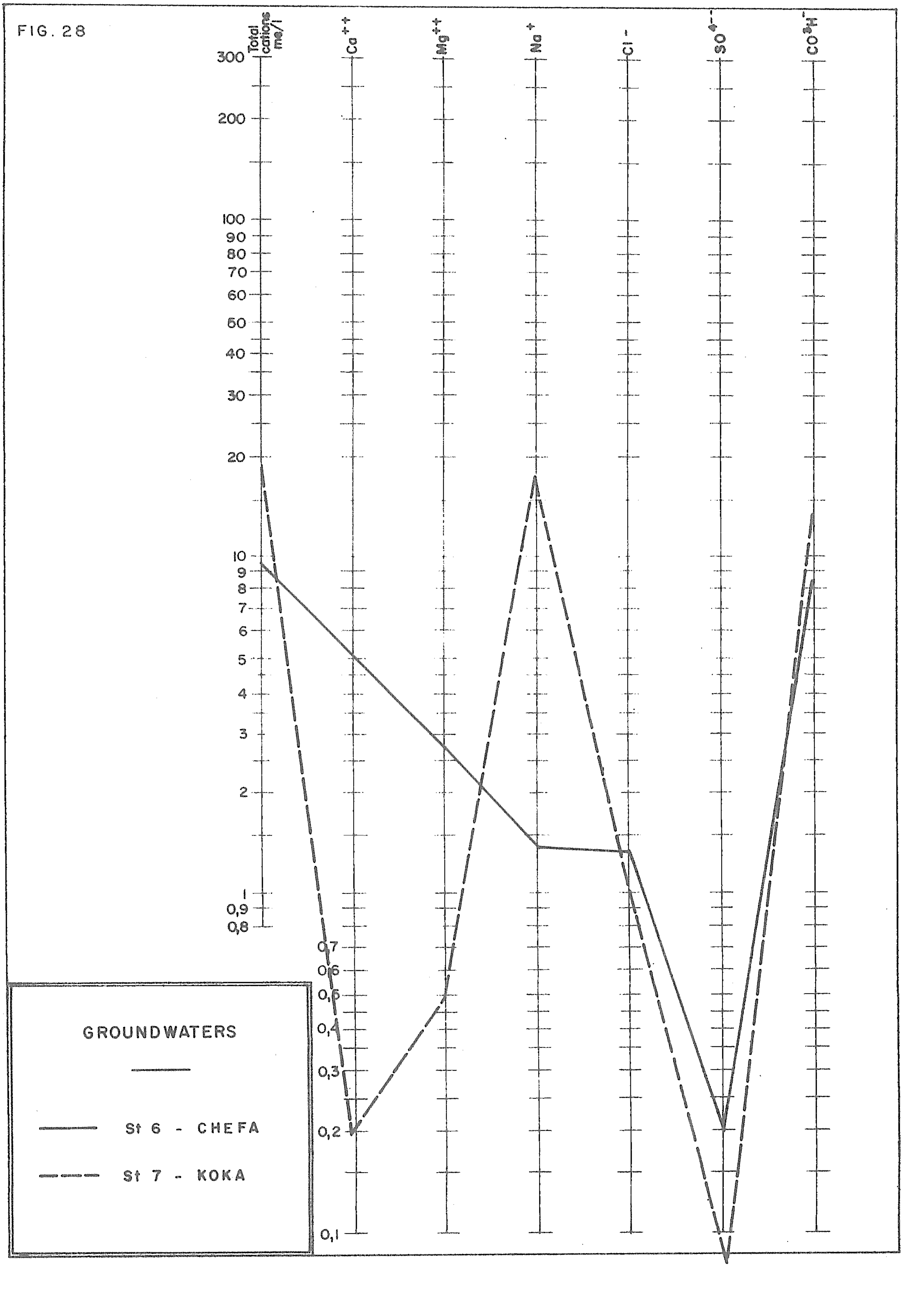


FIG. 28
Total cations me/l
Ca++
Mg++
Na+
Cl-
SO4--
CO3H-
300
200
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
2
1
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
GROUNDWATERS
St 6 - CHEFA
St 7 - KOKA

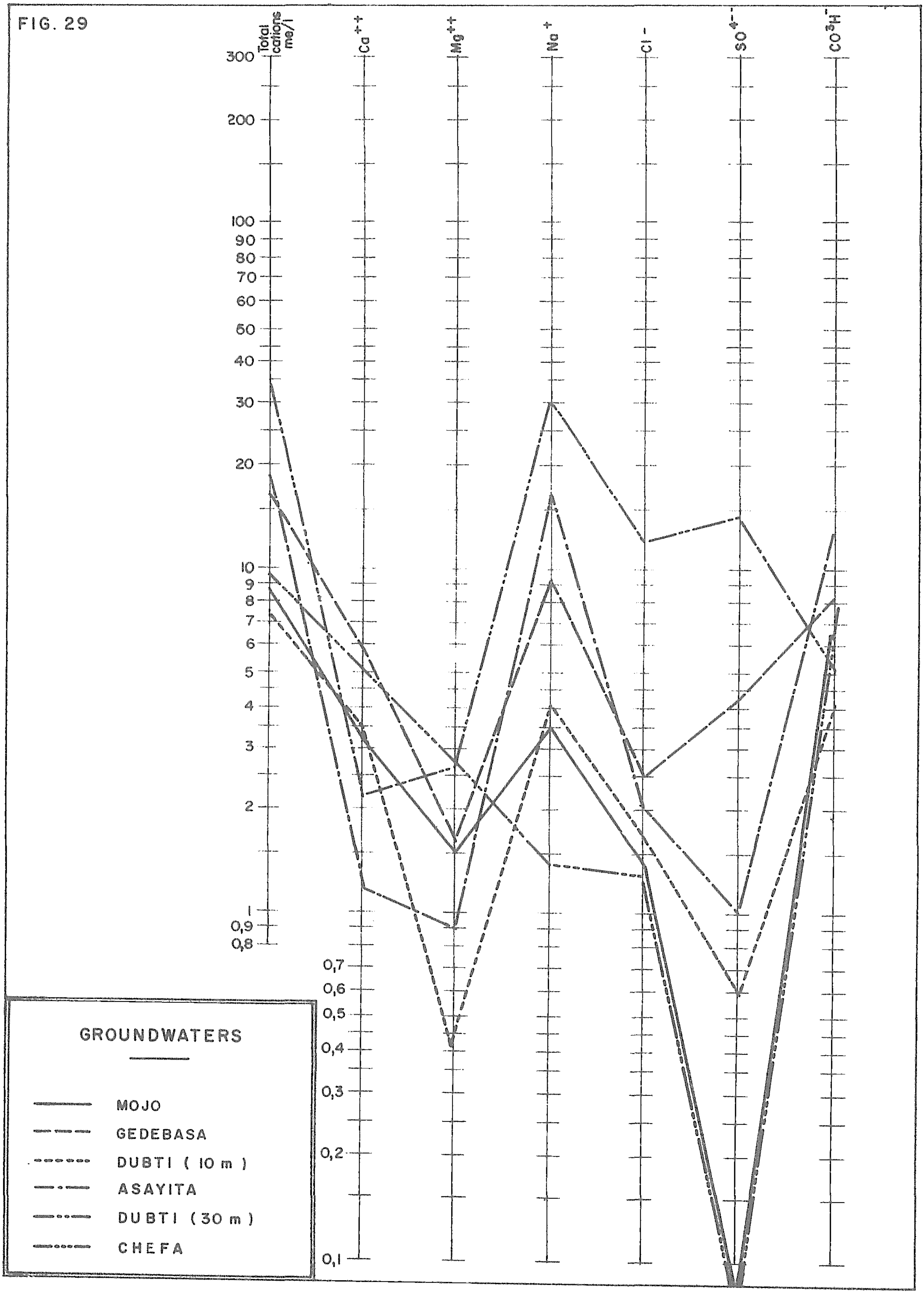
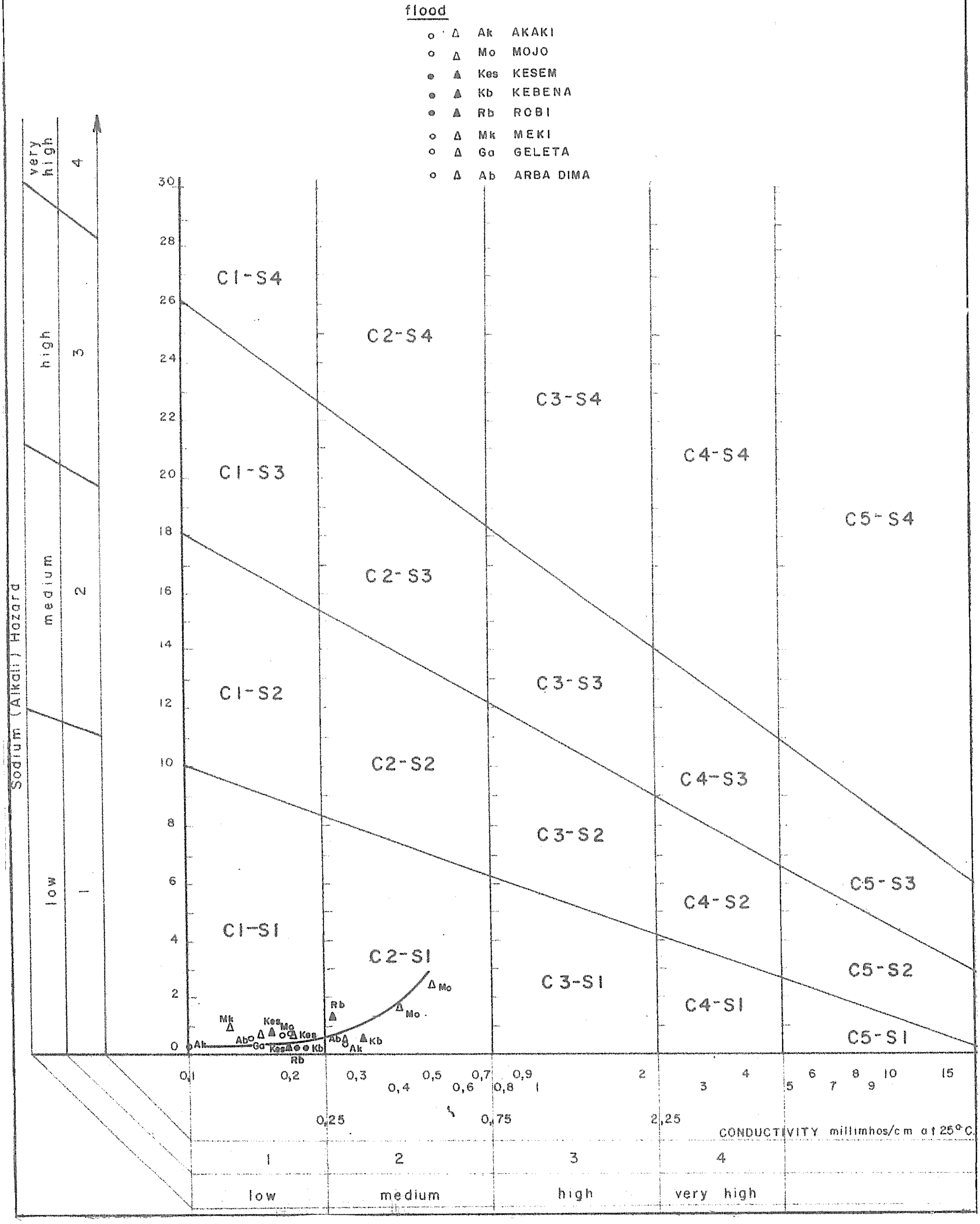


FIG. 29
Total cations me/l
Ca^{++}
Mg^{++}
Na^{+}
Cl^{-}
SO^{4--}
$CO^{3}H^{-}$
300
200
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
2
1
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
GROUNDWATERS
MOJO
GEDEBASA
DUBTI (10 m)
ASAYITA
DUBTI (30 m)
CHEFA

CLASSIFICATION OF IRRIGATION WATERS

FIG. 30

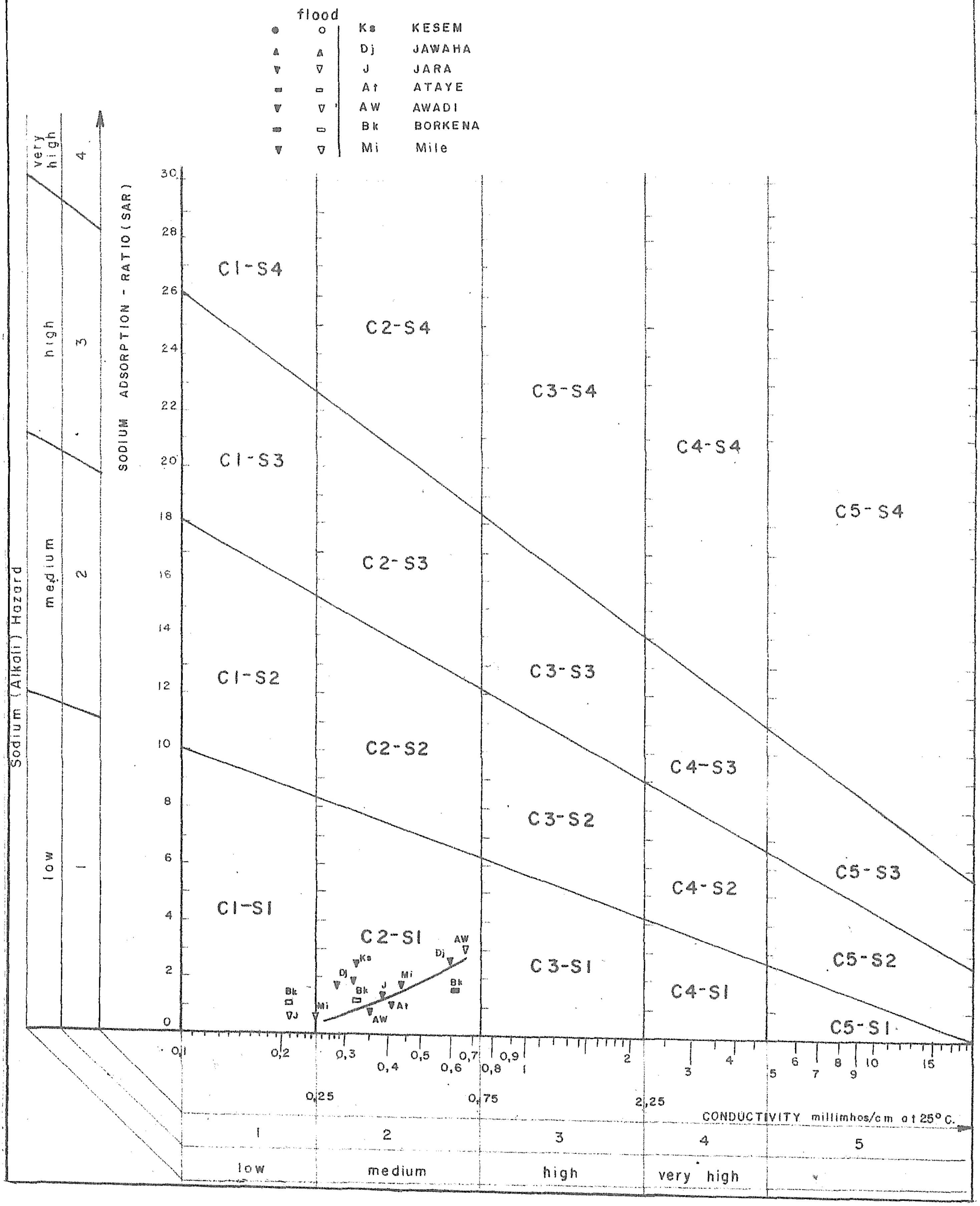
UPPER BASIN TRIBUTARIES



CLASSIFICATION OF IRRIGATION WATERS

FIG. 31

MIDDLE VALLEY TRIBUTARIES



SOIL CLASSIFICATION - MAPPING UNITS AND TYPICAL PROFILES

Table 4.

SOIL CLASSIFICATION: Soil groups	SOIL CLASSIFICATION: Sub-groups	SOIL SERIES	SOIL PHASES	MAPPING UNITS 1:1 000 000	MAPPING UNITS 1:250 000	MAPPING UNITS 1:100 000 Middle Valley	MAPPING UNITS 1:100 000 Lower Plains	Typical profiles
Alluvial soils	On recent calcareous deposits	- Medium to moderately fine interlayered texture	- Subject to seasonal waterlogging - Zone of dried-up channels, medium salinity, microrelief with holes and channels	1c	Ac	- -	111 112	TMT53 DRD37
		- Medium to moderately fine interlayered texture, saline	- Zone of dried-up channels, microrelief with holes and channels		As	-	112a	AAS62
		- Moderately fine to fine interlayered texture, occasionally alkaline at deeper levels	- Deep subject to seasonal waterlogging - Deep zone of dried up channels		Ac	- -	121 122	TMT51 DRD125
		- Moderately fine to fine interlayered texture, occasionally alkaline	- Moderately deep on horizons of variable texture and color			-	13	DRD123
	On recent very slightly or non-calcareous deposits	- Medium texture		1nc	Anc	11	-	KK4
		- Interlayered medium to moderately fine texture	- Deep - Dark color horizon with moderately fine texture at deeper levels			121 122	- -	BKB27 MMS52
		- Moderately fine to fine texture	- Microrelief with holes			13	-	MMS302
		- Medium to fine texture, occasionally saline			As	2	-	MAL18
Vertisols	grey vertisols on calcareous materials – on recent alluvial materials – calcareous	- Fine structure - Coarse structure, alkaline	- Gilgai microrelief - Subject to flooding	2c	Vc	- -	21 22	DRD13 DRD107
	grey vertisols on calcareous materials – on recent alluvial materials – slightly calcareous	- Fine structure - Coarse structure				51 52	- -	MMS358 MMS312
	grey vertisols on calcareous materials – on old calcareous alluvial and colluvial materials	- Fine structure, slightly saline at deeper levels			Vf	71	-	AAS64
		- Coarse structure	- Salinity low to nil		Vl	- -	81 82	HMA53 AAS55
		- Coarse structure, slightly saline	- Medium salinity in the top soil - Slightly saline at deeper levels			72	-	LLD31
	grey vertisols on calcareous materials – on calcareous materials in the runoff zones	- Coarse structure	- Deep - Moderately deep on basalt gravel colluvia - Moderately deep with basalt gravels, generally covered by runoff loam		Vt	611 612 613	- - -	HMA1 MMS350 HMA8
	grey vertisols on very slightly or non calcareous materials – on recent alluvial materials	- Fine, self mulching structure	- Deep, fine texture, gilgai microrelief - Deep, with highly developed mulch - Moderately deep on loamy horizons - Shallow on interlayered alluvia, microrelief with holes	2nc	Vnc	311 312 313 314	- - - -	MAL21 MMS120 MMS317 MMS319
		- Coarse structure, slightly alkaline	- Moderately fine to fine texture - Moderately fine texture on interlayered alluvia, microrelief with holes and channels in dried-up areas			321 322	- -	MMS352 KKB120
		- Coarse structure, slightly hydromorphic	- Subject to seasonal waterlogging during floods			4	-	MMS327
	grey vertisols on non differentiated materials			2nd(+3,+4)	-	-	-	-
	brown vertisols on non differentiated volcanic materials			6	-	-	-	-
	brown to reddish brown vertisols on basalt			5	-	-	-	-
Semi arid brown soils	on soft calcareous materials			7a	Bc	82	-	MMS314
	on gravelly calcareous materials				Bg	83	-	MMS85
	on volcanic tuff and basalt debris				Bp	84	-	MMH26
	on non differentiated material			7nd	-	-	-	-
Saline soils	on old calcareous alluvial and colluvial materials	- Medium texture	- Medium salinity - Medium salinity at deeper levels	8	S	11	411 412 42	KK323-TMT22 TT29 TMT17
		- Moderately fine texture	- Medium to high salinity at deeper levels					
Saline alkali soils	on old calcareous alluvia or colluvia		- High salinity	9	Sa	12	5	KAW22-TT37
	on recent alluvia		- Subject to seasonal waterlogging, low to medium salinity		Ha	62		MAL4
Hydromorphic soils	on recent alluvial materials – calcareous		- Subject to temporary flooding	11c	Hc	-	31	DRD27
	on recent alluvial materials – very slightly or non calcareous		- Subject to temporary flooding	11nc	Hnc	61	-	MAL20
	on non differentiated materials			4	-	-	-	-
Organic hydromorphic soils	on recent calcareous alluvial materials		- Subject to seasonal waterlogging - Permanently waterlogged	12	Ho	-	321 322	TTN25 -
	on non differentiated materials				-	-	-	-
Regosols	resulting from erosion – on semi-arid brown soils	- On soft alluvia and colluvia - On gravelly alluvia and colluvia - On basalt-gravel colluvia - On soft pumice and volcanic tuff colluvia - On gravelly pumice and volcanic tuff colluvia		13b	E	91 92 93 94 95	- - - - -	MMS16 MMS349 MMH16 MMH3 -
	resulting from erosion – from red soils			13r		-	-	-
	resulting from erosion – on non differentiated materials			13nd	Er	-	-	-
	saline regosols – on non differentiated materials			10	Sr	10	-	GMGW1
	sandy regosols – on dunes			14	D	-	7	-
Lithosols and skeletal soils	on volcanic materials – on rocks and basalt rock debris, lava			15v(+5+6)	H	131	81 82	- -
	on volcanic materials – on shells and calcareous tuff							
	on non differentiated materials			15nd (+3)				

Table 36. STAGE-DISCHARGE RELATIONSHIPS.

H = stage reading (m)

Q = discharge (m3/s)

Station	H	Q	H	Q	H	Q	H	Q	H	Q	H	Q	H	Q	H	Q	H	Q	H	Q	H	Q	H	Q	H	Q	H	Q	H	Q	H	Q	H
1 Awash at Teji	0.00	0.150	0.10	0.36	0.20	0.67	0.30	1.000	0.60	2.000	1.00	3.500	1.20	4.650	1.60	7.700	2.00	11.400	2.50	16.150	3.00	21.200	3.60	28.900	4.40	43.900	5.00	57.000	5.20	61.700			
3 Awash at Melka Kentare	0.20	0.290	0.30	1.090	0.40	2.99	0.60	0.410	0.90	14.64	1.20	27.70	1.40	39.16	1.60	52.97	2.00	87.000	2.40	136.300	2.80	190.000	3.20	248.000	3.80	335.000	4.20	394.000					
5 Akaki at Akaki village	0.20	0.280	0.25	0.520	0.30	1.050	0.40	2.950	0.50	4.760	0.70	9.500	1.00	17.900	1.40	32.400	1.70	46.200	2.00	62.000	2.40	87.500	3.00	133.500	3.60	186.000	4.00	226.800	4.60	292.000	5.20	359.500	5.9
4 Awash at Melka Gorge	0.00	1.060	0.10	1.600	0.20	2.300	0.40	4.300	0.60	6.900	1.00	14.500	1.40	28.500	1.80	48.000	2.20	71.000	2.60	96.500	3.40	162.500	4.00	224.000	5.00	330.000	6.00	436.000	7.45	589.700			
6 Mojo at Mojo village	0.49	0.026	0.60	0.050	0.70	0.090	0.75	0.440	0.80	1.200	0.90	3.000	1.00	5.000	1.10	8.000	1.20	14.000	1.40	31.000	1.80	68.500	2.00	95.000	2.20	126.500	2.50	188.500	2.80	259.000	3.65	543.600	
7 Mojo near lake Gelilea	0.80	0.200	1.00	0.400	1.20	0.900	1.30	1.300	1.40	1.700	1.60	2.700	2.00	5.800	2.40	10.200	2.80	16.600	3.20	25.700	4.00	48.700	4.00	66.000	5.00	77.600							
27 Meki at Meki village	0.01	0.004	0.10	0.040	0.20	0.160	0.30	0.370	0.40	0.730	0.50	1.340	0.70	3.030	0.90	4.800	1.20	7.400	1.60	11.800	1.90	15.900	2.40	25.200	2.90	65.000	3.70	75.680	4.60	116,080	5.10	138.060	6.0
28 Awash at Wenji	0.10	12.800	0.20	14.600	0.40	18.800	0.60	23.600	0.90	31.600	1.20	39.600	1.60	51.400	2.60	83.000																	
8 Geleta at Sire Road Bridge	0.40	0.130	0.50	0.850	0.60	2.250	0.80	6.900	1.00	19.700	1.20	40.800	1.60	98.000	2.20	182.000	2.50	224.000															
9 Awash at Metehara	0.40	4.800	0.60	6.200	0.80	7.800	1.00	10.000	1.40	15.400	1.90	24.400	2.50	41.250	3.00	56.500	3.60	74.800	4.40	99.000	5.00	117.000	6.00	147.000	7.00	178.000							
29 Arba Dima	0.10	0.100	0.20	0.600	0.25	1.000	0.30	1.400	0.45	4.000	0.00	0.900	1.00	34.000	1.40	63.000	1.80	92.200	2.40	148.000	3.00	211.000	3.35	250.720									
10 Awash at Awash station	0.70	6.500	0.80	11.500	0.90	17.000	1.10	26.500	1.40	50.000	1.60	66.000	1.90	94.000	2.20	125.000	2.60	173.500	3.10	253.000	4.00	417.500	4.60	528.500									
13 Arba at the ford of Micso road	0.01	0.320	0.10	0.850	0.20	1.520	0.40	4.100	0.50	7.200	0.60	11.000	0.80	19.000	1.20	43.000	1.60	76.000	2.00	114.000	2.40	155.000	3.00	215.000	3.70	265.000	4.20	335.000	4.60	375.000			
14 Upper Kesem at Sendafa	0.01	0.020	0.05	0.100	0.10	0.200	0.30	0.700	0.40	1.050	0.50	1.500	0.70	2.650	1.00	5.100	1.40	10.050	1.80	16.150	2.40	26.350	2.90	35.450	3.60	47.710	4.10	56.310	4.50	62.310			
15 Upper Kesem at Mikawa Fort	0.10	0.036	0.20	0.058	0.40	0.152	0.60	0.650	0.90	2.200	1.10	3.000	1.60	8.400	1.90	12.900	2.40	23.700	3.20	47.500	4.00	71.500	5.00	100.500	5.20	106.300							
11 Kesem at Awora Melka	0.46	0.010	0.50	0.150	0.60	1.120	0.70	2.920	0.80	5.460	0.90	8.940	1.00	13.000	1.20	23.800	1.42	23.800	1.60	36.400	1.80	56.600	2.00	112.000	2.20	250.000	2.40	309.000	3.10	500.000	3.50	600.000	
12 Kebena	0.16	0.140	0.20	0.440	0.30	1.000	0.50	3.860	0.90	16.500	1.20	33.000	1.60	71.000	2.00	125.000	2.40	200.000	2.60	247.000	3.40	454.000											
18 Robi at Robi village	0.30	0.050	0.45	0.150	0.50	0.300	0.60	0.320	0.70	1.950	0.80	3.620	0.90	6.500	1.20	22.800	1.60	82.000	2.20	142.000	2.80	266.500	3.00	320.000	3.40	450.000							
19 Jawaha	0.10	0.100	0.20	0.300	0.40	1.750	0.70	6.750	1.00	20.000	1.40	50.600	1.80	83.000	2.20	115.280	2.70	154.980	3.00	178.600	3.60	225.840	4.30	257.200									
16 Awash at Hertale	0.44	17.000	0.60	21.000	0.80	26.000	1.00	32.000	1.40	45.600	1.80	61.400	2.20	79.400	2.90	113.000	3.60	152.600	4.20	193.200	4.80	246.600	5.40	330.200	5.74	393.000							
20 Ataye	0.10	0.050	0.20	0.220	0.30	0.570	0.40	1.050	0.60	2.710	1.00	7.010	1.20	9.130	1.70	15.100	2.20	22.100															
21 Jara	0.10	0.030	0.20	0.090	0.30	0.170	0.40	0.294	0.60	0.610	0.80	1.430	1.00	3.400	1.20	6.800	1.40	11.500	1.90	28.500	2.10	35.970	2.80	61.660	4.00	105,700							
22B Borkena Swamp inlet	0.01	0.040	0.05	0.200	0.10	0.400	0.20	0.900	0.30	1.800	0.40	2.700	0.60	5.700	0.80	8.900	1.20	18.400	1.80	60.000	2.20	98.920	2.80	157.480	3.30	204.300							
22A Borkena Swamp outlet	0.60	0.030	0.70	0.120	0.80	0.360	1.00	1.600	1.40	7.600	2.00	28.400	2.40	65.600	2.80	141.600	3.00	192.000	3.50	322.400													
24 Mile at Mile village	0.30	0.400	0.40	1.200	0.50	2.200	0.70	5.600	0.90	14.200	1.20	55.400	1.40	117.400	1.80	243.000	2.30	400.000	2.50	460.000													
25 Awash at Dubti	0.20	5.000	0.40	9.000	0.60	14.000	1.00	26.000	1.00	50.000	2.00	71.000	2.40	96.000	3.00	145.000	3.60	199.000	4.00	238.000	4.60	304.000	5.00	358.000	6.00	562.000	6.40	658.000					
26A Awash at Asayita	0.00	10.600	0.10	12.400	0.20	14.100	0.50	19.700	0.70	23.400	1.10	31.200	1.60	41.200	1.90	48.700	2.20	61.000															